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A Linear Programming Approach to the Optimum Farm Organizations for Selected Farm Sizes Under Dryland and Partially Irrigated Conditions in the Missouri Slope Region of the Oahe Unit

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A LINEAR PROGRAMMING APPROACH TO THE OPTIMUM FARM ORGANIZATIONS FOR SELECTED FARM SIZES UNDER DRYLAND AND PARTIALLY IRRIGATED CONDITIONS IN THE MISSOURI SLOPE REGION OF THE OAHE UNIT

BY

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A LINEAR PROGRAMMING APPROACH TO THE OPTIMUM FARM ORGANIZATIONS FOR SELECTED FARM SIZES UNDER DRYLAND AND PARTIALLY IRRIGATED CONDITIONS IN THE MISSOURI SLOPE REGION OF THE OAHE UNIT

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

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CHAPTER I

INTRODUCTION

Statement of the Problem

The purpose of this study is to determine optimum farm organizations for selected sizes of dryland and partially irrigated farms in central Sully County, South Dakota. For the purpose of this study, optimum farm organization is that combination of enterprises which yields maximum return from a given amount of resources in terms of net income to the farmer.

The farmers in central Sully County will soon have to make a decision as to whether or not they wish to continue their present dryland farming or alter it so as to include a system of partially irrigated farming. The results of this study will provide a basis on which to make a comparison of the relative profitability of dryland and partially irrigated farming.

The Oahe Dam has been constructed across the Missouri River north of Pierre, South Dakota. This makes possible the storage of large quantities of water that will be available for irrigating parts of central South Dakota.[1] This includes the area that was considered in this study, namely, the Missouri Slope Region of the Oahe Unit

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[1]Rex D. Helfinstine, Economic Potentials of Irrigated and Dryland Farming in Central South Dakota, Bulletin 444, p. 3, Agricultural Experiment Station, South Dakota State College: Brookings, South Dakota, 1955.

located in Sully County.[2]

Need for the Study

There is a need for further research as to the optimum farm organizations under dryland and partially irrigated conditions. The use of computers for analysis makes it possible to expand the model and consider varying sizes of farm organizations. Availability of water changes production conditions which will affect farm organization. There is a need to compare present organizations with estimates of farm organizations with available irrigation water. Little is known about farming under irrigated conditions in this area.

Objectives of the Study

The objectives of this study for the Missouri Slope Area were:

1. To determine the optimum farm organizations under dryland conditions for 640-, 1280-, and 2560-acre farms.

2. To determine the optimum farm organizations under partially irrigated conditions for 560-, 1080-, and 2240-acre farms.

3. To compare the returns to land, labor, and capital and to determine the relative profitability of each.

Linear Programming

The tool that was employed in this study for determining optimum farm organizations was linear programming. Linear programming is a mathematical technique for specifying how to use limited resources

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[2]See Figure I.

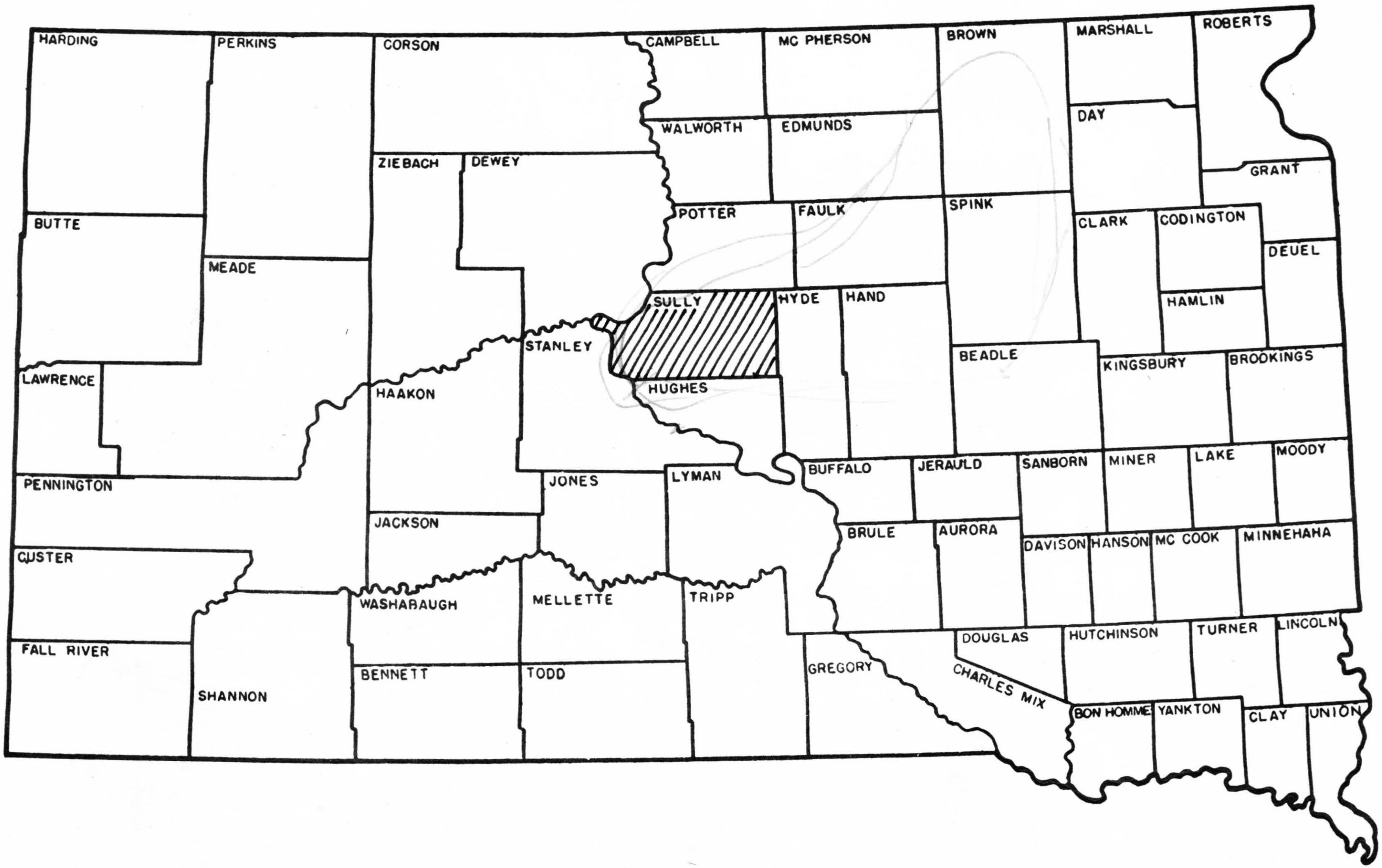

Figure I. Location of the area included in the study or capacities to obtain a particular objective, such as to maximize profit or to minimize costs when those resources have alternative uses. Linear programming systematizes, for certain conditions, the process of selecting the most desirable course of action from a number of courses of action.[3] It does this by solving a linear function of a number of variables which are subjected to a number of restraints in the form of linear inequalities.[4]

Several basic assumptions are used in linear programming. They are:[5]

1. Linearity: Which is the restriction that the variables or unknowns must occur to the first power. No squares, cubes, or other powers are permissible, nor may one variable be multiplied by another. This means that input factors combine in fixed proportions at all levels of output.

2. Additivity: Which means that the activities must be additive in that when two or more are used, their total product must equal the sum of their individual products.

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[3]Robert O. Ferguson and Lauren R. Sargent, Linear Programming: Fundamentals and Applications, p. 3, McGraw-Hill Book Company, Inc.: New York, 1958.

[4]Clifford D. Harmelink, A Linear Programming Approach To The Optimum Farm Organization For A Typical 480-acre Farm Under Partially Irrigated Conditions In Central South Dakota, p. 3, M.S. Thesis, South Dakota State College: Brookings, South Dakota, December, 1959.

[5]Charles E. French, "Activity Analysis: An Agricultural Marketing Tool," Journal of Farm Economics, Vol. 37, 1236-1248, 1955.

3. Divisibility: Which assumes that factors can be used and commodities produced in quantities which are fractional units. This means that an activity can be indicated to be a continuous straight line.

4. Finiteness: Which assumes that there is a limit to the number of alternative activities and to the resource restrictions which need to be considered.

The linear programming technique is carried out as follows:

1. A mathematical model (or set of equations) is formulated from the word problem. This set of equations is to follow a certain form.

2. The mathematical model is solved, using standard computational steps (algorithms).[6]

By a model is meant a small-scale version of a larger situation that has essential features and characteristics of the larger problem.[7]

In the formulation of the mathematical model, the equations in the model need not express rigorously every facet or every fine point which could conceivably affect the problem at hand. Assumptions and approximations may be necessary.

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[6] For a complete description of the simplex method, see Earl O. Heady and Wilfred Candler, Linear Programming Methods, p. 53, Iowa State College Press: Ames, Iowa, 1958.

[7] Robert O. Ferguson and Lauren R. Sargent, Linear Programming: Fundamentals and Applications, p. 175, McGraw-Hill Book Company, Inc.: New York, 1958.

