



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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Abstract:

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GREENFIELDS DIVISION, SUN RIVER PROJECT

by

JOHN C. BOWER

A THESIS

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in

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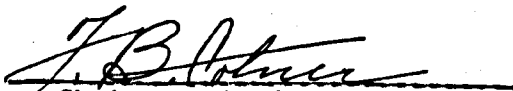
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In Charge of Major Work



Chairman, Examining Committee



Chairman, Graduate Committee

Bozeman, Montana
June, 1938

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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-

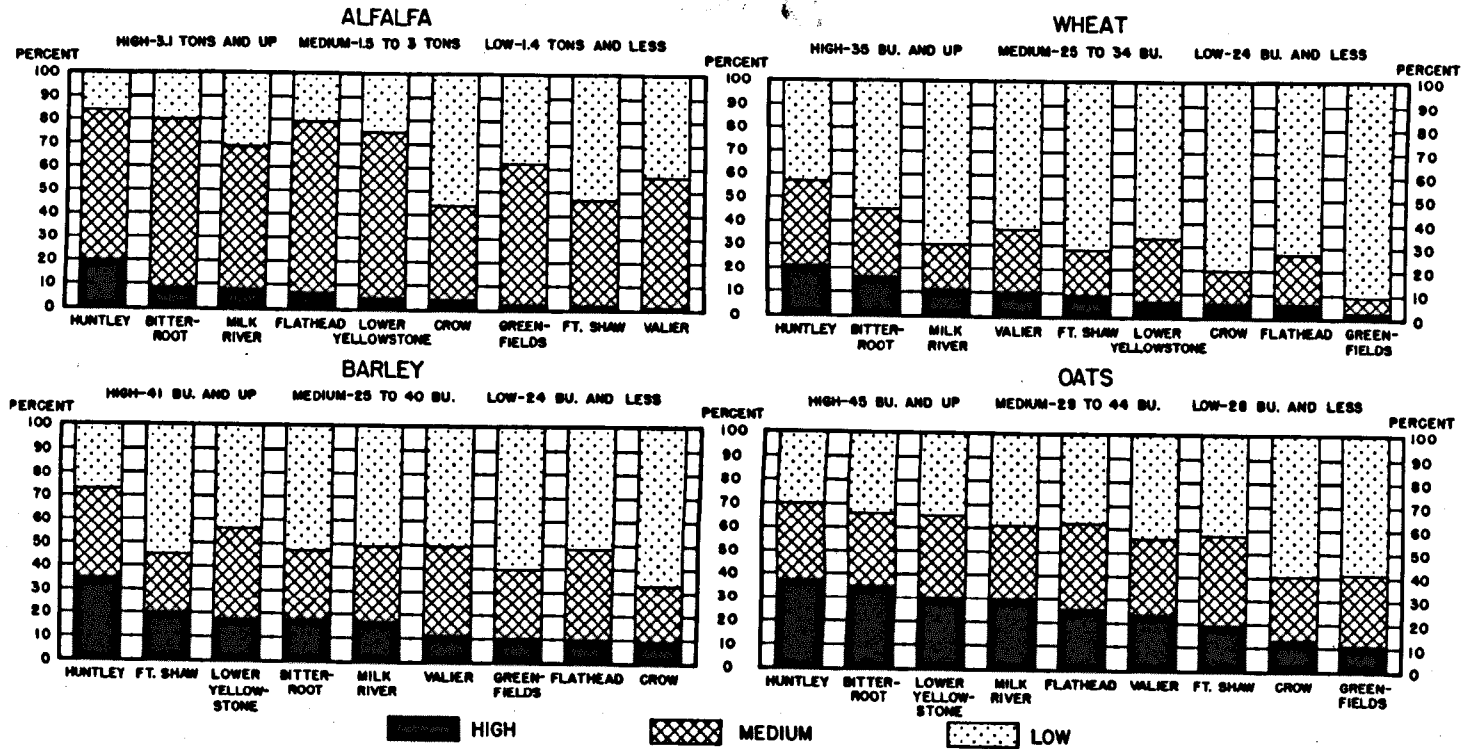


FIGURE 1.--PER CENT OF FARMS RECEIVING HIGH, LOW, AND MEDIUM YIELDS

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

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.

