A decision model of combine ownership
by Haifie Loo Lai

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Applied Economics
Montana State University
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Abstract:
General characteristics of the harvesting operation for wheat and barley are explored. Data associated
with harvesting variables are collected for the Triangle Area in Montana. A simulation model is
constructed which incorporates the critical factors involved in the harvesting operation. Strategies for
combine ownership are determined through cost calculation via the computer simulation model. It is
found that for small farms partly own combining and partly custom combining is the best alternative.
For larger farms, however, farmers are better off completely doing their own combining.
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A DECISION MODEL OF COMBINE OWNERSHIP

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HAIFIE LOO LAI

A thesis submitted in partial fulfillment of the requirements for the degree of

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in

Applied Economics

Approved:

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ABSTRACT

General characteristics of the harvesting operation for wheat and barley are explored. Data associated with harvesting variables are collected for the Triangle Area in Montana. A simulation model is constructed which incorporates the critical factors involved in the harvesting operation. Strategies for combine ownership are determined through cost calculation via the computer simulation model. It is found that for small farms partly own combining and partly custom combining is the best alternative. For larger farms, however, farmers are better off completely doing their own combining.
CHAPTER I
INTRODUCTION

Problem Statement

Since World War II, through the rapid development of technology, there has been a trend toward mass production by substituting capital for labor. In agriculture, because of the seasonal character of production, this trend increases the penalties associated with untimely operations. The time limits involved in agricultural production do not allow extended usage of the larger investment for mass production. Farm management in developed countries has thus moved to a new stage requiring the discipline of business management to ensure minimum loss. Harvest, for example, has become one of the critical seasonal operations which needs detailed systems analysis. The total volume of the crop has expanded but time limits imposed by climate and quality considerations have not changed. Thus, selection of an optimum harvest system is of critical importance to farmers. An efficient selection and utilization of the harvesting machinery can contribute substantially to the minimization of total cost.

In Montana, where agriculture constitutes the most important sector of the economy, investigation of the most efficient farming system certainly cannot be neglected. For harvest, farmers in Montana have four different systems to choose from: (1) use of custom services to avoid the commitment of fixed costs; (2) purchase of large machines of
higher capacity and higher fixed costs; (3) purchase of less costly, lower capacity machines; or (4) some combination of the above. The choice depends on the harvesting rate, fixed costs, and variable costs. Due to the uncertainty of the harvesting operation these costs are not some unique value. The cost varies with the physical and yearly environmental factors. For the per unit cost curve of a machinery system, a theoretical distribution exists due to all possible interactions between the probabilistic harvest variables. Traditional budgeting analysis provides only guidelines for farmers in selecting alternative machinery systems. More precise information is provided by a cost analysis which includes the dynamic nature of variables which vary year by year due to different environmental factors.

To determine strategies for harvesting machine ownership, the Triangle Area in Montana (northcentral Montana including part of Cascade, Teton, Pondera, Toole, Liberty, Hill, and Chouteau counties) was chosen. This area is a predominantly agricultural area specializing in grain production with rather uniform farming practices and climatic characteristics. The dynamics of the harvesting operation will be analyzed to give more details of a system's performance and behavior under changing environmental conditions. This information will place farmers in a better position for decision making.
Summary of Past Work

Several different methods have been used before to approach this specific machinery selection problem. Traditional budgeting analysis has been used widely to provide general guidelines in selecting alternative machinery systems. However, the dynamic nature of the critical variables involved suggests that the approach may omit important cost variables. In the United States, Heady and Krenz [11] have developed a modification of the traditional budgeting analysis. They categorized a historical weather sequence into five categories, then for each category they calculated the net returns for a machinery combination at various acreage levels. The return in each weather category was then weighted to obtain an expected value at each acreage level. This procedure provided more information than the traditional static cost analysis method but was still based on rather simplified assumptions.

A better approach that has been employed is systems analysis through simulation. In England, Donaldson [6] and Dalton [4] both used simulation to investigate the harvesting operation. Both were concerned mainly with the relationships between harvesting moisture content, dryer capacity, and combine header work rate. Donaldson included part of the dynamic effects of weather in the analysis. However, due to the lack of data, some probabilistic factors were still taken as assumptions. Dalton incorporated more detailed relationships
between interacting variables in the analysis through mathematical equations estimated from experimental data.

Van Kampen [28] in the Netherlands also constructed a simulation model by including detailed relationships between the most critical interacting variables. He applied this model to study the chain of operations involved in the organization of harvesting, transportation, drying, and storage of the grains with a number of header widths and auxiliary equipment. The Australian model constructed by Ryan [22] is simpler. Due to the lack of experimental data, Ryan used agronomists' estimates of the dynamic variables. This simulation evaluated a contract harvesting system, a power take-off harvesting system, and a self-propelled harvesting system.

Proposed Problem-Solving Method

From the survey of past work investigating the machinery selection problem, simulation appears to be the most rewarding approach. Because of the complexity of the harvesting operation and the large number of stochastic variables involved, no other mathematical programming model is better suited. Systems simulation approach allows investigation of the complex harvesting operation by building into the computer model the dynamic aspects of harvesting. The stochastic variables are also specified as density functions, instead of as single-valued deterministic variables. This descriptive model of the
actual harvesting system can then be run over a number of "years" to investigate the performance of each given machinery system at different acreage levels. Each "year" a new set of harvesting conditions is provided. Parameters may also be altered to test their effect on the system with little or no addition to the computational load of the researcher. In other words, simulation allows the researcher to try out a whole set of alterations to the existing state of affairs without much computational effort. Through such "experimentation," the interaction of the systems' performance can be made clear. Hence, this is the approach proposed here to analyze combine ownership strategies.

Objectives of the Study

The objectives of this study are:

1) To identify, and where appropriate estimate, the probability distributions of variables that affect the harvesting operation.

2) To estimate the cost curves of the harvesting operation under different machinery systems.

3) To identify the most critical elements which affect the cost of harvesting and reveal the characteristics of the system's performance.

4) To establish some criteria for selecting the optimal machinery system.
CHAPTER II

METHODOLOGY

Systems simulation approach is used in this study. A descriptive model of the actual harvesting system is first built into the computer. Experimentation to determine the system's behavior can then be easily performed. Building this descriptive model so that the results of the experimentation fit closely to reality is important. The characteristics of the actual system and its interacting environmental variables must be carefully investigated. In this chapter, the general characteristics of the problem area, the critical factors and variables involved, and the simulation model developed are discussed in Sections 1, 2, and 3, respectively.

1. Characteristics of the Farms in the Triangle Area

Farm Size

According to a survey [9] conducted in 1972, the average size of a farm in 1972 was 1,985 acres. The acreage planted was 48 percent of the acreage operated. In this area, due to relatively low annual moisture, crop-fallow rotation is almost a universal practice.

Major Crops

Three major crops in this area are winter wheat, spring wheat, and barley. Given no government intervention and the relative prices in the past, winter wheat is the major crop.
Machinery Use

According to the survey, out of 176 operators 92.6 percent own combines. Approximately 62 percent hired no custom combining during the six-year period, 1967-1972. Only 6 percent hired their entire crop combined each of the six years. The remaining 32 percent varied the amount of custom combining hired from year to year. It is usually possible to hire custom combining from the local area if a farmer is behind in harvesting, however, the possibility is rather low. Only very limited amounts of drying capacity are available in the area.

Farming Activities

For a winter wheat-fallow enterprise, the sequence of operations is depicted in Figure 2-1.

2. Critical Factors and Variables

Weather is the source of all changing environmental factors in harvesting operations. It affects the cost of combining directly through the length of harvest period, grain weather damage, and indirectly through biological factors such as crop yields and grain shatter losses. Under an optimal harvesting condition, gains can be obtained from a higher rate of work, longer working time allowed per day, and higher quality and larger quantity harvested. However, the longer harvesting is delayed waiting for an optimal harvesting day,
Figure 2-1. Sequence of Operations for Winter Wheat-Fallow Enterprise.
the higher the losses incurred from grain weather damage, grain shattering, and idle labor hours. Somewhere in between the two extremes there lies the minimum cost.

The selection of a particular combine depends not only upon the factors discussed above, but is also affected by the availabilities of custom services and the fixed and operating costs incurred by ownership. These relationships are illustrated in Figure 2-2.

The variables thus identified in the model are:

1) length of harvest period;
2) non-harvestable days within the harvest period;
3) grain-weather damage;
4) crop yield;
5) grain shatter losses;
6) fixed costs;
7) operating costs;
8) rate of work;
9) working time allowed per day; and
10) availability of custom combining.

3. Simulation Procedures

Estimates of the distribution of costs under alternative machinery systems are obtained through simulation. At the beginning of the simulation an acreage level is set. A specific combine size and the
Figure 2-2. Relationships Between the Critical Factors.
harvesting system is selected. The simulation starts from the first
day of the harvesting season on the first year. Each day the harvesting
condition is examined to determine the number of work hours available
on that day. According to the particular harvesting system selected,
checks are then made to determine whether custom combine services are
needed, and if so, the possibility of their availability. Then the
operating cost incurred and the cost from shattering loss are calculated.
This procedure moves on day by day until the last day of the season, or
until the total acreage is harvested. Charges for repair, engine oil,
and other lubricants are added next to the accumulated cost over the
whole season. This procedure is repeated for the second year, third
year, and so on to the fifteenth year. The present value of total cost
is obtained by adding up the present value of each season's accumulated
cost and the present value of the total ownership cost. This cost
represents the present value of the accumulated total cost over 15
years. In this study the simulation is run for two acreage levels,
960 acres and 2,240 acres, and three different harvesting systems. The
three different harvesting systems are as follows.

Harvest By Own Combine

These farmers have their own combine and utilize it to harvest
the entire crop. They would hire custom combining only after half of
the season has passed, and they have less than 40 percent of their
acreage harvested. The only custom combining service they can possibly find is from their neighbors who have excess capacity. The simulation procedure of this harvesting system is illustrated in Figure 2-3.

Harvesting Partly By Own Combine And Partly By Custom Combine

These farmers hire some of their crop combined. In practice, the percentage usually varies year by year. Larger farms usually have a greater percentage of their crop custom combined than smaller farms. The time that the custom combiner will arrive is set in advance, however, it is still subject to change due to harvesting period weather and the level of yield for the year. The simulation procedure is illustrated in Figure 2-4.

Harvesting Entirely by Custom Combine

These farmers hire all of their crop combined. The time that the custom combiner will arrive is again set in advance, and it is still subject to change due to harvesting season weather. The simulation procedure of this system is illustrated in Figure 2-5.

