T H E S I S

THE RELATION OF KANSAS CLIMATE TO THE INCREASED PRODUCTIVITY OF THE STATE

by

Oliver H. Gish
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The Relation of Kansas Climate to the Increased Productivity of the State.

Kansas, a portion of the great western plains, once considered incapable of sustaining a civilized society, now one of the foremost agricultural states in the United States, presents a marked transformation, the cause of which has at times been a source of considerable conjecture. Has a change in climate effected this transformation or has the transformation, however, producted affected the climate? To answer this shall be the object of this discussion.

The term climate in its proper use has reference to the sum total of weather conditions, the term implying at least a degree of permanency for we speak of the weather of a certain day or month or year but to speak of the climate of a place one refers to its mean weather conditions.

One of the primary factors in the climate of a place is its latitude. In Kansas this does not result in much variety of climate, as the difference in latitude between the southern and northern boundries is but three degrees with a difference in temperature of 6 degrees Fahr. and a harvest period beginning about two weeks earlier in the southern than in the northern part.

In some countries one may pass from frigid through temperate to torrid climate, by a few miles journey down a mountain side, but no such variation is found in Kansas, whose surface is undulating and gently rising toward the west at the rate of eight feet per mile. Beginning in the lower eastern portion of the state and passing westward in the same degree of latitude, the mean annual temperature of a number of stations of varying altitudes are as follows: Kansas City, Mo., 53.°2 Fahr; Lawrence, 53.°3; Topeka, 53.°3; Manhattan, 53.°5; Salina 54.°6; Hays, 54.°; Gove 52.°4; and Wallace 51.°6. From Kansas City to Manhattan the altitude increases 137 ft. If the temperature followed the vertical temperature gradient that of Manhattan should be 0.°7 lower than that of Kansas City, while there is an actual increase of 0.°3. From Manhattan to Wallace the altitude increases 2,203 ft. and simply from change in altitude we might expect 7.° decrease in temperature, while only 1.°9 are recorded.

Of course temperatures near the earth's surface do not follow the vertical temperature gradient, that is do not decrease at the rate of 1.°6 for each 300 ft. increase in altitude, be cause the radient heat, which is the chief factor in warming the air, is more active near the earth, than at greater distances. It is also probable that the greater tree growth and other vegetation in the eastern part of tend to reduce the mean temperature of this portion somewhat, but a more potent factor, is the greater moisture in the eastern part, which on evaporation, "stores up" as latent heat, much heat energy that in the west adds to the temperature of the air.

Within itself Kansas offers no great obstruction, such as mountain barriers, to an equable distribution of climate, but less than two hundred miles from the western border of the state, stretching across the United States from north to south stand the Rocky Mountains, and yet farther west the Sierra Nevada and Coast Ranges, to intercept the moisture laden westerlies, which otherwise might provide with refreshing rains, the land for two thousand miles inward.

As a probable result of this barrier, a belt of arid and semi-arid country lying from seventy-five to one-hundred and filty miles east of the mountains, and varying in width from one hundred to three and four hundred miles at places, extends north and south across the United States and includes a considerable portion of western Kansas. The moisture of the pacific being thus barred from reaching Kansas, we must look elsewhere for the source of our rains.

Though of the 82,080 sq. mi. of Kansas surface, 384 sq. mi. is water surface yet no lakes or marshy areas large enough to affect the climate are found in the state, this area representing drainage courses. Hence, Kansas is exceptionally well drained and if its rainfall upon plains thatched with buffalo grass or other sodded vegetation as is the case in much of western Kansas, it can be little wonder that the country is soon left dry and unproductive.

Other large bodies of water than the Pacific Ocean, whose vapors may later become our rains, then, are the far-off Atlantic or the Great Lakes, but in either of these we would be compelled to assume, east winds, continuous for several days, a condition contrary to theory as well as to observed facts. The only source, then, which remains is the Gulf of Mexico. That the Gulf of Mexico is the chief source of our atmosphereic moisture is corroborated by observed facts. The Kansas State Agricultural College Meteorological records show repeatedly, that after two or three days of south wind rain generally follows. Not always, however is the south wind followed so soon by rain. Sometimes these winds blod several weeks, getting hotter and drier, until vegetation standing in the soil is as dry as through it were in the swath.

