# A LINEAR PROGRAMMING MODEL FOR MACHINERY AND IMPLEMENT SELECTION FOR CENTRAL KANSAS DRYLAND FARMS

by


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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

## LIST OF FIGURES

# CHAPTER I

# INTRODUCTION

Central Kansas farmers as all United States farmers are faced with making resource allocation decisions in response to changing prices, technology, and variable weather conditions. Farm resource allocation decisions are made in a continually changing setting. Technological developments provide for more output from current use of resource or new resources that can be employed in the production of food and fiber. Input prices and prices received for farm products are beyond the control of the individual farmer. Climatic conditions can harm or enhance the productivity of a farmer's resources.

Variable weather conditions and prices coupled with changing farm size make optimum resource allocation decisions for the central Kansas farmers complex. One of the many resource allocation decisions farmers make is machinery selection. A farmer selecting field machinery must identify his critical field operations and estimate the time needed to complete these field operations. After identifying the critical field operations and the time allowed to complete them, the size of machine and/or implement can be determined (3).

Some of the more recent trends in central Kansas agriculture include an increase in both machinery investment per acre and farm size. In central Kansas, average farm crop machinery investment per acre has increased 89 per cent since 1970, from $25.25 in 1970, to $47.67 per acre in 1977 (1,2). Average crop acres increased 20 per cent since 1970, from 678 acres in 1970 to 816 acres in 1977 (1,2).

## Machinery Selection Data

To calculate time available to complete a field operation, the farmer needs to know how many days weather will allow field work. Field workdays are an estimate of the frequency of occurrence of the time available for the completion of field operations.

The need to complete many field operations may occur simultaneously, thus the farmer must decide which operation can be postponed, and which field operation is to be undertaken to maximize returns. Timeliness is the completing of field operations at an optimum time in regard to crop quantity and quality (4). Every field operation from seedbed preparation to harvest has a timeliness aspect. Late removal of weeds from stubble of fallow ground can deplete soil moisture and/or nutrients from ensuing crop production.

The interaction of agronomic, economic, engineering, and meterological relationships provide a complex situation for the machinery selection decision of farmers. If these relationships can be quantified, then the complex situation can be solved by a systematic approach. Models have been developed to aid farmers in selecting machine size. Many of the models are location specific due to diverse weather and cropping practices.

Due to a lack of data, the majority of machinery selection models have not had timeliness estimates for field operations incorporated within them. To provide a tool to aid central Kansas farmers in the selection of machinery and implements, the inclusion of timeliness is critical for meaningful results.

## Objective of Study

Develop and test a linear program model for central Kansas dryland cash crop farmers that selects the most profitable combination of three crops and:

a) machinery and implement sizes given acreage limits,

b) crop acreage given machinery and implement sizes,

c) and timeliness of field operations.

Six tractor and two combine machinery sizes are studied, while crop acreage is constrained. Implement size is a function of tractor size. Machinery selection variables considered are costs, machine capacity, field workdays, labor, and timeliness.

## Review of Literature

Computer simulation and linear program models to aid farmers in the selection of farm machinery and implements began being developed and refined in the early 1960's (5,6). Two digital computer programs were developed for machinery selection during the period. Link (6) approached the complexities of machinery and implement selection by a scheduling of field operations mode of research. Simons (7) approach was to allot time for the completion of field operations. In 1967 Donnel Hunt (5) adopted and updated the manner of study used by Simons with a fortran program.

Hunt's model selected the number and size of implements based on power limits of tractor size; measured in power take-off horsepower units at minimum costs levels for given crops and acreage. Timeliness estimates were not included in the model. Early models were limited by computer storage space, and the state of the arts in agrometerological data for field workday estimates.

In 1968 the American Society of Agricultural published papers on computers and management of farm machinery (3). This publication includes a partial bibliography of programs available at that time for machinery selection, timeliness estimates for field operations, and field workday methodology.

Chandler divided machinery selection models into first and second generation. First generation models being applicable only to specific research projects. Second generation models are those applicable to extension work, having the ability to be applied and altered to fit a large number of farm situations (3).

A second generation linear program model was developed to study alternative farm plans for Purdue's Top Farmers Conference in 1968 (3). The Automatic Corn Budget was primarily designated to solve for the most profitable way to schedule corn production, but was modified to handle machinery selection problems. Purdue currently at Grain Crop Top Farmer Workshops employs the Automatic Cropping Budget to aid farmers in crop planning, including machinery selection (2).

In 1973, Smeilder (8) modified Hunt's first generation program into a second generation program with a broader spectrum of application. Smeilder's work included more recent information on tractor drawbar performance, and implement power take-off shaft requirements. Smeilder's model required crop mix to be given.

Burrow and Seimens (1) developed a least cost computer program model to assist and educate corn-soybean farmers in machinery selection for the corn belt area. The model's characteristics included:

a) timeliness costs in regard to date of corn planting,

b) specified mix of corn and soybean acreage on farms from 300 to 2000 acres,

c) scheduling of field operations,

d) field workday probabilities, and

e) machinery fixed and variable costs.

To test the model two computer runs were made for each size of farm studied. The first run was used to determine the number of tractors, combines, and labor needed for a specific farm size. The second run determined the least cost machinery combination. All costs were varied, to study machinery costs effects on income. Results included:

a) near 980 crop acres the cost associated with timeliness was equal to another hired hand,

b) price variations of inputs showed large effects on income,

c) repair costs had little effect on income, and

d) timeliness can have a significant impact on machine selection (1).

In 1976 Hughes and Holtman's (4) machinery selection computer model consisted of four main procedures; system power requirements determination, field machine selection, tractor selection, and cost analysis.

The basic characteristic of the Hughes and Holtman model was that they assumed a farmer is interested in completing a field operation by a predetermined date, rather than in a specified time interval. The authors used and conclude that machinery should be selected as a system, as opposed to selecting machinery as separate individual units.

In 1977, Tice (9) developed a linear program machinery selection model for northeast Kansas cash grain farmers. Tice's model selected the most profitable combination of crops and machinery. Total crop acreage was limited, and the most profitable mix of four possible crops was chosen for a specific set of machinery. Timeliness estimates for date of planting were incorporated in the model. Field workday estimates were varied between wet and dry years.

The linear program model for central Kansas farmers of this study differs from other machinery selection models in that field workdays available, cropping practices, and timeliness estimates are a function of the region studied. The model contains timeliness estimates for planting and the harvesting of crops. The model can select machinery for a given acreage, or state the acreage a given set of machinery can adequately farm.

# CHAPTER II

# MODEL DEVELOPMENT

## Mathematical Description

Linear programming is a planning method that is often helpful in decisions requiring a choice among a large number of alternatives.

> "The technique of linear programming can be applied whenever the objective is to optimize (maximize or minimize as the case may be) the function f(x) where $f(x) = FX + K$. f(x) is linear and:
>
> F is a functional,
> K is a constant, and
> X ranges over a convex polyhedral set of points.
>
> The maximization (or minimization) of the objective function is subject to certain linear constraints. The usual way of writing a maximization problem in a matrix form is:
>
> $$\text{Maximize } Z = C'X \text{ subject to } AX \overset{>}{\underset{<}{=}} B,\ X \geq 0$$
>
> 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 (commodities to produce),
>
> B is an $m \times 1$ vector of resource or other restrictions, and
>
> $C'X = Z$ is the objective function.

In algebraic form this can be written as:

$$\text{Maximize } Z = c_1x_1 + c_2x_2 + \cdots c_nx_n$$

$$\text{subject to (1) } a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1$$

$$\text{(2) } a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x \leq b_2$$

$$\text{(3) } a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mm}x_n \leq b_m$$

$$x_1 \geq 0, \quad x_2 \geq 0 , \ldots, x_n \geq 0.\text{"}$$ [1]

Assumptions of the linear program model include linearity, additivity, divisibility, and singled valued expectations.

The linearity assumption gives the model proportional returns as opposed to diminishing returns. A curvilinear function can be approximated by linear segments.

"Additivity implies the absence of any interaction among the activities of the resources."[1] Activities are additive in linear programming, meaning that income, cost or resource used from several activities total the sum of income, cost, or resource used by individual activities.[3]

Divisibility suggests that partial or fractional levels of activities and resources are possible solutions, such as 595.5 acres of wheat production, 90.3 hours of labor per period, or 0.5 combine for wheat harvest. Labor and acreage fractional solutions can often be rounded to the nearest whole unit without having significant impact on the optimum solution. The divisibility assumption can have important implications in the solution for a farm's optimum machinery needs. Rounding fractional machinery selection results to the nearest integer may distort the optimum solution. When a linear program model due to the divisibility assumption gives a solution of 0.5 combine, mixed integer programming can be used in further analysis to study solutions that contain 0.0 or 1.0 combine.

Single-value exceptions means that resource supplies, input-output coefficients are known with certainty. "This imparts the model to be deterministic."[1]

## General Equations

The left hand side of each equation consists of the technical coefficients (a's), and the activities or variables (x's). Positive technical coefficients may reflect the demand that one unit of the activity makes on the resources represented by the equation (2). A negative technical coefficient means that an activity or variable increases the supply of the resource represented by the row or equation. The right hand side (RHS) gives resource restraints or restrictions (b's). Resource constraints may be in the form of less-than-or-equal-to (G), greater-than-or-equal-to (L), or equal-to (E). The L and E restraints are used in the central Kansas machinery selection model.

Positive coefficients in the objective equation (1) are income, whereas negative coefficients are reductions to the objective equation. The objective equation's coefficients are gross returns less variable costs. Variable costs are relevant in decision making because they affect the rate of change of total costs; fixed costs contribute to the level of total costs.

Model equations describe the interrelationships among parts of a central Kansas farming system that affect the selecting of machinery and implements. Machinery and implement selection is a function of variable costs, yields, farm size, labor availability, timeliness, field workdays, and machinery capacity.

The linear program model for central Kansas machinery and implement selection consists of 204 equations. Three groups of equations are in the model; resource equations state the available amounts of a specified resource and its usage by activities requiring that resource; transfer equations that provide the service or output of one activity to be transferred in the model to another activity (2); and the objective equation being maximized.

## Resource Equations

Production equations state the bushels produced (a's) for each acre of wheat and grain sorghum activity. Production equations are the ($\leq$) type with zero as their right-hand-side values. Linked to by transfer equations or contained directly within production equations are penalties (a's) for the untimely sowing and harvesting of wheat and grain sorghum. Wheat untimeliness penalties for drilling and harvesting demand bushels from the wheat production equation. A series of (L) type penalty transfer equations (PENLGS1 - PENLGS5) link grain sorghum planting penalties to the grain sorghum production equation. Grain sorghum harvest penalty transfer equations (PENLGS6 - PENLGS13) are of (E) type, and link penalties for untimely grain sorghum harvest to the grain sorghum production equation.

Farm acreage is constrainted by three equations. An equation of the (L) type states the land available (RHS), cropland required (a's) for each crop activity. Non-use of land is possible, but substitution of land from one crop activity to another is not allowed. When the effect of wet years on machinery selection is studied, three land equations prohibit the model from specializing in the production of a crop activity that has field operations that occur during drier periods of the year.

Labor is available in weekly and bi-weekly equations for crop production. The labor requirements (a's) are the hours needed to complete field operations. The restraints for labor in weekly and bi-weekly equations are the (L) type, and the right-hand-side values are defined in terms of field workdays. Twelve weekly and nineteen bi-weekly labor equations are used to describe the important labor periods throughout the year. Weekly labor equations are used for late spring and early summer months, to be consistent with the use of weekly penalties for untimely wheat harvest and alfalfa haying operations. Wheat harvest and alfalfa haying activities have labor parameters in both weekly and bi-weekly labor equations.

Equations of the (E) and (L) type state the field operations that must occur for each acre of crop production undertaken. Grain sorghum planting-fertilizing and alfalfa drilling-fertilizing equations are the (E) type; all other field operation equations are the (L) type. The right-hand-side value for all field operation equations is zero.

Drilling-fertilizing, harvesting, planting-fertilizing, swathing, baling, hay hauling-stacking, and row crop cultivating equation units are per acre. Positive technical coefficients in each per acre field operation equation state the number of times each field operation must occur. Combine and implement activities supply units to their respective field operation equations. Linked to a per acre field operation equation is a transfer equation for each size of combine or implement considered in the model, that demands one unit from the field operation equation. The right-hand-side value for each combine and implement size transfer equation is zero. Grain sorghum planting-fertilizing transfer equations for each size of planter considered are the (E) type; all other per acre equipment size transfer equations are of the (L) type. Alternative equipment size time period field operation activities (x's) supply per acre units to their respective combine and implement transfer equations to allow the completion of field operations.

The unit for all plowing, disking, springtoothing field operations is one hour, positive technical coefficients state the time in which one acre can be worked. Negative technical coefficients in disking, plowing, and springtoothing field operation equations supply units in field operation equations which are demanded by per hour field operation transfer equations. Per hour field operation and per hour field operation transfer equations are the (L) type, with zeros are their right-hand-side values. All per hour field operation equations are linked to machinery capacity equations.

The model contains three sets of (L) type machinery capacity equations. Machinery capacity equations units are hours, and their right-hand-side values are defined in terms of field workdays.

Combine capacity equations are in weekly intervals for wheat harvest, and bi-weekly intervals for grain sorghum harvest. Small tractor capacity equations are on a weekly basis; the other tractor capacity equations are in bi-weekly intervals.

## Transfer Equations

The per acre combine field operation equations are linked by transfer columns (variables) to combine capacity equations. Technical coefficients in combine capacity equations state the time required to harvest one acre. Swathing, baling, drilling-fertilizing and hay hauling-stacking per acre units are transferred to small tractor capacity equations whose technical coefficients state the time required to accomplish the field operations. Plowing, disking, springtoothing field operation equations' hour per acre units are transferred to tractor capacity equations. Planting-fertilizing, drilling-fertilizing, and row cultivating time period activities have hour per acre parameters in tractor capacity equations.

A set of (L) type equations (PL/CU4R - PL/CU18R) require that each acre of grain sorghum planted with a selected size of row planter is cultivated with a row cultivator of the same size. Another set of (L) type; zero right-hand-side value equations (SWALMA.5 - SWALAU.3), require that swathing and baling activities occur during the same weekly period.

Objective Equation

The objective equation's coefficients are gross returns less variable costs for the alfalfa activity, wheat and grain sorghum's variable cost per acre less machinery and implement repair and fuel costs, machinery repair and fuel and implements repair activities' variable costs, grain sorghum and wheat's market prices, grain drying costs, and alfalfa penalties.

Form and Function of General Equations

A listing of model equations is given in Appendix I. To facilitate an understanding of the form and function of the model's equations the following is a general outlay of equations where:

a = subscript for the crop alfalfa

g = subscript for planting period

h = subscript for harvesting period

i = subscript for the crops wheat and grain sorghum

j = subscript for baling, combing, drilling-fertilizing, planting, hauling-stacking, row cultivating, and swathing

k = subscript for disking, plowing, and springtoothing

l = subscript for combination of too-early and too-late planting linked with too-early and too-late harvest

s = subscript for size of machine or implement used for field work

t = subscript for period in which field operations occurs

The nomenclature, description, and units of each activity in the model are given in Tables I - III in Appendix II. The tables in Appendix II are grouped by wheat, grain sorghum, and alfalfa categories respectively. For the general outlay of equations the following capital letters and subscripts are employed to represent the technical coefficients of the model's equations and are defined as:

$A_i$ is operation j on C acres of crop i using size machinery s

$C_i$ is acres of crop i

$F_{ji}$ is the cost of field operation j for crop i

$G_i$ is hour(s) of labor per unit of period j

$K_i$ is the variable cost excluding fuel and repair cost of crop i

$M_i$ is hours of machine time required per unit of capacity period

$P_i$ is the price per unit of crop i

$Q_i$ is the amount sold of crop i

$L_i$ is the jth type of penalty of crop i

$R_a$ is the return per acre less variable cost of alfalfa per acre

$T_{ji}$ is the cost of primary tillage implement k for crop i

$Y_i$ is the yield per acre of crop i

The general outlay of equations is presented according to the order in which the general equations were discussed. The word in parenthesis following each general equation's restraint defines that equation's units. The second number preceding each equation in parenthesis is the number that equation can be found by in Appendix I.

A) OBJECTIVE

1. (1) Maximize $OBJ = \Sigma P_i Q_i + \Sigma R_a C_i - \Sigma K_i C_i - \Sigma\Sigma F_{ji} C_i - \Sigma\Sigma T_{ji} C_i - \Sigma\Sigma L_i C_i$

B) PRODUCTION

2. (2,3) $-Y_iC_i + \Sigma L_{ij} + Q_i \leq 0$ (bushel)

C) PENALTY EQUATIONS LINKING PLANTING TO HARVEST

3. Planting (140 - 144)

$\Sigma\Sigma A_{ig} - \Sigma\Sigma L_{il} \leq 0$ (bushel)

4. Harvest (145 - 152)

$\Sigma\Sigma A_{ih} - \Sigma\Sigma L_{il} \leq 0$ (bushel)

D) LAND

5. (23,24) $C_i \leq b_i$ (acre)

6. (25) $C_a \leq b_a$ (acre)

E) LABOR

7. (40 - 70) $\Sigma\Sigma\Sigma G_{iajks}A_{iagks} \leq b_i$ (hour)

F) MACHINE CAPACITY

8. (71 - 115) $\Sigma\Sigma C_{iaj} - \Sigma\Sigma\Sigma M_{iajk} \leq b_i$(hour)

G) TRANSFER EQUATION LINKING FIELD WORK TO ALTERNATIVE TIME PERIODS

9. (12)

$\Sigma\Sigma A_{iaj} - \Sigma\Sigma A_{iajt} \leq b_i$ (acre)

## Activities

Activities (x's) of the central Kansas machinery selection model are grouped into the following categories: crop production, tractor size, field operation and field operation transfer, penalties for untimely field operations and penalty transfer, and crop selling.

### Crop Production Activities

Crops included in the model are wheat, grain sorghum, and alfalfa. The unit for each crop production activity is one acre. Wheat and grain sorghum activities state each crop's variable cost less fuel and repair cost in the objective equation, bushels produced in a production equation for each crop, cropland required in a land equation for each crop, and per acre field operations. The per acre field operations required for wheat are drilling-fertilizing and combining. Fuel and repair costs are the objective coefficients in the field operation activities. The grain sorghum activity's field operations are planting-fertilizing, row crop cultivating, and combining. Each acre of grain sorghum produced must be planted-fertilized and combined, and row crop cultivated twice. The alfalfa production activity states the per acre return less variable cost in the objective equation, and cropland requirement in the land equation (CPLDALF).

## Tractor Size

Field operations, except combining, require a tractor. Tractor size is differentiated by horsepower, and one unit of large tractor activity is one hour. A small tractor activity is the power source for alfalfa swathing, baling, drilling-fertilizing, and hauling-stacking.

In the model the activity representing use of the small tractor is linked by the transfer equation (TALFALF2) to the per acre alfalfa production activity. This activity states that each acre of alfalfa must be drilled-fertilized, swathed, baled, and hauled and stored three times. Baling, drilling-fertilizing, hauling-storing work is linked to one of several time period field operation activities that have hour per acre parameters in the small tractor capacity equations.

The variable cost of operating the small tractor is considered in the alfalfa budget.

Activities representing the use of the large tractor provides the power source for all tillage and planting operations (Table 1). The study considers six sizes of the large tractor for field operations. Each tractor has a set of tillage implement widths based on tractor power. Field tillage operations are disking, plowing, and springtoothing.

TABLE 1

FIELD OPERATIONS POWER SOURCES

| Field Operation | Power Source | |
|---|---|---|
| | Small Tractor | Large Tractor |
| Alfalfa | | |
| Baling | x | |
| Swathing | x | |
| Drilling and fertilizing | x | |
| Hauling and stacking | x | |
| Plowing | | x |
| Springtoothing | | x |
| Grain Sorghum | | |
| Disking | | x |
| Plowing | | x |
| Planting and fertilizing | | x |
| Row cultivating | | x |
| Wheat | | |
| Disking | | x |
| Springtoothing | | x |
| Drilling and fertilizing | | x |

Each size of tractor studied is separated into three activities (TRWHT, TRGS, and TRCAL), and each tractor activity is linked by a transfer equation to the wheat, grain sorghum, or alfalfa production activity. A crop acre may be disked or springtoothed more than once. The activity for the large tractor specifies the hours per acre required for field tillage operations for the crop to which it is linked.

Field Operation and Field Operation Transfer

Each tillage operation specified in a large tractor activity is linked by a transfer equation to alternative tillage time periods. Hour per acre units are transferred from large tractor activities to field tillage transfer activities, and then these units are transferred to time period tillage activities which have unit parameters in labor and tractor capacity equations. The hour per acre repair cost for each size of tillage implement plus its power source's fuel and repair costs, is contained in the objective equation for each time period tillage activity.

Per acre field operations specified in wheat and grain sorghum production activities are the selection possibilities in the model. Crop production field operation equations each have at least three alternative machine and implement sized activities that supply units to them. Size is in terms of machine or implement effective working width. One of two combine activity sizes or a custom combine activity may be selected for wheat and grain sorghum harvests. One of five activities of sizes of wheat drilling-fertilizing may be selected to plant wheat acreage. Row crop planter and cultivator activity selection possibilities are from five activity sizes. The smaller the sizes of the larger tractor, the selection of implement sizes is limited to those suited to its size.

Each machine or implement size activity is linked by a transfer equation to alternative time period activities for the completion of per acre field operations. Alternative time period activities for per acre field operations have hour per acre units for each size of machine or implement considered in labor, and tractor or combine capacity equations. Combining, row cultivating, row planting-fertilizing, and wheat drilling-fertilizing time period activities for each size of machine or implement considered have their per acre variable cost plus their respective power source's fuel and oil repair cost per acre in the objective equation.

Alfalfa harvest equipment in the model is of a fixed size. Alfalfa hauling-stacking activities demand labor and small tractor time for the removal of hay bales from the field. Hired labor activities consist of custom hay hauling and stacking.

## Penalties for Untimely Field Operations and Penalty Transfer

Penalties in the model state the per acre reduction in yield or dollar loss for the untimely completion of planting, drilling, and harvesting field operations. Designated optimum planting, drilling, and harvesting time period have no penalties.

Each acre of wheat produced supplies a predetermined yield in the wheat production equation. When wheat is drilled or harvested in time period field operation activities other than those as designated as optimum, bushels are demanded from the wheat production equation. Bushel penalties for untimely time period field operations activities units are per acre. Another penalty associated with pre-optimum harvest of wheat is drying cost. The cost of drying an acre's production of wheat to a storable moisture content is in the objective equation for each pre-optimum time period harvest activity.

The grain sorghum production activity supplies a predetermined yield in the grain sorghum production equation. The penalty for each possible planting and harvesting time period activity is combined in a grain sorghum penalty activity that demands bushels from the grain sorghum production equation. The optimum combination of planting and harvesting times has no penalty. A planting period's penalty is linked by a transfer equation (PENLGS1 - PENLGS5) to a respective penalty activity. Each harvest period's penalty is linked to a penalty activity by a transfer equation (PENLGS6 - PENLGS13).

Harvesting grain sorghum acreage in pre-optimum combine time period activities has a predetermined drying cost per acre. The objective equation is reduced by the number of acres harvested during the pre-optimum combine time period activity times the cost of drying.

Alfalfa time period penalty activity units are the dollar(s) reduction in per acre return less variable cost in the objective equation for the untimely swathing of alfalfa. For each one of the three possible hay cuttings, there are three time period activities to both swath and bale the alfalfa acres in production. For each cutting and each time period in which alfalfa is swathed, one unit is demanded in an alfalfa penalty transfer equation (PENALF1 - PENALF9). Each swathing time period activity for each cutting in a penalty transfer equation supplies one unit to one of the nine alfalfa penalty activities.

Selling Activities

Two crop selling activities for wheat and grain sorghum are in the model. Bushels of wheat produced is supplied by the wheat production activity to the wheat production equation. Bushels produced that are not demanded by penalties are demanded by the wheat selling activity. The positive technical coefficient in the objective equation for the wheat selling activity is a predetermined price.

General linkages of model activities are illustrated in the flow diagram in Figure 1.

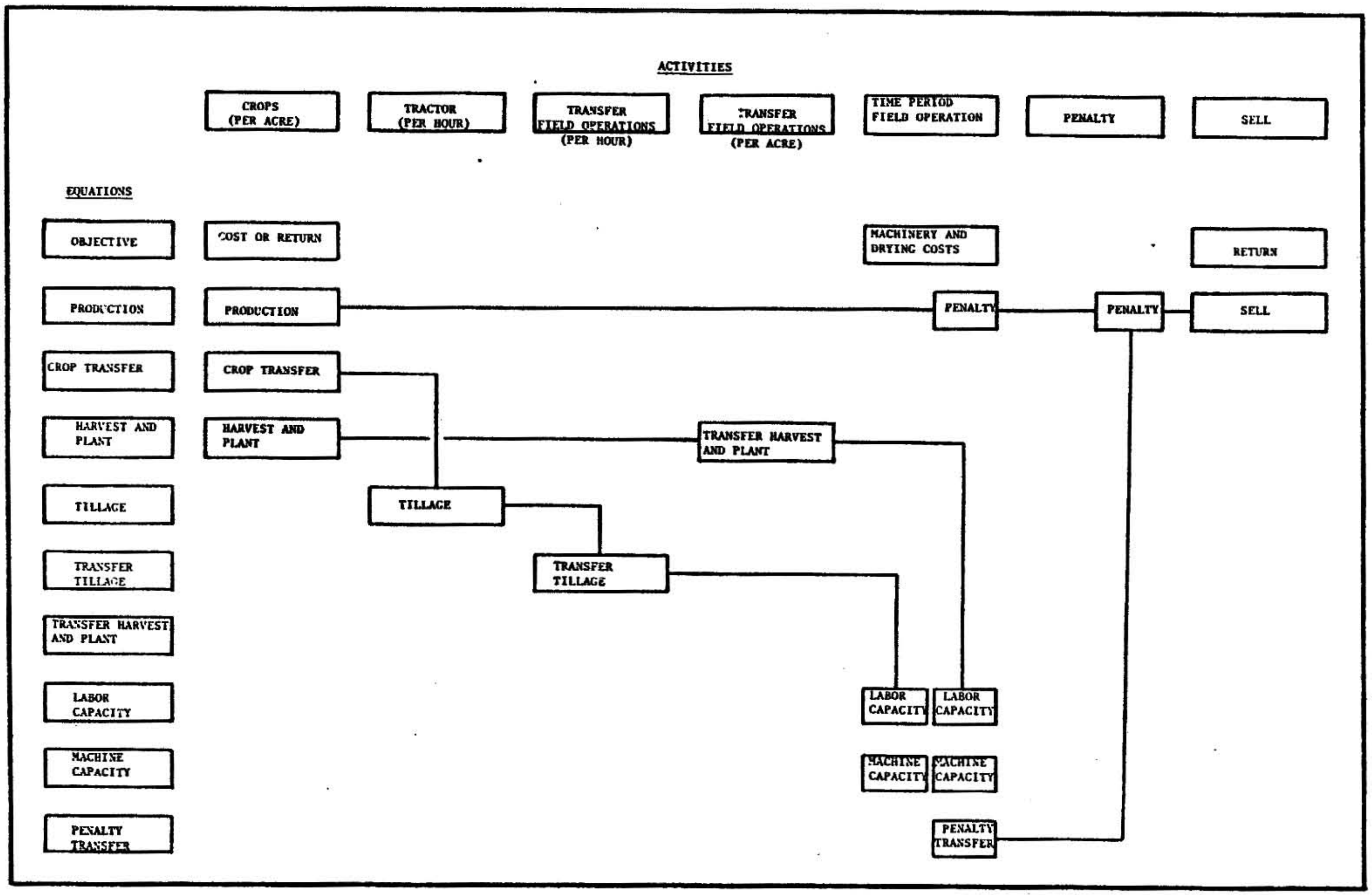



FIGURE 1: GENERAL MODEL

# CHAPTER III

# DATA AND PROCEDURE

## Penalty Estimation

The model considers grain sorghum and wheat penalties for untimely planting, pre-optimum and delayed harvest, and the cost of drying wet grain to a storable moisture content. Alfalfa penalties are for untimely cutting.

### Grain Sorghum Planting Penalty Estimates

Estimates of penalties for untimely grain sorghum planting are from an 11 year date of seeding study conducted at the South Central Experiment Field near Hutchinson, Kansas (31). The field experiment date associated with the highest average yield is the assumed optimum planting time and this yield was given an index equal to 100. The yields associated with the remaining experimental planting dates were indexed as a per cent of the optimum dates yield (Table 2). Model time periods were adjusted to field experiment time period designations such that; May 1 - 15 equals Early May. The yield indexes and planting dates were plotted, and linear approximation was used to estimate a yield index for the model's July 1 - 15 period as 87.5% of optimum (Figure 2).

TABLE 2

GRAIN SORGHUM YIELD BY DATE OF PLANTING

| Field Experiment Time | Field Experiment Avg. Yield bu./ac. | Index | Model Period |
|---|---|---|---|
| Early May | 48.6 | 78.0 | May 1-15 |
| Late May | 50.3 | 80.7 | May 16-31 |
| Early June | 62.3 | 100.0 | June 1-15 |
| Late June | 58.6 | 94.1 | June 16-30 |
| Early July* | | 87.0 | July 1-15 |

* Linear approximation.

Source: Modified version of Table 8 in "Report of Progress 269," Agricultural Experiment Station, Kansas State University, Manhattan, Kansas (1976).

The Farm Facts (1972-1976) average grain sorghum yield of 46.8 bushels per acre harvested was multiplied times each planting date's index number. The product from each multiplication was subtracted from the 46.8 bushel per acre yield to obtain a per acre estimate of planting penalties (Table 5).