PRECIPITATION IN INCHES
 SEPT. 1 TO AUG. 31
 AND
 * WATER DUTY IN FEET

PER CENT OF IRRIGABLE
 ACRES IRRIGATED

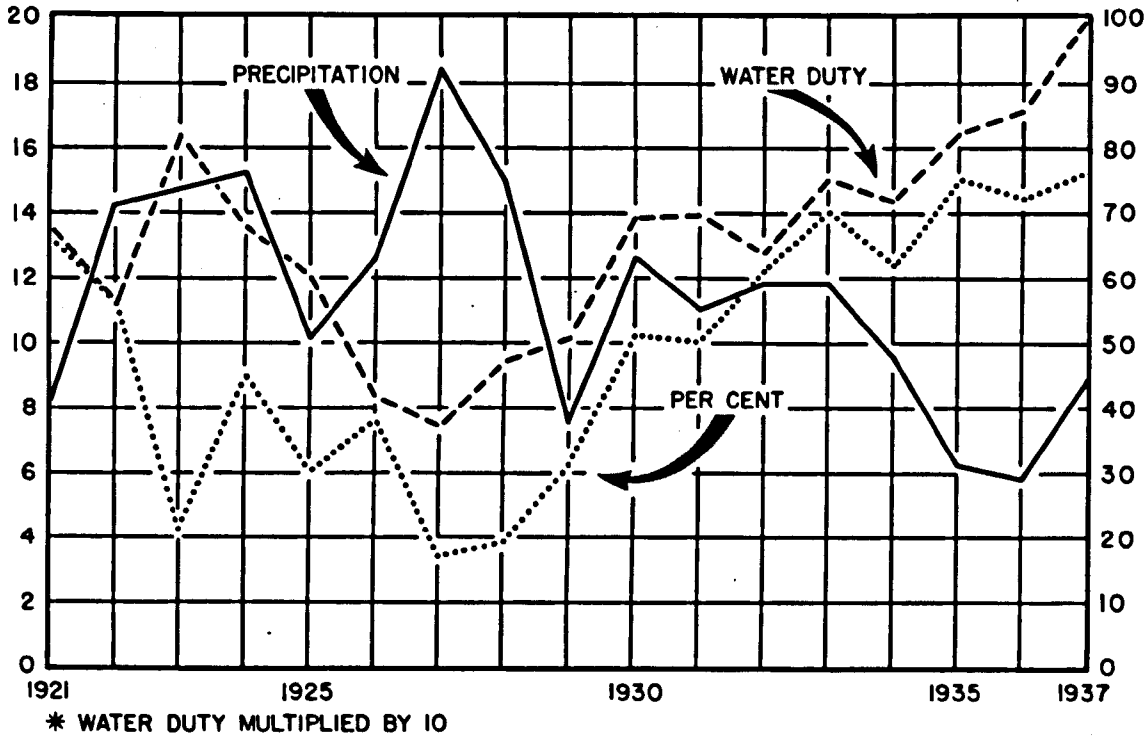


FIGURE 2.—PRECIPITATION, WATER DUTY, AND IRRIGABLE ACRES IRRIGATED

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

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

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

^{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

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 $(53 - 43) \times 30$ 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,

^{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

<u>Project</u>	<u>Per cent Soil Conserving</u>	<u>Per cent Soil Deplet.</u>	<u>Per cent Neutral</u>	<u>Total</u>
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

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

^{9/} Appendix C.

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

^{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 aggregative 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

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.