According to the records of this station it is not often that this vicinity has been visited by the destruction which these winds are charged with bringing to the country farther west of us. However, from July 23 to 31, 1894, a typical hot-wind is recorded here. It blew from points in the south quadrant the entire period of seven days. The temperature rose to 102°, 107° and 109° Fahr., the relative humidity falling to 22% on the fourth day and averaging about 40% as observed at 2 p. m. daily for the seven days. Prospects of the corn crop were destroyed, not even good fodder being had from it.

From the records of these winds may be obtained a suggestion that probably the arid regions of western Texas and New Mexico are an important factor in this effect, for the resultant wind of the period just mentioned was more west of south than the normal wind direction, and further evincing this is the fact that the resultant wind directions of the two driest periods on record here, 1876 to 1879 and 1890 to 1894, inclusive, when compared with the resultant wind directions of the two wet periods, 1870 to 1875, and 1902 to 1905 inclusive, are seen to be more west of south in the former than in the latter. This however, as other hypotheses that have been offered to explain the cause of the hot winds of Kansas and Texas is not wholly satisfactory.

Now it has been seen that two important factors in Kansas climate are the Rocky Mountains and the arid southwest. If man could level the Rockies or sink the arid southwest beneath the sea he might be sure that the climate of Kansas would change especially that of the wester portion. But whether cultivation or vegetation can be made to provide what the Rockies deprive us of or whether these can obstruct the injurious effects which come upon us from the arid southwest, shall now be considered.

That cultivated soil is a better moisture absorbent and conserver than uncultivated soil and that the former tends to lessen the range of temperature as far as its influence extends, is the sum of what may be claimed for cultivation, beyond what it may do indirectly in supporting a vegetation. A cultivated soil is a better absorbent and better radiator of heat than a bare, hard packed or uncultivated soil, while the latter is a better conductor and reflector than the former, and as is well known, will give rise to inversion of temperature and favors frost formation, in its season.

While the cultivated soil may promote convection of the atmostphere, especially in the morning when the air is calm and cool; but in order that the convection currents thus set up may act in rain production, the area in which this condition of soil exists would necessarily be large and uniform in surface. But the cultivated soil is covered with vegetation much of the time, and as it is well distributed over the areas, we shall consider; cultivation cannot be said to be directly an accountable factor in climate, at least in rain production. It would be easier to conceive of a hard, uncultivated, soil with high capillary power as aiding rain production, by giving a considerable amount of moisture to the atmosphere in the form of watery vapor. Willis L. Moore, Chief of the U. S. Weather Bureau, says, bearing on this subject; "If the clouds were low down close to the soil the hot (uncultivated) soil might add a little heat to evaporate the cloud particle, preventing rain and causing the cloud to rise a little higher, but the ordinary cumulus cloud which is several thousand feet above ground, the dry or moist soils would have no influence upon, unless the areas were of such magnitude as one-hundred miles square."

Whether the vegetation promotes the condensation of moisture is a much disputed question, and a review here of the conclusion that such authorities as Becquerel, M. Mathieu, and Willis . Moore, have reached from their investigations, may be of not little interest.

If vegetation does promote the condensation of moisture, then it is assumed to follow that forests would show this most distinctly and hence it is upon forests that observations and investigations have been made.

From a series of investigations of the rainfall over forests Becquerel concludes that forests increase the rainfall considerably. Bur some sources of error in his work were then evident and M. Mathieu then set about taking data avoiding the more evident sources of error in Becquerel's work, and in his conclusions he says the increase in rainfall in the afforested region attributable to the effects of the forest was 15.5 m. m. over that of the disafforested.

Dr. J. M. Anders says, "Forests may slightly promote the condensation of moisture by inducing upward movements of the air, as mountains are known to do on an extensive scale." But their action in this respect cannot be taken into much account, because the rate of adiabatic cooling, upon which condensation, by this rising of the air depends, is but 1.°6 Fahr. for each 300 ft. ascent, so that for the average height of forests and the prevailing humidity, the temperature would seldom be lowered to the dew point by this means; and in a region of great humidity, this adiabatic change would be considerably retarded by the release of latent heat by the first condensation.

Observations made by the forest meteorological stations of Bavaria, Alsace - Loraine, France, Switzerland, and Italy, show that the increase of rainfall over forest regions is more pronounced in winter than in summer. This can probably be accounted for in that the vertical temperature gradient is greater in winter than in summer, so that it will not be necessary to force the air so high at this time of year in order to reduce it to dew point temperature. Another explanation may be that the forest air which is known to be warmer than the surrounding air, in winter, when cooled by currents of colder air passing over and mixing with it, will yield up some of its moisture. While in summer the mixing of the cooler air of the forest with overflowing warmer currents, would not as likely result in condensation, because the amount of air which would necessarily be cooled in order to yield moisture is vastly the greater.

