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The Effect of Climate and Soil upon Agriculture

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II. THE EFFECT OF CLIMATE AND SOIL UPON AGRICULTURE

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Field studies in farm management are at present almost wholly confined to measuring the profitableness of a farm business and analyzing the effect of those factors which fall largely within the control of the farm operator. While factors beyond individual control have always been recognized in field work, very little attempt has thus far been made to measure their influence upon farming. It is true that with present weather, soil, botanical, census, and farm management data only preliminary measurements can be made, but nevertheless such measurements do much toward correlating what at present are disconnected facts in agricultural science. The use of these measurements in farm management appears to be of particular importance in a region of low rainfall or low temperature. In a state such as Nebraska it is quite impossible to analyze intelligently either our eastern or western types of farming without first analyzing the influence of natural factors.

The discussion which follows illustrates briefly an analysis of the effect of a few interesting and important variations in climate and soil. In order to give a broad veiw of this analysis the more detailed facts secured from local data have been oriented with respect to broad geographic principles.

The border regions of agriculture in North America, Europe, and Asia are determined by low rainfall or low temperature. In central United States, southern Russia, and western China successful agricultural practices are in harmony with critically low rainfall. In southern Canada and northern Russia they are in harmony with critically low temperature. While moisture and temperature are the chief concerns of border regions, soil fertility is the chief concern of a region well within critical lines.

Figs. 1, 2, and 3 illustrate the relative importance of moisture, soil fertility, and temperature, as limiting factors in crop production.

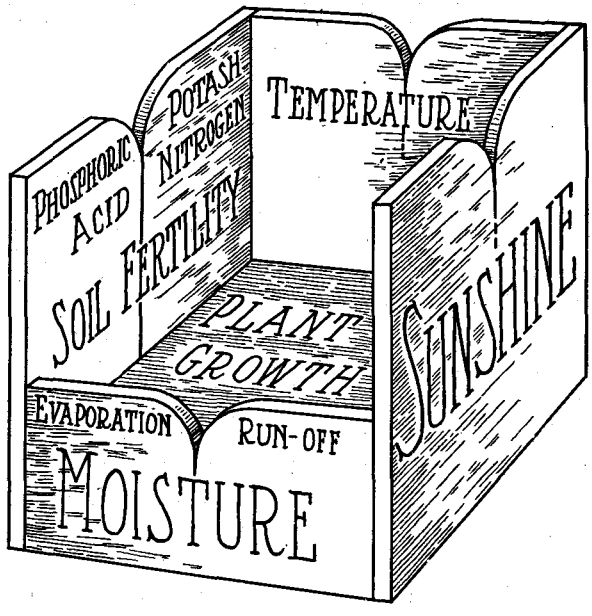


FIG. 1. Moisture the limiting factor in the Great Plains.

Climate and soil are best described as natural factors over which, in the large, we have little or no control. In contrast with natural factors there are so-called artificial factors. These lie to a certain extent within the control of individuals or groups of individuals. Government, organized commerce, and the organization of private business serve as illustrations.

In an early day people of western Nebraska and similar regions were not inclined to look upon climate and soil as fixed. They expected them to be greatly modified as a result of breaking new land and growing cultivated crops. This idea lasted only so long as they lacked actual experience with the country. A few years of effort made it plain that to do profitable farming it was necessary to conform to the natural conditions of the region. This

conformation has now reached a stage where the organization of farm business may be used as a measure of the effective value of climate and soil.

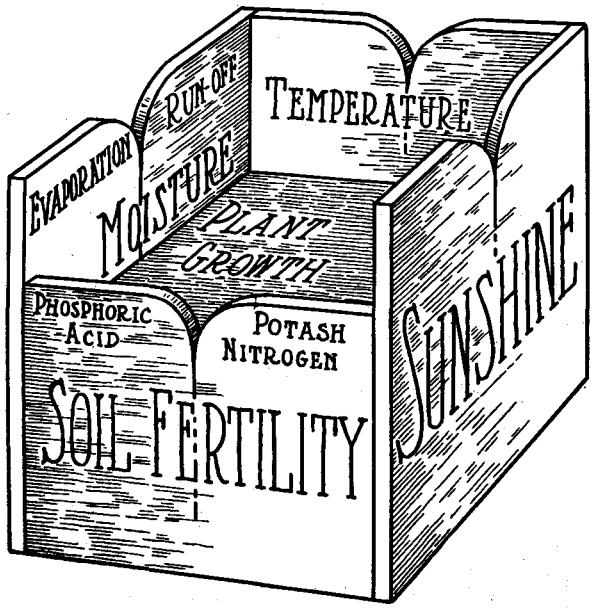


FIG. 2. Soil fertility the limiting factor in the east and similar agricultural regions.

Artificial factors in Nebraska are distributed almost directly proportional to the people. In fact, the relation between the two is so close that it would appear that each individual carried a unit charge of that force necessary to produce what is termed artificial. This is well illustrated by the distribution of our towns and railroads; also by the variation in the size of our congressional districts and counties. If the relation between natural factors, artificial factors, and people were not so close the analysis of the various effects of climate and soil in this state would be more difficult.

