A preliminary analysis of factors affecting crop yields on irrigated land with special reference to Greenfields Division, Sun River Project
by John C Bower

A THESIS Submitted to the Graduate Committee in Partial Fulfillment of the Requirements For the Degree of Master of Science in Agricultural Economics
Montana State University

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A PRELIMINARY ANALYSIS OF FACTORS AFFECTING CROP YIELDS ON IRRIGATED LAND WITH SPECIAL REFERENCE TO GREENFIELDS DIVISION, SUN RIVER PROJECT

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Chairman, Examining Committee

Chairman, Graduate Committee

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

A PRELIMINARY ANALYSIS OF FACTORS AFFECTING CROP YIELDS ON IRRIGATED LAND WITH SPECIAL REFERENCE TO GREENFIELDS DIVISION, SUN RIVER PROJECT

ABSTRACT

The object of this study was to analyze factors affecting crop yields on the Greenfields division of Sun River Irrigation project. The development of a feasible method was a primary problem in the analysis. The scope and detail of the study was limited by the quantity of data available. Water duty in the area has been low and varied with precipitation, however, use has continued to increase the past three years. Farm units operated by their owners received 18 per cent more irrigation water in 1936 than units being rented. Ten per cent more water was applied to class 2 than class 1 land in 1936. Crop yields in the area have been relatively low for irrigated land, but production on farm units operated by the owner was 10 per cent greater than on rented units in 1936. Crop yields averaged about 11 per cent higher in 1936 on class 1 than on class 2 land. Crop yields were found to vary with quantity of water used and time of use.

INTRODUCTION

Irrigation in Montana

Montana has 1,594,912 acres or 8.2 per cent of the nation's irrigated land. This accounted for 15 per cent of the crop land of the state in 1934. Of all the farms and ranches of the state, 27 per cent were partly or entirely irrigated in 1934. Thirty-three per cent of the state's farm population are on irrigated farms. The property held and operated by them accounts for 36 per cent of the value of all farm land and buildings in Montana. That there is some good dry land in the state which produces satisfactory crop yields each year must not be overlooked, however, since much of the dry land cannot be depended upon as a source of production and income year in and year out, the irrigated areas of the state are generally considered the stable element of Montana's agriculture. For this reason, due consideration should be given to the development of the latter lands as an aid to the livestock industry and the agricultural income of the state.

Objectives of and Reasons for the Present Analysis

Low Yields and Variations.—On the basis of four crops (alfalfa hay, wheat, oats, and barley) grown on all projects in Montana, the Greenfields division of the Sun River Irrigation project ranks very low in yield per acre, as shown in figure 1. The relatively low production on the division has a vital effect on the social and economic welfare of the area and adjacent territory and is important from the point of view of the Recla-

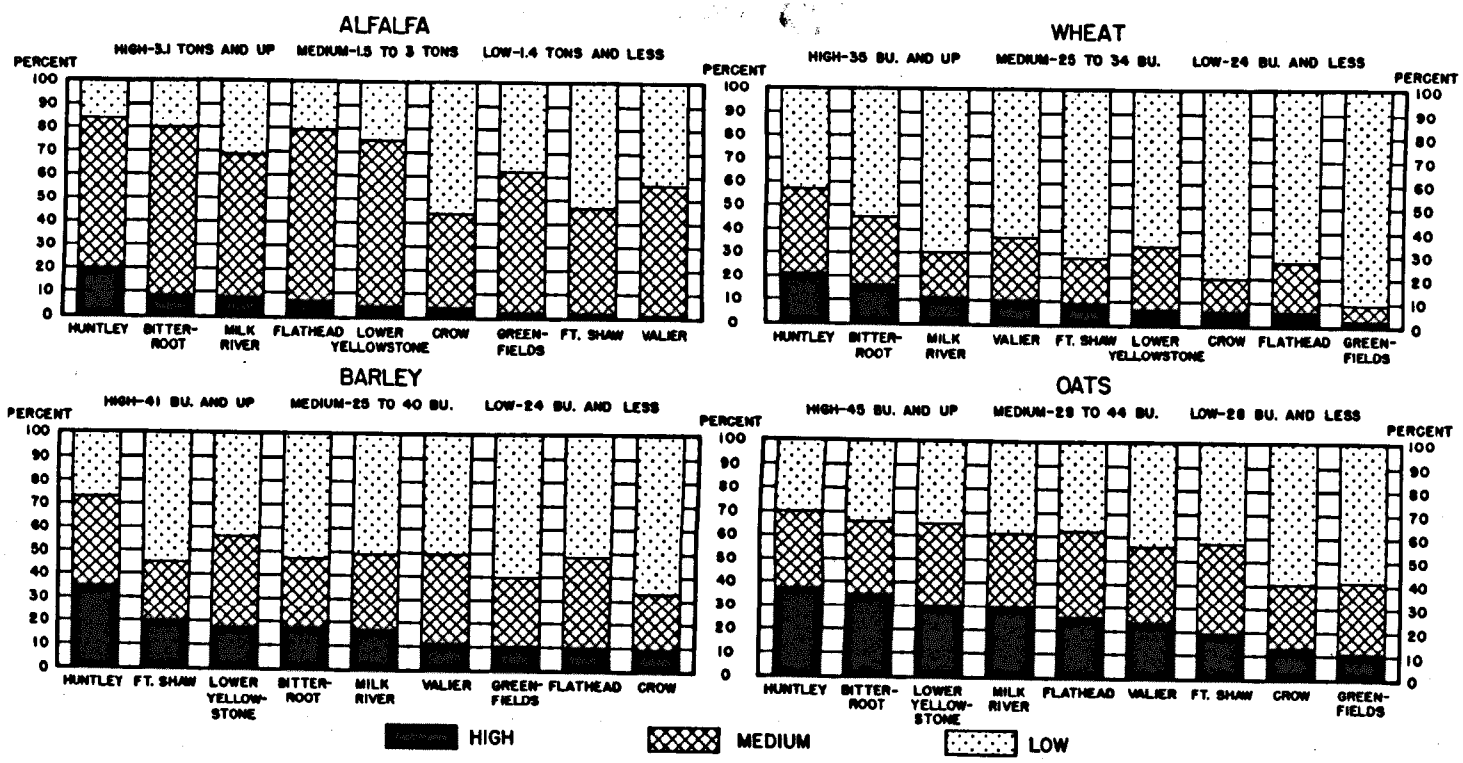

FIGURE 1.--PER CENT OF FARMS RECEIVING HIGH, LOW, AND MEDIUM YIELDS

Montana Irrigation Projects

1932-1935 Average

mation Bureau since construction charges amount to about $100 per acre(1935). The wide variation or range in yields between "farm units" indicates the possibility of getting higher production on the division. The two factors--low average production and extreme variation--raise the question of causation and possible remedies. A "farm unit" as used in this study means an area of land reported on a farm census card, most of which are either 80 or 160 acres, and "a farm" is used to mean an area of land organized as an operating unit and may consist of one or more "farm units".

Low Water Use and Varying with Precipitation.--Throughout the period for which irrigation water has been available for the Greenfields division, the philosophy (of the dry-land farmer) if it rains, we will get a crop without irrigation, has prevailed up to recent years. This has resulted in a wide variation in the per cent of the irrigable area being irrigated from year to year (figure 2 and appendix J) but this is not entirely responsible for low yield, as the water supply previous to 1929 was not adequate to meet the demand. 1/ In addition, the average acre feet of water used per acre, throughout the entire 18 year period during which water has been available, has been lower than on other projects of the state and nation. 2/ Generally speaking, there has been a tendency for the per cent of irrigable acreage irrigated and the duty per irrigated acre to vary inversely with precipitation on other new projects in Montana

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1/ Slagsvold, P. L. An Analysis of the Present Status of Agriculture on the Sun River Irrigation Project, Mont. Agri. Exp. Sta. Bul. 321, pp. 14 and 33.

2/ Teele, Ray P. The Economics of Land Reclamation in the United States. A. W. Shaw Co. N. Y. 1927. p.191, and unpublished data in the files of Mont. Agri. Exp. Sta.

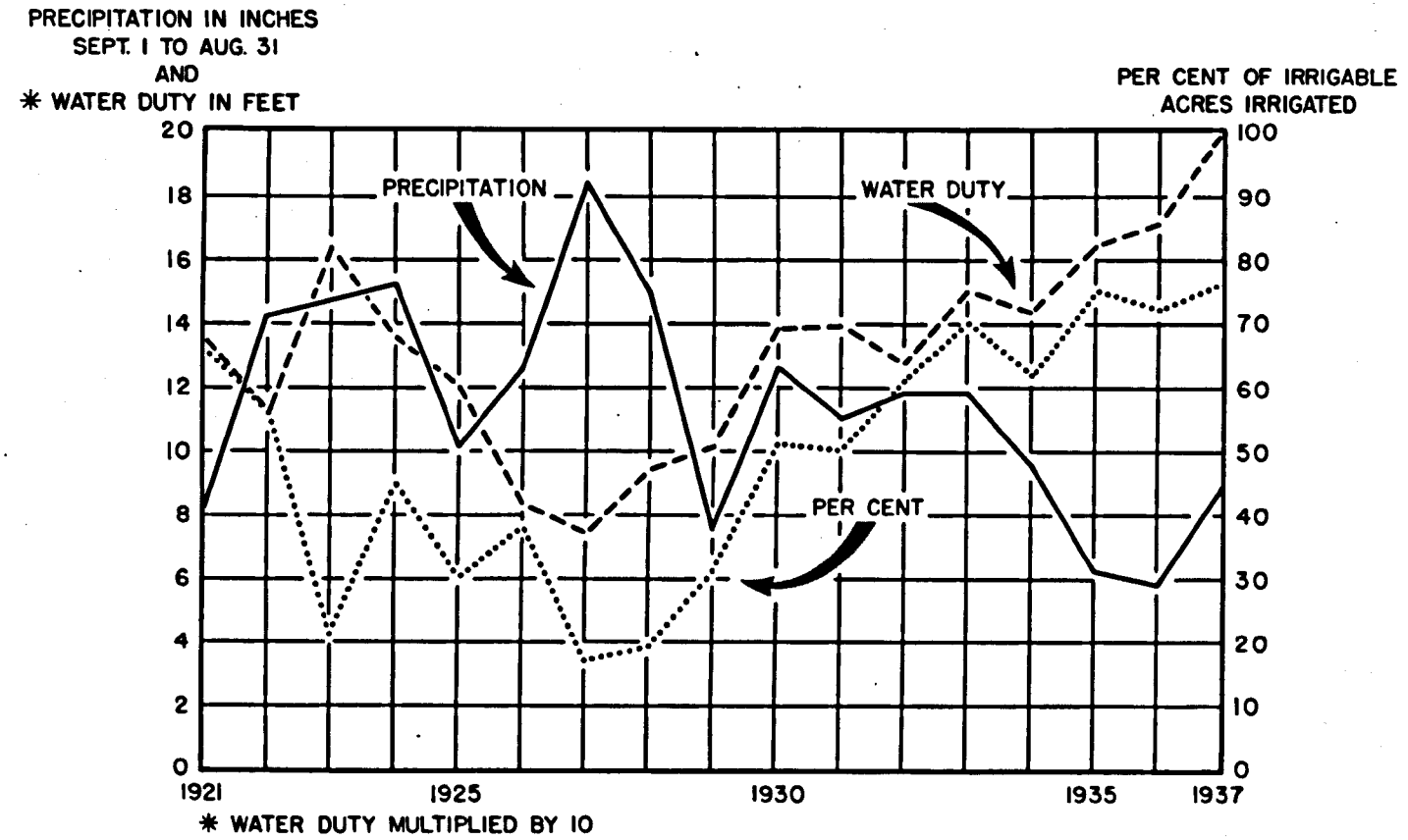

FIGURE 2.—PRECIPITATION, WATER DUTY, AND IRRIGABLE ACRES IRRIGATED

Greenfields Division, Sun River Project

1921 to 1937

as well as on the Greenfields division of the Sun River project.

Low Income.--The average gross income for the four year period 1932-1935 on this division was the third lowest of the projects of the state, which ranged from $7 to $31 per farm acre. Since the construction costs of the irrigation facilities for a project do not vary directly with income per acre, the problem of increasing the returns is a vital problem facing the residents of this division as well as the Reclamation Bureau. A low income per acre consequently infers a low income for the project which is also very significant. 3/

Objectives and Purpose.--Inasmuch as the gross income of the division is dependent upon production, and the income is relatively low, the object of the present study was to analyze the available data to determine the various factors affecting yields and to determine their relation to it. Such a study might develop information which may suggest improved management practices, more intelligent use of water, and more equitable distribution of the repayment burden on the basis of the natural productive ability of the soil. Since little or no work along this line has been undertaken previously, a major problem was to determine methods of approach and to discover what additional basic data might be needed.

Description of Area Studied

Location.--The Sun River project, developed by the United States Reclamation Bureau, is located in Teton and Cascade counties, about 30 miles north and west of Great Falls (figure 3). The project is in two

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3/ Slagsvold, P. L. and Mathews, J. D. Some Economic and Social Aspects of Irrigation in Montana. Mont. Agri. Exp. Sta. Bul. 354, 1938.

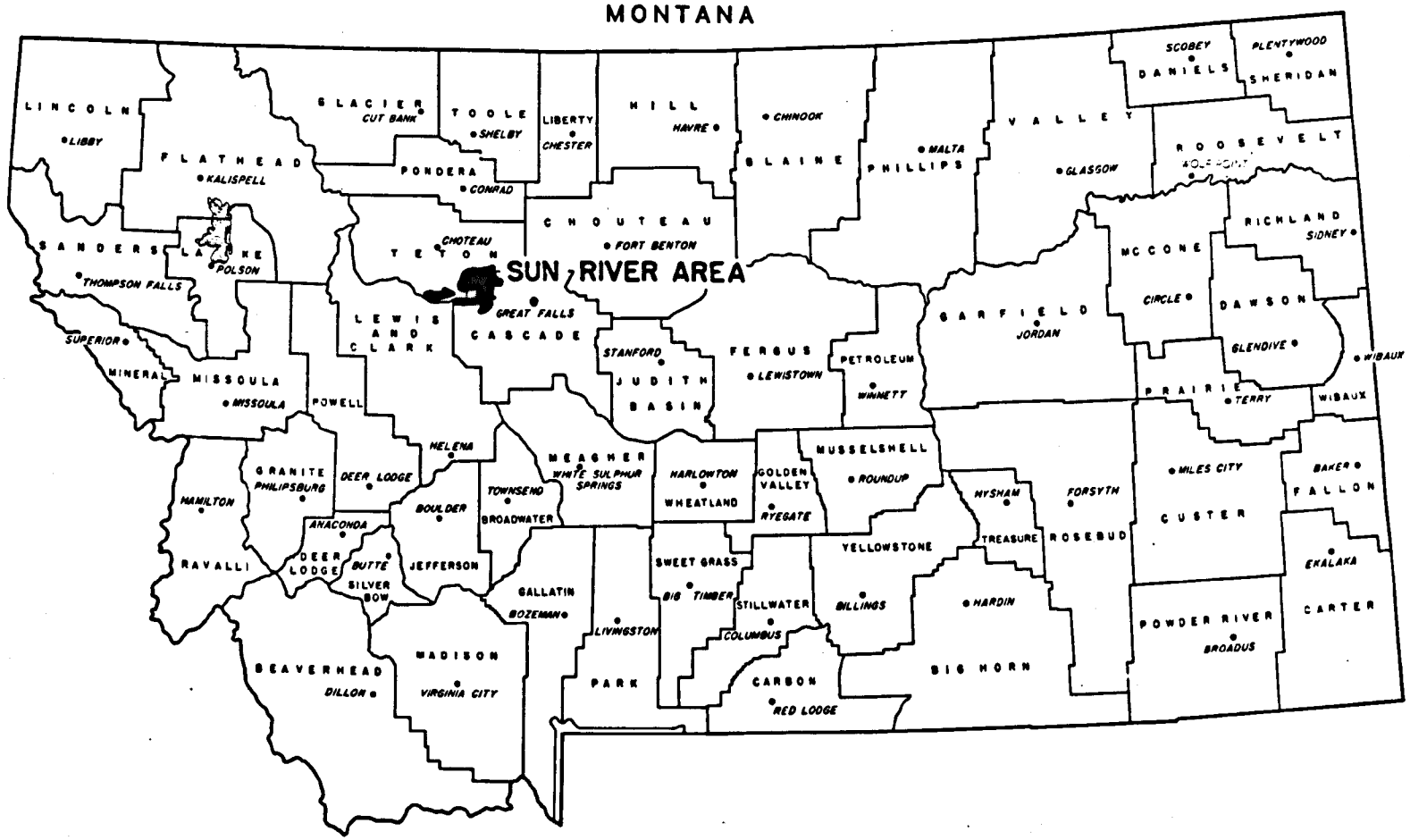

FIGURE 3.—LOCATION OF THE SUN RIVER IRRIGATION PROJECT

main divisions, namely, Fort Shaw and Greenfields.

