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# A Basis for Rating the Productivity of Soils on the Plains of Eastern Colorado

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# A Basis for Rating the Productivity of Soils on the Plains of Eastern Colorado

LINDSEY A. BROWN[1]

THE utility of soil surveys has been increased greatly in recent years by the addition of productivity ratings to the information contained in soil survey reports. These ratings are included in a chapter in each soil survey report entitled "Classification of Soil Types According to Productivity." (2)[2] This classification compares the inherent productivity of each soil recognized for each of the leading crops in the area to a standard, namely, 100; this is the rating given a soil that is considered to be inherently the most productive in the United States for the crop under consideration and which occupies sufficient acreage to warrant classing it as the standard soil for that crop. The rating 100 is called the base index and is the standard with which the productivity of all other soils for any particular crop is compared. Thus, a soil estimated as being one-half as productive for a given crop as the one having the base index rating receives an index of 50. A few unusually productive soils of small total acreage may have an index above 100 for a specified crop.

It is the object of this paper to discuss some of the difficulties encountered and to suggest some methods to use in estimating productivity ratings of soils developed on the high plains of eastern Colorado.

The methods that have been used to arrive at the values given as the productivity indices have varied considerably. In some instances quantitative experimental yields have been used as a basis; in others rather reliable farm yields are the basis; in still others the farmers' estimated yield averages and the agricultural investigators' estimates are used as a basis for ratings. The estimated yields methods are fairly accurate in the more or less humid regions of the country, where unusually high yields and crop failures are rather rare. However, in the high plains region climatic and soil conditions are such that yields are occasionally several times higher than the average, and complete crop failures are more or less common.

In general, it may be said that the cultivated soils in eastern Colorado (and in the high plains of adjoining states) contain enough available nutrients to produce the maximum crop obtainable with the best seed and tillage practices, but production is limited by the low precipitation.

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[1]Associate Agronomist, Colorado Experiment Station. The writer is indebted to Robert Gardner of the Colorado Experiment Station for guidance in statistically analyzing the data and for criticizing the manuscript; to W. C. Bourne for summarizing the precipitation data; to F. A. Hayes of the Bureau of Chemistry and Soils, O. R. Mathews of the Division of Dry-Land Agriculture, Bureau of Plant Industry, Alvin Kezer and D. W. Robertson of the Colorado Experiment Station, and Arthur Anderson of the Farm Security Administration, for criticizing the manuscript; and to O. R. Mathews, B. F. Barnes, H. Haas, and J. F. Brandon of the Division of Dry-Land Agriculture, Bureau of Plant Industry, for furnishing recent yield and precipitation data from the dry-land stations.

[2]Reference to "Literature Cited."

The mean annual precipitation of eastern Colorado varies from 11 to 18.3 inches, but even this great variation does not tell the story completely, as variation in individual years is from 2.4 inches in the Arkansas Valley in 1894 to 36.2 inches in 1915 in the northeastern part of the State.

It is common knowledge that crop yields vary with the amount of precipitation on the plains, but any statement of how closely yield and precipitation are related must be based on quantitative crop yields obtained under conditions where all variables except climate are kept as uniform as possible from year to year and where the climatic factors, chiefly precipitation, are recorded in the near vicinity of the field where yields are obtained. Variation in the distribution as well as in the amount of precipitation from year to year makes it highly desirable to have results for as many years as possible.

The Division of Dry-Land Agriculture of the U. S. Department of Agriculture, either alone or in cooperation with the States, has obtained crop yields in a manner fulfilling the above-mentioned desirable specifications at a number of field stations throughout the high plains. Unfortunately, only one of these field stations is located in Colorado, this one being at Akron. Other field stations that are situated on soils and subjected to climatic conditions similar to those in at least parts of eastern Colorado are located at Colby and Garden City, Kans., and Dalhart, Tex. It is a monument to the good judgment of the agricultural investigators who started and continued the work of these stations that each is situated on soil and in a climatic region that represents large areas of the plains. Furthermore, the rotations and plot treatments started in the early days of the stations have been continued each successive year; thus, after 30 years we have records of crop production on the plains that are invaluable as a guide in further work and which could not or cannot be duplicated in a shorter period of years.

Average yields of the more important crops and mean annual precipitation obtained at Akron, Colo., Colby and Garden City, Kans., and Dalhart, Tex., are given in table 1. These yields are based on those obtained on all plots not fallowed the previous year or receiving amendments of any kind. The data are furnished by the Division of Dry-Land Agriculture, Bureau of Plant Industry, U. S. Department of Agriculture.