During the past three years (1913–1916) Farm Management Surveys have been conducted in Merrick, Fillmore, Gage, Seward,

Dakota, Thurston, Richardson, Johnson, Box Butte, Phelps, Dawes, and Kimball counties. The adaptation of farm business to natural conditions in these different areas is striking. A contrast of eastern and western farming will illustrate some of the adjustments necessary to meet a marked decrease in the effective

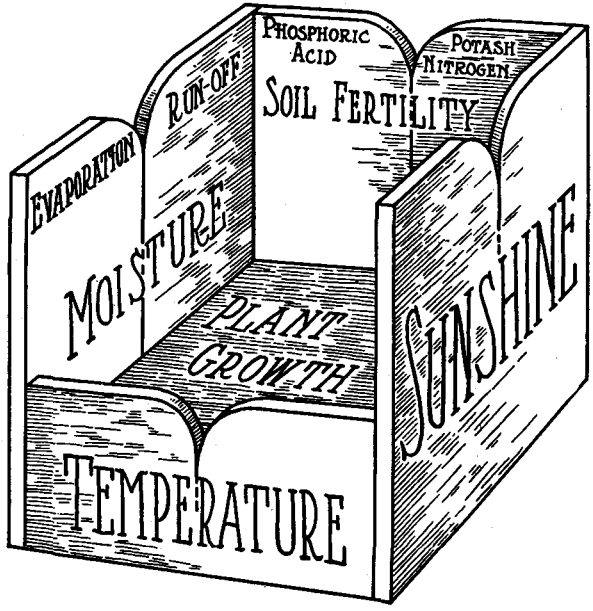


FIG. 3. Temperature the limiting factor in the north.

value of natural factors. Observation and measurements confirm the fact, that of all the elements entering into natural factors, moisture and texture of soil are the most important in this state.

The sparse plant growth on our western uplands compared with the more dense plant growth on adjacent valley or irrigated lands, affords ample proof of the low effective value of moisture in western Nebraska. From a mere observation of these facts, however, it does not follow that well-organized upland farms in western Nebraska are unprofitable. Such facts simply indicate that a very large area is needed to produce plant food sufficient

for an average family living. For example, on some of the table lands in western Nebraska a section and a half of land at present produces plant food about equivalent in value to that produced on a quarter section of upland in the southeastern part of the state.

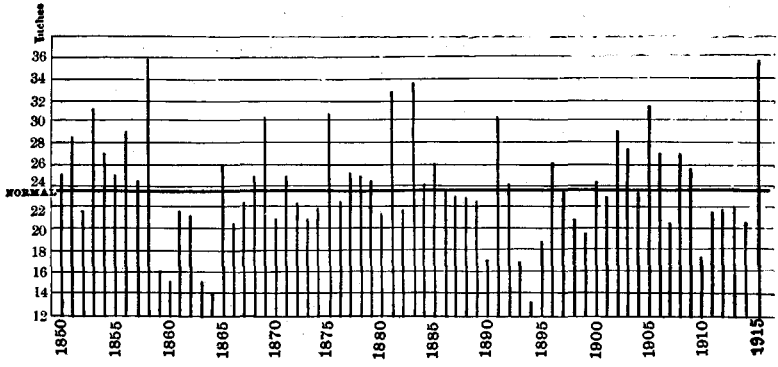


FIG. 4. Average annual precipitation for Nebraska from 1850 to 1915.

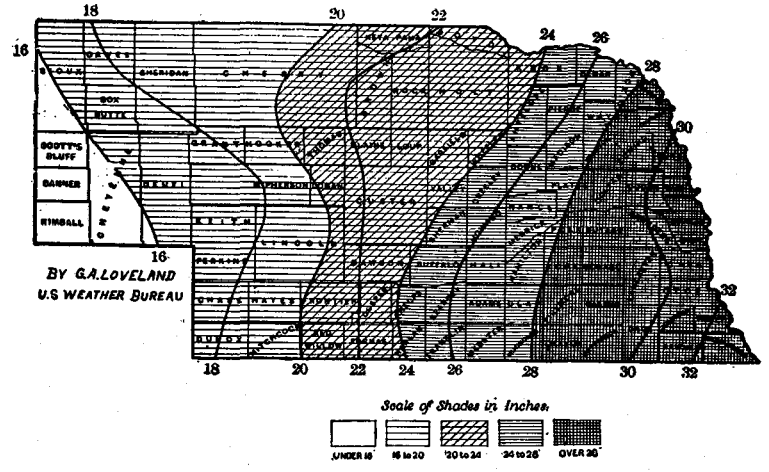


FIG. 5. Average annual precipitation.

Actual measurements show that the total capital, labor, and profits on average farms well adapted to western conditions are about the

same as on average farms well adapted to southeastern Nebraska. Though a time may come when it will be profitable for people to decrease the average size of farm or increase the average amount

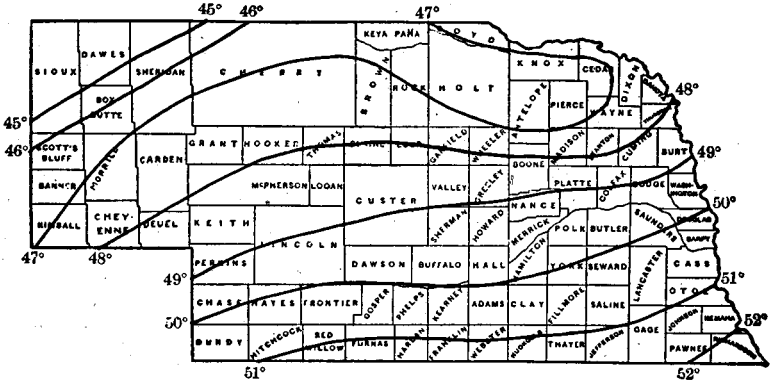


FIG. 6. Mean annual temperature.

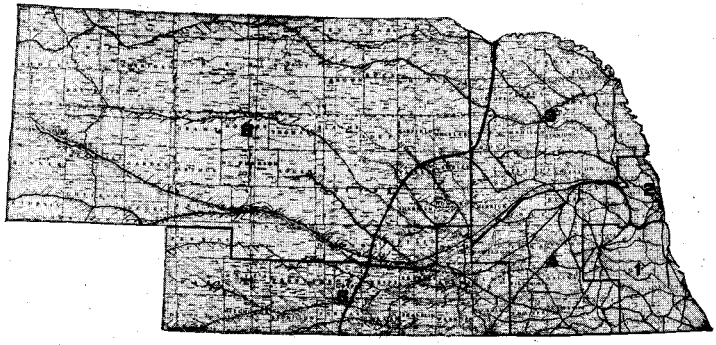
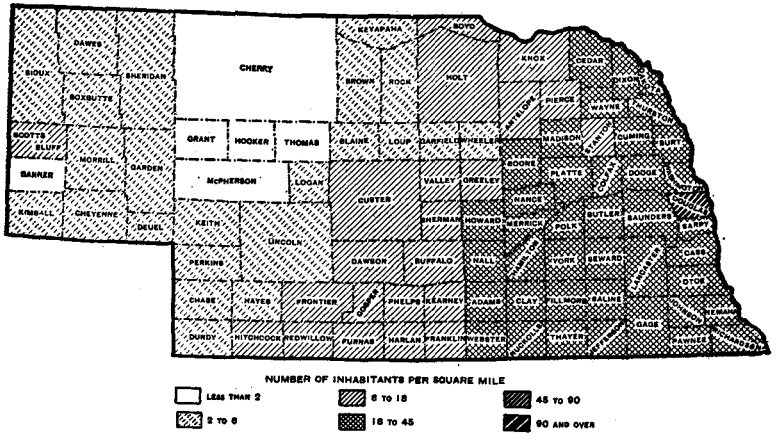