Some say that forests generally have a lower barometric pressure than surrounding regions, and by thus "attracting" storm centers result in more rainfall over forest regions. This is doubtful. Again it is argued that the greater amount of water-vapor given off from a forest should increase precipitation. It is indeed astonishing to one who has never given the matter much thought to learn of the great amount of water given up by a forest in transpiration. Dr. J. M. Anders says, "It is computed from experimental tests, that they give off in this way, twelve times as much water as is evaporated directly from the soil in which they stand, twice as much as goes up from the free soil, and more than is emitted from an equal body of water." While it is conceivable that this may greatly aid the formation of dew, which of itself is no small benefit to growing crops where properly utilized, yet according to the theory of rain formation generally accepted by meteorologists, it is not evident that this abundant supply of water vapor would increase the rainfall over the forest area in consideration.

The average temperature of forests is lower than in open regions similarly located, owing to the vast amount of solar energy, converted into potential energy as plant food and structures by photo-synthesis. The temperatures throughout the year are more moderate and the humidity is always greater than in unwooded regions.

Herr Woeikoff says; "The influence of forests in diminishing evaporation from water and soil is so great that it cannot be accounted for alone by the lower temperatures of the hot months, the greater general humidity or even the shade, but their protection from wind is greater than all the other factors in checking evaporation.

What is true of forests is an exaggeration of lesser vegetation, such as the staple crops of Kansas. If forests aid moisture condensation by causing upward currents in the air or by supporting a body of air differing in temperature from that which may blow over it, if vast forests of lofty trees thus increase precipitation only 15.5 m. m. (0.61in) per year, it would be at the best a very small increase that a vegetation such as corn or wheat would produce.

A comparison of meteorological data of Kansas, especially of the western part, where records have been kept from the first settlement of those portions, before any vegetation except the native prairie grasses grew there, until now when a great part is under cultivation, may reveal some facts which, though they be contrary to our theories or expectations, nevertheless deserve our respect.

According to the record kept at the Kansas State Agricultural College, beginning in 1859, the mean annual rainfall for 48 years is 30.45 inches. In the first 24 years of this record 14 years fell below this normal, with a total shortage of 77.53 in. In the following 24 years, 10 years fell below this with a total shortage of 44.78 inches, while the total precipitation for the first 24 years was 723.52 inches and that of the last 24 years was 735.97 inches or 12.45 inches more in the last half than in the first, or an increase of one half inch per year in the last 24 years. However, this will not justify a conclusion that the rainfall is increasing here, for besides some shortcomings of the early records and errors that were sometimes made in esposing the rain guage, there is what seems to me a more important consideration which would increase the total of the last division.

According to Brückner, periodical variations are found, in reviewing meteorological records to be quite common, having a time between extremes of about 35 years. By plotting the average annual precipitation fove year periods in inches as ordinates and each, year divisible by five, as abscissa, curve No. 2, Plate I, is obtained which shows a period in the records of the college, with a high extreme at from 1877 to 1878 and another at 1902 to 1903. From this it is evident that the first 24 year period must include a greater proportion of the low part of the oscillatious than the latter 24 years. Agaim, a considerable portion of these 12 inches increase might be accounted for by other abnormal conditiins, for in the month of May, 1903 (year of the flooding on most of the Kansas River Systems) the total rainfall was 8.4 inches above normal.

The mean annual temperature for this station from 1859 to 1906 is 53.°5, from 1884 to 1906 is 53.°67, showing a slight increase in the latter part of the record, but so small that it may hardly be accounted at all, and even larger differences than this are shown to be due to difference in thermometers, as they get older, difference in esposure and differences in the height of the thermometers from the ground.