## Pre-Optimum Grain Sorghum Harvest Penalty Estimates

> "Maturity and standability (stalk strength) are two of the major characteristics affecting grain sorghum yield in Kansas. There are five general categories of grain loss:
>
> 1. Preharvest losses due to shatter and severe lodging.
> 2. Header, or gathering losses consists of grain which is not delivered to the threshing unit due to reel shatter or gathering efficiency.
> 3. Cylinder loss refers to the grain which is left in the head. Cracked grain is sometimes included in this category.
>
> 4&5. Walker and shoe losses are usually very hard to distinguish in the field and are usually lumped together." (17)

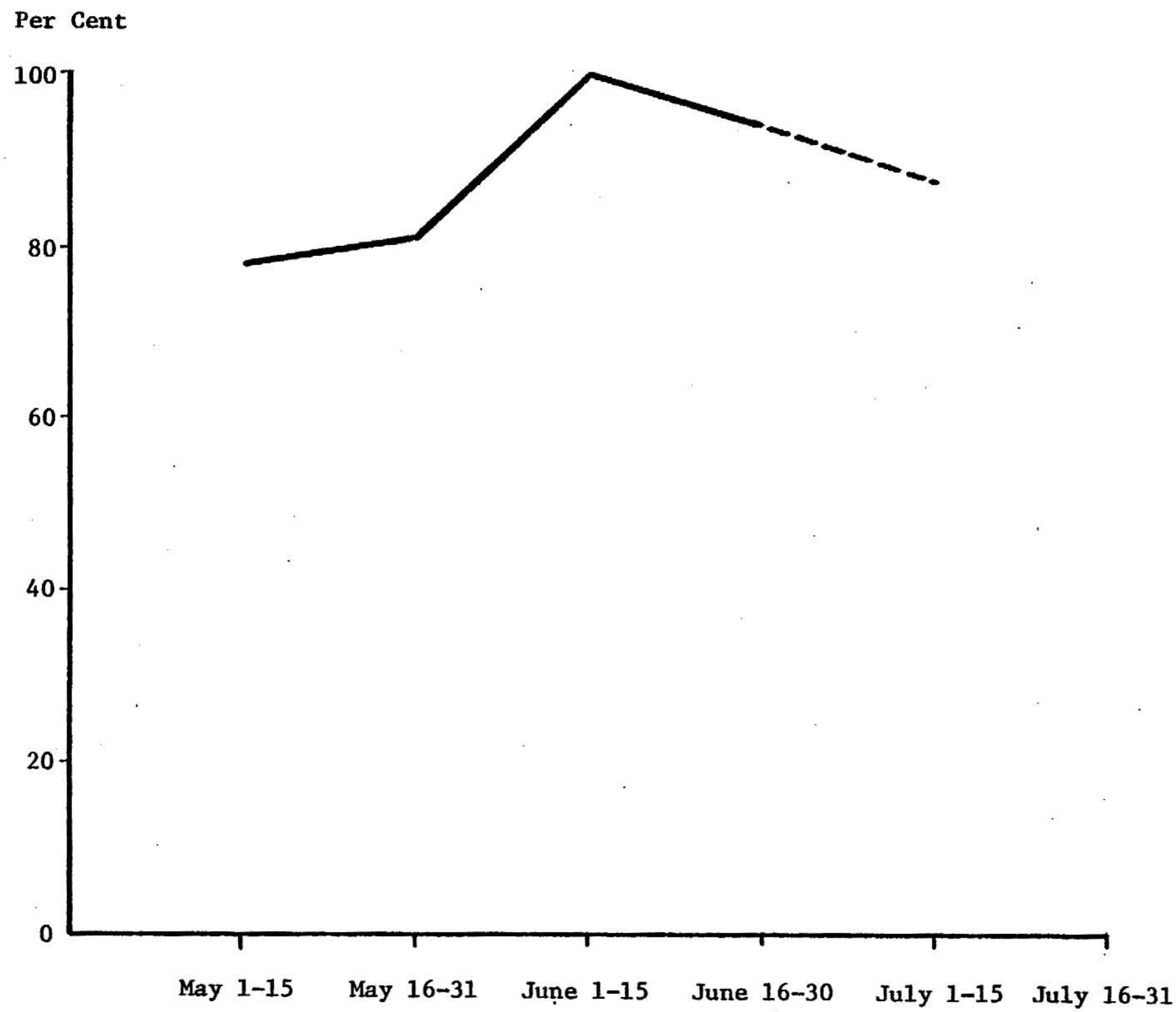



FIGURE 2: GRAIN SORGHUM YIELD INDEX AT DIFFERENT PLANTING DATES

The pre-optimum harvest period is defined as that period when the field grain moisture content is greater than 14 per cent. To estimate grain losses that occur from pre-optimum combining, results from a two year Kansas study on grain sorghum harvesting losses were employed. To adapt the research results for estimation of pre-optimum harvest penalties, the following steps were taken:

a) losses for each of the three cylinder clearances and speeds were averaged by date (Table 3),

b) to obtain an optimum date that has no loss associated with it (Oct. 9), five per cent was subtracted from each date's averaged loss,

c) the resulting Sept. 25 and Oct. 2 losses were averaged to obtain a 12 per cent estimate bushel loss for pre-optimum harvest, and

d) the 12 per cent estimated pre-optimum harvest loss was multiplied time the 46.8 bu./ac. average yield to derive a 5.6 bu./ac. penalty.

Another cost associated with harvesting grain sorghum before 14 per cent field moisture is reached is drying.

> "Grain shrinks as it dries. The higher the moisture level, the greater will be the shrink as the grain is dried to a storable level. Because shrink occurs, discounts are used to equalize the value of dry matter of wet grain with a bushel of dry grain. A common discount for grain sorghum is one cent per hundred weight for each 1/4 per cent moisture above 14 per cent." (15)

This translates into a 0.56 cent per bushel charge for each 1/4 per cent moisture content level above 14 per cent, or 2.24 cents per one per cent moisture. To apply the drying cost to the model the following steps were taken:

a) subtract 14 per cent moisture from each harvesting date's respective moisture level given in Table 3;

TABLE 3

GRAIN SORGHUM HARVEST LOSS IN PER CENT OF TOTAL YIELD AS RELATED TO GRAIN MOISTURE

| | Date | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | September 25 | | | October 2 | | | October 9 | | | October 16 | | |
| Moisture Per Cent | | 27.8 | | | 23.4 | | | 14.7 | | | 13.2 | |
| Trial* | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) |
| Per Cent Loss** | 25 | 18 | 23 | 16 | 11 | 8 | 6 | 5 | 4 | 0.5 | 4.5 | 5.8 |
| Average Per Cent Loss | | 22 | | | 12 | | | 5 | | | 6 | |

* Combine Cylinder

| Clearance (mm) | Speed (m/m) |
|---|---|
| (1) 6.35 | 1490 |
| (2) 11.11 | 1244 |
| (3) 15.88 | 998 |

** Loss consists of shoe, walker, cylinder, header, and preharvest.

Source: Fairbanks, G.E., Johnson, W.H., Schrock, M.D., and Nath, Surya. "Grain Sorghum Harvesting Loss Study," Paper presented at the 1976 Winter Meeting of the American Society of Agricultural Engineers, Chicago, Ill. Dec. 14-17, 1976.

b) multiply the result by 2.24 cents to derive per bushel drying cost;

c) the Sept. 25 and Oct. 2 drying costs were averaged to obtain an estimate of the pre-optimum harvest's periods per bushel drying cost of $0.26 per bushel;

d) the 5.6 bushel pre-optimum penalty was subtracted from the 46.8 bu./ac. average yield; the remaining 41.2 bu./ac. yield was multiplied times $0.26 to obtain a $10.71 per acre pre-optimum harvest drying cost estimate.

Grain Sorghum Delayed Harvest Penalty Estimates

Delayed harvest periods are the post-optimum periods when grain sorghum is left standing in the field after 14 per cent moisture is reached. Delayed harvest loss studies for grain sorghum are not available, thus information on corn delayed harvest losses was applied. Research (4) indicates that corn yield is reduced 0.003 bushel per day of harvest delay. The procedure for using the 0.003 timeliness coefficient for delayed grain sorghum harvest is as follows:

a) four delayed harvest periods are considered that are 15 days (two weeks) in length (Table 4);

b) the mid point number of days of delay for each delayed harvest period were multiplied times the 0.003 timeliness coefficient (Table 4);

c) the products from (b) were each multiplied times the 46.8 bu./ac. yield to derive per period per acre bushel penalty estimates.

One hundred and twenty day maturity grain sorghum is assumed for the model. "From planting date to physiological maturity, grain sorghum moisture content will be between 25 to 40 per cent." (17) The field drying time in days from physiological maturity to a 14 per cent moisture level in the model is 25 days (17). From planting date to optimum harvest date is 145 days.

TABLE 4

DELAYED GRAIN SORGHUM HARVEST PENALTY ESTIMATES

| Delayed Harvest Bi-weekly Period | Interval Days of Delay | Midpoint of Interval Days of Delay* | Penalty Estimate Bu./Ac. |
|---|---|---|---|
| 1 | 1 - 15 | 7.5 | 1.1 |
| 2 | 16 - 30 | 23.0 | 3.2 |
| 3 | 31 - 56 | 38.5 | 5.4 |
| 4 | 47 - 62 | 54.5 | 7.7 |

* Midpoints are used since grain sorghum does not experience the ear drop phenomenon as does corn.

Optimum harvest date is then a function of planting date. From the midpoint of a planting period to the midpoint of a harvest period is 145 days. Table 5 presents each possible combination of harvest and planting penalties. Planting in the June one period (June 1-15) and harvesting in the October second (Oct. 16-31) period is the only combination of planting and harvesting times that does not contain a penalty.

## Wheat Planting Penalty Estimates

Date of wheat planting field experiment studies are not available for the central Kansas area; therefore, data from a nineteen year field experiment study on wheat's planting dates effect on yield conducted at Hays, Kansas, was used to estimate central Kansas planting penalties (Table 6). The planting date (Sept. 29) from the study associated with the highest average yield was given the index equal to 100; the

TABLE 5

GRAIN SORGHUM PENALTY ESTIMATES

| Planting Period | Harvest Period | Planting Penalty Bu./Ac. | Harvest Penalty Bu./Ac. | Drying Cost $/Ac. | Total Bushel Loss Bu./Ac. |
|---|---|---|---|---|---|
| | Sept. 1 | 10.3 | 5.6 | $10.71 | 15.9 |
| | Sept. 2 | 10.3 | 0.0 | | 10.3 |
| May 1 | Oct. 1 | 10.3 | 1.1 | | 11.4 |
| (May 1-15) | Oct. 2 | 10.3 | 3.2 | | 13.5 |
| | Nov. 1 | 10.3 | 5.4 | | 10.7 |
| | Nov. 2 | 10.3 | 7.7 | | 18.0 |
| | Sept. 2 | 9.0 | 5.6 | $10.71 | 14.6 |
| | Oct. 1 | 9.0 | 0.0 | | 9.0 |
| May 2 | Oct. 2 | 9.0 | 1.1 | | 10.1 |
| (May 16-31) | Nov. 1 | 9.0 | 3.2 | | 12.2 |
| | Nov. 2 | 9.0 | 5.4 | | 14.4 |
| | Dec. 1 | 9.0 | 7.7 | | 16.7 |
| | Oct. 1 | 0.0 | 5.6 | $10.71 | 5.6 |
| | Oct. 2 | 0.0 | 0.0 | | 0.0 |
| June 1 | Nov. 1 | 0.0 | 1.1 | | 1.1 |
| (June 1-15) | Nov. 2 | 0.0 | 3.2 | | 3.3 |
| | Dec. 1 | 0.0 | 5.4 | | 5.4 |
| | Dec. 2 | 0.0 | 7.7 | | 7.5 |
| | Oct. 2 | 2.8 | 5.6 | $10.71 | 8.4 |
| | Nov. 1 | 2.8 | 0.0 | | 2.8 |
| June 2 | Nov. 2 | 2.8 | 1.1 | | 3.9 |
| (June 16-30) | Dec. 1 | 2.8 | 3.2 | | 6.0 |
| | Dec. 2 | 2.8 | 5.4 | | 8.2 |
| | Nov. 1 | 5.9 | 5.6 | $10.71 | 11.5 |
| July 1 | Nov. 2 | 5.9 | 0.0 | | 5.9 |
| (July 1-15) | Dec. 1 | 5.9 | 1.1 | | 7.0 |
| | Dec. 2 | 5.9 | 3.2 | | 9.1 |

yields associated with the remaining planting dates were indexed as a per cent of the Sept. 29 yield.

TABLE 6

WHEAT PLANTINGS DATES YIELD AND YIELD INDEXES

| Hays, Kansas 19 years Date Planted* | Yield (Bu./Ac.)* | Yield Index |
|---|---|---|
| Sept. 8 | 20.0 | 82.0 |
| Sept. 15 | 21.8 | 89.3 |
| Sept. 22 | 23.2 | 95.1 |
| Sept. 29 | 24.4 | 100.0 |
| Oct. 6 | 22.9 | 93.9 |
| Oct. 13 | 19.7 | 80.7 |
| Oct. 20 | 17.7 | 72.5 |

* Hayne, E. G. et al., "Growing Wheat in Kansas," Agricultural Experiment Station, Kansas State University, Manhattan, Kansas, Bulletin 463, (Jan. 1964), p. 29.

The "Wheat Production Handbook" suggests optimum planting dates for central Kansas are from September 25 to October 10.

Wheat planting period intervals in the model are two weeks in length. The optimum planting periods in the model are designated as October 1 - 15, approximating the Zone 3 (September 25 - October 10) planting time recommendation.

Planting dates that fall within the model's bi-weekly periods were used to estimate those periods' planting penalties (Table 7). Linear approximation for the November 1 - 15 plantings period's penalty would result in a 50 per cent reduction in yield. Because field experiment data are not available to support the use of such a large planting penalty for this period, the October 13 index is applied (Figure 3).

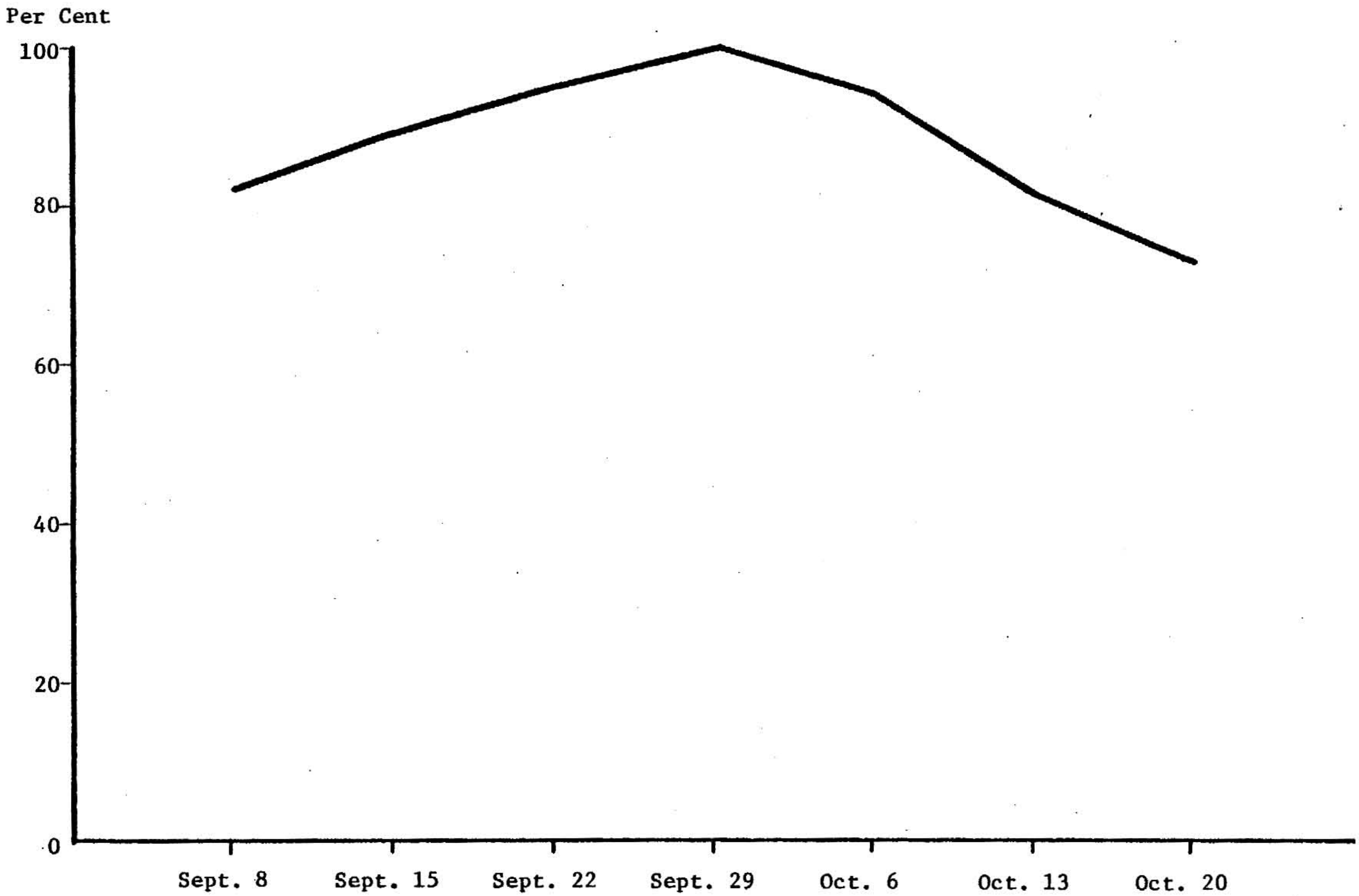



FIGURE 3: WHEAT YIELD INDEX AT DIFFERENT PLANTING DATES

TABLE 7

WHEAT PLANTING PERIODS AND PENALTY ESTIMATES

| Hays Experiment Date | Model Period | Index | Index Times Average Yield (Bu./Ac.) | Penalty (Bu./Ac.) |
|---|---|---|---|---|
| Sept. 8 | Sept. 1 - 15 | 82.0 | 23.7 | 5.4 |
| Sept. 22 | Sept. 16 - 30 | 95.1 | 27.7 | 1.3 |
| Sept. 29 | Oct. 1 - 15 | 100.0 | 29.1 | 0.0 |
| Oct. 13 | Oct. 16 - 31 | 80.7 | 23.5 | 5.6 |
| Oct. 20 | Nov. 1 - 15 | 72.5 | 21.1 | 8.0 |

The Farm Facts (1972-1976) continuous cropped wheat yield per acre planted for central Kansas is 29.1 bushels. The 29.1 bushel yield was assigned to the optimum planting period (Oct. 1-15). Penalty estimates for the remaining planting periods were solved for by multiplying their respective yield indexes times 29.1 bushels, and subtracting the result from 29.1 to obtain a bushel per acre penalty estimate for untimely wheat planting (Table 7).

## Wheat Pre-Optimum Harvest

The time that wheat harvest begins in central Kansas is usually between June 12 - 26 (24). The average date that harvest begins is the assumed optimum period and is designated as period June 5 (June 15-23) in the model. The pre-optimum period is that period when the field moisture content by weight of grain is between 16 and 13 per cent.

Wheat has reached physiological maturity when the plant's grain kernels contain 30 to 35 per cent moisture by weight (45). The moisture content of the grain kernels must drop approximately 50 per cent before the grain is ready for combining (45).

While the field grain moisture content is decreasing after physiological maturity, grain moisture content is not static. Moisture content of grain kernels passes through a diurnal cycle which depends on the difference between nighttime and daytime relative humidities.

Research (23) shows for Ohio conditions that the drying rate for wheat grain from physiological maturity to a harvest ripe stage (14 per cent moisture) appears to be about 2.5 per cent per day. For Ohio, normal drying time from 20 to 14 per cent moisture is approximately 4 days (23). Research (13) indicates that for Canadian conditions there may be only three days between 20 and 14 per cent field moisture.

Wheat harvest by combine should not begin until the grain moisture content has reached 20 per cent (13,25). Natural and mechanical losses that occur from harvesting wheat grain between 20 and 14 per cent moisture are not significant. Campbell and McQuitty, in evaluating their harvest simulation model, maintain:

> "Results from the harvest models indicated that mechanical and natural losses, as set out by Dodds and Johnson are not large enough to be significant. The average differences in total grain losses between moist and dry harvesting systems were all under 0.1 bushels per acre. Average total grain losses for the harvesting systems tested were in the range of 2%-3% of total yield." (10)

The model does not contain a yield loss penalty for pre-optimum harvesting, due to the relatively small losses that occur when grain is harvested at moisture levels between 20 and 14 per cent field moisture levels.

Kansas commercial elevators will not accept wheat grain with a moisture content in excess of 16 per cent. Typical commercial elevator docks (reduction in price) per bushel vary from 12 to 2 cents by moisture content (Table 8).

The pre-optimum harvest penalty based on moisture content is 10 cents, which is the average cost of the 16 and 15.5 per cent moisture's docks (Table 8). The 10 cent dock was applied to reflect the pre-optimum period's drying cost rather than a diurnal moisture phenomenon. The per acre drying cost is $2.91 for the June 4 (June 8-15) pre-optimum harvest period.

TABLE 8

KANSAS COMMERCIAL ELEVATOR MOISTURE DOCKAGE

| Moisture Content by Weight (Per Cent) | Dockage (¢/Bu.) |
|---|---|
| 16.0 | 12 |
| 15.5 | 8 |
| 15.2 | 7 |
| 15.0 | 6 |
| 14.5 | 4 |
| 14.2 | 3 |
| 14.0 | 2 |
| 13.0 | 0 |

Source: Manhattan Cooperative Elevator, Manhattan, Kansas, June 1, 1978.

Conceivably wheat harvested in the week long pre-optimum period due to varying field drying rates could have a moisture content greater than 16 per cent. Model adjustments can easily be made if the pre-optimum period is unwarrantly biased.

Delayed Wheat Harvest Penalty Estimates

Delayed harvest period losses are estimated with a timeliness coefficient. Research (4) indicates that wheat yield is reduced by 0.003 bushel per day of delay. The total number of days of delay in each weekly period was multiplied by the timeliness coefficient, and these resulting products for each delayed harvest period were then multiplied times the 29.1 average bushel yield to derive a per acre penalty estimate (Table 9).

TABLE 9

DELAYED WHEAT HARVEST PENALTY ESTIMATES

| Model Period | Calendar Date | Days of Delay | Penalty (Bu./Ac.) |
|---|---|---|---|
| June 5 | June 16-23 | 0 | 0 |
| June 6 | June 24-30 | 7 | 0.6 |
| July 3 | July 1-7 | 14 | 1.2 |
| July 4 | July 8-15 | 22 | 1.9 |
| July 5 | July 16-23 | 30 | 2.6 |
| July 6 | July 24-31 | 38 | 3.3 |

Alfalfa Penalty Estimates

"The goal of the alfalfa producer is to obtain the largest yield of high quality forage consistent with reasonable stand survival." (42) The relationship between stage of growth (maturity stage), yield (tons of dry matter per acre), and quality (protein content) is that as the alfalfa plant matures, yield increases and quality decreases (Table 10).

TABLE 10

AVERAGE CONTENT OF SEVERAL CHEMICAL CONSTITUENTS IN THE FIRST-GROWTH OF ALFALFA OVER A THREE YEAR PERIOD, 1959 - 1961, AT MADISON, WISCONSIN

| Stage of Growth | Dry Matter lbs./acre | Per Cent Protein | Per Cent Fiber | Per Cent TDN* |
|---|---|---|---|---|
| Vegetative | 989 | 31.2 | 12.9 | 87.0 |
| Prebud | 1920 | 26.8 | 15.4 | 82.6 |
| Early bud | 3454 | 22.2 | 22.8 | 72.8 |
| First flower | 4659 | 18.2 | 33.0 | 60.1 |
| Full bloom | 6627 | 15.5 | 32.2 | 60.0 |
| Green seed pod | 6693 | 14.8 | 43.3 | 57.4 |

* Total Digestible Nutrients

Source: Rohwider, Dwayne A., "Maintaining Forage Stands for Efficient Production," University of Wisconsin Extension, A-2907, Jan. 1978, p. 7.

Many investigations on the subject of maturity stage cutting's effect on dry matter yield, feed value, and stand persistence have been conducted (20,32,44). Most investigations are based on stage of development (maturity stage) and have shown harvesting alfalfa at the 10 per cent bloom stage is the best compromise for acceptable herbage yield, nutrient yield, and stand persistence (41).

Quantifying the relationships between stage of growth, protein content, and herbage yield for a linear program model containing penalties for the untimely cutting of alfalfa consists of three procedures:

a) determining the economic value of alfalfa cut at varying growth stages,

b) estimating dry matter yield in tons per acre for different growth stages per cutting, and

c) estimating the normal occurrence of growth stages per cutting by calendar date.

Rohwider et al. (33) have proposed a legume hay marketing guide for the valuing of alfalfa, cut at different stages of maturity (Table 11). To use Rohwider's et al. relative feed values for varying growth stages as a means of estimating penalties for untimely alfalfa harvest, the following steps were taken:

a) the cutting of alfalfa before the early bloom (1/10 bloom) stage is detrimental to stand persistence (41,44). For this reason the cutting of alfalfa during the pre bloom stage of plant development is not allowed in this analysis,

b) the relative feed values ranges given for the early and mid bloom were each averaged, the mid point for each range was assumed to be a representative value for that maturity stage (Table 11),

c) the relative feed value of 100 for the full bloom and later stages was applied as a representative value for that maturity stage, and

d) the relative feed value calculated mid points for early and mid bloom growth stages, and the full bloom's relative feed value (100) were indexed. The early bloom's relative feed value's mid point was given an index equal to 100 and the remaining growth stages feed values were indexed as a per cent of the early bloom's mid point feed value (Table 11).

The 1/10 bloom (early bloom) alfalfa growth stage for the first cutting in central Kansas occurs approximately on May 15 (42). Salmon (34) found the average interval between the 1/10 bloom (early bloom) and full bloom stage is 11 days. A more recent study (19) for Ohio conditions placed the average interval from early to full bloom stage at 12 days.

TABLE 11

MATURITY STAGES AND FEED VALUES OF ALFALFA HAY

| Grades | Stage of Maturity International Term | Definition | Physical Description* | Relative Feed Value | Mid Point | Index |
|---|---|---|---|---|---|---|
| 1. Legume Hay | Pre bloom | Bud to first flower; stage at which stems are beginning to elongate just before blooming. | 40 to 50% leaves; green; less than 5% foreign material, free of mold, musty odor, dust, etc. | 140 | - | - |
| 2. Legume Hay | Early bloom | Early to mid bloom; stage between initiation of bloom and stage in which 1/2 of the plants are in bloom. | 35 to 45% leaves; light green to green; less than 10% foreign material; free of mold, musty odor, dust, etc. | 124-140 | 132 | 100.00 |
| 3. Legume Hay | Mid bloom | Mid to full bloom; stage in which 1/2 or more of the plants are in bloom. | 25 to 40% leaves; yellow green to green; less than 15% foreign material; free of mold, musty odor; dust, etc. | 101-123 | 112 | 84.85 |
| 4. Legume Hay | Full bloom | Full bloom and beyond. | Less than 30% leaves; brown to green; less than 20% foreign material; slightly musty odor, etc. | 100 | 100 | 75.76 |

* Per cent leaves is proportion by weight.

Source: Rohwider, D.A.; Barnes, R.F.; and Jorgensen, N. "Marketing Hay on the Basis of Analysis," How Far With Forages for Meat and Milk Production." American Forage and Grassland Council, Lexington, Kentucky, (1977) p. 32.

The regrowth period in Kansas from cutting alfalfa at the 1/10 bloom stage to an aftermath regrowth stage of 1/10 bloom is an average 31 days (34,42). The average number of days between cutting from full bloom to full bloom growth stages is 39.8 days (34).

The weekly alfalfa periods used in the model and the approximate growth stage interval associated with each weekly period are given in Table 12. Growth stage intervals are applied for model use, rather than specific growth stages, i.e. (1/10 bloom), because of the relatively rapid plant development from one growth stage to another per cutting.

The number of days between each growth stage interval to an identical interval in a following cutting in the model is between 32 and 39 days. Per cutting intervals between first flower to mid bloom stage and mid to full bloom stage are 8 to 15 days in length.

There are normally three dryland alfalfa cuttings yearly in central Kansas (30,42). Kansas Farm Facts (1966-1976) average alfalfa yield per acre harvested for central Kansas is 2.85 tons of dry matter. Kansas Crops Planting to Harvest statistics place the majority of alfalfa cuttings occurrence by calendar date between the mid and full bloom growth stages. The 2.85 tons per acre yield was portioned over three cuttings so that the sum of the cuttings yields at the mid to full bloom growth intervals equals the average yield. The remaining growth stage interval's yields per cutting were solved for by applying index numbers as follows:

a) for each cutting yields (ton/acre) associated with the growth stages 1/10 bloom and mid bloom, mid bloom and full bloom, and full bloom and seed stage were averaged to obtain an average yield for growth intervals per cutting, i.e. (yield 1/10 bloom + yield mid bloom)/2 = first flower to mid bloom growths interval's average yield (Table 12), and

b) the growth interval per cutting associated with the highest yield was set equal to 100 for each cutting and the remaining two growth intervals' yields per cutting were indexed as a per cent of the highest yield per cutting (Table 12).

The following procedure was used to derive dollar per acre penalty estimates for the untimely harvesting of alfalfa:

a) growth interval yields for each cutting were multiplied times their appropriate feed value indexes to reflect forage quality per growth interval per cutting,

b) each growth intervals' yield times feed value index product for each cutting was multiplied by the alfalfa price $37.26, (corn-alfalfa ratio times $2.00 corn), and

c) the second and third growth interval's yield time feed value index time price values per cutting were subtracted from the first growth interval's yield times feed value index per cutting to obtain a per acre penalty estimate (Table 13).

Multiple Right-Hand-Side

Buller, Langemeir, Kasper, and Stone (6) estimated the frequency of occurrence of field workdays in bi-monthly periods for six Kansas regions with the 'Versatile Soil Moisture System.' The frequency of occurrence of field workdays was estimated for the months April through October. Meteorological data were not available to allow estimation of field workdays for the winter months March, November, and December with the 'Versatile Soil Moisture System.' Estimates of field workdays for the months March, November, and December were made as follows: March

TABLE 12

ESTIMATED CENTRAL KANSAS ALFALFA YIELD PER CUTTING

| Stage of Growth[1] | Yield (ton/ac.) | Time Interval | Interval Average Yield (ton/ac.) | Interval Average Yield Index | Estimated Central Kansas Yield (ton/ac.) |
|---|---|---|---|---|---|
| | | FIRST CUTTING | | | |
| Bud | 0.91 | | | | |
| 1/10 bloom | 1.11 | | | | |
| | | First flower to mid bloom | 1.15 | 92.00 | 1.18 |
| Mid bloom | 1.18 | | | | |
| | | Mid bloom to full bloom | 1.21 | 97.00 | 1.24 |
| Full bloom | 1.23 | | | | |
| | | Full bloom and beyond | 1.25 | 100.00 | 1.29 |
| Seed stage | 1.27 | | | | |
| | | SECOND CUTTING | | | |
| Bud | 0.64 | | | | |
| 1/10 bloom | 0.87 | | | | |
| | | First flower to mid bloom | 0.89 | 97.00 | 0.92 |
| Mid bloom | 0.91 | | | | |
| | | Mid bloom to full bloom | 0.93 | 100.00 | 0.96 |
| Full bloom | 0.94 | | | | |
| | | Full bloom and beyond | 0.93 | 100.00 | 0.96 |
| Seed stage | 0.92 | | | | |
| | | THIRD CUTTING | | | |
| Bud | 0.47 | | | | |
| 1/10 bloom | 0.50 | | | | |
| | | First flower to mid bloom | 0.54 | 86.00 | 0.56 |
| Mid bloom | 0.58 | | | | |
| | | Mid bloom to full bloom | 0.63 | 100.00 | 0.65 |
| Full bloom | 0.68 | | | | |
| | | Full bloom and beyond | 0.54 | 86.00 | 0.56 |
| Seed stage | 0.40 | | | | |

[1]Salmon, A.C.; Swanson, C.O.; and McCampbell, C.W. "Experiments Relating to Time of Cutting Alfalfa," Kansas Agricultural Experiment Station Technical Bulletin 15, (1925), p. 32.