FIG. 7. Congressional district, towns, and railroads. Compare the west half of the map with the east half.

of labor per farm in these two regions, there is good reason to believe that the ratio which now exists between them will not be greatly affected.



Rural population is defined as that residing outside of incorporated places having 2,500 inhabitants or more.

FIG. 8. Density of rural population (census 1910).

Some parts of the above discussion will be made more clear by a graphic illustration (Fig. 10) of average southern Nebraska farms. Soil texture and topography are much the same from Dundy county to Richardson. The differences that exist in soils along this scale are probably slightly to the advantage of the

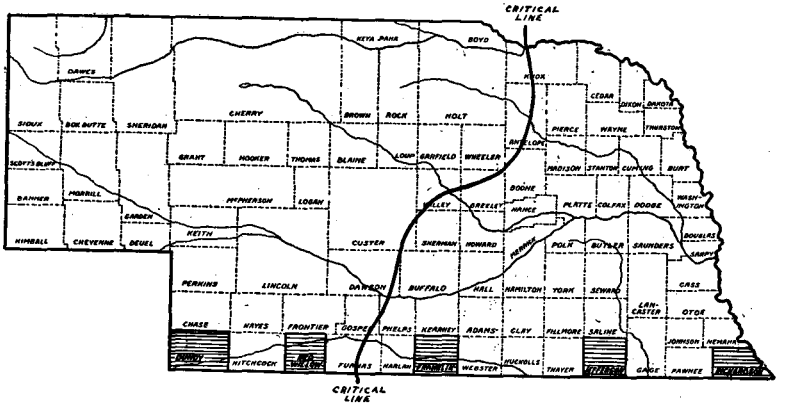


FIG. 9. Counties entering into a scale of study across southern Nebraska.

DATA ENTERING INTO A SCALE OF STUDY ACROSS SOUTHERN NEBRASKA

County	Dundy	Red Willow	Franklin	Jefferson	Richardson
Rainfall	18 in.	21 in.	26 in.	29 in.	32 in.
Growing season	140 d.	150 d.	155 d.	165 d.	165 d.
Farm area	640 a.	353 a.	235 a.	189 a.	158 a.
Crop area	269 a.	260 a.	193 a.	155 a.	136 a.
Total farm capital	$11,974	$12,708	$13,404	$15,663	$16,092
Man labor per farm	1.6	1.6	1.6	1.6	1.6

coarser and more open soils in the western counties. With important variations in soil practically eliminated, climate in this scale becomes the effective factor. Growing season along our

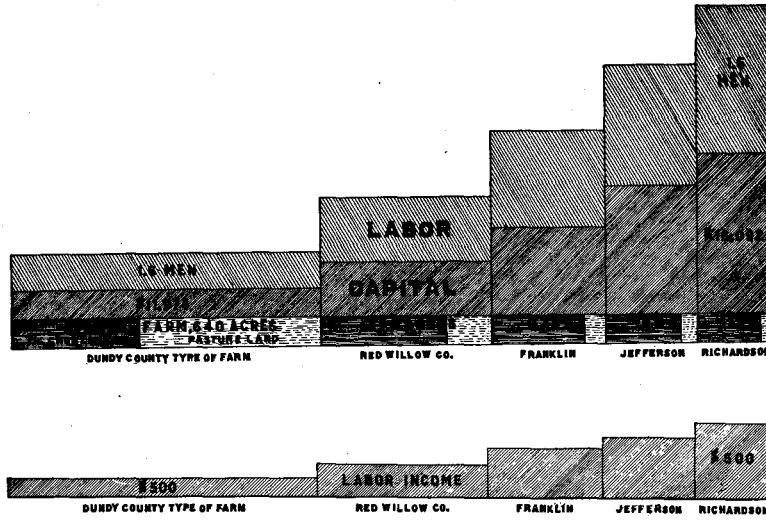


FIG. 10. The organization of southern Nebraska farms. See Fig. 9. (Labor income is a measure of the profitableness of a farm business. It is determined by subtracting farm expenses and a fair rate of interest on capital from the farm receipts.)

southern boundary varies from 165 to 140 days while rainfall varies from 32 to 18 inches. Generally speaking, rainfall below 24 inches or growing season below 125 days becomes an effective limiting factor in ordinary farming. Since nowhere

along this line the growing season falls below 140 days, the element moisture proves to be the important limiting factor.

In the scale chosen, the size of farm varies from an average of 158 acres in Richardson to an average of 640 acres in Dundy. The technical use of the word *farm* refers to the land directly operated by one man. He may own all the land, rent all the land, or own part and rent part. At first thought it might appear that farms at the western end of the scale are larger simply because the country is relatively new. This cannot be correct, however, for when the government first disposed of the land the average size of farm was nearer 160 than 640 acres.