TABLE 1.—*Average yields of important crops on continuously cropped land and precipitation at four dry-land field stations.*

| Crop | Akron | Colby | Garden City | Dalhart |
|---|---|---|---|---|
| | *Bushels* | *Bushels* | *Bushels* | *Bushels* |
| Corn | 11 | 14 | —[1] | — |
| Milo | — | — | 16 | 20 |
| Kafir | — | — | 13 | 17 |
| | *Hundredweight* | *Hundredweight* | *Hundredweight* | *Hundredweight* |
| Kafir—total | — | — | 33 | 46 |
| Mean annual | *Inches* | *Inches* | *Inches* | *Inches* |
| precipitation[2] | 17.4 | 17.5 | 17.6 | 17.6 |
| | *Bushels* | *Bushels* | *Bushels* | *Bushels* |
| Winter wheat[3] | 10 | 16 | 7 | — |
| Barley | 17 | 19 | — | — |
| Oats | 18 | — | — | — |
| Mean annual | *Inches* | *Inches* | *Inches* | *Inches* |
| precipitation[2] | 17.3 | 17.6 | 16.6 | 17.6 |

[1]Yields not determined, as the varieties and management practices adapted to soil and climatic conditions are too new or are still in the process of development.

[2]Annual precipitation for row crops is for the 12-month period ending September 30 and for small grains ending June 30.

[3]Exactly the same series of years were not used for the different types of crops on the same stations.

On the basis of average yields shown for the four field stations, we can readily figure productivity indices for the soils on these stations and in regions of similar climatic conditions.

TABLE 2.—*Standard yields for use in determining productivity ratings. (These yields rate a soil 100.)*

| Crop | Yields |
|---|---|
| | *Bushels* |
| Corn | 50 |
| Grain sorghum | 40 |
| Wheat (all kinds) | 25 |
| Barley | 40 |
| Oats | 50 |
| | *Tons* |
| Forage sorghum | 4 |

Table 2 shows the standard yields for use in determining productivity ratings according to the system used by the Bureau of Chemistry and Soils (6), and table 3 gives the productivity index for the various soils and crops on these stations.

The productivity ratings in table 3 may be considered to be as accurate as any recorded. However, their use is extremely limited for the following reasons:

1. They cannot be stated as accurately giving the inherent productivity in regions of higher or lower mean annual precipitation, even if the soils are quite similar.

TABLE 3.—*Productivity ratings of soils on field stations in and near eastern Colorado based on standard yields as given in table 2.*

| | Location and soil type | | | |
|---|---|---|---|---|
| Crop | Akron, Colo. Akron loam[1] | Colby, Kans. Keith silt loam | Garden City, Kans. Richfield silt loam | Dalhart, Tex. Amarillo sandy loam |
| Corn | 22 | 28 | — | — |
| Milo | — | — | 40 | 50 |
| Kafir | — | — | 30 | 42 |
| Kafir, total | — | — | 44 | 55 |
| Winter wheat | 40 | 64 | 28 | — |
| Barley | 42 | 42 | — | — |
| Oats | 36 | — | — | — |

[1]Soil series designations are those that correspond to the series as mapped in Colorado but not as yet correlated by the Bureau of Chemistry and Soils.

2. They do not show whether the ratings are due to relatively consistent yields or erratic, very high yields alternating with frequent crop failures.

In order to extend the usefulness of these ratings, the relation of yields to precipitation was studied.

Hallsted and Mathews (5) showed the importance of stored soil moisture in winter wheat yields.

Table 4 shows the annual precipitation (ending September 30) and row-crop yields in the descending order of amounts of precipitation on the four field stations considered.

Table 5 shows important small grain yields and annual precipitation for the period ending June 30.

To extend the use of the data in tables 4 and 5, we may proceed by either of two systems as follows:

1. Divide the yields into groups depending on the range in precipitation under which they were produced, and calculate an average yield for each crop for each rather narrow range in precipitation recognized. Yields and precipitation are recorded in tables 4 and 5 in such manner as to facilitate visualizing this method of separating the yields.

TABLE 4.—*Annual precipitation and yields for row crops at four dry-land stations.*