TABLE 13

ALFALFA PENALTY ESTIMATES

| Model Growth Interval | Time Interval | Interval Average Yield (ton/ac.) | Interval Feed Value Index | (1) Interval Average Yield Times Feed Value Index | (1) Times Alfalfa Price | Penalty Estimate ($/ac.) |
|---|---|---|---|---|---|---|
| | | First Cutting | | | | |
| First flower to mid bloom | 1 (May 16-23) | 1.18 | 100.00 | 1.18 | $43.97 | 0.00 |
| Mid bloom to full bloom | 2 (May 24-31) | 1.24 | 84.85 | 1.05 | $39.12 | $4.77 |
| Full bloom and beyond | 3 (June 1-7) | 1.29 | 75.76 | 0.98 | $36.51 | $7.85 |
| | | Second Cutting | | | | |
| First flower to mid bloom | 4 (June 16-23) | 0.92 | 100.00 | 0.92 | $34.28 | 0.00 |
| Mid bloom to full bloom | 5 (June 24-30) | 0.81 | 84.85 | 0.81 | $30.18 | $4.03 |
| Full bloom and beyond | 6 (July 1-7) | 0.73 | 75.76 | 0.73 | $27.10 | $7.18 |
| | | Third Cutting | | | | |
| First flower to mid bloom | 7 (July 16-23) | 0.56 | 100.00 | 0.56 | $20.12 | 0.00 |
| Mid bloom to full bloom | 8 (July 24-31) | 0.65 | 84.85 | 0.53 | $19.91 | $0.21 |
| Full bloom and beyond | 9 (Aug. 1-7) | 0.56 | 75.75 | 0.41 | $15.24 | $4.88 |

has fewer field workdays than April because March normally has less precipitation and cooler temperatures than April; November and December have fewer field workdays than October because November and December normally have cooler temperatures and less precipitation than October. When precipitation occurs, cooler temperatures in March, November, and December will prolong upper layer soil drying time as compared to warmer months.

Buller's et al. field workday estimates for central Kansas are grouped in weekly or bi-weekly periods to fit how the model describes the important labor periods throughout the year. Five sets of field workday estimates are studied. The average number of field workdays set is based on "weighting each number of workdays by the probability of that number of workdays occurring" (6).

The right-hand-side values for labor are varied to study the effects of wet years in terms of field workdays on machinery and crop selection. To simulate the impact of wet years on machinery and crop selection, the four wettest years' (1951, 1957, 1965, and 1967) field workday data records are used (Table 14). The bi-weekly field workday periods for the late spring and early summer months are calculated by the summing of two weekly periods (Table 14).

TABLE 14

FIELD WORKDAY ESTIMATES

| Period | Average | Year 1951 | 1957 | 1965 | 1967 |
|---|---|---|---|---|---|
| March 1-15 | 9* | 9* | 9* | 9* | 9* |
| March 16-31 | 9* | 9* | 9* | 9* | 9* |
| April 1-15 | 11 | 4 | 3 | 8 | 5 |
| April 16-30 | 11 | 8 | 11 | 14 | 14 |
| May 1-7 | 4 | 3 | 0 | 6 | 5 |
| May 8-15 | 6 | 2 | 2 | 6 | 5 |
| May 16-23 | 6 | 0 | 3 | 6 | 8 |
| May 24-31 | 4 | 6 | 5 | 4 | 5 |
| June 1-7 | 4 | 5 | 1 | 0 | 7 |
| June 8-15 | 5 | 0 | 6 | 0 | 6 |
| June 16-23 | 5 | 1 | 0 | 6 | 1 |
| June 24-30 | 5 | 0 | 0 | 0 | 3 |
| July 1-7 | 5 | 2 | 4 | 2 | 2 |
| July 8-15 | 6 | 3 | 8 | 6 | 1 |
| July 16-23 | 6 | 6 | 7 | 8 | 1 |
| July 24-31 | 6 | 8 | 8 | 8 | 3 |
| August 1-7 | 6 | 6 | 7 | 7 | 5 |
| August 8-15 | 6 | 0 | 8 | 8 | 7 |
| August 16-31 | 12 | 16 | 15 | 5 | 16 |
| September 1-15 | 10 | 2 | 10 | 5 | 7 |
| September 16-30 | 9 | 11 | 12 | 2 | 4 |
| October 1-15 | 12 | 15 | 7 | 11 | 4 |
| October 16-31 | 12 | 11 | 0 | 12 | 14 |
| November 1-15 | 9* | 9* | 9* | 9* | 9* |
| November 16-30 | 9* | 9* | 9* | 9* | 9* |
| December 1-15 | 8* | 8* | 8* | 8* | 8* |
| December 16-31 | 8* | 8* | 8* | 8* | 8* |
| Total | 203 | 161 | 169 | 176 | 175 |

* Estimates not directly calculated by the Versatile Soil Moisture System.

NOTE: A workday contains 10 hours, so labor available in average year for March 1-15 is 90 hours.

## Machinery and Implement Data

### Large Tractor Data

Tractor size is in terms of power take-off horsepower units (pto hp). Large tractor sizes studied range from 90 to 215 pto hp (Table 15). Tractor list prices were obtained from machinery and implement dealers; no options are included in list prices.[1] (Table 15)

A tractor's pto hp is converted to drawbar horsepower (Table 15). "Useable drawbar horsepower refers to the amount of power you should assume to be available to pull an implement for a given set of conditions" (5). Conditions consist of speed in miles per hour, tire slippage, and draft (soil resistance). Bowers (5) gives conversion factors of 0.55 for tilled soil and 0.64 for firm soil as a means of converting pto hp to useable drawbar horsepower. Useable drawbar horsepower is applied to solve for field tillage implement widths for each size of large tractor studied.

### Large Tractor Field Tillage Implement Sets

Field tillage implement widths for each size of large tractor studied are determined from the following formula:

$$\text{"Implement Width} = \frac{\text{Useable Drawbar Horsepower} \times 375}{\text{M.P.H.} \times \text{Draft (lbs. per foot of width)"}} \quad (5)$$

The constant 375 in the formula is a standard factor used in drawbar horsepower formulas. "Draft is the total force parallel to the direction of travel required to propel the implement." (2) For the central Kansas area, a medium (loam) soiltype is assumed for draft estimation

## TABLE 15

## LARGE TRACTOR DATA AND COST ESTIMATES

| Tractor Size[1] (pto hp) | Usable Horsepower (Tilled Soil) | Usable Horsepower (Firm Soil) | List Price | Depreciation[2] | Total[3] Variable Cost ($/hr.) | Repair[4] Cost ($/hr.) | Fuel[5] Cost ($/hr.) | Oil and[6] Lubrication Cost ($/hr.) |
|---|---|---|---|---|---|---|---|---|
| 90 (2WD) | 49.5 | 57.6 | $20,600 | $1751 | $ 4.87 | $2.06 | $2.44 | $0.37 |
| 110 (2WD) | 60.5 | 70.4 | $28,000 | $2520 | $ 6.23 | $2.80 | $2.98 | $0.45 |
| 130 (2WD) | 71.5 | 83.2 | $33,000 | $2805 | $ 7.35 | $3.30 | $3.52 | $0.53 |
| 155 (4WD) | 85.3 | 99.2 | $39,000 | $3315 | $ 8.07 | $3.24 | $4.20 | $0.63 |
| 180 (4WD) | 99.0 | 115.2 | $43,000 | $3655 | $ 9.18 | $3.57 | $4.88 | $0.73 |
| 215 (4WD) | 118.3 | 137.2 | $49,000 | $4165 | $10.88 | $4.07 | $5.28 | $0.87 |

1 (WD) is number of drive wheels.
2 Depreciation is based on a 15% salvage value for tractors with a ten year useful life.
3 Total hourly variable cost is the sum of repair, fuel, and oil-lubrication costs.
4 Repair costs are:

a) 2 wheel drive tractor ; $\frac{\text{Initial List Price}}{\$1{,}000} * 0.10 = \$/\text{hr.}$ (36)

b) 4 wheel drive tractor ; $\frac{\text{Initial List Price}}{\$1{,}000} * 0.083 = \$/\text{hr.}$ (36).

5 Fuel cost is : 0.043 * tractor's maximum pto hp = gal./hr. times $0.63 gal. diesel (36).
6 Oil and lubrication cost is 15% of total fuel costs (36).

(Table 16). Typical field travel speeds for field tillage operations are presented in Table 16.

The firm soil's computed useable drawbar horsepower (Table 15) for each tractor size is used to solve for moldboard plow implement width. Tilled soil's computed useable drawbar horsepower values (Table 15) for each tractor size are used to determine tandem disk and springtooth implement widths (Table 16).

## Machinery and Implement Selection Possibilities

The model selects combine, row planter, row cultivator, and grain drill widths. For each tractor size studied the model can select either a 20 foot, 24 foot, or a 24 foot custom combine for wheat and grain sorghum harvests. Row planter, row cultivator, and grain drill selection possibilities are a function of tractor size. With larger tractor sizes of 155, 180, and 215 pto hp, the model allows selecting 16, 25, and 33 foot grain drills and 6, 8, 12, or 18 row crop planters and cultivators. For the tractor size of 130 pto hp, the model can select from 4, 6, 8, or 12 row crop planters and cultivators and 8, 13, 16, or 25 foot grain drills. For the 90 and 110 pto hp tractor sizes, the model can select from 4, 6, or 8 row crop equipment and 8, 13, or 16 foot grain drills.

## Crop Machinery and Implement Field Operations Per Acre

Field operations for each acre of wheat, grain sorghum, and alfalfa produced are from "Labor Requirements of Central Kansas Crops" (Table 17). Alfalfa field preparation and planting time is prorated over a

TABLE 16

LARGE TRACTOR IMPLEMENTS SETS AND DATA

| Tillage Operation | Draft[1] (lbs./ft. of width) | Typical[2] Speed (M.P.H.) | Tractor and Tillage Implement Sets, Tractor pto hp: 90 | 110 | 130 | 155 | 180 | 215 |
|---|---|---|---|---|---|---|---|---|
| Moldboard plow | 1,000 | 4.5 | 3-16 | 4-16 | 5-16 | 6-16 | 7-16 | 9-16 |
| Tandem disk | 250 | 5.0 | 15'3" | 18' | 21' | 25'2" | 30'2" | 38'3" |
| Wheeled springtooth | 190 | 5.0 | 21' | 24' | 27' | 33' | 36' | 48' |

[1] Source: 1977 Agricultural Engineers Yearbook. American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, Mi. (1977), p. 331.

[2] Source: Schrock, Mark D., "Avoiding Machinery Bottlenecks," Cooperative Extension Service, Kansas State University, Manhattan, Kansas (Oct. 1977).

five year period. The possible times of occurrence of field operations are shown in Figure 4.

## Field Capacity of Farm Machinery and Labor Coefficients

Field capacity is the effective actual rate of performance of field work (2). For the central Kansas study, field capacity is expressed as the rate in hours per acre that field operations can be accomplished. The capacity formula is in terms of total time.

$$\text{"Total Time} = \frac{8.25}{S \times EW \times E} \times 1.25 + \frac{8.25}{S \times EW \times E} \times 0.125$$

where S = traveling speed over field in miles per hour

EW = effective width, width over which the machine works

E = field efficiency, ratio of the effective field capacity to theoretical field capacity expressed in per cent

The 1.25 coefficient is used to reflect additional travel time to and from field, equipment adjustments, repair and maintenance.

The 0.125 coefficient is an indirect labor charge for the time required for accounting, managing, marketing, auto and pickup use and purchasing repair parts." (25)

Labor coefficients are identical to machinery coefficients, except for combine field operations. Labor coefficients for harvesting are double the machinery coefficients to allow for a combine operator, travel time to and from fields for hauling grain to storage. Table 19 states the machinery coefficients for all field operations except the baling and hauling of alfalfa hay.

TABLE 17

FIELD OPERATIONS PER ACRE

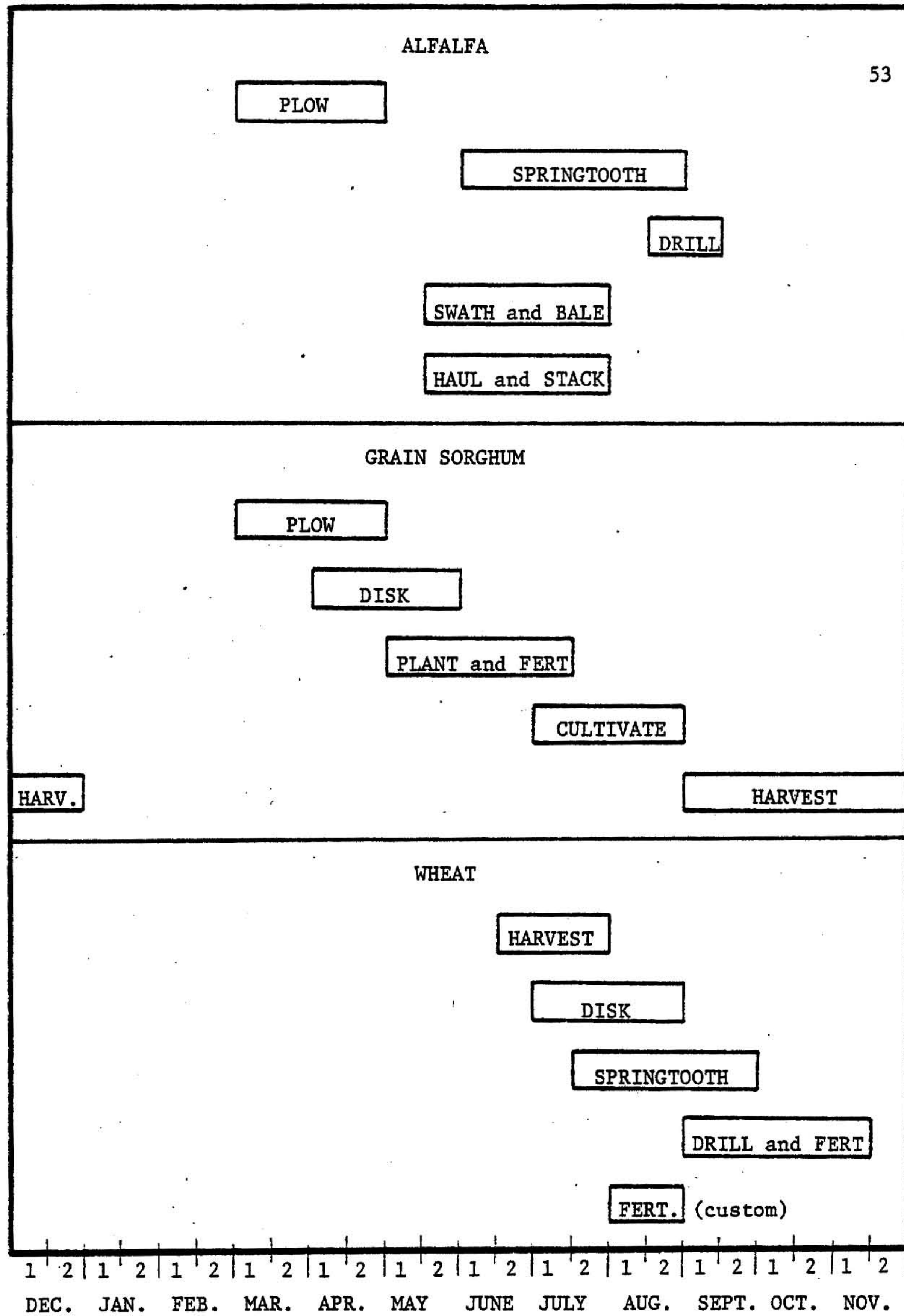
| Field Operation | Times Over | Months |
|---|---|---|
| | WHEAT | |
| Tandem disk | 2 | July, August |
| Wheeled springtooth | 3 | August, September |
| Anhydrous fertilizer | 1 | August |
| Drill/fertilizer | 1.06 | September, October |
| Combine | 1 | June, July |
| | GRAIN SORGHUM | |
| Moldboard plow | 1 | March |
| Tandem disk | 1 | May |
| Planter/fertilizer | 1.1 | May, June, July |
| Row cultivator | 2 | July, August |
| Combine | 1 | |
| | ALFALFA* | |
| Moldboard plow | 0.2 | March, April |
| Wheeled springtooth | 0.6 | June, July, August |
| Drill/fertilizer | 0.2 | August, September |
| Swather | 3 | May, June, July |
| Baler | 3 | May, June, July |

* Alfalfa plowing and springtooth operations are prorated over five years.

Source: Modified version of: "Labor Requirements of Central Kansas Crops." Agricultural Experiment Station, Kansas State University. Bulletin 589.

FIGURE 4: CROP CALENDAR






Sources 1. "Kansas Crops Planting to Harvest 1963-1973," Kansas Crop and Livestock Reporting Service, Topeka, Kansas, 1974.

2. Kasper, John L.; Langemeir, Larry N.; and Buller, Orlan H., "Labor Requirements of Central Kansas Crops," Agricultural Experiment Station, Kansas State University, Manhattan, Kansas, Bulletin 589, July 1974.

Machinery capacity for baling alfalfa is normally expressed in tons per hour (2). Coefficients in terms of tons per hour would not meet the desired hour per acre field capacity rate used in the model. Research (38) indicates that labor requirements for conventional baling is 0.16 man hour per ton of hay. Alfalfa yields per growth interval per cutting were each multiplied times the 0.16 per hour baling coefficient to determine the man hours per acre. The resulting values were multiplied times a 0.0625 indirect labor charge factor, as used in the total time equation for all other field work. The resulting products for each growth interval per cutting were summed to derive per acre baling machinery and labor coefficients (Table 18).

Research (38) indicates that hauling one mile and storing baled hay takes 1.11 man hours per ton. The alfalfa yields per growth interval per cutting were multiplied times the 1.11 man hours per ton to derive per acre hay hauling and storing labor coefficients (Table 18). Hay bales are assumed to weigh 75 pounds. The cost of custom hauling and storing hay is $0.25 per bale. The ton per acre yield per cutting was multiplied times 2000 pounds and then divided by 75 pounds; this result was then multiplied times $0.25 to obtain per acre custom hauling and storing costs per cutting (Table 18).

## Machinery and Implement Cost Estimates

Tractor and combine variable costs are repair and maintenance, oil and lubrication, and fuel. Implement variable cost is repair and maintenance cost. Per acre field operations (combining, grain drilling, row cultivating, row planting) were multiplied by their respective hour

TABLE 18

HAY BALING, HAY STORAGE AND HAULING MACHINERY AND LABOR COEFFICIENTS; AND CUSTOM HAY HAULING AND STORAGE COSTS

| | Baling (hr./ac.) | Haul and Store (hr./ac.) | Custom Haul and Store ($/ac.) |
|---|---|---|---|
| First Cutting | | | |
| First flower to mid bloom | 0.25 | 1.31 | $7.87 |
| Mid bloom to full bloom | 0.27 | 1.38 | $8.27 |
| Full bloom and beyond | 0.28 | 1.43 | $8.60 |
| Second Cutting | | | |
| First flower to mid bloom | 0.20 | 1.02 | $6.13 |
| Mid to full bloom | 0.21 | 1.07 | $6.40 |
| Full bloom and beyond | 0.21 | 1.07 | $6.40 |
| Third Cutting | | | |
| First flower to mid bloom | 0.12 | 0.62 | $3.73 |
| Mid bloom to full bloom | 0.14 | 0.72 | $4.33 |
| Full bloom and beyond | 0.12 | 0.62 | $3.73 |

per acre machinery coefficients to obtain per acre variable cost estimates. The objective row costs for field operations that require a large tractor are a tractor's per acre repair and maintenance, oil and lubrication, and fuel cost plus the implements' per acre repair and maintenance cost (Table 19).

Repair and maintenance variable cost for combines, tractors, and implements are estimated with annual repair cost estimators. Annual repair cost estimators are used in the following manner:

$$\frac{\text{Machine or Implement Initial List Price}}{\$1{,}000} \times \text{Annual Repair Cost Estimator} = \text{Hourly Repair and Maintenance Cost (36)}$$

Schlender and Schrock (36) compiled the annual repair cost estimators from data published in the Agricultural Engineers Yearbook. Annual repair cost estimators are: 0.1 for two wheel drive tractors; 0.083 for four wheel drive tractors; and 0.3 for combines; and 0.48 for tillage tools.

Hourly repair and maintenance costs estimated with annual repair cost estimators are the average hourly costs for the machine or implement life; therefore, estimated costs are greater than actual costs incurred for the first segment of a machine's or implement's life and are lower than actual costs incurred for the last segment of machine or implement life (36).

Average diesel fuel consumption per hour is estimated to be 0.043 times a tractor's maximum pto hp (2). The price of diesel fuel is $0.63 per gallon. A tractor's maximum pto hp times 0.043 product is multiplied by the diesel fuel price to obtain estimated per hour fuel costs (2).

TABLE 19

MACHINERY AND IMPLEMENT DATA AND COSTS

| Implement | Speed[1] (M.P.H.) | Field[1] Efficiency | Effective Width (feet) | Machinery Coefficient (hr./ac.) | Purchase[2] Price | Implement Variable Cost | Tractor + Implement Variable Cost | Annual[3] Depreciation |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Per hour | Per hour | |
| Moldboard plow | | | | | | | | |
| 3-16 | 4.5 | 80% | 4.0 | 0.78 | $ 2,845 | $1.37 | $ 6.24 | $ 254.50 |
| 4-16 | 4.5 | 80% | 5.3 | 0.59 | $ 4,184 | $2.01 | $ 8.24 | $ 418.50 |
| 5-16 | 4.5 | 80% | 6.7 | 0.47 | $ 6,845 | $3.39 | $10.64 | $ 684.50 |
| 6-16 | 4.5 | 80% | 8.3 | 0.39 | $ 7.625 | $3.66 | $11.73 | $ 762.50 |
| 7-16 | 4.5 | 80% | 9.6 | 0.34 | $ 8,700 | $4.18 | $13.36 | $ 870.55 |
| 9-16 | 4.5 | 80% | 11.5 | 0.26 | $10,600 | $5.18 | $16.33 | $1,060.00 |
| Tandem disk | | | | | | | | |
| 15.25' | 5.0 | 80% | 15.25 | 0.19 | $ 3,911 | $1.88 | $ 6.75 | $ 391.10 |
| 18.00' | 5.0 | 80% | 18.00 | 0.16 | $ 4,277 | $2.05 | $ 8.28 | $ 427.70 |
| 21.00' | 5.0 | 80% | 21.00 | 0.14 | $ 7,357 | $3.54 | $10.89 | $ 737.50 |
| 25.17' | 5.0 | 80% | 25.17' | 0.11 | $10,282 | $4.94 | $13.01 | $1,028.20 |
| 30.17' | 5.0 | 80% | 30.17' | 0.09 | $11,541 | $5.54 | $14.72 | $1,154.10 |
| 38.25' | 5.0 | 80% | 38.25' | 0.07 | $16,178 | $7.76 | $18.52 | $1,617.80 |
| Wheeled springtooth | | | | | | | | |
| 21.00' | 5.0 | 80% | 21.00 | 0.14 | $ 1,800 | $0.86 | $ 5.73 | $ 180.00 |
| 24.00' | 5.0 | 80% | 24.00 | 0.12 | $ 2,158 | $1.04 | $ 7.72 | $ 218.50 |
| 27.00' | 5.0 | 80% | 27.00 | 0.11 | $ 2,500 | $1.20 | $ 8.55 | $ 250.00 |
| 33.00' | 5.0 | 80% | 33.00 | 0.09 | $ 3,200 | $1.54 | $ 9.61 | $ 320.00 |
| 36.00 | 5.0 | 80% | 36.00 | 0.08 | $ 3,400 | $1.63 | $10.81 | $ 340.00 |
| 48.00 | 5.0 | 80% | 48.00 | 0.06 | $ 5,200 | $2.50 | $13.26 | $ 520.00 |

TABLE 19 (Continued)

| Implement | Speed[1] (M.P.H.) | Field[1] Efficiency | Effective Width (feet) | Machinery Coefficient (hr./ac.) | Purchase Price[2] | Implement Variable Cost | | Tractor + Implement Varibale Cost | | | | | | Annual[3] Depreciation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Per Hour | Per Acre | 90 hp | 110 hp | 130 hp | 155 hp | 180 hp | 215 hp | |
| | | | | | | | | Per Acre | | | | | | |
| Row Planter | | | | | | | | | | | | | | |
| 4-row, 30" row | 4.0 | 55.0% | 10.00 | 0.52 | $ 5,700 | $2.74 | $1.42 | $3.96 | $4.66 | $5.25 | - | - | - | $ 570.00 |
| 6-row, 30" row | 4.0 | 55.0% | 15.00 | 0.34 | $ 6,900 | $3.31 | $1.13 | $2.78 | $3.24 | $3.62 | $3.87 | $4.25 | $4.78 | $ 690.00 |
| 8-row, 30" row | 4.0 | 55.0% | 20.00 | 0.26 | $ 8,900 | $4.27 | $1.10 | $2.38 | $2.73 | $3.02 | $3.21 | $3.50 | $3.91 | $ 890.00 |
| 12-row, 30" row | 4.0 | 55.0% | 30.00 | 0.17 | $11,765 | $5.65 | $0.96 | - | - | $2.21 | $2.33 | $2.52 | $2.79 | $1,176.50 |
| 18-row, 30" row | 4.0 | 55.0% | 45.00 | 0.11 | $18,000 | $8.64 | $0.95 | - | - | - | $0.87 | $0.96 | $1.09 | $1,800.00 |
| Row Cultivator | | | | | | | | | | | | | | |
| 4-row, 30" row | 4.5 | 72.5% | 10.00 | 0.35 | $ 1,500 | $ .72 | $0.25 | $1.96 | $2.43 | $2.82 | - | - | - | $ 150.00 |
| 6-row, 30" row | 4.5 | 72.5% | 15.00 | 0.23 | $ 2,650 | $1.27 | $0.29 | $1.41 | $1.73 | $1.98 | $2.15 | $2.40 | $2.77 | $ 265.00 |
| 8-row, 30" row | 4.5 | 72.5% | 20.00 | 0.17 | $ 3,700 | $1.78 | $0.30 | $1.13 | $1.36 | $1.55 | $1.67 | $1.86 | $2.13 | $ 370.00 |
| 12-row, 30" row | 4.5 | 72.5% | 30.00 | 0.12 | $ 4,800 | $2.30 | $0.29 | - | - | $1.16 | $1.24 | $1.38 | $1.57 | $ 480.00 |
| 18-row, 30" row | 4.5 | 72.5% | 45.00 | 0.08 | $ 5,900 | $2.83 | $0.23 | - | - | - | $0.87 | $0.96 | $1.09 | $ 590.00 |
| Grain Drill | | | | | | | | | | | | | | |
| 8 foot | 5.0 | 72.5% | 8.33 | 0.38 | $ 4,260 | $1.62 | $0.62 | $2.47 | $2.98 | $3.41 | - | - | - | $ 426.00 |
| 13 foot | 5.0 | 72.5% | 13.17 | 0.23 | $ 5,260 | $2.70 | $0.62 | $1.74 | $2.05 | $2.31 | - | - | - | $ 526.00 |
| 16 foot | 5.0 | 72.5% | 16.76 | 0.19 | $ 8,520 | $4.09 | $0.78 | $1.70 | $1.96 | $2.17 | $2.31 | $2.52 | $2.82 | $ 852.00 |
| 25 foot | 5.0 | 72.5% | 25.00 | 0.12 | $12,780 | $6.13 | $0.80 | - | - | $1.75 | $1.85 | $1.99 | $2.20 | $1,278.00 |
| 33 foot | 5.0 | 72.5% | 33.33 | 0.08 | $17,040 | $8.13 | $0.84 | - | - | - | $1.46 | $1.56 | $1.70 | $1,704.00 |

TABLE 19 (Continued)

| Machine or Implement | Speed[1] (M.P.H.) | Field[1] Effieicncy | Effective Width (feet) | Machinery Coefficient (hr./ac.) | Purchase[2] Price | Variable Cost Per Acre | Annual[3] Depreciation |
|---|---|---|---|---|---|---|---|
| Swather | | | | | | | |
| 111", pto | 5.0 | 77.5% | 9.25 | 0.20 | $ 4,850 | - | $ 485.00 |
| Baler | | | | | | | |
| square bales, pto | - | - | - | - | $ 4,960 | - | $ 496.00 |
| Combine | | | | | | | |
| 20 ft. Wheat | 4.5 | 72.5% | 20.00 | 0.34 | $41,000 | $2.23 | $3,690.00 |
| 20 ft. Grain Sorghum | 3.5 | 62.5% | 20.00 | 0.48 | $ ' ' | $2.72 | $ ' ' |
| 24 ft. Wheat | 4.5 | 72.5% | 24.0 | 0.30 | $55,000 | $2.45 | $4,950.00 |
| 24 ft. Grain Sorghum | 3.5 | 62.5% | 24.0 | 0.40 | $ ' ' | $3.11 | $ ' ' |

1 Source: Schrock, Mark D, "Avoiding Machinery Bottlenecks," Cooperative Extension Service, Kansas State University, (Oct. 1976).

2 Source: Interview machinery and implement dealers in Hutchinson, Kansas (June, 1978).

3 Depreciation values are based on 10 per cent salvage value for combine with a ten year useful life; remaining implement depreciation based on ten year useful life with no salvage value. Depreciation method is straight line.

Schlender and Schrock (36) estimated fuel consumption for wheat and grain sorghum harvests to be 1.00 and 1.6 gallons per acre, respectively.

Kansas State University Farm Management Guide: "Custom Rates for Harvesting and Haying Operations," was used to estimate custom combine per acre rates of $9.42 and $10.64 for wheat and grain sorghum harvests, respectively. The custom rate for wheat anhydrous ammonia application per acre is $2.57 (28).

Alfalfa haying equipment size is fixed in the model. Power take-off swather and baler list prices and annual depreciations are given in Table 19. The per acre repair and maintenance, oil and lubrication, and fuel costs for haying equipment is given in the crop budget section. The small tractor is assumed to be fully depreciated.

