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# THE LAND OF YOUR POSSESSION[1]

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WHEN we say that "man does not live by bread alone" we imply that bread comes first. Over the greater part of the earth and for at least three fourths of our two billion planetary population the will to eat is the primary urge of "eternally hungry man." "It was farming time, everybody talked about the land," was the way one old-timer summed up his motivations as one of the pioneers of the Middle West during the high tide of migration off the stony hillsides of New England to the flatter acres of the prairie plains. While the historical aspects of land use and land dependence tempt me to make excursions, I yield to the temptation at one point only. The title of my address is taken from Joshua, 1: 15, in recognition of the early land movements recorded in our common book of wisdom.

[1] Public lecture before the General Session of the American Association for the Advancement of Science, Minneapolis, Minn., June 26, 1935.

This antiquarian choice is supported by findings in Young's 1,000-page Analytical Concordance, which has about 1,600 citations on land (metaphorical and literal), while the two other main themes of the Bible, love and sin, come off with but 600 and 300 citations, respectively! The "pioneer fringe" was clearly recognized in that far day: "There remaineth yet very much land to be possessed." The migrants had an equally clear purpose: "That ye may live, go in and possess the land." In 1930 a wheat farmer of the High Plains of western Kansas, who had recently migrated from the eastern part of the state, answered my question of purpose as trenchantly as the record runs in Deuteronomy: "I came here, Mister, because I had to live." Cheap land, high-price wheat and the wet-period success of other High Plains farmers had drawn him forward to the degree that high taxes and high interest charges on the older farm had pushed him away.

That man now lives in a major zone of climatic risk, and it is the purpose of this address to look at his environment from the point of view of science.

The prairie and plains land that the American farmer for a century had gone into and possessed that he might live was "open to the plow," as it has been described, but much of it lacked other desirable qualities. Some of the deficiencies, such as timber in the treeless plains region, were first supplied by barge or rail from the nearest or the most profitable sources—notably, in time, the Great Lakes pine forests. The disadvantage of a thin farm crop in the drier western parts of the Great Plains was offset to some degree by large-scale farming machinery. The improved tin can made the cheap distribution of fruit possible and safe in places where fruit could not be grown profitably or at all. Tractor and header techniques helped lower the wheat farmer's production costs in some areas by vastly reducing man-power requirement. Good roads and motor transport in the past two decades have enabled him to push out farther and farther from the railways as the time and cost of haulage have been reduced. Land that changed use from stock to grain was bought at what seemed relatively low prices. The world market was still regarded as a reservoir of unlimited capacity. Extension of farm land was extension of our agricultural empire. Up to the time of the world war, as Dr. R. W. Murchie, of the University of Minnesota, points out,[2] the line of division had not become clear between the Neo-Malthusian philosophy according to which the world's population would presently require more food than the land could supply (with general birth control imminent) and the opposite philosophy, "imperialistic at heart," which "called for the speedy development and exploitation of the natural resources and the redistribution of population through migration." Migration was still encouraged in order that the frontier zone of agricultural land might be speedily occupied. "Canada throughout its history as a Dominion provided an excellent example of the effects of this policy" upon increasing national strength.

Almost with the speed and devastation of an epidemic there have overrun the world within the past decade new forces or old forces raised to new levels of power. The world wheat market became overshadowed by a menacing carry-over. In many sections the price of wheat fell below the cost of hauling it to market. Some communities in Saskatchewan, accustomed to the

[2] "Agricultural Progress on the Prairie Frontier," 1935, p. 1 (one of a series published by Macmillan of Toronto).

