ON EVAPORATION FROM A CIRCULAR SURFACE OF A LIQUID.

By H. C. BURGER.

(Reprinted from Science Abstracts, Phys. Sec., Apr. 30, 1919. p. 171. Abs. from K. Akad. Amsterdam, Proc. 21, 3, pp. 271-276, 1919.)

In literature on evaporation the opinion is often expressed or assumed as axiomatic that evaporation from a circular surface is proportional to the area, i. e., to the square of the radius of the surface. Stefan, however, showed that theoretically evaporation by diffusion into a quiescent atmosphere would be proportional to the first power of the radius. Miss Thomas and A. Ferguson [Abs. 71 (1918)] found experimentally that the power of the radius which was necessary to produce the observed results was between 1 and 2. In a dark, very quiet room the power was 1.4; in a lighted room it was 1.5 to 1.6; in the open air it was 1.65.

The author by a mathematical treatment of the diffusion of vapor into a flowing gas, finds that evaporation should be proportional to the 5/3d power of the radius. This agrees with the value found by Thomas and Ferguson for the open air.—*R. C.*

CULTIVATION DOES NOT INCREASE THE RAINFALL.[1]

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SYNOPSIS.—Cultivation does not increase the rainfall in the semiarid region. There are well-defined sequences of increasing and decreasing annual rainfall amounts, but there has been no progressive increase or decrease during the past 50 years.

It is not possible to predict the approximate precipitation for any year from past records.

INTRODUCTION.

The land in the Great Plains States is easily cultivated and is naturally very fertile. Wherever sufficient moisture is available, either from rainfall or by irrigation, large crops are possible.

In eastern Texas, Oklahoma, and Kansas, and in southeastern Nebraska, the average annual rainfall is over 30 inches, and it is so well distributed that serious droughts are not of frequent occurrence.

In eastern New Mexico, Colorado, and Wyoming, extreme western Texas, Oklahoma, and Kansas, western Nebraska and South Dakota, central and western North Dakota, and eastern Montana, the average annual rainfall is between 10 and 20 inches and droughts are frequent. In the years of light rainfall, or poor distribution, there is not sufficient moisture for crops unless irrigation is possible. Even in the region where the annual rainfall averages between 20 and 25 inches, crops suffer in the years of light or poorly distributed rainfall. This is particularly true in the southern portion of the Great Plains where the summer temperature is high and evaporation is, consequently, greater than in the northern part. The 20-inch average annual rainfall line follows roughly the 100th meridian of longitude, being considerably west of it in Texas and Oklahoma, slightly west in Kansas and Nebraska, slightly east in South Dakota, and considerably east in North Dakota, as is shown in figure 1.

As a well-distributed rainfall of about 20 inches each year is necessary for crops, unless irrigated, it follows that the western Great Plains is a rather critical region for growing general farm crops. Even when the so-called dry-farming practice is resorted to, crop failures are not unknown.

Years of abundant and well-distributed rainfall encourage a western extension of the cultivated area, and when there is a succession of favorable years farm operations may be pushed so far into the semiarid districts that in ordinary years the rainfall is entirely insufficient for crop needs, and disaster results. During these periods of unusual rainfall, the opinion is frequently expressed *that the rainfall is increasing and that this increase must* be due to the enlargement of the areas of cultivation.

Disregarding the arguments which might be presented to show that the effect of cultivation in the semiarid region must be negligible in causing the variation in