## Crop Budgets

The objective value maximizes gross returns less variable costs for alfalfa production. Wheat and grain sorghum objective values are the per acre variable costs of production less fuel, oil and repair costs. Wheat, grain sorghum, and alfalfa per acre variable costs are partially from Kansas State University Extension publications (Table 20). Prices are each crop's respective cumulative average crop price to corn ratio (1959 - 1977) times two dollars the price of corn. Returns from wheat and grain sorghum activities enter the objective equation through separate crop selling activities from their respective production equations.

TABLE 20

CROP BUDGETS AND CROP ACTIVITY OBJECTIVE ROW VALUES

| Variable Costs (per acre) | Alfalfa[1] | Grain Sorghum[2] | Wheat[3] |
|---|---|---|---|
| Seed (Alfalfa prorated over 5 years) | $ 3.15 | $ 1.00 | $ 3.00 |
| Herbicide and Insecticide | 9.50 | 13.25 | 1.50 |
| Fertilizer and Lime | 3.05 | 13.50 | 12.00 |
| Fuel and Oil | 3.00 | | |
| Machinery and Equipment Repairs | 6.40 | | |
| Custom Hire (Wheat - anhydrous) | | | 2.57 |
| Miscellaneous (Alfalfa - includes twine) | 10.60 | 2.50 | 2.50 |
| Crop Variable Costs | $35.70 | $30.25 | $21.57 |

| Returns (per acre) | Alfalfa (ton) | Grain Sorghum (bushel) | Wheat (bushel) |
|---|---|---|---|
| Price | $37.26 | $ 1.70 | $ 2.76 |
| Yield: First Cutting (May 16-23) | 1.18 | | |
| Second Cutting (June 16-23) | 0.92 | | |
| Third Cutting (July 16-23) | 0.54 | | |
| | 2.64 | 46.8 | 29.1 |
| Crop Activity Objective Row Values | $62.67 | -$30.25 | -$21.57 |

[1] Modified version of: McReynolds, Kenneth L. and Figurski, Leo. "Alfalfa Costs and Returns," KSU Farm Management Guides MF-263, Cooperative Extension Service, Kansas State University (Oct. 1977).

[2] Modified version of: McReynolds, Kenneth L. and Figurski, Leo. "Dryland Grain Sorghum Costs and Returns," KSU Farm Management Guides MF-271, Cooperative Extension Service, Kansas State University (Oct. 1977).

[3] Modified version of: McReynolds, Kenneth L. and Figurski, Leo. "Continuous Cropped Winter Wheat," KSU Farm Management Guide MF-261, Cooperative Extension Service, Kansas State University (Oct. 1977).

## Procedure

Several linear programming routines for each large tractor (90, 110, 130, 155, 180, and 215 pto hp) are made. The first routine for each tractor size contains hours in the labor, combine, and tractor right-hand-side resource restraints based on an average rainfall year's estimated field workdays. The remaining linear programming routines for each tractor size studied contain labor, combine, and tractor hourly restraints based on the estimated frequency of occurrence of field workdays for the years 1951, 1957, 1965, and 1967.

For each linear program routine, cropland is limited to 600 acres of wheat, 600 acres of grain sorghum, and 55 acres of alfalfa. Farm Management Association Number 2 records state total crop acres for high production "All Americans" and average farms in 1977 were respectively 1207 acres and 816 acres. Acreage restrictions were placed on specified crops to avoid dramatic shifts from one crop to another from average rainfall to higher than average rainfall years.

Combine selection alternatives are the same for each linear program routine in which tractor size is changed. The small tractor is available for each computer routine. Repair costs for tillage implements are changed in conjunction with the selection of the large grator. The computer routines are varied as stated above and contain the following wheat drill and row crop equipment selection possibilities for each tractor size studied:

Tractor size is 90 pto hp with implement selection possibilities including 4, 6, or 8 row crop planters and cultivators and wheat grain drill widths of 8, 13, or 16 feet;

Tractor size is 110 pto hp with implement selection possibilities including 4, 6, or 8 row crop planters and cultivators and wheat grain drill widths of 8, 13, or 16 feet;

Tractor size is 130 pto hp with implement selection possibilities including 4, 6, 8, or 12 row crop planters and cultivators and wheat grain drill widths of 8, 13, 16, or 25 feet;

Tractor size is 155 pto hp with implement selection possibilities including 6, 8, 12, or 18 row crop planters and cultivators and wheat grain drill widths of 16, 25, or 33 feet;

Tractor size is 180 pto hp with implement selection possibilities including 8, 12, or 18 row crop planters and cultivators and wheat grain drill widths of 16, 25, or 33 feet;

Tractor size is 215 pto hp with implement selection possibilities including 8, 12, or 18 row crop planters and cultivators and wheat grain drill implement widths of 16, 25, or 33 feet.

# CHAPTER IV

# RESULTS

Table 21 reports the objective values, crop acres selected, and large tractor hours for alternative sizes for the field work days estimated for 1951, 1957, 1965, and 1967 and the average year. The objective value of the results for each tractor's size is greater for a year based on the average number of field workdays than for the years 1951, 1957, 1965, and 1967 which had higher than average rainfall (Table 21). The affect of increased precipitation on yields for the years 1951, 1957, 1965, and 1967 is not accounted for in the model, but delays in the completion of planting and harvesting activities are considered as penalties in the model. Economic cost of land idled because of rain is not included in the objective. The affect of below normal precipitation on field work due lack of sufficient data is not studied in the model.

## Analysis of Results for the Average Year

Smaller sizes of tractors show fewer acres, use more labor, and generally less income (Table 21). As tractor size is increased from 90 to 215 pto hp in a year with average rainfall, total tractor hours decrease, while objective values increase until the 180 pto hp size. With identical acreage of 1,255 acres, the objective value for the

TABLE 21

RESULTS: OBJECTIVE VALUES, CROP ACRES SELECTED, AND LARGE TRACTOR HOURS

| Tractor Size | Year | Objective Value | Income Per Cent of Average Year | Crop Acres | | | | Large Tractor Hours |
|---|---|---|---|---|---|---|---|---|
| | | | | Wheat | Grain Sorghum | Alfalfa | Total | |
| 90 PTO HP | Average | $37,118.11 | 100.0 | 405.1 | 498.7 | 55.0 | 958.8 | 1,220.3 |
| " | 1951 | $24,508.39 | 66.0 | 329.6 | 363.3 | 0.0 | 692.9 | 913.6 |
| " | 1957 | $30,040.44 | 80.9 | 476.8 | 312.9 | 16.7 | 806.4 | 975.2 |
| " | 1965 | $29,359.00 | 79.1 | 491.3 | 317.6 | 18.4 | 827.3 | 1,006.7 |
| " | 1967 | $29,237.90 | 78.8 | 259.1 | 457.2 | 55.0 | 771.3 | 1,007.4 |
| 110 PTO HP | Average | $39,660.55 | 100.0 | 546.2 | 389.0 | 54.7 | 989.9 | 1,026.5 |
| " | 1951 | $25,675.34 | 64.7 | 336.1 | 444.0 | 0.0 | 780.1 | 907.2 |
| " | 1957 | $31,690.29 | 79.9 | 563.3 | 257.2 | 16.7 | 837.2 | 853.5 |
| " | 1965 | $31,396.40 | 79.2 | 556.8 | 317.8 | 15.9 | 890.5 | 930.9 |
| " | 1967 | $30,508.70 | 76.9 | 289.5 | 471.5 | 55.0 | 816.0 | 921.6 |
| 110 PTO HP | Average | $39,602.24 | 100.0 | 546.2 | 388.7 | 55.0 | 989.9 | 1,026.2 |
| (24 foot & | 1951 | $25,567.97 | 64.6 | 336.1 | 444.0 | 0.0 | 780.1 | 907.2 |
| custom | 1957 | $31,613.72 | 79.8 | 536.1 | 294.7 | 16.7 | 847.5 | 881.0 |
| combine) | 1965 | $31,370.66 | 79.2 | 558.4 | 349.3 | 7.9 | 915.6 | 947.2 |
| " | 1967 | $30,433.76 | 76.8 | 298.6 | 471.4 | 55.0 | 825.0 | 921.6 |
| 110 PTO HP | Average | $39,529.62 | 100.0 | 546.2 | 388.7 | 55.0 | 989.9 | 1,026.1 |
| (20 foot & | 1951 | $25,167.71 | 63.7 | 324.1 | 444.0 | 0.0 | 768.1 | 896.6 |
| custom | 1957 | $30,735.44 | 77.8 | 538.3 | 257.2 | 16.7 | 812.2 | 831.4 |
| combine) | 1965 | $31,109.59 | 78.7 | 556.8 | 307.8 | 15.9 | 880.5 | 917.1 |
| " | 1967 | $30,464.48 | 77.1 | 300.6 | 478.7 | 46.4 | 825.7 | 932.0 |

TABLE 21 (Continued)

| Tractor Size | Year | Objective Value | Income Per Cent of Average Year | Crop Acres | | | | Large Tractor Hours |
|---|---|---|---|---|---|---|---|---|
| | | | | Wheat | Grain Sorghum | Alfalfa | Total | |
| 130 PTO HP | Average | $48,056.55 | 100.0 | 588.2 | 600.0 | 54.7 | 1,242.9 | 1,070.3 |
| " | 1951 | $31,491.77 | 65.5 | 376.9 | 577.2 | 0.0 | 954.1 | 880.3 |
| " | 1957 | $38,167.84 | 79.4 | 505.0 | 600.0 | 0.0 | 1,105.0 | 999.8 |
| " | 1965 | $36,836.62 | 76.7 | 539.2 | 600.0 | 0.0 | 1,139.2 | 1,025.4 |
| " | 1967 | $38,113.32 | 79.3 | 375.2 | 600.0 | 45.0 | 1,020.2 | 909.6 |
| 155 PTO HP | Average | $51,567.64 | 100.0 | 600.0 | 600.0 | 55.0 | 1,255.0 | 821.5 |
| " | 1951 | $40,134.55 | 77.8 | 491.4 | 600.0 | 0.0 | 1,091.4 | 750.3 |
| " | 1957 | $46,312.66 | 89.8 | 600.0 | 600.0 | 51.5 | 1,251.5 | 821.0 |
| " | 1965 | $45,148.10 | 87.6 | 600.0 | 600.0 | 51.5 | 1,251.5 | 821.0 |
| " | 1967 | $47,361.58 | 91.8 | 600.0 | 600.0 | 2.9 | 1,202.9 | 814.2 |
| 155 PTO HP | Average | $51,536.62 | 100.0 | 600.0 | 600.0 | 55.0 | 1,255.0 | 821.5 |
| (24 foot & | 1951 | $39,986.03 | 77.5 | 491.4 | 600.0 | 0.0 | 1,091.4 | 750.3 |
| custom | 1957 | $46,260.35 | 89.7 | 600.0 | 600.0 | 51.5 | 1,251.5 | 821.1 |
| combine) | 1965 | $45,109.32 | 87.5 | 600.0 | 600.0 | 54.5 | 1,254.5 | 821.7 |
| " | 1967 | $47,351.59 | 91.8 | 600.0 | 600.0 | 2.9 | 1,202.9 | 814.8 |
| 155 PTO HP | Average | $51,214.32 | 100.0 | 600.0 | 600.0 | 55.0 | 1,255.0 | 821.5 |
| (20 foot & | 1951 | $39,150.93 | 76.4 | 468.0 | 600.0 | 0.0 | 1,068.0 | 736.7 |
| custom | 1957 | $44,835.10 | 87.5 | 600.0 | 600.0 | 30.0 | 1,230.0 | 818.0 |
| combine) | 1965 | $44,750.60 | 87.3 | 600.0 | 600.0 | 46.0 | 1,246.0 | 820.3 |
| " | 1967 | $45,889.72 | 89.6 | 549.2 | 600.0 | 22.7 | 1,171.9 | 787.3 |

TABLE 21 (Continued)

| Tractor Size | Year | Objective Value | Income Per Cent of Average Year | Crop Acres: Wheat | Crop Acres: Grain Sorghum | Crop Acres: Alfalfa | Crop Acres: Total | Large Tractor Hours |
|---|---|---|---|---|---|---|---|---|
| 180 PTO HP | Average | $51,688.42 | 100.0 | 600.0 | 600.0 | 55.0 | 1,255.0 | 737.0 |
| " | 1951 | $41,949.06 | 81.2 | 537.5 | 600.0 | 0.0 | 1,137.5 | 697.6 |
| " | 1957 | $46,607.97 | 90.2 | 600.0 | 600.0 | 55.0 | 1,255.0 | 737.0 |
| " | 1965 | $45,622.20 | 88.3 | 600.0 | 600.0 | 55.0 | 1,255.0 | 737.0 |
| " | 1967 | $48,400.68 | 93.6 | 600.0 | 600.0 | 27.8 | 1,227.8 | 733.5 |
| 215 PTO HP | Average | $51,422.70 | 100.0 | 600.0 | 600.0 | 55.0 | 1,255.0 | 632.8 |
| " | 1951 | $41,949.06 | 85.5 | 594.6 | 600.0 | 0.0 | 1,194.6 | 625.6 |
| " | 1957 | $46,421.03 | 90.2 | 600.0 | 600.0 | 55.0 | 1,255.0 | 632.8 |
| " | 1965 | $45,512.80 | 85.5 | 600.0 | 600.0 | 55.0 | 1,255.0 | 632.8 |
| " | 1967 | $49,181.71 | 95.6 | 600.0 | 600.0 | 54.5 | 1,254.5 | 632.7 |

215 pto hp tractor is \$245.72 less than the 180 pto hp tractor's. Tractor hours for the 215 pto hp tractor are 104.2 hours less than those for the 180 pto hp tractor in a year of average rainfall.

The greatest increase in the objective values and crop acreage in a year with average rainfall occurs when tractor size is increased from 110 pto hp to 130 pto hp. The objective value increases \$8,396.00, while crop acres increase by 281.1 acres, or a \$29.55 increase in the objective value for each additional acre.

The divisibility assumption of linear programming was observed in the model's combine selection, by using a fractional unit of each of the two sizes. Two additional computer runs were made for both the 110 and 155 pto hp tractors, one of the additional runs containing only the 20 foot and custom combine, and the other run containing the 24 foot and custom combine selection options.

Increasing tractor size from 130 pto hp in an average rainfall year to 155 pto hp increases the objective value \$3,511.09, while total acres increase 12.1. The return per acre in this instance is \$290.17. As tractor size is increased from 155 to 180 pto hp, the objective value increases \$120.78, and total acreage is unchanged.

Tractor hours associated with the 180 pto hp tractor are 84.5 hours less than the hours associated with the 155 pto hp tractor. The marginal increase in return per additional acre farmed is greatest when tractor horsepower is increased from 130 pto hp to 155 pto hp. The return per tractor hour (objective value/tractor hours) increases as tractor horsepower is increased, and is greatest for the 215 pto hp tractor.

Custom hire expenses when the 130 pto hp tractor is used are $4,419.66, which is composed of a $3,880.32 expense for custom wheat combining and $539.34 for custom hay hauling. Penalties incurred when the 130 pto hp tractor is used are $1,542.92.

Table 21 shows results for three combinations of the 155 pto hp tractor and combine sizes. In the average rainfall year custom hire expenses are $1,033.08, most of which is custom wheat combining expense. Total penalties for the 155 pto hp tractor in an average rainfall year are $944.14 greater than the 130 pto hp tractor's.

The greater capacity of the 155 pto hp tractor allows less labor to be used in tilling or planting, freeing more labor for wheat combining activities. Penalties for untimely field operations increase less than the decrease of custom hire expenses. Thus there is a net gain of $3,511 in the objective value for the 155 pto hp tractor as compared with the 130 pto hp tractor.

Optimum tractor size, given the 1,255 acre restraint, can be chosen from either the 155, 180, or 215 pto hp tractors. All three tractor sizes have the capacity for 1,255 acres in an average rainfall year. The objective value increases $120.78 when tractor size is increased from 155 to 180 pto hp. Increasing tractor size from 180 to 215 pto hp decreases the objective value $245.72.

Tractor hours for the 155, 180, and 215 pto hp tractors are respectively 821.5, 737.0, and 632.8 hours. Profit maximization favors the 180 pto hp tractor, while time minimization favors the 215 pto hp tractor. Plans of expanding farm size would also favor the largest tractor.

## Analysis of Results for the Wet Years

Farmers do not know whether the next season will be usually wet or dry. Thus, their flexibility to adjust machinery sizes, once they have determined the season is usually wet, is rather limited. However, it is usual to evaluate how optimum machinery sizes and crop acres can be affected by above average rainfall.

The wettest year on record in many areas of Kansas was 1951 (6). Thus, it is useful to consider the size of machinery necessary to do work required based on expectations of an average year. There may be some farmers who plan machinery size necessary to accomplish all work in the worst case instead of the average. Whereas other farmers may plan machinery sizes on a less conservative philosophy and plan on being able to get the work done in most years, say 80 per cent of the years. The penalty of having more capacity than is needed in the average is the higher ownership cost on the larger machines.

A large difference in crop acres selected with tractor sizes of 90, 110, and 130 pto hp occurs among the years studied. The objective values for the 90, 110, and 130 pto hp tractors decrease from their respective average rainfall year's values in 1951 by 34.0 to 36.3 per cent. Crop acres decrease from an average rainfall year's selection 27.7 to 23.2 per cent in 1951. Having fewer field workdays available results in having fewer total acres and less income (Table 21).

The 90, 110, and 130 pto hp tractors in this study do not have the capacity to accomplish the same field work that occurs in average rainfall years when field workdays are limited in higher than average rainfall years. Selecting tractors to accomplish field work for average rainfall years can lead to large income and acreage reductions when higher than average rainfall occurs.

The results for the higher than average rainfall years for the 155, 180, and 215 pto hp tractors are similar. Objective values decrease from an average year's values in 1951 by 23.6 to 14.5 per cent, while total acreage decreases from 13 to 5 per cent. The capacity to accomplish field work in less time reduces the effect of higher than average rainfall years on the 155, 180, and 215 pto hp tractors' results as compared to the 90, 110, and 130 pto hp tractors' results in terms of income and acres farmed. The larger capacity of the 155, 180, and 215 pto hp tractors in relation to the acreage restraint (1,255 acres) limits income and acreage variability in higher rainfall years.

Due to lower estimated per acre variable costs (Table 19) for wider row planters, row cultivators, and grain drills, the model selects the widest available row planter, row cultivator, and grain drill for each tractor size studied.

The custom combine harvesting option is not selected for grain sorghum, but is selected for wheat harvest (Table 22). Grain sorghum harvest occurs in the fall when no other field work occurs, leaving available labor for grain sorghum harvesting. Conversely, wheat harvest occurs during a highly labor intensive time of the year (Figure 4).

For the 90 and 110 pto hp tractors, the model selects the 24 foot and custom combine for wheat harvest and both the 20 and 24 foot combines for harvesting grain sorghum. The model selects the 24 foot

TABLE 22

CROP ACRES SELECTED FOR VARIOUS SIZE COMBINES BY TRACTOR SIZE, BY CROP AND BY YEAR, AND GRAIN DRILL, ROW PLANTER, AND ROW CULTIVATOR SIZES SELECTED

| | Combine (acres) | | | | | | Grain Drill (width) | Row Planter and Cultivator (width) |
|---|---|---|---|---|---|---|---|---|
| | Wheat | | | Grain Sorghum | | | | |
| Year | 20 ft. | 24 ft. | Custom | 20 ft. | 24 ft. | Custom | | |
| | | | | 90 PTO HP | | | | |
| Average | 0.0 | 71.8 | 333.3 | 198.7 | 300.0 | 0.0 | 16.76' | 20.0' (8 row) |
| 1951 | 0.0 | 263.0 | 66.7 | 363.3 | 0.0 | 0.0 | 16.76' | 20.0' (8 row) |
| 1957 | 0.0 | 467.8 | 0.0 | 88.2 | 224.7 | 0.0 | 16.76' | 20.0' (8 row) |
| 1965 | 0.0 | 91.3 | 400.0 | 317.6 | 0.0 | 0.0 | 16.76' | 20.0' (8 row) |
| 1967 | 0.0 | 43.5 | 215.6 | 457.2 | 0.0 | 0.0 | 16.76' | 20.0' (8 row) |
| | | | | 110 PTO HP | | | | |
| Average | 0.0 | 178.6 | 367.6 | 389.0 | 0.0 | 0.0 | 16.76' | 20.0' (8 row) |
| 1951 | 0.0 | 269.4 | 66.7 | 444.0 | 0.0 | 0.0 | 16.76' | 20.0' (8 row) |
| 1957 | 0.0 | 563.3 | 0.0 | 257.2 | 0.0 | 0.0 | 16.76' | 20.0' (8 row) |
| 1965 | 0.0 | 156.8 | 400.0 | 317.6 | 0.0 | 0.0 | 16.76' | 20.0' (8 row) |
| 1967 | 0.0 | 31.8 | 266.7 | 471.5 | 0.0 | 0.0 | 16.76' | 20.0' (8 row) |
| | | | | 110 PTO HP (24 ft. combine option omitted) | | | | |
| Average | 157.5 | --- | 388.7 | 388.7 | --- | 0.0 | 16.76' | 20.0' (8 row) |
| 1951 | 257.4 | --- | 66.7 | 444.0 | --- | 0.0 | 16.76' | 20.0' (8 row) |
| 1957 | 538.3 | --- | 0.0 | 257.2 | --- | 0.0 | 16.76' | 20.0' (8 row) |
| 1965 | 156.8 | --- | 400.0 | 308.7 | --- | 0.0 | 16.76' | 20.0' (8 row) |
| 1967 | 33.9 | --- | 266.7 | 478.7 | --- | 0.0 | 16.76' | 20.0' (8 row) |

TABLE 22 (Continued)

| Year | Combine (acres): Wheat 20 ft. | Wheat 24 ft. | Wheat Custom | Grain Sorghum 20 ft. | Grain Sorghum 24 ft. | Grain Sorghum Custom | Grain Drill (width) | Row Planter and Cultivator (width) |
|---|---|---|---|---|---|---|---|---|
| | | | | 110 PTO HP (20 ft. combine option omitted | | | | |
| Average | --- | 178.6 | 367.6 | --- | 388.7 | 0.0 | 16.76' | 20.0' (8 row) |
| 1951 | --- | 269.4 | 66.7 | --- | 444.0 | 0.0 | 16.76' | 20.0' (8 row) |
| 1957 | --- | 536.0 | 0.0 | --- | 294.7 | 0.0 | 16.76' | 20.0' (8 row) |
| 1965 | --- | 158.4 | 400.0 | --- | 349.3 | 0.0 | 16.76' | 20.0' (8 row) |
| 1967 | --- | 31.8 | 266.7 | --- | 471.5 | 0.0 | 16.76' | 20.0' (8 row) |
| | | | | 130 PTO HP | | | | |
| Average | 0.0 | 175.4 | 412.8 | 300.0 | 300.0 | 0.0 | 25.0' | 30.0' (12 row) |
| 1951 | 0.0 | 310.2 | 66.7 | 577.2 | 0.0 | 0.0 | 25.0' | 30.0' (12 row) |
| 1957 | 0.0 | 505.0 | 0.0 | 374.0 | 226.0 | 0.0 | 25.0' | 30.0' (12 row) |
| 1965 | 0.0 | 139.2 | 400.0 | 510.7 | 89.3 | 0.0 | 25.0' | 30.0' (12 row) |
| 1967 | 0.0 | 122.8 | 252.4 | 25.0 | 575.0 | 0.0 | 25.0' | 30.0' (12 row) |
| | | | | 155 PTO HP | | | | |
| Average | 52.6 | 473.7 | 73.7 | 75.0 | 525.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1951 | 0.0 | 424.8 | 66.7 | 600.0 | 0.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1957 | 0.0 | 600.0 | 0.0 | 150.6 | 449.4 | 0.0 | 33.33' | 45.0' (18 row) |
| 1965 | 0.0 | 200.0 | 400.0 | 150.6 | 449.4 | 0.0 | 33.33' | 45.0' (18 row) |
| 1967 | 0.0 | 333.3 | 266.7 | 25.6 | 574.4 | 0.0 | 33.33' | 45.0' (18 row) |
| | | | | 155 PTO HP (24 ft. option omitted) | | | | |
| Average | 470.6 | --- | 129.4 | 600.0 | --- | 0.0 | 33.33' | 45.0' (18 row) |
| 1951 | 401.3 | --- | 66.7 | 600.0 | --- | 0.0 | 33.33' | 45.0' (18 row) |
| 1957 | 600.0 | --- | 0.0 | 600.0 | --- | 0.0 | 33.33' | 45.0' (18 row) |
| 1965 | 200.0 | --- | 400.0 | 600.0 | --- | 0.0 | 33.33' | 45.0' (18 row) |
| 1967 | 282.6 | --- | 266.6 | 600.0 | --- | 0.0 | 33.33' | 45.0' (18 row) |

TABLE 22 (Continued)

| Year | Combine (acres) Wheat 20 ft. | Wheat 24 ft. | Wheat Custom | Grain Sorghum 20 ft. | Grain Sorghum 24 ft. | Grain Sorghum Custom | Grain Drill (width) | Row Planter and Cultivator (width) |
|---|---|---|---|---|---|---|---|---|
| | | | | 155 PTO HP (20 ft. option omitted) | | | | |
| Average | --- | 533.3 | 66.7 | --- | 600.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1951 | --- | 424.7 | 66.7 | --- | 600.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1957 | --- | 600.0 | 0.0 | --- | 600.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1965 | --- | 200.0 | 400.0 | --- | 600.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1967 | --- | 333.3 | 266.7 | --- | 600.0 | 0.0 | 33.33' | 45.0' (18 row) |
| | | | | 180 PTO HP | | | | |
| Average | 286.9 | 313.1 | 0.0 | 75.0 | 525.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1951 | 0.0 | 470.8 | 66.7 | 600.0 | 0.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1957 | 65.2 | 534.8 | 0.0 | 150.0 | 450.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1965 | 0.0 | 200.0 | 400.0 | 157.6 | 442.4 | 0.0 | 33.33' | 45.0' (18 row) |
| 1967 | 0.0 | 333.3 | 266.7 | 25.0 | 575.0 | 0.0 | 33.33' | 45.0' (18 row) |
| | | | | 215 PTO HP | | | | |
| Average | 276.2 | 323.8 | 0.0 | 75.0 | 525.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1951 | 0.0 | 527.9 | 66.7 | 600.0 | 0.0 | 0.0 | 33.33' | 45.0' (18 row) |
| 1957 | 61.5 | 538.5 | 0.0 | 150.6 | 449.4 | 0.0 | 33.33' | 45.0' (18 row) |
| 1965 | 61.1 | 138.9 | 400.0 | 150.5 | 449.4 | 0.0 | 33.33' | 45.0' (18 row) |
| 1967 | 0.0 | 333.3 | 266.7 | 25.6 | 574.4 | 0.0 | 33.33' | 45.0' (18 row) |

A) Refer to procedure for possible implement selection sizes for each large tractor size.

combine for harvesting grain sorghum when zero penalties are incurred and chooses the smaller (20 foot) combine for harvesting in delayed harvest periods when penalties are incurred. With increasing penalties in delayed harvest periods and greater variable costs per of the 24 foot combine above the 20 foot combine, the model selects the smaller combine for late grain sorghum harvest periods.

In 1957, zero field workdays are available in the June 5 and June 6 designated wheat custom combine labor periods. Two additional computer results for both the 110 and 155 pto hp tractors show a definite advantage for the 24 foot combine over the 20 foot combine when zero field workdays are available in the June 5 and June 6 labor periods. With all other factors held constant in 1957 for the 110 pto hp tractor result, there is an \$828.28 increase in the objective value for using the 24 foot combine for both wheat and grain sorghum harvests. The model shows for the 155 pto hp tractor that using the 24 foot combine increases the objective value \$1,425.25 over the same result for the 20 foot combine in 1957 (Table 21).

Costs and returns enter into the grain sorghum combine selection decision; while costs, returns, and labor availability enter into the wheat combine selection decision. For both the 110 and 155 pto hp tractors, the objective values for each are largest when the 24 foot and custom combine are employed for wheat harvest, and the 20 and 24 foot combines are used for grain sorghum harvest. Additional results with either the 20 foot and custom combine, or the 24 foot combine and custom combine for both grain sorghum and wheat harvest show an advantage for the 24 foot combine over the 20 foot combine (Table 21).

The majority of wheat penalties incurred are from delayed harvest (Table 23). For smaller tractor sizes (90 and 110 pto hp) the largest wheat planting penalties occurred in 1957. Larger tractor sizes (130 - 215 pto hp) only experienced wheat planting penalties in 1967. The largest wheat planting penalty is 297.3 bushels for the 110 pto hp tractor in 1957. This amounts to approximately only 2 per cent of the total bushel production of 15,013.7 bushels in 1957. Selection of the largest possible grain drill per tractor size minimizes the occurrence of wheat planting penalties. For the 155, 180, and 215 pto hp tractors, wheat harvest penalties reduce total yield by approximately 8 per cent. The wheat drying cost penalty is incurred, but not to a significant degree. The largest drying cost penalty is $514.19 in 1967 for the 155 pto hp result. Harvesting wheat in the wet grain harvest period is generally avoided.

Grain sorghum drying costs are not incurred. In an average rainfall year the 90, 110, and 130 pto hp tractors do not have enough planting capacity to avoid grain sorghum planting penalties on selected acres. For the 155, 180, and 215 pto hp tractors in an average rainfall year, planting capacity is sufficient that zero penalties are incurred. The largest grain sorghum planting penalties occur in 1965 when zero field workdays are available during the optimum planting period which has no penalty. Grain sorghum harvest penalties were small in average rainfall years and were greatest at 12 per cent of total production for the 130 pto hp tractor in 1965.