The Greenfields division was chosen for this analysis from the nine major projects of the state because more basic data, such as classification of land, were available for it. The relative slowness of development and low average yields with extreme variation, were additional reasons for selecting this area for study.

This division, a somewhat rectangular shaped plateau with three benches, is quite uniquely elevated some 200 feet above the surrounding valleys. 4/ The Fort Shaw division lies along the river some 200 to 400 feet lower than the Greenfields division.

Development.—The Fort Shaw division is the older of the two areas, having been developed in 1908. The Greenfields division was investigated by the Reclamation Bureau in 1903, but recommendations for its development were not made until 1910. Some construction was begun in 1913, but the relatively wet years which followed resulted in exceptionally high crop yields and a restriction of irrigation activities. Dry years and high prices for agricultural products during the war years revived the interest in irrigation, and water was made available to 25,000 acres in 1920 and additional construction has taken place from time to time until 55,273 acres were irrigable by 1936.

Originally the Greenfields plateau was a part of the Montana cattle range, but beginning in 1902 it was settled by dry-land farmers. In spite of the increasing availability of water, the division is relatively young

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4/ For a diagramatic view, see Irrigation in a Dry-Farming Region. Reprint from Geographical Review, Oct. 1934, pp. 596-604.

and there is a marked tendency for the previously established dry-farming practices to defer the "coming of age" of the division as an irrigated area.

Growing Season.--With an average elevation of 3,800 feet and a maximum of 4,000 feet, the area is one of the highest of the major irrigated projects of the state. The average number of "heat units" 5/ and the precipitation are relatively low in comparison with other irrigation projects in Montana.

These three factors--elevation, heat units, and precipitation--are responsible for the short growing season, which averages about 120 days.

Crops Grown.--Because of the relatively high altitude, the short growing season, and the newness of the division, the variety of crops grown is not as great as on many of the projects in the state, some of which are more fully developed and are favored with better natural growing conditions for many northern irrigated crops. The small grains, namely, wheat, oats, and barley, occupied 47 per cent of the cropped acres of the division in 1936, with hay (primarily alfalfa), peas, and pasture accounting for an additional 49.6 per cent (table I). Potatoes, mustard, gardens, sugar beets, corn, etc., made up the remaining 3.4 per cent. The 1932-1935 four year average of soil depleting 6/ crops was 68 per cent of the total

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5/ The heat units was calculated with 43° F. as the base. If the mean temperature for a given month is 53°F., the number of heat units is (53 - 43) x 30 or 300. A more accurate measure would be to use as the base the temperature at which plant growth starts. Such a base, however, would vary according to soil, altitude, and so on, so that a comparison of different areas would be difficult. This method of measuring temperature was used by P. L. Slagsvold in "An Analysis of the Present Status of Agriculture on the Sun River Irrigation Project". Mont. Agri. Exp. Sta. Bul. 321.

6/ Classification of soil building and soil depleting crops is according to the United States Conservation Program.

TABLE I.--LAND USE

Greenfields Division, Sun River Project

1936

	Acres	Per Cent
Total Cropped	45,590	100
Wheat	17,930	39.3
Alfalfa Hay	8,334	18.3
Peas	7,166	15.7
Natural pasture	5,201	11.4
Oats	2,060	4.5
Barley	1,451	3.2
Other hay	1,313	2.9
Clover pasture	572	1.3
Miscellaneous	1,563	3.4

cropped acres of the division (table II). This is 16 per cent higher than the average of all projects of the state for the same period.

Livestock.—Table III shows the number of irrigated acres per animal unit to be high relative to other irrigated projects of the state. Considering the low ratio of feed crops to cash crops, such as wheat and peas, on the division, one would expect to find a correspondingly high ratio between irrigated acres and animal units. Dairy cattle, beef cattle, and sheep are the important productive livestock on the division in the order named. Hogs and poultry are kept in small numbers only.

Size of Farms and Trends.—The irrigable area per farm averaged 192 acres for the four year period 1932-1935. 7/ This is the third largest of all projects and indicates an extensive type of farming. Beginning in 1935, the Resettlement Administration purchased some of the larger blocks of land and divided them into farms averaging about 120 acres in size. One hundred twenty-five such units were established by December 1937. About 9,000 additional acres were developed for irrigation during this three year period, but the net effect was a decrease in the average size of farm. As the project becomes more fully developed, a further decrease in size may be expected.

Soil.—The soil of the division varies from gravelly to clay loams which are underlaid with varying amounts of gravel. The land classes,

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7/ Unpublished data in files of Mont. Agri. Exp. Sta.

TABLE II.--SOIL CONSERVING AND SOIL DEPLETING ACRES

In Per Cent of Total Cropped Acres
Montana Irrigation Projects
1932-1935 Average

Project	Per cent Soil Conserving	Per cent Soil Deplet.	Per cent Neutral	Total
Average - all projects	46.1	52.5	1.4	100
Valier	17	83	-	100
Lower Yellowstone	30	70	-	100
Sun River-Greenfields	32	68	-	100
Huntley	36	64	-	100
Crow	56	44	-	100
Milk River	61	39	-	100
Bitterroot	50	38	12	100
Sun River-Fort Shaw	66	34	-	100
Flathead	67	32	1	100

TABLE III.--IRRIGATED ACRES PER ANIMAL UNIT

Montana Irrigation Projects
1932-1935 Average

Project	Irrigated acres per animal unit
Average of all projects	2.5
Valier	4.9
Sun River-Greenfields	3.5
Crow	2.8
Sun River-Fort Shaw	2.2
Huntley	2.1
Bitterroot	1.8
Milk River	1.8
Flathead	1.6
Lower Yellowstone	1.4

which serve as a major basis for the present study, are based on the productivity and ease of handling of the soil and the topography for irrigation. 8/ The classification was made by the Reclamation Bureau in 1927 to serve as a guide in future developments and as a basis for water charges. Since it was based on existing soil characteristics and topographical features, together with any apparent drainage or tillage problems, the classification may be subject to change with changes in economic problems and further development of seepage.

Land class 1 contains the lands on the project which appeared to have equal value from the standpoint of productivity, ease of irrigation, topography and freedom from apparent tillage or serious drainage problems. Class 2 lands are somewhat inferior to class 1 because of adverse topography which may make irrigation and tillage more difficult and expensive. Class 2 lands may also be less productive than class 1. Since land classes 1 and 2 comprise nearly 89 per cent (figure 4) of the area in the division, farm units on any one of the three land classes of lower productivity were insufficient in number for this analysis and have not been considered. 9/

Source of Data and Their Adequacy

The major portion of the data used in this analysis was obtained from the Reclamation office at Fairfield which is the headquarters for the Sun River project. The data on crops grown, acreages, yields, and water

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8/ DeYoung, William, Soil Survey of the Sun River Irrigation Project, Mont. Agri. Exp. Sta. Bul. 207.

9/ Appendix C.

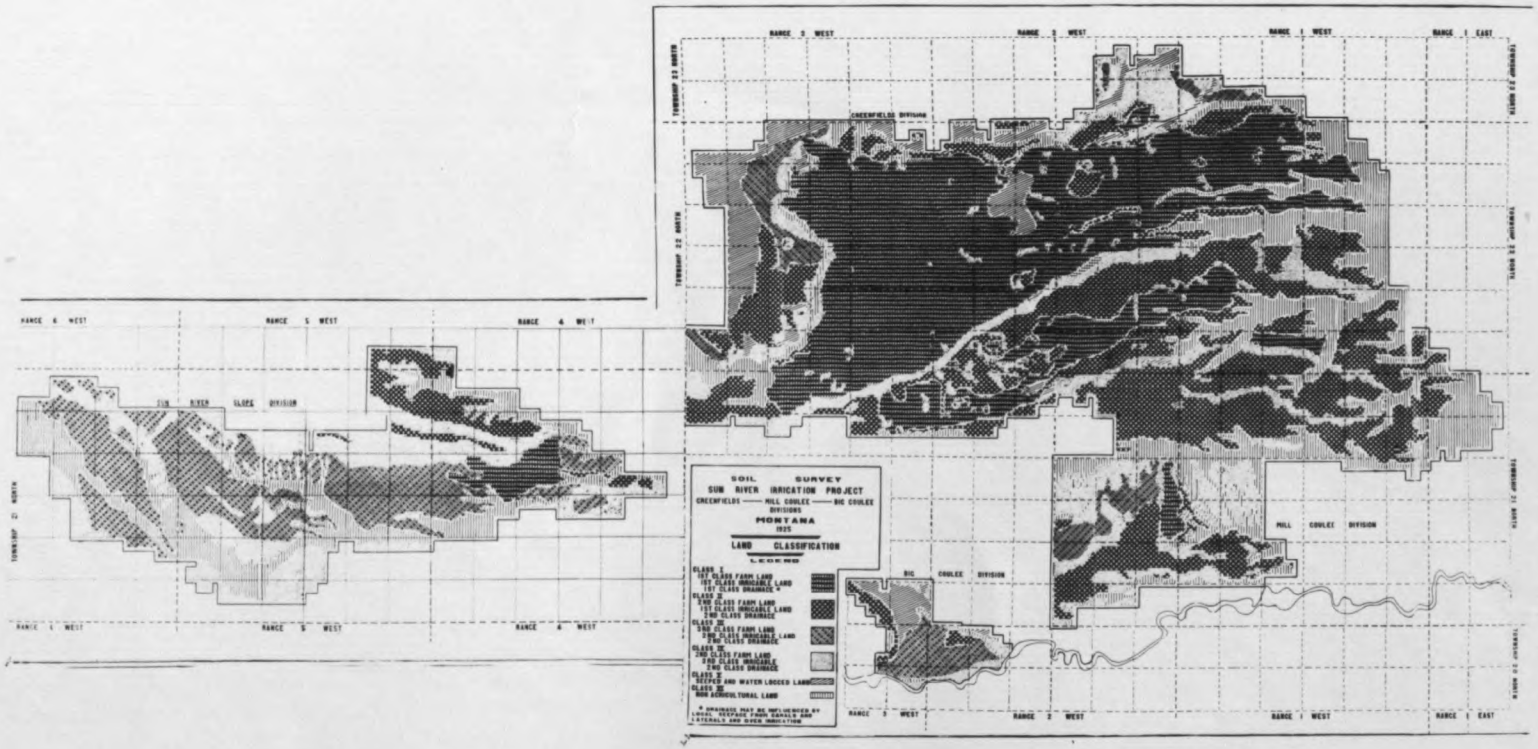

FIGURE 4.--LAND CLASSIFICATION MAP

Greenfields Division, Sun River Project

duty and use by farm units is available from the project office, as well as much other general information which is included in the annual report of the project manager. Climatological data were taken from the United States Weather Bureau publications. Soil and topographical data were taken from a recent survey of the project. 10/ Much of the data are taken in the form of a census, and may therefore be subject to some human error.

Many phases of the present analysis have been limited because of insufficient detail in available data. This is particularly true in regard to water use, farm organization, and farm management data. To make a satisfactory study of the relations of water duty and use, data should be available by time, frequency, and quantity used for each crop and field within the farm units. In order to analyze the relationship of rotation, tillage, and other farm practices, information in more detail than is now available will be required. A more complete census of farms in the division is recommended to fulfill this need. Some sample studies with farms keeping accounts on cost of operation and irrigation practices would be very desirable. The fact that the project is relatively new and is still developing will result in some change in organization and type of farming for several years to come.

Method of Analysis

For most purposes, the crop and acreage data by farm units were used in making the present analysis. The average yields and frequency of yields were correlated with water duty and use, land classification, tenure

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10/ DeYoung, William, op cit.

of operator, and land use. In a few instances, data by farms were used to advantage but this proved generally unsatisfactory for the entire analysis because it was impossible to get a sufficient number of cases in which all the acreage of a farm was composed of the same class of land. The water duty data also are reported by farm units and could not be as readily and completely analyzed if the units had been combined into farms.

The climatic data were analyzed by months for each of the 17 years for which data were available, to determine their relation to crop yields and water duty. The land class map of the soil survey of the project was used in classifying the farm units according to the class of land on which they were located.

RELATION OF YIELD, LAND CLASS, AND TYPE OF TENURE

Yield Analysis

Except to determine the relationship of yield on the owned land separate from that on the rented portion of the owner-renter farms, 11/ the farm unit was used in the yield analysis. The yields of each crop were analyzed by the weighted average method and the frequency of occurrence, to show the range as well as averages. In addition to this, each farm unit was given an aggrevative productivity rating based on the average project yield of each crop as being equal to 100 and weighted by the acreage of each crop on the unit. 12/

11/ Farms which are part owned and part rented.

12/ Example: An 80 acre farm unit with 65 acres of wheat producing 14 bu. per acre and 15 acres of alfalfa hay producing 1.5 tons per acre. The project average yield for wheat is 10.6 bu. and 1.7 tons for alfalfa hay. Continued.

The extreme range in wheat yields per acre (by per cent of farm units) according to type of tenure on land class 1 is shown in figure 5. The three units making up the 4.4 per cent of the owned units in the 32.1 to 36 bushel class received between three and four times the average yield of 11.8 bushels per acre for all the class 1 land. About 8 per cent of all units and between 7 and 8 per cent of the units of each type of tenure received yields of over 20 bushels per acre. About 24 per cent of all units in land class 1 received 8 bushels per acre or less. The same wide variation in yields between farm units existing for all other crops grown on the division. From all indications, it is possible to increase the average yields of crops on the division and it is one purpose of this study to determine how this may be accomplished.

Relation of Yield and Land Class

According to the soil survey, land classes 1 and 2 were quite similar in apparent inherent productive ability, but the topography of class 2 land is more uneven, making leveling, irrigating, and tilling more difficult and hence probably more costly. The soil profile of some of the class 2 lands contains hardpan or cemented layers which restrict drainage and root growth. It was believed that over a period of years

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12/ continued.

Method:

Wheat 14 bu. + 10.6 bu. = rating of 1.32 x 65 acres = 85.8
Alfalfa hay 1.5 ton + 1.7 ton = rating of .88 x 15 acres = 13.2
85.8 + 13.2 = 99.
99 ÷ 80 acres = 1.2375 or productivity rating of 123.75 per cent of average for project.