The simulation of these three harvesting systems will consider two cropping patterns, 100 percent winter wheat, and 70 percent winter wheat-30 percent barley.
Figure 2-3. Harvest by Own Combine.
Figure 2-4. Harvest by Own Combine and Custom Combine.
Figure 2-5. Harvest by Custom Combine.
CHAPTER III
DEFINITION OF VARIABLES AND DATA COLLECTION

The preceding chapters have outlined the problem, the simulation procedure, and generally discussed the variables and parameters. In the first section of this chapter all variables and parameters are first defined in order and then each is discussed in detail. The data used, including the collection procedure, are presented in the second section.

1. Definition of Variables

1) Year set: The weather pattern for the year considered.

2) Crop yield set: The level of crop yield under the particular weather and growing conditions.

3) Starting date of harvest: The starting date of harvest under the particular weather and growing conditions.

4) Harvesting pattern of each day: The weather condition of each day of the specific year.

5) The condition for harvest: The determination of whether harvest is possible on a day.

6) Available working hours in a day: The determination of working hours per day.

7) Combine performance: The capacity of the combine under different conditions.

8) Ending date of harvest: The last date of harvest of the specific year.

9) Field losses: The losses from weather damage due to untimeliness.

10) The date when farmers start considering the possibility of hiring custom service.
11) The percentage which serves as a guide to decide whether to hire custom service or not.

12) Possibility of custom service: The probability of obtaining custom service under different conditions.

The criteria of these variables are determined as follows,

Year Set

Assume that the weather pattern will not change in the near future. It is possible to calculate a probability distribution for different levels of annual precipitation. However, the criterion of using annual precipitation may not be the most appropriate one. Although it is important to the production and harvesting operation, the distribution of moisture throughout the year may be more important than the absolute amount. In addition to moisture other weather variables and the interaction among them are important.

Crop Yield

The level of crop yield is affected by many biological and environmental factors. The amount of rainfall, the temperature, the soil condition, the level of nitrogen applied, and the variety grown are among the important ones. Usually, the historical data available do not guarantee that the same soil condition prevailed due to constantly improving technology. Also, yield data do not give the true level since it already includes the weather losses incurred. Besides, losses are
further affected by many probabilistic factors. Therefore, it is simply impossible to obtain enough appropriate data to calculate the conditional probability needed. Thus, the approach proposed here is, for each variety of crop, to use actual crop yield records adjusted by adding the amount of estimated shatter loss.

Starting Date of Harvest

The starting date of harvest is affected by the variety grown, the soil condition, nitrogen level applied, precipitation during growing season, and the date of seeding. The date of seeding is further affected by the weather conditions of the previous year. Again, this is a conditional probability. Our choice is hence limited to select one fixed date making the starting date deterministic rather than probabilistic. This same method was used by Donaldson [6] and Ryan [22].

Harvesting Pattern of Each Day

The weather condition on the same day of each year is different due to changing weather. This is again a conditional probability. Even if there were historical data over 60 or 70 years, it is still insufficient to calculate conditional probability distributions with a high degree of confidence.

Totaling the problems encountered so far leaves one choice; that is, to use actual weather records. This approach has been used before in the Netherlands [28]. By assuming that the actual weather pattern can
be expected to prevail in the near future, this approach should provide a meaningful result.

The Condition For Harvest

Presence of moisture on the straw and kernel is the main factor in determining whether combining is impossible or not. The first condition for harvest is thus rain free. For the purpose of safe shipping and storing of the grain, the kernel moisture level must be less than 17 percent according to Van Kampen [28]. Still, from the viewpoint of machine efficiency and quality of grain, the most desirable stage of harvest is when the grain moisture level is between 17 percent and 22 percent according to Johnson [15].

In order to use these criteria to determine whether harvest is possible, two questions arise: (1) how to classify a day as rain free? and (2) how to obtain the grain moisture level?

Donaldson [6] answered the first question by defining a rain-free day as a day with less than 0.01 inch daily precipitation. However, due to different environmental characteristics, this figure may not be suitable to the Triangle Area. With respect to the second problem, there are no grain moisture records available for the area. No theoretical formula relating physical characteristics and moisture level has been developed. Hence, moisture level cannot serve as a guide to determine the possibility of harvesting. The criterion
selected to determine whether a day is harvestable, partly harvestable, or non-harvestable is the amount of daily precipitation. This approach has been used before in Australia [22].

Available Working Hours In Each Day

Dew and precipitation are the two main factors affecting the kernel and straw moisture content and hence the available working hours per day. In order to calculate exactly the available working hours, grain moisture content in the standing crop at any time must be identified. Formulas do exist for the wetting and drying of grain by dew and precipitation. However, they were obtained by curve fitting. The formulas obtained thus may very well be particular to the specific area studied. So far, no such relationships have been studied in the Triangle Area. Even if the formulas can be used in the Triangle Area it is still impossible to calculate the required information due to lack of data on some variables. Such variables are the duration of precipitation, the initial moisture level, and the radiation per day.

Donaldson [6] overcame this problem by making certain assumptions. He assumed that the days when harvesting is possible for some periods before rain will be balanced by periods when combining is impracticable because of rain late on the previous day. And during a rain-free day, combining is physically possible for a period of about 12 hours—from 1000 hours to 2200 hours.
In this problem, four situations exist:

1) A rain-free day after a rain-free day. The starting time and ending time of harvest will be normal; that is, only affected by dew.

2) A rain-free day after a rainy day. Depending on the amount of precipitation on the previous day, different lengths of delay in the starting time will occur.

3) A rainy day after a rain-free day. The chance of precipitation in the Triangle Area is the greatest in late afternoon. Farmers usually quit working after a late afternoon shower. It is therefore probably reasonable to assume a normal starting time and an early ending time.

4) A rainy day after a rainy day. Unless the amount of precipitation is too great, it is quite reasonable to have a late starting time and an early ending time.

Considering these four situations, a method is proposed. The method is to classify a day as rain-free day, partly-harvestable rainy day, and non-harvestable rainy day by amounts of daily precipitation. When the daily precipitation is less than A inches, it is a rain-free day. The only effect influencing combine operations is dew. The ending time can be obtained through information provided by agronomists and others familiar with the area. The starting time will depend on the weather condition on the previous day. When the daily precipita-
tion is greater than B inches, it is a non-harvestable rainy day. No working hours are available. When the daily precipitation is between A and B inches, it is a partly-harvestable rainy day. Depending on the weather condition on the previous day, a starting time can be set. Also, depending on the various amounts of daily precipitation on that day, different ending times can be set.

Combine Performance

Combine performance measured in acres per hour can be determined by the formula given below.

\[
\text{Effective Capacity (acres/hour)} = \frac{\text{Speed in mi./hr.} \times \text{width in ft.} \times \text{field efficiency given as a decimal}}{100}
\]

where field efficiency is the portion of total field time the machine actually performs its function; the speed is determined by the power of the machine and the crop condition; and the width is determined by the type and size of the machine chosen.

Ending Date of Harvest

In the Triangle Area, harvest is usually completed by the middle of August. Harvesting operations can continue as long as the crop can stand in the field. However, the longer the crop stands, the greater the field loss will be. The limiting date when the field loss becomes untolerable is variable. It is much simpler, though, to set some time
limit such as September 15. In the simulation model, harvesting is performed whenever conditions allow operation. It is quite likely then, that by September 15 the harvesting operation will be completed. If not, the field losses by that time are most probably so great that the unharvested crop can be viewed as a total loss.

Field Losses

The main field loss in the Triangle Area is shattering loss from wind after the crop is mature. The only estimates of shattering loss were done by Fajersson and Krantz in Sweden [8] and by Johnson [15] in Ohio. However, they did not try to relate the loss with weather conditions. In the Triangle Area, no empirical data are available. The only estimates are from agronomists' experiences.

Another field loss that affects the decision of machine ownership is from hail. The yield records used reflect this loss.

Date and Percentage of Harvest Completed Which Determine When to Hire Custom Service

These values should reflect farmers' views on the progress of the harvesting operation and also on the risk they are willing to take.

Possibility of Custom Service

Three types of custom service exist:
1) Probability of obtaining custom service when no advance appointment has been made.

2) Probability of obtaining custom service with an advance appointment made. The harvesting operation is designed to be done partly by custom combine.

3) Probability of obtaining custom service with an advance appointment made. The harvesting operation is designed to be done completely by custom combine.

According to the 1971 report of the Royal Commission on Farm Machinery [23], custom service took different forms. Usually, custom service is provided by large operations that move thousands of miles, beginning in Texas and moving northward. In other cases, it is provided by a small local operation which may have two or three machines. In other situations, it is provided by a farmer with surplus capacity—usually for a neighbor. However, custom operations are never available when they are most wanted. There are two reasons for this: (1) all other producers in the same area will want them at about the same time, and (2) the time when they will be needed varies from season to season and cannot be predicted more than a few weeks ahead.

Referring to the three types of custom service, the availability of custom combining is variable. The reason being that the harvesting operation is dependent upon the weather condition even when an advance appointment has been made. Hence, the probability of the availability
of custom combining must be established. But this is empirically impossible since there are no appropriate data to estimate this probability. Thus, the approach suggested is to use two different sets of arbitrary probability values, an optimistic and a pessimistic view. This approach reflects the cost differences incurred by the availability of custom service.

2. Collection of Data

Given the above definitions and criterion for each variable, the data were collected in the following manner. Moccasin is selected as the representative location. Although Moccasin is not in the Triangle Area the Agricultural Experiment Station and the United States Weather Bureau records at this location provide a substantial proportion of the data needed.

Acreage Level

The acreage levels selected for this study are 960 acres and 2,240 acres. The smaller acreage approximates that of the average size farm in the Triangle Area. The larger acreage provides a point of reference as farm size increases.

Custom Combine Rate

According to Luft's report [18] and other verbal contacts, $8.00 per acre was a common charge for the 1974 season. An extra 5 cents
per bushel charge is added when crop yields of more than 20 bushels per acre are obtained.

Number of Years Considered
It is estimated that the economic life of a combine is approximately 15 years. Also, due to the availability of weather and crop yield records, 15 years are used.

Crop Variety and the Order of Harvesting
Two winter wheat varieties, Cheyenne and Winalta, and one barley variety, Piroline, are the three major crop varieties in the Triangle Area. Because of the severe shattering loss of Cheyenne, the order of harvesting is first Cheyenne, second, Winalta, and lastly, Piroline.

Duration of Harvesting Season
From past experience in the Moccasin area, starting date of harvest for winter wheat and barley is around August 1. Harvesting is usually completed by the middle or end of August on an average year. The harvest operation can continue as long as the crop is standing. However, because of the severe shattering loss in that area, the total crop may be lost completely. Hence, the period from August 1 to September 15 is chosen as the harvesting season.
Per Hour Labor Cost

The per hour charge for farm labor in this area is usually $2.00.