| Akron | | Colby | | Garden City | | | | Dalhart | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Precipitation | Corn | Precipitation | Corn | Precipitation | Milo | Kafir | Kafir | Precipitation | Milo | Kafir | Kafir |
| *Inches* | *Bushels* | *Inches* | *Bushels* | *Inches* | *Bushels* | *Bushels* | *Cwt.* | *Inches* | *Bushels* | *Bushels* | *Cwt.* |
| 26.8[1] | 25 | 28.3[1] | 50 | 33.0[1] | 33 | 18 | 29 | 27.2[1] | 39 | 33 | 55 |
| 23.2 | 36 | 26.0 | 52 | 27.4 | 51 | 38 | 68 | 25.1 | 24 | 24 | 66 |
| 21.4 | 31 | 25.6 | 46 | 26.4 | — | 17 | 48 | 24.4 | 54 | 42 | 100 |
| 21.1 | 8 | 22.6 | 23 | 26.3 | 30 | 33 | 68 | 24.1 | 31 | 28 | 54 |
| 20.9 | 9 | 22.0 | 26 | 21.8 | 26 | 23 | 34 | 23.1 | 22 | 24 | 47 |
| 20.4 | 21 | 21.4 | 20 | 20.7 | 35 | 22 | 44 | 22.9 | 19 | 26 | 50 |
| 20.0 | 12 | 20.3 | 1[2] | | | | | 21.8 | 39 | 36 | 80 |
| | | | | | | | | 20.3 | 25 | 29 | 69 |
| | | | | | | | | 20.2 | 21 | 13 | 38 |
| 19.1 | 11 | 19.4 | 16 | 19.2 | 35 | 34 | 72 | 19.9 | 24 | 28 | 42 |
| 19.0 | 5 | 18.6 | 11 | 18.2 | 7 | 11 | 36 | 19.6 | 30 | 22 | 57 |
| 18.8 | 11 | 17.8 | 20 | 17.4 | 16 | 19 | 51 | 19.6 | 31 | 28 | 47 |
| 18.8 | 15 | 17.3 | 4 | 17.1 | 11 | 9 | 29 | 19.6 | 34 | 0[2] | 58 |
| 18.5 | 14 | 17.2 | 8 | | | | | 19.4 | 28 | 29 | 42 |
| 17.3 | 4 | 17.0 | 3 | | | | | 19.1 | 10 | 16 | 31 |
| 17.1 | 18 | | | | | | | 18.6 | 27 | 24 | 107 |
| | | | | | | | | 18.5 | 21 | 15 | 42 |
| | | | | | | | | 17.4 | 24 | 23 | 54 |
| 16.8 | 11 | 16.0 | 7 | 16.6 | 2 | 1 | 32 | 16.6 | 10 | 10 | 42 |
| 16.4 | 11 | 15.9 | 12 | 16.4 | — | 0 | 18 | 16.1 | 10 | 13 | 31 |
| 15.9 | 4 | 15.4 | 21 | 16.4 | — | 4 | 30 | | | | |
| 15.9 | 2 | 14.1 | 1 | 15.3 | 36[2] | 30[2] | 52[2] | | | | |
| 15.3 | 5 | | | 15.2 | 3 | 3 | 13 | | | | |
| 14.7 | 4 | | | 15.1 | 4 | 8 | 30 | | | | |
| 14.1 | 8 | | | 15.1 | 11 | 8 | 24 | | | | |
| | | | | 14.7 | 17 | 17 | 37 | | | | |
| 13.4 | 6 | 13.5 | 1 | 13.3 | 7 | 5 | 29 | 13.6 | 15 | 18 | 40 |
| 12.9 | 0 | 12.9 | 0 | 12.2 | 0 | 0 | 16 | 13.5 | 9 | 13 | 40 |
| 12.6 | 1 | 11.4 | 0 | 9.5 | 0 | 0 | 0 | 13.3 | 3 | 0 | 51 |
| 11.9 | 3 | 10.6 | 0 | 9.4 | 0 | 0 | 8 | 11.4 | 13 | 5 | 26 |
| 11.8 | 0 | 10.6 | 0 | 9.0 | 0 | 0 | 0 | 11.0 | 2 | 1 | 19 |
| 11.1 | 0 | 8.5 | 0 | | | | | 10.3 | 0 | 0 | 0 |
| 10.7 | 1 | | | | | | | 10.1 | 1 | 0 | 18 |
| | | | | | | | | 9.6 | 3 | 4 | 15 |
| | | | | | | | | 8.6 | 0 | 0 | 21 |

[1]Precipitation for 12-month period ending September 30.
[2]These yields not used, as they were largely due to factors other than the year's precipitation or its distribution.
Data to 1926 after Chilcott (3). Data 1926 to 1937 from Mathews and Brown (7), Mathews, Barnes, Haas, and Brandon by private communication.

2. Calculate the normal yield for any given amount of precipitation from a regression equation based on all the yields and on amounts of precipitation under which they were produced for each crop.

These data will be studied in both manners and then compared.

Study of Data by Grouping

Dividing the yield years into groups depending on amount of precipitation is an arbitrary process at best. However, after considerable study and discussion, the following groups were used:

1. OVER 20 INCHES ANNUALLY.[1] This group includes all years in eastern Colorado that are considerably above normal and includes

[1]Annual precipitation in relation to row crops is in all cases considered as the 12-month period ending September 30, and for small grains the 12-month period ending June 30.