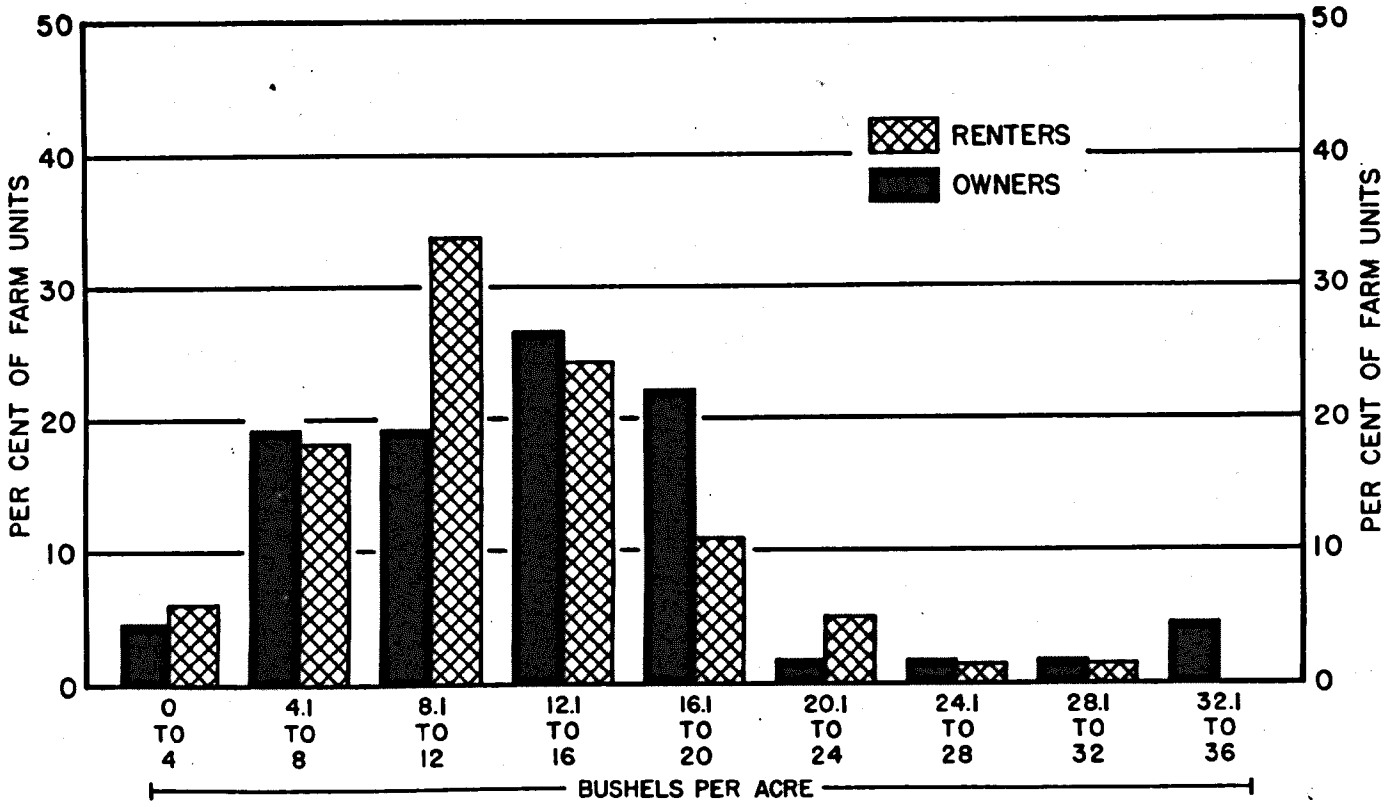

FIGURE 5.—WHEAT YIELDS BY TYPE OF TENURE

In Per Cent of Farm Units
Greenfields Division, Sun River Project
Land Class 1
1936

the water table would rise in these areas, thereby further decreasing their value relative to class 1 lands. 13/ The 150 miles of drains already indicates the accuracy of this prediction.

Since land classes 3, 4, and 5 account for a total of only 12.3 per cent of the agricultural land of the division and for the most part is scattered over it in strips (figure 4), only classes 1 and 2 were analyzed in this study. In making the analysis, only farm units located entirely within one class of land were used. Accordingly, the results are based on 170 units of class 1 and 76 units of class 2 land. The units within each of the two classes of land are divided almost equally by type of tenure, therefore, the influence of this factor should not affect the results. In analyzing land class relationships, average yields and frequency of occurrence have been used.

Productivity Ratings.--The distribution of farm units in each class of land according to productivity ratings is shown in figure 6. 14/ In general, there is a predominance of class 2 units in the lower productivity brackets with class 1 units in the majority in most of the higher productivity groups. About twice as many land class 2 as class 1 units are in the productivity groups below 75. More than three times as many class 1 as class 2 units are in the productivity groups above 175. This indicates higher average production on the land class 1 farm units than on those of class 2 land.

13/ DeYoung, op cit.

14/ Appendix D.

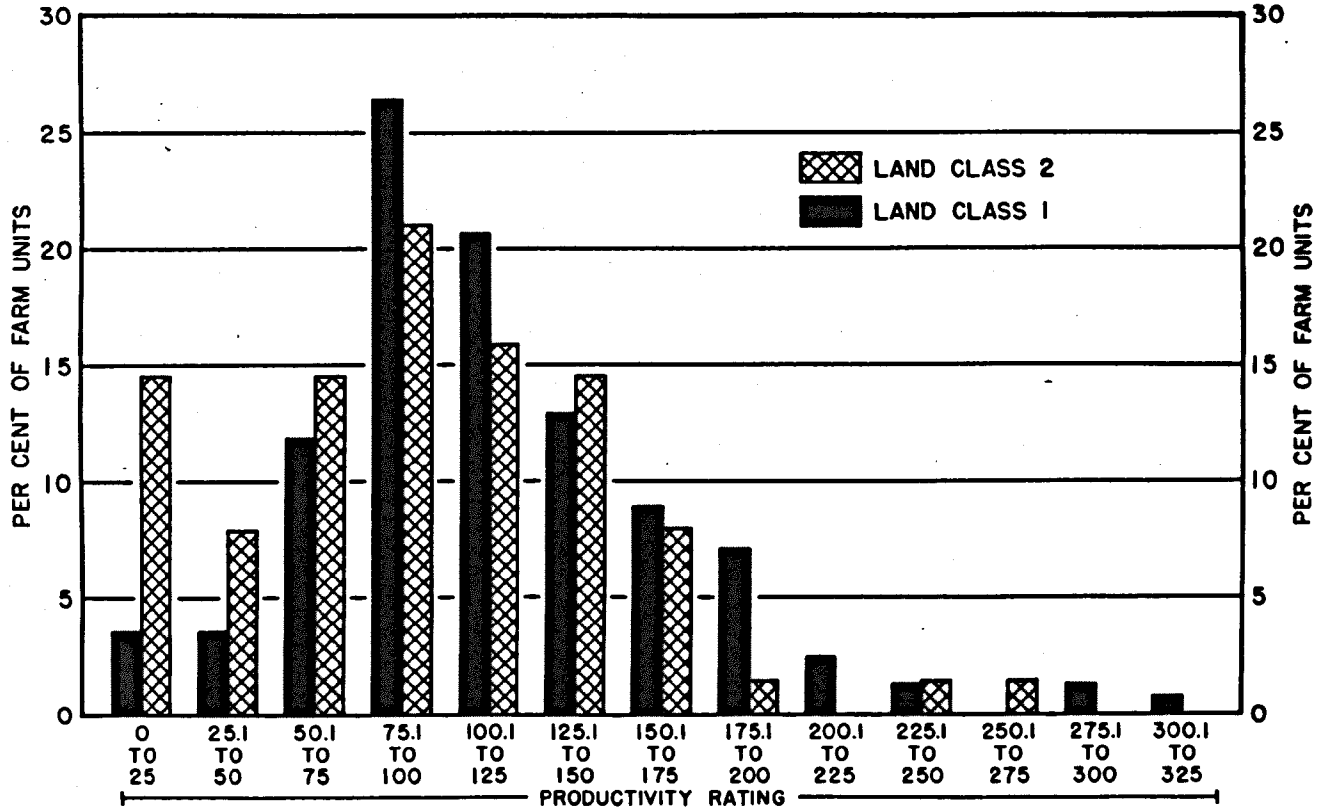

FIGURE 6.—PRODUCTIVITY RATING OF FARM UNITS

In Per Cent of Total Units in Each Land Class
Greenfields Division, Sun River Project
1936

Average Yields.—The variation in the 1936 average yields on land class 1 and 2 units is consistently in favor of class 1 units, but is greater for some crops than for others (figure 7). 15/ These differences are greatest by crops in the following order; barley, oats, peas, alfalfa hay, and wheat. Using the differences of the yields of each of the five crops weighted by their relative importance in acreage on the division for the year, the average production on class 1 land was 13.6 per cent greater than on class 2. Since oats and barley together made up less than 8 per cent of the cropped acres in 1936, and yields of these two crops varied widely between classes of land, the average difference was again calculated on the basis of the three major crops namely, wheat, alfalfa hay, and peas. This gave an average difference of 10.2 per cent in favor of class 1 land. Since the three latter crops accounted for over 73 per cent of the total cropped acres on the division and not one of the three crops for less than 15 per cent, the results may be considered as representative of the production for the year.

Relationship of Yield and Type of Tenure

The analysis of the relation of yield and type of tenure was made primarily on the basis of individual farm units within one class of land. Owned units are designated as those being operated by the owner, and rented units are those being rented. Owned units may be operated in conjunction with one or more rented units by one party or vice versa, but in this analysis each is treated separately on the basis of the type of tenure

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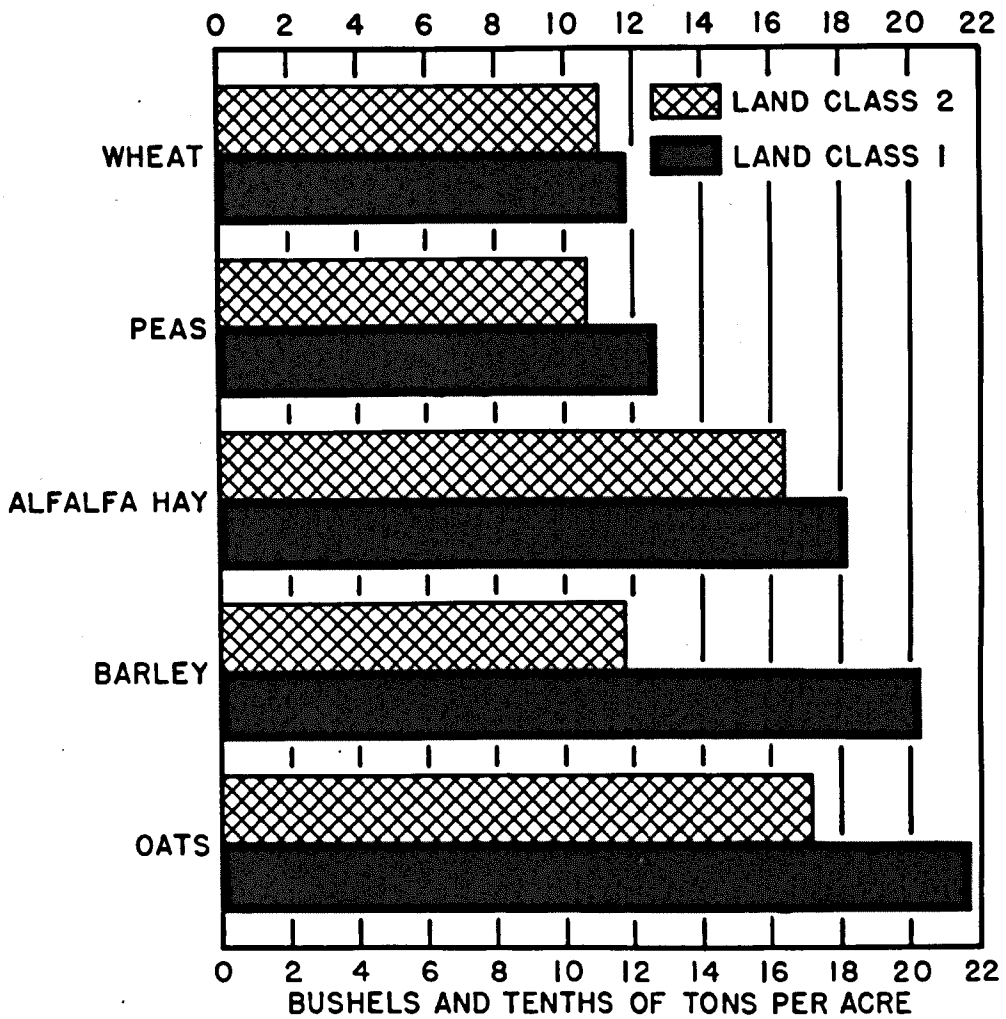
15/ Appendix E.



NOTE: GRAIN IN BUSHELS, HAY IN TENTHS OF TONS

FIGURE 7.--AVERAGE CROP YIELDS BY CLASS OF LAND

Greenfields Division, Sun River Project

1936

of the individual unit. Many of the farmers, however, operate all owned or all leased land.

In addition to this analysis, consideration was given to relationships on the owned separate from the rented units of fifteen owner-renter farms which will be discussed later.

Productivity Ratings.--Figure 8 shows land class 1 units classified according to their productivity ratings and type of tenure. 16/ The rented units predominate in the classes below 125 and the owned units are in the majority in the brackets of higher production with the exception of the last four brackets which are represented by five cases only. About 73 per cent of the class 1 rented units are in the productivity groups below 125 and only 58.6 per cent of the owned units are in these low brackets. About 41 per cent of the owned units are in the productivity classes of 125, or greater, and only 27.2 per cent of the rented units are in these groups. This indicates a higher average production on the owned than on the rented units of land class 1.

Average Yields.--The variations in average crop yields is not consistently in favor of one type of tenure on either class of land, as is shown in figure 9. 17/ The owners received higher yields of wheat and oats on the average on both classes of land than did the renters. The yield of peas for owners on land class 1 was higher than for renters, but

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16/ Appendix D.

17/ Appendix E.