Other stations whose records will be considered, are selected so that each may represent a different part of the state. They are Concordia, in the north central part; Wichita, in the south central part; Hays in the north-west-central part; Dodge

City, in the somewhat southwestern part; and Wallace, in the extreme western part. The following table will compare the earlier with the later parts of the records of precipitation:

Name of Station.	From	to	Precipi-tation, inches	
Concordia	1886	to 1895	247.64	Increase in latter part
	1895	to 1905	298.54	
Wichita	1889	to 1897	253.37	Increase in latter part.
	1898	to 1906	298.72	
Hays	1869	to 1887	449.21	
	1888	to 1906	440.98	Decrease in latter part.
Dodge City	1867	to 1886	393.97	Increase
	1887	to 1906	411.41	
				Decrease.
Wallace	1870	to 1889	313.31	
	1885	to 1905	292.72	

This comparison can hardly be said to show definitely that the rainfall is either increasing or decreasing, taking the state in general. With the exception of Dodge City, those records in this tabulation, showing an increase in the last half, are comparatively short and the first half contained the exceptionally dry period of which 1893 and 1894 are the extremes, and the later period contains the extremely wet period of which 1902 and 1903 are the extremes at this station.

Now, in order to see the relation between production of staple crops and rainfall, curves plotted by letting one small space upward represent an inch of rainfall and on plate I, four spaces to right indicate one year and on plate II, five such spaces represent one year. Curve No. 3, Plate I is a representation of the production of corn at Manhattan (Riley County).

Curves Nos. 3 and 4, Plate II of wheat and corn respectively at Dodge City; Curve No. 1 on each plate is for the annual rainfall throughout the record of the respective stations; while No 5 on each plate represents the total precipitation from April to September, inclusive, and No. 6, from October to March inclusive.

From these curves it will be seen thaat the productivity of this county does not vary directly as the precipitation, or vice versa, and that other factors, such as hot winds and equable distribution of moisture often determine the crop production. The curves showing the seasonal distribution seem to show no definite and regular relation between seasonal distribution and productivity. They also seem to indicate further that the rainfall has not been better distributed to the growing season, of late years than earlier. The seasonal distribution for Manhattan and Dodge City in numbers is as follows:

City	From to	Season. Oct. to Mar.	Season. Apr. to Sept.	Per cent during growing season.
Manhattan	1859 to 1882	181.21	542.61	74.9
	1883 to 1906	183.54	572.53	75.7
Dodge City	1867 to 1886	82.73	292.64	77.9
	1887 to 1906	93.22	305.24	76.6

This would indicate a slight increase at Manhattan and a somewhat larger decrease at Dodge City. It further shows what is generally quite well recognized that the annual precipitation is better distributed to the growing months in the western than in the eastern part of the state.

The curves for the corn yield at Manhattan and for corn and wheat yields at Dodge City, show that the yield per acre has gradually decreased at these two places. This, if true, is probably due to the fact that the acreage has been increased in later years to the neglect of cultivation, and partly because of inaccuracy of crop reports, the earlier reports being given out of the exaggerating optimism of new settlers in a new home; sometimes subject to the dilating influences of real estate booms and local pride, while the later reports have been collected through a better developed system.

From the foregoing considerations it seems unwarrantable to assert that the climate of Kansas, western Kansas in partucular, is changing. At Dodge City in the more general representation of the annual precipitation (curve No. 2, Plate II.) we notice a period similar to that at Manhattan, with one high extreme at f from 1880 to 1885; another at about 1900, and consequently we should expect, assuming the precipitation constant in other respects, a greater total for the last half of the record than for the first, while this as in other cases on record does not indicate a general increase in precipitation, as in ten or fif- teen years from now this may be counteracted by a shortage of precipitation.

In conclusion, if we would assign one cause for the change wrought in Kansas in the last half century, rather than ascribing the change to an alteration of so indomitable a feature as the climate, it would seem to me more nearly right, to say that it is the skillful and economical use and adaptation made of the bounties of nature by the industrious Kansas farmer, that this change is due.

By proper tillage, by well appointed wind-breaks, such as strips of trees and hedges, and by planting a vegetation and practicing a cultivation which aids the soil in absorbing and con-conserving what moisture falls upon the land and by a careful selection of crops and varieties especially adapted to the climatic conditions, some phase of agriculture can be followed with profit in nearly every square mile of Kansas land.

Oliver H. Gish, '08.

PLATE I.