TABLE 5.—*Annual precipitation and yields for small grains at three dry-land stations.*

| Akron | | | Colby | | | Garden City | |
|---|---|---|---|---|---|---|---|
| Precipitation[1] *Inches* | Wheat *Bushels* | Barley *Bushels* | Precipitation[1] *Inches* | Wheat *Bushels* | Barley *Bushels* | Precipitation[1] *Inches* | Wheat *Bushels* |
| 25.7 | 16 | 32 | 24.3 | 25 | 49 | 25.3 | 25 |
| 23.4 | 22 | 55 | 23.8 | 24 | 17 | 25.3 | 23 |
| 23.3 | 15 | 18 | 22.2 | 32 | 29 | 22.5 | 9 |
| 22.8 | 12 | 11 | 21.3 | 30 | 44 | 20.7 | 7 |
| 20.3 | 6 | 47 | 21.3 | 25 | 50 | 20.1 | 20 |
| 20.3 | 14 | 12 | 21.3 | 17 | 6 | | |
| 20.1 | 14 | 32 | 21.3 | 6 | 36 | | |
| | | | 20.9 | 22 | 9 | | |
| | | | 20.2 | 29 | 43 | | |
| | | | 20.2 | 33 | 50 | | |
| | | | 20.1 | 31 | 19 | | |
| 19.4 | 34 | 31 | 19.5 | 22 | 18 | 19.6 | 21 |
| 18.9 | 26 | 38 | | | | 17.3 | 2 |
| 18.3 | 12 | 34 | | | | 17.2 | 12 |
| 18.2 | 7 | 26 | | | | | |
| 16.9 | 12 | 14 | 16.7 | 18 | 15 | 16.3 | 0 |
| 16.8 | 1 | 7 | 16.2 | 14 | 25 | 16.0 | 0 |
| 16.7 | 7 | 6 | 15.6 | 3 | 7 | 15.2 | 14 |
| 16.5 | 3 | 12 | 15.4 | 26 | 20 | 14.5 | 2 |
| 16.5 | 4 | 19 | 15.3 | 3 | 0 | 14.5 | 0 |
| 16.0 | 2 | 2 | 14.0 | 13 | 1 | | |
| 15.9 | 4 | 6 | | | | | |
| 15.5 | 7 | 9 | | | | | |
| 14.6 | 7 | 5 | | | | | |
| 14.5 | 4 | 4 | | | | | |
| 14.2 | 14 | 11 | | | | | |
| 13.7 | 17 | 17 | 13.1 | 2 | 1 | 13.8 | 0 |
| 13.4 | 2 | 8 | 11.8 | 0 | 1 | 13.2 | 0 |
| 12.6 | 5 | 4 | 11.1 | 0 | 0 | 12.8 | 2 |
| 12.2 | 4 | 1 | 10.2 | 0 | 0 | 11.0 | 2 |
| 11.2 | 1 | 2 | 10.1 | 0 | 0 | 10.5 | 0 |
| | | | | | | 9.2 | 0 |

[1]Precipitation is for the 12-month period ending June 30.
Data to 1926 after Chilcott (3).
Data 1926 to 1937 from Mathews and Brown (7), Mathews, Barnes, Haas, and Brandon by private communication.

most of the years when bumper crops are obtained by the majority of farmers. They may be considered "good" years.

2. FROM 17 TO 20 INCHES ANNUALLY. This range in precipitation includes most of the so-called fair to good years. They may be called "fair" years. Yields under this precipitation may be very low under poor rainfall distribution or poor farm practices, but high yields are not uncommon.

3. FROM 14 TO 17 INCHES ANNUALLY. This range in precipitation includes the poor to fair years. They are subsequently called "poor" years. High yields are obtained only following years of very high precipitation. Low yields and failures are common.

4. LESS THAN 14 INCHES ANNUALLY. Crop failures will practically always occur under this amount of precipitation on the so-called "hardlands."[1] "Semi-hardlands" may produce small crops. Years in this group are referred to as "failure" years.

[1]"Hardland" is a local term used to designate soils of loam, silt loam, clay loam, and sandy clay loam topsoil textures. "Semi-hardland" likewise refers to soils of loamy sand to fine sandy loam topsoil textures. Very fine sandy loam may in some cases be considered as "hardland" and in others as "semi-hardland."

The horizontal lines in tables 4 and 5 separate the yields into the precipitation groups described. Table 6 shows the yield distribution by groups. It is unfortunate that some groups contain so few years. To partially eliminate this difficulty, the corn and barley yields for Akron and Colby and the wheat yields for Akron, Colby, and Garden City are summarized together. These are logical combinations, as all three stations are on so-called "hardlands." Akron and Colby are in regions of similar temperature.