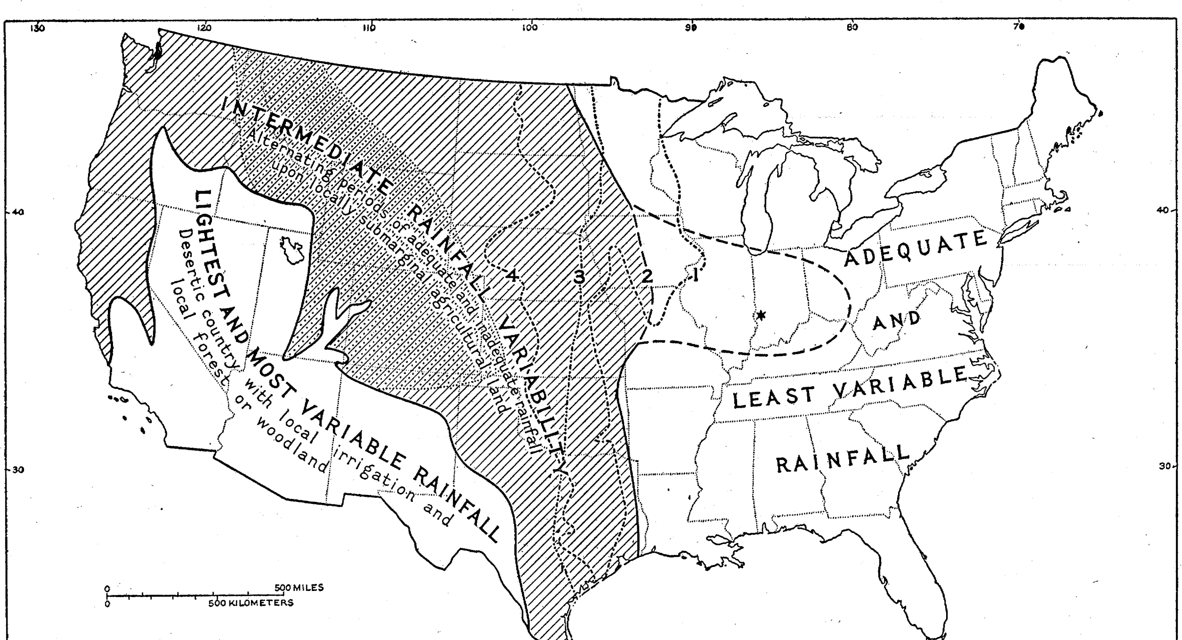


FIG. 1. Map of the United States illustrating the broad grouping of agricultural problems in three regions. In the easternmost region crops are in general dependable (see the local moderate exception marked by a broken line in the Middle West); in the central and northwestern region crops require specialized and extensive land engineering with limited irrigation; in the southwestern region water engineering is the basis of local agricultural development. Line 1 represents the eastern limit of "dry" years (see definition in descriptive caption of Fig. 2); line 2 represents the eastern margin of a western area of rainfall variability notably higher than that of the eastern part of the United States; line 3 divides the so-called humid East from the arid West on the basis of precipitation effectiveness; line 4 is the eastern border of territory having at least an occasional "desert" year.

power tractor, have gone back to draft horses for farm power. Many of the new settlers of the Peace River country of Alberta and British Columbia are starting at the horse-and-wagon stage, for pasture is cheaper than gasoline; and it has been rediscovered that time has less value than capital invested in costly and dispensable machines that are idle most of the year.

Our own wheat belt has experienced a revolution. The accompanying "risk maps" show some of the physical handicaps of the region. In many sections a farm can now be bought for less than the price of the buildings—the land is thrown in as a mere *situs*. Wheat production on the High Plains, and adjacent areas to the east and north, has been in a state of unstable equilibrium for some time, owing, among other things, to the 90-day work periods of the one-crop wheat lands of the region brought into cultivation largely since 1915. When the drop in the market price of grain was followed by the severest drought of our pride in the use of reason in other arcs of human experience. It is said that Kansas is the only state in the Union that contains more trees now than it did before it was settled. But even here man's benevolence and wisdom are limited to the eastern two thirds of the state. In the western third, right in *the area of greatest climatic and agricultural risk,* the protective sod has been ripped off and the soil pulverized by the repeated cultivation essential to dry-farming, with the result that whole fields have taken flight. In some places the ground has been literally blown off down to the plow sole.

We habitually hope for the better with respect to those destructive forces that we have long attributed to Providence. Perhaps this year the drought will end. But even if that desirable change is realized, the bad effects will last for some time; and hope plays but little part in bringing back a state of balance that man right now continues to disturb with criminal thoughtlessness. Hope will not bring the sod cover back.