The construction of the linear programming model gives a mathematical picture of the problem to be resolved. The optimum farm organizations are to be obtained from this model by using a standard program in the IBM 1620 computer by Lou Davis and Art Nickel. This program employs the dual algorithm to obtain a first feasible solution, and the simplex algorithm to select activities that make the greatest contribution to total net return.

One of the advantages of particular interest to the economist who uses linear programming is that it yields many computational byproducts concerning the marginal values of resources and the stability of the optimum farm organization with little additional effort.[8] The associated shadow price of an activity is the marginal value, an indicator of how much net cash revenue would be increased by the addition of one unit of the restrictive resource.

A primary consideration of alternative organizations of farms in any area is their relative stability in the presence of price and yield fluctuations. Minor additional arithmetic with the optimum allocation will yield this type of information. The price ranges for which the model indicates no change in optimum farm organization are calculated. A comparison of these prices with historical price variation adjusted to a given level will indicate the degree of production, price, and income stability in any given agricultural area.

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[8]Clifford D. Harmelink, A Linear Programming Approach To The Optimum Farm Organization For A Typical 480-acre Farm Under Partially Irrigated Conditions In Central South Dakota, p. 4, M.S. Thesis, South Dakota State College: Brookings, South Dakota, December, 1959.

Some other advantages of linear programming are as follows. The marginal value associated with the withdrawal of one acre of land from the optimum allocation to grow any of the alternative crops can be determined directly. An inventory of surplus resources that are not completely utilized is available which may serve as a guide to consideration of long-run adjustments in the organization. The opportunity costs of the non-optimum activities are calculated. The opportunity cost is the amount of profit sacrificed per unit of alternative not recommended for the optimum plan. Linear programming requires the researcher to make an explicit statement as to the assumptions and restrictions that provide the frame work of the optimum farm organization.[9]

Data for the study are gathered from other research that has been completed at South Dakota State College. Estimates are also obtained from the Agronomy and Animal Science Departments. A survey of the Oahe Region was completed in July, 1961. Information obtained from this survey included equipment used, practices employed, sizes of farms, land use, and attitude toward irrigation.

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[9] Ibid.

CHAPTER II

CHARACTERISTICS OF THE AREA

The farm model constructed was intended to be representative of farms in the Missouri Slope Region of the Oahe Unit. Several simplifying assumptions were made concerning the characteristics of the typical farm situations.

Climate

South Dakota, because of its inland position, has a climate characterized by extremes of summer heat, winter cold, and rapid fluctuations of temperature. The climate in the Missouri Slope Region of the Oahe Unit is such that the region is considered in the high risk zone for production of dryland crops. This is because of unfavorable distribution of growing-season rainfall and also because of variability over a period of years. The average annual precipitation is about 16 inches at the Onida station, and about 70 percent of this falls in May to September. The average length of the growing season is about 140 days. The temperature ranges from an extreme of 115 degrees above zero in the summer to 37 degrees below zero in the winter, with an average July temperature of 76 degrees.[1]

[1]Report on Oahe Unit, p. 92, U.S. Department of the Interior, Bureau of Reclamation, Region 6, Appendix D--Project Lands, Missouri-Oahe Project Office: Huron, South Dakota, June, 1960.

Soil

The Missouri Slope area is located within the Chestnut soil zone.[2] The area is made up of undulating or sloping, well drained, grayish brown silt loams and loams.[3] The arable soil group is characterized by weathered loess overlying glacial drift or till, and the non-arable lands are usually glacial drift areas with a very thin or no-silt covering, or low flat areas of dense orman-type clay without natural relief. Some of the problems inherent in this kind of soil are maintenance of organic matter and nitrogen and moisture conservation.

Topography

The Missouri Slope begins with an elevation of 1900 feet above sea level in the northeast corner of the area and declines to 1800 feet in the southwest corner, a distance of 27 miles. This is an average drop of 3.70 feet per mile. The basic surface relief is marked by gently-rolling to rolling topography. Depressions or potholes of varying sizes are a natural feature of physical geography. During a cycle of wet years, the larger ones hold surface runoff throughout the year, and in dry years they become a source of hay and pasture.

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[2]Fred C. Westin, Leo F. Puhr, and George J. Buntley, Soils of South Dakota, p. 10, Soil Survey Series Pamphlet No. 3, Agronomy Department, Agricultural Experiment Station, South Dakota State College: Brookings, South Dakota, March, 1959.

[3]Ibid., p. 15.

Drainage

Surface drainage is imperfect and incomplete. The rolling and complex topography is conducive to fast runoff. Many potholes or depressions have not been drained. These hold some water in the area where it is lost to evaporation and deep percolation. Internal drainage is generally adequate under dryland conditions for all but the depressional areas. Closed tile drains will be necessary to remove deep percolation losses from irrigation.

Land Classification

Land in the area has been classified as to its suitability for irrigation purposes by the Bureau of Reclamation (Table 1). It was determined that 32 percent of the land in the Missouri Slope Region would be irrigable providing that drainability was established. The irrigable land included 43.8 percent Class 1 land and 56.2 percent Class 2 land.

Table 1. Land Classification of Missouri Slope for Irrigation

Class	Amount acres	% of total	% of irrigable
1	16,442	14.0	43.8
2	21,095	18.0	56.2
3	0	0	0
Total irrigable	37,537	32.0	100
Non-irrigable	79,676	68.0	
Total	117,213	100	

Source: U.S. Bureau of Reclamation, Huron, South Dakota.

Land Use

The South Dakota Crop and Livestock Reporting Service shows small grain, corn, and alfalfa as the principal crops grown in the Missouri Slope area (Table 2). These crops make up 90 percent of all the cropland in the area.

The farms in the area are large. Large ranch units utilize the land from the Missouri River to within the western boundary of the Missouri Slope area, yet most farms in the area produce both livestock and grain, either small grain or corn. Farm organization varies in type from cash-grain to livestock, depending upon the soil, topography, the amount of native grass and the operator's preference.

Table 2. Principal Crops as a Percentage of All Cropland (excluding wild hay) for Sully County

Crop	% of Cropland
Corn	17
Barley	3
Oats	19
Wheat	34
Alfalfa	14
Total	90

Source: South Dakota Crop & Livestock Reporting Service: South Dakota Agriculture, 1961.

Farm Sizes

Table 3 shows a breakdown of the farms by acreage groups. The 640-, 1280-, and 2560-acre farms are the most representative farm sizes in the area.

Table 3. Number of Farms in Each Acreage Group for Missouri Slope Area in Sully County

Acres	Number of farms
80 - 239	1
240 - 399	2
400 - 559	3
560 - 719	4
720 - 879	2
880 - 1039	0
1040 - 1199	2
1200 - 1359	4
1360 - 1519	3
1520 - 1679	1
1680 - 1839	0
1840 - 1999	3
2000 - 20,620	14
Total	39

Source: Survey of Missouri Slope Area of Sully County, 1961.

CHAPTER III

THE MODEL

The construction of the linear programming model gave a mathematical picture of the problem to be resolved.

Farm Sizes Considered

The sizes selected were intended to be representative of the typical farms in the area. The dryland farm sizes that were selected were 640-, 1280-, and 2560-acre farms. Up to 32 percent, but not more than 320 acres of land, was allowed to go into irrigation. Throughout the study it was assumed that the total land value of the partially irrigated farms should equal the value before irrigation. Since the value of irrigated land was estimated to exceed the average value of dryland by \$64 per acre, this called for a reduction in dryland farm sizes. The following formula was used for the conversion:

$$V_1F_1 = V_1F_2 + V_2F_3$$

$$F_3 = .32\ F \leq R$$

$$F = F_2 + F_3$$

where

F = the partially irrigated farm size.

F_1 = the original dryland farm size.

F_2 = the dryland portion of the partially irrigated farm.

F_3 = the irrigated portion of the partially irrigated farm.

V_1 = the value of land, buildings, and equipment for dryland per acre.

V_2 = the value of land, buildings, and equipment for partially irrigated land per acre.

R = the maximum acreage of land that can be irrigated (320 acres).

F is rounded to the nearest even multiple of 80 acres.

In this way, the 640-acre dryland farm was reduced to a 560-acre partially irrigated farm. The same procedure was used for reducing the other dryland farm sizes. See Table 4.

Table 4. Farm Sizes Used in the Linear Programming Model

Dryland	Partially irrigated
640	560
1280	1080
2560	2240

Activities Considered

The terms activity and process are used interchangeably in this study. Activity and process are "a way of doing things." An activity or process denotes "a set of ratios obtaining among rates of consumption of various inputs and rates of production of various outputs."[1]

Available computer space and time made it necessary to limit the number of activities to be considered to a minimum. Therefore, only typical activities, differing significantly from each other, and

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[1] Robert Dorfman, Paul Samuelson, and Robert Solow, Linear Programming and Economic Analysis, p. 132, McGraw-Hill Book Company, Inc.: New York, 1958.

representative of types of productive enterprises, were considered.

Tables 5 and 6 show the production processes that were considered in the linear programming model.