Results for the 90 and 110 pto hp tractors in the years 1957 and 1965 show a shift in acreage from grain sorghum to wheat. The June 1

TABLE 23

PENALTIES INCURRED

PART A: WHEAT PENALTIES INCURRED

| Year | Planting Penalty (bu.) | Harvest Penalty (bu.) | Total Penalty (bu.) | Drying Cost ($) | Total[a] Penalty ($) |
|---|---|---|---|---|---|
| | | Large Tractor Size | | | |
| | | 90 PTO HP | | | |
| Average | 0.0 | 1.4 | 1.4 | 0.00 | 3.86 |
| 1951 | 0.0 | 482.0 | 482.0 | 0.00 | 1,330.32 |
| 1957 | 156.6 | 969.0 | 1,134.6 | 0.00 | 3,131.50 |
| 1965 | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 |
| 1967 | 83.3 | 133.5 | 216.8 | 0.00 | 598.40 |
| | | 110 PTO HP | | | |
| Average | 0.0 | 89.2 | 89.2 | 0.00 | 246.20 |
| 1951 | 0.0 | 501.1 | 501.1 | 0.00 | 1,383.04 |
| 1957 | 297.3 | 1,081.0 | 1,378.8 | 51.91 | 3,856.03 |
| 1965 | 14.7 | 78.4 | 93.1 | 0.00 | 256.96 |
| 1967 | 137.7 | 163.7 | 301.4 | 0.00 | 831.70 |
| | | 110 PTO HP (24 ft. combine option omitted) | | | |
| Average | 0.0 | 96.5 | 96.5 | 0.00 | 266.43 |
| 1951 | 0.0 | 494.7 | 494.7 | 0.00 | 1,365.37 |
| 1957 | 262.9 | 1,066.0 | 1,328.9 | 0.00 | 3,867.19 |
| 1965 | 14.7 | 86.3 | 101.0 | 0.00 | 278.76 |
| 1967 | 140.5 | 163.5 | 304.0 | 0.00 | 840.42 |
| | | 110 PTO HP (20 ft. combine option omitted) | | | |
| Average | 0.0 | 89.2 | 89.2 | 0.00 | 246.74 |
| 1951 | 0.0 | 501.1 | 501.1 | 0.00 | 1,383.04 |
| 1957 | 259.7 | 1,105.8 | 1,365.5 | 153.73 | 3,926.51 |
| 1965 | 16.9 | 29.7 | 46.6 | 0.00 | 128.62 |
| 1967 | 137.8 | 163.6 | 301.4 | 0.00 | 831.86 |
| | | 130 PTO HP | | | |
| Average | 0.0 | 117.3 | 117.3 | 0.00 | 323.80 |
| 1951 | 0.0 | 612.3 | 612.3 | 0.00 | 1,689.95 |
| 1957 | 0.0 | 1,095.1 | 1,095.1 | 0.00 | 3,022.48 |
| 1965 | 0.0 | 114.1 | 114.1 | 0.00 | 314.97 |
| 1967 | 117.1 | 177.3 | 294.4 | 0.00 | 812.54 |

TABLE 23

PENALTIES INCURRED

PART A: WHEAT PENALTIES INCURRED (Continued)

| Year | Planting Penalty (bu.) | Harvest Penalty (bu.) | Total Penalty (bu.) | Drying Cost ($) | Total[a] Penalty ($) |
|---|---|---|---|---|---|
| | | Large Tractor Size | | | |
| | | 155 PTO HP | | | |
| Average | 0.0 | 505.3 | 505.3 | 157.47 | 1,552.10 |
| 1951 | 0.0 | 943.2 | 943.2 | 0.00 | 2,578.39 |
| 1957 | 0.0 | 1,407.0 | 1,407.0 | 0.00 | 3,883.32 |
| 1965 | 0.0 | 408.8 | 408.8 | 0.00 | 1,128.29 |
| 1967 | 249.1 | 232.3 | 481.4 | 554.19 | 1,882.85 |
| | | 155 PTO HP (24 ft. combine option omitted) | | | |
| Average | 0.0 | 458.2 | 458.2 | 138.91 | 1,403.14 |
| 1951 | 0.0 | 916.9 | 916.9 | 0.00 | 2,530.64 |
| 1957 | 0.0 | 1,291.3 | 1,291.3 | 124.92 | 3,688.91 |
| 1965 | 0.0 | 401.6 | 401.6 | 0.00 | 1,108.42 |
| 1967 | 179.0 | 226.3 | 425.3 | 504.18 | 1,173.88 |
| | | 155 PTO HP (20 ft. combine option omitted) | | | |
| Average | 0.0 | 519.3 | 519.3 | 157.47 | 1,590.74 |
| 1951 | 0.0 | 943.2 | 943.2 | 0.00 | 2,578.39 |
| 1957 | 0.0 | 1,405.7 | 1,405.7 | 0.00 | 3,879.73 |
| 1965 | 0.0 | 445.4 | 445.4 | 0.00 | 1,124.98 |
| 1967 | 249.1 | 232.3 | 481.4 | 549.55 | 1,878.21 |
| | | 180 PTO HP | | | |
| Average | 0.0 | 651.9 | 651.9 | 157.47 | 1,956.71 |
| 1951 | 0.0 | 1,072.5 | 1,072.5 | 0.00 | 2,960.10 |
| 1957 | 0.0 | 1,432.8 | 1,432.8 | 0.00 | 3,954.53 |
| 1965 | 0.0 | 445.4 | 445.4 | 0.00 | 1,229.30 |
| 1967 | 249.1 | 284.5 | 533.6 | 549.53 | 2,022.27 |
| | | 215 PTO HP | | | |
| Average | 0.0 | 638.6 | 638.6 | 528.28 | 2,290.82 |
| 1951 | 0.0 | 1,275.7 | 1,275.7 | 0.00 | 3,520.93 |
| 1957 | 0.0 | 1,428.0 | 1,428.0 | 0.00 | 3,941.28 |
| 1965 | 0.0 | 442.4 | 442.4 | 0.00 | 1,221.02 |
| 1967 | 249.1 | 291.9 | 541.0 | 549.55 | 2,042.71 |

(a) Sum of planting and harvest penalties times $2.76 price per bushel of wheat, plus drying cost.

TABLE 23

PENALTIES INCURRED

PART B: GRAIN SORGHUM PENALTIES INCURRED

| Year | Planting Penalty (bu.) | Harvest Penalty (bu.) | Total Penalty (bu.) | Drying Cost ($) | Total[b] Penalty ($) |
|---|---|---|---|---|---|
| | | Large Tractor Size | | | |
| | | 90 PTO HP | | | |
| Average | 515.8 | 28.5 | 544.3 | 0.00 | 925.31 |
| 1951 | 1,698.3 | 669.2 | 2,367.5 | 0.00 | 4,024.72 |
| 1957 | 0.0 | 1,588.3 | 1,588.3 | 0.00 | 2,795.78 |
| 1965 | 2,341.5 | 251.7 | 2,593.2 | 0.00 | 4,408.44 |
| 1967 | 7.6 | 178.9 | 186.5 | 0.00 | 317.05 |
| | | 110 PTO HP | | | |
| Average | 208.3 | 71.5 | 279.8 | 0.00 | 475.66 |
| 1951 | 2,502.6 | 45.3 | 2,547.9 | 0.00 | 4,331.43 |
| 1957 | 721.0 | 204.3 | 925.3 | 0.00 | 1,573.01 |
| 1965 | 2,250.0 | 491.0 | 2,741.0 | 0.00 | 4,659.70 |
| 1967 | 47.0 | 181.4 | 228.4 | 0.00 | 388.28 |
| | | 110 PTO HP (24 ft. combine option omitted) | | | |
| Average | 207.2 | 74.0 | 281.2 | 0.00 | 478.04 |
| 1951 | 2,502.6 | 39.3 | 2,541.9 | 0.00 | 4,321.23 |
| 1957 | 721.0 | 204.1 | 925.1 | 0.00 | 1,572.84 |
| 1965 | 2,412.7 | 301.1 | 2,713.8 | 0.00 | 4,613.46 |
| 1967 | 67.8 | 181.9 | 249.7 | 0.00 | 421.43 |
| | | 110 PTO HP (20 ft. combine option omitted) | | | |
| Average | 207.2 | 19.0 | 226.2 | 0.00 | 384.54 |
| 1951 | 2,502.9 | 3.9 | 2,506.8 | 0.00 | 4,261.60 |
| 1957 | 721.0 | 247.3 | 968.3 | 0.00 | 1,646.11 |
| 1965 | 2,700.0 | 500.0 | 3,200.0 | 0.00 | 5,440.00 |
| 1967 | 47.0 | 117.2 | 164.2 | 0.00 | 297.14 |
| | | 130 PTO HP | | | |
| Average | 332.6 | 324.5 | 675.1 | 0.00 | 1,117.04 |
| 1951 | 2,928.4 | 44.0 | 2,972.4 | 0.00 | 5,053.08 |
| 1957 | 1,442.0 | 1,172.0 | 2,614.0 | 0.00 | 4,443.80 |
| 1965 | 3,485.8 | 884.8 | 4,370.6 | 0.00 | 7,430.02 |
| 1967 | 0.0 | 329.4 | 329.4 | 0.00 | 559.98 |

TABLE 23

PENALTIES INCURRED

PART B: GRAIN SORGHUM PENALTIES INCURRED (Continued)

| Year | Planting Penalty (bu.) | Harvest Penalty (bu.) | Total Penalty (bu.) | Drying Cost ($) | Total[b] Penalty ($) |
|---|---|---|---|---|---|
| | | Large Tractor Size | | | |
| | | 155 PTO HP | | | |
| Average | 0.0 | 489.5 | 489.5 | 0.00 | 831.98 |
| 1951 | 1,683.0 | 202.6 | 1,885.6 | 0.00 | 3,205.52 |
| 1957 | 239.4 | 1,641.5 | 1,880.9 | 0.00 | 3,197.53 |
| 1965 | 1,229.2 | 1,552.3 | 2,781.5 | 0.00 | 4,728.55 |
| 1967 | 0.0 | 329.4 | 329.4 | 0.00 | 559.98 |
| | | 155 PTO HP (24 ft. combine option omitted) | | | |
| Average | 0.0 | 728.2 | 728.2 | 0.00 | 1,237.94 |
| 1951 | 1,664.4 | 202.4 | 1,866.8 | 0.00 | 3,173.56 |
| 1957 | 1,439.4 | 1,243.6 | 2,683.0 | 0.00 | 4,561.10 |
| 1965 | 2,799.2 | 336.1 | 3,135.3 | 0.00 | 5,330.01 |
| 1967 | 0.0 | 594.8 | 594.8 | 0.00 | 1,011.16 |
| | | 155 PTO HP (20 ft. combine option omitted) | | | |
| Average | 0.0 | 489.4 | 489.4 | 0.00 | 831.98 |
| 1951 | 1,683.0 | 152.2 | 1,835.2 | 0.00 | 3,199.84 |
| 1957 | 287.1 | 1,596.6 | 1,883.7 | 0.00 | 3,202.29 |
| 1965 | 1,297.4 | 1,528.1 | 2,825.5 | 0.00 | 4,803.35 |
| 1967 | 0.0 | 329.4 | 329.4 | 0.00 | 559.98 |
| | | 180 PTO HP | | | |
| Average | 0.0 | 489.4 | 489.4 | 0.00 | 831.98 |
| 1951 | 1,665.0 | 220.6 | 1,885.6 | 0.00 | 3,205.52 |
| 1957 | 180.5 | 1,637.2 | 1,817.7 | 0.00 | 3,090.09 |
| 1965 | 1,696.3 | 869.0 | 2,565.3 | 0.00 | 4,361.01 |
| 1967 | 0.0 | 329.4 | 329.4 | 0.00 | 559.98 |
| | | 215 PTO HP | | | |
| Average | 0.0 | 489.4 | 489.4 | 0.00 | 831.98 |
| 1951 | 1,683.0 | 202.6 | 1,885.6 | 0.00 | 3,205.52 |
| 1957 | 154.0 | 1,656.0 | 1,810.0 | 0.00 | 3,077.00 |
| 1965 | 888.5 | 1,673.2 | 2,561.7 | 0.00 | 4,354.89 |
| 1967 | 0.0 | 329.4 | 329.4 | 0.00 | 559.98 |

(b) Sum of planting and harvest penalties times $1.70 price per bushel of grain sorghum.

TABLE 23

PENALTIES INCURRED

PART C: ALFALFA AND TOTAL PENALTIES INCURRED

| Year | Alfalfa Penalty ($) | Total(c) Penalty Per Year ($) | Per Cent of Total Penalty: Wheat | Grain Sorghum | Alfalfa |
|---|---|---|---|---|---|
| | | Large Tractor Size | | | |
| | | 90 PTO HP | | | |
| Average | 102.10 | 1,031.27 | 0.4 | 89.7 | 9.9 |
| 1951 | ---- | 5,355.04 | 28.4 | 72.5 | --- |
| 1957 | 119.91 | 6,047.19 | 51.8 | 46.2 | 2.0 |
| 1965 | ---- | 4,408.44 | 0.0 | 100.0 | --- |
| 1967 | 201.39 | 1,116.84 | 53.6 | 28.4 | 18.0 |
| | | 110 PTO HP | | | |
| Average | 102.10 | 823.96 | 29.9 | 57.7 | 12.4 |
| 1951 | ---- | 5,714.47 | 24.2 | 75.8 | --- |
| 1957 | 119.91 | 5,548.95 | 69.5 | 28.3 | 2.2 |
| 1965 | ---- | 4,916.66 | 5.2 | 94.8 | --- |
| 1967 | 186.44 | 1,406.42 | 59.1 | 27.6 | 13.2 |
| | | 110 PTO HP (24 ft. combine option omitted) | | | |
| Average | 106.85 | 852.23 | 31.3 | 56.1 | 12.5 |
| 1951 | ---- | 5,686.50 | 24.0 | 76.0 | --- |
| 1957 | 119.91 | 5,559.84 | 69.5 | 28.3 | 2.2 |
| 1965 | ---- | 4,892.22 | 5.7 | 94.3 | --- |
| 1967 | 108.08 | 1,369.93 | 61.3 | 30.8 | 7.9 |
| | | 110 PTO HP (20 ft. combine option omitted) | | | |
| Average | 102.04 | 733.37 | 33.6 | 52.4 | 14.0 |
| 1951 | ---- | 5,644.64 | 24.5 | 75.5 | --- |
| 1957 | 119.91 | 5,692.53 | 69.0 | 29.9 | 2.1 |
| 1965 | ---- | 5,588.53 | 2.3 | 97.7 | --- |
| 1967 | 186.44 | 1,297.44 | 64.1 | 21.5 | 14.4 |
| | | 130 PTO HP | | | |
| Average | 102.08 | 1,542.92 | 21.0 | 72.4 | 6.6 |
| 1951 | ---- | 6,743.03 | 25.1 | 74.9 | --- |
| 1957 | ---- | 7,466.28 | 40.5 | 59.5 | --- |
| 1965 | ---- | 7,744.99 | 4.1 | 95.9 | --- |
| 1967 | 96.36 | 1,468.88 | 55.3 | 38.1 | 6.6 |

TABLE 23

PENALTIES INCURRED

PART C: ALFALFA AND TOTAL PENALTIES INCURRED (Continued)

| Year | Alfalfa Penalty ($) | Total[c] Penalty Per Year ($) | Per Cent of Total Penalty: Wheat | Grain Sorghum | Alfalfa |
|---|---|---|---|---|---|
| | | Large Tractor Size | | | |
| | | 155 PTO HP | | | |
| Average | 102.98 | 2,487.06 | 62.4 | 33.5 | 4.1 |
| 1951 | ---- | 5,783.91 | 44.6 | 55.4 | --- |
| 1957 | 862.34 | 7,943.19 | 48.9 | 40.3 | 10.8 |
| 1965 | 363.31 | 6,220.15 | 18.1 | 76.1 | 5.8 |
| 1967 | 14.20 | 2,457.03 | 76.6 | 22.8 | 0.6 |
| | | 155 PTO HP (24 ft. combine option omitted) | | | |
| Average | 102.10 | 2,743.18 | 51.2 | 45.1 | 3.7 |
| 1951 | ---- | 5,704.80 | 44.4 | 55.6 | --- |
| 1957 | 425.24 | 8,675.25 | 42.5 | 52.6 | 4.9 |
| 1965 | 166.84 | 6,605.27 | 16.8 | 80.7 | 2.5 |
| 1967 | 110.78 | 2,295.82 | 51.1 | 44.0 | 4.9 |
| | | 155 PTO HP (20 ft. combine option omitted) | | | |
| Average | 102.08 | 2,524.80 | 63.0 | 33.0 | 4.0 |
| 1951 | ---- | 5,698.23 | 45.2 | 54.8 | --- |
| 1957 | 868.34 | 7,950.36 | 48.8 | 40.3 | 10.9 |
| 1965 | 379.61 | 6,307.94 | 17.8 | 76.2 | 6.0 |
| 1967 | 14.15 | 2,452.34 | 76.6 | 22.8 | 0.6 |
| | | 180 PTO HP | | | |
| Average | 132.16 | 2,920.85 | 67.0 | 28.5 | 4.5 |
| 1951 | ---- | 6,165.62 | 48.0 | 52.0 | --- |
| 1957 | 379.41 | 7,424.03 | 53.3 | 41.6 | 5.1 |
| 1965 | 420.87 | 6,011.18 | 20.5 | 72.5 | 7.0 |
| 1967 | 172.28 | 2,754.53 | 73.4 | 20.3 | 6.3 |
| | | 215 PTO HP | | | |
| Average | 175.31 | 3,298.11 | 69.5 | 25.2 | 5.3 |
| 1951 | ---- | 6,726.45 | 52.3 | 47.7 | --- |
| 1957 | 718.27 | 7,736.55 | 50.9 | 39.8 | 9.3 |
| 1965 | 414.41 | 5,990.32 | 20.4 | 72.7 | 6.9 |
| 1967 | 542.46 | 3,145.15 | 64.9 | 17.8 | 17.3 |

[c] Sum of wheat, grain sorghum, and alfalfa penalties.

labor period of 1965, the optimum wheat harvest period, has six field workdays. In 1965 no field workdays are available in the grain sorghum optimum planting period, and pre-optimum planting results in a penalty of 19 per cent of potential yield, and delayed planting competes for labor with wheat harvest. Due to lack of planting capacity and fewer field workdays than average, there is a shift from grain sorghum to wheat acreage for the 90 and 110 pto hp tractors in 1965.

The custom combine selection option is available for only the June 5 and June 6 labor periods of wheat harvest (June 8 - July 31). Zero field workdays were available in the optimum grain sorghum harvesting period of 1957. The wheat custom selection option is not possible in 1957, due to zero field workdays that occur in the June 5 and June 6 labor periods. Without the custom wheat harvest option, labor cannot be freed from wheat harvest for summer row crop cultivation. Lack of optimum harvest period and reduced labor for summer row crop cultivation reduces grain sorghum acreage selected for the 90 and 110 pto hp tractors in 1957.

In a year of average rainfall for the 90 pto hp tractor, 958.8 crop acres are selected; and similarly in 1951 for the 130 pto hp tractor, 954.1 acres are selected. The objective values for the 90 pto hp tractor in an average rainfall year and for the 130 pto hp tractor in 1951 are respectively $37,118.11 and $31,491.77. The objective value for the 90 pto hp tractor in 1951 on 692.2 selected acres is $24,508.39 or 34 per cent less than the average rainfall year's objective value. The analysis and implication of using a 130 pto hp tractor so a minimum of 950 acres can be farmed in the wettest year follows.

The total penalty on 958.8 acres selected in an average rainfall year for the 90 pto hp tractor is $1,031.27. In 1951 the total penalty for untimely field operations by the 130 pto hp tractor is $6,743.03. In an average rainfall year on 950.0 acres the penalty for the 130 pto hp tractor would be $1,031.27 or less. The difference between the 90 pto hp tractor's penalty and the 130 pto hp tractor's penalty in 1951 is $5,711.76. Adding the $5,711.76 difference to the 130 pto hp tractor's 1951 objective value result gives an estimated objective value for the 130 pto hp tractor in an average rainfall year on 950 acres of $37,203.53.

Total tractor hours are 338 hours less for the 130 pto hp tractor on 954.1 acres than are the 90 pto hp tractor's on 958.8 acres. Using the larger 130 pto hp tractor on 950 acres would result in nearly identical income in average rainfall years and would greatly reduce lo-ses incurred in a year such as 1951 by 50 per cent. Tractor capacity in this instance increases more than the variable cost of operating the larger tractor, giving the advantage in terms of income and labor to the larger tractor in 950 acres.

As tractor capacity is increased from 90 to 130 pto hp, custom hire expenses increase. As tractor capacity is increased from 130 pto hp to 215 pto hp, custom hire expenses decrease. As tractor horsepower increases from 90 to 110 to 130 pto hp, wheat acres custom combined respectively for each tractor size in an average rainfall year are 333.3 acres, 367.8 acres, and 412.8 acres. Custom hay hauling expenses for the 90, 110, and 130 pto hp tractors are respectively \$539.29, \$539.34, and \$539.34.

In 1951 and 1957, higher than average rainfall years, custom hire expenses decrease from those incurred by all tractor sizes in an average rainfall year. This is due in 1957 to the fact that zero field workdays are available in the wheat custom combine labor periods, allowing no custom wheat harvest. In 1951 only one field workday is available during the two wheat custom combine labor periods, limiting wheat acres custom harvest and thus custom hire expenses.

Custom wheat combine expenses increase as tractor size is increased from 90 to 130 pto hp to free labor for tractor related activities. In an average rainfall year for the 155, 180, and 215 pto hp tractors, wheat acres custom combined are respectively 73.7, 0.0, and 0.0 acres. The greater capacity to accomplish tractor field work of the 155, 180, and 215 pto hp tractors enables labor to be available for wheat harvest without the need of significant custom hire.

In years of higher than average rainfall, except 1957, all tractor sizes rely on some custom combining for wheat acreage selected (Table 22). The model assumes that when field time is too limited to complete harvesting with owned combine, custom harvestors are available and ready to cut. In practice this is not likely to be the case for many farmers. Custom harvestors may have moved to another area where crop harvesting is possible, or the competition among local custom harvesting may be high. The effect of this assumption is that the model may under estimate the true penalty of wet weather during harvest.

# CHAPTER V

# SUMMARY AND CONCLUSIONS

Six tractor and two combine machinery sizes were studied with a linear program model to select the most profitable combination of machinery and implement sizes given acreage limits, crop acreage, and the timeliness of field operations.

The divisibility assumption of linear programming was observed in the model's selection of combine size, and additional programming showed in higher than average rainfall years the income benefits of the 24 foot combine over the 20 foot combine.

Smaller tractors used more labor, farmed fewer acres, received less income, and had wider fluctuations in crop acres selected and income in higher than average rainfall years than did the larger tractors. Given the 1,255 acre restraint, time minimization favors the 215 pto hp tractor, while income maximization favors the 180 pto hp tractor. Plans of farm size expansion would also favor the 215 pto hp tractor.

For the 90, 110, and 130 pto hp tractors, crop acres selected for an average rainfall year are greatly reduced in higher than average rainfall years. For these tractors smaller acreage than the average rainfall year's selection need be considered. For the 130 pto hp tractor, 950 acres would allow less variance in income and farm size from wet to dry years than the 1,242.9 acres selected based on average year's rainfall.

As information about machinery variable cost and timeliness estimations improves, so will go the information of machinery selection models. This linear program does have information that is useful to farmers for selecting farm of machine size.

## Suggestions for Improving the Model

One difficulty with the study is that crop acres were allowed to adjust to the fewer field workdays during the above average rainfall years. Farmers are not likely to adjust acreage since they do not have advance knowledge of rainfall during planting or harvest time. One possible modification would be to allow the model to select the optimum acreage for the average year. Then lock in this acreage by crop for the wet years. This assumes the farmers plan their organization for the average year. An alternative strategy could be tested in a similar way.

Another modification in the model could be to limit the amount of custom harvesting during above average rainfall years. The amount of custom harvesting available in the average year or above average rainfall years requires data not now available. But one suggestion might be to limit the amount of custom harvesting during above average rainfall years to the amount used in the average year.

APPENDIX

# ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

```
WHEAT     -OBJ       +CPLDWHT   -WHTPD     +PLT,WHT   +HARV,WHT  +TWHEAT
TRWHT155  +DISWHT1   +DISWHT2   +SPT,WHT1  +SPT,WHT2  +SPT,WHT3  -TWHEAT
CMWT20    -HARV,WHT  +CMBWHT20
20CWJN4   -OBJ       +LAB,JN.1  +LAB,JN.4  +CMB,JN.4  -CMBWHT20
20CWJN5   -OBJ       +LAB,JN.2  +LAB,JN.5  +CMB,JN.5  -CMBWHT20
20CWJN6   -OBJ       +WHTPD     +LAB,JN.2  +LAB,JN.6  +CMB,JN.6  -CMBWHT20
20CWJL3   -OBJ       +WHTPD     +LAB,JL.1  +LAB,JL.3  +CMB,JL.3  -CMBWHT20
20CWJL4   -OBJ       +WHTPD     +LAB,JL.1  +LAB,JL.4  +CMB,JL.4  -CMBWHT20
20CWJL5   -OBJ       +WHTPD     +LAB,JL.2  +LAB,JL.5  +CMB,JL.5  -CMBWHT20
20CWJL6   -OBJ       +WHTPD     +LAB,JL.2  +LAB,JL.6  +CMB,JL.6  -CMBWHT20
CMWT24    -HARV,WHT  +CMBWHT24
24CWJN4   -OBJ       +LAB,JN.1  +LAB,JN.4  +CMB,JN.4  -CMBWHT24
24CWJN5   -OBJ       +LAB,JN.2  +LAB,JN.5  +CMB,JN.5  -CMBWHT24
24CWJN6   -OBJ       +WHTPD     +LAB,JN.2  +LAB,JN.6  +CMB,JN.6  -CMBWHT24
24CWJL3   -OBJ       +WHTPD     +LAB,JL.1  +LAB,JL.3  +CMB,JL.3  -CMBWHT24
24CWJL4   -OBJ       +WHTPD     +LAB,JL.1  +LAB,JL.4  +CMB,JL.4  -CMBWHT24
24CWJL5   -OBJ       +WHTPD     +LAB,JL.2  +LAB,JL.5  +CMB,JL.5  -CMBWHT24
24CWJL6   -OBJ       +WHTPD     +LAB,JL.2  +LAB,JL.6  +CMB,JL.6  -CMBWHT24
CCWHT1    -HARV,WHT  +TCCWHT1
CCJN5     -OBJ       +CUS,JN.5  -TCCWHT1
CCJN6     -OBJ       +WHTPD     +CUS,JN.6  -TCCWHT1
DIS,WHT1  -DISWHT1   +TDISWHT1
DW,TJL.1  -OBJ       +LAB,JL.1  +TRC,JL.1  -TDISWHT1
DW,TJL.2  -OBJ       +LAB,JL.2  +TRC,JL.2  -TDISWHT1
DIS,WHT2  -DISWHT2   +TDISWHT2
DWT2JL.2  -OBJ       +LAB,JL.2  +TRC,JL.2  -TDISWHT2
DW,TAU.1  -OBJ       +LAB,AU.1  +TRC,AU.1  -TDISWHT2
SPTHWHT1  -SPT,WHT1  +TSPTWHT1
STWTAU.1  -OBJ       +LAB,AU.1  +TRC,AU.1  -TSPTWHT1
STWTAU.2  -OBJ       +LAB,AU.2  +TRC,AU.2  -TSPTWHT1
SPTHWHT2  -SPT,WHT2  +TSPTWHT2
ST2WTAU1  -OBJ       +LAB,AU.1  +TRC,AU.1  -TSPTWHT2
ST2WTAU2  -OBJ       +LAB,AU.2  +TRC,AU.2  -TSPTWHT2
SPTHWHT3  -SPT,WHT3  +TSPTWHT3
STWTSE.1  -OBJ       +LAB,SE.1  +TRC,SE.1  -TSPTWHT3
STWTSE.2  -OBJ       +LAB,SE.2  +TRC,SE.2  -TSPTWHT3
16PLTWT   -PLT,WHT   +PLTWHT16
25PLTWT   -PLT,WHT   +PLTWHT25
33PLTWT   -PLT,WHT   +PLTWHT33
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16PWSE.1   -OBJ       +WHTPD     +LAB,SE.1 +TRC,SE.1 -PLTWHT16
16PWSE.2   +WHTPD     -OBJ       +LAB,SE.2 +TRC,SE.2 -PLTWHT16
16PWOC.1   -OBJ       +LAB,OC.1 +TRC,OC.1 -PLTWHT16
16PWOC.2   -OBJ       +WHTPD     +LAB,OC.2 +TRC,OC.2 -PLTWHT16
16PWNO.1   -OBJ       +WHTPD     +LAB,NO.1 +TRC,NO.1 -PLTWHT16
25PWSE.1   -OBJ       +WHTPD     +LAB,SE.1 +TRC,SE.1 -PLTWHT25
25PWSE.2   -OBJ       +WHTPD     +LAB,SE.2 +TRC,SE.2 -PLTWHT25
25PWOC.1   -OBJ       +LAB,OC.1 +TRC,OC.1 -PLTWHT25
25PWOC.2   -OBJ       +WHTPD     +LAB,OC.2 +TRC,OC.2 -PLTWHT25
25PWNO.1   -OBJ       +WHTPD     +LAB,NO.1 +TRC,NO.1 -PLTWHT25
33PWSE.1   -OBJ       +WHTPD     +LAB,SE.1 +TRC,SE.1 -PLTWHT33
33PWSE.2   -OBJ       +WHTPD     +LAB,SE.2 +TRC,SE.2 -PLTWHT33
33PWOC.1   -OBJ       +LAB,OC.1 +TRC,OC.1 -PLTWHT33
33PWOC.2   -OBJ       +WHTPD     +LAB,OC.2 +TRC,OC.2 -PLTWHT33
33PWNO.1   -OBJ       +WHTPD     +LAB,NO.1 +TRC,NO.1 -PLTWHT33
SELLWHT    +OBJ       +WHTPD
GRSORG     -OBJ       +CPLDGS    -GSPD     +PLT,GS   +CULT,GS  +HARV,GS  +TGRSORG
TRGS155    +PLOW,GS   +DISK,GS   -TGRSORG
PLOWG,S    -PLOW,GS   +TPLOWGS
PG,SMR.1   -OBJ       +LAB,MR.1 +TRC,MR.1 -TPLOWGS
PG,SMR.2   -OBJ       +LAB,MR.2 +TRC,MR.2 -TPLOWGS
PG,SAP.1   -OBJ       +LAB,AP.1 +TRC,AP.1 -TPLOWGS
PG,SAP.2   -OBJ       +LAB,AP.2 +TRC,AP.2 -TPLOWGS
DISKG,S    -DISK,GS   +TDISKGS
DG,SAP.1   -OBJ       +LAB,AP.1 +TRC,AP.1 -TDISKGS
DG,SAP.2   -OBJ       +LAB,AP.2 +TRC,AP.2 -TDISKGS
DG,SMA.1   -OBJ       +LAB,MA.1 +TRC,MA.1 -TDISKGS
DG,SMA.2   -OBJ       +LAB,MA.2 +TRC,MA.2 -TDISKGS
PLTGS6R    -PLT,GS    +PLTGS6    +PL/CU6R
PLTGS8R    -PLT,GS    +PLTGS8    +PL/CU8R
PLTGS12R   -PLT,GS    +PLTGS12   +PL/CU12R
PLTGS18R   -PLT,GS    +PLTGS18   +PL/CU18R
6PGSM1     -OBJ       +LAB,MA.1 +TRC,MA.1 -PLTGS6    +PENLGS1
6PGSM2     -OBJ       +LAB,MA.2 +TRC,MA.2 -PLTGS6    +PENLGS2
6PGSJN1    -OBJ       +LAB,JN.1 +TRC,JN.1 -PLTGS6    +PENLGS3
6PGSJN2    -OBJ       +LAB,JN.2 +TRC,JN.2 -PLTGS6    +PENLGS4
6PGSJL1    -OBJ       +LAB,JL.1 +TRC,JL.1 -PLTGS6    +PENLGS5
8PGSM1     -OBJ       +LAB,MA.1 +TRC,MA.1 -PLTGS8    +PENLGS1
8PGSM2     -OBJ       +LAB,MA.2 +TRC,MA.2 -PLTGS8    +PENLGS2
8PGSJN1    -OBJ       +LAB,JN.1 +TRC,JN.1 -PLTGS8    +PENLGS3
```

```
20CGSDE2   -OBJ       +LAB,DE.2 +CMB,DE.2 -CMBGS20  +PENLGS13
CMGS24     -HARV,GS   +CMBGS24
24CGSSE1   -OBJ       +LAB,SE.1 +CMB,SE.1 -CMBGS24  +PENLGS6
24CGSSE2   -OBJ       +LAB,SE.2 +CMB,SE.2 -CMBGS24  +PENLGS7
24CGSOC1   -OBJ       +LAB,OC.1 +CMB,OC.1 -CMBGS24  +PENLGS8
24CGSOC2   -OBJ       +LAB,OC.2 +CMB,OC.2 -CMBGS24  +PENLGS9
24CGSNO1   -OBJ       +LAB,NO.1 +CMB,NO.1 -CMBGS24  +PENLGS10
24CGSNO2   -OBJ       +LAB,NO.2 +CMB,NO.2 -CMBGS24  +PENLGS11
24CGSDE1   -OBJ       +LAB,DE.1 +CMB,DE.1 -CMBGS24  +PENLGS12
24CGSDE2   -OBJ       +LAB,DE.2 +CMB,DE.2 -CMBGS24  +PENLGS13
CCGS1      +TCCGS1    -HARV,GS
CCGSOC2A   -OBJ       +GSPD     -TCCGS1   +CUS,OC.2 -PENLGS1  -PENLGS9
CCGSOC2B   -OBJ       +GSPD     -TCCGS1   +CUS,OC.2 -PENLGS2  -PENLGS9
CCGSOC2C   -OBJ       -TCCGS1   +CUS,OC.2 -PENLGS3  -PENLGS9
GSMA1SE1   -OBJ       +GSPD     -PENLGS1  -PENLGS6
GSMA1SE2   +GSPD      -PENLGS1  -PENLGS7
GSMA1OC1   +GSPD      -PENLGS1  -PENLGS8
GSMA1OC2   +GSPD      -PENLGS1  -PENLGS9
GSMA1NO1   +GSPD      -PENLGS1  -PENLGS10
GSMA1NO2   +GSPD      -PENLGS1  -PENLGS11
GSMA2SE2   -OBJ       +GSPD     -PENLGS2  -PENLGS7
GSMA2OC1   +GSPD      -PENLGS2  -PENLGS8
GSMA2OC2   +GSPD      -PENLGS2  -PENLGS9
GSMA2NO1   +GSPD      -PENLGS2  -PENLGS10
GSMA2NO2   +GSPD      -PLNLGS2  -PENLGS11
GSMA2DE1   +GSPD      -PENLGS2  -PENLGS12
GSJN1OC1   -OBJ       +GSPD     -PENLGS3  -PENLGS8
GSJN1OC2   -PENLGS3   -PENLGS9
GSJN1NO1   +GSPD      -PENLGS3  -PENLGS10
GSJN1NO2   +GSPD      -PENLGS3  -PENLGS11
GSJN1DE1   +GSPD      -PENLGS3  -PENLGS12
GSJN1DE2   +GSPD      -PENLGS3  -PENLGS13
GSJN2OC2   -OBJ       +GSPD     -PENLGS4  -PENLGS9
GSJN2NO1   +GSPD      -PENLGS4  -PENLGS10
GSJN2NO2   +GSPD      -PENLGS4  -PENLGS11
GSJN2DE1   +GSPD      -PENLGS4  -PENLGS12
GSJL1NO1   -OBJ       +GSPD     -PENLGS5  -PENLGS10
GSJL1NO2   +GSPD      -PENLGS5  -PENLGS11
GSJL1DE1   +GSPD      -PENLGS5  -PENLGS12
GSJL1DE2   +GSPD      -PENLGS5  -PENLGS13
```