After long and trying experiences people in the western counties are more and more coming to understand that conditions there are very different from those even a short distance east. But regardless of this fact there is even to-day no clear idea of the rapid change from favorable to adverse conditions after passing the 24-inch line of rainfall. The number of acres required to pasture a horse or cow may be used as a rough measure of this change. To provide five months' pasture for a mature animal in western Nebraska requires about four times the number of acres necessary in eastern Nebraska. From this fact alone it is not out of reason to infer that a decrease in the effective value of moisture reduces the available pasture growth from 1 to about ¼. Man is as dependent upon plant growth as are other animals. All of the food which he consumes is derived either directly or indirectly from plants. Since in Dundy county the effective value of moisture is such that the total usable pasture growth is only about ¼ that in Richardson, it is not surprising to find that the size of farm must be at least four times that in Richardson. Many people though recognizing a decrease in native vegetation in western Nebraska hold strongly to the idea that correct cultivation is the only thing necessary to produce high average yields. All open-minded field studies in this state indicate that in general cultivated plant growth per acre varies quite in harmony with the growth of native vegetation. If it were true that 160 acres of land in Dundy county naturally produced plant food equivalent in value to that produced on 160 acres in Richardson—capital,

labor, and profits per acre in the two regions would be practically equal. But when it becomes necessary to harvest, either directly or indirectly, four quarter sections in order to gather an economic unit of plant food, it is not surprising to find that capital, labor and profits per acre are cut down to about one fourth.

The adjustment of farm business to conditions of climate and soil is so complete in Nebraska to-day that it is not far wrong to state that the price of land in area X is to the price of land in area Y as the profitable size of farm in area Y is to the profitable size of farm in area X. This proportion is a fair index even where the ratio of land prices is as extreme as \$6.00 to \$125.00 per acre. Judging from farm surveys there is good reason to believe that at present an average profitable farm business in western Nebraska can be conducted on about 85 per cent of the capital necessary in eastern Nebraska. This is in a large measure due to the fact that where plant growth is sparse and farms of necessity become large, business, educational, and social advantages fall to the point where people hesitate to settle unless financial returns are proportionately increased.

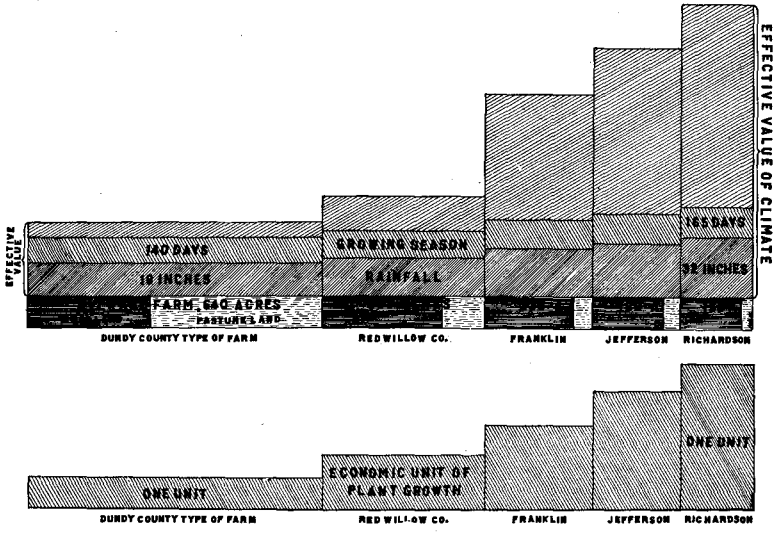


FIG. 11. Effective value of climate measured in terms of plant food having economic value.

Fig. 10 might be described as artificial accounting with soils under a range of effective moisture variations. In contrast with artificial accounting an attempt is made in Fig. 11 to illustrate what might be called natural accounting. The proportions of this figure are correct in so far as the size of farm in this region is a function of natural factors. Furthermore, since soil, temperature, and sunshine are not limiting elements in this scale the variations observed can be attributed largely to moisture.

Using the size of farm as a function of natural factors it is possible to illustrate, with a fair degree of accuracy, the effective value of such elements as moisture, temperature, and soil. Under the head of soil it will be possible to isolate some of the effects of topography and texture.

Lines 1, 2, 3, 4, and 5, Fig. 12, serve as indexes to graphs shown in Figs. 13 and 14.

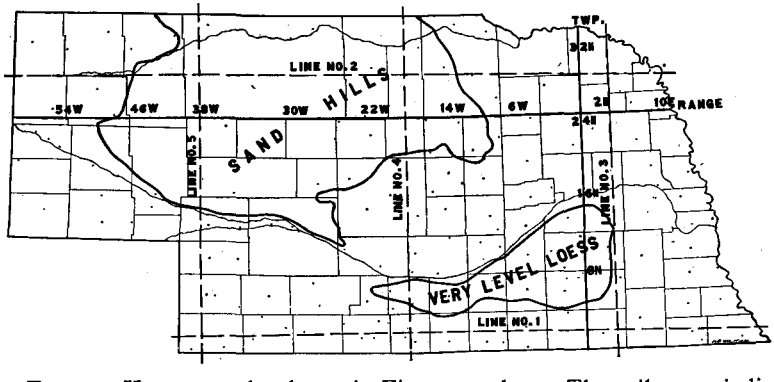


FIG. 12. Key to graphs shown in Figs. 13 and 14. The soil areas indicated are the ones having the greatest effect upon the trend of the graphs.