Table 5. Production Processes Considered for Typical Farms, Sully County*

Description of activity		Unit of measure
Dryland crops		
X_{20}	Corn used for grain	acre
X_{21}	Corn used for silage	acre
X_{22}	Barley	acre
X_{23}	Oats	acre
X_{24}	Wheat	acre
X_{25}	Alfalfa used for hay	acre
X_{26}	Alfalfa used for pasture	acre
Livestock operations		
X_{27}	Beef herd	cow-calf
X_{28}	Long fed steers, grain-hay ration	head
X_{29}	Long fed steers, grain-silage ration	head
X_{30}	Short fed calves, grain-hay ration	head
X_{31}	Short fed calves, grain-silage ration	head
X_{32}	Spring swine enterprise	sow-litter
X_{33}	Fall swine enterprise	sow-litter
X_{34}	Sheep flock	ewe-lamb
X_{35}	Lambs on feed	head
Labor hiring		
X_{36}	Off-season labor hired	hour
X_{37}	April labor hired	hour
X_{38}	May labor hired	hour
X_{39}	June labor hired	hour
X_{40}	July labor hired	hour
X_{41}	August labor hired	hour
X_{42}	September labor hired	hour
X_{43}	October labor hired	hour
Purchase and sale of feed grain		
X_{44}	Grain sold, corn equivalent	ton
X_{45}	Grain bought, corn equivalent	ton

*When these activities are included in the partially irrigated model, they are numbered X_{24} through X_{49}.

Table 6. Additional Production Processes Considered for Partially Irrigated Farms, Sully County

Description of activity		Unit of measure
Irrigated crops		
X_{50}	Corn used for grain	acre
X_{51}	Corn used for silage	acre
X_{52}	Barley	acre
X_{53}	Oats	acre
X_{54}	Wheat	acre
X_{55}	Alfalfa used for hay	acre
X_{56}	Alfalfa used for pasture	acre
X_{57}	Potatoes	acre
X_{58}	Sugar beets	acre

Long fed steers are bought at 400 pounds and sold at 1050 pounds. Short fed calves are bought at 400 pounds and sold at 700 pounds.

Budgets of Production Enterprises

Activity budgets or cost and returns schedules were determined for each of the various activities to obtain the net effect on total farm returns associated with the operation of each of the activities. A negative net profit coefficient denotes a cost or a decrease in profit associated with the activity. A positive net profit coefficient denotes the profit associated with the activity.

Present prices were used in computing the returns from the various farm operations. The costs that were involved in the various farm operations were present costs (1962).

Table 7 is a typical activity budget. Tractor costs, repairs, seed, fertilizer, and interest were considered the variable costs. One acre of dryland corn increases profit by $8.92.

Table 7. Costs and Returns, Dryland Corn

Item	Amount
Tractor costs	$ 2.32
Repairs	.45
Seed	1.77
Fertilizer	3.18
Capital Interest	.46
Total cost	8.18
Yield	19 bu.
Price	.90
Return	17.10
Net return	8.92

Fixed costs are not included in the activity budgets. They are deducted after the optimum program has been obtained. The fixed costs are explained and analyzed in Chapter VI.

The activity budgets for the remaining crop and livestock enterprises are given in the Appendix in Tables 27 and 28. These budgets gave the figures used in the model to determine the optimum farm organization. The net profit coefficients are summarized in Table 8.

Table 8. Summary of Activity Budgets--Crop and Livestock Production

	Enterprise	Unit	Net returns
	Dryland crops		
X_{20}	Corn	acre	$ 8.92
X_{21}	Corn silage	acre	-10.61
X_{22}	Barley	acre	8.95
X_{23}	Oats	acre	11.59
X_{24}	Wheat	acre	17.09
X_{25}	Alfalfa hay	acre	11.90
X_{26}	Alfalfa pasture	acre	-6.04
	Irrigated crops		
X_{50}	Corn	acre	$ 37.00
X_{51}	Corn silage	acre	-32.24
X_{52}	Barley	acre	26.32
X_{53}	Oats	acre	26.96
X_{54}	Wheat	acre	49.26
X_{55}	Alfalfa hay	acre	60.72
X_{56}	Alfalfa pasture	acre	-11.34
X_{57}	Potatoes	acre	376.18
X_{58}	Sugar beets	acre	182.32
	Livestock operations		
X_{27}	Beef-cow herd	cow-calf	$ 76.85
X_{28}	Long-fed steers, grain-hay ration	head	74.33
X_{29}	Long-fed steers, grain-silage ration	head	57.06
X_{30}	Short-fed calves, grain-hay ration	head	61.57
X_{31}	Short-fed calves, grain-silage ration	head	53.62
X_{32}	Spring swine enterprise	sow-litter	235.32
X_{33}	Fall swine enterprise	sow-litter	235.32
X_{34}	Sheep flock	ewe-lamb	15.95
X_{35}	Lambs on feed	head	1.69

Purchase and Sale Activities

Other activities were selling of grain, buying of grain, labor, and raising of native pasture. The net profit coefficients were computed to complete the necessary set.

The feed grains were expressed in terms of corn equivalent units. Corn was priced at 90 cents a bushel and weighed 56 pounds per bushel. Thus, the selling activity would yield \$32.14 per ton sold. Corn would be purchased 10 cents above the selling price, that is \$1.00 per bushel or \$35.72 per ton.

If labor was required beyond that furnished by the farm operator and his family, it was assumed that it could be hired at the seasonal rate of 1 dollar per hour. Thus, the labor hiring activities have a net profit coefficient of -1 dollar per hour.

The Net Profit Equation

Equations are specific statements in mathematical form. The net profit equation states that the total net returns from the optimum farm organization consists of the sum of the net returns per unit level of each activity times the active level of the activity in the optimum farm program. Hence, the maximization of the net profit equation subject to the resource, institutional, and conservation restrictions defines the optimum farm program.

The net profit equation used in this study was as follows:

$$Z = \sum_{i=1}^{M} C_i X_i$$

where $Z =$ total net returns

$C_i =$ the cost/return per unit of activity i.

$X_i =$ the level of each activity i.

The variables X_{20} through X_{45} refer to the level of the farm activities which were considered in the programming model. A list of these variables and a definition of each is presented in Table 5. In addition to these variables, the partially irrigated model considered the activities listed in Table 6.

The Restrictions Imposed

A linear programming problem does not exist unless resources are restricted or limited. For most planning or choice problems there are restrictions which set limits on the kinds of plans which can be considered. For a producing farm restrictions are defined by the fixed quantities of certain resources. A farm may have a given amount of land of several types, fixed space for buildings, and a given amount of machinery, labor, and capital.

In addition to these restrictions there were both institutional restrictions and conservation restrictions employed. The restrictions on the resources were determined by the limits of the available supply of each resource.

The restrictions and restriction inequalities are presented in the discussion that follows.

Land. $B_1 \geq X_c$

where B_1 represents total cropland and X_c crop acreage.

This equation limits the amount of cropland on each farm. It was assumed that 37 percent of the land was cropland. Thus, a 640-acre dryland farm would have 237 acres of cropland, a 1280-acre dryland farm would have 474 acres of cropland, and a 2560-acre farm would have 947 acres of cropland. For the partially irrigated farms, a 560-acre farm would have 207 acres of cropland, a 1080-acre farm would have 400 acres of cropland, and a 2240-acre farm would have 829 acres of cropland.

<u>Capital</u>. $B_2 \geq X_c + X_L + X_h + X_g$

where B_2 represents capital, X_c capital required to produce crops, X_L capital required to produce livestock, X_h capital required to hire labor, and X_g capital required to purchase grain.

The amount of operating capital was limited. The land was considered to be completely operator owned. It was also assumed that the farm operator would have the necessary machinery, equipment, and buildings to carry out any specified farm program. Under a partially irrigated system, it was assumed he could raise the necessary capital to inaugurate an irrigation system. The farm operator would impute a 6 percent charge on all operating capital required. The capital was estimated from the 1961 survey of the Missouri Slope Region of the Oahe Unit. It is an average of the amount of operating capital in each farm group. A constant amount of capital was used for each of the farm sizes. The small farms had $16,358 of capital available. The medium-sized farms had $22,259 of capital available. The large farms had $41,728 of capital available.

<u>Labor</u>. $B_3 \geq X_c + X_L - X_h$

where B_3 represents total labor, X_c total man-hours used to produce crops, X_L total man-hours used to produce livestock, and X_h total man-hours of labor hired.

$B_m \geq X_c + X_L - X_h$

where B_m represents the monthly labor available, X_c monthly man-hours of labor used to produce crops, X_L monthly man-hours of labor used to produce livestock, and X_h monthly man-hours of labor hired. B_4, B_5, B_6, B_7, B_8, B_9, and B_{10} represented April, May, June, July, August, September, and October labor, respectively.

These inequalities represented the labor restrictions. It was necessary to include a total labor restriction because of the limited amount of total labor available for production purposes. It was also necessary to restrict the amount of labor available for the various months because of the limited supply. The months listed above were included in the model because this was the time when the heaviest demands on labor would be made. It was assumed that the farm operator possessed sufficient managerial abilities to inaugurate any farm program specified by the linear programming model. It was assumed that the farm operator and his family would furnish up to 24 ten-hour days of man labor per month to carry out a specified farm program. Thus, it was assumed that the farms had available 2500 hours of total labor and 240 hours of labor for April, May, June, July, August, September, and October. This does not include overhead labor. If the amount of labor furnished by the farm operator and his family was not enough, it was assumed he could hire the additional labor required at the seasonal rate.