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8PGSJN2    -OBJ       +LAB,JN.2 +TRC,JN.2 -PLTGS8    +PENLGS4
8PGSJL1    -OBJ       +LAB,JL.1 +TRC,JL.1 -PLTGS8    +PENLGS5
12PGSM1    -OBJ       +LAB,MA.1 +TRC,MA.1 -PLTGS12   +PENLGS1
12PGSM2    -OBJ       +LAB,MA.2 +TRC,MA.2 -PLTGS12   +PENLGS2
12PGSJN1   -OBJ       +LAB,JN.1 +TRC,JN.1 -PLTGS12   +PENLGS3
12PGSJN2   -OBJ       +LAB,JN.2 +TRC,JN.2 -PLTGS12   +PENLGS4
12PGSJL1   -OBJ       +LAB,JL.1 +TRC,JL.1 -PLTGS12   +PENLGS5
18PGSM1    -OBJ       +LAB,MA.1 +TRC,MA.1 -PLTGS18   +PENLGS1
18PGSM2    -OBJ       +LAB,MA.2 +TRC,MA.2 -PLTGS18   +PENLGS2
18PGSJN1   -OBJ       +LAB,JN.1 +TRC,JN.1 -PLTGS18   +PENLGS3
18PGSJN2   -OBJ       +LAB,JN.2 +TRC,JN.2 -PLTGS18   +PENLGS4
18PGSJL1   -OBJ       +LAB,JL.1 +TRC,JL.1 -PLTGS18   +PENLGS5
CULG,S6    -CULT,GS   +CULGS6    -PL/CU6R
CULG,S8    -CULT,GS   +CULGS8    -PL/CU8R
CULG,S12   -CULT,GS   +CULGS12   -PL/CU12R
CULG,S18   -CULT,GS   +CULGS18   -PL/CU18R
6CGSJL1    -OBJ       +LAB,JL.1 +TRC,JL.1 -CULGS6
6CGSJL2    -OBJ       +LAB,JL.2 +TRC,JL.2 -CULGS6
6CGSAU1    -OBJ       +LAB,AU.1 +TRC,AU.1 -CULGS6
6CGSAU2    -OBJ       +LAB,AU.2 +TRC,AU.2 -CULGS6
8CGSJL1    -OBJ       +LAB,JL.1 +TRC,JL.1 -CULGS8
8CGSJL2    -OBJ       +LAB,JL.2 +TRC,JL.2 -CULGS8
8CGSAU1    -OBJ       +LAB,AU.1 +TRC,AU.1 -CULGS8
8CGSAU2    -OBJ       +LAB,AU.2 +TRC,AU.2 -CULGS8
12CGSJL1   -OBJ       +LAB,JL.1 +TRC,JL.1 -CULGS12
12CGSJL2   -OBJ       +LAB,JL.2 +TRC,JL.2 -CULGS12
12CGSAU1   -OBJ       +LAB,AU.1 +TRC,AU.1 -CULGS12
12CGSAU2   -OBJ       +LAB,AU.2 +TRC,AU.2 -CULGS12
18CGSJL1   -OBJ       +LAB,JL.1 +TRC,JL.1 -CULGS18
18CGSJL2   -OBJ       +LAB,JL.2 +TRC,JL.2 -CULGS18
18CGSAU1   -OBJ       +LAB,AU.1 +TRC,AU.1 -CULGS18
18CGSAU2   -OBJ       +LAB,AU.2 +TRC,AU.2 -CULGS18
CMGS20     -HARV,GS   +CMBGS20
20CGSSE1   -OBJ       +LAB,SE.1 +CMB,SE.1 -CMBGS20   +PENLGS6
20CGSSE2   -OBJ       +LAB,SE.2 +CMB,SE.2 -CMBGS20   +PENLGS7
20CGSOC1   -OBJ       +LAB,OC.1 +CMB,OC.1 -CMBGS20   +PENLGS8
20CGSOC2   -OBJ       +LAB,OC.2 +CMB,OC.2 -CMBGS20   +PENLGS9
20CGSNO1   -OBJ       +LAB,NO.1 +CMB,NO.1 -CMBGS20   +PENLGS10
20CGSNO2   -OBJ       +LAB,NO.2 +CMB,NO.2 -CMBGS20   +PENLGS11
20CGSDE1   -OBJ       +LAB,DE.1 +CMB,DE.1 -CMBGS20   +PENLGS12
```

```
SELLGS    +OBJ        +GSPD
ALFALFA   +OBJ        +CPLOWALF   +TALFALF1  +TALFALF2
TRCAL155  +PLOW,AF    +SPTH,AF1   +SPTH,AF2  +SPTH,AF3  -TALFALF1
SMALTRC   +DRFT,AF    +SWAT,AF1   +BAL,AF1   +H/S,AF1   +SWAT,AF2  +BAL,AF2   +H/S,AF2   +SWAT,AF3  +BAL,AF3   +H/S,AF3   -TALFALF2
PLOWALF   -PLOW,AF    +TPLOWALF
PALFMR.1  -OBJ        +LAB,MR.1   +TRC,MR.1  -TPLOWALF
PALFMR.2  -OBJ        +LAB,MR.2   +TRC,MR.2  -TPLOWALF
PALFAP.1  -OBJ        +LAB,AP.1   +TRC,AP.1  -TPLOWALF
PALFAP.2  -OBJ        +LAB,AP.2   +TRC,AP.2  -TPLOWALF
SPTHALF1  -SPTH,AF1   +TSPTH1
STALFJN1  -OBJ        +LAB,JN.1   +TRC,JN.1  -TSPTH1
STALFJN2  -OBJ        +LAB,JN.2   +TRC,JN.2  -TSPTH1
SPTHALF2  -SPTH,AF2   +TSPTH2
STALFJL1  -OBJ        +LAB,JL.1   +TRC,JL.1  -TSPTH2
STALFJL2  -OBJ        +LAB,JL.1   +TRC,JL.2  -TSPTH2
SPTHALF3  -SPTH,AF3   +TSPTH3
STALFAU1  -OBJ        +LAB,AU.1   +TRC,AU.2  -TSPTH3
STALFAU2  -OBJ        +LAB,AU.2   +TRC,AU.2  -TSPTH3
DRFTALF   -DRFT,AF    +TDRFTALF
DFAFAU2   +LAB,AU.2   +STRCAU.2   -TDRFTALF
DFAFSE1   +LAB,SE.1   +STRCSE.1   -TDRFTALF
SWATH1    -SWAT,AF1   +TSWATH1
SWALMA5   +LAB,MA.2   +LAB,MA.5   +STRCMA.5  -TSWATH1   +SWALMA.5  +PENALF1   +SW/HSMA5
SWALMA6   +LAB,MA.2   +LAB,MA.6   +STRCMA.6  -TSWATH1   +SWALMA.6  +PENALF2   +SW/HSMA6
SWALJN3   +LAB,JN.1   +LAB,JN.3   +STRCJN.3  -TSWATH1   +SWALJN.3  +PENALF3   +SW/HSJN3
BALE1     -BAL,AF1    +TBALE1
BALEMA5   +LAB,MA.2   +LAB,MA.5   +STRCMA.5  -TBALE1    -SWALMA.5
BALEMA6   +LAB,MA.2   +LAB,MA.6   +STRCMA.6  -TBALE1    -SWALMA.6
BALEJN3   +LAB,JN.1   +LAB,JN.3   +STRCJN.3  -TBALE1    -SWALJN.3
SWATH2    -SWAT,AF2   +TSWATH2
SWALJN5   +LAB,JN.2   +LAB,JN.5   +STRCJN.5  -TSWATH2   +SWALJN.5  +PENALF4   +SW/HSJN5
SWALJN6   +LAB,JN.2   +LAB,JN.6   +STRCJN.6  -TSWATH2   +SWALJN.6  +PENALF5   +SW/HSJN6
SWALJL3   +LAB,JL.1   +LAB,JL.3   +STRCJL.3  -TSWATH2   +SWALJL.3  +PENALF6   +SW/HSJL3
BALE2     -BAL,AF2    +TBALE2
BALEJN5   +LAB,JN.2   +LAB,JN.5   +STRCJN.5  -TBALE2    -SWALJN.5
BALEJN6   +LAB,JN.2   +LAB,JN.6   +STRCJN.6  -TBALE2    -SWALJN.6
BALEJL3   +LAB,JL.1   +LAB,JL.3   +STRCJL.3  -TBALE2    -SWALJL.3
SWATH3    -SWAT,AF3   +TSWATH3
SWALJL5   +LAB,JL.2   +LAB,JL.5   +STRCJL.5  -TSWATH3   +SWALJL.5  +PENALF7   +SW/HSJL5
SWALJL6   +LAB,JL.2   +LAB,JL.6   +STRCJL.6  -TSWATH3   +SWALJL.6  +PENALF8   +SW/HSJL6
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SWALAU3     +LAB,AU.1  +LAB,AU.3  +STRCAU.3 -TSWATH3   +SWALAU.3 +PENALF9   +SW/HSAU3
BALE3       -BAL,AF3   +TBALE3
BALEJL5     +LAB,JL.2  +LAB,JL.5  +STRCJL.5 -TBALE3    -SWALJL.5
BALEJL6     +LAB,JL.2  +LAB,JL.6  +STRCJL.6 -TBALE3    -SWALJL.6
BALEAU3     +LAB,AU.1  +LAB,AU.3  +STRCAU.3 -TBALE3    -SWALAU.3
TH/S1       -H/S,AF1   +TH/SAF1
TH/SMA5     -TH/SAF1   +TH/SMA.5
TH/SMA6     -TH/SAF1   +TH/SMA.6
TH/SJN3     -TH/SAF1   +TH/SJN.3
H/SMA5      +LAB,MA.2  +LAB,MA.5  +STRCMA.5 -TH/SMA.5 -SW/HSMA5
CH/SMA5     -OBJ       -TH/SMA.5  -SW/HSMA5
H/SMA6      +LAB,MA.2  +LAB,MA.6  +STRCMA.6 -TH/SMA.6 -SW/HSMA6
CH/SMA6     -OBJ       -TH/SMA.6  -SW/HSMA6
H/SJN3      +LAB,JN.1  +LAB,JN.3  +STRCJN.3 -TH/SJN.3 -SW/HSJN3
CH/SJN3     -OBJ       -TH/SJN.3  -SW/HSJN3
TH/S2       -H/S,AF2   +TH/SAF2
TH/SJN5     -TH/SAF2   +TH/SJN.5
TH/SJN6     -TH/SAF2   +TH/SJN.6
TH/SJL3     -TH/SAF2   +TH/SJL.3
H/SJN5      +LAB,JN.2  +LAB,JN.5  +STRCJN.5 -TH/SJN.5 -SW/HSJN5
CH/SJN5     -OBJ       -TH/SJN.5  -SW/HSJN5
H/SJN6      +LAB,JN.2  +LAB,JN.6  +STRCJN.6 -TH/SJN.6 -SW/HSJN6
CH/SJN6     -OBJ       -TH/SJN.6  -SW/HSJN6
H/SJL3      +LAB,JL.1  +LAB,JL.3  +STRCJL.3 -TH/SJL.3 -SW/HSJL3
CH/SJL3     -OBJ       -TH/SJL.3  -SW/HSJL3
TH/S3       -H/S,AF3   +TH/SAF3
TH/SJL5     -TH/SAF3   +TH/SJL.5
TH/SJL6     -TH/SAF3   +TH/SJL.6
TH/SAU3     -TH/SAF3   +TH/SAU.3
H/SJL5      +LAB,JL.2  +LAB,JL.5  +STRCJL.5 -TH/SJL.5 -SW/HSJL5
CH/SJL5     -OBJ       -TH/SJL.5  -SW/HSJL5
H/SJL6      +LAB,JL.2  +LAB,JL.6  +STRCJL.6 -TH/SJL.6 -SW/HSJL6
CH/SJL6     -OBJ       -TH/SJL.6  -SW/HSJL6
H/SAU3      +LAB,AU.1  +LAB,AU.3  +STRCAU.3 -TH/SAU.3 -SW/HSAU3
CH/SAU3     -OBJ       -TH/SAU.3  -SW/HSAU3
PENALMA5    -PENALF1
PENALMA6    -OBJ       -PENALF2
PENALJN3    -PENALF3   -OBJ
PENALJN5    -PENALF4
PENALJN6    -OBJ       -PENALF5
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PENALJL3  -OBJ       -PENALF6
PENALJL5  -PENALF7
PENALJL6  -OBJ       -PENALF8
PENALAU3  -OBJ       -PENALF9
B         +CPLDWHT   +CPLDGS    +PLDALF    +LAB,JA.1  +LAB,JA.2  +LAB,AP.1  +LAB,AP.2  +LAB,MA.1  +LAB,MA.2  +LAB,MA.3  +LAB,MA.6  +LAB,JN.1
          +LAB,JN.2  +LAB,JN.3  +LAB,JN.4  +LAB,JN.5  +LAB,JN.6  +LAB,JL.1  +LAB,JL.2  +LAB,JL.3  +LAB,JL.4  +LAB,JL.5  +LAB,JL.6  +LAB,AU.1
          +LAB,AU.2  +LAB,AU.3  +LAB,SE.1  +LAB,SE.2  +LAB,OC.1  +LAB,OC.2  +LAB,NO.1  +LAB,NO.2  +LAB,DE.1  +LAB,DE.2  +TRC,MR.1  +TRC,MR.2
          +TRC,AP.1  +TRC,AP.2  +TRC,MA.1  +TRC,MA.2  +TRC,JN.1  +TRC,JN.2  +TRC,JL.1  +TRC,JL.2  +TRC,AU.1  +TRC,AU.2  +TRC,SE.1  +TRC,SE.2
          +TRC,OC.1  +TRC,OC.2  +TRC,NO.1  +STRCMA.5  +STRCMA.6  +STRCJN.3  +STRCJN.5  +STRCJN.6  +STRCJL.3  +STRCJL.5  +STRCJL.6  +STRCAU.3
          +STRCAU.2  +STRCSE.1  +CUS,JN.5  +CUS,JN.6  +CMB,JN.4  +CMB,JN.5  +CMB,JN.6  +CMB,JL.3  +CMB,JL.4  +CMB,JL.5  +CMB,JL.6  +CMB,SE.1
          +CMB,SE.2  +CMB,OC.1  +CMB,OC.2  +CMB,NO.1  +CMB,NO.2  +CMB,DE.1  +CMB,DE.2  +CUS,OC.2
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 1  OBJ          -21.56999 * WHEAT     -   5.24000 * 20CWJN4   -   2.23000 * 20CWJN5   -   2.23000 * 20CWJN6   -   2.23000 * 20CWJL3
               -   2.23000 * 20CWJL4   -   2.23000 * 20CWJL5   -   2.23000 * 20CWJL6   -   5.35000 * 24CWJN4   -   2.45000 * 24CWJN5
               -   2.45000 * 24CWJN6   -   2.45000 * 24CWJL3   -   2.45000 * 24CWJL4   -   2.45000 * 24CWJL5   -   2.45000 * 24CWJL6
               -   9.40000 * CCJN5     -   9.40000 * CCJN6     -  13.01000 * DW,TJL.1  -  13.01000 * DW,TJL.2  -  13.01000 * DWT2JL.2
               -  13.01000 * DW,TAU.1  -   9.61000 * STWTAU.1  -   9.61000 * STWTAU.2  -   9.61000 * ST2WTAU1  -   9.61000 * ST2WTAU2
               -   9.61000 * STWTSE.1  -   9.61000 * STWTSE.2  -   2.31000 * 16PWSE.1  -   2.31000 * 16PWSE.2  -   2.31000 * 16PWOC.1
               -   2.31000 * 16PWOC.2  -   2.31000 * 16PWNO.1  -   1.85000 * 25PWSE.1  -   1.85000 * 25PWSE.2  -   1.85000 * 25PWOC.1
               -   1.85000 * 25PWOC.2  -   1.85000 * 25PWNO.1  -   1.46000 * 33PWSE.1  -   1.46000 * 33PWSE.2  -   1.46000 * 33PWOC.1
               -   1.46000 * 33PWOC.2  -   1.46000 * 33PWNO.1  +   2.76000 * SELLWHT   -  30.25000 * GRSORG    -  11.73000 * PG,SMR.1
               -  11.73000 * PG,SMR.2  -  11.73000 * PG,SAP.1  -  11.73000 * PG,SAP.2  -  13.01000 * DG,SAP.1  -  13.01000 * DG,SAP.2
               -  13.01000 * DG,SMA.1  -  13.01000 * DG,SMA.2  -   3.87000 * 6PGSM1    -   3.87000 * 6PGSM2    -   3.87000 * 6PGSJN1
               -   3.87000 * 6PGSJN2   -   3.87000 * 6PGSJL1   -   3.21000 * 8PGSM1    -   3.21000 * 8PGSM2    -   3.21000 * 8PGSJN1
               -   3.21000 * 8PGSJN2   -   3.21000 * 8PGSJL1   -   2.33000 * 12PGSM1   -   2.33000 * 12PGSM2   -   2.33000 * 12PGSJN1
               -   2.33000 * 12PGSJN2  -   2.33000 * 12PGSJL1  -   1.84000 * 18PGSM1   -   1.84000 * 18PGSM2   -   1.84000 * 18PGSJN1
               -   1.84000 * 18PGSJN2  -   1.84000 * 18PGSJL1  -   2.15000 * 6CGSJL1   -   2.15000 * 6CGSJL2   -   2.15000 * 6CGSAU1
               -   2.15000 * 6CGSAU2   -   1.67000 * 8CGSJL1   -   1.67000 * 8CGSJL2   -   1.67000 * 8CGSAU1   -   1.67000 * 8CGSAU2
               -   1.24000 * 12CGSJL1  -   1.24000 * 12CGSJL2  -   1.24000 * 12CGSAU1  -   1.24000 * 12CGSAU2  -   0.87000 * 18CGSJL1
               -   0.87000 * 18CGSJL2  -   0.87000 * 18CGSAU1  -   0.87000 * 18CGSAU2  -   2.72000 * 20CGSSE1  -   2.72000 * 20CGSSE2
               -   2.72000 * 20CGSOC1  -   2.72000 * 20CGSOC2  -   2.72000 * 20CGSNO1  -   2.72000 * 20CGSNO2  -   2.72000 * 20CGSDE1
               -   2.72000 * 20CGSDE2  -   3.11000 * 24CGSSE1  -   3.11000 * 24CGSSE2  -   3.11000 * 24CGSOC1  -   3.11000 * 24CGSOC2
               -   3.11000 * 24CGSNO1  -   3.11000 * 24CGSNO2  -   3.11000 * 24CGSDE1  -   3.11000 * 24CGSDE2  -  10.64000 * CCGSOC2A
               -  10.64000 * CCGSOC2B  -  10.64000 * CCGSOC2C  -  10.71000 * GSMA1SE1  -  10.71000 * GSMA2SE2  -  10.71000 * GSJN1OC1
               -  10.71000 * GSJN2OC2  -  10.71000 * GSJLINO1  +   1.70000 * SELLGS    +  62.67000 * ALFALFA   -  11.73000 * PALFMR.1
               -  11.73000 * PALFMK.2  -  11.73000 * PALFAP.1  -  11.73000 * PALFAP.2  -   9.61000 * STALFJN1  -   9.61000 * STALFJN2
               -   9.61000 * STALFJL1  -   9.61000 * STALFJL2  -   9.61000 * STALFAU1  -   9.61000 * STALFAU2  -   7.87000 * CH/SMA5
               -   8.27000 * CH/SMA6   -   8.63000 * CH/SJN3   -   6.13000 * CH/SJN5   -   6.43000 * CH/SJN6   -   6.43000 * CH/SJL3
               -   3.73000 * CH/SJL5   -   4.33000 * CH/SJL6   -   3.73000 * CH/SAU3   -   4.77000 * PENALMA6  -   7.85000 * PENALJN3
               -   4.03000 * PENALJN6  -   7.18000 * PENALJL3  -   0.21000 * PENALJL6  -   4.88000 * PENALAU3
             OBJECTIV

 2  WHTPD        -29.09999 * WHEAT     +   0.70000 * 20CWJN6   +   1.70000 * 20CWJL3   +   2.00000 * 20CWJL4   +   2.70000 * 20CWJL5
               +   3.30000 * 20CWJL6   +   0.70000 * 24CWJN6   +   1.70000 * 24CWJL3   +   2.00000 * 24CWJL4   +   2.70000 * 24CWJL5
               +   3.30000 * 24CWJL6   +   0.70000 * CCJN6     +   5.40000 * 16PWSE.1  +   1.30000 * 16PWSE.2  +   3.00000 * 16PWOC.2
               +   8.00000 * 16PWNO.1  +   5.40000 * 25PWSE.1  +   1.30000 * 25PWSE.2  +   3.00000 * 25PWOC.2  +   8.00000 * 25PWNO.1
               +   5.40000 * 33PWSE.1  +   1.30000 * 33PWSE.2  +   3.00000 * 33PWOC.2  +   8.00000 * 33PWNO.1  +   1.00000 * SELLWHT
               <=          0.0

 3  GSPD         -46.79999 * GRSORG    +  13.40000 * CCGSOC2A  +  10.20000 * CCGSOC2B  +  15.90000 * GSMA1SE1  +  10.30000 * GSMA1SE2
               +  11.40000 * GSMA1OC1  +  13.40000 * GSMA1OC2  +  15.80000 * GSMA1NO1  +  17.89999 * GSMA1NO2  +  14.60000 * GSMA2SE2
               +   9.00000 * GSMA2OC1  +  10.20000 * GSMA2OC2  +  12.40000 * GSMA2NO1  +  14.30000 * GSMA2NO2  +  16.39999 * GSMA2DE1
               +   5.60000 * GSJN1OC1  +   1.10000 * GSJN1NO1  +   3.20000 * GSJN1NO2  +   5.30000 * GSJN1DE1  +   7.40000 * GSJN1DE2
               +   8.40000 * GSJN2OC2  +   2.80000 * GSJN2NO1  +   3.90000 * GSJN2NO2  +   6.00000 * GSJN2DE1  +  11.60000 * GSJLINO1
               +   5.70000 * GSJLINO2  +   7.00000 * GSJLIDE1  +   9.20000 * GSJLIDE2  +   1.00000 * SELLGS
               <=          0.0

 4  DISWHT1        0.11000 * TRWHT155  -   1.00000 * DIS,WHT1
               <=          0.0

 5  DISWHT2        0.11000 * TRWHT155  -   1.00000 * DIS,WHT2
               <=          0.0

 6  SPT,WHT1       0.09000 * TRWHT155  -   1.00000 * SPTHWHT1
               <=          0.0
 7  SPT,WHT2       0.09000 * TRWHT155  -   1.00000 * SPTHWHT2
               <=          0.0

 8  SPT,WHT3       0.09000 * TRWHT155  -   1.00000 * SPTHWHT3
               <=          0.0

 9  PLT,WHT        1.06000 * WHEAT     -   1.00000 * 16PLTWT   -   1.00000 * 25PLTWT   -   1.00000 * 33PLTWT
               <=          0.0

10  HARV,WHT       1.00000 * WHEAT     -   1.00000 * CMWT20    -   1.00000 * CMWT24    -   1.00000 * CCWHT1
               <=          0.0

11  HARV,GS        1.00000 * GRSORG    -   1.00000 * CMGS20    -   1.00000 * CMGS24    -   1.00000 * CCGS1
               <=          0.0

12  CMBWHT20       1.00000 * CMWT20    -   1.00000 * 20CWJN4   -   1.00000 * 20CWJN5   -   1.00000 * 20CWJN6   -   1.00000 * 20CWJL3
               -   1.00000 * 20CWJL4   -   1.00000 * 20CWJL5   -   1.00000 * 20CWJL6
               <=          0.0
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```
13  CMBWHT24     1.00000 * CMWT24    -  1.00000 * 24CWJN4  -  1.00000 * 24CWJN5  -  1.00000 * 24CWJN6  -  1.00000 * 24CWJL3
             -   1.00000 * 24CWJL4   -  1.00000 * 24CWJL5  -  1.00000 * 24CWJL6
             <=        0.0

14  CMBGS20      1.00000 * CMGS20    -  1.00000 * 20CGSSE1 -  1.00000 * 20CGSSE2 -  1.00000 * 20CGSDC1 -  1.00000 * 20CGSDC2
             -   1.00000 * 20CGSNO1  -  1.00000 * 20CGSNO2 -  1.00000 * 20CGSDE1 -  1.00000 * 20CGSDE2
             <=        0.0

15  CMBGS24      1.00000 * CMGS24    -  1.00000 * 24CGSSE1 -  1.00000 * 24CGSSE2 -  1.00000 * 24CGSDC1 -  1.00000 * 24CGSDC2
             -   1.00000 * 24CGSNO1  -  1.00000 * 24CGSNO2 -  1.00000 * 24CGSDE1 -  1.00000 * 24CGSDE2
             <=        0.0

16  TCCWHT1      1.00000 * CCWHT1    -  1.00000 * CCJN5    -  1.00000 * CCJN6
             <=        0.0

17  TCCGS1       1.00000 * CCGS1     -  1.00000 * CCGSDC2A -  1.00000 * CCGSDC2B -  1.00000 * CCGSDC2C
             <=        0.0

18  CUS,GC.2     0.20000 * CCGSDC2A  +  0.20000 * CCGSDC2B +  0.20000 * CCGSDC2C
             <=       96.00000

19  PLOW,GS      0.38000 * TRGS155   -  1.00000 * PLOWG,S
             <=        0.0

20  DISK,GS      0.11000 * TRGS155   -  1.00000 * DISKG,S
             <=        0.0
21  PLT,GS       1.10000 * GRSORG    -  1.00000 * PLTGS6R  -  1.00000 * PLTGS8R  -  1.00000 * PLTGS12R -  1.00000 * PLTGS18R
             =         0.0

22  CULT,GS      2.00000 * GRSORG    -  1.00000 * CULG,S6  -  1.00000 * CULG,S8  -  1.00000 * CULG,S12 -  1.00000 * CULG,S18
             <=        0.0