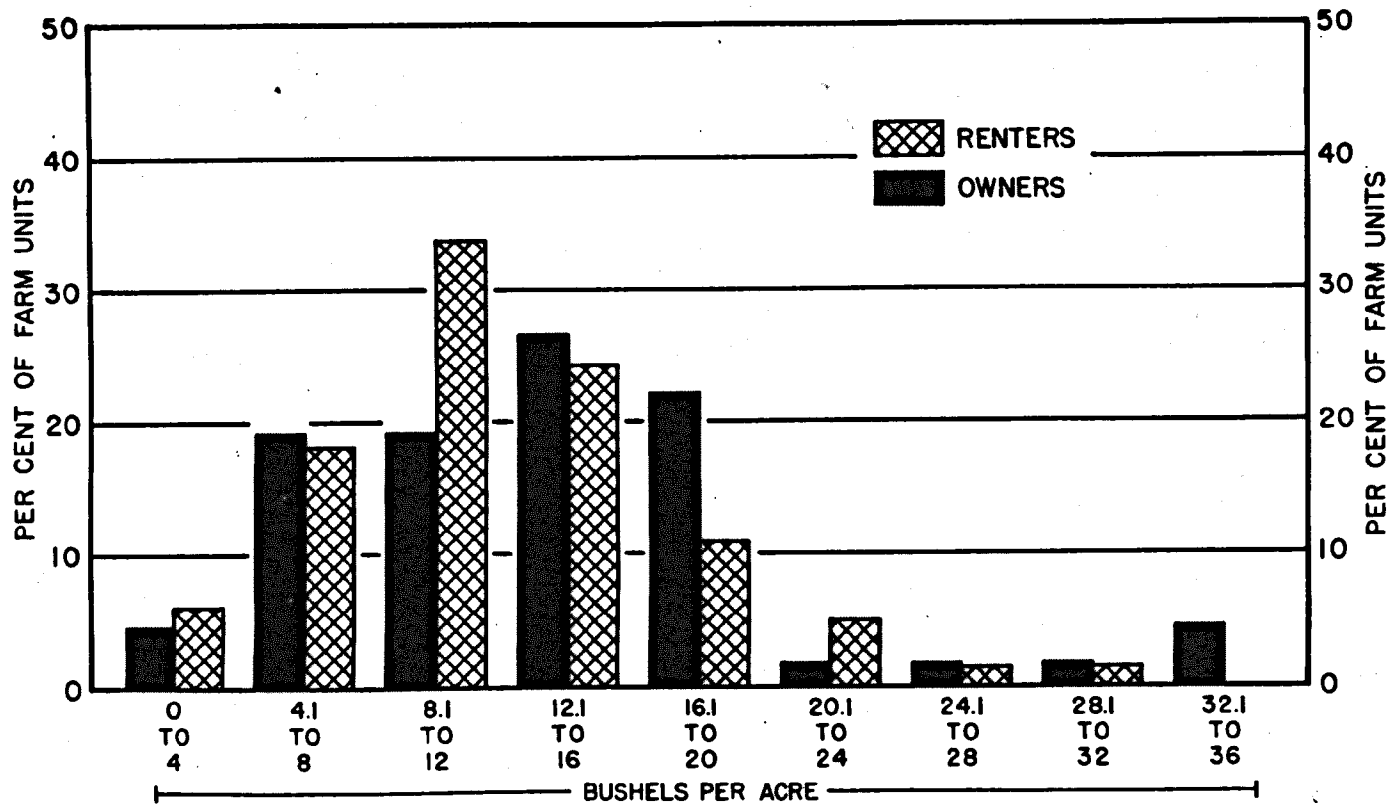


FIGURE 5.—WHEAT YIELDS BY TYPE OF TENURE

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.