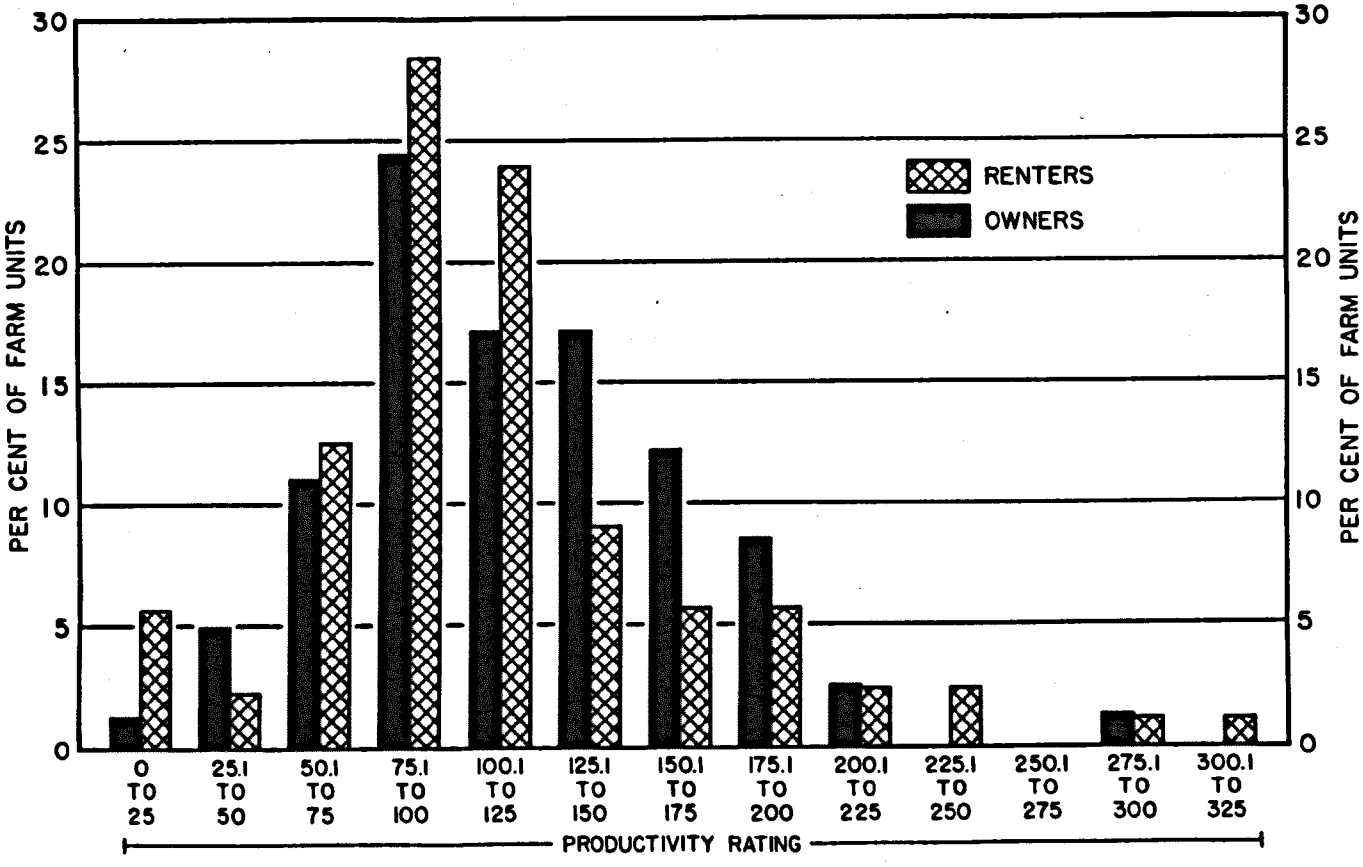

FIGURE 8.--PRODUCTIVITY RATINGS OF FARM UNITS BY TYPE OF TENURE

Greenfields Division, Sun River Project
Land Class 1
1936

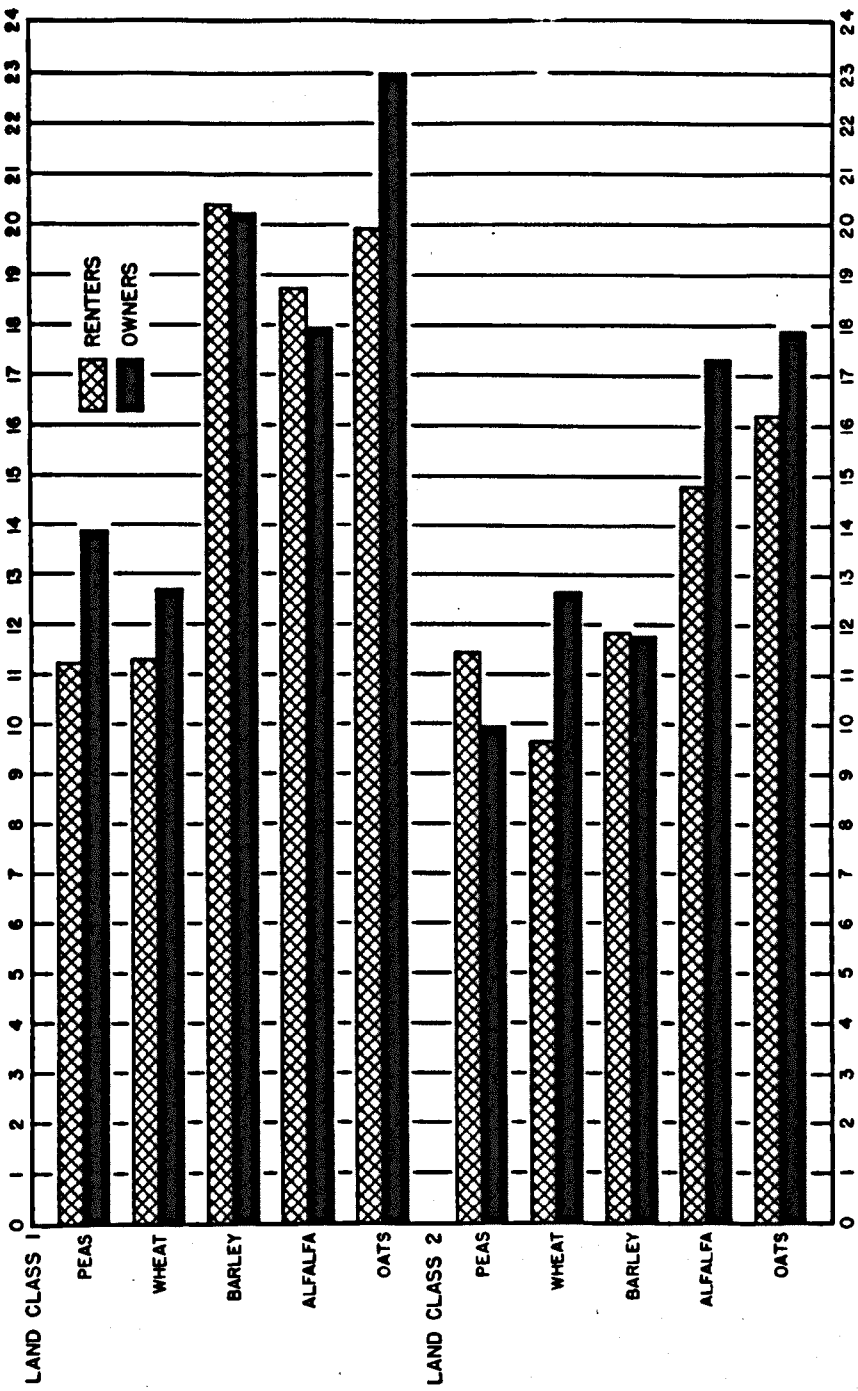

FIGURE 9.—AVERAGE CROP YIELDS BY TYPE OF TENURE AND CLASS OF LAND

Greenfields Division, Sun River Project

1936

was lower on land class 2. The yield of alfalfa hay for renters was higher on land class 1 than for owners, but was lower on land class 2. The yield of barley was about equal by type of tenure on each class of land.

Using the differences of yields between the two types of tenure for the three crops, wheat, alfalfa hay, and peas, weighted by the relative importance of each crop on the division in 1936, the average production on the owned units of land class 1 was 10.9 per cent greater than on rented units of the same land class. Similarly, the average production of owned units on land class 2 was 18.1 per cent greater than on rented units. Oats and barley were not included in these results because of the relatively small acreage represented by them.

Relation of Yield on Owned Units and Rented Units of Owner-Renter Farms.--To determine the relation of yield on rented separate from the owned units making up fifteen owner-renter farms on land class 1, the yields of the three crops, wheat, alfalfa hay, and peas, were used. The average yields of all three crops are consistently greater on the owned than on the rented units. The average yields of alfalfa hay and peas are considerably greater on the owned units, but the difference in the yield of wheat is not appreciably significant (table IV). Weighting the difference in yields as done above, production on the owned units of these owner-renter farms was 8.4 per cent greater than on the rented units. This is a 2.5 per cent smaller difference than occurred between all owned and rented units on class 1 lands and may be indicative of better farm management practices on the part of the owner-renter farmer on all lands

TABLE IV.--CROP YIELDS BY TYPE OF TENURE

Greenfields Division, Sun River Project

Land Class 1

1936

	Wheat	Peas	Alfalfa
Owner-Renter	13.7	13.7	1.8
Owned part	13.9	14.8	1.89
Rented part	13.6	11.7	1.68

operated by him.

Land Use Related to Land Class and Type of Tenure

The analysis of land use on the division was limited and is quite general in nature because of the lack of detail of the available data. Of the 45,590 cropped acres in the division in 1936, about 39 per cent was used for the production of wheat (table 1). This is twice as much as was devoted to any other one crop. About 20 per cent was used for alfalfa and sweet clover, indicating the low ratio of soil conserving to soil depleting crops. The remaining acreage was mostly used for small grains, grain hay, and miscellaneous crops.

In analyzing 252 farms irrespective of class of land, 40.5 per cent were found to have been diversified to the extent of growing all of the three major crops, wheat, alfalfa hay, and peas; 21 per cent produced wheat and alfalfa; and 17.5 per cent grew wheat and peas (table V). The remaining 21 per cent were primarily one-crop farms growing either wheat, peas, or alfalfa hay as a cash crop.

Land Use Related to Land Class.—The variation in the ratio of soil conserving to soil depleting acres between land classes 1 and 2 is not significant, each having approximately 20 per cent of the crop land in alfalfa and clover. Of the 22,193 acres used in the production of the major crops and analyzed by class of land, 18/ 10,365 acres or 46.7 per cent was used in the production of wheat, 22 per cent each for alfalfa hay and peas, and the balance for oats and barley. The use by class of

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18/ Wheat, alfalfa hay, peas, oats and barley.

TABLE V.—DIVERSITY OF FARMS BY TYPE OF TENURE

Greenfields Division, Sun River Project

1936

Type of Farm	Per Cent of Farms			
	All	Owners	Renters	Owner-Renter
Total	100	100	100	100
Wheat, peas, & alfalfa hay	40.5	36.1	44.8	44.4
Wheat & alfalfa hay	21.0	20.5	19.7	24.1
Wheat & peas	17.5	14.8	13.2	29.6
Wheat	11.9	17.2	11.8	-
Alfalfa hay	6.0	5.7	9.2	1.9
Others	3.1	5.7	1.3	-
Number of Farms	252	122	76	54

land varied considerably from these figures. Wheat accounts for 8 per cent more acreage on class 2 than on class 1 land and peas more than compensate for this difference (figure 10. 19/

Land Use Related to Type of Tenure.—Land use varied considerably by type of tenure, as indicated in table VI showing the acreages used by each crop in per cent of the total by land classes and tenure of operator. Of the class 1 land, 48.9 per cent of that owned was used in the production of wheat and feed grain crops in 1936. Of that rented, 62.3 per cent was used in the production of wheat and feed grains. This is the most significant variation in the use of land by type of tenure. To offset the increased acreage of grain crops grown on the rented units, peas and alfalfa hay were produced in greater proportions on the owned units.

The variation in land use by type of tenure within each class of land is more significant than indicated above, as is shown in figure 11. 20/ In each class of land there is a pronounced tendency for more wheat, an annual, and less alfalfa hay, a perennial, to be grown on the rented than on the owned units. On land class 1, a greater percentage of the acreage of owned than of rented land is devoted to pea production but on class 2 land this relationship is reversed.

19/ Appendix F.

20/ Appendix F.

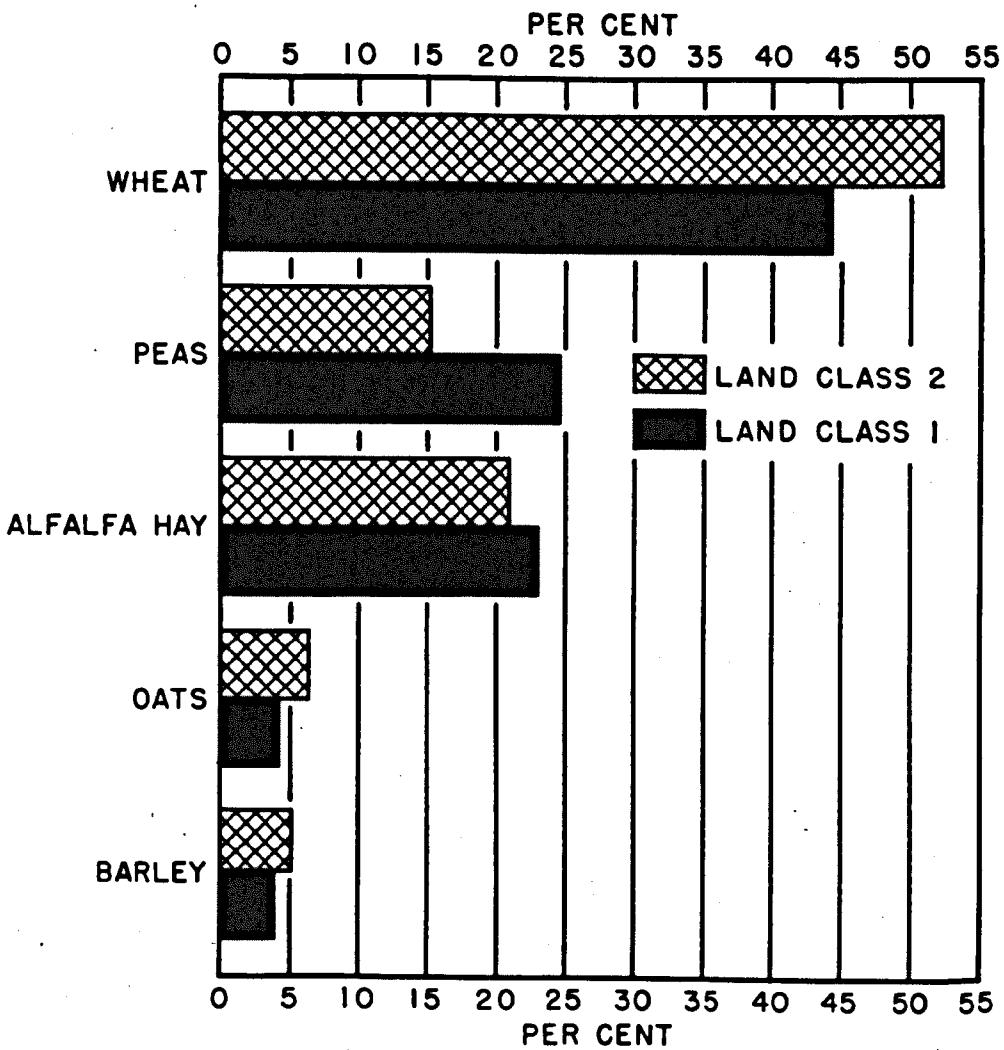

FIGURE 10.—LAND USE BY CLASS OF LAND

In Per Cent of Total Acreage of Major Harvested Crops
Greenfields Division, Sun River Project
1936

TABLE VI.--LAND USE BY LAND CLASS AND TYPE OF TENURE

Greenfields Division, Sun River Project

1936

	Both	Owner	Renter
	Per Cent	Per Cent	Per Cent
Land Classes 1 and 2			
Total	100	100	100
Wheat	46.7	38.1	54.8
Peas	21.9	24.6	19.3
Alfalfa hay	22.3	26.5	18.4
Oats	4.8	6.0	3.7
Barley	4.3	4.8	3.8
Land Class 1			
Total	100	100	100
Wheat	44.3	33.1	54.4
Peas	24.7	29.3	20.6
Alfalfa hay	22.9	27.1	19.1
Oats	4.2	5.4	3.0
Barley	3.9	5.1	2.9
Land Class 2			
Total	100	100	100
Wheat	52.3	48.7	56.0
Peas	15.2	14.4	16.1
Alfalfa hay	21.0	25.3	16.5
Oats	6.4	7.3	5.5
Barley	5.1	4.3	5.9

FIGURE 11.—LAND USE BY TYPE OF TENURE AND CLASS OF LAND

In Per Cent of Total Acres of Major Crops
Greenfields Division, Sun River Project
1936

RELATION OF WATER USE, LAND CLASS, TYPE OF TENURE, AND YIELDS

Water Use

Problems of Analysis.--Inasmuch as available annual water use records give information only of the month, quantity, and number of deliveries by farm units and not by separate crops and fields within the unit, a primary problem in attacking this factor of the analysis was the determination of method of approach.

From a sample of 33, 19, and 10 one-crop farm units growing only grain, alfalfa, and peas, respectively, it was found that the average water duty per acre by crops was as follows:

Alfalfa	2.54 acre feet per acre
Grain	1.18 " " " "
Peas	1.23 " " " "

From the above figures, 2.5 acre feet per acre for alfalfa and 1.2 for grain and peas combined was assumed to have been the average water used. On the basis of this ratio (1.2 to 2.5 or 1 to 2.08) of water used by the two types of crops (clover, alfalfa and miscellaneous crops at 2.5, and grain, grain hay, peas, and pasture at 1.2 acre feet per acre), an index of water duty, weighted by the acreage of each type of crop, was calculated for each farm unit. 21/

21/ Example: An 80 acre farm unit with 65 acres of wheat and 15 acres of alfalfa. The water duty for the unit is 150 acre feet.

Method:	Acres		Ratio of water use		Total	
Wheat	65	x	1.2	=	78.0	= 67.5% of 115.5
Alfalfa	15	x	2.5	=	37.5	= 32.5% of 115.5
					115.5	100%

(continued)

These base figures do not take into account variations in amount of water used by type of tenure and land class but have been used primarily to establish a ratio between the two types of crops and to serve as a base from which other comparisons might be made. 22/ To retain the water duty on a comparable basis, adjustments were made on farm units not growing alfalfa but receiving water in September.

Inadequacies of Analysis.—The inadequacies of the present method are fully realized and a satisfactory detailed water use analysis cannot be made until data by crops and fields within the farm unit are available, which will make possible a study of optimum water use by individual crops. A program for obtaining such data is under way and deserves the cooperation of every water user.

Water Duty by Land Class

From the methods used in determining land classes 1 and 2, one might safely assume that for equivalent production, more water would be necessary on class 2 than on class 1 land, because of its more uneven

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	Per cent		Tot. water duty		Water duty		Acres		Duty A. ft. per acre
Wheat	67.5	x	150	=	101.25	÷	65	=	1.56
Alfalfa	32.5	x	150	=	48.75	÷	15	=	3.25
Wheat	1.56	÷	1.2	=	130 per cent	)	Index of 130		
Alfalfa	3.25	÷	2.5	=	130 per cent	)			

22/ It is also possible that the water duty on these sample units growing only one crop is not representative of the average water used by crops on the division.

topography and the coarser soil texture. Figure 12 shows a tendency for land class 1 units to concentrate in the classes of lower water duty with the class 2 units predominating in the higher classes. 23/ Of the class 1 units, 71.2 per cent are in the water use classes of 100.1-125 or lower. Of the class 2 units, only 55.3 per cent are in these lower brackets. Proportionately, there are twice as many class 2 as class 1 units in the water use groups of 200 and over. These facts indicate that, on the average, heavier applications of water are made on class 2 than on class 1 lands. On the basis of average water duty per irrigated acre, (table VII) class 2 lands have received 10 per cent more water than class 1. 24/

Water Duty by Type of Tenure

For this phase of the analysis, the farm units were classified according to the indices of water used per acre. Figure 13 shows a tendency for less water to have been used on the rented units, on the average, than on the owned units. 25/ The rented units predominate in the classes of lowest water use and the owned units outweigh them in the brackets of highest use. It is interesting to note also that no owners on class 1 land used less than 50 per cent of average water duty, but

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23/ Appendix G.