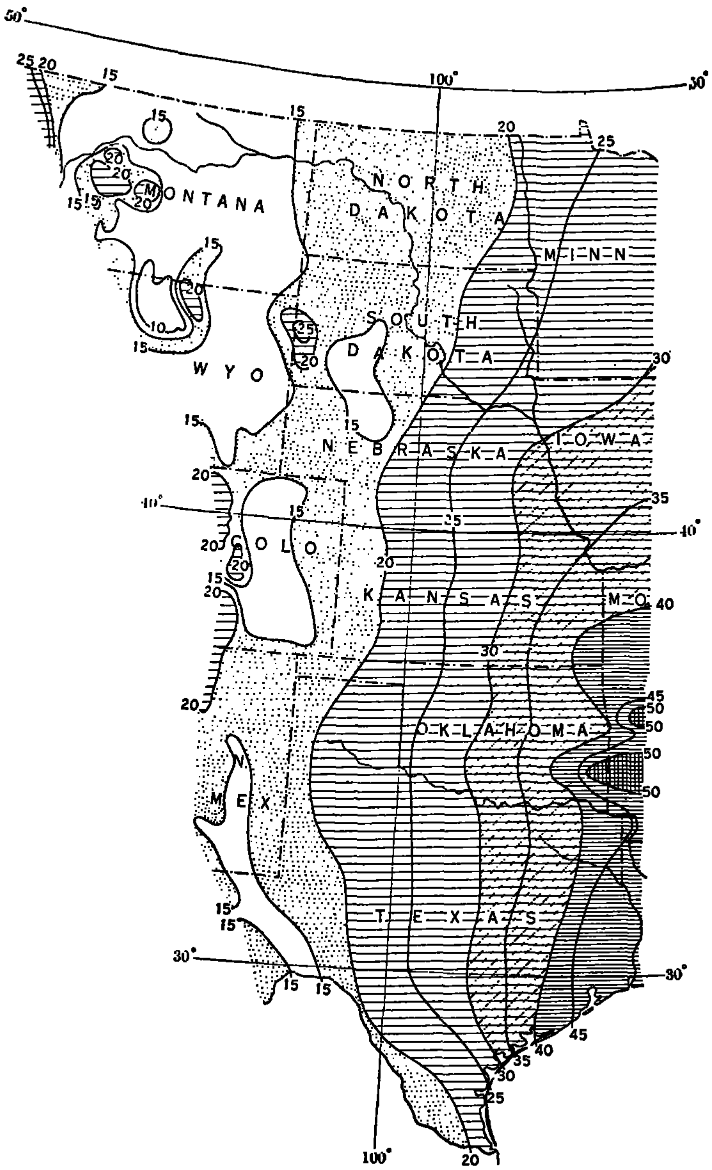

FIG. 1.—Map showing the average annual precipitation in that part of the United States lying between the 93d and the 113th parallels of longitude. (From advance folio, Atlas of Am. Agric.)

temperature and humidity necessary to produce an increase in the amount of rainfall, we have turned our

[1] Presented before a joint meeting of the American Meteorological Society and Association of American Geographers, St. Louis, Mo., Dec. 31, 1919.

attention to ascertaining whether there has, or has not, been an increase in the precipitation over the Great Plains. All available rainfall records in that district were collected, tabulated, and charted in the following graphs:

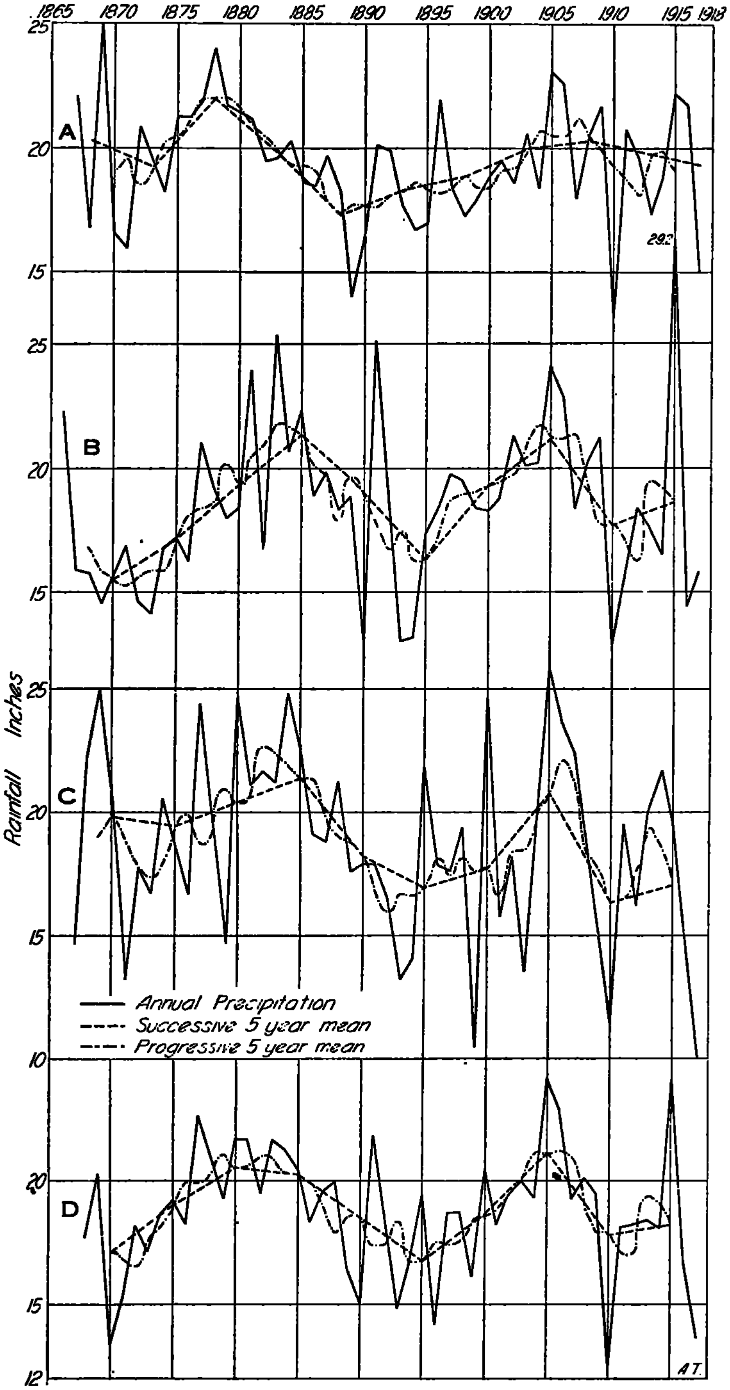

FIG. 2.—Curves showing the average annual precipitation in (A) North Dakota, South Dakota, western Minnesota, central and eastern Montana, and northeastern Wyoming, 43 stations; (B) Nebraska, central and western Kansas, eastern Colorado, and southeastern Wyoming, 38 stations; (C) western Oklahoma and Texas and central and eastern New Mexico, 40 stations; (D) average of the above, 121 stations.

Figure 2 (A) shows curves of the annual rainfall, and the successive and progressive 5-year averages of the annual rainfall from 1867 to 1917, inclusive, for North Dakota, South Dakota, western Minnesota, and central and eastern Montana. Care was taken in this, as well as in the data for the other curves, to keep the stations well balanced between the wetter eastern and drier western parts of the districts.

The curves in A show a rise in the rainfall amounts from the early to the late seventies, followed by a rather sharp decrease to about 1889–90, and then a uniform increase until 1905 and 1906, and after that a moderate decrease.

The average annual rainfall for the first 25 years of this period is 19.6 inches and for the last 25 years 19.4 inches. The average precipitation for each 10 years, beginning with 1868, is shown in Table 1.

TABLE 1.—*Precipitation for each 10 years from 1868 to 1917, inclusive, in the northern Great Plains.*

Period.	Precipitation (inches).
1868–1877	19.8
1878–1887	20.4
1888–1897	18.0
1898–1907	19.5
1908–1917	19.1

Diagram B gives similar curves for the same period for Nebraska, central and western Kansas, eastern Colorado, and southeastern Wyoming. This indicates a wider variation in the annual rainfall than in the northern States, but the same two crests in the curve. One striking difference between them, however, is that, while in A the first crest was centered in 1877 to 1879, in B it was not reached until about 6 years later. As the second crest comes at about the same time in the two areas, the time between the two crests is 29 years in the northern area and only about 23 years in the central.

The average precipitation for the first 25 years of the period in the Central Great Plains was 18.4 inches, and in the second 18.7 inches. The average for each 10 years is given in Table 2.

TABLE 2.—*Precipitation for each 10 years from 1868 to 1917, inclusive in the central Great Plains.*

Period.	Precipitation (inches).
1868–1877	16.3
1878–1887	20.4
1888–1897	17.6
1898–1907	20.2
1908–1917	18.2

In graph C there are similar curves for the southern Great Plains States, including western Oklahoma and Texas and eastern New Mexico. The first crest in this 50-year curve is at about the same time as in the central division, while the middle depression is slightly later than in either of the others.

The average annual rainfall for the 25 years from 1868 to 1892, inclusive, was 19.8 inches and for the next 25 years only 17.8 inches. The average for each 10 years is shown in Table 3.

TABLE 3.—*Precipitation for each 10 years from 1868 to 1917, inclusive, and for the 12 years from 1852 to 1862 and 1867 in the southern Great Plains.*

Period.	Precipitation (inches).
1852–1862 and 1867 (12 years)	18.8
1868–1877	19.6
1878–1887	20.8
1888–1897	17.5
1898–1907	19.3
1908–1917	16.7

In graph D the data, from which graphs A, B, and C were prepared, were averaged so that this shows the annual and progressive and successive 5-year mean precipitation for the whole western Great Plains region.

This indicates two well-defined crests in rainfall about 25 years apart, with the low part of the curves at the beginning, middle, and end of the period of 50 years.