Price of Crops

The most current agricultural prices reported by the Montana Crop and Livestock Reporting Service are $3.95 per bushel and $2.55 per bushel in Montana for winter wheat and barley, respectively. 1/

Specifications and Costs of Combines

Five different sizes of combines are used for this study. The five are identified by header widths to preserve manufacturer anonymity. The models and specifications associated with each header width are characteristic of combines currently being purchased in the Triangle Area. The prices are the most current manufacturer suggested retail price. 2/ The 22-foot header width combine is selected as the machine used by custom combiners. The specifications, prices, and the costs involved in maintaining these combines are listed in Table III-1.

1/ The $2.55 per bushel price for barley is a weighted price of malting and feed barley.

2/ September, 1974.
TABLE III-1. SPECIFICATIONS, PRICES, AND COSTS FOR MAINTENANCE OF DIFFERENT COMBINES.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Units</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>22</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field efficiency [16]</td>
<td>74</td>
<td>72</td>
<td>70</td>
<td>68</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Speed [16]</td>
<td>Mph.</td>
<td>2.8</td>
<td>3.0</td>
<td>3.3</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Weight</td>
<td>Lb.</td>
<td>11,368</td>
<td>14,818</td>
<td>17,282</td>
<td>17,546</td>
<td>17,810</td>
</tr>
<tr>
<td>Price [14]</td>
<td>Dols.</td>
<td>19,800</td>
<td>25,100</td>
<td>30,050</td>
<td>30,150</td>
<td>30,250</td>
</tr>
</tbody>
</table>

Transportation charge [14]: $5.00/100 lb.
Annual repair charge [17]: 6.5 percent of new cost
Engine oil and other lubricant charges [1]: 15 percent of fuel consumption cost
Wear-out life: 15 years

Probabilities of Getting Custom Combines

As indicated in the previous section, arbitrary values which reflect people's views about the availability of custom combines are used. Also, since large-scale farmers have an advantage in hiring custom services compared with smaller-scale farms even though they pay the same rate, the probabilities should be different for different acreage level farms. The probabilities of getting custom combines with an advance appointment are also different from those without an advance appointment. Therefore, the probability estimates are broken down into two classes.
Without An Advance Appointment

This is the case where farmers decide to harvest using their own combine completely, but end up hiring a custom combiner in order to complete the harvesting operation with possible minimum loss. It is felt that when half of the harvesting season is over and less than 40 percent of the crop is harvested, farmers will probably start considering custom combines. Therefore, this situation is selected and built into the simulation program as a policy strategy. For these farmers, the only custom combining they can possibly find is from their neighbors who have excess capacity. However, it usually will be very difficult since all other farmers in the same area will want them at about the same time. Also, in this case, the size of the farm will probably not make too much difference in obtaining the custom combining service. The probabilities used are presented in Table III-2.

With An Advance Appointment

Assuming that an appointment has been made so the custom combiner should arrive as soon as the crop is ready to be harvested, the probabilities used are presented in Table III-3.

The probability of getting custom combining is "1" if custom service is available on the previous day.
Table III-2. Probabilities of Getting Custom Combine Without an Advance Appointment.

<table>
<thead>
<tr>
<th>( n^{th} ) Day of the Harvesting Season</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimistic</td>
</tr>
<tr>
<td>1-22</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>.15</td>
</tr>
<tr>
<td>24</td>
<td>.15</td>
</tr>
<tr>
<td>25</td>
<td>.15</td>
</tr>
<tr>
<td>26</td>
<td>.15</td>
</tr>
<tr>
<td>27</td>
<td>.15</td>
</tr>
<tr>
<td>28</td>
<td>.20</td>
</tr>
<tr>
<td>29</td>
<td>.20</td>
</tr>
<tr>
<td>30</td>
<td>.20</td>
</tr>
<tr>
<td>31</td>
<td>.25</td>
</tr>
<tr>
<td>32</td>
<td>.25</td>
</tr>
<tr>
<td>33</td>
<td>.25</td>
</tr>
<tr>
<td>34</td>
<td>.25</td>
</tr>
<tr>
<td>35</td>
<td>.30</td>
</tr>
<tr>
<td>36</td>
<td>.30</td>
</tr>
<tr>
<td>37</td>
<td>.30</td>
</tr>
<tr>
<td>38</td>
<td>.35</td>
</tr>
<tr>
<td>39</td>
<td>.45</td>
</tr>
<tr>
<td>40</td>
<td>.55</td>
</tr>
<tr>
<td>41</td>
<td>.60</td>
</tr>
<tr>
<td>42</td>
<td>.65</td>
</tr>
<tr>
<td>43</td>
<td>.70</td>
</tr>
<tr>
<td>44</td>
<td>.75</td>
</tr>
<tr>
<td>45</td>
<td>.85</td>
</tr>
<tr>
<td>46</td>
<td>.90</td>
</tr>
</tbody>
</table>
TABLE III-3. PROBABILITIES OF GETTING CUSTOM COMBINE WITH AN ADVANCE APPOINTMENT.

<table>
<thead>
<tr>
<th>n&lt;sup&gt;th&lt;/sup&gt; Day of the Harvesting Season</th>
<th>960 Acres Probability</th>
<th>2,240 Acres Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimistic</td>
<td>Pessimistic</td>
</tr>
<tr>
<td>1</td>
<td>.75</td>
<td>.70</td>
</tr>
<tr>
<td>2</td>
<td>.80</td>
<td>.75</td>
</tr>
<tr>
<td>3</td>
<td>.80</td>
<td>.75</td>
</tr>
<tr>
<td>4</td>
<td>.80</td>
<td>.75</td>
</tr>
<tr>
<td>5</td>
<td>.85</td>
<td>.80</td>
</tr>
<tr>
<td>6</td>
<td>.90</td>
<td>.85</td>
</tr>
<tr>
<td>7</td>
<td>.90</td>
<td>.85</td>
</tr>
<tr>
<td>8</td>
<td>.95</td>
<td>.90</td>
</tr>
<tr>
<td>9</td>
<td>.95</td>
<td>.90</td>
</tr>
<tr>
<td>10</td>
<td>.95</td>
<td>.90</td>
</tr>
<tr>
<td>11</td>
<td>.95</td>
<td>.90</td>
</tr>
<tr>
<td>12</td>
<td>.95</td>
<td>.90</td>
</tr>
<tr>
<td>13</td>
<td>1.00</td>
<td>.95</td>
</tr>
<tr>
<td>14-46</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Starting and Ending Work Times on Each Day

The starting and ending work times of each day depend on the amount of precipitation on the previous day and on the day considered, respectively. The corresponding figures are listed in Table III-4. 3/

TABLE III-4. WORKING TIME SCHEDULE.

<table>
<thead>
<tr>
<th>Daily Precipitation (inches)</th>
<th>Ending Work Time on the Day</th>
<th>Effect on Next Day's Starting Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.009</td>
<td>10:00 p.m.</td>
<td>10:00 a.m.</td>
</tr>
<tr>
<td>0.010-0.049</td>
<td>6:30 p.m.</td>
<td>11:00 a.m.</td>
</tr>
<tr>
<td>0.050-0.099</td>
<td>4:30 p.m.</td>
<td>12:00 a.m.</td>
</tr>
<tr>
<td>0.100-0.149</td>
<td>Harvesting Not Possible</td>
<td>1:00 p.m.</td>
</tr>
<tr>
<td>0.150-0.199</td>
<td>&quot;</td>
<td>2:00 p.m.</td>
</tr>
<tr>
<td>0.200-0.249</td>
<td>&quot;</td>
<td>3:00 p.m.</td>
</tr>
<tr>
<td>&gt; 0.250</td>
<td>&quot;</td>
<td>Harvesting Not Possible</td>
</tr>
</tbody>
</table>

It is possible that several hours after a light afternoon rain farmers will start working again. This is balanced by moving the ending time later in the day.

Shatter Loss

Estimates of shatter loss from agronomists are listed in Table III-5 for Cheyenne, Winalta, and Piroline.

3/ These values were determined from agronomists' experiences and the rules used by Johnson [15] in determining harvesting strategies.
### TABLE III-5. SHATTER LOSS ON DAILY BASIS.

<table>
<thead>
<tr>
<th>Day After Crop is Ready</th>
<th>Percent Loss Per Day for Cheyenne</th>
<th>Winalta</th>
<th>Piroline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2-5</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>6</td>
<td>2.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>7</td>
<td>2.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>8</td>
<td>2.0</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>9-13</td>
<td>2.0</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>14</td>
<td>1.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>15</td>
<td>1.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>16-17</td>
<td>1.5</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>18-20</td>
<td>1.0</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>21-22</td>
<td>1.0</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>23-27</td>
<td>0.7</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>28-30</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>31-35</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>36-40</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>41-46</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Crop Yield Level

Crop yields recorded at the Moccasin Agricultural Experiment Station from 1957-1971 are used in this study [19]. One bushel per acre is added to obtain a true yield before any shattering loss occurred. In 1962, 1965, 1967, and 1969, hail damage, winter kill, dry weather, and June frost, respectively, resulted in no yield record. Hence "0.0" yield levels are used for these years because crop damage from bad weather prior to the harvest also affects the decision of machine ownership. For Winalta, there is no record from 1957-1961. Arbitrary values are therefore used. These are derived by comparing the yield record of Cheyenne and Winalta during the years from 1963-1971. The crop yield levels are shown in Table III-6.

Ownership Cost

Taxes, insurance, and price paid for the machine are the main components of machine ownership cost.

Taxes

According to the county assessor, tax is charged in the following manner. Taxable value is 20 percent of the assessed value, and taxable value times mill levy $4/ gives the tax charged on the machine. The

$4/ Average mill levy of the Moccasin area (1973-1974) is 160.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheyenne</td>
<td>42.7</td>
<td>37.4</td>
<td>39.3</td>
<td>27.3</td>
<td>28.9</td>
<td>0.0</td>
<td>34.5</td>
<td>48.9</td>
<td>37.5</td>
<td>37.5</td>
<td>44.0</td>
<td>44.7</td>
<td>0.0</td>
<td>32.6</td>
<td>43.6</td>
</tr>
<tr>
<td>Winalta</td>
<td>40.0</td>
<td>35.8</td>
<td>37.3</td>
<td>27.0</td>
<td>28.3</td>
<td>0.0</td>
<td>33.8</td>
<td>44.0</td>
<td>0.0</td>
<td>35.8</td>
<td>41.6</td>
<td>38.3</td>
<td>0.0</td>
<td>32.0</td>
<td>40.7</td>
</tr>
<tr>
<td>Pirolne</td>
<td>34.9</td>
<td>70.1</td>
<td>48.5</td>
<td>26.8</td>
<td>33.9</td>
<td>54.8</td>
<td>45.1</td>
<td>39.3</td>
<td>41.9</td>
<td>52.2</td>
<td>0.0</td>
<td>59.1</td>
<td>0.0</td>
<td>24.0</td>
<td>47.5</td>
</tr>
</tbody>
</table>
assessed value of the machine each year can be obtained from the schedule shown in Table III-7, where $200 is the minimum assessed value as long as the machine is still usable. Also, for the purpose of simplification, the value is always rounded up or down to hundreds or fifties.