In table 6, yields above the maximum stated for a crop may be considered high yields. Those under the minimum stated may be considered as crop failures. Several interesting relationships are shown in this table. Some of them have been previously pointed out by Mathews and Brown (7). To appreciate fully these relationships, one must remember that the Akron, Colby, and Garden City stations are on so-called "hardland" soils, while the Dalhart station is on a so-called "semi-hardland" or sandy loam soil. Dalhart and particularly Garden City are in regions of hotter summer temperatures and lower humidity, so evaporation losses are probably greater than at the more northern stations. The relationships are as follows:

1. A year's precipitation of over 20 inches will produce a high yield of corn over half of the time on "hardlands."

2. High yields of corn with less than 20 inches precipitation were never obtained at Colby or Akron.

3. Corn crop failures were virtually assured with less than 14 inches of precipitation.

4. Grain sorghum yields are considerably higher on the "hardlands" at Garden City under 17 to 20 inches precipitation than are corn yields at Colby and Akron. Grain sorghum yields on "hardlands" failed at about the same level of precipitation at Garden City as corn yields at Colby and Akron. However, it should be remembered that summer temperatures and humidity are more detrimental to crop growth at the station where the sorghum yields were obtained than where corn yields were recorded.

5. Sorghum forage yields, indicated from total kafir weights at Garden City and Dalhart, were much more dependable in dry years than were grain sorghum yields, and the "semi-hardland" of Dalhart produced much higher yields of forage on any amount of precipitation than did the "hardland" of Garden City.

TABLE 6.—*Yield distribution in the precipitation groups at the four dry-land field stations.*

| Precipitation group | Akron and Colby | | | | Garden City | | | | Dalhart | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Corn[1] | | | | Milo and kafir[1] | | | | Milo and kafir[1] | | | |
| | Over 25 bu. | 15 to 25 bu. | 5 to 14 bu. | Under 5 bu. | Over 25 bu. | 15 to 25 bu. | 5 to 14 bu. | Under 5 bu. | Over 25 bu. | 15 to 25 bu. | 5 to 14 bu. | Under 5 bu. |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Over 20 in. | 54 | 23 | 23 | 0 | 64 | 36 | 0 | 0 | 61 | 33 | 6 | 0 |
| 17 to 20 in. | 0 | 31 | 46 | 23 | 25 | 25 | 50 | 0 | 47 | 47 | 6 | 0 |
| 14 to 16.9 in. | 0 | 9 | 55 | 36 | 0 | 17 | 25 | 58 | 0 | 0 | 100 | 0 |
| Under 14 in. | 0 | 0 | 8 | 92 | 0 | 0 | 20 | 80 | 0 | 11 | 22 | 67 |
| | Barley[2] | | | | Sorghum Forage[1,3] | | | | Sorghum Forage[1,3] | | | |
| | Over 25 bu. | 15 to 25 bu. | 5 to 14 bu. | Under 5 bu. | Over 50 Cwt. | 30 to 50 Cwt. | 10 to 29 Cwt. | Under 10 Cwt. | Over 50 Cwt. | 30 to 50 Cwt. | 10 to 29 Cwt. | 10 to 30 Cwt. |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Over 20 in. | 61 | 17 | 22 | 0 | 33 | 50 | 17 | 0 | 78 | 22 | 0 | 0 |
| 17 to 20 in. | 80 | 20 | 0 | 0 | 50 | 25 | 25 | 0 | 44 | 56 | 0 | 0 |
| 14 to 16.9 in. | 6 | 12 | 59 | 23 | 0 | 56 | 44 | 0 | 0 | 100 | 0 | 0 |
| Under 14 in. | 0 | 10 | 10 | 80 | 0 | 0 | 40 | 60 | 11 | 22 | 56 | 11 |
| | Akron, Colby and Garden City — Wheat[2] | | | | | | | | | | | |
| | Over 25 bu. | 12 to 25 bu. | 4 to 11 bu. | Under 4 bu. | | | | | | | | |
| | *Percent* | *Percent* | *Percent* | *Percent* | | | | | | | | |
| Over 20 in. | 57 | 26 | 17 | 0 | | | | | | | | |
| 17 to 20 in. | 50 | 25 | 12 | 13 | | | | | | | | |
| 14 to 16.9 in. | 5 | 27 | 27 | 41 | | | | | | | | |
| Under 14 in. | 0 | 6 | 13 | 81 | | | | | | | | |

[1]Precipitation is for the 12-month period ending September 30.
[2]Precipitation is for the 12-month period ending June 30.
[3]Based on total weights of kafir.

6. Small grain failures were almost unknown where precipitation amounts were above 17 inches per year.

7. High yields of small grains were obtained on only one occasion on less than 17 inches precipitation.

8. Small grain failed in more than three-fourths of the years that less than 14 inches precipitation fell.

## Study of Data by Statistical Analysis

The regression of yield on precipitation was calculated by the methods of Fisher (4). The regression of row-crop yields on precipitation for the 12-month period ending September 30 provides an equation whereby the "good", "fair", "poor", and "failure" yields can be estimated quite accurately from the precipitation.

Small grain yields, likewise, could be estimated fairly well on the basis of the precipitation for the 12-month period ending June 30.

A comparison of actual wheat yields at Akron with those estimated by the formula developed by Mathews and Brown (7) showed that their formula was significantly more accurate for estimating yields than the regression equation based on total precipitation for the 12-month period ending June 30. However, the latter basis was necessarily used, as it was highly desirable to have a similar basis for estimating yields for all crops.