The average precipitation for the 25 years from 1868 to 1892, inclusive, was 19.2 inches, and from 1893 to 1917, inclusive, 18.4 inches. The average for each 10 years is shown in Table 4.

TABLE 4.—*Precipitation for each 10 years from 1868 to 1917, inclusive, over the western Great Plains.*

Period.	Precipitation (inches).
1868–1877	18.1
1878–1887	20.4
1888–1897	17.5
1898–1907	19.9
1908–1917	18.4

There has been a decided increase in the area unerd cultivation in the Great Plains States during the past 50 years as brought out by figures in Table 5.

If increasing the area under cultivation in any district increased the precipitation, we should expect a steady rise in the annual rainfall amount over the region covered by this study. Instead of finding a regular increase, the graphs in figure 2 make plain that there are well-defined but comparatively short periods of increasing and decreasing rainfall, but which can not be due to cultivation. The crop area is being extended into the drier region because of crop adaptation and better farming methods. Moisture is conserved that formerly ran off, dry-farming methods are being adopted, and crops better adapted to the region are being planted.

An interesting fact in connection with the precipitation records is that dry years occasionally occur during a wet period or wet years in a dry period. This is brought out by the light rainfall in 1882 in graph B, and the very heavy rainfall in 1915 in graph D.

TABLE 5.—*Acreage of certain grain crops in the Great Plains States.*

Crop and State.	Year.			
	1867	1882	1892	1917
Barley:	*Acres.*	*Acres.*	*Acres.*	*Acres.*
Kansas	224	20,882	13,901	750,000
Nebraska	222	156,000	90,223	213,000
The Dakotas		28,273	321,693	2,845,000
Montana		1,852	5,032	90,000
Corn:				
Kansas	6,555	472,619	1,547,175	9,156,000
Nebraska	11,479	400,119	1,615,393	9,240,000
The Dakotas		140,000		3,940,000
Montana		492	1,080	81,000
Oats:				
Kansas	6,555	472,619	1,547,175	2,284,000
Nebraska	11,479	400,119	1,615,393	3,038,000
The Dakotas		140,000	1,174,449	4,500,000
Montana		28,000	66,323	680,000
Wheat:				
Kansas	89,285	1,573,000	4,070,724	3,737,000
Nebraska	9,917	1,657,000	1,253,564	997,000
The Dakotas		720,000	5,410,077	10,716,000
Montana		42,812	41,761	1,727,000

The opinion is expressed by some students of weather data that dry and wet years come in groups of two or three each, but this belief is not substantiated by these charts. In other words, it is not possible to predict what the total precipitation for any year will be from past records. A wet year may be followed by another wet one or by a very dry year, or vice versa. For example, the dry year of 1890, in graph B, was followed by one of the wettest in the whole period, while the dry year of 1913 was followed by one equally dry.

In graph D it will be seen that the wet year of 1877 was followed by one nearly as wet; that of 1891 by a rainfall not far from the normal; that of 1905 by another wet year, and 1915 by one with considerably less precipitation than the normal.

AUSTRALIAN DROUGHTS.

By CHESTER RICHARDSON.

[Dated: Currie, King Island, Tasmania, Oct. 25, 1919.]

Although the primary causes of drought are unknown, an indicator apparently of immediate value is the mean temperature difference for the months June, July, and August, between the southern portion of Australia, and the source from which the latter obtains its rainfall in *the months names*, viz, the belt of drift weather, which in normal winters extends along a fairly direct line from west to east, in proximity to the 40th parallel of latitude in the Great Southern Ocean. The highest mean temperature difference between the belt and the southern seaboard of Australia obtains in usual winter seasons, when the elements contained in the belt traverse the course above-mentioned. In these conditions, the mean land temperature being higher than that of the belt, the cooler air of the latter shows landwards in convectional circulation to restore equilibrium. The result is SW. winds and rain upon the land.

The lowest mean temperature difference occurs when the belt—from some cause at present unknown—curves northward, or over a portion of the South Indian Ocean, and, in regaining its easting, carries with it atmosphere of considerably higher temperature than when traversing the 40th parallel course. The effect of this warm general NW. wind is to cause the dry land air to flow *toward* the belt, and as a consequence, drought or droughty conditions ultimately ensue.[1] Since such a northward curvature over the Indian Ocean seems to persist for months at a time, persistent NW. winds in Westralia and Tasmania may give indication of a droughty season to follow.

[1] Perhaps associated with the distribution of ocean surface temperatures. Cf. MONTHLY WEATHER REVIEW, November, 1918, 46: 510–514.