**TABLE III-7. SCHEDULE FOR CALCULATING ASSESSED VALUE.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Assessed Value (% of new price)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

**Insurance**

Insurance is charged as a percentage of the current market value of the machine; 0.6 percent is used in this study. The market values of the machine at each year are obtained from the schedule in Table III-8 [2].

The total ownership cost incurred during the 15 years of machine life can be visualized from the following cash-flow diagram, Figure 3-1.

Considering the time value of money, the present value of the total ownership cost for each model is determined and presented in Table III-9.
TABLE III-8. MARKET VALUES OF MACHINE.

<table>
<thead>
<tr>
<th>Beginning of Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
</tr>
</tbody>
</table>

Remaining Values (\% of list price)
100.0 56.80 50.90 45.50 40.70 36.50 32.60 29.20 26.10 23.40 20.90 18.70

Figure 3-1. Ownership Cost Over 15 Year Span.
TABLE III-9. PRESENT VALUES OF OWNERSHIP COSTS.

<table>
<thead>
<tr>
<th>Item</th>
<th>Combine Header Width (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16</td>
</tr>
<tr>
<td>Present Value of Ownership Cost</td>
<td>19,936.97</td>
</tr>
</tbody>
</table>

The operating costs and performance rates of combines are presented in Table III-10.

TABLE III-10. OPERATING COSTS AND PERFORMANCE RATES.

<table>
<thead>
<tr>
<th>Item</th>
<th>Combine Header Width (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16</td>
</tr>
<tr>
<td>Operating Cost Per Hour</td>
<td>$3.33</td>
</tr>
<tr>
<td>Performance Rate Per Hour</td>
<td>4.0 acres</td>
</tr>
</tbody>
</table>
CHAPTER IV

ANALYSIS OF RESULTS

Three harvesting systems are investigated for two cropping patterns and two acreage levels. For the completely own combining system the harvesting costs of owning one, two, or three machines are determined. For the partly own combining and the partly custom combining system, the harvesting costs of owning one or two machines and hiring two custom combines are determined. For the completely custom combining system, the costs of hiring two, three, or four custom combines are determined. A computer program written in FORTRAN IV is constructed for this purpose. The program, the variables used in the program, and the usage instructions are presented in the appendix. An example of the simulation output, tables of the present value of costs of the entire simulation results, and the present values of the total crop are presented first in this chapter. An analysis of the results is then given in the second section.

1. Simulation Results

The output of the program gives the annual shattering loss cost, the annual sum of shattering cost and operating cost, and the present value of total harvesting cost over 15 years. An example is shown below. This is for 960 acres of cropping pattern 1, 70 percent Cheyenne–30 percent Piroline, using the partly own combining and the partly custom combining system with two 22-foot custom combines and one 24-foot own combine.
TABLE IV-1. SIMULATION RESULTS OF 960-ACRE FARM WITH ONE 24-FOOT OWN COMBINE AND TWO 22-FOOT CUSTOM COMBINES.

<table>
<thead>
<tr>
<th>Year</th>
<th>Shatter Loss</th>
<th>Accumulated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,902.87</td>
<td>7,091.94</td>
</tr>
<tr>
<td>2</td>
<td>2,416.93</td>
<td>5,514.41</td>
</tr>
<tr>
<td>3</td>
<td>1,794.77</td>
<td>5,002.21</td>
</tr>
<tr>
<td>4</td>
<td>1,190.32</td>
<td>4,139.24</td>
</tr>
<tr>
<td>5</td>
<td>1,247.35</td>
<td>4,230.74</td>
</tr>
<tr>
<td>6</td>
<td>31.23</td>
<td>1,129.82</td>
</tr>
<tr>
<td>7</td>
<td>1,597.94</td>
<td>4,701.98</td>
</tr>
<tr>
<td>8</td>
<td>2,345.36</td>
<td>5,639.87</td>
</tr>
<tr>
<td>9</td>
<td>2,014.18</td>
<td>5,182.87</td>
</tr>
<tr>
<td>10</td>
<td>1,799.33</td>
<td>4,968.00</td>
</tr>
<tr>
<td>11</td>
<td>1,627.12</td>
<td>3,914.82</td>
</tr>
<tr>
<td>12</td>
<td>3,125.30</td>
<td>6,449.07</td>
</tr>
<tr>
<td>14</td>
<td>1,983.09</td>
<td>5,046.18</td>
</tr>
<tr>
<td>15</td>
<td>2,575.41</td>
<td>5,875.48</td>
</tr>
</tbody>
</table>

Present value of the accumulated cost plus ownership cost over 15 years is $83,884.04.
Complete simulation results are presented in Tables IV-2 and IV-3. After initial runs were made, it was found that no difference in cost resulted when the optimistic and pessimistic probabilities differed by 0.05 for the first 10–15 days. Thus, additional runs were made with a very pessimistic probability of obtaining custom combine service. These results are presented in Tables IV-2 and IV-3 under the heading "Probability Set 2." These probability distributions are presented in Table IV-4.

The present values of the total crop over 15 years for the two cropping patterns considered are:

1) Cropping pattern 1: 70 percent Cheyenne-30 percent Pirolone
   
   Present value of the crop over 15 years is $959,220 for 960 acres and $2,238,210 for 2,240 acres.

2) Cropping pattern 2: 50 percent Cheyenne-50 percent Winalta
   
   Present value of the crop over 15 years is $966,328 for 960 acres and $2,254,767 for 2,240 acres.

2. Analysis and Conclusions

As shown in Table IV-2, for the completely own combining system with cropping pattern 1, total cost at first decreases as the total combine capacity increases. The increasing capacity reduces the number of days necessary to harvest the crop. Thus, shatter loss cost is decreasing faster than ownership costs are increasing. However, when combine capacity reaches the level of owning three machines, the
### TABLE IV-2. SIMULATION RESULTS OF 960-ACRE FARM.

<table>
<thead>
<tr>
<th>Harvest System</th>
<th>Cropping Pattern</th>
<th>Combines</th>
<th>Present Value of Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Owned No. Size</td>
<td>Custom No. Size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ft.</td>
<td>Ft.</td>
</tr>
<tr>
<td>Completely Owned</td>
<td>1</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Partly Owned-Partly Custom</td>
<td>1</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
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*Cropping pattern 1 is 70 percent Cheyenne—30 percent Piroline. Cropping pattern 2 is 50 percent Cheyenne—50 percent Winalta.*
TABLE IV-3. SIMULATION RESULTS OF 2,240-ACRE FARM.

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<th>Cropping Pattern*</th>
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*Cropping pattern 1 is 70 percent Cheyenne-30 percent Pirolene.
Cropping pattern 2 is 50 percent Cheyenne-50 percent Winalta.
### Table IV-4. Probability Set 2.

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decreased shattering loss cost is more than offset by the increased ownership cost incurred. The least-cost machine combination lies at owning two 24-foot combines with a cost of $116,585.50. The same pattern of cost distribution is observed with cropping pattern 2. The least cost is $10,942.19 with two 24-foot combines. It can be seen that the cost is much lower with cropping pattern 2 than with cropping pattern 1. This is due to the fact that a larger percentage of Cheyenne is planted in cropping pattern 1, and Cheyenne is the variety with the highest shattering rate.

For the partly own combining and the partly custom combining system, total cost also decreases first with increasing machine capacity and then increases as the machines owned increase to more than one. The least-cost combination for cropping pattern 1 is $83,884.04 with one 24-foot combine owned and two 22-foot combines provided by custom service. For cropping pattern 2, the least cost is $78,743.63 with the same machine combinations. Again, due to less severe shattering loss involved with cropping pattern 2, the associated total cost is lower with this cropping pattern. The trade-off between shattering loss cost and ownership cost is still the factor accounting for the decreasing and then increasing total cost curve.

For the completely custom combining system, total cost decreases as the number of custom combines hired increases. Since operating cost for a specific acreage level and cropping pattern is constant...
for this system, shattering loss cost is the main factor in determining machine selection. The more machines used, the faster the crop is harvested, and hence the less the shattering loss cost. Consequently, the total cost is lower. Total cost, and hence shattering loss cost, will increase only when the harvesting operation is delayed due to unavailability of custom service. In this study, the difference between the probabilities of hiring three custom combines and hiring two custom combines is not large enough to make the delay in harvesting serious enough to cause total cost to increase. The least-cost machine selection for this system for cropping pattern 1 is $89,783.44 with three 22-foot custom combines and $80,829.69 for cropping pattern 2 with the same machine combination.

Over the three systems, the system of partly own combining and partly custom combining system gives the lowest total cost. With decreased probabilities of getting custom combines, the least-cost combination remains partly own combining and partly custom combining. For cropping pattern 1, least cost increases to $101,771.73 and for cropping pattern 2, least cost increases to $90,750.32. However, with the decreased probability of obtaining custom service the second lowest cost combination now changes from the completely custom combining system to the completely own combining system.

The same analysis applies to the 2,240-acre level farm. As shown in Table IV-3, for the completely own combining system with both
cropping patterns, the same pattern of cost distribution is observed. The least cost is $235,067.75 with three 24-foot combines owned for cropping pattern 1, and $207,915.44 for cropping pattern 2. Again, shattering loss cost is much less in cropping pattern 2. By comparing the 2,240-acre level farm with the 960-acre level farm, it is seen that larger combine capacity is needed, and the associated total cost is much higher.

For the partly own combining and the partly custom combining system, again, the same pattern of cost distribution is observed. However, larger machine capacity is needed now with the least cost being $237,970.05 for cropping pattern 1 and $216,276.27 for cropping pattern 2 with two 24-foot combines owned and two 22-foot combines hired.

For the completely custom combining system, the least cost lies at $262,815.19 for cropping pattern 1 and $226,870.00 for cropping pattern 2 with four 22-foot custom combines hired.

The system of completely own combining now gives the lowest total cost for 2,240-acre level farm. With increasing difficulties of obtaining custom combines, even more advantages can be obtained by completely own combining.

The components of total harvesting cost are the fixed cost, the operating cost, and the shattering loss cost. Fixed cost includes ownership cost, repair cost, and general lubrication charges. The
operating cost for a certain system is relatively constant regardless of the number of machines used. For the own combining system, labor cost and fuel consumption cost are the only components of the operating cost with these being paid according to the number of hours used. The total number of labor and machine hours used for a specific acreage level is always constant. In custom combining, operating cost is $8/acre plus 5 cents per bushel for yields over 20 bushels per acre. Therefore, the choice of the least-cost machine of a specific system is actually a trade-off between the fixed cost and the shattering loss cost. By comparing the different systems, however, operating cost also plays a very important role.