Both the linear and quadratic relationships of yields and precipitation of the crops studied which were grown on the four field stations were calculated. The quadratic regression was significantly better in the case of corn yields and precipitation at Akron and Colby than was the linear. All other data showed no significant advantage of quadratic over linear correlation.

The normal yield for any given amount of precipitation is readily calculated from the regression equation resulting from the statistical analysis of precipitation-yield relationship. Data from two or three stations have been combined when the stations were situated on soils that are similar in texture in the upper foot. The main reason for this is to make use of the calculated yields over a wide area, with a smaller error due to considerable range in climatic conditions.

Table 7 gives the average yield of each crop within the four arbitrary precipitation groups and the normal yield calculated from the average precipitation within that group by use of the regression equations.

No dry-land station in or near northeastern Colorado and situated on sandy loam or "semi-hardland" soils has recorded corn yields. In this part of the state corn is an important crop, particularly on

TABLE 7.—*Average and calculated normal yields of crops in the four precipitation groups.*

| Precipitation group | Average precipitation of group | Yields on "hardlands" | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Corn | | Grain sorghums | | Forage sorghums | | Wheat | | Barley | |
| | | Average[1] | Normal[2] | Average[1] | Normal[2] | Average[1] | Normal[2] | Average[1] | Normal[2,3] | Average[1] | Normal[2] |
| | *Inches* | *Bushels* | *Bushels* | *Bushels* | *Bushels* | *Cwt.* | *Cwt.* | *Bushels* | *Bushels* | *Bushels* | *Bushels* |
| Over 20 inches | 23.1 | 27 | 27 | 30 | 24 | 49 | 45 | 20 | 21 | 31 | 34 |
| 17 to 20 inches | 18.5 | 11 | 12 | 18 | 15 | 47 | 34 | 17 | 14 | 29 | 21 |
| 14 to 16.9 inches | 15.5 | 8 | 6 | 7 | 10 | 26 | 27 | 7 | 8 | 10 | 12 |
| Under 14 inches | 11.6 | 1 | 2 | 1 | 3 | 11 | 18 | 2 | 2 | 3 | 1 |

| Precipitation group | Average precipitation of group | Yields on "semi-hardlands" | | | | | |
|---|---|---|---|---|---|---|---|
| | | Corn | | Grain sorghums | | Forage sorghums | |
| | | Average[1] | Normal[4] | Average[1] | Normal[2] | Average[1] | Normal[2] |
| | | | *Bushels* | *Bushels* | *Bushels* | *Cwt.* | *Cwt.* |
| Over 20 inches | 23.1 | None to average | 25 | 29 | 31 | 62 | 63 |
| 17 to 20 inches | 18.5 | | 20 | 24 | 21 | 53 | 48 |
| 14 to 16.9 inches | 15.5 | | 12 | 11 | 14 | 37 | 39 |
| Under 14 inches | 11.6 | | 4 | 5 | 5 | 26 | 27 |

[1]"Average" yields are the numerical average of all yields produced under the amount of precipitation within the various groups at dry-land field stations.

[2]"Normal" yields are calculated from the regression equation for each crop, using the average precipitation of each group as shown in second column.

[3]Calculated from formula based on precipitation for 12-month period ending June 30. The formula by Mathews and Brown (7) gives more accurate wheat-yield estimates for individual years.

[4]Estimated as explained on pages 11 and 13.

the sandy loam soils. In order to arrive at a figure that is representative of corn yields on this type of land, it is necessary to use all means available in order to feel we are obtaining an accurate estimate. We may proceed on the basis of the following assumptions, observations and quantitative data:

1. Observation indicates corn yields are higher on "semi-hardland" than on "hardland," except in very wet years. Also, corn crop failure is more frequent on "hardlands."

2. We may assume that "semi-hardland" exceeds "hardland" as corn-producing land in about the same manner as the two types of land compare in grain sorghum production.

On the basis of the foregoing reasoning, the following corn yields are estimated as a fair normal yield in northeastern Colorado, on sandy loam soils:

| | |
|---|---|
| Under 14 inches precipitation | 4 bushels |
| 14 to 16.9 inches precipitation | 12 bushels |
| 17 to 20 inches precipitation | 20 bushels |
| Over 20 inches precipitation | 25 bushels |

## Application of Normal Yields to Eastern Colorado Conditions

Eastern Colorado is topographically well suited to the use of big machinery in growing field crops. When sufficient precipitation is received, satisfactory yields are obtained. However, a large part of the region receives less than enough precipitation to produce a crop in a large proportion of the years.

A study of the climatological data collected by the Weather Bureau from eastern Colorado was made. Precipitation data were summarized as totals for the 12-month periods ending June 30 and September 30. Annual totals were then segregated into groups of the same limitations used in studying the yield-precipitation data from the dry-land stations.