24/ Weighted by the method illustrated in footnote 21. On the basis of duty weighted by acres regardless of type of crop, class 2 lands received only 9 per cent more than class 1. This difference may be accounted for by the lower ratio of alfalfa to grain on class 2 than on class 1 land.

25/ Appendix G.

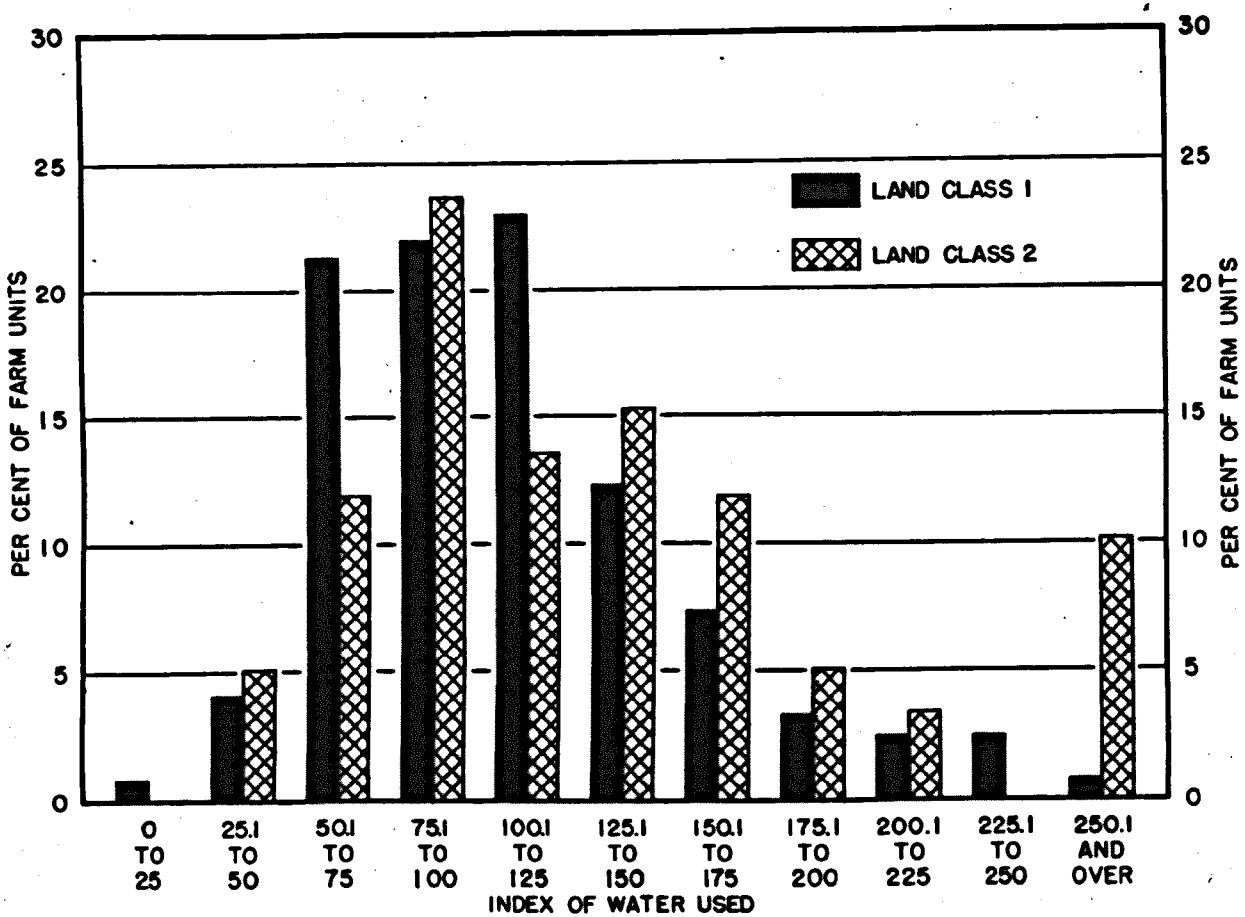

FIGURE 12.--INDICES OF WATER DUTY PER ACRE BY CLASS OF LAND

In Per Cent of Total Farm Units in Each Land Class
Greenfields Division, Sun River Project
1936

TABLE VII. AVERAGE WATER USED PER ACRE BY TYPE OF TENURE, CLASS OF LAND AND TYPE OF CROP

1936

	Acre Feet Per Acre		
	Both	Owner	Renter
Land classes 1 and 2			
Alfalfa 2/	2.78	2.99	2.55
Grain and peas	1.33	1.44	1.22
Land class 1			
Alfalfa 2/	2.69	2.90	2.49
Grain and peas	1.29	1.39	1.20
Land class 2			
Alfalfa 2/	2.95	3.16	2.68
Grain and peas	1.42	1.51	1.29
Water used in per cent of average 3/			
Land classes 1 and 2	111	120	102
Land class 1	108	116	100
Land class 2	118	126	107

1/ Weighted by acreage and type of crop at the ratio of 1 to 2.08 for grains and alfalfa, respectively.

2/ Includes alfalfa, clover, garden and tame pasture.

3/ Base of 1.2 and 2.5 acre feet for grain and alfalfa, respectively, was used. Results are the same for all crops because a constant ratio between crops is used.

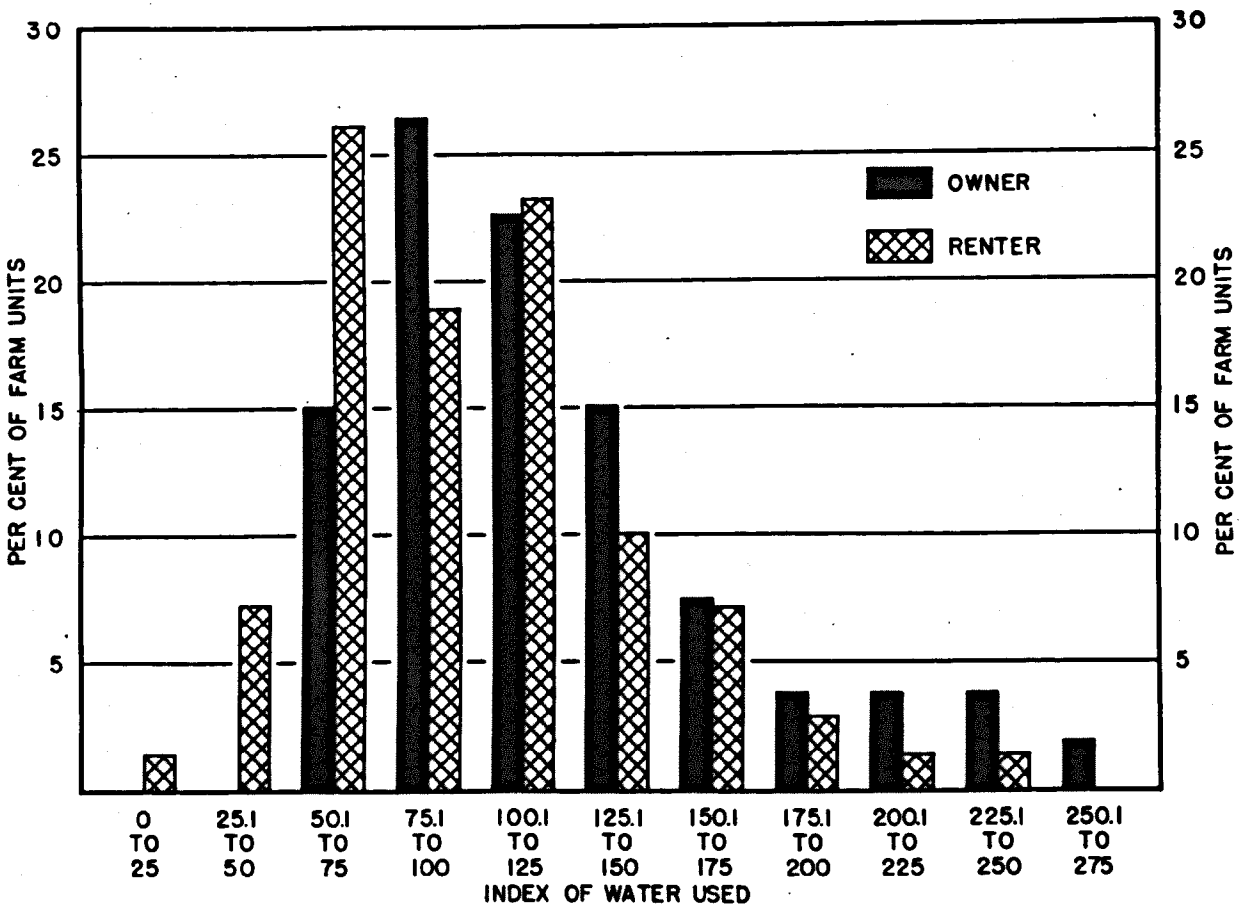

FIGURE 13.--INDICES OF WATER DUTY PER ACRE

In Per Cent of Total Farm Units by Type of Tenure
Land Class 1
Greenfields Division, Sun River Project
1936

8.6 per cent of the renters did and that proportionately more than twice as many owned as rented units are in the water use classes above 175. On the basis of the average water duty per acre, the class 1 owned units received 16 per cent more water than rented units of the same class. On land class 2 the owned units received 19 per cent more than was applied to the rented units. Since the acreage of class 1 land is almost twice that of class 2, the average increase in water duty is 17 per cent in favor of the owned units.

To determine the relation of water duty on rented, separate from owned units of the owner-renter farms, the same fifteen farms on land class 1 used in making the production analysis were studied. The owned units of these owner-renter farms received 5 per cent more water on the average than the rented units, (table VIII). This is less than one-third the difference existing between all owned and rented units studied.

On the average, the land operated by these 15 owner-renters received more water than all land class 1 units studied. This may account some for the apparent higher yields received by the owner-renter operators.

Water Use Related to Yields.--"The relationship between the amount of water applied and the yield of any crop is more or less indefinite because yield is dependent on many other factors such as variety of crop, preparation of seed bed, time of planting, cultivation, competition with weeds, temperature, rainfall, fertility of the soil, the time of irrigation, and other factors. In general, however, the yield increases with, but not in direct proportion to, the amount of water applied. After a certain

TABLE VIII.--AVERAGE WATER USED PER ACRE BY TYPE OF TENURE

Greenfields Division, Sun River Project

Land Class 1

1936

	Owner-Renter	Owned Part	Rented Part
Alfalfa 1/	2.77	2.83	2.71
Grain and peas	1.33	1.36	1.30

1/ Includes alfalfa, clover, gardens, and tame pasture.

limit is reached, additional irrigation may actually reduce the yield. Water logging of the soil through excessive irrigation is harmful to most farm crops." 26/ The importance of the above quotation was fully appreciated before attempting this analysis. There existed, however, a desire to determine possible approximate relations which might be suggestive of methods and directions to be followed in future studies in the field in addition to bring out facts which might suggest improvements in the use of irrigation on the division.

The relationship between productivity ratings and indices of water used by class of land is shown in figure 14 A, which bears out the above statement (by Monson) in showing a general tendency for production to increase with additional use of water until reaching a certain point. 27/ In this analysis the maximum seems to be 125 to 150 per cent of the average, after which yields tend to decrease. The relative effectiveness of applications of irrigation water on crop yields by class of land is also shown in this figure. Equal applications of water give lower yields on class 2 than on class 1 land. The variation in the effectiveness of water on the two classes of land decreases as increased quantities of water are applied until a maximum duty of 125.1 to 150 per cent of the project average is reached. At this point the results for both classes of land are almost equal. 28/

26/ Monson, O. W., Methods of Irrigation for Montana, Mont. Ext. Ser. Bul. 157, p. 4.

27/ Appendix I.

28/ Appendix I.

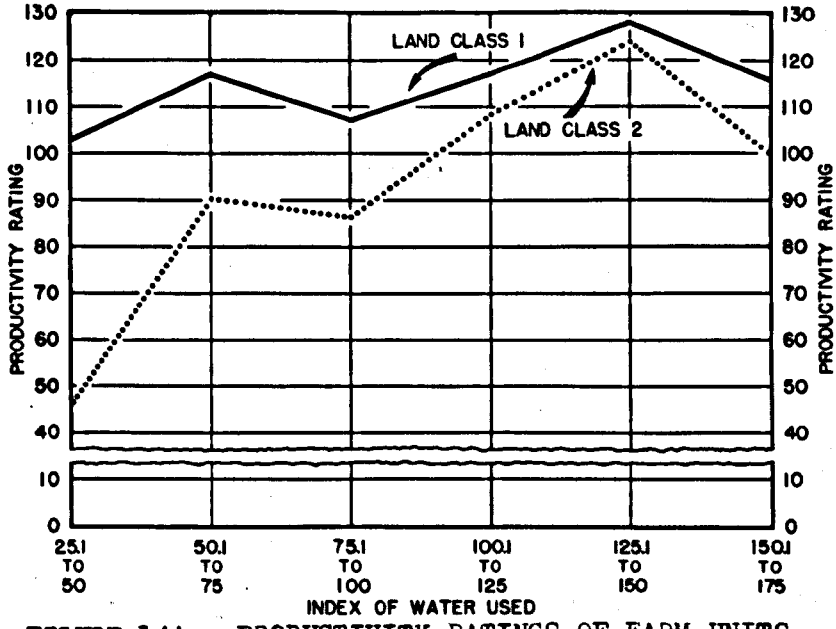

FIGURE 14A.—PRODUCTIVITY RATINGS OF FARM UNITS AND INDICES OF WATER USED PER ACRE BY CLASS OF LAND
Greenfields Division, Sun River Project, 1936

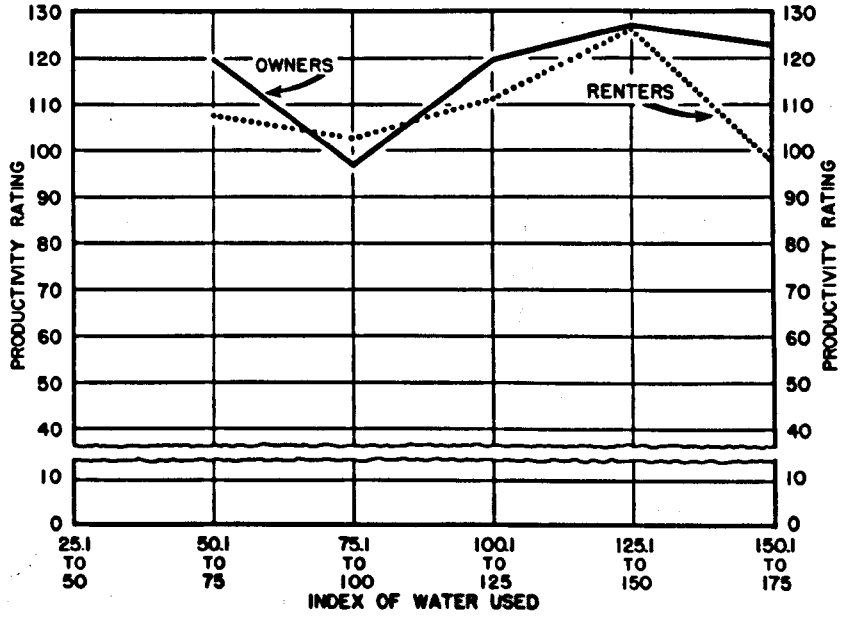

FIGURE 14B.—PRODUCTIVITY RATINGS OF FARM UNITS AND INDICES OF WATER USED PER ACRE
BY TYPE OF TENURE
Greenfields Division, Sun River Project
Land Classes 1 and 2
1936

From the data available, no apparent explanation of the relationships of productivity and water duty by types of tenure, as shown in figure 14 B, could be ascertained. 29/ The sample of farm units used was relatively small but the acreage was divided approximately equal between types of tenure.

The productivity ratings and indices of water used are aggregates of all crops on each farm unit, therefore, it is impossible to determine the approximate optimum water use by individual crops.

With more detailed water use information it will be possible to make a similar study showing the relationship of water duty and yield by crops instead of a combination of all crops as was done in the present analysis.