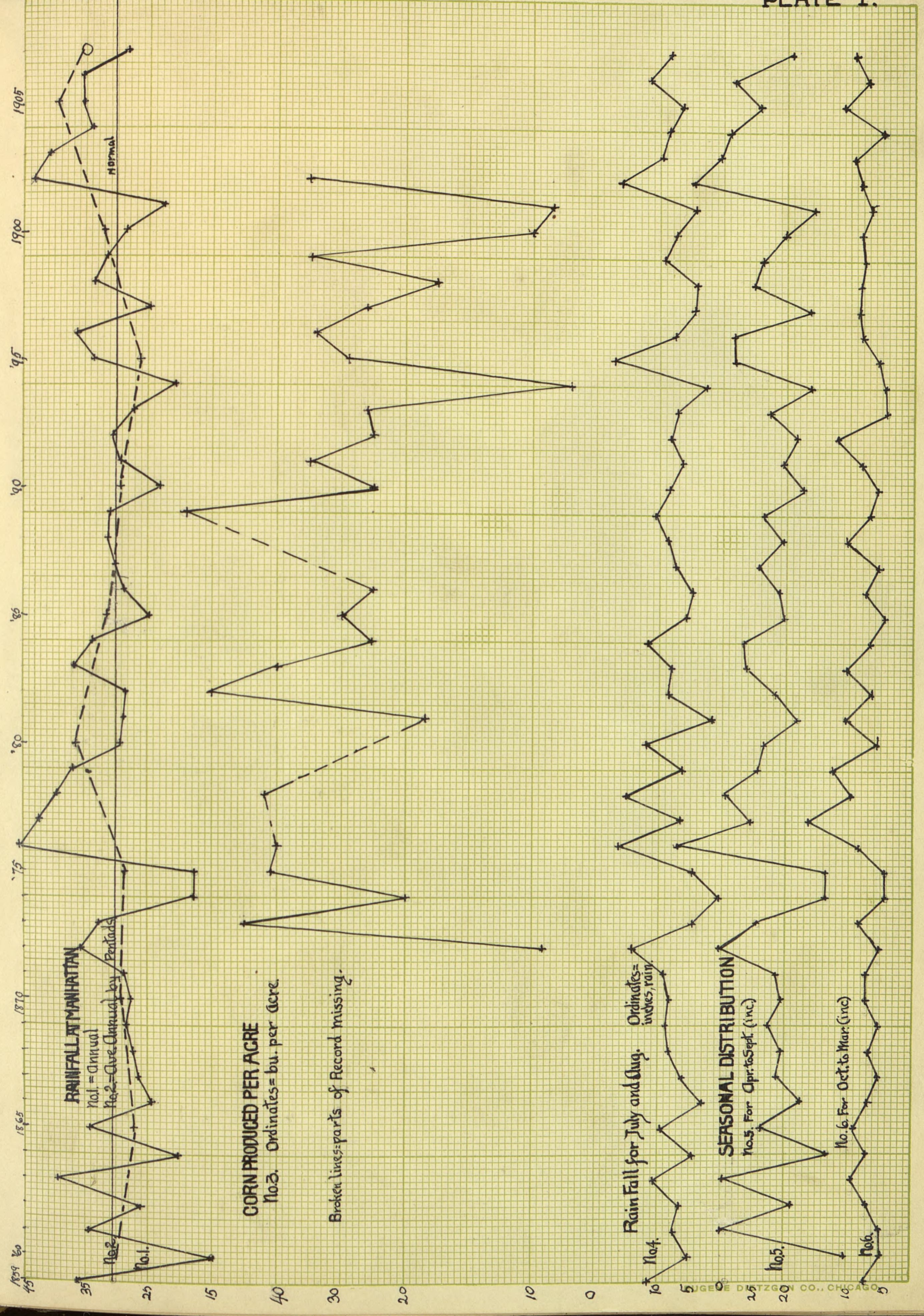
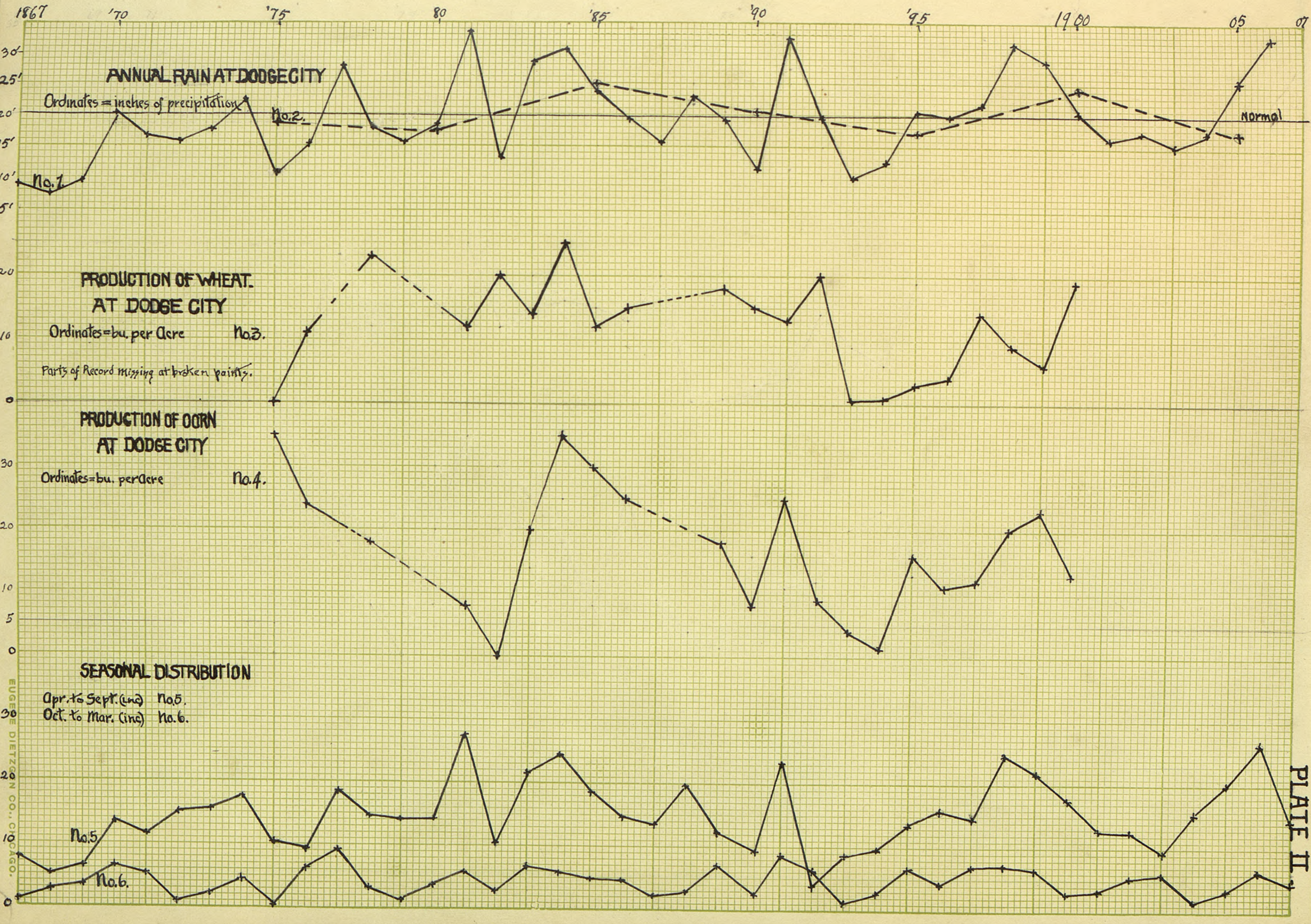