<u>Pasturage</u>. $B_{11} \geq X_p + X_L$

where B_{11} represents the AUM (Animal Unit Month) of pasture available, X_p AUM of alfalfa pasture produced, and X_L AUM of pasture used by the livestock enterprises.

Because of the limited number of acres of pasture available, it was necessary to place a restriction on the amount that could be used in the model. It was assumed that 52 percent of the land was native pasture. Thus, a 640-acre dryland farm would have 333 acres of native pasture, a 1280-acre dryland farm would have 666 acres of native pasture, and a 2560-acre dryland farm would have 1331 acres of native pasture. For the partially irrigated farms, a 560-acre farm would have 291 acres of native pasture, a 1080-acre farm would have 562 acres of native pasture, and a 2240-acre farm would have 1165 acres of native pasture. These acreages were converted to AUM by multiplying the number of acres times the AUM per acre.

<u>Hay</u> <u>and</u> <u>Silage</u>. $B_{12} \geq -X_h + X_L$

where B_{12} represents the tonnage of hay available, X_h tonnage of hay produced, and X_L tonnage of hay used by the livestock enterprises.

The typical farm had 5 percent of its cropland in hay, so this restriction was used in the model.

$B_{13} \geq X_s + X_L$

where B_{13} represents the tonnage of silage available, X_s tonnage of silage produced, and X_L the tonnage of silage used by the livestock enterprises.

This restriction assumes that the amount of silage produced would equal the amount used by the livestock enterprises.

Feed Grain. $B_{14} \geq -X_g + X_L + X_s - X_p$

where B_{14} represents the tonnage of feed grain available, $-X_g$ the feed grain tonnage produced, X_L the tonnage of feed grain used by the livestock enterprises, X_s the tonnage of feed grain sold, and X_p the tonnage of feed grain purchased.

The amount of feed grain produced or purchased would equal the amount used by the livestock enterprises or sold directly.

Hog Housing. $B_h \geq X_s$

where B_h represents the swine restriction and X_s the number of hogs produced. B_{15} and B_{16} represented the spring swine and fall swine, respectively.

A limitation had to be placed on hog production. It was assumed that the farm operator did not possess sufficient building facilities to produce more than the restriction amount. The restrictions used were 30 litters for a 640-acre dryland farm, 40 litters for a 1280-acre farm, and 50 litters for a 2560-acre farm. The same restrictions were used for a 560-, 1080-, and a 2240-acre partially irrigated farm.

Wheat Allotment. $B_{17} \geq X_w$

where B_{17} represents the wheat allotment and X_w the wheat acreage.

An example of an institutional restriction used in the model was the wheat allotment. It was assumed that the acreage of wheat would not exceed 15 percent of the farm size. Thus, a 640-acre dryland farm could raise 96 acres of wheat, a 1280-acre dryland farm could raise 192 acres of wheat, and a

2560-acre dryland farm could raise 384 acres of wheat. For the partially irrigated farms, a 560-acre farm could raise 84 acres of wheat, a 1080-acre farm could raise 162 acres of wheat, and a 2240-acre farm could raise 336 acres of wheat.

Agronomic Restrictions. $B_{18} \leq X_a$

where B_{18} represents the minimum legume restriction, and X_a the alfalfa acreage.

Conservation restrictions were also incorporated into the model. For conservation purposes it was assumed that the cropping system included at least one-tenth legumes on the dryland cropland.

Companion Crop for Alfalfa. $B_{19} \leq 4X_s - X_a$

where B_{19} is zero, X_s small grain acreage, and X_a the alfalfa acreage.

It was also necessary to insist on a small grain and alfalfa ratio so that there would be assurance of a companion crop for the planting of the legume. One acre of alfalfa allows the operator to plant 4 acres of small grain per year.

Additional Restrictions for Irrigation

In addition to these restrictions, the partially irrigated model incorporated the following.

Land. $B_{20} \geq X_c$

where B_{20} represents the irrigated cropland and X_c the irrigated crop acreage.

A restriction was placed on the amount of land that could be irrigated. A 560-acre partially irrigated farm could irrigate

175 acres of cropland. A 1080-acre partially irrigated farm could irrigate 320 acres of cropland. A 2240-acre partially irrigated farm could irrigate 320 acres of cropland.

Agronomic Restrictions. $B_{21} \leq X_a$

where B_{21} represents the minimum irrigated legume restriction and X_a the irrigated alfalfa acreage.

For conservation purposes it was assumed that the cropping system included at least one-fourth legumes on the irrigated cropland and one-tenth legumes on the dryland cropland.

Companion Crop for Alfalfa. $B_{22} \leq 4X_s - X_a$

where B_{22} is zero, X_s the small grain, and X_a the alfalfa acreage.

It was also necessary to insist on a small grain and legume ratio so that there would be assurance of a companion crop for the planting of the legumes. One acre of alfalfa allows the operator to plant 4 acres of small grain.

Potato and Sugar Beet. $B_{23} \geq X_p$

where B_{23} represents the potato and sugar beet restriction and X_p the potato and sugar beet acreage.

The production of potatoes and sugar beets was limited to 35 acres for a 560-acre partially irrigated farm, 50 acres for a 1080-acre partially irrigated farm, and 50 acres for a 2240-acre partially irrigated farm. A restriction had to be placed on these enterprises because the manager did not possess sufficient managerial abilities to handle a potato and sugar beet operation larger than this. If no restriction had been placed on them, they would enter into the optimum farm program at an undesirably high level. Widespread production of potatoes by many farmers could lower prices and profits, while production of sugar beets is restricted by quota.

Input-Output Relationships

The basic data upon which this study was based are given in Tables 24 through 28 in the Appendix. These data were compiled from the Bureau of Reclamation figures, data supplied by the Animal Science and Agronomy Departments at South Dakota State College, and other figures worked out by Professor Rex Helfinstine.

The input-output relationships make up the body of the initial tableaus in the following chapter. The input-output coefficients were computed for the activity budgets of Tables 27 and 28.

CHAPTER IV

THE DRYLAND AND PARTIALLY IRRIGATED MODELS

The Dryland Initial Tableau

Table 9 is the initial tableau that was coded and fed into the IBM computer.[1]

The initial tableau represents an initial solution where all resources are being disposed and not used. The amounts of restrictions B_1, B_2, and B_3 are the levels of the so-called disposal activities. The main body of this tableau is made up of the restrictive equations with the resource supplies on the left in the B columns. The B_1, B_2, and B_3 columns represent the level of resource supplies available on a 640-, 1280-, and 2560-acre dryland farm, respectively.

The columns represent the available productive activities, and the figures in the column cells represent the amount of restricted resource required per unit of productive activity. A negative coefficient indicates the addition to the level of restrictive resource per unit of activity.

The figures on the c and C row represent the net marginal revenue or net marginal cost associated with a unit of a particular activity. A positive figure on the c and C row means that the corresponding activity will add to profits if it is shifted into the plan,

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[1]The identity matrix of disposal activities need not be coded in the computer program used (IBM 1620 Program Library, No. 10.1.002).

considering the fact that other activities must be reduced. A negative figure indicates the cost per unit of activity shifted into the plan.

The net revenue coefficient of the feed grain production activities has been reduced by the value of the grain produced. Instead each activity contributes the quantity harvested, measured in tons, directly to the grain disposition activity. This allows flexibility in the use of grain.

Four alternatives were considered in respect to the feed grain activities. These alternatives were raising the grain and feeding it to the livestock, selling it through the grain selling activity, feeding all grain raised and buying additional feed grain, or neither production nor feeding of grain.

The value of the grain is determined by the activities selected. Since grain may be sold, it is always worth the selling price of 90 cents per bushel. If corn is bought, the value of the raised grains is equal to the value of the corn bought which is $1.00 per bushel. If none is sold or bought, but some grain is raised and fed, it may be worth anything between 90 cents and $1.00 per bushel. In these cases the effective net revenue of the feed grain activities is somewhat higher than that given in Table 8.

The Partially Irrigated Initial Tableau

Table 10 shows the additions to the tableau for the partially irrigated farms. This is merely added to the end of the real variables on the dryland model, and with the real variable numbers corrected and resource additions noted, the initial tableau would be complete.

In the partially irrigated model, the alternative was given that irrigation could be employed, not employing irrigation, or using some combination of irrigation and dryland farming. Irrigation was not forced into the optimum program.

The B_1, B_2, and B_3 columns of Table 10 represent the level of resource supplies available on a 560-, 1080-, and 2240-acre partially irrigated farm, respectively.