It is recognized, however, that quantity of water used is not all important and that time and frequency of application is equally significant, as shown in tables IX A, IX B, IX C. The farm units represented in tables IX A and IX B were chosen on the basis of the extreme relationship between yield and water used, and those in table IX C on the basis of the extremely absolute high and low yields. The units in all three tables were analyzed in detail in an attempt to explain the cause or causes for their respective yield and water use relationships.

Units having low production relative to water use were found to have been irrigated very little in June on the average (Table IX A). The units having high production relative to quantity of water used were, on

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29/ Appendix I.

TABLE IX A--QUANTITY OF WATER USED,
VARIATIONS IN TIME OF USE, AND PRODUCTION
By Farm Units
Greenfields Division, Sun River Project
Land Class 1
1936

Farm unit number	Productivity rating	Index of water use	Crops grown	Water used in per cent				
				May	June	July	Aug.	Sept.
Low yields*								
1	21	68	Grain only	-	-	100	-	-
2	23	56	Grain only	-	1	99	-	-
3	34	104	Grain only	-	2	88	10	-
4	34	97	Grain only	-	2	79	19	-
5	92	275	Grain only	-	-	66	34	-
6	58	168	Grain only	-	39	56	5	-
7	43	118	Grain and alfalfa	-	8	61	31	-
8	61	117	Grain and alfalfa	-	15	85	-	-
9	75	238	Peas, grain and alfalfa	-	16	71	13	-
10	53	178	Peas, grain and alfalfa	12	20	46	15	7
11**	42	103	Peas, grain and alfalfa	15	38	47	-	-
12	89	188	Peas, grain and alfalfa	14	33	34	19	-

* In relation to quantity of water used.
** Includes some crop failure.

TABLE IX B. QUANTITY OF WATER USED,
VARIATION IN TIME OF USE, AND PRODUCTION
By Farm Units
Greenfields Division, Sun River Project
Land Class 1
1936

Farm unit number	Productivity rating	Index of water use	Crops grown	Water used in per cent				
				May	June	July	Aug.	Sept.
High Yields*								
1	212	65	Grain only	-	62	38	-	-
2	178	67	Grain only	-	54	46	-	-
3	142	62	Grain only	-	59	41	-	-
4	222	73	Peas only	-	32	68	-	-
5	162	58	Peas only	-	-	100	-	-
6	186	75	Peas and grain	-	40	60	-	-
7	186	83	Peas and grain	-	49	51	-	-
8	170	87	Peas and grain	-	30	70	-	-
9	208	112	Peas and grain	-	54	46	-	-
10	105	30	Grain and alfalfa	-	36	36	28	-
11	132	46	Grain and alfalfa	-	45	55	-	-
12	145	26	Peas, grain and alfalfa	7	22	42	16	13

* In relation to quantity of water used.

TABLE IX C. QUANTITY OF WATER USED, TIME OF USE, AND PRODUCTION

By Farm Units
Greenfields Division, Sun River Project
Land Class 1
1936

Farm unit number	Productivity rating	Index of water use	Crops grown	Water used in per cent				
				May	June	July	Aug.	Sept.
Low Yields								
1	22	56	Grain only	-	1.5	98.5	-	-
2	28	35	Grain only	-	2.9	89.6	7.5	-
3	37	206	Grain only	-	3.9	65.2	30.9	-
4	42	80	Peas, alfalfa and grain	0.9	13.8	44.2	41.1	-
5	53	81	Alfalfa and grain	6.4	57.9	35.7	-	-
6	53	62	Peas, alfalfa and grain	-	23.7	76.3	-	-
7	59	76	Peas and grain	-	2.7	87.6	9.7	-
8	59	49	Alfalfa and grain	1.9	48.3	17.5	32.3	-
High Yields								
1	324	128	Alfalfa	19.1	15.1	37.1	13.2	15.5
2	292	209	Peas, alfalfa and grain	4.1	28.7	37.7	13.4	16.1
3	208	112	Peas and grain	-	53.5	46.5	-	-
4	196	239	Alfalfa and grain	17.2	16.3	22.2	2.5	41.8
5	194	172	Peas and grain	-	41.1	58.9	-	-
6	194	123	Alfalfa	34.6	5.1	32.1	26.7	1.5
7	193	163	Alfalfa and grain	10.3	18.9	53.9	16.9	-
8	189	203	Grain	16.1	47.5	36.4	-	-

the average, irrigated quite heavily in June as well as in July (table IX B). The same reason may be advanced as being at least partially responsible for the extremely high and low yields found in table IX C. The units of low productivity show either a low water duty or very little applied in June or a combination of both. The high producing units show higher than average water duty, much of which is used early in the growing season and the remainder spread over the later months.

Because of a break in the main canal in June of the year (1936) for which water use was studied, the results may not be indicative of a true picture of what water use might have been on the division, but serves very well to bring out the relationships between yields, water duty and time of use. 30/

Inasmuch as the farmers on this division are paying a flat rate per acre which entitles them to two acre feet of water and the average used in the past eight years was less than 1.5 acre feet, it seems as if the yields could be increased on many units by using more water without increasing the water cost. It is encouraging, however, to see that the average water duty has tended to increase since 1927, and that there is some indication of an increasing amount of water being used in the early part of the growing season.

Since the water holding capacity of a soil varies with its texture, it is difficult to determine optimum amounts per application for any

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30/ The water used by months in per cent of the total for the year for the last nine years is shown in apprndix O. Some relationships of water used by months, precipitation and wheat yields are shown in appendices M and N.

definite area without experimental trials. Three inches of water per foot of soil in a form available to plants seems to be considered as the maximum water holding capacity of the heavier soils. The water holding capacity of the lighter soils will decrease with the coarseness of the texture. The natural conclusion then would be, the lighter the soil and the more shallow rooted the crop, the more frequent and less heavy should be the applications of water.

Three units in the high production group of table IX C were growing some alfalfa and show an appreciable amount of water used in September. These units also show higher than average total water duty for the season, some of which undoubtedly was applied after the growing season for the use of crops to be produced the next year. A study of such a practice over a period of years should prove very fruitful.

LAND USE RELATED TO YIELDS

Inasmuch as available information regarding the rotation of crops on the units of the division is very meager, a comprehensive study of the relationship of land use and yields is impossible. The present analysis of this factor is merely an attempt to show the possibilities of such a study and to point out the need for additional data before a satisfactory analysis can be made.

The productivity ratings of farm units growing peas are higher on the average, than on all farm units, as indicated in figure 15. 31/ All

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31/ A comparison of units growing peas with a small sample of units never having grown peas shows the same relationship even more emphatically, but is not shown because of the inadequacy of the sample.

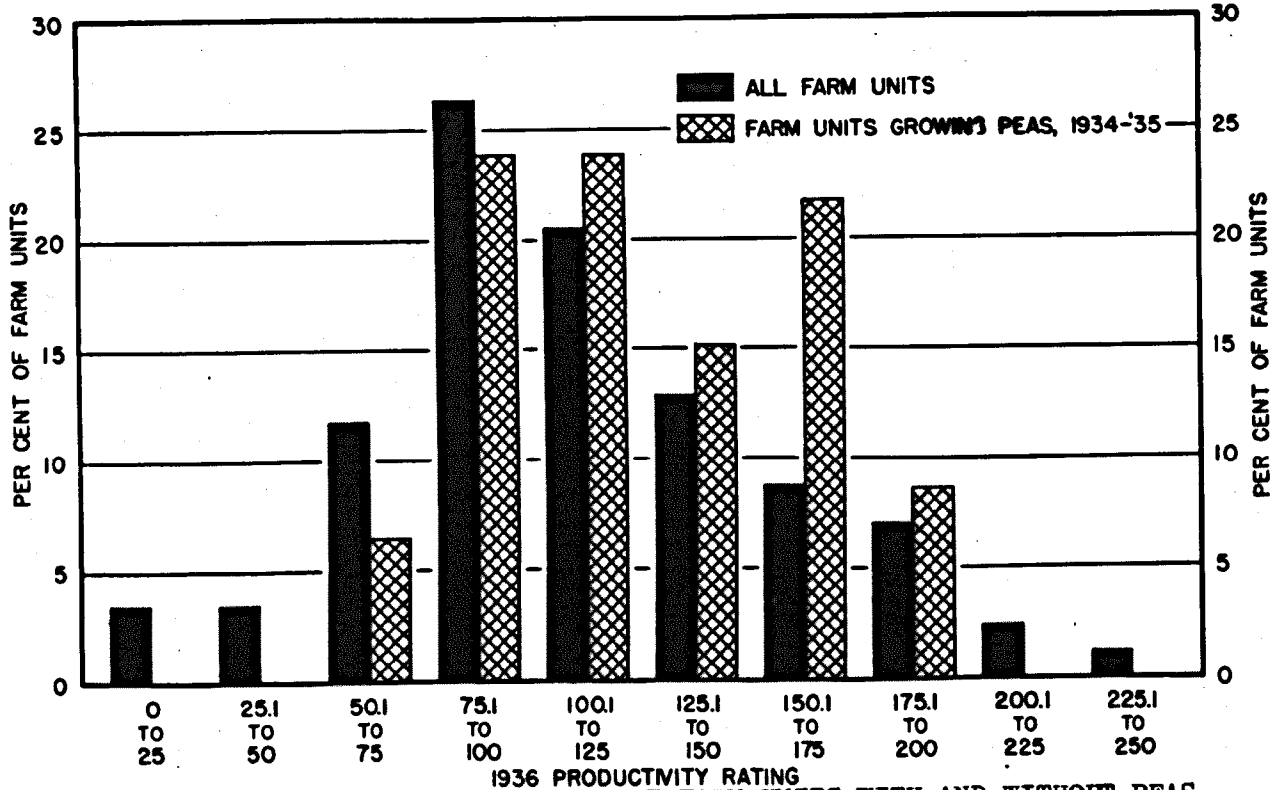

FIGURE 15.—PRODUCTIVITY RATINGS OF FARM UNITS WITH AND WITHOUT PEAS IN THE CROP ROTATION

Greenfields Division, Sun River Project
Land Class 1
1936

farm units show some higher and some lower ratings than those growing peas but, the predominance of the latter units in the higher productivity classes quite definitely indicates possible favorable effects of peas in the rotation.

The average yield of wheat on all land class 1 farm units in 1936 was 11.77 bushels per acre and 13.38 bushels on units growing peas the two previous years (table X). This is a difference of 1.61 bushels per acre, or 13.7 per cent of the former yield. It is appreciated that many factors other than the growing of the peas may be partially responsible for the increased yields.

The relative effect of alfalfa on crop yields cannot be determined for this division, as the seedings are not generally rotated on various fields as are peas. The weaknesses of the present management practices on the division are summarized in the following statement. "A high proportion of cash grain which is not balanced by leguminous soil conserving crops, livestock, or commercial fertilizer is a factor contributing to soil depletion and low yields...." 32/

CLIMATE RELATED TO YIELDS

Problems in Yield Analysis in Relation to Climatic Factors

To make a comprehensive climatic study would entail analysis of precipitation, temperature, and wind velocity by days. The primary pur-

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32/ Slagsvold, P. L. and Lord, H. H., The Conservation of Montana's Irrigated Lands, Mont. Agri. Exp. Sta. Bul. 350. p. 3.

TABLE X.--WHEAT YIELDS ON ALL FARM UNITS AND UNITS GROWING PEAS

Greenfields Division, Sun River Project
Land Classes 1 and 2
1936

	Acres	Average yield	Production in bushels
Units growing peas--1934 and 1935	1,929	13.38	25,814
All units	6,912	11.77	81,354

pose in this paper, however, is to point out the importance of variations in total precipitation and heat units by months and years. The factor of evaporation has not been considered because of lack of data. It is fully appreciated that no definite relations between the climatic factors and yields may be established for the division by this study, but some possible effects may be suggested.

Heat Units and Precipitation Related to Yield

The precipitation of 18.4 inches in the 1926-1927 growing season, and 5.8 inches in the 1935-1936 season is a difference of 11.6 inches. 33/ This variation is twice the amount of the 1935-1936 total precipitation. Such extreme variations in precipitation present problems uncommon to most agricultural areas. The farmers are undecided as to when and how heavy to irrigate.

The temperature on this division varies considerably also and is reflected in growing conditions and length of growing season. In 1927 the total heat units were 1900 (figure 16). 34/ In 1936 the figure was 3100. This is an increase of about 63 per cent and is important from the standpoint of plant growth. For best results, however, the two factors—precipitation and heat units—must occur in desirable combinations.

In general it may be said that yields on the division have varied with precipitation. Figure 17 shows that wheat yields follow variations

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33/ Crop year, Sept. 1 to Aug. 31.

34/ Appendix K.