It is obvious from the results that operating cost of custom combining is a very critical element for cost determination. The total operating cost for large farms overwhelms the advantage it has in less ownership cost. Large farms are better off to pay the fixed cost involved with ownership instead of paying the high operating cost with custom combining. For smaller farms, less machine capacity is needed, thus the total operating cost is relatively more compatible with the ownership cost. Partly own combining and partly custom combining becomes more feasible. With increasing difficulties of acquiring custom combines, however, shattering loss cost becomes important. The result of unavailability of custom service leads to the increasing
shatter loss. To some extent, even small farms will be better off by owning their combines to avoid the ever increasing shatter loss cost.

Further, by comparing the two cropping patterns, it is seen that the shattering loss cost involved in cropping pattern 1, 70 percent Cheyenne–30 percent Piroline, is much more critical than in cropping pattern 2, 50 percent Cheyenne–50 percent Winalta. Therefore, if the availability of the custom service cannot be assured, farms planting cropping pattern 1 should be more aware of the fact and own their combines.

Another factor to be considered in selecting the best harvesting system is the alternative use of operator time if custom service is used. It is very difficult in this respect to put a dollar value on this factor. However, considering the $2.00 per hour labor cost as the opportunity cost of operator time, the total value can be evaluated. This sum is small, though, compared with the shattering loss cost, the fixed cost, and the operating cost involved with custom combining. It can therefore be neglected in the decision rule.

As shown in Chapter I, there have been studies investigating various aspects of the harvesting operation. However, none of these has been specifically directed at the same problem. Consequently, close comparison cannot be made between the final results. But, as indicated by almost all of the previous investigations, shattering loss cost has proven to be one of the most critical factors. In this
study, with the data used, custom combine rate is observed as the most critical factor which determines the least-cost system. Shattering loss cost can be a very big cost element depending on the number of machines used. In the case of the least-cost machine combinations found in each system, they are of about the same magnitude as the operating cost of custom combines. However, the difference of shattering loss costs between the different systems is not significant when the probabilities of getting custom service are relatively good. It is, therefore, not a critical factor in selecting the harvesting system. It can be critical, though, if the availability of custom service is not assured. It is also critical in deciding the number of combines used within each harvesting system.

In conclusion, this study investigates the variables involved in harvesting operations and estimates the cost distributions of harvesting under different machinery systems. It is found from the simulation that operating cost associated with custom combining, shattering loss cost, and ownership cost are the three main factors which determine the least-cost machine combination. Operating cost can be reduced by more ownership; shattering loss cost can be reduced by quick harvesting operation which can be done via custom combining, ownership, or both; ownership cost can be reduced by more utilization of custom service. The choice then depends on the availability of
custom service, the trade-off between the operating cost, ownership cost, and the associated shattering loss cost.

In this study, the criteria of least cost is used for the determination of best harvesting system. The result of the simulation shows that partly own combining and partly custom combining is the best alternative for small farms. For larger farms, completely own combining is better. These are, of course, all based on the data collected and assumptions made in Chapter III.

Further investigation of this problem should consider the assumptions made about some of the probabilistic variables. These assumptions should be replaced by results of analysis of experimental data. This was not done in this study due to unavailability of data. More combinations of machines may also be explored.
APPENDIX I

LIST OF VARIABLES

1) ACC — The accumulated operating and shattering cost.
2) ANAC — Number of acres completed in harvesting.
3) ANACC — Number of acres completed in harvesting by custom combines.
4) ANWH — Number of work hours on a day.
5) AL — Acreage level considered.
6) ASC1, ASC2, ASC3, ASC4 — Average speed of own combine no. 1, own combine no. 2, own combine no. 3, and own combine no. 4, respectively.
7) ASCC1, ASCC2, ASCC3, ASCC4 — Average speed of custom combine no. 1, custom combine no. 2, custom combine no. 3, and custom combine no. 4, respectively.
8) CCR — Custom combine rate.
9) CF — Coefficient for adjusting the time value of money.
10) COC — Per hour fuel consumption cost.
11) CY(I,J) — Crop yield of the Ith variety on the Jth year.
12) DP(I,J) — Daily precipitation amount of the Ith day of the Jth yr.
13) EWT — Ending work time on a day.
14) FE1, FE2, FE3, FE4 — Field efficiency of own combine no. 1, own combine no. 2, own combine no. 3, and own combine no. 4, respectively.
15) FEC1, FEC2, FEC3, FEC4 — Field efficiency of custom combine no. 1, custom combine no. 2, custom combine no. 3, and custom combine no. 4, respectively.
16) HFC — Per hour fuel consumption (gal./hr.).
17) HW1, HW2, HW3, HW4 — Header width of own combine no. 1, own combine no. 2, own combine no. 3, and own combine no. 4, respectively.
18) HWC1, HWC2, HWC3, HWC4 — Header width of custom combine no. 1, custom combine no. 2, custom combine no. 3, and custom combine no. 4, respectively.

19) IAL — Counter for the acreage level, 1 for 960 acres and 2 for 2,240 acres.

20) ICCP(N) — Counter for the availability of getting custom combining on the Nth day. It equals "0" when custom service is not available, and equals "1" when custom service is available.

21) IDSCC — The date when a farmer starts considering hiring custom combining.

22) IM — Number of years considered.

23) IX — Any odd-numbered integer to be used to simulate random numbers.

24) M — The total number of days of the harvesting season.

25) P(I) — Unit price of crop variety I ($/bu.).

26) PAC(I) — Percentage of acres planted of crop variety I.

27) PC1, PC2, PC3, PC4 — New cost of combine no. 1, combine no. 2, combine no. 3, and combine no. 4, respectively.

28) PDC — Percentage of custom work planned to be done.

29) PGCC(N) — Probability of getting custom combine on the Nth day.

30) POD — Price of diesel fuel.

31) PSCC — The percentage when farmers start considering hiring custom combine.

32) PVOC1, PVOC2, PVOC3, PVOC4 — Present value of ownership cost of combine no. 1, combine no. 2, combine no. 3, and combine no. 4, respectively.

33) SLPD(IVAR) — Daily shattering loss of crop variety IVAR.

34) SWT — Starting work time on a day.

35) TATC — Total accumulated cost.
APPENDIX II

USAGE INSTRUCTION OF THE SIMULATION PROGRAM

This simulation model is designed to simulate the total cost for a given harvesting system and cropping pattern. It simulates daily conditions during the considered harvesting season and calculates the daily cost incurred. These daily costs are accumulated for 15 years and the present value is then given. The program can be used to test five different cropping patterns: 100 percent Cheyenne, 100 percent Winalta, 100 percent Pirolne, combination of Cheyenne and Pirolne, and combination of Cheyenne and Winalta. It can also be used to test three different harvesting systems: completely own combine, completely custom combine, or combination of own combine and custom combine. For own combine, up to four machines can be put in; for custom combine, up to four machines can be put in; for combination of own combine and custom combine, up to two machines can be put in for custom combine, and up to four machines can be put in for own combine.

Program Inputs

When punching up the input variables, the following rules apply:

1) Those variables with first letters being 'I', 'N', or 'M' are read in as fixed point values.

2) All the other input variables not covered by rule (1) are read in as floating point values.

3) All variable input fields are right justified unless the decimal point is punched.
4) Depending on the number of combines used, the header width, the field efficiency, the average speed, the ownership cost are entered accordingly. When left as blank, it is taken as zero which means the particular machine is not used.

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<th>61-65</th>
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<tr>
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<td>CY(3,3)</td>
<td>CY(3,4)</td>
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<td>CY(3,15)</td>
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**Third Card Set: Probability Data**

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<tr>
<td>Variable</td>
<td>PGCC(1)</td>
<td>PGCC(2)</td>
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<td>PGCC(16)</td>
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<th>76-80</th>
</tr>
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<tbody>
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<td>Variable</td>
<td>PGCC(17)</td>
<td>...</td>
<td>PGCC(32)</td>
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<table>
<thead>
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<th>66-70</th>
</tr>
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<tbody>
<tr>
<td>Variable</td>
<td>PGCC(33)</td>
<td>...</td>
<td>PGCC(46)</td>
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</tbody>
</table>

**Fourth Card Set: Daily Precipitation Data**

Sixteen (16) daily precipitation records (DP(I,J)) are punched on one card with each occupying five columns. The order of the data is DP(1,1), DP(2,1) ... DP(46,1), DP(1,2) ... DP(46,15).
Fifth Card Set

First card: Column 1-5
Variable PDC

Second card: Column 1-5 6-10 11-15 16-20 21-25 26-30
Variable PAC(1) P(1) PAC(2) P(2) PAC(3) P(3)

Sixth Card Set

First card: Column 1-5 6-10 11-15 16-20 21-25 26-30 31-35
Variable HW1 HW2 HW3 HW4 FE1 FE2 FE3
Column 36-40 41-45 46-50 51-55 56-60 61-65 66-70
Variable FE4 ASC1 ASC2 ASC3 ASC4 CCR PSCC
Column 71-75 76-80
Variable PHLC COC

Second card: Column 1-5 6-10 11-15 15-20 21-25 26-30 31-35
Variable HWC1 HWC2 HWC3 HWC4 FEC1 FEC2 FEC3
Column 36-40 41-45 46-50 51-55 56-60 61-70 71
Variable FEC4 ASCC1 ASCC2 ASCC3 ASCC4 AL IAL

Third card: Column 1-10 11-20 21-30 31-40 41-50 51-60 61-70
Variable PVOC1 PVOC2 PVOC3 PVOC4 PC1 PC2 PC3
Column 71-80
Variable PC4
APPENDIX III
COMPUTER PROGRAM OF COMBINE OWNERSHIP