RAINFALL AT MANHATTAN
No.1 = Annual
No.2 = Ave. Annual by Pentads
Normal
No.1.
No.2
CORN PRODUCED PER ACRE
No.3. Ordinates = bu. per acre
Broken lines = parts of Record missing.
Rain Fall for July and Aug. Ordinates = inches rain
No.4.
SEASONAL DISTRIBUTION
No.5 For Apr. to Sept. (inc.)
No.5.
No.6 For Oct. to Mar. (inc)
No.6.
1859
'60
1865
1870
'75
'80
'85
'90
'95
1900
1905
EUGENE DIETZGEN CO., CHICAGO.

PLATE II.


1867
'70
'75
80
'85
'90
'95
1900
05
07
ANNUAL RAIN AT DODGE CITY
Ordinates = inches of precipitation
No.1.
No.2.
Normal
30'
25'
20'
15'
10'
5'
PRODUCTION OF WHEAT.
AT DODGE CITY
Ordinates=bu. per Acre
No.3.
Parts of Record missing at broken points.
20
10
0
PRODUCTION OF CORN
AT DODGE CITY
Ordinates=bu. per Acre
No.4.
30
20
10
5
0
SEASONAL DISTRIBUTION
Apr. to Sept. (ins) No.5.
Oct. to Mar. (ins) No.6.
No.5
No.6.
30
20
10
0
EUGENE DIETZGEN CO., CHICAGO.