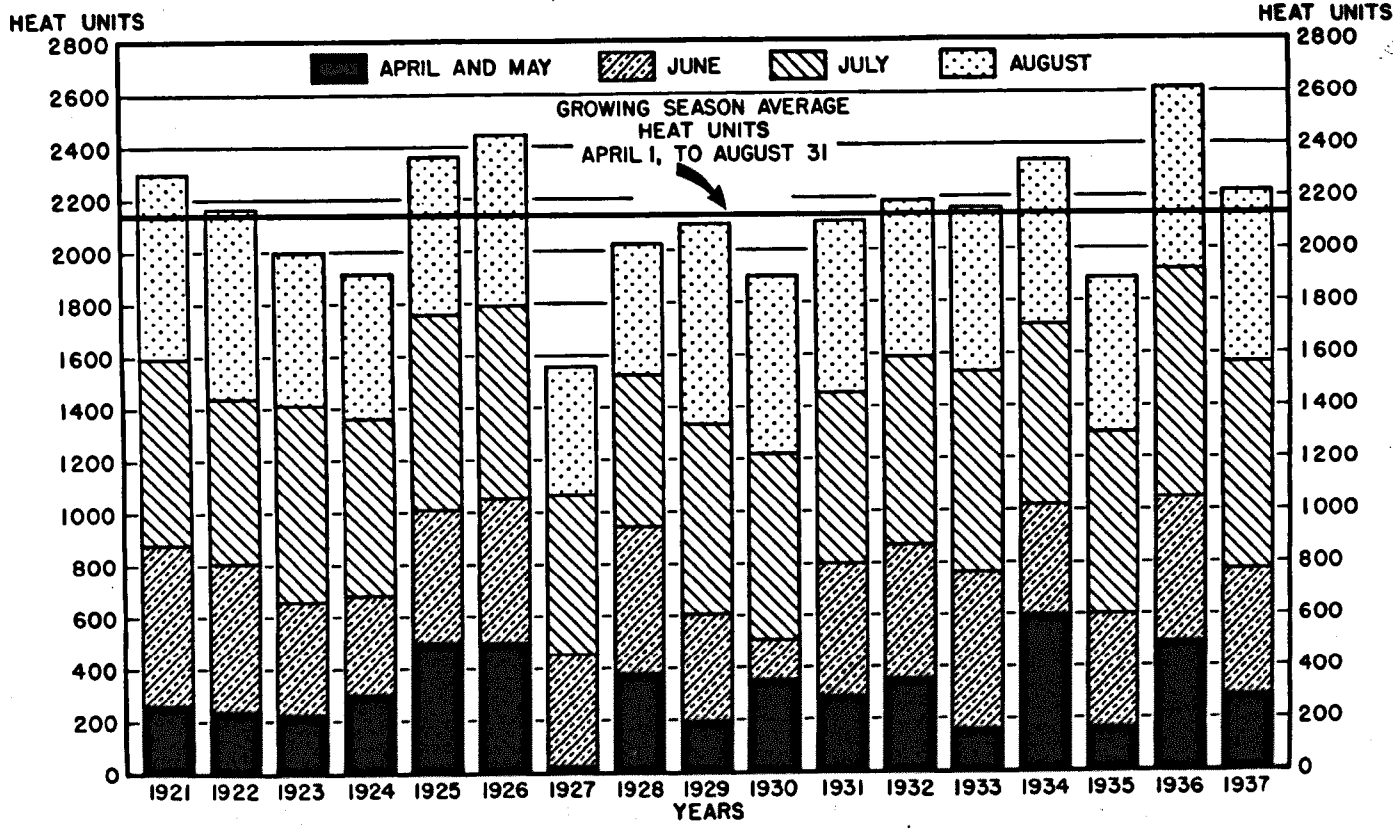

FIGURE 16.—CUMULATIVE HEAT UNITS BY MONTHS

Greenfields Division, Sun River Project

1921 to 1937

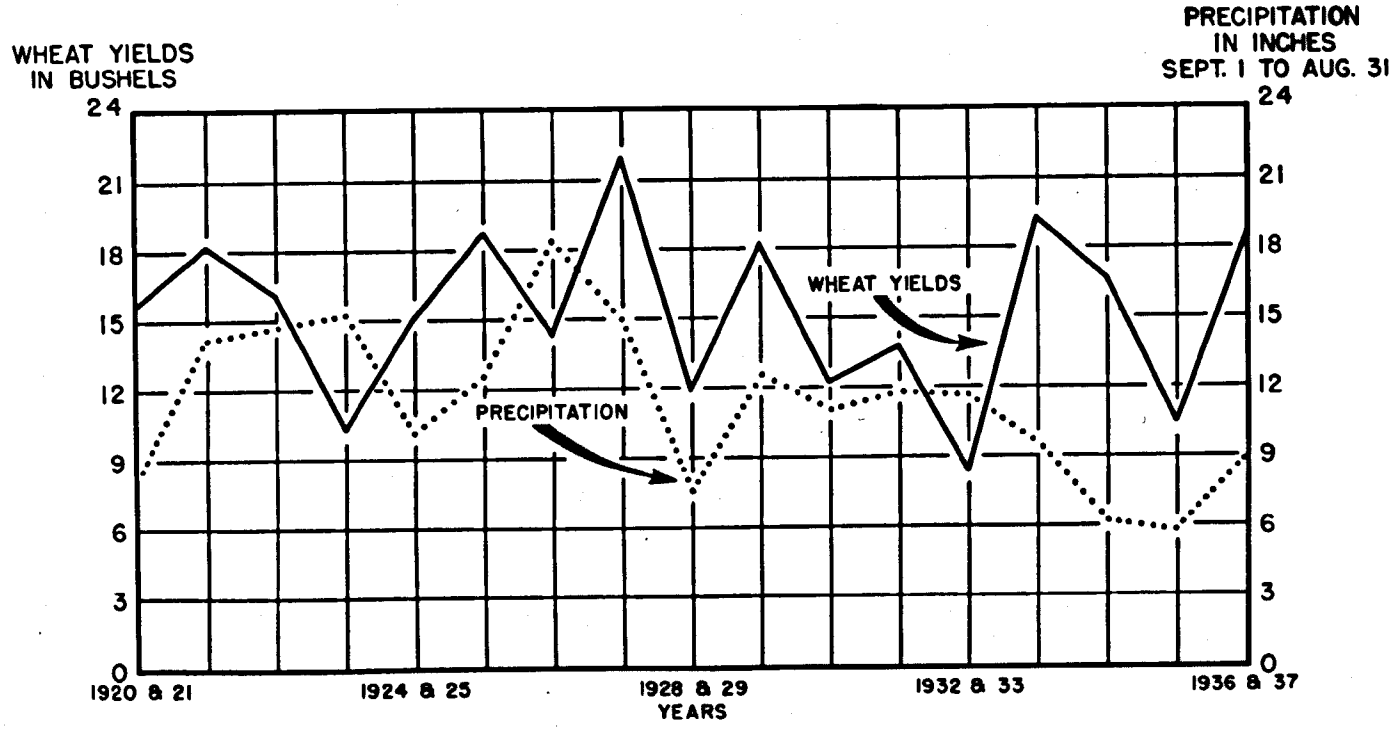

FIGURE 17.—CROP YEAR PRECIPITATION AND ANNUAL AVERAGE WHEAT YIELDS

Greenfields Division, Sun River Project

1921 to 1937

in the crop year precipitation quite directly, except for the years 1927, 1933, and 1934. 35/ The precipitation for the crop year 1926-27 was the highest for the division since records were started in 1895. The spring was very cold and crops did not begin to grow until June. In addition to this, the heat units for June, July, and August were only 85 per cent of the average for the 17 year period studied.

The low yield in 1933 may be partially accounted for by a late wet spring, which retarded plantings, followed by two months of severe drouth in June and July (figures 16 and 18). 36/ The high yield of 1934 may be attributed to the unusually favorable spring temperature with twice the average June precipitation.

The almost record low yield of 1936 may be explained by the extremes in climate for that year. A cold April and a warm May followed by an extreme drouth in June and July caused the yields of all crops to fall to a minimum.

35/ Appendix J.

36/ Appendix K and L.

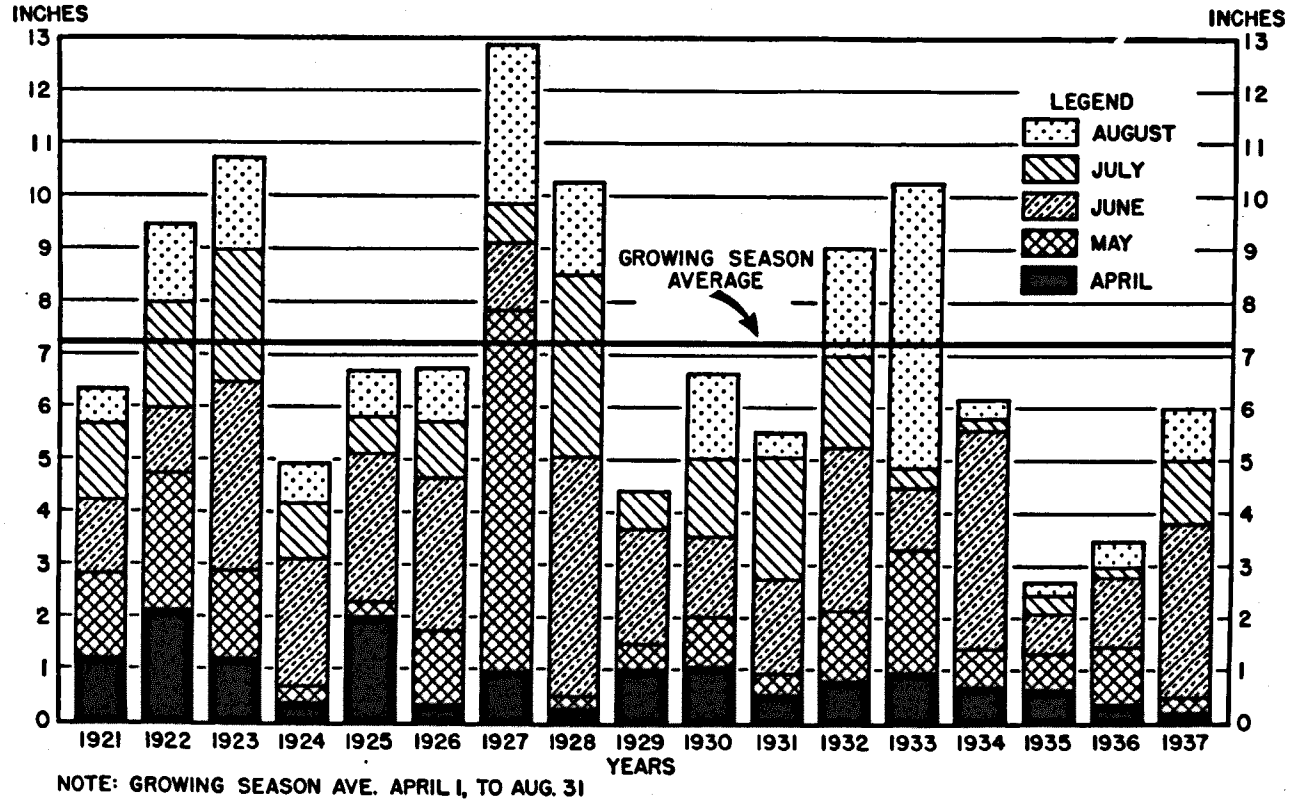

FIGURE 18.—CUMULATIVE PRECIPITATION BY MONTHS

Greenfields Division, Sun River Project

1921 to 1937

SUMMARY AND CONCLUSIONS

Problems

In studying these relationships, the development of a feasible method of analysis was a primary problem. Previous attempts by others to analyze the water use data had proven generally unsatisfactory but served as an aid in developing the present method. It was found that farms organized as operating units could not be used as a basis for the analysis because too few were located within any one class of land.

Need of Other Data for Analysis

In the present analysis the only facts available on water use were those dealing with the quantity and date of delivery by farms units. Information on cropping practices, rotations, and farm management is very meager and indefinite. With additional data on the use of water by crops and fields, land use, crop rotations and management, a much more satisfactory analysis may be made.

CONCLUSIONS FROM DATA AVAILABLE

In analyzing the available data, quite definite relations have been established for some factors, and generalities have been drawn regarding others. The average water duty is low on the division and has varied with precipitation, indicating a reluctance to use water if there was a possibility of getting considerable natural moisture. The drouth of the last four years has had a stimulating effect on the use of water on the project both in irrigable acres irrigated and average duty per irrigated acre.

Ten per cent more water per irrigated acre was used on class 2 than class 1 land which may be an indication of the relative porosity and surface irregularity of the two soils. Owned farm units received 18 per cent more water than rented units and may be accounted for, at least in part, by the relative insecurity of the term of tenure.

The growing of peas, which are assumed to be rotated, resulted in increased wheat yields, but few alfalfa seedings have been broken up to be included in the rotation.

Yields on the project generally have been low and vary widely from one farm unit to another, indicating possible inconsistencies in management, cropping practices, and water use. Yields averaged 11 per cent higher on class 1 than on class 2 lands, with variations by crops. Owner operated farm units show average production per acre 10 per cent greater than rented units although the variation by crops is not consistently in favor of one type of tenure. Higher yields on owned units are partially to be accounted for by the higher water duty and better land use.

Yields do vary with water duty. However, the time of application was found to be equally important, with applications in the early growing season giving most satisfactory results in 1936.

The findings of this study indicate that average crop yields on the division may be increased through a more intelligent use of irrigation water and improved rotation practices. The results of experimental work with fertilizers on alfalfa on the division indicate that superphosphate may be used profitably, but the work has not been carried on extensively enough to make definite recommendations at this time.

ACKNOWLEDGMENT

The author is indebted to Dr. P. L. Slagsvold for criticizing the thesis and for the many helpful suggestions in analyzing and organizing it, and to J. D. Mathews for suggestions in the analysis, organization, and presentation of the thesis material. Acknowledgment is due also to A. W. Walker and W. C. Windecker for their cooperation in making data available and for helpful suggestions in the analysis of them.

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BIBLIOGRAPHY

1. Brown, Ralph H. 1934. Irrigation in a Dry-Farming Region. Reprint from Geographical Review, October.

2. DeYoung, William. 1927. Soil Survey of the Sun River Irrigation Project. Mont. Agri. Exp. Sta. Bul. 207.

3. Monson, O. W. 1937. Methods of Irrigation for Montana. Mont. Agri. Ext. Serv. Bul. 157.

4. Patton, P. 1927. The Relationships of Weather to Crops in the Plains Region of Montana. Mont. Agri. Exp. Sta. Bul. 206.

5. Pittman, D. W. and Stewart, George. 1930. Twenty-Eight Years of Irrigation Experiments Near Logan, Utah. 1902-1929, Inc. Utah. Agri. Exp. Sta. Bul. 321.

6. Slagsvold, P. L. 1936. Analysis of the Present Status of the Sun River Irrigation Project. Mont. Agri. Exp. Sta. Bul. 321.

7. Slagsvold, P. L. and Lord, H. H. 1937. The Conservation of Montana's Irrigated Lands, Mont. Agri. Exp. Sta. Bul. 350.

8. Slagsvold, P. L. and Mathews, J. D. 1937. Some Economic and Social Aspects of Irrigation in Montana. Mont. Agri. Exp. Sta. Bul. 354.

9. Teele, Ray P. 1927. The Economics of Land Reclamation in the United States. A. W. Shaw Co., New York.

APPENDIX A.—ACREAGE OF CROP YIELDS BY MONTANA IRRIGATION PROJECTS

1932-1935 Average

	Wheat	Alfalfa Hay	Oats	Barley
	Bu.	Ton	Bu.	Bu.
Greenfields	14.5	1.65	26.5	16.6
Milk River	14.7	1.8	30.0	24.7
Flathead	17.5	1.9	32.8	22.5
Valier	19.3	1.55	29.8	23.8
Lower Yellowstone	21.1	1.95	37.5	27.3
Bitterroot	22.7	2.1	38.2	25.6
Huntley	25.9	2.3	37.1	31.95

Source: Unpublished data in files of Mont. Agri. Exp. Sta.

APPENDIX B.--ACREAGE OF SELECTED CROPS BY LAND CLASS AND TYPE OF TENURE

Greenfields Division, Sun River Project

1936

	Both	Owner	Renter
Land Classes 1 and 2			
Total Acres	22,197	10,757	11,440
Wheat	10,365	4,094	6,271
Peas	4,855	2,648	2,207
Alfalfa hay	4,953	2,851	2,102
Oats	1,073	646	427
Barley	951	518	433
Land Class 1			
Total Acres	15,591	7,377	8,214
Wheat	6,912	2,448	4,464
Peas	3,849	2,160	1,689
Alfalfa hay	3,567	1,997	1,570
Oats	649	399	250
Barley	614	373	241
Land Class 2			
Total Acres	6,606	3,380	3,226
Wheat	3,453	1,646	1,807
Peas	1,006	488	518
Alfalfa hay	1,386	854	532
Oats	424	247	177
Barley	337	145	192

APPENDIX C.--WHEAT YIELDS BY TYPE OF TENURE

Greenfields Division, Sun River Project
Land Class 1
1936

Bushels per acre	Per cent of farm units		
	Both	Owner	Renter
All farms	100	100	100
0-4	5.3	4.4	6.0
4.1-8	18.5	19.1	18.1
8.1-12	27.2	19.1	33.8
12.1-16	25.2	26.4	24.1
16.1-20	15.9	22.1	10.8
20.1-24	3.3	1.5	4.8
24.1-28	1.3	1.5	1.2
28.1-32	1.3	1.5	1.2
32.1-36	2.0	4.4	-
Number of farm units	151	68	83

APPENDIX D.—FARM UNITS ACCORDING TO PRODUCTIVITY RATINGS

In Per Cent of Total Units by Class of Land and Type of Tenure
Greenfields Division, Sun River Project
1936

Productivity rating	Land Class 1			Land Class 2		
	Both	Owner	Renter	Both	Owner	Renter
Total	100	100	100	100	100	100
0-25	3.5	1.2	5.7	14.5	12.5	16.7
25.1-50	3.5	4.9	2.3	7.9	12.5	2.8
50.1-75	11.8	11.0	12.5	14.5	10.0	19.4
75.1-100	26.4	24.4	28.4	21.0	17.5	25.0
100.1-125	20.6	17.1	23.9	15.8	20.0	11.1
125.1-150	12.9	17.1	9.0	14.5	12.5	16.7
150.1-175	8.8	12.2	5.7	7.9	10.0	5.5
175.1-200	7.1	8.5	5.7	1.3	-	2.8
200.1-225	2.4	2.4	2.3	-	-	-
225.1-250	1.2	-	2.3	1.3	2.5	-
250.1-275	-	-	-	1.3	2.5	-
275.1-300	1.2	1.2	1.1	-	-	-
300.1-325	.6	-	1.1	-	-	-
Number of farm units	170	82	88	76	40	36

APPENDIX E.—AVERAGE CROP YIELDS BY CLASS OF LAND AND TYPE OF TENURE

Greenfields Division, Sun River Project

1936

	Classes 1 and 2	Land Class 1	Land Class 2
All Farm Units			
Wheat	11.53	11.77	11.06
Peas	12.30	12.72	10.69
Alfalfa hay	1.77	1.82	1.64
Oats	19.99	21.81	17.18
Barley	17.31	20.33	11.80
Owner Farm Units			
Wheat	12.66	12.69	12.63
Peas	13.15	13.88	9.93
Alfalfa hay	1.77	1.79	1.73
Oats	21.04	23.00	17.87
Barley	17.86	20.23	11.76
Renter Farm Units			
Wheat	10.79	11.27	9.63
Peas	11.28	11.24	11.41
Alfalfa hay	1.77	1.87	1.48
Oats	18.39	19.93	16.21
Barley	16.64	20.48	11.82

Note: Grain in bushels and hay in tons per acre.

APPENDIX F.—IRRIGATED ACRES BY CLASS OF LAND, TYPE OF TENURE, AND TYPE OF CROP GROWN

Greenfields Division, Sun River Project
1936

	Acres irrigated		
	Both	Owner	Renter
Land Class 1 and 2			
All crops	21,187	10,531	10,656
Alfalfa 1/	5,505	3,050	2,455
Grain and peas	15,682	7,481	8,201
Land Class 1			
All crops	14,309	6,790	7,519
Alfalfa 1/	3,720	1,889	1,831
Grain and peas	10,589	4,901	5,688
Land Class 2			
All crops	6,878	3,741	3,137
Alfalfa 1/	1,785	1,161	624
Grain and peas	5,093	2,580	2,513

1/ Includes alfalfa, clover, garden and tame pasture.