1.000 DIMENSION ICFP(50),DP(50,15),CT(5,15),PGCC(50),PAC(3),P(')
2.000 COMMON N,J,AL,CT,P,PAC,ANAC
3.000 C READ IN PROGRAM PARAMETERS
4.000 READ(105,1,IX,M,IM,IDSCC,POD,HPC)
5.000 READ(105,2)((CY(I,J),J=1,IM),I=1,M)
6.000 READ(105,2)(PGCC(I),I=1,M)
7.000 READ(105,2)((DP(I,J),I=1,M),J=1,IM)
8.000 READ(105,12)PDC
9.000 READ(105,13)(PAC(I),I=1,3)
10.000 READ(105,2)HW1,HW2,HW3,HW4,FE1,FE2,FE3,FE4,ASC1,
11.000 ASC2,ASC3,ASC4,CRC,PSCC,PHLC,COC
12.000 READ(105,3)HWCl,HWC2,HWC3,HWC4,PCC1,FEC1,FEC2,FEC3,
13.000 FEC4,ASCC1,ASCC2,ASCC3,ASCC4,AL,IAL
14.000 READ(105,24)PVOC1,PVOC2,PVOC3,PVOC4,PCC,
15.000 IPC2,PC3,PC4
16.000 C WRITE OUT HEADINGS
17.000 WRITE(108,4)
18.000 IF(PDC.EQ.1.)GO TO 6
19.000 IF(PDC.EQ.0.)GO TO 7
20.000 IF(HW1.0.AND.HW2.EQ.0.)IV=1
21.000 IF(HW2.0.AND.HW3.EQ.0.)IV=2
22.000 IF(HW3.0.AND.HW4.EQ.0.)IV=3
23.000 IF(HW4.0.)IV=4
24.000 GO TO (68,69,38,11)IV
25.000 68 WRITE(108,402)HW1,HWCl,HWC2,PAC(1),PAC(2),PAC(3),PDC
26.000 GO TO 501
27.000 69 WRITE(108,404)HW1,HW2,HWC1,HWC2,PAC(1),PAC(2),PAC(3),PDC
28.000 GO TO 501
29.000 38 WRITE(108,39)HW1,HW2,HW3,HWC1,HWC2,PAC(1),PAC(2),PAC(3),PDC
30.000 GO TO 501
31.000 11 WRITE(108,14)HW1,HW2,HW3,HW4,HWCl,HWC2,PAC(1),PAC(2),PAC(3),PDC
32.000 GO TO 501
33.000 6 IF(HW2.0.AND.HW3.EQ.0.)IV=1
34.000 IF(HW3.0.AND.HW4.EQ.0.)IV=2
35.000 IF(HW4.0.)IV=3
36.000 GO TO (25,26,27)IV
37.000 25 WRITE(108,8)HWCl,HWC2,PAC(1),PAC(2),PAC(3)
38.000 GO TO 501
39.000 26 WRITE(108,9)HWCl,HWC2,HWC3,PAC(1),PAC(2),PAC(3)
40.000 GO TO 501
41.000 27 WRITE(108,10)HWCl,HWC2,HWC3,HWC4,PAC(1),PAC(2),PAC(3)
42.000 GO TO 501
43.000 7 IF(HW1.0.AND.HW2.EQ.0.)IV=1
44.000 IF(HW2.0.AND.HW3.EQ.0.)IV=2
45.000 IF(HW3.0.AND.HW4.EQ.0.)IV=3
46.000 IF(HW4.0.)IV=4
47.000 GO TO (48,49,58,19)IV
48.000 48 WRITE(108,59)HW1,HWCl,PAC(1),PAC(2),PAC(3)
49.000 GO TO 501
50.000 49 WRITE(108,66)HW1,HW2,HWCl,PAC(1),PAC(2),PAC(3)
51.000 GO TO 501
52.000 58 WRITE(108,67)HW1,HW2,HW3,HWCl,PAC(1),PAC(2),PAC(3)
53.000 GO TO 501
54.000 19 WRITE(108,35)HW1,HW2,HW3,HW4,HWCl,PAC(1),PAC(2),PAC(3)
55.000 C INITIALIZE VARIABLES
56.000 501 TATC=PVOC1+PVOC2+PVOC3+PVOC4
57.000 IF(PDC.EQ.1.)TATC=0.
58.000 J=1
59.000 305 ANAC=0.
60.000 IF(PAC(2).EQ.0.AND.PAC(3).EQ.0.)IVAR=1
61.000 IF(PAC(1).EQ.0.AND.PAC(2).EQ.0.)IVAR=2
62.000 IF(PAC(1).GT.0.AND.PAC(2).GT.0.)IVAR=3
63.000 IF(PAC(1).GT.0.AND.PAC(3).GT.0.)IVAR=4
64.000 IF(PAC(1).GT.0.AND.PAC(2).GT.0.)IVAR=5
65.000 ANACC=0.
66.000 N=0
67.000 CNH=0.
68.000 ACC=0.
69.000 CPF=0.
70.000 TSLPD=0.
71.000 PICC=0.
72.000 C DETERMINE HARVESTING PATTERN AND NUMBER OF WORK HOURS
73.000 GO TO (308,309,310,311,312) IVAR
74.000 308 IF(CY(1,J).GT.0.)GO TO 499
75.000 313 ATC=0.
76.000 GO TO 498
77.000 309 IF(CY(2,J).GT.0.)GO TO 499
78.000 GO TO 313
79.000 310 IF(CY(3,J).GT.0.)GO TO 499
80.000 GO TO 313
81.000 311 IF(CY(1,J).EQ.0.AND.CY(3,J).EQ.0.)GO TO 313
82.000 IF(CY(1,J).EQ.0.AND.CY(2,J).GT.0.)GO TO 499
83.000 IF(CY(1,J).GT.0.AND.CY(2,J).EQ.0.)GO TO 318
84.000 GO TO 499
85.000 312 IF(CY(1,J).EQ.0.AND.CY(2,J).EQ.0.)GO TO 313
86.000 IF(CY(1,J).EQ.0.AND.CY(3,J).GT.0.)GO TO 321
87.000 IF(CY(1,J).GT.0.AND.CY(2,J).EQ.0.)GO TO 318
88.000 GO TO 499
89.000 317 IVAR=3
90.000 AL=PAC(3)*AL
91.000 GO TO 499
92.000 318 IVAR=1
93.000 AL=PAC(1)*AL
94.000 GO TO 499
95.000 321 IVAR=2
96.000 AL=PAC(2)*AL
97.000 499 IF(PDC.LT.1.)GO TO 128
98.000 ACC=CCR*AL
99.000 128 DO 500 I=1,M
100.000 N=N+1
101.000 IF(DP(1,J).GE.0.10)GO TO 20
102.000 IF(DP(1,J).LE.0.009)GO TO 21
103.000 IF(DP(1,J).GE.0.01.AND.DP(1,J).LE.0.049)GO TO 22
104.000 IF(DP(1,J).GE.0.050.AND.DP(1,J).LE.0.099)GO TO 23
105.000 20 IH=1
106.000 GO TO 60
107.000 21 IH=2
108.000 GO TO 30
109.000 22 IH=3
110.000 GO TO 30
111.000  23 IPHP=4  
112.000  30 IK=1-1  
113.000  IF(IK.EQ.0)GO TO 41  
114.000  IF(DP(IK,J).GT.0.250)GO TO 40  
115.000  IF(DP(IK,J).LE.0.009)GO TO 41  
116.000  IF(DP(IK,J).GE.0.010.AND.DP(IK,J).LE.0.049)GO TO 42  
117.000  IF(DP(IK,J).GE.0.050.AND.DP(IK,J).LE.0.099)GO TO 43  
118.000  IF(DP(IK,J).GE.0.100.AND.DP(IK,J).LE.0.149)GO TO 44  
119.000  IF(DP(IK,J).GE.0.150.AND.DP(IK,J).LE.0.199)GO TO 45  
120.000  IF(DP(IK,J).GE.0.200.AND.DP(IK,J).LE.0.249)GO TO 46  
121.000  40 IPHP=1  
122.000  GO TO 50  
123.000  41 IPHP=2  
124.000  GO TO 50  
125.000  42 IPHP=3  
126.000  GO TO 50  
127.000  43 IPHP=4  
128.000  GO TO 50  
129.000  44 IPHP=5  
130.000  GO TO 50  
131.000  45 IPHP=6  
132.000  GO TO 50  
133.000  46 IPHP=7  
134.000  50 GO TO(61,52,53,54,55,56,57)IPHP  
135.000  52 SWT=10.  
136.000  GO TO 60  
137.000  53 SWT=11.  
138.000  GO TO 60  
139.000  54 SWT=12.  
140.000  GO TO 60  
141.000  55 SWT=13.  
142.000  GO TO 60  
143.000  56 SWT=14.  
144.000  GO TO 60  
145.000  57 SWT=15.  
146.000  60 GO TO(61,62,63,64)IPHP  
147.000  61 GO TO(105,105,105,106,110)IVAR  