It will be observed that the rate of change in Graph No. 1, Fig. 13, increases rapidly after passing Range 22 W. Graph No. 2 indicates the rate at which size of farm changes across northern Nebraska. In this graph a rapid increase in the rate of change is observed just west of Range 6 W. It is significant to observe that both graphs show a rapid rise as soon as mean annual precipi-

tation drops below 24 inches. If it were not for sand hills between Range 46 W and 6 W in northern Nebraska, Graph No. 2 would probably follow parallel to and 50 to 100 acres above

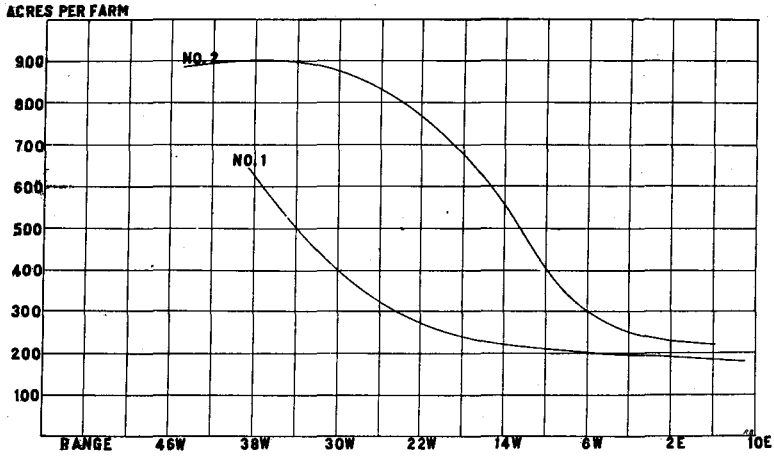


FIG. 13. Graphs illustrating the rate at which size of farm changes along east and west lines in Nebraska. (See Fig. 12, lines 1 and 2.)

Graph No. 1. Any effect due to lower temperature must lie within this narrow margin. From these observations it would seem that though temperature in this state has an important effect upon certain farm enterprises, it has but comparatively little effect upon farming as a whole.

Graphs along north and south lines in the state (Fig. 14) will serve as a partial check on conclusions drawn from a study of variation along east and west lines.

Graph No. 3 across eastern Nebraska lies well east of the line of critical moisture. But for the effect of extremely level land reducing the size of farm near T 8 N, and for the effect of rolling land together with slightly sandier soil increasing the size of farm near T 24 N, there is little fluctuation. Judging from these measurements topography has at least as important an effect upon size of farm as temperature.

Graph No. 4 is typical of central Nebraska. A slight decrease

in the size of farm south of T 8 N is caused by level upland and the Platte Valley. North of T 8 N critical moisture and sand hills cause an abrupt increase in the size of farm.

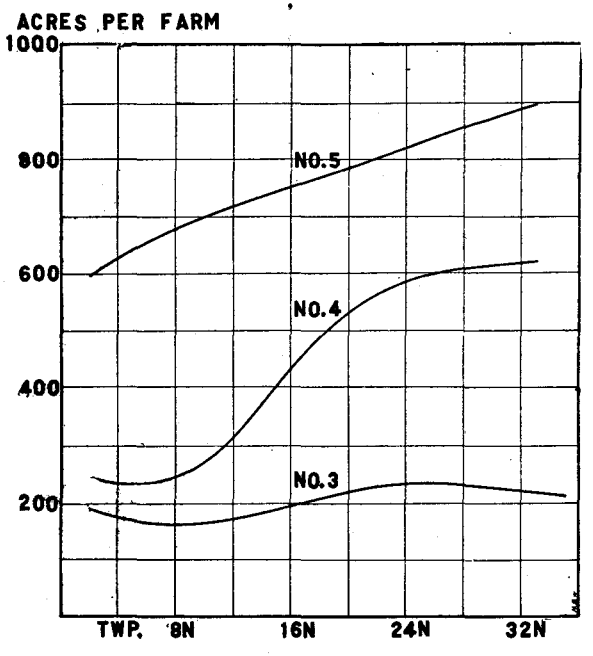


FIG. 14. Graphs illustrating the rate at which size of farm changes along north and south lines in Nebraska. (See Fig. 12, lines 3, 4 and 5.)

Graph No. 5 is a composite of several drawn for western Nebraska. Moisture gives it its position relative to graphs No. 3 and No. 4 while topography and soil texture are the principal elements determining its trend.

Though the above study is based largely on Nebraska data it has more than a local bearing. Moisture problems from southern Texas to the head of the Mississippi river are closely related. To the south they are influenced by high temperature, while to the north they are modified by low temperature. From the head of the Mississippi northwest into Saskatchewan and Alberta a

lobe of favorable summer temperature determines, to a large extent, the boundaries of the Canadian agricultural area recently opened. In the southern part of this lobe the problems of low temperature are more commonly blended with problems of low rainfall than is true farther north.

Figs. 15, 16, and 18 illustrate the approximate location and nature of critical agricultural lines in the northern hemisphere.

FIG. 15. Critical agricultural lines in North America.

The distribution of native vegetation relative to these lines is very marked. The boundary lines of agricultural regions thus far well developed follow closely the boundaries between northern

coniferous and broad-leaved forests, the boundaries between temperate and semi-desert grass lands, and the boundaries between northern coniferous forests and semi-desert grass lands.

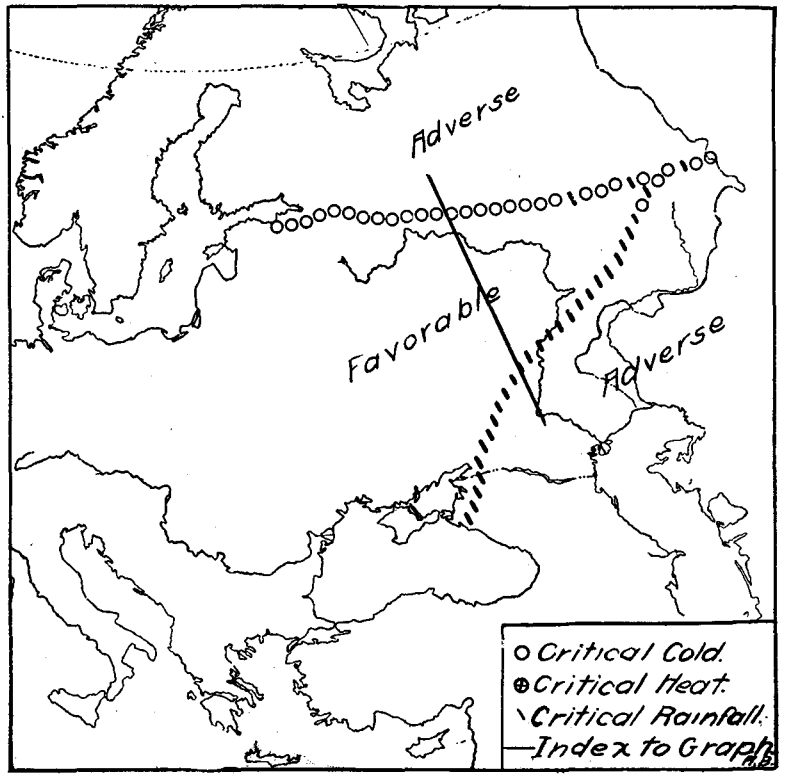


FIG. 16. Critical agricultural lines in Europe.