Figures in this table represent 86 renter and 80 owner operated farm units on land class 1 and 40 owner and 35 renter farm units on land class 2.

APPENDIX G.--INDICES OF WATER DUTY PER ACRE

In Per Cent of Total Farm Units by Type of Tenure and Class of Land
Greenfields Division, Sun River Project
1936

Water use indices	Per cent of farm units					
	Land Class 1			Land Class 2		
	Both	Owner	Renter	Both	Owner	Renter
Total	100	100	100	100	100	100
0-25	.8	-	1.4	-	-	-
25.1-50	4.1	-	7.2	5.2	3.2	7.4
50.1-75	21.3	15.1	26.2	12.1	12.9	11.1
75.1-100	22.0	26.5	18.9	24.2	25.8	22.2
100.1-125	23.0	22.5	23.3	13.8	12.9	14.9
125.1-150	12.3	15.1	10.1	15.5	9.7	22.2
150.1-175	7.4	7.5	7.2	12.1	12.9	11.1
175.1-200	3.3	3.8	2.9	5.2	6.5	3.7
200.1-225	2.5	3.8	1.4	3.4	3.2	3.7
225.1-250	2.5	3.8	1.4	-	-	-
250.1-275	.8	1.9	-	3.4	6.5	-
275.1-300	-	-	-	-	-	-
300.1-325	-	-	-	1.7	-	3.7
325.1-350	-	-	-	-	-	-
350.1-375	-	-	-	1.7	3.2	-
375.1-400	-	-	-	1.7	3.2	-
Number of farm units	122	53	69	58	31	27

APPENDIX H.--UNWEIGHTED AVERAGE WATER DUTY PER ACRE BY TYPE OF TENURE AND CLASS OF LAND 1/

Greenfields Division, Sun River Project
1936

	Acre feet per acre		
	Both	Owner	Renter
Land Classes 1 and 2	1.71	1.89	1.53
Land Class 1	1.66	1.81	1.51
Land Class 2	1.81	2.02	1.56
In Per Cent of Average 2/			
Land Classes 1 and 2	100	111	89
Land Class 1	97	106	88
Land Class 2	106	118	91

1/ Weighted by acres irrigated but not by type of crop.

2/ Average acre feet per acre used on land classes 1 and 2 is 1.71.

APPENDIX I.--PRODUCTIVITY RATINGS OF FARM UNITS AND INDICES OF WATER USED PER ACRE

By Class of Land and Type of Tenure
Greenfields Division, Sun River Project
1936

Index of water used	Both		Owner		Renter	
	No. farm units	Productivity rating	No. farm units	Productivity rating	No. farm units	Productivity rating
Land Classes 1 and 2						
25.1-50	8	75	2	16	6	94
50.1-75	33	112	12	120	21	108
75.1-100	44	100	23	97	21	103
100.1-125	38	115	16	120	22	111
125.1-150	22	127	11	127	11	126
150.1-175	16	92	7	123	9	98
Land Class 1						
25.1-50	4	103	-	-	4	103
50.1-75	27	117	9	122	18	114
75.1-100	28	107	15	103	13	112
100.1-125	28	117	11	116	17	118
125.1-150	14	128	7	127	7	130
150.1-175	9	116	4	124	5	110
Land Class 2						
25.1-50	4	46	2	16	2	77
50.1-75	6	90	3	111	3	69
75.1-100	16	86	8	85	8	88
100.1-125	10	108	5	128	5	89
125.1-150	8	124	4	128	4	120
150.1-175	7	100	3	122	4	84

APPENDIX J.--PRECIPITATION, WATER DUTY, IRRIGABLE ACRES IRRIGATED, AND AVERAGE ANNUAL WHEAT YIELDS

Greenfields Division, Sun River Project
1921 - 1937

Year	Precipitation in inches	Water duty A. ft. per acre	Pct. of irri. A. irrigated	Wheat yield in bu.
1921	8.2	1.35	66	15.7
1922	14.2	1.12	56	18.1
1923	14.7	1.64	21	16.0
1924	15.2	1.35	45	10.2
1925	10.1	1.20	30	15.0
1926	12.6	.83	38	18.6
1927	18.4	.74	17	14.2
1928	14.9	.94	19	21.9
1929	7.5	1.01	31	11.9
1930	12.6	1.38	51	18.2
1931	11.0	1.39	50	12.2
1932	11.8	1.27	61	13.7
1933	11.8	1.50	70	8.4
1934	9.5	1.43	62	19.3
1935	6.2	1.64	75	16.7
1936	5.8	1.71	72	10.6
1937	8.3	2.02	76	18.6

Note: Precipitation for crop year, Sept. 1 to Aug. 31 ending in year given.

Climatological data from U. S. Weather Bureau publications. Records previous to 1927 kept at Fort Shaw. Station was moved to Fairfield January 1, 1927.

APPENDIX K.--CUMULATIVE HEAT UNITS BY MONTHS

Greenfields Division, Sun River Project

1921 - 1937

	April	April and May	April 1 to June 30	April 1 to July 31	April 1 to Aug. 31	April 1 to Sept.30	April 1 to Oct. 31
1921	-	258	879	1593	2295	2562	2871
1922	-	237	804	1440	2169	2655	2832
1923	-	225	657	1407	1998	2394	2409
1924	-	300	678	1359	1917	2325	2475
1925	126	498	1008	1758	2364	2664	2664
1926	96	495	1053	1794	2442	3003	3312
1927	-	9	450	1062	1560	1803	1893
1928	-	375	942	1521	2025	2304	2526
1929	-	186	606	1338	2100	2580	2634
1930	171	345	504	1218	1902	2238	2238
1931	-	282	798	1452	2112	2442	2544
1932	54	351	867	1587	2187	2580	2613
1933	-	156	762	1530	2160	2478	2526
1934	150	597	1023	1713	2343	2532	2703
1935	-	153	603	1296	1884	2295	2298
1936	-	492	1050	1923	2613	2979	3105
1937	-	285	771	1563	2217	2646	2859

Note: Heat units calculated with 43° F. as the base. If the mean temperature for a given month is 53° F., the number of heat units is (53-43) x 30 or 300.

Records previous to 1927 kept at Fort Shaw Station moved to Fairfield January 1, 1927.

APPENDIX L.--CUMULATIVE PRECIPITATION BY MONTHS

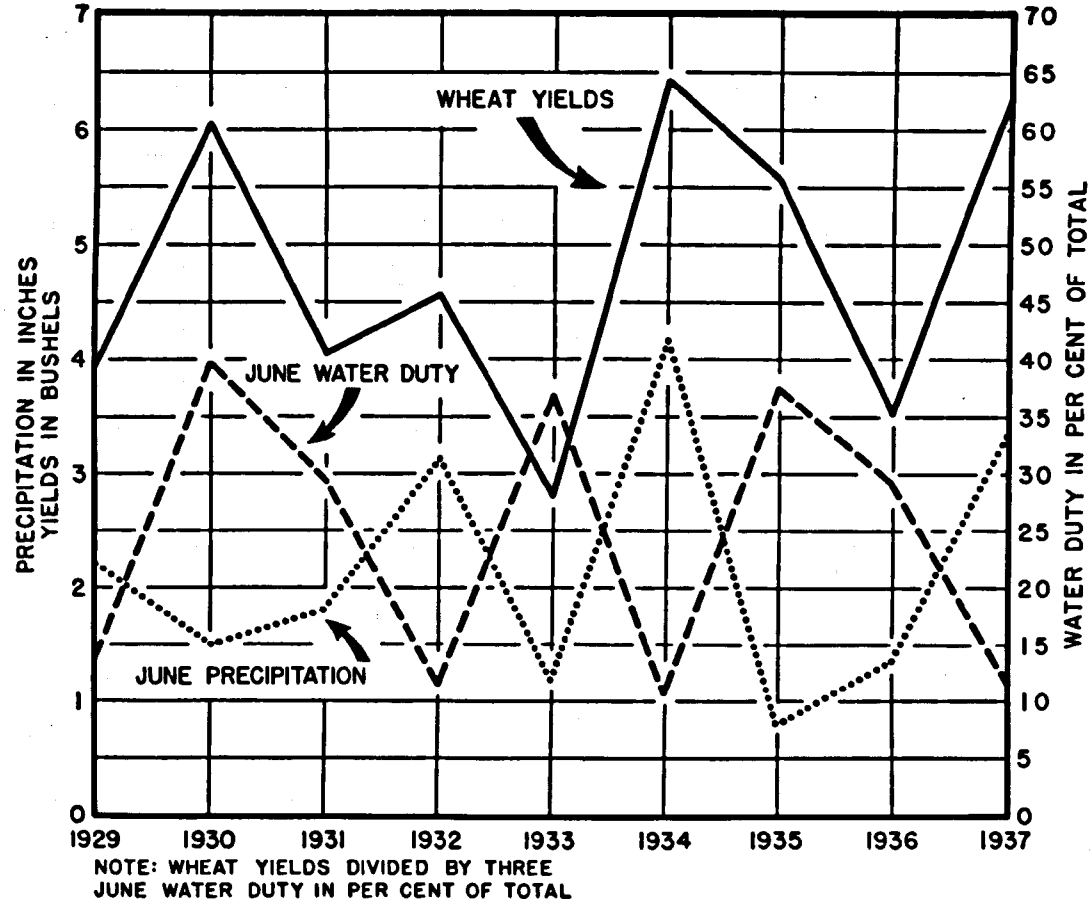
Greenfields Division, Sun River Project

1921-1937

	April	April and May	April 1 to June 30	April 1 to July 31	April 1 to Aug. 31	April 1 to Sept. 30	Sept. 1 to Aug. 31
1921	1.26	2.85	4.25	5.69	6.38	7.03	8.23
1922	2.16	4.76	6.00	8.01	9.59	10.10	14.25
1923	1.24	2.90	6.49	9.01	10.75	10.95	14.66
1924	0.36	0.69	3.12	4.19	4.96	5.95	15.23
1925	2.04	2.28	5.13	5.82	6.72	9.22	10.11
1926	0.36	1.75	4.67	5.72	6.77	9.71	12.52
1927	0.98	7.85	9.14	9.87	12.98	13.37	18.43
1928	0.28	0.47	5.08	8.51	10.29	10.69	14.92
1929	1.01	1.52	3.72	4.41	4.41	5.57	7.49
1930	1.07	2.02	3.54	5.02	6.68	8.76	12.58
1931	0.54	0.94	2.75	5.07	5.56	6.49	10.95
1932	0.80	2.15	5.26	7.00	9.05	9.05	11.84
1933	0.95	3.34	4.50	4.86	10.28	11.14	11.79
1934	0.70	1.44	5.60	5.77	6.17	7.37	9.53
1935	0.63	1.36	2.12	2.45	2.69	3.33	6.16
1936	0.36	1.47	2.82	2.96	3.47	4.32	5.75
1937	0.15	0.48	3.83	5.00	6.00	7.24	8.81

Source: Dlimatological Data, U. S. Weather Bureau Publications. Records kept at Fort Shaw previous to 1927, station moved to Fairfield January 1, 1927.

APPENDIX M

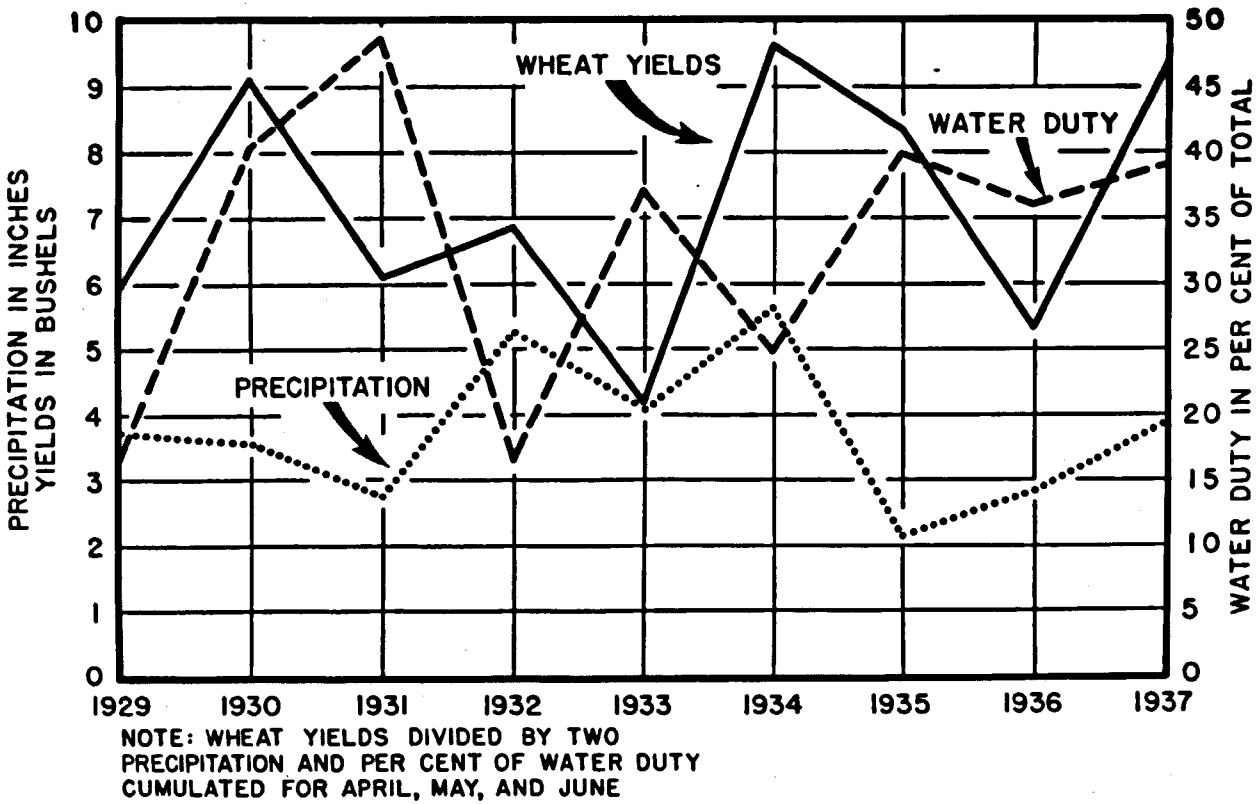


WHEAT YIELDS, JUNE WATER DUTY,
AND JUNE PRECIPITATION

Greenfields Division, Sun River Project

1929 to 1937

APPENDIX N



WHEAT YIELDS, WATER DUTY, AND PRECIPITATION

Greenfields Division, Sun River Project

1929 to 1937

APPENDIX O.--WATER DELIVERY BY MONTHS

Greenfields Division, Sun River Project

1929-1937

Year	Total	April	May	June	July	Aug.	Sept.	Oct.
1929	12,253	-	324	1,723	9,752	454	-	-
1930	28,550	-	257	11,308	11,508	3,786	1,691	-
1931	33,294	-	6,465	9,797	13,962	2,983	87	-
1932	36,510	-	1,849	4,149	23,617	6,241	533	121
1933	50,128	-	180	18,514	24,616	6,818	-	-
1934	42,107	-	5,939	4,505	23,766	6,305	1,283	309
1935	58,597	-	1,322	21,968	25,735	9,199	373	-
1936	68,115	-	4,777	19,747	31,389	6,226	5,717	259
1937	86,589	614	23,267	10,362	40,296	9,664	1,687	699

Per Cent

Year	Total	April	May	June	July	Aug.	Sept.	Oct.
1929	100	-	2.6	14.1	79.6	3.7	-	-
1930	100	-	0.9	39.6	40.3	13.3	5.9	-
1931	100	-	19.4	29.4	41.9	9.0	0.3	-
1932	100	-	5.1	11.4	64.6	17.1	1.5	0.3
1933	100	-	0.4	36.9	49.1	13.6	-	-
1934	100	-	14.1	10.7	56.4	15.0	3.1	0.7
1935	100	-	2.3	37.5	43.9	15.7	0.6	-
1936	100	-	7.0	29.0	46.1	9.1	8.4	0.4
1937	100	0.7	26.9	12.0	46.5	11.2	1.9	0.8