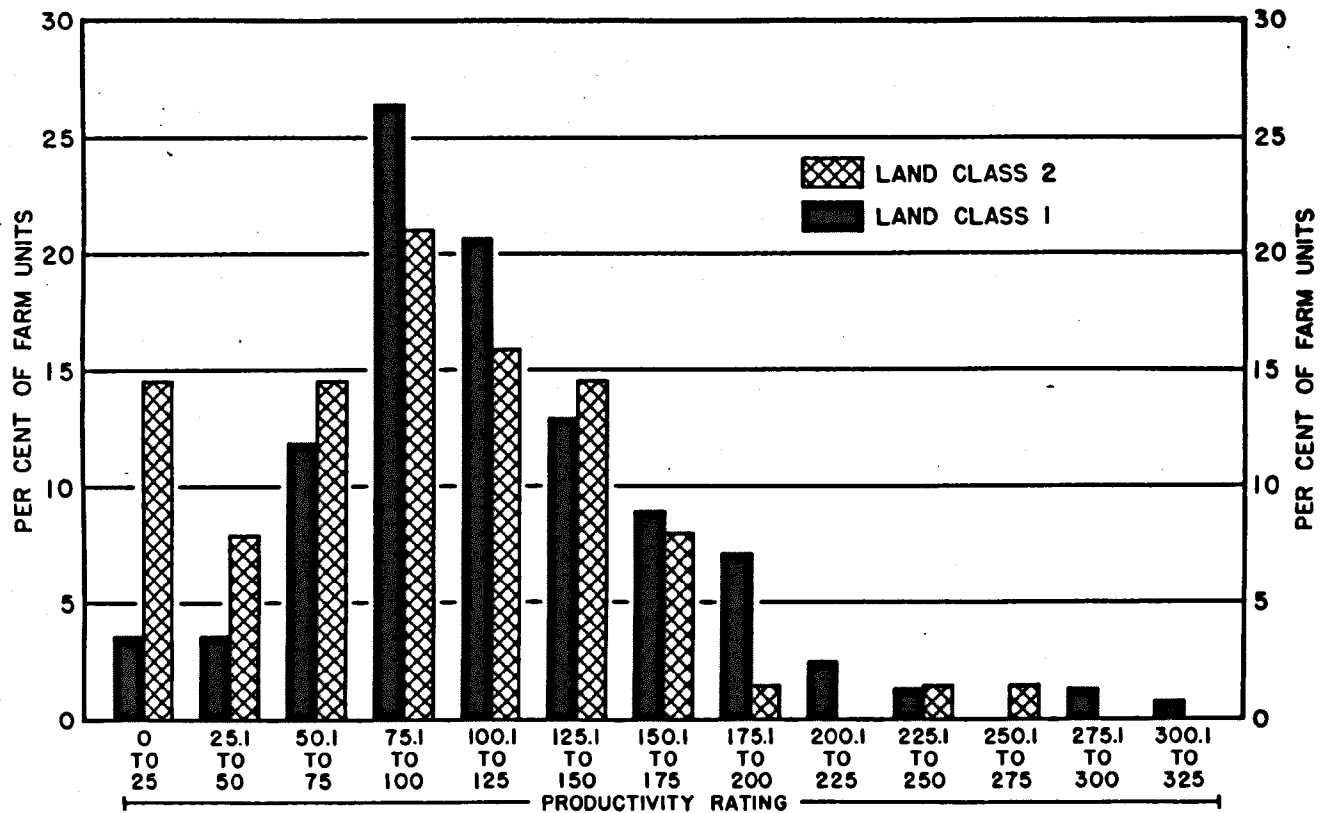


FIGURE 6.—PRODUCTIVITY RATING OF FARM UNITS

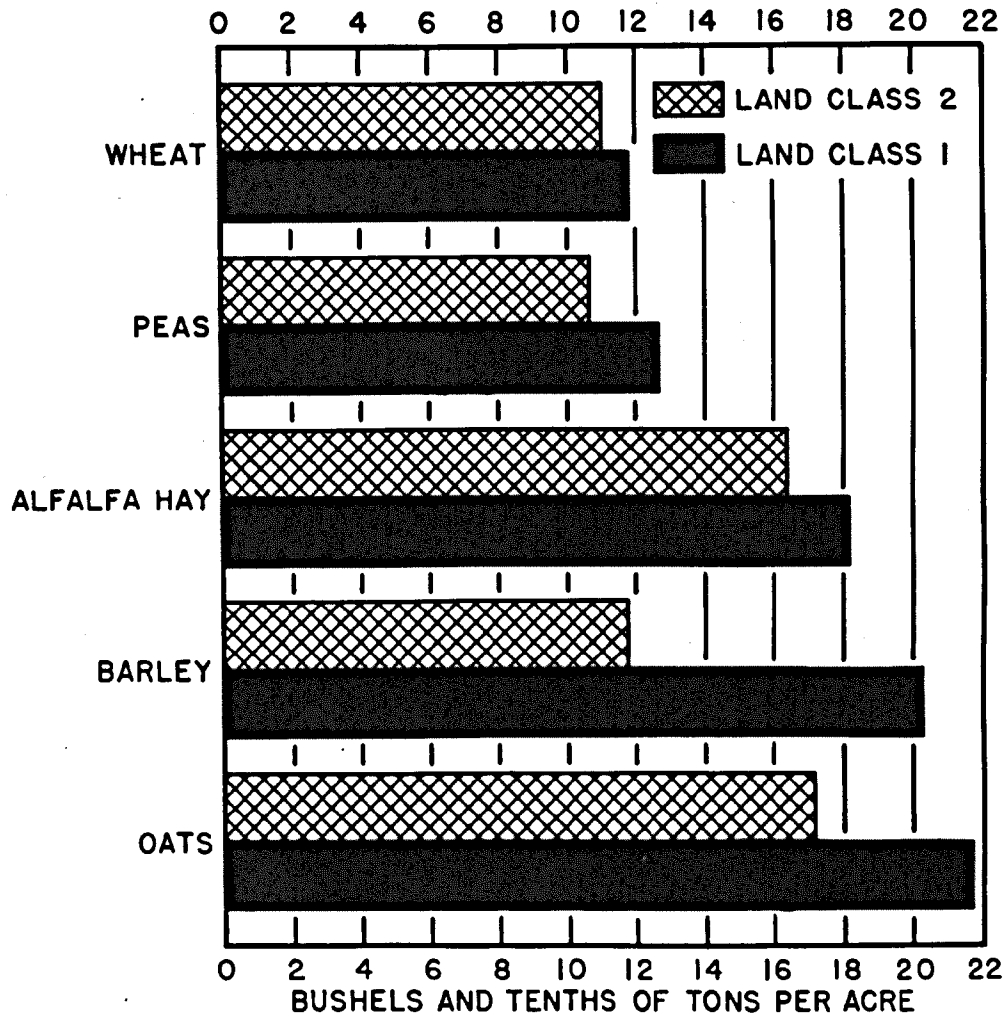
In Per Cent of Total Units in Each Land Class
 Greenfields Division, Sun River Project
 1936