23  CPLDWHT      1.00000 * WHEAT
             <=      600.00000

24  CPLDGS       1.00000 * GRSORG
             <=      600.00000

25  CPLDALF      1.00000 * ALFALFA
             <=       55.00000

26  DRFT,AF      1.10000 * SMALTRC   -  1.00000 * DRFTALF
             =         0.0

27  PLOW,AF      0.08000 * TRCAL155  -  1.00000 * PLOWA,F
             <=        0.0

28  SPTH,AF1     0.02000 * TRCAL155  -  1.00000 * SPTHALF1
             <=        0.0

29  SPTH,AF2     0.02000 * TRCAL155  -  1.00000 * SPTHALF2
             <=        0.0

30  SPTH,AF3     0.02000 * TRCAL155  -  1.00000 * SPTHALF3
             <=        0.0

31  SWAT,AF1     1.00000 * SMALTRC   -  1.00000 * SWATH1
             <=        0.0
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32  BAL,AF1        1.00000 * SMALTRC   -   1.00000 * BALE1
               <=     0.0

33  H/S,AF1        1.00000 * SMALTRC   -   1.00000 * TH/S1
               <=     0.0

34  SWAT,AF2       1.00000 * SMALTRC   -   1.00000 * SWATH2
               <=     0.0

35  BAL,AF2        1.00000 * SMALTRC   -   1.00000 * BALE2
               <=     0.0
36  H/S,AF2        1.00000 * SMALTRC   -   1.00000 * TH/S2
               <=     0.0

37  SWAT,AF3       1.00000 * SMALTRC   -   1.00000 * SWATH3
               <=     0.0

38  BAL,AF3        1.00000 * SMALTRC   -   1.00000 * BALE3
               <=     0.0

39  H/S,AF3        1.00000 * SMALTRC   -   1.00000 * TH/S3
               <=     0.0

40  LAB,MR.1       1.00000 * PG,SMR.1 +   1.00000 * PALFMR.1
               <=     90.00000

41  LAB,MR.2       1.00000 * PG,SMR.2 +   1.00000 * PALFMR.2
               <=     90.00000

42  LAB,AP.1       1.00000 * PG,SAP.1 +   1.00000 * DG,SAP.1 +   1.00000 * PALFAP.1
               <=     110.00000

43  LAB,AP.2       1.00000 * PG,SAP.2 +   1.00000 * DG,SAP.2 +   1.00000 * PALFAP.2
               <=     120.00000

44  LAB,MA.1       1.00000 * DG,SMA.1 +   0.34000 * 6PGSM1   +   0.26000 * 8PGSM1   +   0.17000 * 12PGSM1  +   0.11000 * 18PGSM1
               <=     100.00000

45  LAB,MA.2       1.00000 * DG,SMA.2 +   0.34000 * 6PGSM2   +   0.26000 * 8PGSM2   +   0.17000 * 12PGSM2  +   0.11000 * 18PGSM2
               +   0.24000 * SWALMA5  +   0.24000 * SWALMA6  +   0.25000 * BALEMA5  +   0.25000 * BALEMA6  +   1.31000 * H/SMA5
               +   1.38000 * H/SMA6
               <=     100.00000

46  LAB,MA.5       0.24000 * SWALMA5  +   0.25000 * BALEMA5  +   1.31000 * H/SMA5
               <=     60.00000

47  LAB,MA.6       0.24000 * SWALMA6  +   0.25000 * BALEMA6  +   1.38000 * H/SMA6
               <=     40.00000

48  LAB,JN.1       0.34000 * 20CWJN4  +   0.30000 * 24CWJN4  +   0.34000 * 6PGSJN1  +   0.26000 * 8PGSJN1  +   0.17000 * 12PGSJN1
               +   0.11000 * 18PGSJN1 +   1.00000 * STALFJN1 +   0.24000 * SWALJN3  +   0.28000 * BALEJN3  +   1.43000 * H/SJN3
               <=     90.00000

49  LAB,JN.2       0.34000 * 20CWJN5  +   0.34000 * 20CWJN6  +   0.30000 * 24CWJN5  +   0.30000 * 24CWJN6  +   0.34000 * 6PGSJN2
               +   0.26000 * 8PGSJN2  +   0.17000 * 12PGSJN2 +   0.11000 * 18PGSJN2 +   1.00000 * STALFJN2 +   0.24000 * SWALJN5
               +   0.24000 * SWALJN6  +   0.20000 * BALEJN5  +   0.21000 * BALEJN6  +   1.02000 * H/SJN5   +   1.07000 * H/SJN6
               <=     130.00000
50  LAB,JN.3       0.24000 * SWALJN3  +   0.28000 * BALEJN3  +   1.43000 * H/SJN3
               <=     40.00000

51  LAB,JN.4       0.34000 * 20CWJN4  +   0.30000 * 24CWJN4
               <=     50.00000
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52  LAB,JN.5     0.34000 * 20CWJN5   +   0.30000 * 24CWJN5   +   0.24000 * SWALJN5   +   0.20000 * BALEJN5   +   1.02000 * H/SJN5
             <=      50.00000

53  LAB,JN.6     0.34000 * 20CWJN6   +   0.30000 * 24CWJN6   +   0.24000 * SWALJN6   +   0.21000 * BALEJN6   +   1.07000 * H/SJN6
             <=      50.00000

54  LAB,JL.1     0.34000 * 20CWJL3   +   0.34000 * 20CWJL4   +   0.30000 * 24CWJL3   +   0.30000 * 24CWJL4   +   1.00000 * DW,TJL.1
             +   0.34000 * 6PGSJL1   +   0.26000 * 8PGSJL1   +   0.17000 * 12PGSJL1  +   0.11000 * 18PGSJL1  +   0.23000 * 6CGSJL1
             +   0.17000 * 8CGSJL1   +   0.12000 * 12CGSJL1  +   0.08000 * 18CGSJL1  +   1.00000 * STALFJL1  +   1.00000 * STALFJL2
             +   0.24000 * SWALJL3   +   0.21000 * BALEJL3   +   1.07000 * H/SJL3
             <=     110.00000

55  LAB,JL.2     0.34000 * 20CWJL5   +   0.34000 * 20CWJL6   +   0.30000 * 24CWJL5   +   0.30000 * 24CWJL6   +   1.00000 * DW,TJL.2
             +   1.00000 * DWT2JL.2  +   0.23000 * 6CGSJL2   +   0.17000 * 8CGSJL2   +   0.12000 * 12CGSJL2  +   0.08000 * 18CGSJL2
             +   0.24000 * SWALJL5   +   0.24000 * SWALJL6   +   0.12000 * BALEJL5   +   0.14000 * BALEJL6   +   0.62000 * H/SJL5
             +   0.72000 * H/SJL6
             <=     120.00000

56  LAB,JL.3     0.34000 * 20CWJL3   +   0.30000 * 24CWJL3   +   0.24000 * SWALJL3   +   0.21000 * BALEJL3   +   1.07000 * H/SJL3
             <=      50.00000

57  LAB,JL.4     0.34000 * 20CWJL4   +   0.30000 * 24CWJL4
             <=      60.00000

58  LAB,JL.5     0.34000 * 20CWJL5   +   0.30000 * 24CWJL5   +   0.24000 * SWALJL5   +   0.12000 * BALEJL5   +   0.62000 * H/SJL5
             <=      60.00000

59  LAB,JL.6     0.34000 * 20CWJL6   +   0.30000 * 24CWJL6   +   0.24000 * SWALJL6   +   0.14000 * BALEJL6   +   0.72000 * H/SJL6
             <=      60.00000

60  LAB,AU.1     1.00000 * DW,TAU.1  +   1.00000 * STWTAU.1  +   1.00000 * ST2WTAU1  +   0.23000 * 6CGSAU1   +   0.17000 * 8CGSAU1
             +   0.12000 * 12CGSAU1  +   0.08000 * 18CGSAU1  +   1.00000 * STALFAU1  +   0.24000 * SWALAU3   +   0.12000 * BALEAU3
             +   0.62000 * H/SAU3
             <=     110.00000

61  LAB,AU.2     1.00000 * STWTAU.2  +   1.00000 * ST2WTAU2  +   0.23000 * 6CGSAU2   +   0.17000 * 8CGSAU2   +   0.12000 * 12CGSAU2
             +   0.08000 * 18CGSAU2  +   1.00000 * STALFAU2  +   0.06000 * DFAFAU2
             <=     120.00000
62  LAB,AU.3     0.24000 * SWALAU3   +   0.12000 * BALEAU3   +   0.62000 * H/SAU3
             <=      60.00000

63  LAB,SE.1     1.00000 * STWTSE.1  +   0.19000 * 16PWSE.1  +   0.13000 * 25PWSE.1  +   0.09000 * 33PWSE.1  +   0.48000 * 20CGSSE1
             +   0.40000 * 24CGSSE1  +   0.06000 * DFAFSE1
             <=     100.00000

64  LAB,SE.2     1.00000 * STWTSE.2  +   0.19000 * 16PWSE.2  +   0.13000 * 25PWSE.2  +   0.09000 * 33PWSE.2  +   0.48000 * 20CGSSE2
             +   0.40000 * 24CGSSE2
             <=      90.00000

65  LAB,OC.1     0.19000 * 16PWOC.1  +   0.13000 * 25PWOC.1  +   0.09000 * 33PWOC.1  +   0.48000 * 20CGSOC1  +   0.40000 * 24CGSOC1
             <=     110.00000

66  LAB,OC.2     0.19000 * 16PWOC.2  +   0.13000 * 25PWOC.2  +   0.09000 * 33PWOC.2  +   0.48000 * 20CGSOC2  +   0.40000 * 24CGSOC2
             <=     120.00000

67  LAB,NO.1     0.19000 * 16PWNO.1  +   0.13000 * 25PWNO.1  +   0.09000 * 33PWNO.1  +   0.48000 * 20CGSNO1  +   0.40000 * 24CGSNO1
             <=      90.00000

68  LAB,NO.2     0.48000 * 20CGSNO2  +   0.40000 * 24CGSNO2
             <=      90.00000

69  LAB,DE.1     0.48000 * 20CGSDE1  +   0.40000 * 24CGSDE1
             <=      90.00000
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70  LAB,DE.2      0.48000 * 20CGSDE2 +    0.40000 * 24CGSDE2
              <=      80.00000

71  TRC,MR.1      1.00000 * PG,SMR.1 +    1.00000 * PALFMR.1
              <=      90.00000

72  TRC,MR.2      1.00000 * PG,SMR.2 +    1.00000 * PALFMR.2
              <=      90.00000

73  TRC,AP.1      1.00000 * PG,SAP.1 +    1.00000 * DG,SAP.1 +    1.00000 * PALFAP.1
              <=     110.00000

74  TRC,AP.2      1.00000 * PG,SAP.2 +    1.00000 * DG,SAP.2 +    1.00000 * PALFAP.2
              <=     120.00000

75  TRC,MA.1      1.00000 * DG,SMA.1 +    0.34000 * 6PGSM1   +    0.26000 * 8PGSM1   +    0.17000 * 12PGSM1  +    0.11000 * 18PGSM1
              <=     100.00000
76  TRC,MA.2      1.00000 * DG,SMA.2 +    0.34000 * 6PGSM2   +    0.26000 * 8PGSM2   +    0.17000 * 12PGSM2  +    0.11000 * 18PGSM2
              <=     100.00000

77  TRC,JN.1      0.34000 * 6PGSJN1  +    0.26000 * 8PGSJN1  +    0.17000 * 12PGSJN1 +    0.11000 * 18PGSJN1 +    1.00000 * STALFJN1
              <=      90.00000

78  TRC,JN.2      0.34000 * 6PGSJN2  +    0.26000 * 8PGSJN2  +    0.17000 * 12PGSJN2 +    0.11000 * 18PGSJN2 +    1.00000 * STALFJN2
              <=     130.00000

79  TRC,JL.1      1.00000 * DW,TJL.1 +    0.34000 * 6PGSJL1  +    0.26000 * 8PGSJL1  +    0.17000 * 12PGSJL1 +    0.11000 * 18PGSJL1
              +   0.23000 * 6CGSJL1  +    0.17000 * 8CGSJL1  +    0.12000 * 12CGSJL1 +    0.08000 * 18CGSJL1 +    1.00000 * STALFJL1
              <=     110.00000

80  TRC,JL.2      1.00000 * DW,TJL.2 +    1.00000 * DWT2JL.2 +    0.23000 * 6CGSJL2  +    0.17000 * 8CGSJL2  +    0.12000 * 12CGSJL2
              +   0.08000 * 18CGSJL2 +    1.00000 * STALFJL2
              <=     120.00000

81  TRC,AU.1      1.00000 * DW,TAU.1 +    1.00000 * STWTAU.1 +    1.00000 * ST2WTAU1 +    0.23000 * 6CGSAU1  +    0.17000 * 8CGSAU1
              +   0.12000 * 12CGSAU1 +    0.08000 * 18CGSAU1
              <=     110.00000

82  TRC,AU.2      1.00000 * STWTAU.2 +    1.00000 * ST2WTAU2 +    0.23000 * 6CGSAU2  +    0.17000 * 8CGSAU2  +    0.12000 * 12CGSAU2
              +   0.08000 * 18CGSAU2 +    1.00000 * STALFAU1 +    1.00000 * STALFAU2
              <=     120.00000

83  TRC,SE.1      1.00000 * STWTSE.1 +    0.19000 * 16PWSE.1 +    0.13000 * 25PWSE.1 +    0.09000 * 33PWSE.1
              <=     130.00000

84  TRC,SE.2      1.00000 * STWTSE.2 +    0.19000 * 16PWSE.2 +    0.13000 * 25PWSE.2 +    0.09000 * 33PWSE.2
              <=      70.00000

85  TRC,OC.1      0.19000 * 16PWOC.1 +    0.13000 * 25PWOC.1 +    0.09000 * 33PWOC.1
              <=     110.00000

86  TRC,OC.2      0.19000 * 16PWOC.2 +    0.13000 * 25PWOC.2 +    0.09000 * 33PWOC.2
              <=     120.00000

87  TRC,NO.1      0.19000 * 16PWNO.1 +    0.13000 * 25PWNO.1 +    0.09000 * 33PWNO.1
              <=      90.00000

88  STRCMA.5      0.24000 * SWALMA5  +    0.25000 * SALEMA5  +    1.31000 * H/SMA5
              <=      60.00000

89  STRCMA.6      0.24000 * SWALMA6  +    0.25000 * SALEMA6  +    1.38000 * H/SMA6
              <=      40.00000
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 90  STRCJN.3   <=  0.24000 * SWALJN3  +  0.28000 * BALEJN3  +  1.43000 * H/SJN3
                     40.00000
 91  STRCJN.5   <=  0.24000 * SWALJN5  +  0.20000 * BALEJN5  +  1.02000 * H/SJN5
                     50.00000
 92  STRCJN.6   <=  0.24000 * SWALJN6  +  0.21000 * BALEJN6  +  1.07000 * H/SJN6
                     50.00000
 93  STRCJL.3   <=  0.24000 * SWALJL3  +  0.21000 * BALEJL3  +  1.07000 * H/SJL3
                     50.00000
 94  STRCJL.5   <=  0.24000 * SWALJL5  +  0.12000 * BALEJL5  +  0.62000 * H/SJL5
                     60.00000
 95  STRCJL.6   <=  0.24000 * SWALJL6  +  0.14000 * BALEJL6  +  0.72000 * H/SJL6
                     60.00000
 96  STRCAU.3   <=  0.24000 * SWALAU3  +  0.12000 * BALEAU3  +  0.62000 * H/SAU3
                     60.00000
 97  STRCAU.2   <=  0.06000 * DFAFAU2
                    120.00000
 98  STRCSE.1   <=  0.06000 * DFAFSE1
                    100.00000
 99  CUS,JN.5   <=  0.15000 * CCJN5
                     50.00000
100  CUS,JN.6   <=  0.15000 * CCJN6
                     50.00000
101  CMB,JN.4   <=  0.17000 * 20CWJN4  +  0.15000 * 24CWJN4
                     50.00000
102  CMB,JN.5   <=  0.17000 * 20CWJN5  +  0.15000 * 24CWJN5
                     50.00000
103  CMB,JN.6   <=  0.17000 * 20CWJN6  +  0.15000 * 24CWJN6
                     50.00000
104  CMB,JL.3   <=  0.17000 * 20CWJL3  +  0.15000 * 24CWJL3
                     50.00000
105  CMB,JL.4   <=  0.17000 * 20CWJL4  +  0.15000 * 24CWJL4
                     60.00000
106  CMB,JL.5   <=  0.17000 * 20CWJL5  +  0.15000 * 24CWJL5
                     60.00000
107  CMB,JL.6   <=  0.17000 * 20CWJL6  +  0.15000 * 24CWJL6
                     60.00000
108  CMB,SE.1   <=  0.24000 * 20CGSSE1 +  0.20000 * 24CGSSE1
                    100.00000
109  CMB,SE.2   <=  0.24000 * 20CGSSE2 +  0.20000 * 24CGSSE2
                     90.00000
110  CMB,CC.1   <=  0.24000 * 20CGSCC1 +  0.20000 * 24CGSCC1
                     88.00000
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111  CMB,OC.2     0.24000 * 20CGSOC2 +   0.20000 * 24CGSOC2
               <=  96.00000
112  CMB,NO.1     0.24000 * 20CGSNO1 +   0.20000 * 24CGSNO1
               <=  72.00000
113  CMB,NO.2     0.24000 * 20CGSNO2 +   0.20000 * 24CGSNO2
               <=  72.00000
114  CMB,DE.1     0.24000 * 20CGSDE1 +   0.20000 * 24CGSDE1
               <=  64.00000
115  CMB,DE.2     0.24000 * 20CGSDE2 +   0.20000 * 24CGSDE2
               <=  64.00000
116  TDISWHT1     1.00000 * DIS,WHT1 -   1.00000 * DW,TJL.1 -   1.00000 * DW,TJL.2
               <=  0.0
117  TDISWHT2     1.00000 * DIS,WHT2 -   1.00000 * DWT2JL.2 -   1.00000 * DW,TAU.1
               <=  0.0
118  TSPTWHT1     1.00000 * SPTHWHT1 -   1.00000 * STWTAU.1 -   1.00000 * STWTAU.2
               <=  0.0
119  TSPTWHT2     1.00000 * SPTHWHT2 -   1.00000 * ST2WTAU1 -   1.00000 * ST2WTAU2
               <=  0.0
120  TSPTWHT3     1.00000 * SPTHWHT3 -   1.00000 * STWTSE.1 -   1.00000 * STWTSE.2
               <=  0.0
121  PLTWHT16     1.00000 * 16PLTWT  -   1.00000 * 16PWSE.1 -   1.00000 * 16PWSE.2 -   1.00000 * 16PWOC.1 -   1.00000 * 16PWOC.2
               -  1.00000 * 16PWNO.1
               <=  0.0
122  PLTWHT25     1.00000 * 25PLTWT  -   1.00000 * 25PWSE.1 -   1.00000 * 25PWSE.2 -   1.00000 * 25PWOC.1 -   1.00000 * 25PWOC.2
               -  1.00000 * 25PWNO.1
               <=  0.0
123  PLTWHT33     1.00000 * 33PLTWT  -   1.00000 * 33PWSE.1 -   1.00000 * 33PWSE.2 -   1.00000 * 33PWOC.1 -   1.00000 * 33PWOC.2
               -  1.00000 * 33PWNO.1
               <=  0.0
124  TWHEAT       1.00000 * WHEAT    -   1.00000 * TRWHT155
               <=  0.0
125  TPLOWGS      1.00000 * PLOWG,S  -   1.00000 * PG,SMR.1 -   1.00000 * PG,SMR.2 -   1.00000 * PG,SAP.1 -   1.00000 * PG,SAP.2
               <=  0.0
126  TDISKGS      1.00000 * DISKG,S  -   1.00000 * DG,SAP.1 -   1.00000 * DG,SAP.2 -   1.00000 * DG,SMA.1 -   1.00000 * DG,SMA.2
               <=  0.0
127  TGRSGRG      1.00000 * GRSGRG   -   1.00000 * TRGS155
               <=  0.0
128  PLTGS6       1.00000 * PLTGS6R  -   1.00000 * 6PGSM1   -   1.00000 * 6PGSM2   -   1.00000 * 6PGSJN1  -   1.00000 * 6PGSJN2
               -  1.00000 * 6PGSJL1
               =   0.0
129  PLTGS8       1.00000 * PLTGS8R  -   1.00000 * 8PGSM1   -   1.00000 * 8PGSM2   -   1.00000 * 8PGSJN1  -   1.00000 * 8PGSJN2
               -  1.00000 * 8PGSJL1
               =   0.0
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130  PLTGS12     1.00000 * PLTGS12R -   1.00000 * 12PGSM1  -   1.00000 * 12PGSM2  -   1.00000 * 12PGSJN1 -   1.00000 * 12PGSJN2
             -   1.00000 * 12PGSJL1
             =       0.0

131  PLTGS18     1.00000 * PLTGS18R -   1.00000 * 18PGSM1  -   1.00000 * 18PGSM2  -   1.00000 * 18PGSJN1 -   1.00000 * 18PGSJN2
             -   1.00000 * 18PGSJL1
             =       0.0

132  CULGS6      1.00000 * CULG,S6  -   1.00000 * 6CGSJL1  -   1.00000 * 6CGSJL2  -   1.00000 * 6CGSAU1  -   1.00000 * 6CGSAU2
             <=      0.0
133  CULGS8      1.00000 * CULG,S8  -   1.00000 * 8CGSJL1  -   1.00000 * 8CGSJL2  -   1.00000 * 8CGSAU1  -   1.00000 * 8CGSAU2
             <=      0.0

134  CULGS12     1.00000 * CULG,S12 -   1.00000 * 12CGSJL1 -   1.00000 * 12CGSJL2 -   1.00000 * 12CGSAU1 -   1.00000 * 12CGSAU2
             <=      0.0

135  CULGS18     1.00000 * CULG,S18 -   1.00000 * 18CGSJL1 -   1.00000 * 18CGSJL2 -   1.00000 * 18CGSAU1 -   1.00000 * 18CGSAU2
             <=      0.0

136  PL/CU6R     1.00000 * PLTGS6R  -   1.00000 * CULG,S6
             <=      0.0

137  PL/CU8R     1.00000 * PLTGS8R  -   1.00000 * CULG,S8
             <=      0.0

138  PL/CU12R    1.00000 * PLTGS12R -   1.00000 * CULG,S12
             <=      0.0

139  PL/CU18R    1.00000 * PLTGS18R -   1.00000 * CULG,S18
             <=      0.0

140  PENLGS1     0.91000 * 6PGSM1   +   0.91000 * 8PGSM1   +   0.91000 * 12PGSM1  +   0.91000 * 18PGSM1  -   1.00000 * CCGSOC2A
             -   1.00000 * GSMA1SE1 -   1.00000 * GSMA1SE2 -   1.00000 * GSMA1OC1 -   1.00000 * GSMA1OC2 -   1.00000 * GSMA1NO1
             -   1.00000 * GSMA1NO2
             <=      0.0

141  PENLGS2     0.91000 * 6PGSM2   +   0.91000 * 8PGSM2   +   0.91000 * 12PGSM2  +   0.91000 * 18PGSM2  -   1.00000 * CCGSOC2B
             -   1.00000 * GSMA2SE2 -   1.00000 * GSMA2OC1 -   1.00000 * GSMA2OC2 -   1.00000 * GSMA2NO1 -   1.00000 * GSMA2NO2
             -   1.00000 * GSMA2DE1
             <=      0.0

142  PENLGS3     0.91000 * 6PGSJN1  +   0.91000 * 8PGSJN1  +   0.91000 * 12PGSJN1 +   0.91000 * 18PGSJN1 -   1.00000 * CCGSOC2C
             -   1.00000 * GSJN1OC1 -   1.00000 * GSJN1OC2 -   1.00000 * GSJN1NO1 -   1.00000 * GSJN1NO2 -   1.00000 * GSJN1DE1
             -   1.00000 * GSJN1DE2
             <=      0.0

143  PENLGS4     0.91000 * 6PGSJN2  +   0.91000 * 8PGSJN2  +   0.91000 * 12PGSJN2 +   0.91000 * 18PGSJN2 -   1.00000 * GSJN2OC2
             -   1.00000 * GSJN2NO1 -   1.00000 * GSJN2NO2 -   1.00000 * GSJN2DE1
             <=      0.0

144  PENLGS5     0.91000 * 6PGSJL1  +   0.91000 * 8PGSJL1  +   0.91000 * 12PGSJL1 +   0.91000 * 18PGSJL1 -   1.00000 * GSJL1NO1
             -   1.00000 * GSJL1NO2 -   1.00000 * GSJL1DE1 -   1.00000 * GSJL1DE2
             <=      0.0

145  PENLGS6     1.00000 * 20CGSSE1 +   1.00000 * 24CGSSE1 -   1.00000 * GSMA1SE1
             =       0.0
146  PENLGS7     1.00000 * 20CGSSE2 +   1.00000 * 24CGSSE2 -   1.00000 * GSMA1SE2 -   1.00000 * GSMA2SE2
             =       0.0

147  PENLGS8     1.00000 * 20CGSOC1 +   1.00000 * 24CGSOC1 -   1.00000 * GSMA1OC1 -   1.00000 * GSMA2OC1 -   1.00000 * GSJN1OC1
             =       0.0

148  PENLGS9     1.00000 * 20CGSOC2 +   1.00000 * 24CGSOC2 -   1.00000 * CCGSOC2A -   1.00000 * CCGSOC2B -   1.00000 * CCGSOC2C
             -   1.00000 * GSMA1OC2 -   1.00000 * GSMA2OC2 -   1.00000 * GSJN1OC2 -   1.00000 * GSJN2OC2
             =       0.0
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149  PENLGS10        1.00000 * 20CGSN01 +   1.00000 * 24CGSN01 -   1.00000 * GSMAIN01 -   1.00000 * GSMA2N01 -   1.00000 * GSJN1N01
                 -   1.00000 * GSJN2N01 -   1.00000 * GSJLIN01
                 =         0.0

150  PENLGS11        1.00000 * 20CGSN02 +   1.00000 * 24CGSN02 -   1.00000 * GSMAIN02 -   1.00000 * GSMA2N02 -   1.00000 * GSJN1N02
                 -   1.00000 * GSJN2N02 -   1.00000 * GSJLIN02
                 =         0.0

151  PENLGS12        1.00000 * 20CGSDE1 +   1.00000 * 24CGSDE1 -   1.00000 * GSMA2DE1 -   1.00000 * GSJN1DE1 -   1.00000 * GSJN2DE1
                 -   1.00000 * GSJLIDE1
                 =         0.0

152  PENLGS13        1.00000 * 20CGSDE2 +   1.00000 * 24CGSDE2 -   1.00000 * GSJN1DE2 -   1.00000 * GSJLIDE2
                 =         0.0

153  TSWATH1         1.00000 * SWATH1   -   1.00000 * SWALMA5  -   1.00000 * SWALMA6  -   1.00000 * SWALJN3
                 <=        0.0

154  TBALE1          1.00000 * BALE1    -   1.00000 * BALEMA5  -   1.00000 * BALEMA6  -   1.00000 * BALEJN3
                 <=        0.0

155  TSWATH2         1.00000 * SWATH2   -   1.00000 * SWALJN5  -   1.00000 * SWALJN6  -   1.00000 * SWALJL3
                 <=        0.0

156  TBALE2          1.00000 * BALE2    -   1.00000 * BALEJN5  -   1.00000 * BALEJN6  -   1.00000 * BALEJL3
                 <=        0.0

157  TSWATH3         1.00000 * SWATH3   -   1.00000 * SWALJL5  -   1.00000 * SWALJL6  -   1.00000 * SWALAU3
                 <=        0.0

158  TBALE3          1.00000 * BALE3    -   1.00000 * BALEJL5  -   1.00000 * BALEJL6  -   1.00000 * BALEAU3
                 <=        0.0

159  TALFALF1        1.00000 * ALFALFA  -   1.00000 * TRCAL155
                 <=        0.0
160  TALFALF2        1.00000 * ALFALFA  -   1.00000 * SMALTRC
                 =         0.0

161  TPLOWALF        1.00000 * PLOWA.F  -   1.00000 * PALFMR.1 -   1.00000 * PALFMR.2 -   1.00000 * PALFAP.1 -   1.00000 * PALFAP.2
                 <=        0.0

162  TSPTH1          1.00000 * SPTHALF1 -   1.00000 * STALFJN1 -   1.00000 * STALFJN2
                 <=        0.0

163  TSPTH2          1.00000 * SPTHALF2 -   1.00000 * STALFJL1 -   1.00000 * STALFJL2
                 <=        0.0

164  TSPTH3          1.00000 * SPTHALF3 -   1.00000 * STALFAU1 -   1.00000 * STALFAU2
                 <=        0.0

165  TDRFTALF        1.00000 * DRFTALF  -   1.00000 * DFAFAU2  -   1.00000 * DFAFSE1
                 =         0.0

166  SWALMA.5        1.00000 * SWALMA5  -   1.00000 * BALEMA5
                 <=        0.0

167  SWALMA.6        1.00000 * SWALMA6  -   1.00000 * BALEMA6
                 <=        0.0
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168  SWALJN.3  <=  1.00000 * SWALJN3  -  1.00000 * BALEJN3
                  0.0
169  SWALJN.5  <=  1.00000 * SWALJN5  -  1.00000 * BALEJN5
                  0.0
170  SWALJN.6  <=  1.00000 * SWALJN6  -  1.00000 * BALEJN6
                  0.0
171  SWALJL.3  <=  1.00000 * SWALJL3  -  1.00000 * BALEJL3
                  0.0
172  SWALJL.5  <=  1.00000 * SWALJL5  -  1.00000 * BALEJL5
                  0.0
173  SWALJL.6  <=  1.00000 * SWALJL6  -  1.00000 * BALEJL6
                  0.0
174  SWALAU.3  <=  1.00000 * SWALAU3  -  1.00000 * BALEAU3
                  0.0
175  PENALF1   <=  1.00000 * SWALMA5  -  1.00000 * PENALMA5
                  0.0
176  PENALF2   <=  1.00000 * SWALMA6  -  1.00000 * PENALMA6
                  0.0
177  PENALF3   <=  1.00000 * SWALJN3  -  1.00000 * PENALJN3
                  0.0
178  PENALF4   <=  1.00000 * SWALJN5  -  1.00000 * PENALJN5
                  0.0
179  PENALF5   <=  1.00000 * SWALJN6  -  1.00000 * PENALJN6
                  0.0
180  PENALF6   <=  1.00000 * SWALJL3  -  1.00000 * PENALJL3
                  0.0
181  PENALF7   <=  1.00000 * SWALJL5  -  1.00000 * PENALJL5
                  0.0
182  PENALF8   <=  1.00000 * SWALJL6  -  1.00000 * PENALJL6
                  0.0
183  PENALF9   <=  1.00000 * SWALAU3  -  1.00000 * PENALAU3
                  0.0
184  TH/SAF1   <=  1.00000 * TH/S1    -  1.00000 * TH/SMA5  -  1.00000 * TH/SMA6  -  1.00000 * TH/SJN3
                  0.0
185  TH/SMA.5  <=  1.00000 * TH/SMA5  -  1.00000 * H/SMA5   -  1.00000 * CH/SMA5
                  0.0
186  TH/SMA.6  <=  1.00000 * TH/SMA6  -  1.00000 * H/SMA6   -  1.00000 * CH/SMA6
                  0.0
187  TH/SJN.3  <=  1.00000 * TH/SJN3  -  1.00000 * H/SJN3   -  1.00000 * CH/SJN3
                  0.0
188  TH/SAF2   <=  1.00000 * TH/S2    -  1.00000 * TH/SJN5  -  1.00000 * TH/SJN6  -  1.00000 * TH/SJL3
                  0.0
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189  TH/SJN.5  <=  1.00000 * TH/SJN5  -  1.00000 * H/SJN5   -  1.00000 * CH/SJN5
                   0.0
190  TH/SJN.6  <=  1.00000 * TH/SJN6  -  1.00000 * H/SJN6   -  1.00000 * CH/SJN6
                   0.0