The natural factors which give such striking characteristics to the distribution of native vegetation give equally striking characteristics to the distribution of people and the organization of farm business. A study of graphs based upon the area of land per person in the United States (Figs. 18 and 19), Russia (Fig. 20), and China (Fig. 21) will serve as a general index to the rate at which the organization of farm business changes near

critical lines. It is interesting to observe that the rate of change in Europe and Asia is much the same as in America.

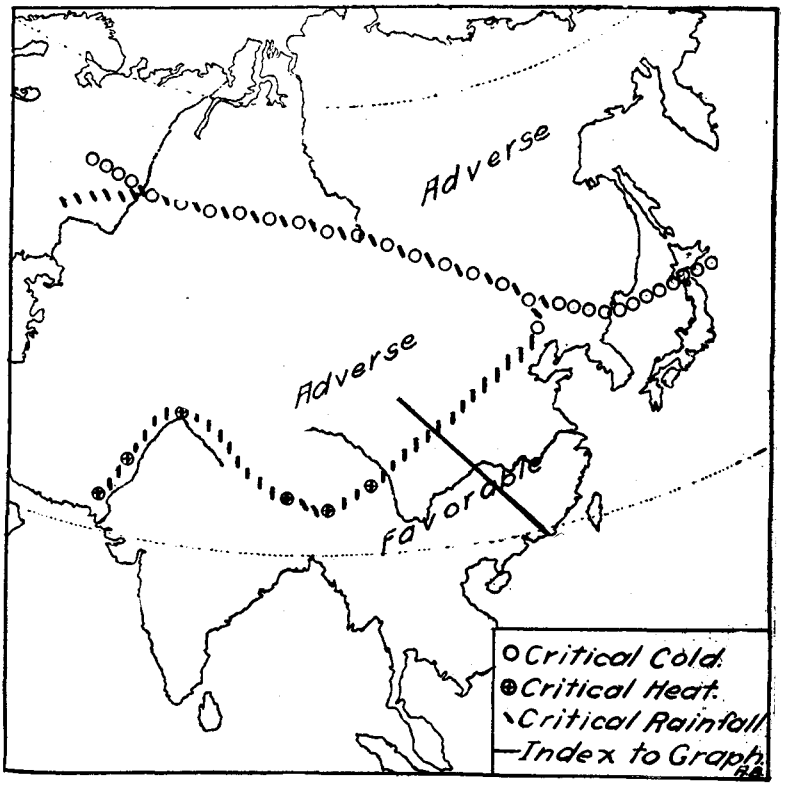


FIG. 17. Critical agricultural lines in Asia.

In the United States it has been a common experience of thrifty farmers from such states as Ohio, Indiana, and Illinois to fail for a number of years while learning to farm in regions of low rainfall or low temperature. It is not uncommon in the drier parts of the west to-day to hear a farmer say: "I sold my place back east and came to this country with enough money for a good start, but I lost it all, and now I'm just beginning to make it back." A review of the experiences of such men invariably reveals the

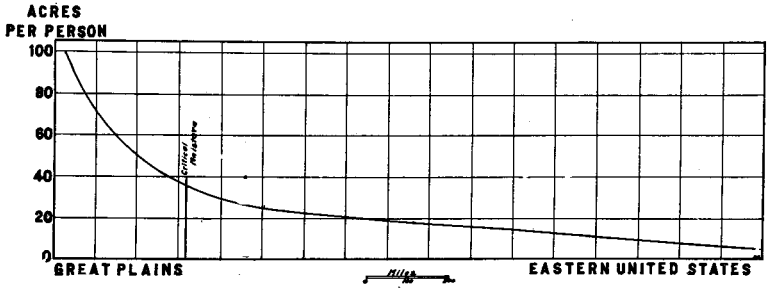


FIG. 18. Land per person increases rapidly near the line of critical moisture. (See Index to Graph, Fig. 15.)

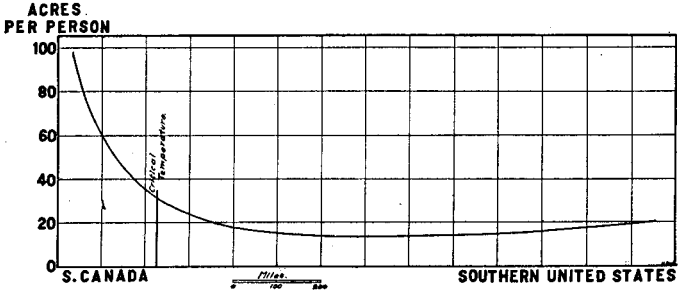


FIG. 19. Land per person increases rapidly near the line of critical temperature. (See Index to Graph, Fig. 15.)