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

^{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

^{16/} Appendix D.

^{17/} Appendix E.

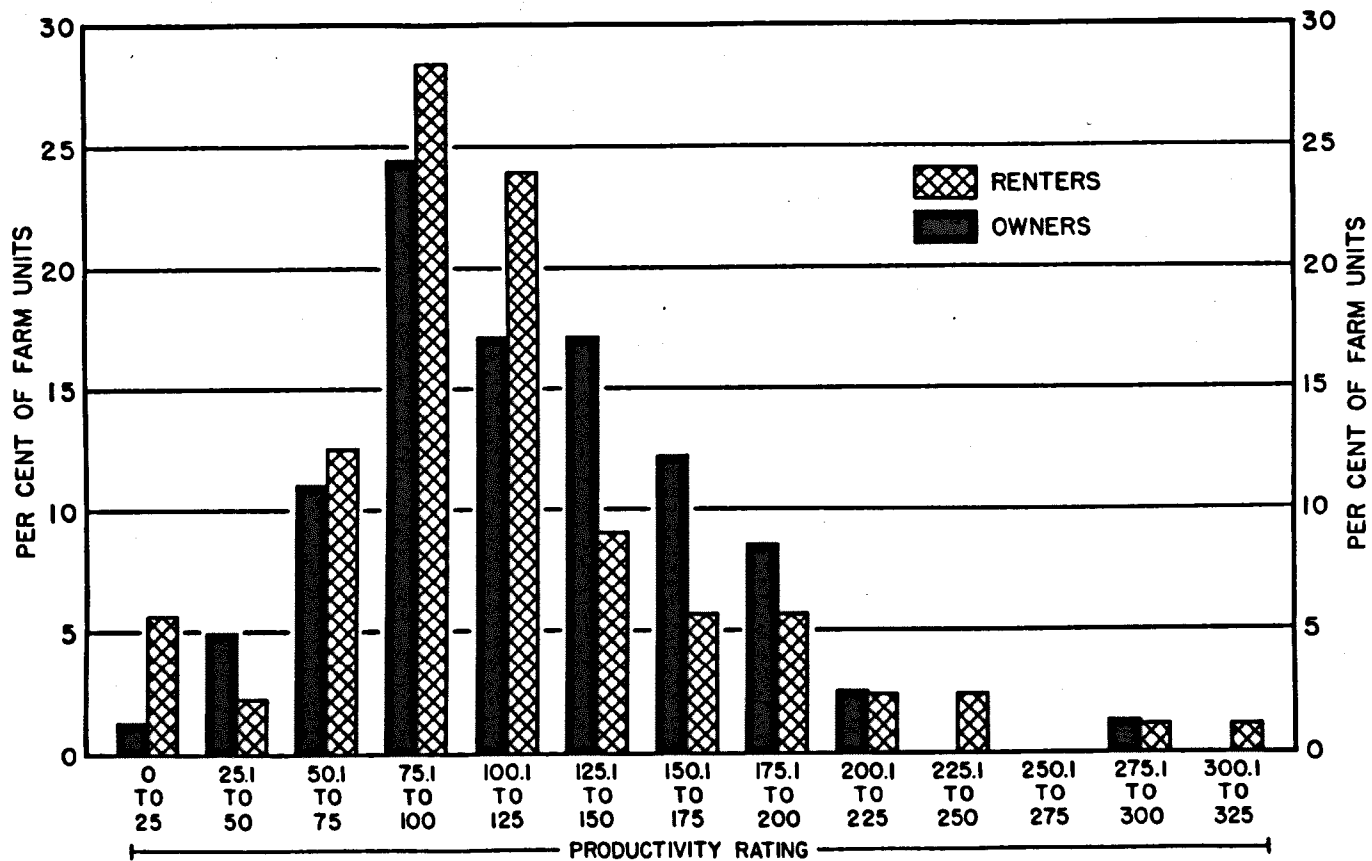


FIGURE 8.--PRODUCTIVITY RATINGS OF FARM UNITS BY TYPE OF TENURE

Greenfields Division, Sum River Project