Table 9. The Initial Tableau for the Determination of the Optimum Farm Organizations for Selected Farm Sizes Under Dryland Conditions in Central South Dakota

			c		-8.18	-10.61	-7.05	-6.41	17.09	-9.10	-6.04
	Activity		Level				Real Activities				
C		B_1	B_2	B_3	P_{20}	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}	P_{26}
0	P_1	237	474	947	1	1	1	1	1	1	1
0	P_2	163.58	222.59	417.28	.0772	.1001	.0665	.0605	.0765	.0915	.0570
0	P_3	2500	2500	2500	2.2	6.6	1.4	1.4	1.4	3.5	0
0	P_4	240	240	240	.264	.264	.588	.588	.588	0	0
0	P_5	240	240	240	.704	.726	0	0	0	0	0
0	P_6	240	240	240	.418	.396	0	0	0	1.75	0
0	P_7	240	240	240	.176	.198	.406	.406	.406	1.75	0
0	P_8	240	240	240	0	0	.406	.406	.406	0	0
0	P_9	240	240	240	0	5.016	0	0	0	0	0
0	P_{10}	240	240	240	.638	0	0	0	0	0	0
0	P_{11}	249.8	499.5	998.2	0	0	0	0	0	0	-1.8
0	P_{12}	38.4	76.8	153.6	0	0	0	0	0	-2.4	0
0	P_{13}	0	0	0	0	-10.0	0	0	0	0	0
0	P_{14}	0	0	0	-1.064	0	-.864	-.816	0	0	0
0	P_{15}	30	40	50	0	0	0	0	0	0	0
0	P_{16}	30	40	50	0	0	0	0	0	0	0
0	P_{17}	96	192	384	0	0	0	0	1	0	0
0	P_{18}	23.70	47.40	94.70	0	0	0	0	0	-1	-1
0	P_{19}	0	0	0	0	0	-4.0	-4.0	-4.0	1	1
	C	0	0	0	-8.18	-10.61	-7.05	-6.41	+17.09	-9.70	-6.04

Table 9. (continued)

			c		76.85	74.33	57.06	61.57	53.62	235.32
	Activity		Level				Real Activities			
C		B_1	B_2	B_3	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}	P_{32}
0	P_1	237	474	947	0	0	0	0	0	0
0	P_2	163.58	222.59	417.28	2.6483	1.0814	1.2391	1.0728	1.1451	.9333
0	P_3	2500	2500	2500	10.0	3.468	3.468	2.0	2.0	20.0
0	P_4	240	240	240	1.4	.4	.4	0	0	3.0
0	P_5	240	240	240	.5	.4	.4	0	0	2.5
0	P_6	240	240	240	.2	.267	.267	0	0	1.5
0	P_7	240	240	240	.1	0	0	0	0	1.5
0	P_8	240	240	240	.2	0	0	0	0	1.5
0	P_9	240	240	240	.3	0	0	0	0	2.5
0	P_{10}	240	240	240	.4	.4	.4	.4	.4	.5
0	P_{11}	249.8	499.5	998.2	11.9	3.5	3.5	0	0	2.5
0	P_{12}	38.4	76.8	153.6	3.587	1.75	0	.75	0	0
0	P_{13}	0	0	0	2.427	0	5.2	0	3.0	0
0	P_{14}	0	0	0	0	2.576	2.24	2.632	2.352	5.6
0	P_{15}	30	40	50	0	0	0	0	0	1
0	P_{16}	30	40	50	0	0	0	0	0	0
0	P_{17}	96	192	384	0	0	0	0	0	0
0	P_{18}	23.70	47.40	94.70	0	0	0	0	0	0
0	P_{19}	0	0	0	0	0	0	0	0	0
	C	0	0	0	+76.85	+74.33	+57.06	+61.57	+53.62	+235.32

Table 9. (continued)

			c		235.32	15.95	1.69	-1.00	-1.00	-1.00
	Activity		Level				Real Activities			
C		B_1	B_2	B_3	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}	P_{38}
0	P_1	237	474	947	0	0	0	0	0	0
0	P_2	163.58	222.59	417.28	.9333	.1120	.1941	.01	.01	.01
0	P_3	2500	2500	2500	20.0	2.0	1.215	-1	-1	-1
0	P_4	240	240	240	.5	.26	0	0	-1	0
0	P_5	240	240	240	1.0	.12	0	0	0	-1
0	P_6	240	240	240	.5	.06	0	0	0	0
0	P_7	240	240	240	.5	.04	0	0	0	0
0	P_8	240	240	240	1.0	.08	0	0	0	0
0	P_9	240	240	240	3.5	.08	0	0	0	0
0	P_{10}	240	240	240	3.5	.14	.38	0	0	0
0	P_{11}	249.8	499.5	998.2	2.5	1.456	0	0	0	0
0	P_{12}	38.4	76.8	153.6	0	.7	.22	0	0	0
0	P_{13}	0	0	0	0	0	0	0	0	0
0	P_{14}	0	0	0	5.6	.05	.123	0	0	0
0	P_{15}	30	40	50	0	0	0	0	0	0
0	P_{16}	30	40	50	1	0	0	0	0	0
0	P_{17}	96	192	384	0	0	0	0	0	0
0	P_{18}	23.70	47.40	94.70	0	0	0	0	0	0
0	P_{19}	0	0	0	0	0	0	0	0	0
	C	0	0	0	+235.32	+15.95	+1.69	-1.00	-1.00	-1.00

Table 9. (continued)

		c			-1.00	-1.00	-1.00	-1.00	-1.00	16.07	-17.86
	Activity		Level					Real Activities			
C		B_1	B_2	B_3	P_{39}	P_{40}	P_{41}	P_{42}	P_{43}	P_{44}	P_{45}
0	P_1	237	474	947	0	0	0	0	0	0	0
0	P_2	163.58	222.59	417.28	.01	.01	.01	.01	.01	0	.1786
0	P_3	2500	2500	2500	-1	-1	-1	-1	-1	0	0
0	P_4	240	240	240	0	0	0	0	0	0	0
0	P_5	240	240	240	0	0	0	0	0	0	0
0	P_6	240	240	240	-1	0	0	0	0	0	0
0	P_7	240	240	240	0	-1	0	0	0	0	0
0	P_8	240	240	240	0	0	-1	0	0	0	0
0	P_9	240	240	240	0	0	0	-1	0	0	0
0	P_{10}	240	240	240	0	0	0	0	-1	0	0
0	P_{11}	249.8	499.5	998.2	0	0	0	0	0	0	0
0	P_{12}	38.4	76.8	153.6	0	0	0	0	0	0	0
0	P_{13}	0	0	0	0	0	0	0	0	0	0
0	P_{14}	0	0	0	0	0	0	0	0	1	-1
0	P_{15}	30	40	50	0	0	0	0	0	0	0
0	P_{16}	30	40	50	0	0	0	0	0	0	0
0	P_{17}	96	192	384	0	0	0	0	0	0	0
0	P_{18}	23.70	47.40	94.70	0	0	0	0	0	0	0
0	P_{19}	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	-1.00	-1.00	-1.00	-1.00	-1.00	+16.07	-17.86

Table 10. The Irrigated Portion of the Initial Tableau for the Determination of the Optimum Farm Organizations for Selected Farm Sizes Under Partially Irrigated Conditions in Central South Dakota

				c	-27.80	-32.24	-21.68	-21.04	49.26
	Activity		Level				Real Activities		
C		B_1	B_2	B_3	P_{50}	P_{51}	P_{52}	P_{53}	P_{54}
0	P_1	207	400	829	1	1	1	1	1
0	P_2	163.58	222.59	417.28	.2623	.3051	.2045	.1985	.2145
0	P_3	2500	2500	2500	6.7	10.7	3.0	3.0	3.0
0	P_4	240	240	240	1.273	.856	1.89	1.89	1.89
0	P_5	240	240	240	.603	.642	0	0	0
0	P_6	240	240	240	1.474	1.498	.66	.66	.66
0	P_7	240	240	240	1.742	1.712	.48	.48	.48
0	P_8	240	240	240	.804	.749	0	0	0
0	P_9	240	240	240	0	5.029	0	0	0
0	P_{10}	240	240	240	.469	.214	0	0	0
0	P_{11}				0	0	0	0	0
0	P_{12}	126	243	504	0	0	0	0	0
0	P_{13}	0	0	0	0	-27.0	0	0	0
0	P_{14}	0	0	0	-4.032	0	-2.592	-1.637	0
0	P_{15}	30	40	50	0	0	0	0	0
0	P_{16}	30	40	50	0	0	0	0	0
0	P_{17}	84	162	336	0	0	0	0	1
0	P_{18}	3.2	8.0	50.9	0	0	0	0	0
0	P_{19}	0	0	0	0	0	0	0	0
0	P_{20}	175	320	320	1	1	1	1	1
0	P_{21}	43.75	80	80	0	0	0	0	0
0	P_{22}	0	0	0	0	0	-4.0	-4.0	-4.0
0	P_{23}	35	50	50	0	0	0	0	0
	C				-27.80	-32.24	-21.68	-21.04	+49.26

Table 10. (continued)