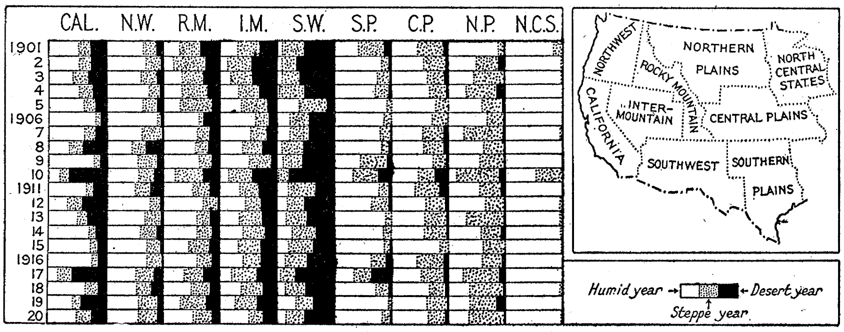


FIG. 2. Diagram, after Russell, showing the prevalence of desert, steppe and humid years in the western United States in the period 1901–1920. The classification is based on the records of 569 stations and the limiting values are defined thus: "at the mean annual temperature of 55° F. places receiving between 9.5 and 14.0 inches are classed as Steppe . . . those receiving less than 9.5 inches as Desert. . . . At 70° F., Desert areas may receive as much as 13 inches of precipitation." (R. J. Russell: Climates of California, *Univ. of California Publs. in Geogr.*, Vol. 2, No. 4, 1926, p. 76.)

record, and wide-spread wind erosion followed the drought, the economic distress characteristic of the 80's and 90's was intensified, and the general problems of land use and the ultimate economic fate of the people in the area were laid on the lap of the Federal Government.

Now the will of man is once more recognized as a part of nature. The environment of the drier parts of the Great Plains has suddenly had injected into it a new psychological element. For the drought and the dust storms are in part what we think they are. They are not merely malign nature. While in simple teleological phrase it may be said that God made the drought for ends of his own, it was man who raised the dust because he did not have the proper ends in view. We have long recognized our extraordinarily illogical contrarieties in some respects, in contrast to

After the fields have had their top-soil blown off, we enter a long period of both waiting and experimentation to see if the grass will grow again or if a wetter period in the future may not be required to restore the cover, with some areas eroding meanwhile to a still more extreme stage of destruction. Some of the effects of plowing and wind-stripping will be projected into the future, we can be sure. In our troubled times we can see the wisdom of a Bacon, who wrote of "Seditions and Troubles" that one of the first remedies was "the improvement and husbanding of the soil."

In any event, and whatever the balance between hope on the one hand and soil and weather possibilities on the other, we ask, wisely, I think, what kind of people and what kind of society will the high-risk areas of the western Great Plains support? Do we want that kind? Our people are our greatest resource.

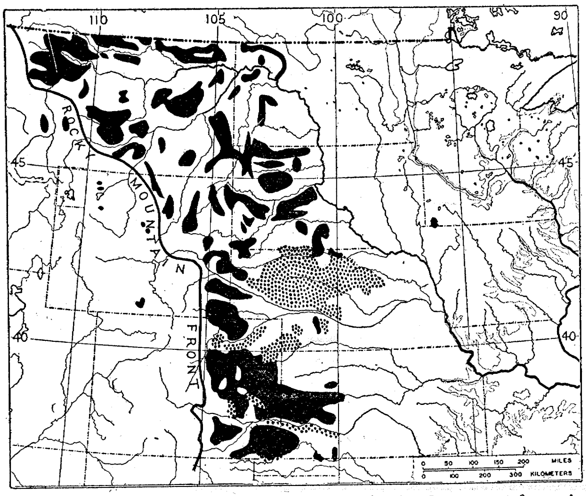


FIG. 3. Solid black represents principal areas of agricultural risk in the Central and Northern Great Plains (see text); stippling represents "sand-hills." From land-classification maps of the United States Geological Survey.

"Tell me what society you want," says Zimmerman, "and I will tell you what your resources are." We are dealing with a social, that is, a cultural complex as well as with a complex of natural conditions and forces. Walter, of the Meteorological Service of British East Africa, wrote in a paper read before the Kenya Society for the Study of Race Improvement: "I desire to call particular attention to a point which is often missed by research workers when the human element is in question. Do not let us generalize! A climate suitable for one type [of settler] may be very unsuitable for another. . . ." Once nature seemed capricious, but the deeper we study her the better able we find ourselves to master or deflect or avoid some of her forces. It is man himself who now also needs understanding and control by reason. If nature were as capricious as man we might well give up. If we invoke the aid of science, what relation have its rationalities, points of view and results (including perhaps its forecasts) to the problem of land use in the marginal areas of the Great Plains?