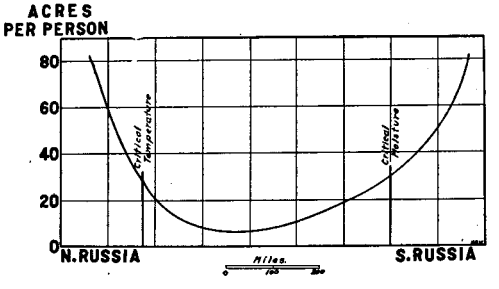


FIG. 20. Land per person from northern to southern Russia. (See Index to Graph, Fig. 16.)

fact that they are to-day conducting their business on a plane very different from that on which they made their first attempts. Misconceptions regarding the plane of profitable business on the adverse side of critical lines are not wholly confined to the prac-

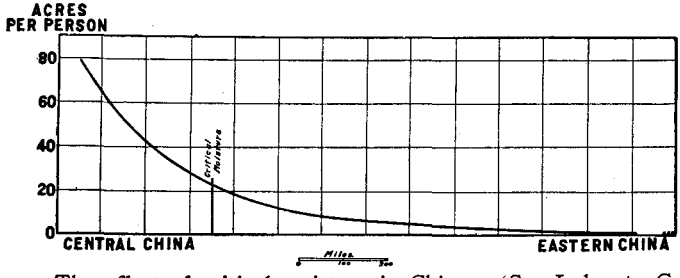


FIG. 21. The effect of critical moisture in China. (See Index to Graph, Fig. 17.)

tical agriculturist. Scientists working on the problems of our border regions have not infrequently had experiences somewhat similar to those of eastern farmers. The same may be said of large business organizations—as for example, loan companies. It is gratifying to observe, however, that general farm experience supplemented by scientific study is gradually solving a number of the most difficult problems peculiar to border regions.

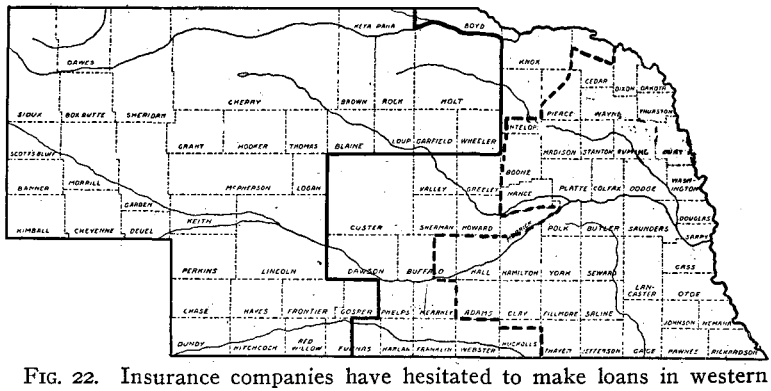


FIG. 22. Insurance companies have hesitated to make loans in western Nebraska. The solid line shows what at one time was the western limit for the Union Central Life Insurance Company. The broken line marks what at one time was the western limit for the Northwestern Life Insurance Company.

A clearer understanding of what constitutes a profitable farm business west of the line of critical moisture will in time do away with much of the element of risk now entering into loans made on western land.

Observe the relation which lines on this map bear to lines indicated on the following maps.

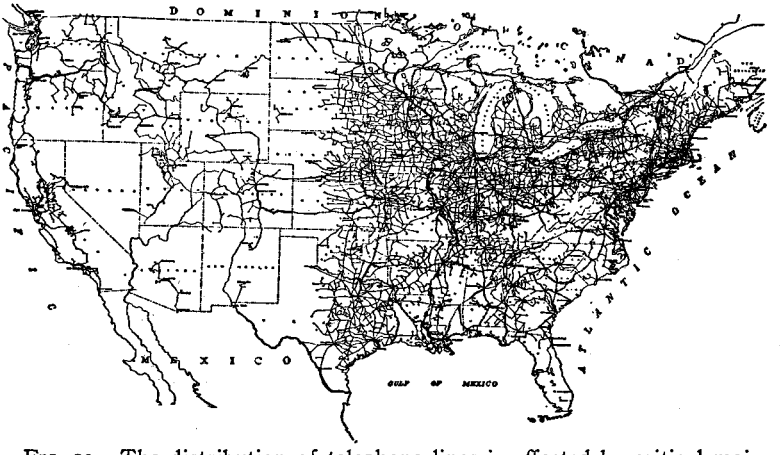


FIG. 23. The distribution of telephone lines is affected by critical moisture and critical temperature. Compare the figures with Figs. 22, 24, 25.

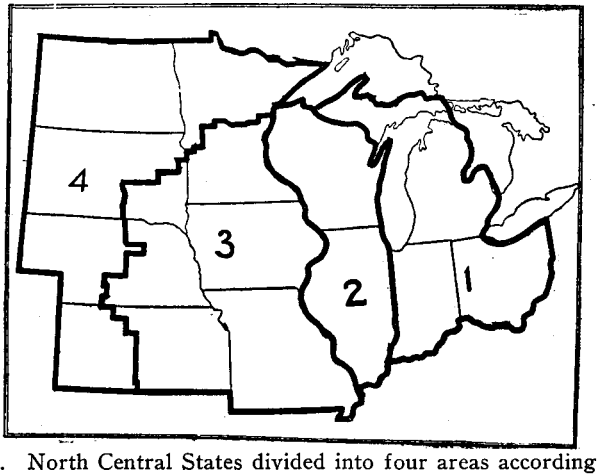


FIG. 24. North Central States divided into four areas according to type of farming. Division made by the Office of Farm Management, Washington, D. C., in recent fence investigations. (U. S. Dept. of Agriculture Bulletin 321.) Compare this figure with Figs. 22, 23 and 25.