191  TH/SJL.3  <=  1.00000 * TH/SJL3  -  1.00000 * H/SJL3   -  1.00000 * CH/SJL3
                   0.0

192  TH/SAF3   <=  1.00000 * TH/S3    -  1.00000 * TH/SJL5  -  1.00000 * TH/SJL6  -  1.00000 * TH/SAU3
                   0.0

193  TH/SJL.5  <=  1.00000 * TH/SJL5  -  1.00000 * H/SJL5   -  1.00000 * CH/SJL5
                   0.0

194  TH/SJL.6  <=  1.00000 * TH/SJL6  -  1.00000 * H/SJL6   -  1.00000 * CH/SJL6
                   0.0

195  TH/SAU.3  <=  1.00000 * TH/SAU3  -  1.00000 * H/SAU3   -  1.00000 * CH/SAU3
                   0.0

196  SW/HSMA5  <=  1.00000 * SWALMA5  -  1.00000 * H/SMA5   -  1.00000 * CH/SMA5
                   0.0

197  SW/HSMA6  <=  1.00000 * SWALMA6  -  1.00000 * H/SMA6   -  1.00000 * CH/SMA6
                   0.0

198  SW/HSJN3  <=  1.00000 * SWALJN3  -  1.00000 * H/SJN3   -  1.00000 * CH/SJN3
                   0.0

199  SW/HSJN5  <=  1.00000 * SWALJN5  -  1.00000 * H/SJN5   -  1.00000 * CH/SJN5
                   0.0

200  SW/HSJN6  <=  1.00000 * SWALJN6  -  1.00000 * H/SJN6   -  1.00000 * CH/SJN6
                   0.0

201  SW/HSJL3  <=  1.00000 * SWALJL3  -  1.00000 * H/SJL3   -  1.00000 * CH/SJL3
                   0.0

202  SW/HSJL5  <=  1.00000 * SWALJL5  -  1.00000 * H/SJL5   -  1.00000 * CH/SJL5
                   0.0

203  SW/HSJL6  <=  1.00000 * SWALJL6  -  1.00000 * H/SJL6   -  1.00000 * CH/SJL6
                   0.0

204  SW/HSAU3  <=  1.00000 * SWALAU3  -  1.00000 * H/SAU3   -  1.00000 * CH/SAU3
                   0.0
```

TABLE 1A

WHEAT ACTIVITIES NOMENCLATURE, DESCRIPTION and UNITS

| Nomenclature | Description | Units |
|---|---|---|
| WHEAT | Wheat production | acre |
| TRWHT155 | Links tractor for field tillage to the wheat production activity | hr./ac. |
| CMWT20 | Links alternative time periods for harvesting wheat with a 20 ft. combine to the wheat production activity | acre |
| 20CWJN4 | 20 ft. combine wheat June 8-15 | acre |
| 20CWJN5 | 20 ft. combine wheat June 16-23 | acre |
| 20CWJN6 | 20 ft. combine wheat June 24-30 | acre |
| 20CWJL3 | 20 ft. combine wheat July 1-7 | acre |
| 20CWJL4 | 20 ft. combine wheat July 8-15 | acre |
| 20CWJL5 | 20 ft. combine wheat July 16-23 | acre |
| 20CWJL6 | 20 ft. combine wheat July 24-31 | acre |
| CMWT24 | Links alternative time periods for harvesting wheat with a 24 ft. combine to the wheat production activity | acre |
| 24CWJN4 | 24 ft. combine wheat June 8-15 | acre |
| 24CWJN5 | 24 ft. combine wheat June 16-23 | acre |
| 24CWJN6 | 24 ft. combine wheat June 24-30 | acre |
| 24CWJL3 | 24 ft. combine wheat July 1-7 | acre |
| 24CWJL4 | 24 ft. combine wheat July 8-15 | acre |
| 24CWJL5 | 24 ft. combine wheat July 16-23 | acre |
| 24CWJL6 | 24 ft. combine wheat July 24-31 | acre |
| CCWHT1 | Links alternative time periods for hiring a 24 ft. custom combine to the wheat production activity | acre |

TABLE 1A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| CCJN5 | 24 ft. custom combine wheat June 16-23 | acre |
| CCJN6 | 24 ft. custom combine wheat June 24-30 | acre |
| DIS,WHT1 | Links alternative time periods for first disking of wheat acreage to TRWHT155 | hr./ac. |
| DW,TJL.1 | Disk wheat acreage July 1-15 | hr./ac. |
| DW,TJ1.2 | Disk wheat acreage July 16-31 | hr./ac. |
| DIS,WHT2 | Links alternative time periods for second disking of wheat acreage to TRWHT155 | hr./ac. |
| DWT2JL.2 | Disk wheat acreage July 16-31 | hr./ac. |
| DW,TAU.1 | Disk wheat acreage August 1-15 | hr./ac. |
| SPTHWHT1 | Links alternative time periods for first springtoothing of wheat acreage to TRWHT155 | hr./ac. |
| STWTAU.1 | Springtooth wheat acreage August 1-15 | hr./ac. |
| STWTAU.2 | Springtooth wheat acreage August 16-31 | hr./ac. |
| SPTHWHT2 | Links alternative time periods for second springtoothing of wheat acreage to TRWHT155 | hr./ac. |
| ST2WTAU1 | Springtooth wheat acreage August 1-15 | hr./ac. |
| ST2WTAU2 | Springtooth wheat acreage August 16-31 | hr./ac. |
| SPTHWHT3 | Links alternative time periods for third springtoothing of wheat acreage to TRWHT155 | hr./ac. |
| STWTSE.1 | Springtooth wheat acreage Sept. 1-15 | hr./ac. |
| STWTSE.2 | Springtooth wheat acreage Sept. 16-30 | hr./ac. |
| 16PLTWT | Links alternative time periods for drilling wheat with a 16 ft. drill to wheat production | acre |

TABLE 1A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| 25PLTWT | Links alternative time periods for drilling wheat with a 25 ft. drill to wheat production | acre |
| 33PLTWT | Links alternative time periods for drilling wheat with a 33 ft. drill to wheat production | acre |
| 16PWSE.1 | 16 ft. drill wheat acreage Sept. 1-15 | acre |
| 16PWSE.2 | 16 ft. drill wheat acreage Sept. 16-30 | acre |
| 16PWOC.1 | 16 ft. drill wheat acreage Oct. 1-15 | acre |
| 16PWOC.2 | 16 ft. drill wheat acreage Oct. 16-31 | acre |
| 16PWNO.1 | 16 ft. drill wheat acreage Nov. 1-15 | acre |
| 16PWNO.2 | 16 ft. drill wheat acreage Nov. 16-30 | acre |
| 25PWSE.1 | 25 ft. drill wheat acreage Sept. 1-15 | acre |
| 25PWSE.2 | 25 ft. drill wheat acreage Sept. 16-30 | acre |
| 25PWOC.1 | 25 ft. drill wheat acreage Oct. 1-15 | acre |
| 25PWOC.2 | 25 ft. drill wheat acreage Oct. 16-31 | acre |
| 25PWNO.1 | 25 ft. drill wheat acreage Nov. 1-15 | acre |
| 25PWNO.2 | 25 ft. drill wheat acreage Nov. 16-30 | acre |
| 33PWSE.1 | 33 ft. drill wheat acreage Sept. 1-15 | acre |
| 33PWSE.2 | 33 ft. drill wheat acreage Sept. 16-30 | acre |
| 33PWOC.1 | 33 ft. drill wheat acreage Oct. 1-15 | acre |
| 33PWOC.2 | 33 ft. drill wheat acreage Oct. 16-31 | acre |
| 33PWNO.1 | 33 ft. drill wheat acreage Nov. 1-15 | acre |
| 33PWNO.2 | 33 ft. drill wheat acreage Nov. 16-30 | acre |
| SEELWHT | Sell wheat production | bu. |

TABLE 2A

GRAIN SORGHUM ACTIVITIES NOMENCLATURE, DESCRIPTION, and UNITS

| Nomenclature | Description | Units |
|---|---|---|
| GRSORG | Grain Sorghum production activity | acre |
| TRGS155 | Links tractor for field tillage to the grain sorghum production activity | hr./ac. |
| PLOW,S | Links alternative time periods for plowing grain sorghum to TRGS155 | hr./ac. |
| PG,SMR.1 | Plow grain sorghum acreage March 1-15 | hr./ac. |
| PG,SMR.2 | Plow grain sorghum acreage March 16-31 | hr./ac. |
| PG,SAP.1 | Plow grain sorghum acreage April 1-15 | hr./ac. |
| PG,SAP.2 | Plow grain sorghum acreage April 16-30 | hr./ac. |
| DISKG,S | Links alternative time periods for disking grain sorghum to TRGS155 | hr./ac. |
| DG,SAP.1 | Disk grain sorghum acreage April 1-15 | hr./ac. |
| DG,SAP.2 | Disk grain sorghum acreage April 16-30 | hr./ac. |
| DG,SMA.1 | Disk grain sorghum acreage May 1-15 | hr./ac. |
| DG,SMA.2 | Disk grain sorghum acreage May 16-31 | hr./ac. |
| PLTGS6R | Links alternative time periods for planting grain sorghum with a 6 row planter to grain sorghum production | acre |
| PLTGS8R | Links alternative time periods for planting grain sorghum with an 8 row planter to grain sorghum production | acre |
| PLTGS12R | Links alternative time periods for planting grain sorghum with a 12 row planter to grain sorghum production | acre |
| PLTGS18R | Links alternative time periods for planting grain sorghum with an 18 row planter to grain sorghum production | acre |

TABLE 2A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| 6PGSM1 | 6 row plant grain sorghum acreage May 1-15 | acre |
| 6PGSM2 | 6 row plant grain sorghum acreage May 16-31 | acre |
| 6PGSJN1 | 6 row plant grain sorghum acreage June 1-15 | acre |
| 6PGSJN2 | 6 row plant grain sorghum acreage June 16-30 | acre |
| 6PGSJL1 | 6 row plant grain sorghum acreage July 1-15 | acre |
| 8PGSM1 | 8 row plant grain sorghum acreage May 1-15 | acre |
| 8PGSM2 | 8 row plant grain sorghum acreage May 16-31 | acre |
| 8PGSJN1 | 8 row plant grain sorghum acreage June 1-15 | acre |
| 8PGSJN2 | 8 row plant grain sorghum acreage June 16-30 | acre |
| 8PGSJL1 | 8 row plant grain sorghum acreage July 1-15 | acre |
| 12PGSM1 | 12 row plant grain sorghum acreage May 1-15 | acre |
| 12PGSM2 | 12 row plant grain sorghum acreage May 16-31 | acre |
| 12PGSJN1 | 12 row plant grain sorghum acreage June 1-15 | acre |
| 12PGSJN2 | 12 row plant grain sorghum acreage June 16-30 | acre |
| 12PGSJL1 | 12 row plant grain sorghum acreage July 1-15 | acre |
| 18PGSM1 | 18 row plant grain sorghum acreage May 1-15 | acre |

TABLE 2A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| 18PGSM2 | 18 row plant grain sorghum acreage May 16-31 | acre |
| 18PGSJN1 | 18 row plant grain sorghum acreage June 1-15 | acre |
| 18PGSJN2 | 18 row plant grain sorghum acreage June 16-30 | acre |
| 18PGSJL1 | 18 row plant grain sorghum acreage July 1-15 | acre |
| CULG,S6 | Links alternative time periods for cultivating grain sorghum with a 6 row cultivator to grain sorghum production | acre |
| CULG,S8 | Links alternative time periods for cultivating grain sorghum with an 8 row cultivator to grain sorghum production | acre |
| CULG,S12 | Links alternative time periods for cultivating grain sorghum with a 12 row cultivator to grain sorghum production | acre |
| CULG,S18 | Links alternative time periods for cultivating grain sorghum with an 18 row cultivator to grain sorghum production | acre |
| 6CGSJL1 | 6 row cultivate grain sorghum July 1-15 | acre |
| 6CGSJL2 | 6 row cultivate grain sorghum July 16-31 | acre |
| 6CGSAU1 | 6 row cultivate grain sorghum Aug. 1-15 | acre |
| 6CGSAU2 | 6 row cultivate grain sorghum Aug. 16-31 | acre |
| 8CGSJL1 | 8 row cultivate grain sorghum July 1-15 | acre |
| 8CGSJL2 | 8 row cultivate grain sorghum July 16-31 | acre |
| 8CGSAU1 | 8 row cultivate grain sorghum Aug. 1-15 | acre |
| 8CGSAU2 | 8 row cultivate grain sorghum Aug. 16-31 | acre |
| 12CGSJL1 | 12 row cultivate grain sorghum July 1-15 | acre |
| 12CGSJL2 | 12 row cultivate grain sorghum July 16-31 | acre |

TABLE 2A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| 12CGSAU1 | 12 row cultivate grain sorghum Aug. 1-15 | acre |
| 12CGSAU2 | 12 row cultivate grain sorghum Aug. 16-31 | acre |
| 18CGSJL1 | 18 row cultivate grain sorghum July 1-15 | acre |
| 18CGSJL2 | 18 row cultivate grain sorghum July 16-31 | acre |
| 18CGSAU1 | 18 row cultivate grain sorghum Aug. 1-15 | acre |
| 18CGSAU2 | 18 row cultivate grain sorghum Aug. 16-31 | acre |
| CMGS20 | Links alternative time periods for harvesting grain sorghum with a 20 ft. combine to grain sorghum production | acre |
| 20CGSSE1 | 20 ft. combine grain sorghum Sept. 1-15 | acre |
| 20CGSSE2 | 20 ft. combine grain sorghum Sept. 16-30 | acre |
| 20CGSOC1 | 20 ft. combine grain sorghum Oct. 1-15 | acre |
| 20CGSOC2 | 20 ft. combine grain sorghum Oct. 16-31 | acre |
| 20CGSNO1 | 20 ft. combine grain sorghum Nov. 1-15 | acre |
| 20CGSNO2 | 20 ft. combine grain sorghum Nov. 16-30 | acre |
| 20CGSDE1 | 20 ft. combine grain sorghum Dec. 1-15 | acre |
| 20CGSDE2 | 20 ft. combine grain sorghum Dec. 16-31 | acre |
| CMGS24 | Links alternative time periods for harvesting grain sorghum with a 24 ft. combine to grain sorghum production | acre |
| 24CGSSE1 | 24 ft. combine grain sorghum Sept. 1-15 | acre |
| 24CGSSE2 | 24 ft. combine grain sorghum Sept. 16-30 | acre |
| 24CGSOC1 | 24 ft. combine grain sorghum Oct. 1-15 | acre |
| 24CGSOC2 | 24 ft. combine grain sorghum Oct. 16-31 | acre |
| 24CGSNO1 | 24 ft. combine grain sorghum Nov. 1-15 | acre |
| 24CGSNO2 | 24 ft. combine grain sorghum Nov. 16-30 | acre |

TABLE 2A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| 24CGSDE1 | 24 ft. combine grain sorghum Dec. 1-15 | acre |
| 24CGSDE2 | 24 ft. combine grain sorghum Dec. 16-31 | acre |
| CCGS1 | Links alternative time periods for harvesting grain sorghum with a 24 ft. custom combine to grain sorghum production | acre |
| CCGSOC2A | 24 ft. custom combine grain sorghum Oct. 16-31, planted May 1-15 | acre |
| CCGSOC2B | 24 ft. custom combine grain sorghum Oct. 16-31, planted May 16-31 | acre |
| CCGSOC2C | 24 ft. custom combine grain sorghum Oct. 16-31, planted June 1-15 | acre |
| GSMA1SE1 | Grain sorghum penalty for planting May 1-15, and harvesting Sept. 1-15 | bu./ac. |
| GSMA1SE2 | Grain sorghum penalty for planting May 1-15, and harvesting Sept. 16-30 | bu./ac. |
| GSMA1OC1 | Grain sorghum penalty for planting May 1-15, and harvesting Oct. 1-15 | bu./ac. |
| GSMA1OC2 | Grain sorghum penalty for planting May 1-15, and harvesting Oct. 16-31 | bu./ac. |
| GSMA1NO1 | Grain sorghum penalty for planting May 1-15, and harvesting Nov. 1-15 | bu./ac. |
| GSMA1NO2 | Grain sorghum penalty for planting May 1-15, and harvesting Nov. 16-30 | bu./ac. |
| GSMA2SE2 | Grain sorghum penalty for planting May 16-31, and harvesting Sept. 16-30 | bu./ac. |
| GSMA2OC1 | Grain sorghum penalty for planting May 16-31, and harvesting Oct. 1-15 | bu./ac. |
| GSMA2OC2 | Grain sorghum penalty for planting May 16-31, and harvesting Oct. 16-31 | bu./ac. |
| GSMA2NO1 | Grain sorghum penalty for planting May 16-31, and harvesting Nov. 1-15 | bu./ac. |

TABLE 2A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| GSMA2NO2 | Grain sorghum penalty for planting May 16-31, and harvesting Nov. 16-30 | bu./ac. |
| GSMA2DE1 | Grain sorghum penalty for planting May 16-31, and harvesting Dec. 1-15 | bu./ac. |
| GSJN1OC1 | Grain sorghum penalty for planting June 1-15, and harvesting Oct. 1-15 | bu./ac. |
| GSJN1OC2 | Grain sorghum penalty for planting June 1-15, and harvesting Oct. 16-31 | bu./ac. |
| GSJN1NO1 | Grain sorghum penalty for planting June 1-15, and harvesting Nov. 1-15 | bu./ac. |
| GSJN1NO2 | Grain sorghum penalty for planting June 1-15, and harvesting Nov. 16-30 | bu./ac. |
| GSJN1DE1 | Grain sorghum penalty for planting June 1-15, and harvesting Dec. 1-15 | bu./ac. |
| GSJN1DE2 | Grain sorghum penalty for planting June 1-15, and harvesting Dec. 16-31 | bu./ac. |
| GSJN2OC2 | Grain sorghum penalty for planting June 16-30, and harvesting Oct. 16-31 | bu./ac. |
| GSJN2NO1 | Grain sorghum penalty for planting June 16-30, and harvesting Nov. 1-15 | bu./ac. |
| GSJN2NO2 | Grain sorghum penalty for planting June 16-30, and harvesting Nov. 16-30 | bu./ac. |
| GSJN2DE1 | Grain sorghum penalty for planting June 16-30, and harvesting Dec. 1-15 | bu./ac. |
| GSJL1NO1 | Grain sorghum penalty for planting July 1-15, and harvesting Nov. 1-15 | bu./ac. |
| GSJL1NO2 | Grain sorghum penalty for planting July 1-15, and harvesting Nov. 16-30 | bu./ac. |
| GSJL1DE1 | Grain sorghum penalty for planting July 1-15, and harvesting Dec. 1-15 | bu./ac. |
| GSJL1DE2 | Grain sorghum penalty for planting July 1-15, and harvesting Dec. 16-31 | bu./ac. |
| SELLGS | Sell grain sorghum production | bu. |

TABLE 3A

ALFALFA ACTIVITIES NOMENCLATURE, DESCRIPTION, and UNITS

| Nomenclature | Description | Units |
|---|---|---|
| ALFALFA | Alfalfa production | acre |
| TRCAL155 | Links tractor for field tillage to the alfalfa production activity | hr./ac. |
| SMALTRC | Links small tractor for swathing, baling, drilling, hauling-stacking to the alfalfa production activity | acre |
| PLOWA,F | Links alternative time periods for plowing acreage to TRCAL155 | hr./ac. |
| PALFMR.1 | Plowing of alfalfa acreage March 1-15 | hr./ac. |
| PALFMR.2 | Plowing of alfalfa acreage March 16-31 | hr./ac. |
| PALFAP.1 | Plowing of alfalfa acreage April 1-15 | hr./ac. |
| PALFAP.2 | Plowing of alfalfa acreage April 16-30 | hr./ac. |
| SPTHALF1 | Links alternative time periods for first springtoothing of alfalfa acreage to TRCAL155 | hr./ac. |
| STALFJN1 | Springtooth alfalfa acreage June 1-15 | hr./ac. |
| STALFJN2 | Springtooth alfalfa acreage June 16-30 | hr./ac. |
| SPTHALF2 | Links alternative time periods for second springtoothing of alfalfa acreage to TRCAL155 | hr./ac. |
| STALFJL1 | Springtooth alfalfa acreage July 1-15 | hr./ac. |
| STALFJL2 | Springtooth alfalfa acreage July 16-31 | hr./ac. |
| SPTHALF3 | Links alternative time periods for third springtoothing of alfalfa acreage to TRCAL155 | hr./ac. |
| STALFAU1 | Springtooth alfalfa acreage Aug. 1-15 | hr./ac. |
| STALFAU2 | Springtooth alfalfa acreage Aug. 16-31 | hr./ac. |

TABLE 3A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| DRFTALF | Links alternative time periods for drilling and fertilizing alfalfa acreage to the alfalfa production activity | acre |
| DFAFAU2 | Drill and fertilize alfalfa acreage Aug. 16-31 | acre |
| DFAFSE1 | Drill and fertilize alfalfa acreage Sept. 1-15 | acre |
| SWATH1 | Links alternative time periods of first alfalfa swathing to the SMALTRC activity | acre |
| SWALMA5 | Swathing of alfalfa acreage May 16-23 | acre |
| SWALMA6 | Swathing of alfalfa acreage May 24-31 | acre |
| SWALJN3 | Swathing of alfalfa acreage June 1-7 | acre |
| BALE1 | Links alternative time periods of first alfalfa baling to the SMALTRC activity | acre |
| BALEMA5 | Baling of alfalfa acreage May 16-23 | acre |
| BALEMA6 | Baling of alfalfa acreage May 24-31 | acre |
| BALEJN3 | Baling of alfalfa acreage June 1-7 | acre |
| SWATH2 | Links alternative periods of second alfalfa swathing to the SMALTRC activity | acre |
| SWALJN5 | Swathing of alfalfa acreage June 16-23 | acre |
| SWALJN6 | Swathing of alfalfa acreage June 24-30 | acre |
| SWALJL3 | Swathing of alfalfa acreage July 1-7 | acre |
| BALE2 | Links alternative time periods of second alfalfa baling to the SMALTRC activity | acre |
| BALEJN5 | Baling of alfalfa acreage June 16-23 | acre |
| BALEJN6 | Baling of alfalfa acreage June 24-30 | acre |
| BALEJL3 | Baling of alfalfa acreage July 1-7 | acre |

TABLE 3A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| SWATH3 | Links alternative periods of third alfalfa swathing to the SMALTRC activity | acre |
| SWALJL5 | Swathing of alfalfa acreage July 16-23 | acre |
| SWALJL6 | Swathing of alfalfa acreage July 24-31 | acre |
| SWALAU3 | Swathing of alfalfa acreage Aug. 1-7 | acre |
| BALE3 | Links alternative time periods of third alfalfa baling to the SMALTRC activity | acre |
| BALEJL5 | Baling of alfalfa acreage July 16-23 | acre |
| BALEJL6 | Baling of alfalfa acreage July 24-31 | acre |
| BALEAU3 | Baling of alfalfa acreage Aug. 1-7 | acre |
| TH/S1 | Links first hauling and stacking of alfalfa to a hauling and stacking transfer activity | acre |
| TH/SMA5 | Links TH/S1 to May 16-23 hauling and stacking activity | acre |
| TH/SMA6 | Links TH/S1 to May 24-31 hauling and stacking activity | acre |
| TH/SJN3 | Links TH/S1 to June 1-7 hauling and stacking activity | acre |
| H/SMA5 | Haul and stack alfalfa acreage May 16-23 | acre |
| CH/SMA5 | Hire custom hauling and stacking of alfalfa acreage May 16-23 | acre |
| H/SMA6 | Haul and stack alfalfa acreage May 24-31 | acre |
| CH/SMA6 | Hire custom hauling and stacking of alfalfa acreage May 24-31 | acre |
| H/SJN3 | Haul and stack alfalfa acreage June 1-7 | acre |
| CH/SJN3 | Hire custom hauling and stacking of alfalfa acreage June 1-7 | acre |

TABLE 3A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| TH/S2 | Links second hauling and stacking of alfalfa to a hauling and stacking transfer activity | acre |
| TH/SJN5 | Links TH/S2 to June 16-23 hauling and stacking activity | acre |
| TH/SJN6 | Links TH/S2 to June 24-30 hauling and stacking activity | acre |
| TH/SJL3 | Links TH/S2 to July 1-7 hauling and stacking activity | acre |
| H/SJN5 | Haul and stack alfalfa acreage June 16-23 | acre |
| CH/SJN5 | Hire custom hauling and stacking of alfalfa acreage June 16-23 | acre |
| H/SJN6 | Haul and stack alfalfa acreage June 24-30 | acre |
| CH/SJN6 | Hire custom hauling and stacking of alfalfa acreage June 24-30 | acre |
| H/SJL3 | Haul and stack alfalfa acreage July 1-7 | acre |
| CH/SJL3 | Hire custom hauling and stacking of alfalfa acreage July 1-7 | acre |
| TH/S3 | Links third hauling and stacking of alfalfa to a hauling and stacking transfer activity | acre |
| TH/SJL5 | Links TH/S3 to July 16-23 hauling and stacking activity | acre |
| TH/SJL6 | Links TH/S3 to July 24-31 hauling and stacking activity | acre |
| TH/SAU3 | Links TH/S3 to Aug. 1-7 hauling and stacking activity | acre |
| H/SJL5 | Haul and stack alfalfa acreage July 16-23 | acre |
| CH/SJL5 | Hire custom hauling and stacking of alfalfa acreage July 16-23 | acre |

TABLE 3A (Continued)

| Nomenclature | Description | Units |
|---|---|---|
| H/SJL6 | Haul and stack alfalfa acreage July 24-31 | acre |
| CH/SJL6 | Hire custom hauling and stacking of alfalfa acreage July 24-31 | acre |
| H/SAU3 | Haul and stack alfalfa acreage Aug. 1-7 | acre |
| CH/SAU3 | Hire custom hauling and stacking of alfalfa acreage Aug. 1-7 | acre |
| PENALMA5 | Penalty for swathing alfalfa May 16-23 | $/ac. |
| PENALMA6 | Penalty for swathing alfalfa May 24-31 | $/ac. |
| PENALJN3 | Penalty for swathing alfalfa June 1-7 | $/ac. |
| PENALJN5 | Penalty for swathing alfalfa June 16-23 | $/ac. |
| PENALJN6 | Penalty for swathing alfalfa June 24-30 | $/ac. |
| PENALJL3 | Penalty for swathing alfalfa July 1-7 | $/ac. |
| PENALJL5 | Penalty for swathing alfalfa July 16-23 | $/ac. |
| PENALJL6 | Penalty for swathing alfalfa July 24-31 | $/ac. |
| PENALAU3 | Penalty for swathing alfalfa Aug. 1-7 | $/ac. |

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# A LINEAR PROGRAMMING MODEL FOR MACHINERY AND IMPLEMENT SELECTION FOR CENTRAL KANSAS DRYLAND FARMS

by

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AN ABSTRACT OF A MASTER'S THESIS

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The central Kansas linear program model describes with 204 equations the interrelationships among variable costs, yields, farm size, labor availability, field workdays, and machinery capacity for the selection of machinery and implement sizes. Three types of equations that describe a central Kansas farming system for the purpose of machinery and implement selection are the objective being maximized (gross returns less variable costs), resource, and transfer. Crops considered are wheat, grain sorghum, and alfalfa. Land is restricted to 600 acres of wheat, 600 acres of grain sorghum, and 55 acres of alfalfa.

Activities considered in the model are crop production, field operation, field operation transfer, penalties for untimely field operations, penalty transfer, and crop selling.

Nineteen bi-weekly and twelve weekly labor equations are used to describe the important labor periods throughout the year in the model. Labor equations right-hand-side values are defined in terms of field workdays. Five sets of field workday estimates are studied in the selection of machinery and implement sizes. Field workday estimates considered are for an average rainfall year, for higher than average rainfall years 1951, 1957, 1965, and 1967.

Crop budgets, except machinery and implement variable costs, are from Kansas State University Extension Publications. Crop prices are Kansas 1959 to 1976 cumulative average corn-crop price ratios times $2.00 corn. Machinery and implement variable costs are estimated for each size considered. Tractor and combine variable costs are repair and maintenance, oil and lubrication, and fuel. Implement variable costs are repair and maintenance.

Machinery and implement selection size possibilities by the model are tractor, combine, grain drill, row planter, and row cultivator. Machine and implement size, except tractor, is expressed in terms of effective working width. Tractor size is in terms of power take-off horsepower units. Six large tractor sizes ranging from 90 to 215 pto hp are studied. Plow, disk, and springtooth implement widths for each large tractor size are determined by the means of an implement width formula before entering the model. Combine selection can be from two owned sizes, or a custom combine. Grain drill, row planter, and row cultivator selection possibilities are a function of each large tractor's size. A machinery capacity formula is used to determine the rate (hour per acre) at which each size of machine or implement can process land or crops.

Penalty estimates are considered in the model for wheat and grain sorghum untimely planting, premature and delayed harvest, and the cost of drying grain harvested at a high moisture level to a storable moisture content. Alfalfa penalties are for untimely cutting. For each crop's planting, harvesting, and cutting one period is designated as optimum and does not contain a penalty.

Results for the average rainfall year show that smaller tractors farm fewer acres, use more labor, and receive less income. Tractor sizes always select the widest available grain drill, row planter, and row cultivator possible. Results for each tractor's size show the objective value is greater for a year based on average rainfall year's field workdays than for the higher than average rainfall years 1951, 1957, 1965, and 1967 field workdays. Smaller tractors had wider fluctuations in crop acres selected and income in higher than average rainfall years than did the larger tractors. Given the 1255 crop acre restraint, time minimization favors the 215 pto hp tractor, while income maximization favors the 180 pto hp tractor. Additional programming shows greater benefits of the largest owned combine over the smaller owned and custom combine selection choices.