C	Activity	B_1	B_2	B_3	P_{55}	P_{56}	P_{57}	P_{58}
			c		-20.28	-11.34	+376.18	182.32
	Activity		**Level**			**Real Activities**		
0	P_1	207	400	829	1	1	1	1
0	P_2	163.58	222.59	417.28	.1913	.1070	.6021	.2045
0	P_3	2500	2500	2500	10.8	1.0	17.6	18.2
0	P_4	240	240	240	0	0	.880	1.638
0	P_5	240	240	240	.324	0	7.392	.910
0	P_6	240	240	240	3.348	0	2.464	1.638
0	P_7	240	240	240	3.348	0	2.816	2.184
0	P_8	240	240	240	3.348	.5	2.112	2.184
0	P_9	240	240	240	0	.5	.528	1.092
0	P_{10}	240	240	240	.432	0	1.584	8.736
0	P_{11}				0	-7.9	0	0
0	P_{12}	126	243	504	-9.0	0	0	0
0	P_{13}	0	0	0	0	0	0	-3.4
0	P_{14}	0	0	0	0	0	0	0
0	P_{15}	30	40	50	0	0	0	0
0	P_{16}	30	40	50	0	0	0	0
0	P_{17}	84	162	336	0	0	0	0
0	P_{18}	3.2	8.0	50.9	0	0	0	0
0	P_{19}	0	0	0	0	0	0	0
0	P_{20}	175	320	320	1	1	1	1
0	P_{21}	43.75	80	80	-1	-1	0	0
0	P_{22}	0	0	0	1	1	0	0
0	P_{23}	35	50	50	0	0	1	1
	C				-20.28	-11.34	+376.18	+182.32

CHAPTER V

THE OPTIMUM FARM ORGANIZATIONS

The final tableau gave the optimum farm organization, the marginal value products, the marginal costs, and the stability or sensitivity of the optimum farm program to changes in prices, costs, and available resources.[1]

The Dryland Optimum Farm Organizations

The activities selected for the optimum farm programs are presented in Table 11. The values presented for each of these activities have been rounded-off from the exact mathematical solution to the nearest full integral value. The B columns of the solution tableau contained the active levels of the various activities in the optimum farm program.

The marginal value products are of interest since they indicate possible gains in income through acquisition of scarce resources. They also represent the minimum loss due to a reallocation of the resources or the lack of some of the resources of this model. The C coefficients of the disposal activities (scarce resources) represent the marginal value products of the corresponding resources and are sometimes called shadow prices. They tell us the imputed value of the scarce resources. They indicate, for each resource, how much an additional unit would increase income.

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[1]Stability or sensitivity of the optimum farm program will not be analyzed in this study.

Table 11. The Dryland Optimum Farm Organizations for Selected Farm Sizes, Sully County, Central South Dakota

		Farm Sizes (acres)		
		640	1280	2560
Activity	Unit		Level	
Dryland crops				
Corn	acre	117.3	234.6	447.6
Wheat	acre	96.0	192.0	284.0
Alfalfa hay	acre	15.5	39.8	115.4
Alfalfa pasture	acre	8.2	7.6	0
Native pasture	acre	333.0	666.0	1331
Livestock enterprises				
Spring swine	head	30	40	50
Fall swine	head	30	40	50
Short-fed calves, grain-hay ration	head	27	29	95
Sheep flock	head	79	215	514
Other				
Feed grain bought	tons	14.344	14.252	12.920
Hiring April labor	hour	0	235	413
Hiring May labor	hour	0	91	312
Hiring June labor	hour	0	21	280
Hiring July labor	hour	0	37	317
Hiring August labor	hour	0	0	82
Hiring September labor	hour	0	17	884
Hiring October labor	hour	0	111	355

Table 12 presents the marginal value products of scarce resources of the dryland optimum farm programs. To illustrate, the marginal value product of cropland for a 640-acre dryland farm is $11.53. This means that a one acre decrease of cropland, equals a one acre increase in cropland left idle, would decrease total net returns by $11.53. Conversely, a one acre increase of cropland would add $11.53 to the total net returns of the farm. Thus, the marginal value

Table 12. The Marginal Value Products for Selected Dryland Farm Sizes, Sully County, Central South Dakota

		Farm Sizes (acres)		
		640	1280	2560
Enterprise	Unit	Marginal Value Product Per Unit		
Dryland cropland	acre	$ 11.53	$ 9.05	$ 8.94
Capital	$100	6.23	4.69	3.52
Labor	hour	0 *	1.05	1.04
Native pasture	AUM	6.65	5.16	4.10
Hay	ton	13.20	13.98	18.82
Silage	ton	4.56	1.46	2.68
Feed grain	ton	37.94	37.40	36.98
Spring swine	sow-litter	106.64	92.42	97.54
Fall swine	sow-litter	106.64	92.42	97.54
Wheat allotment	acre	5.09	6.22	6.43

*none hired.

product of cropland for a 640-acre dryland farm was $11.53. Renting additional land would be profitable as long as the rent is less than this amount.

The shadow prices of C coefficients of activities not selected for an optimum program are in fact the opportunity costs per unit of activity added, or the reduction in profit due to the inclusion of a unit of such a non-optimum activity in the final program.

Table 13 presents the marginal costs associated with the real activities that did not enter into the final program. For example, for every acre of barley raised on a 640-acre dryland farm, it would decrease total net returns by $2.60.

The Partially Irrigated Optimum Farm Organization

The real activities in the optimum farm programs are presented in Table 14. The values presented for each of these activities have

Table 13. The Opportunity Costs of Non-Optimum Activities, Selected Dryland Farm Sizes, Sully County, Central South Dakota

		Farm Sizes (acres)		
		640	1280	2560
Enterprise	Unit	Marginal Cost Per Unit		
Corn silage	acre	$ 2.60	$19.75	$13.30
Barley	acre	2.83	1.72	1.70
Oats	acre	0*	1.95	1.93
Alfalfa pasture	acre	0*	0*	7.80
Legume requirement	acre	5.95	6.08	0*
Beef A cow	cow-calf	43.38	29.60	24.05
Long-fed steers, grain-hay ration	head	16.11	12.80	11.53
Long-fed steers, grain-silage ration	head	28.27	16.09	13.65
Short-fed calves, grain-hay ration	head	4.96	0*	0*
Lambs on feed	head	3.31	4.33	4.60
Off-season labor hiring	hour	1.06	0*	0*
Grain selling	ton	5.80	5.26	4.84

*This activity is profitable in this size class and is included in the optimum program (Tables 12 and 13).

been rounded-off from the exact mathematical solution.

The marginal value products and marginal costs are used here in the same context as under the dryland optimum farm organizations. Table 15 presents the marginal value products of resources of the partially irrigated optimum farm programs. To illustrate, the marginal value product of non-irrigated cropland for a 560-acre partially irrigated farm is $14.58. This means that a one acre decrease of cropland (equals a one acre increase in cropland left idle) would decrease total net returns by $14.58. Conversely, a one acre increase of cropland would add $14.58 to the total net returns of the farm. Thus, the marginal value product of cropland for a 560-acre partially irrigated

Table 14. The Partially Irrigated Optimum Farm Organizations for Selected Farm Sizes, Sully County, Central South Dakota

Activity	Unit	Farm Sizes (acres) 560	1080	2240
			Level	
Dryland crops				
Corn	acre	0	0	170.7
Wheat	acre	28.8	72.0	287.4
Alfalfa pasture	acre	3.2	8.0	50.9
Native pasture	acre	291	562	1165
Irrigated crops				
Corn	acre	55.6	114.9	141.4
Wheat	acre	40.7	75.0	48.6
Potatoes	acre	35.0	50.0	50.0
Alfalfa hay	acre	5.9	0	14.6
Alfalfa pasture	acre	37.8	80.0	65.4
Livestock enterprises				
Spring swine	head	30	40	50
Fall swine	head	30	40	50
Short-fed steers	head	0	0	57
Sheep flock	head	256	347	846
Direct purchase of resources				
Feed grain bought	ton	6.238	0	0
Hiring April labor	hour	127	364	685
Hiring May labor	hour	190	380	616
Hiring June labor	hour	50	203	395
Hiring July labor	hour	77	260	500
Hiring August labor	hour	25	155	370
Hiring September labor	hour	0	93	1352
Hiring October labor	hour	0	390	362

Table 15. The Marginal Value Products for Selected Partially Irrigated Farm Sizes, Sully County, Central South Dakota

		Farm Sizes (acres)		
		560	1080	2240
Enterprise	Unit	Marginal Value Products		
Dryland cropland	acre	$ 14.58	$ 8.23	$ 8.85
Capital	$100	12.30	82.45	5.17
Labor	hour	1.12	1.82	1.05
Native pasture	AUM	5.46	5.26	5.22
Hay	1000 lbs.	7.13	2.83	6.77
Silage	1000 lbs.	2.82	3.82	2.69
Feed grain	1000 lbs.	20.06	21.76	18.56
Spring swine	sow-litter	86.65	0	92.48
Fall swine	sow-litter	93.95	0	92.48
Wheat allotment	acre	0	0	6.37
Irrigated land	acre	43.22	17.87	29.77
Potato and sugar beet	acre	307.97	268.32	315.93

farm was $14.58. Renting additional land would be profitable as long as the rent is less than this amount.

Table 16 presents the marginal costs associated with the real activities that did not enter into the final program. For example, for every unit of dryland barley raised on a 560-acre partially irrigated farm, total net returns would decrease by $6.69.