Figure 1 shows the relationship between average precipitation and the percentages of years below 14 inches and above 20 inches precipitation.

Figure 2 illustrates how eastern Colorado may be divided into three major areas, depending on the percentages of years that total precipitation may be expected to fall in the four groups. As a guide to effectiveness of precipitation, the average maximum temperatures for July are shown after Bates (1).

In interpreting the information shown in figure 2, it should be remembered that precipitation is more effective in regions of lower summer temperatures. Thus, we have more successful dry farming in northeastern Colorado than in the Arkansas Valley region, under the same precipitation amounts. Unfortunately, no dependable quantitative data are available which would show us how much these regions differ unless we draw conclusions from the relative yields of wheat at Garden City and Colby under similar precipitation. However, this is not entirely dependable, as Garden City wheat yields too often have been decreased by factors other than limited precipitation.

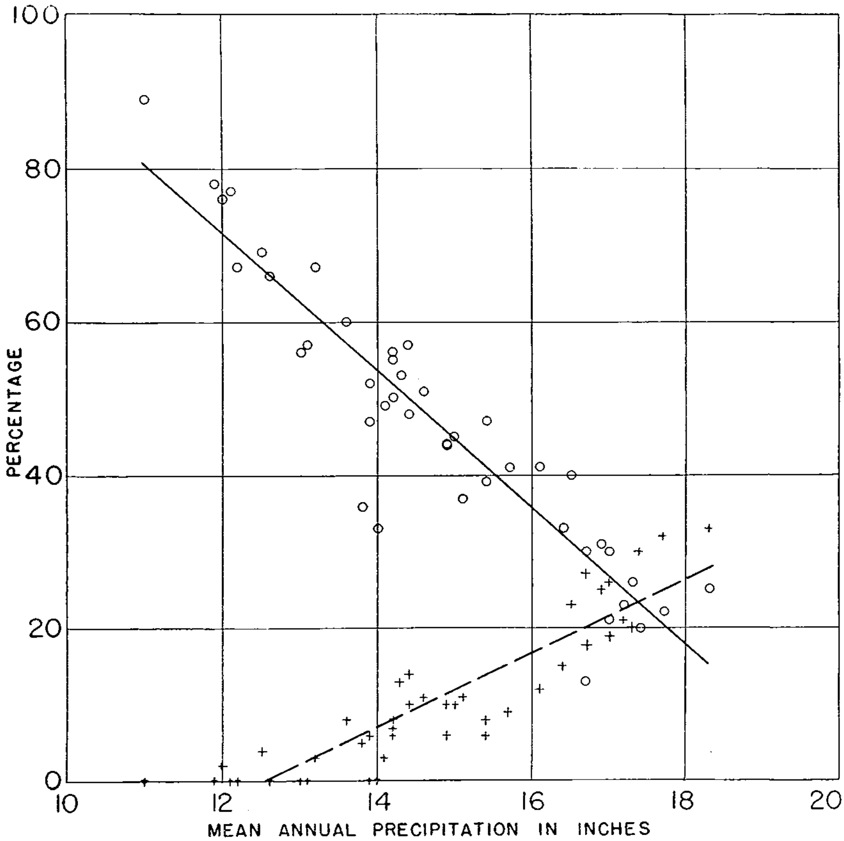


Fig. 1.—Relation of percentages of years having more than 20 inches and less than 14 inches to the mean annual precipitation. The small circles indicate percentages below 14 inches, the plus signs percentages greater than 20 inches.

Table 8 gives the productivity rating for some important eastern Colorado soils and the more important farm crops. The ratings are based on the "normal" shown in table 7 and the relationship given in table 2.

TABLE 8.—*Productivity ratings for some important soils developed in eastern Colorado.*

| Soil Series | Winter wheat | | | | Corn | | | | Forage sorghum | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Under 14 Inches | 14 to 16.9 Inches | 17 to 20 Inches | Over 20 Inches | Under 14 Inches | 14 to 16.9 Inches | 17 to 20 Inches | Over 20 Inches | Under 14 Inches | 14 to 16.9 Inches | 17 to 20 Inches | Over 20 Inches |
| Keith silt loam—I[1]<br>Rosebud silt loam—I<br>Dawes silt loam—I<br>Colby silt loam—II<br>Weld loam—II<br>Prowers loam—III<br>Fort Lyons loam—III [2] | 8 | 32 | 56 | 84 | 4 | 12 | 24 | 54 | 22 | 33 | 43 | 57 |
| Denova fine sandy loam—I<br>Rosebud fine sandy loam—I<br>Otis sandy loam—II [3] | | | | | 8 | 24 | 40 | 50 | 33 | 48 | 60 | 78 |

[1]Roman numerals refer to dominant region in which soil occurs according to figure 2.
[2]Productivity ratings based on information given in tables 2 and 7.
[3]Most of the sandy loam soils in eastern Colorado are devoted to the growing of row and feed crops, so ratings for wheat are not given.