First, neither a scientist nor a government official can handle the problems of the drought on a hunch. We can never solve "the problems of the drought" by stopping the drought. We can only provide to some degree against its effects; and if we were forewarned against its coming the degree of provision against its effects could be greatly increased. Likewise, we can never solve the problems of soil erosion by stopping erosion. We can only reduce the rate of erosion. The effects of drought and soil erosion will outlast all the regulatory schemes of to-day. Amazement at the dust storms should not lead to the neglect of long-range studies. A strong force of experts should be working on the mass of climatological data on the Great Plains accumulated during the past 50 years by the Weather Bureau. If this were done the result would certainly be more valuable over a ten-year period than all the gold produced in the Klondike. Would that a 1935 rush toward this mountain of information followed the Minneapolis meeting of the association! It is such a rush that ought logically to be joined with the rush to plant trees. For the immediate problem of the semiarid western part of the Great Plains is not only where to plant more trees and shrubs, waiting 20 to 30 years for results, but also and more urgently to work out a land-use plan for the grasslands of the vast region west of the proposed shelter belt and to start operating the plan now. The climatic map shows us how vast is this marginal area. Without shelter-belt possibilities, it is in dire need of having its climatological risk defined and its people redistributed accordingly. The relief now provided to three fourths of the population over huge areas has transferred the problem of land use from the local or county agencies to the state and possibly the federal agencies. If re-

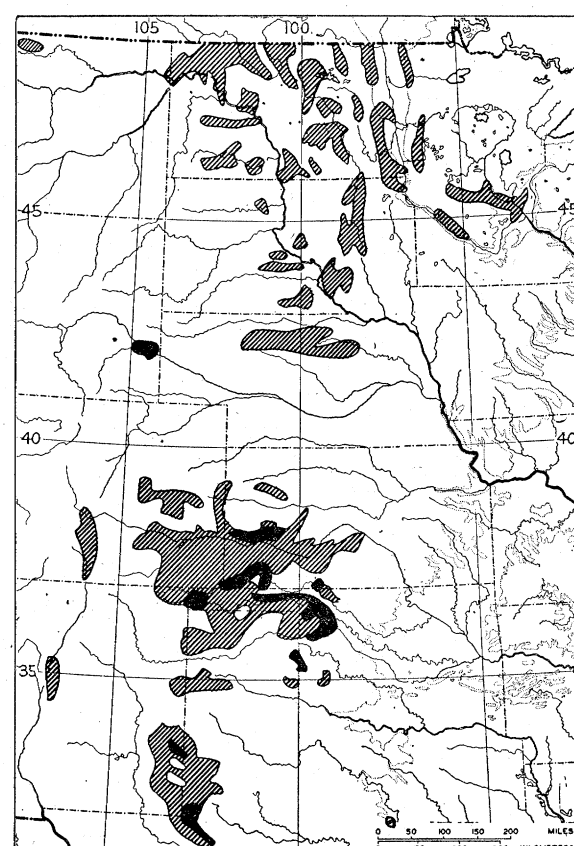


FIG. 4. Areas of most intense recent wind erosion are shown in solid black; less intensely wind-eroded areas are shown by diagonal ruling. From the Soil Conservation Service.

lief is a permanent feature of land use in areas of maximum risk, it is logical that the sources of relief shall have a right to inquire whether the risk shall be allowed to continue.

There has become available during the past few years a set of land-classification maps published by the Conservation Branch of the U. S. Geological Survey. From them I have had traced off two land classes, the so-called "farming-grazing land" and the "grazing-forage" land. The one has "crop failure in dry years," and the other "crop failures except in good years." This may look like a distinction without a difference; but this need not trouble us, for on the map the two types are lumped together. Outside these two areas the land is either so well favored as to involve the farmer in little risk or so ill favored as to exclude farming. In the two types where risk is greatest lies the land on which in favorable years farmers are most strongly tempted to grow wheat. There the wheat farmer literally gambles on the rain. The two types represent areas of maximum risk not because they are occasionally very dry but because they are occasionally so favorably wet as to cause agricultural overextension. To these difficulties has recently been added wide-spread and unexpectedly severe wind erosion. While the farmer is waiting for a return of moister years, the wind carries his farm aloft. The problem of the farmer turns on the question, How far can he go in reaping the bounty of the land in wet years and yet survive the penalties of inevitable drought? The problem of the government is to determine whether a man shall be allowed to grow grain in places where he *can* do so and *ought* not to. Here is a border of settlement of shifting fortunes as distinctive in type as the corn-belt type or the cotton-belt type.[3]