 Land Class 1
 1936

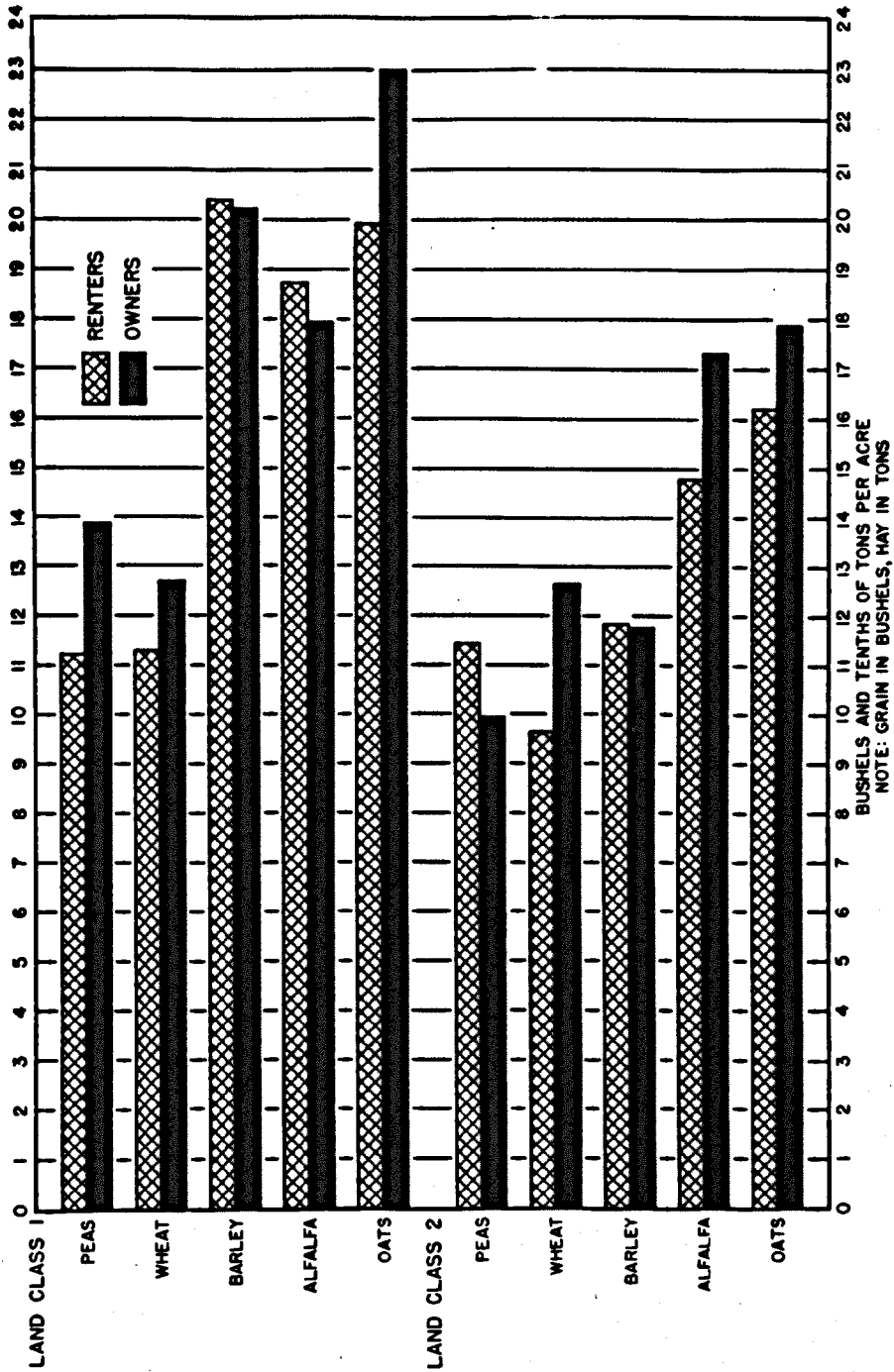


FIGURE 9.—AVERAGE CROP YIELDS BY TYPE OF TENURE AND CLASS OF LAND

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
<u>Owner-Renter</u>	13.7	13.7	1.8
Owned part	13.9	14.8	1.99
Rented part	13.6	11.7	1.68