148.000  106 IF(CPWD.LT.PAC(I))GO TO 113  
149.000  115 IVAR=3  
150.000  GO TO 105  
151.000  113 IF(N.GE.M)GO TO 107  
152.000  116 ACC=ACC+SLFD(IVAR)  
153.000  TSLFD=TSLFD+SLFD(IVAR)  
154.000  GO TO 500  
155.000  107 ACC=ACC+P(1)*CY(1,J)*((PAC(1)*AL)-ANAC)+P(3)*CY(3,J)*PAC(3)*AL  
156.000  GO TO 400  
157.000  110 IF(CPWD.LT.PAC(1))GO TO 114  
158.000  IVAR=2  
159.000  GO TO 105  
160.000  114 IF(N.GE.M)GO TO 112  
161.000  GO TO 116  
162.000  112 ACC=ACC+P(1)*CY(1,J)*((PAC(1)*AL)-ANAC)+P(2)*CY(2,J)*PAC(2)*AL  
163.000  GO TO 400  
164.000  105 IF(N.GE.M)GO TO 100  
165.000  GO TO 116
166.000 100 ACC=ACC+F(IVAR)*CY(IVAR,J)*(AL-ANAC)
167.000 GO TO 400
168.000 62 EW=22.
169.000 GO TO 70
170.000 63 EW=18.5
171.000 GO TO 70
172.000 64 EW=16.5
173.000 70 ANWH=EW+SWT
174.000 TNAC=AL-ANAC
175.000 IF(PDC.EQ.1.)GO TO 15
176.000 RCA=ASC1*HW1*FE1+ASC2*HW2*FE2+ASC3*HW3*FE3+ASC4*HW4*FE4
177.000 IF(PDC.EQ.0.AND.PDC.LT.1.)GO TO 126
178.000 120 ACRE=ANWH/825.*RCA
179.000 IF(ACRE.LE.TNA)GO TO 18
180.000 ANWH=TNAC*825./RCA
181.000 GO TO 18
182.000 15 ACR=ASC1*HW1*FEC1+ASC2*HW2*FEC2+ASC3*
183.000 1 HWC3*FEC3+ASC4*HWC4*FEC4
184.000 ACRE=ANWH/825.*ACR
185.000 IF(ACRE.LE.TNA)GO TO 18
186.000 ANWH=TNAC*825./ACR
187.000 GO TO 18
188.000 126 IF(APCC.GE.PDC) GO TO 120
189.000 CCRE=ASC1*HW1*FEC1+ASC2*HW2*FEC2
190.000 ACRE=ANWH/825.*RCA
191.000 ACRE=ANWH/825.*ACR
192.000 TACRE=ACRE+ACRE
193.000 IF(TACRE.LE.TNA)GO TO 18
194.000 ANWH=TNAC*825./RCA+CCRE
195.000 18 CNWH=CNWH+ANWH
196.000 C DECIDE HIRING CUSTOM COMBINE OR NOT
197.000 IF(PDC.EQ.1.)GO TO 79
198.000 IF(PDC.EQ.0.)GO TO 76
199.000 IF(N.GE.M)GO TO 80
200.000 APCC=ANACC/AL
201.000 IF(APCC.GE.PDC)GO TO 75
202.000 GO TO 79
203.000 76 IF(N.LT.IDSCC)GO TO 75
204.000 IF(N.GE.M)GO TO 80
205.000 IF(CPWD.GE.PSCC)GO TO 75
206.000 C DECIDE WHETHER CUSTOM COMBINE IS POSSIBLE
207.000 79 L=N-1
208.000 IF(L.EQ.0)GO TO 348
209.000 IF(ICCWI.L.EQ.1)GO TO 190
210.000 348 CALL RANDU(IK,KN)
211.000 IRN=RN+100.
212.000 IF(PGCC(N).EQ.0.10)GO TO 150
213.000 IF(PGCC(N).EQ.0.15)GO TO 151
214.000 IF(PGCC(N).EQ.0.20)GO TO 152
215.000 IF(PGCC(N).EQ.0.25)GO TO 153
216.000 IF(PGCC(N).EQ.0.30)GO TO 154
217.000 IF(PGCC(N).EQ.0.35)GO TO 155
218.000 IF(PGCC(N).EQ.0.40)GO TO 156
219.000 IF(PGCC(N).EQ.0.45)GO TO 157
220.000 IF(PGCC(N).EQ.0.50)GO TO 158
IF (PGCC(N).EQ.0.55) GO TO 159
IF (PGCC(N).EQ.0.60) GO TO 160
IF (PGCC(N).EQ.0.65) GO TO 161
IF (PGCC(N).EQ.0.70) GO TO 162
IF (PGCC(N).EQ.0.75) GO TO 163
IF (PGCC(N).EQ.0.80) GO TO 164
IF (PGCC(N).EQ.0.85) GO TO 165
IF (PGCC(N).EQ.0.90) GO TO 166
IF (PGCC(N).EQ.0.95) GO TO 167
GO TO 190
IF (IRN.LE.10) GO TO 190
IF (IRN.LE.15) GO TO 190
IF (IRN.LE.20) GO TO 190
IF (IRN.LE.25) GO TO 190
IF (IRN.LE.30) GO TO 190
IF (IRN.LE.35) GO TO 190
IF (IRN.LE.40) GO TO 190
IF (IRN.LE.45) GO TO 190
IF (IRN.LE.50) GO TO 190
IF (IRN.LE.55) GO TO 190
IF (IRN.LE.60) GO TO 190
IF (IRN.LE.65) GO TO 190
IF (IRN.LE.70) GO TO 190
IF (IRN.LE.75) GO TO 190
IF (IRN.LE.80) GO TO 190
IF (IRN.LE.85) GO TO 190
IF (IRN.LE.90) GO TO 190
IF (IRN.LE.95) GO TO 190
GO TO 191
ICCP(N)=I
GO TO 192
ICCP(N)=0
CALCULATE THE ACCUMULATED COST AND NUMBER OF ACRES COMPLETED
IF (PDC.LT.1) GO TO 91
IF (ICCP(N).EQ.0) GO TO 61
GO TO (95,95,95,450,451)IVAR
IF (N.GE.M) GO TO 452
ANAC=ANAC+ANW8/25.*ACR
276.000 ACC=ACC+SLPD(IVAR)+0.05*(CY(IVAR,J)-20.)*ANWH/825.*ACR
277.000 16 TSLPD=TSLOPD+SLPD(IVAR)
278.000 GO TO 300
279.000
280.000 452 ANAC=ANAC+ANWH/825.*ACR
281.000 ACC=ACC+SLPD(IVAR)+P(IVAR,J)*(AL-ANAC)+
282.000 10.05*(CY(IVAR,J)-20.)*ANWH/825.*ACR
283.000 GO TO 400
284.000 -1 450 IF(CPWD.LT.PAC(1))GO TO 453
285.000 456 IVAR=3
286.000 GO TO 95
287.000
288.000 453 DAC=ANWH/825.*ACR-(PAC(1)*AL-CPWD*AL)
289.000 IF(DAC.GT.0.)GO TO 456
290.000 ANAC=ANAC+ANWH/825.*ACR
291.000 IF(N.GE.M)GO TO 454
292.000 ACC=ACC+SLPD(IVAR)+0.05*(CY(1,J)-20.)*ANWH/825.*ACR
293.000 GO TO 16
294.000
295.000 454 ACC=ACC+SLPD(IVAR)+P(1)*CY(1,J)*(PAC(1)*AL-ANAC)+
296.000 10.05*(CY(1,J)-20.)*ANWH/825.*ACR
297.000 GO TO 17
298.000
299.000 455 DAC=ANWH/825.*ACR-(PAC(1)*AL-CWD*AL)
300.000 IF(DAC.GT.0.)GO TO 168
301.000 ANAC=ANAC+ANWH/825.*ACR
302.000 IF(N.GE.M)GO TO 457
303.000 ACC=ACC+SLPD(IVAR)+0.05*(CY(1,J)-20.)*ANWH/825.*ACR
304.000 GO TO 16
305.000
306.000 457 ACC=ACC+SLPD(IVAR)+P(1)*CY(1,J)*(PAC(1)*AL-ANAC)+
307.000 10.05*(CY(1,J)-20.)*ANWH/825.*ACR
308.000 GO TO 17
309.000
310.000 91 IF(TCPP(N).EQ.0)GO TO -75
311.000
312.000 422 CACR=ANWH/825.*(ASCC1*HWC1*FEC1+ASCC2*HWC2*FEC2)
313.000 GO TO (420,420,420,421,422)IVAR
314.000
315.000 421 IF(CPUSD.LT.PAC(D)GO TO 170
316.000 169 IVAR=3
317.000
318.000 422 IF(CPUSD.LT.PAC(1))GO TO 424
319.000
320.000
321.000 425 ACC=ACC+CCCCR*CACR+0.05*(CY(1,J)-20.)*CACR
322.000
323.000
324.000
325.000
326.000
327.000
328.000
329.000
330.000
GO TO 405