Table 16. The Opportunity Costs of Non-Optimum Activities, Selected Partially Irrigated Farm Sizes, Sully County, Central South Dakota

		Farm Sizes (acres)		
		560	1080	2260
Enterprise	Unit	Marginal Cost		
Dryland				
Corn	acre	$ 4.12	$ 3.63	$ 0
Corn silage	acre	0	.98	0
Barley	acre	6.69	4.51	1.69
Oats	acre	6.94	4.42	1.91
Alfalfa hay	acre	.72	6.11	.67
Beef-cow herd	cow-calf	51.19	174.54	35.68
Long-fed steers, grain-hay ration	head	23.42	82.21	12.83
Long-fed steers, grain-silage ration	head	38.07	120.02	26.83
Short-fed calves, grain-hay ration	head	9.76	89.94	0
Short-fed calves, grain-silage ration	head	16.09	107.08	6.13
Lambs on feed	head	4.73	19.83	4.36
Off-season labor hiring	hour	1.12	0	0
September labor hiring	hour	1.12	0	0
October labor hiring	hour	1.12	0	0
Grain selling	1000 lbs.	3.99	5.69	2.49
Grain buying	1000 lbs.	0	10.82	.22
Legume requirement	acre	11.49	18.97	5.79
Irrigated				
Corn silage	acre	9.21	0	11.01
Barley	acre	18.83	13.70	16.42
Oats	acre	37.37	33.46	33.56
Alfalfa hay	acre	0	8.34	0
Sugar beets	acre	171.40	149.20	183.28
Legume requirement	acre	13.31	48.09	10.33

CHAPTER VI

THE ANALYSIS OF RETURNS

Net returns for dryland and partially irrigated farms:

Farm size	Dryland	Partially irrigated
Small	$12,411	$29,057
Medium	19,360	42,029
Large	30,289	55,690

These figures were rounded to the nearest dollar.

The net returns that were given above is profit to the fixed resources, and not net profit to the firm. To obtain net profit to the firm, fixed costs must be subtracted from these quantities. We obtain the optimum plan even though fixed costs are not subtracted until after the final program is computed. Fixed costs are the same regardless of the program selected and do not affect selection of activity combinations which increase profit.

The fixed costs that must be subtracted are real estate tax, personal property tax, insurance, depreciation on buildings, building repairs, depreciation on machinery, interest on machinery and livestock, interest on real estate, irrigation construction charge, truck expenses, and fencing. These costs were not considered in the model.

See Tables 17 and 18 for an inventory of machinery and equipment found on the various farms. Table 19 summarizes the fixed costs.

Table 20 shows the returns of the dryland and partially irrigated farms after adjusting for fixed costs. The returns to land, labor, and capital were computed by multiplying the marginal value product of the resource and the amount of the resource used in the optimum program.

Table 17. Estimated Average Machinery and Equipment Inventory for Dryland Farm Sizes, Central South Dakota

Item	No.	Size	640-acre farm	1280-acre farm	2560-acre farm
Truck	1	1/2-ton	$1400	$1400	$1400
Truck	1	2-ton	2000	2000	2000
Tractor	1	2-plow		1620	
Tractor	1	3-plow	2045	2045	2045
Tractor	1	4-plow	2470	2470	2470
Tractor	1	5-plow			2895
Plow	1	3-14"	304	304	304
Plow	1	4-14"	365	365	365
Plow	1	5-14"			495
Disc, tandem	1	10'		232	232
Disc, tandem	1	11'		256	
Disc, tandem	1	14'	326		326
Disc, straight	1	21'			235
Harrow	1	25'	72		
Harrow	1	30'		87	
Harrow	1	35'			102
One way	1	16'			375
Lister planter, corn	1	4-row		329	
Planter, corn	1	4-row	264		264
Drill, grain	1	14'	700	700	700
Cultivator, lister	1	4-row		309	
Cultivator	1	4-row	500		500
Combine, w/motor	1	12'	2365		
Combine, SP	1	6'		1510	
Combine, SP	1	14'			3523
Picker, corn	1	1-row	718		
Picker, corn	1	2-row		1232	1232
Baler, twine	1			1036	1036
Field chopper	1	1-row			1214
Swather, SP	1	14'			1212
Swather	1	15'	530		
Swather	1	16'		565	
Swather, SP	1	16'			1385

Table 18. Estimated Average Machinery and Equipment Inventory for Partially Irrigated Farm Sizes, Central South Dakota*

Item	No.	Size	560-acre farm	1080-acre farm	2240-acre farm
Plow, 2-way	1	2-14"	$400	$400	$400
Land leveler	1	10'	330	330	330
Ditcher	1		340	340	340
Other irrigation equipment			150	200	200

*This shows the irrigation equipment required. For a list of the dryland equipment, see Table 17. A 560-acre partially irrigated farm is comparable to the 640-acre dryland farm.

Table 19. Fixed Costs for Selected Farm Sizes, Central South Dakota

Item	640-acre dryland	1280-acre dryland	2560-acre dryland	560-acre partially irrigated	1080-acre partially irrigated	2240-acre partially irrigated
Tax, real estate	$ 540	$1079	$ 2155	$ 695	$ 1320	$ 2296
Tax, personal property	410	512	889	420	508	911
Insurance, personal property	103	128	222	105	127	228
Depreciation, buildings	103	163	310	128	197	372
Depreciation, machinery	205	165	243	153	177	256
Repairs, buildings	120	190	362	149	230	434
Interest on real estate	1079	2158	4310	1390	2640	4592
Interest on machinery and livestock	1231	1536	2667	1259	1524	2734
Expense, truck	1475	1844	2730	1475	1844	2730
Expense, fencing	968	1736	3272	918	1494	2646
Irrigation construction charge				985	1802	1802
Total	6234	9511	17160	7677	11863	19001

Table 20. Comparison of Returns to Dryland and Partially Irrigated Farms

Item	640-acre dryland	560-acre partially irrigated	1280-acre dryland	1080-acre partially irrigated	2560-acre dryland	2240-acre partially irrigated
Total returns	$12411	$29057	$19360	$42029	$30289	$55690
Fixed costs	6324	7677	9511	11863	17160	19001
Net profit	6087	21380	9849	30166	13129	36689
Returns to dryland	2733	467	4290	658	8466	4505
Returns to irrigated land		7564		5718		9526
Returns to native pasture land	1661	1481	2577	2217	4093	4561
Total returns to land	4394	9222	6867	8593	12559	18592
Total returns to labor	*	2800	2625	4550	2600	2625
Total returns to capital	1019	2012	1043	2193	1469	2157

*Labor was never a limiting factor here; there was a surplus of it.

The 560-acre partially irrigated farm made $15,293 more profit than the 640-acre dryland farm. The returns to land, labor, and capital were also greater for the 560-acre partially irrigated farm.

The 1080-acre partially irrigated farm made $20,317 more profit than the 1280-acre dryland farm. The 1080-acre partially irrigated farm had a slightly smaller return per acre on the dryland acreage but exceeded the 1280-acre dryland farm in every other category.

The 2240-acre partially irrigated farm made $23,560 more profit than the 2560-acre dryland farm. The 2240-acre partially irrigated farm had a slightly smaller return per acre on the dryland acreage but exceeded the 2560-acre dryland farm in the other returns listed in the table.

CHAPTER VII

SUMMARY AND CONCLUSIONS

What will the optimum farm organizations yield in terms of net income to the farmer? The purpose of this study was to answer this question for the selected farm sizes. The question was answered through the use of linear programming.

The selected farm sizes were 640-, 1280-, and 2560-acre dryland farms and 560-, 1080-, and 2240-acre partially irrigated farms. The supply of labor available was 240 man-hours per month and 2500 total man-hours per year from the farm operator and his family and also whatever more could profitably be hired. The farm was completely operator owned and had the necessary machinery, equipment, and buildings to carry out any specified farm program. The necessary capital to inaugurate an irrigation system could be raised. Only typical activities were considered in the model.

The study indicated that partially irrigated farming was more profitable than dryland farming for each farm size group. The small, medium, and large partially irrigated farms yielded slightly over $15,000, $20,000, and $23,000 more net profit than the comparable small, medium, and large dryland farms. The smallest partially irrigated farm yielded more net profit than the largest dryland farm size.

The study indicates that the increase in net return to the large partially irrigated farm was substantially reduced as compared to the increase in net return of the medium partially irrigated farm over the small. This seems to indicate that large partially irrigated farms are not substantially more profitable than some smaller partially irrigated farm size.

The returns to land were greater for the partially irrigated farms which would seem to indicate a preference for the partially irrigated farming over a complete dryland farming system. The farm program chosen by an individual farmer depends on the managerial skills and farming talents possessed by the farmer.

This study was intended to serve only as a guide in the selection of the most desirable farming system for the typical farmer. The final decision as to which of the farming systems to choose depends for the most part on the personal preferences and abilities of the farm operator.

There is a need for further research on the problems faced by the farmer in operating over a period of years. Research must be conducted on how to cope with the variability in production and prices from year-to-year. There is a need for further research on the optimum farm organizations over a period of years taking into consideration the withdrawal of funds for the needs of the farm family. More precise input-output relationships concerning the production of various commodities is needed so further research must be conducted in this area.