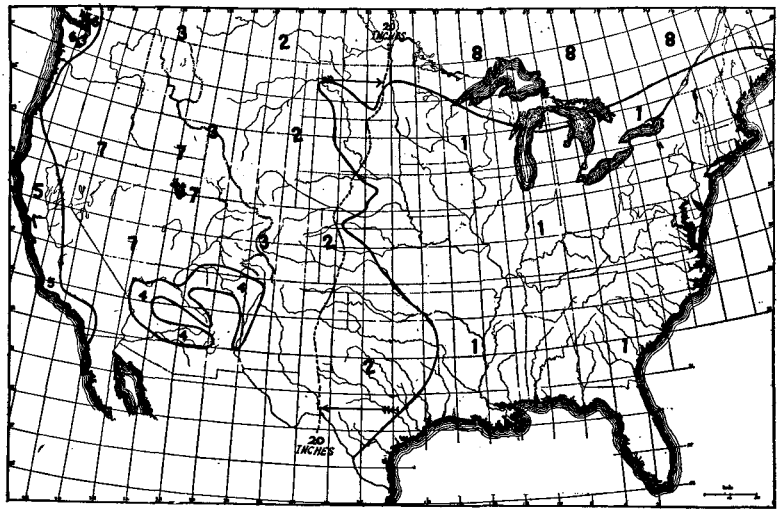


FIG. 25. This map is made to show the regions of more or less stabilized aboriginal occupation in the United States and Canada. In the region numbered (1) on the map, including the eastern half of the United States and a part of the lake and St. Lawrence region of Canada, the aboriginal inhabitants had fixed abodes, lived in permanent houses and cultivated crops of corn, beans, squashes and pumpkins, sunflowers and tobacco. From their permanent villages they made excursions into adjoining regions at certain seasons in quest of various desired products of the native resources. Thus at the western border of region number (1) the village inhabitants made hunting excursions into region number (2) in quest of their supply of meat and other animal products, and also certain vegetable products not available in the region of their fixed homes. They even traveled to region number (3) for some desired products, for example, the lodge pole pine for tent poles, and certain minerals, as obsidian, chalcedony, bentonite, and various other earths and clays.

The tribes resident in region number (2) did not have fixed abodes for the reason that the physical condition of the region did not favor or even permit the cultivation of crops. The supply of their requirements was meager in this region, and had to be sought over a greatly extended range.

The tribes of region number (4) lived in fixed abodes, subsisting by irrigated agriculture. Thus they were found by the Spaniards, the first comers from Europe. The native irrigation works of the region were of great antiquity.

The California region, numbered (5), was one of secluded valleys, the physical control producing community life in fixed abodes.

Region (6), surrounding Puget Sound, was a region of village life, the factor of control in this case being the fisheries. The houses of this region were built of wood from the abundant forest growth.

Region number (7), the Great Basin, and number (3), the Rocky Mountain region, for the purpose of this discussion may be considered similar, in that the meagerness of natural products in both necessitated a thin and mobile population.

There remains to mention region number (8), the Northern Woodland, in which the climatological conditions prevented aboriginal agriculture and necessitated a mobile population, moving about with the seasonal production of various resources which controlled their economic conditions.

(By courtesy of Dr. M. R. Gilmore.)

Compare the figure with Figs. 15, 22, 23 and 24.

A study of Fig. 26 will serve to summarize the foregoing discussion and at the same time orient it with respect to broad geographic principles. The curves drawn illustrate the relation which artificial factors bear to climate and plant growth.

The increase of plant growth from desert to tropical regions is represented by an increase in the height of the shaded areas.

(*a*) The first graph based upon the density of plant growth illustrates the ease with which man can gather plant food.

(*b*) The second graph is, in a sense, the complement of the first. In regions where plant growth is sparse man is dependent upon animals to convert plant food into usable form.

(*c*) With an increase in plant growth there is naturally an increase in the number of inimical plants. In arctic or desert regions weeds and harmful bacteria are relatively scarce and cause man little trouble. In tropical regions they are so numerous that even civilized man is at present unable economically to control them.

(*d–e*) The majority of agricultural people have long been acclimated to temperate conditions. Any attempt to change to a region where a normal body temperature of about 98.6° is not easily maintained results in serious physiological disturbances. These disturbances no doubt lower the vitality of colonists in tropical regions to a point where it has thus far been impossible for them to become independent of climate, and to do what, under

temperate conditions, would be a normal amount of productive labor.

(*f*) Capital in arctic regions includes little more than a crude home, land of extremely low value, dogs, and a few implements. In temperate regions capital includes a better home, valuable land,

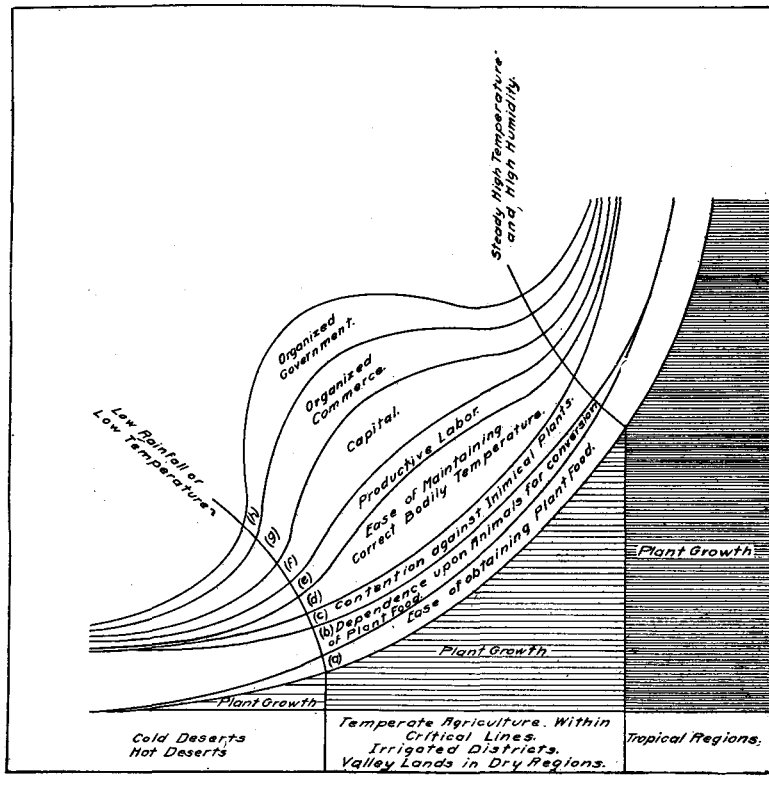


FIG. 26. The relation of artificial factors to climate and plant growth.

more domestic animals, improved implements, and a valued interest in many devices for keeping in touch with people over a wide area. In the tropics capital drops back to a level comparable with that in arctic regions.

(*g*) Organized commerce falls to the level of barter in regions where people are scattered and productive labor runs low.

(*h*) Highly organized government exists in regions where labor is much divided and people become interdependent.

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