170 DAC=ANWH/825.*RCA-(PAC(1)*AL-CPWD*AL)

IF(DAC.GT.0.)GO TO 169

GO TO 405

GO TO 405

IF(CPWD.LT.PAC(1))GO TO 171

IVAR=2

GO TO 405

171 DAC=ANWH/825.*RCA-(PAC(1)*AL-CPWD*AL)

IF(DAC.GT.0.)GO TO 172

GO TO 405

80 ANAC=ANAC+ANWH/825.*RCA

125 GO TO(82,82,82,83,84)IVAR

82 ACC=ACC+IV*PHLC*ANWH+IV*COC*ANWH+SLPD(IVAR)+

IP(IVAR)*CY(IVAR,J)*(AL-ANAC)

GO TO 17

83 IF(CPWD.LT.PAC(1))GO TO 85

173 IVAR=3

GO TO 82

85 DAC=ANWH/825.*RCA-(PAC(1)*AL-CPWD*AL)

IF(DAC.GT.0.)GO TO 173

ACC=ACC+IV*PHLC*ANWH+IV*COC*ANWH+SLPD(IVAR)+P(1)*

ICY(1,J)*(PAC(1)*AL-ANAC)+P(3)*CY(3,J)*PAC(3)*AL

GO TO 17

84 IF(CPWD.LT.PAC(1))GO TO 86

IVAR=2

GO TO 82

86 DAC=ANWH/825.*RCA-(PAC(1)*AL-CPWD*AL)

IF(DAC.GT.0.)GO TO 174

ACC=ACC+IV*PHLC*ANWH+IV*COC*ANWH+SLPD(IVAR)+P(1)*CY(1,J)*

PAC(1)*AL-ANAC)+P(2)*CY(2,J)*PAC(2)*AL

GO TO 17

C DECIDE WHETHER THE SET ACREAGE LEVEL IS COMPLETED AND IF IS, THE

C PRESENT VALUE OF THE ACCUMULATED PER ACRE COST ASSOCIATED

300 CPWD=ANAC/AL

IF(ANAC.LT.AL)GO TO 500

400 ROC=0.065*(PC1+PC2+PC3+PC4)

IF(FDC.EQ.1)GO TO 28

600 EOC=0.15*HFC*CNWH*POD

GO TO 29

28 EOC=0.

WRITE(108,306)J,SLPD,ACC

ATC=ACC+ROC+EOC

GO TO (87,88,89,90,34,92,93,94,33,96,97,98,99,31,32)J

87 CF=0.917

GO TO 498

88 CF=0.842

GO TO 498

89 CF=0.772

GO TO 498

90 CF=0.708

GO TO 498

34 CF=0.650

GO TO 498

92 CF=0.596

GO TO 498
GO TO 498
94 CF-0.502
G O T O 498
95 CF-0.460
G O T O 498
96 CF-0.422
G O T O 498
97 CF-0.388
G O T O 498
98 CF-0.356
G O T O 498
99 CF-0.326
G O T O 498
100 CF-0.299
G O T O 498
101 CF-0.275
G O T O 498
102 CF-0.252
G O T O 498
103 CF-0.228
G O T O 498
104 CF-0.204
G O T O 498
105 CF-0.180
G O T O 498
106 CF-0.156
G O T O 498
107 CF-0.133
G O T O 498
108 CF-0.110
G O T O 498
109 CF-0.087
G O T O 498
110 CF-0.064
G O T O 498
111 CF-0.041
G O T O 498
112 CF-0.018
G O T O 498
113 CF-0.005
G O T O 498
390.000 91 CF-0.032
G O T O 498
391.000 92 CF-0.010
G O T O 498
392.000 93 CF-0.000
G O T O 498
393.000 94 CF-0.022
G O T O 498
394.000 95 CF-0.044
G O T O 498
395.000 96 CF-0.066
G O T O 498
396.000 97 CF-0.088
G O T O 498
397.000 98 CF-0.110
G O T O 498
398.000 99 CF-0.132
G O T O 498
399.000 100 CF-0.154
G O T O 498
400.000 101 CF-0.176
G O T O 498
401.000 102 CF-0.198
G O T O 498
402.000 103 CF-0.220
G O T O 498
403.000 104 CF-0.242
G O T O 498
404.000 105 CF-0.264
G O T O 498
405.000 106 CF-0.286
G O T O 498
406.000 107 CF-0.308
G O T O 498
407.000 108 CF-0.330
G O T O 498
408.000 109 CF-0.352
G O T O 498
409.000 110 CF-0.374
G O T O 498
410.000 111 CF-0.396
G O T O 498
411.000 500 CONTINUE
412.000 C FORM T A T C=TATC+ATC*CF
413.000 J=J+1
414.000 IF(IAL.EQ.1)AL=960.
415.000 IF(IAL.EQ.2)AL=2240.
416.000 IF(J.LT.IM) GO TO 305
417.000 IJ=J-1
418.000 WRITE(108,261)AL,IJ,TATC
419.000 GO TO 307
420.000 500 CONTINUE
421.000 FORMAT STATEMENTS
422.000 1 FORMAT(4I10,F5.2,F5.3)
423.000 2 FORMAT(16F5.2)
424.000 12 FORMAT(F5.2)
425.000 13 FORMAT(6F5.2)
426.000 3 FORMAT(12F5.2,F10.2,I1)
427.000 24 FORMAT(8F10.2)
440.000  402 FORMAT(1HI,IX,'HARVEST BY OWN COMBINE AND CUSTOM COMBINE',
441.000   1/IX,'HEADER WIDTH OF OWN COMBINE=',F5.2,/,IX,'HEADER WIDTH OF ',
442.000   1'CUSTOM COMBINE=',F5.2,IX,F5.2,/,IX,'PERCENTAGE OF ACRES OF ',
443.000   1'CHEYNNE PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF WINALTA ',
444.000   1'PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF PIROLINE PLANTED=',
445.000   1'F4.2,/,IX,'PERCENTAGE OF ACRES CUSTOM COMBINED=',F4.2)
446.000  404 FORMAT(1HI,IX,'HARVEST BY OWN COMBINE AND CUSTOM COMBINE'/IX,
447.000   1'HEADER WIDTH OF OWN COMBINE=',F5.2,IX,F5.2,/,IX,'HEADER WIDTH ',
448.000   1'OF CUSTOM COMBINE=',F5.2,IX,F5.2,/,IX,'PERCENTAGE OF ACRES OF ',
449.000   1'CHEYNNE PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF WINALTA ',
450.000   1'PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF PIROLINE PLANTED=',
451.000   1'F4.2,/,IX,'PERCENTAGE OF ACRES CUSTOM COMBINED=',F4.2)
452.000  39 FORMAT(1HI,IX,'HARVEST BY OWN COMBINE AND CUSTOM COMBINE'/IX,
453.000   1'HEADER WIDTH OF OWN COMBINE=',F5.2,IX,F5.2,/,IX,'HEADER ',
454.000   1'WIDTH OF CUSTOM COMBINE=',F5.2,IX,F5.2,/,IX,'PERCENTAGE OF ',
455.000   1'ACRES OF CHEYNNE PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF ',
456.000   1'WINALTA PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF PIROLINE ',
457.000   1'PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES CUSTOM COMBINED=',F4.2)
458.000  14 FORMAT(1HI,IX,'HARVEST BY OWN COMBINE AND CUSTOM COMBINE'/IX,
459.000   1'HEADER WIDTH OF OWN COMBINE=',F5.2,IX,F5.2,IX,F5.2,/,IX,'HEADER ',
460.000   1'WIDTH OF CUSTOM COMBINE=',F5.2,IX,F5.2,/,IX,'PERCENTAGE OF ',
461.000   1'PERCENTAGE OF ACRES OF CHEYNNE PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF WINALTA PLANTED=',
462.000   1'PERCENTAGE OF ACRES OF PIROLINE PLANTED=',F4.2,/,IX,
463.000   1'F4.2,/,IX,'PERCENTAGE OF ACRES CUSTOM COMBINED=',F4.2)
465.000  4 FORMAT(1HI,/////////////,40X,'SIMULATION PROGRAM OF COMBINE ',
466.000   1'OWNERSHIP')
467.000  8 FORMAT(1HI,IX,'HARVEST BY CUSTOM COMBINE'/IX,'HEADER WIDTH OF ',
468.000   1'CUSTOM COMBINE=',F5.2,IX,F5.2,/,IX,'PERCENTAGE OF ACRES OF CHEYN',
469.000   1'NE PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF WINALTA PLANTED=',
470.000   1'F4.2,/,IX,'PERCENTAGE OF ACRES OF PIROLINE PLANTED=',F4.2)
471.000  9 FORMAT(1HI,IX,'HARVEST BY CUSTOM COMBINE'/IX,'HEADER WIDTH OF ',
472.000   1'CUSTOM COMBINE=',F5.2,IX,F5.2,IX,F5.2,/,IX,'PERCENTAGE OF ACRES O',
473.000   1'CHEYNNE PLANTED=',F4.2,/,IX,'PERCENTAGE OF ACRES OF WINALTA PLA',
474.000   1'STOM=',F4.2,/,IX,'PERCENTAGE OF ACRES OF PIROLINE PLANTED=',F4.2)
475.000 10 FORMAT(1HI,IX,'HARVEST BY CUSTOM COMBINE'/IX,'HEADER WIDTH OF CU',
476.000   1'STOM=',F5.2,IX,F5.2,IX,F5.2,IX,F5.2,IX,F5.2,/,IX,'PERCENTAGE ',
477.000   1'OF ACRES OF CHEYNNE PLANTED=',F4.2,/,IX,'PERCENTAGE ',
478.000   1'OF ACRES OF WINALTA PLANTED=',F4.2,/,IX,'PERCENTAGE ',
479.000   1'OF ACRES OF PIROLINE PLANTED=',F4.2)
481.000 261 FORMAT(1X,'PRESENT VALUE OF THE ACCUMULATED COST OF A ',
482.000   16F6.0,' ACREAGE LEVEL FARM OVER',13,' YEARS IS $',F15.2)
483.000 306 FORMAT(1X,'YEAR ','12 ','/IX,'SHATTER LOSS=$',F8.2,
483.000   11X,'ACCUMULATED COST=$',F8.2)
484.000 307 STOP
485.000 END
486.000 SUBROUTINE RANDU(IY,YFL)
487.000   IY=IX*65539
488.000   IF(IY)<6,6
489.000   5 Y=IY+2147483647+1
490.000   6 YFL=YFL+2147483647
491.000   YFL=YFL*.4656613E-9
492.000   IX=IY
493.000 RETURN
494.000 END
FUNCTION SLPD(IVAR)
DIMENSION CY(5,15),PAC(3),P(5)
COMMON N,J,AL,CY,P,PAC,ANAC
IF(N.EQ.1) GO TO 1
IF(N.GE.2.AND.N.LE.5) GO TO 2
IF(N.GE.6.AND.N.LE.7) GO TO 3
IF(N.EQ.8) GO TO 4
IF(N.GE.9.AND.N.LE.13) GO TO 5
IF(N.GE.14.AND.N.LE.15) GO TO 6
IF(N.GE.16.AND.N.LE.17) GO TO 7
IF(N.GE.18.AND.N.LE.20) GO TO 8
IF(N.GE.21.AND.N.LE.22) GO TO 9
IF(N.GE.23.AND.N.LE.27) GO TO 10
IF(N.GE.28.AND.N.LE.30) GO TO 11
IF(N.GE.31.AND.N.LE.35) GO TO 12
IF(N.GE.36.AND.N.LE.40) GO TO 13
IF(N.GE.41) SLPD=0.
GO TO 25
1 GO TO (14,15,15,16,16) IVAR
14 SLPD=P(1)*0.01*CY(1,J)*(AL-ANAC)
GO TO 25
15 SLPD=0.
GO TO 25
16 SLPD=P(1)*0.01*CY(1,J)*(AL*PAC(1)-ANAC)
GO TO 25
17 SLPD=P(1)*0.005*CY(IVAR,J)*(AL-ANAC)
GO TO 25
18 SLPD=P(1)*0.01*CY(1,J)*(AL*PAC(I)-ANAC)+P(3)*0.005*
19 SLPD=P(1)*0.01*CY(1,J)*(AL*PAC(I)-ANAC)+P(3)*0.005*
GO TO 25
20 SLPD=P(1)*0.02*CY(I,J)*(AL-ANAC)
GO TO 25
21 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(3)*0.005*
GO TO 25
22 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(3)*0.005*CY(3,J)*
23 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(3)*0.005*
GO TO 25
24 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(3)*0.005*CY(3,J)*
25 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(3)*0.005*
GO TO 25
26 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(3)*0.004*
27 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
28 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(3)*0.004*
GO TO 25
29 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
30 SLPD=P(1)*0.02*CY(I,J)*(AL-ANAC)
GO TO 25
31 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
32 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
33 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
34 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
35 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
36 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
37 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
38 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
39 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
40 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
41 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
42 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
43 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
44 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
45 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
46 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
47 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
48 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
49 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
50 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
51 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
52 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
53 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
54 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
55 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
56 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
57 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
58 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
59 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
60 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
61 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
62 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
63 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
64 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
65 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
66 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
67 SLPD=P(1)*0.02*CY(I,J)*(AL*PAC(I)-ANAC)+P(2)*0.004*
GO TO 25
68
29 SLPD-P(1)*0.02*CY(1,J) *(AL*PAC(1)-ANAC)+P(3)*0.003*
30 SLPD-P(1)*0.02*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*0.003*
31 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(3)*0.003*
32 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*0.003*
33 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
34 SLPD-P(IVAR)*0.002*CY(IVAR,J)*(AL-ANAC)
35 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(3)*
36 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
37 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
38 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(3)*
39 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(3)*
40 SLPD-P(1)*0.015*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
41 SLPD-P(IVAR)*0.001*CY(IVAR,J)*(AL-ANAC)
42 SLPD-P(1)*0.005*CY(1,J)*(AL*PAC(1)-ANAC)+P(3)*
43 SLPD-P(1)*0.005*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*0.001*
44 SLPD-P(1)*0.005*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
45 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(3)*0.001*
46 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
47 SLPD-P(1)*0.005*CY(1,J)*(AL*PAC(1)-ANAC)+P(3)*0.001*
48 SLPD-P(1)*0.005*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*0.001*
49 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(3)*
50 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
51 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
52 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
53 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
54 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
55 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
56 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
57 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
58 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
59 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
60 SLPD-P(1)*0.007*CY(1,J)*(AL*PAC(1)-ANAC)+P(2)*
GO TO (28,15,15,49,49) IVAR
SLPD = P(1) * 0.003 * CY (1, J) * (AL * PAC (1) - ANAC)
GO TO 25
GO TO (41, 15, 15, 50, 50) IVAR
SLPD = P(1) * 0.001 * CY (1, J) * (AL * PAC (1) - ANAC)
RETURN
END
LITERATURE CITED


A decision model of combine ownership