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APPENDIX

Table 21. Average Price Received by Farmers for Products Sold, Sully County

Product	Unit	Price received
Corn	bu.	$ .90
Barley	bu.	.80
Oats	bu.	.60
Wheat	bu.	1.80
Potatoes	bu.	1.10
Sugar beets	ton	12.00
Alfalfa hay, baled	ton	18.00
Beef cows	cwt.	15.40
Beef steers, feeders	cwt.	25.00
Beef steers, fat	cwt.	18.00
Ewes	per head	5.00
Lambs	cwt.	22.26
Hogs, 230 lbs., fat	cwt.	17.00
Hogs, 350 lbs., sows	cwt.	10.40
Wool	lb.	.45

Source: Economics Department, South Dakota State College, Brookings, South Dakota.

Table 22. Estimated Average Expenses, Central South Dakota, Projected Level

Item	Unit	Cost rate
Labor	hour	$ 1.00
Water charge (O & M)	acre	5.00
Water charge (construction)	acre	5.63
Depreciation, machinery		10%*
Depreciation, buildings		3%*
Repairs, buildings		3½%*
Taxes, dryland and irrigated		20**
Taxes, personal property		20**
Insurance, personal property		½%*
Interest on real estate investment		4%*
Interest on machinery and livestock		6%*
Leveling land for irrigation	acre	64.00
Dry cropland	acre	70.00
Range pasture	acre	30.00
Irrigated land	acre	134.00***
Total ½-ton pickup truck costs		
15,000 miles annual use	mile	.068
12,500 miles annual use	mile	.068
10,000 miles annual use	mile	.068
7,500 miles annual use	mile	.070
5,000 miles annual use	mile	.071
Total 2-ton truck cost		
15,000 miles annual use	mile	.095
12,500 miles annual use	mile	.097
10,000 miles annual use	mile	.097
7,500 miles annual use	mile	.100
5,000 miles annual use	mile	.104

*Inventory value.
**Mills per dollar, inventory value.
***This figure is the dry cropland value per acre plus the cost of leveling land for irrigation (70 + 64).

Source: Economics Department, South Dakota State College, Brookings, South Dakota.

Table 23. Estimated Average Yields of Crops Used in Linear Programming Analysis, Sully County

Crops	Unit	Yield
Dryland		
Corn for grain	bu.	19
Corn for silage	ton	5
Barley	bu.	20
Oats	bu.	30
Wheat	bu.	28*
Alfalfa hay	ton	1.2
Alfalfa pasture	AUM	1.8
Native pasture	AUM	.75
Irrigated		
Corn for grain	bu.	72
Corn for silage	ton	13.5
Barley	bu.	60
Oats	bu.	80
Wheat	bu.	40+
Alfalfa hay	ton	4.5
Alfalfa pasture	AUM	7.9
Potatoes	bu.	400
Sugar beets	ton	17

*Assumes winter wheat after fallow.
+Assumes winter wheat.

Source: Agronomy Department, South Dakota State College, Brookings, South Dakota.

Table 24. Estimated Rates of Livestock Production, Sully County

Item	Unit	Rate
Calf crop	percent	90
Age of cows at calving	years	$2\frac{1}{2}$
Cows per bull	no.	25
Replacement age of cows	years	8
Lamb crop from ewes 1 yr. and over	percent	100
Death loss, all ewes	percent	6
Replacement age of ewes	years	7
Ewes per ram	no.	25
Pigs raised per litter	no.	7
Sows per boar	no.	20
Weight of steers sold (fat)	lbs.	1050
Weight of steers sold (feeders)	lbs.	700
Weight of beef cows sold	lbs.	1100
Weight of ewes sold	lbs.	120
Weight of lambs sold (fat)	lbs.	100
Weight of lambs sold (feeders)	lbs.	80
Wool sold per ewe and ram	lbs.	9
Weight of pigs sold	lbs.	230
Weight of sows sold	lbs.	350

Source: Economics Department, South Dakota State College, Brookings, South Dakota.

Table 25. Summary of Per Acre Labor Requirements and Seasonal Distribution for Dryland and Irrigated Crops

Crop and operation	Hours per acre man	Percent monthly distribution of labor							
		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Dryland									
Corn grain	2.2	12	32	19	8	0	0	15	14
Corn silage	6.6	4	11	6	3	0	76	0	0
Small grain	1.4	42	0	0	29	29	0	0	0
Alfalfa hay	1.8	0	0	50	50	0	0	0	0
Alfalfa pasture	0	0	0	0	0	0	0	0	0
Irrigated									
Corn grain	6.7	19	9	22	26	12	0	7	5
Corn silage	10.7	8	6	14	16	7	47	2	0
Small grain	3.0	63	0	22	16	0	0	0	0
Alfalfa hay	10.8	0	3	31	31	31	0	4	0
Alfalfa pasture	1.0	0	0	0	0	50	50	0	0
Potatoes	17.6	5	42	14	16	12	3	9	0
Sugar beets	18.2	9	5	9	12	12	6	48	0

Source: Economics Department, South Dakota State College, Brookings, South Dakota.

Table 26. Estimated Average Annual Labor Requirements and Seasonal Distribution for Livestock as Used in Linear Programming Analysis, Sully County

Enterprise	Number	Working hours per head	Monthly requirements	Percentage monthly distribution											
				Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Beef cows	60-79	10		16	14	14	14	5	2	1	2	3	4	10	15
Feeder, Cattle	120-139		.4												
Hogs	10-19	20		8	7	9	11	9	8	8	8	8	8	8	8
Sheep, Farm flock	75-100	2		13	12	15	13	6	3	2	4	4	7	9	12
Feeder Lambs	Less than 100		.4												

Source: Animal Science Department, South Dakota State College, Brookings, South Dakota.

Table 27. Activity Budgets for the Crop Enterprises Used in the Linear Programming Model

	Amounts Per Acre						
Item	Dryland corn silage	Irrigated corn silage	Dryland barley	Irrigated barley	Dryland oats	Irrigated oats	Dryland wheat
Tractor costs	$ 4.18	$ 5.45	$ 1.16	$ 2.09	$ 1.16	$ 2.09	$ 1.16
Repairs	.88	1.14	.31	.56	.31	.56	.31
Seed	1.77	2.37	2.00	2.00	1.40	1.40	3.00
Fertilizer	3.18	16.55	3.18	10.80	3.18	10.80	3.18
Water (O & M)		5.00		5.00		5.00	
Capital	10.01	30.51	6.65	20.45	6.05	19.85	7.65
Interest	.60	1.83	.40	1.23	.36	1.19	.46
Total	10.61	32.24	7.05	21.68	6.41	21.04	8.11
Yield	5 ton	13.5	20 bu.	60 bu.	30 bu.	80 bu.	14 bu.
Price			.80	.80	.60	.60	1.80
Returns			16.00	48.00	18.00	48.00	25.20
Net returns	-10.61	-32.24	8.95	26.32	11.59	26.96	17.09

Table 27. (continued)

	Amounts Per Acre						
Item	Irrigated wheat	Dryland alfalfa hay	Irrigated alfalfa hay	Dryland alfalfa pasture	Irrigated alfalfa pasture	Irrigated potatoes	Irrigated sugar beets
Tractor costs	$ 2.09	$ 2.90	$ 7.08			$ 7.89	$ 7.08
Repairs	.56	.55	1.35			1.50	1.35
Seed	3.00	5.70	5.70	$ 5.70	$ 5.70	42.00	3.20
Fertilizer	10.80					3.82	3.82
Water (O & M)	5.00		5.00		5.00	5.00	5.00
Capital	21.45	9.15	19.13	5.70	10.70	60.21	20.45
Interest	1.29	.55	1.15	.34	.64	3.61	1.23
Total	22.74	9.70	20.28	6.04	11.34	63.82	21.68
Yield	40 bu.	1.2 ton	4.5 ton	1.8 AUM	7.9 AUM	400 bu.	17 ton
Price	1.80	18.00	18.00			1.10	12.00
Returns	72.00	21.60	81.00	—	—	440.00	204.00
Net returns	49.26	11.90	60.72	-6.04	-11.34	376.18	182.32

Table 28. **Activity Budgets for the Livestock Enterprises Used in the Linear Programming Model**

	Amount Per Head								
Item	Beef cow	Feeder steers	Feeder steers	Feeder calves	Feeder calves	Spring swine	Fall swine	Sheep flock	Feeder lambs
Purchased	$232.00	$101.60	$101.60	$101.60	$101.60	$ 45.00	$ 45.00	$ 11.20	$ 14.18
Supplement and salt	32.83	6.59	22.31	5.68	12.91	48.33	48.33		5.23
Capital	264.83	108.19	123.91	107.28	114.51	93.33	93.33	11.20	19.41
Interest	15.89	6.49	8.03	6.15	6.87	5.60	5.60	.67	1.16
Total	48.72	114.68	131.94	113.43	121.38	98.93	98.93	11.87	20.57
Return	92.74	189.00	189.00	175.00	175.00	334.25	334.25	27.82	22.26
Net return	76.85	74.32	57.06	61.57	53.62	235.32	235.32	15.95	1.69