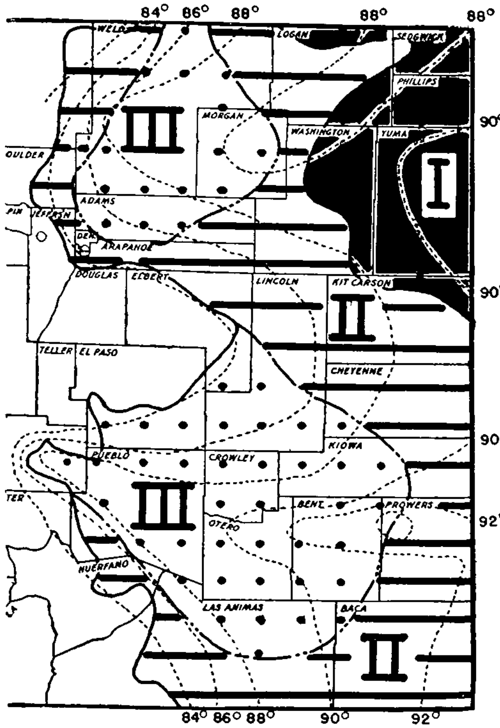


Fig. 2.—Plains part of eastern Colorado, Showing precipitation regions and July mean maximum temperatures. Broken lines indicate mean maximum isotherms, after Bates.

| | I | II | III |
|---|---|---|---|
| | *Percent* | *Percent* | *Percent* |
| Years under 14 inches | 25 | 40 | 70 |
| Years 14 to 17 inches | 25 | 25 | 20 |
| Years 17 to 20 inches | 25 | 20 | 10 |
| Years greater than 20 inches | 25 | 15 | 0 |

It will be noted in table 8 that silt loam and loam soils developed under a wide range in climatic conditions are given the same ratings, but the portion of eastern Colorado where they are developed is indicated after each series name. By reference to figure 2, the distribution of yields may be readily computed. For example, Keith silt loam and Prowers loam are given the same productivity ratings, but the Keith soil is shown as dominantly in region I and Prowers in region III.

Table 9 compares the wheat yields that would normally be produced on the Keith and Prowers soils. It will be noted that this comparison not only shows the total and average yields over a period of 20 years but also indicates how many of each type of years (good, fair, poor, failure) may normally be expected in the regions where these soils are developed.

TABLE 9.—*Comparison of yields produced on Keith silt loam and Prowers loam from information given in tables 2 and 8 and figure 2.*

| | Precipitation group | (1) Percentage of years | (2) Number of years in 20 | (3) Productivity rating, wheat | (4) Yield | (2) x (4) total for 1 acre | |
|---|---|---|---|---|---|---|---|
| | | *Percent* | | | *Bushels* | *Bushels* | |
| Keith silt loam | Under 14 in. | 25 | 5 | 8 | 2 | 10 | |
| | 14 to 16.9 in. | 25 | 5 | 32 | 8 | 40 | |
| | 17 to 20 in. | 25 | 5 | 56 | 14 | 70 | |
| | Over 20 in. | 25 | 5 | 84 | 21 | 105 | |
| | Total for 20 years | | | | | 225 | |
| | Average per year | | | | | 11.3 | |
| | Average productivity rating for wheat | | | | | | 45 |
| Prowers loam | Under 14 in. | 70 | 14 | 8 | 2 | 28 | |
| | 14 to 16.9 in. | 20 | 4 | 32 | 8 | 32 | |
| | 17 to 20 in. | 10 | 2 | 56 | 14 | 28 | |
| | Over 20 in. | 0 | 0 | 84 | 21 | 0 | |
| | Total for 20 years | | | | | 88 | |
| | Average per year | | | | | 4.4 | |
| | Average productivity rating for wheat | | | | | | 18 |

## Summary

Crop yield and precipitation records from four dry-land field stations in and near eastern Colorado served as a basis for estimating probable yields on soils developed in the plains region of eastern Colorado.

The data were studied by dividing the yield years into four precipitation groups (namely, under 14 inches, 14 to 17 inches, 17 to 20 inches, and over 20 inches, total for a year) and by statistical analysis.

Normal yields and productivity ratings for the more important crops under the four rather narrow ranges in precipitation and on two types of land were developed.

With the U. S. Weather Bureau records as a basis, eastern Colorado is divided into three regions, dependent on the percentages of years that are normally in each of the four precipitation groups.

Although Keith silt loam and Prowers loam were given the same productivity ratings under similar precipitation, it was readily shown that the average yield on the Keith soil was nearly three times as much as on the Prowers soils when the region in which they occur in eastern Colorado was considered and the distribution of good, fair, poor, and failure years accounted for.

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