In organizing fundamental climatological research as a basis for expressing degrees of risk in the agricultural gambling belt, we do well to realize that what is caught by the rain gauge is only a statistical expression. "General distribution" maps do not amount to much. We need to know details, subregion by subregion. Generalization is one of the great and useful processes of science, but it has its severe limitations. In habitational studies of the semiarid region we have to know the small but critical regional differences in rainfall habit. The larger the number of rainfall stations we install the more irregular the pattern of isohyetal lines always becomes. Plottings of rainfall probability on the basis of too widely scattered stations suffer accordingly. It is as if one made a topographic map of Montana on the basis of elevations obtained by sounding lines let down from a few balloons equipped with barographs. It is not only the "*land* of your possession" that we want to know about but also the sky over it, the rain that falls upon it, the paths of the storms, the amount and incidence of winter snow, the depth to and the degree of permanence of the ground water, and the degree of reasonableness or lack of response to reason of man settled upon the land. When I asked my guide in Peru how often it rained on the arid coastal hills north of Mollendo, he answered, "Segun el temporal y la Providencia" (according to the weather and to Providence). How far has science really given us a better answer?

First, may I refer to the widely heralded shelterbelt. The map shows its position as originally published in an article in the *New York Times*[4] by the chief forester, F. A. Silcox, and its now revised and more easterly position as published in SCIENCE by Dr. Raphael Zon.[5] The operations of tree planting in this zone will be limited by a number of factors, of which rainfall is one. Graphically to represent the facts on which the general location of the belt is based, critical

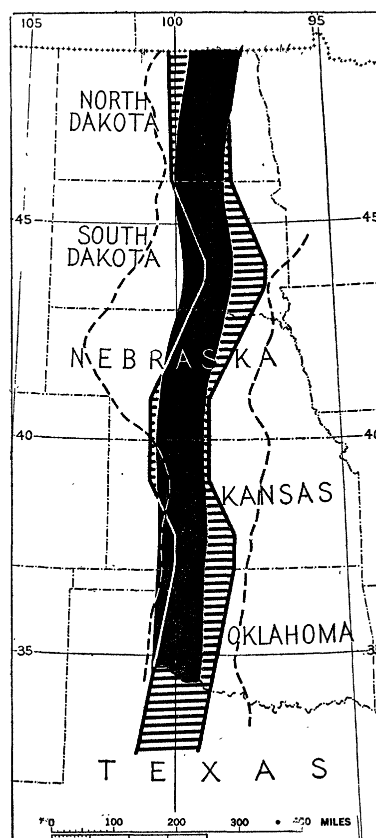


FIG. 5. The solid black indicates the shelterbelt as first located by Silcox, the ruled area represents the location of the belt as modified by Zon. The adjacent lines represent rainfall limits which are described in the accompanying text.

[3] Isaiah Bowman, *Geogr. Rev.*, 21: 22–55, 1931.

[4] *New York Times*, July 29, 1934.

[5] R. Zon, SCIENCE, April 26, 1935, pp. 392–93.

climatic limits are shown on either side. On the left is a broken line west of which more than half of the years (in the period 1910 to 1933) were semiarid and we may therefore conclude that in general trees will not grow on the uplands west of that line unless they are irrigated like a crop. To the right of the shelterbelt is a broken line east of which the rainfall is sufficient to permit trees without special drought-resisting qualities to grow. Between these two outer lines is a broad belt within which drought-resistant species *may* grow and in which all suitable species will do better if planted in the most favorable sites. Obviously, these sites require a study not only of rainfall and snowfall but of the water-holding capacity of the soil, the depth to adequate moisture zones, prevalence and duration of hot winds, slope exposure, and the like, as well as the degree of success of tree-planting experiments of the past under closely observed and well-analyzed conditions. Tree-plantings toward the eastern margin of the shelterbelt are more likely to succeed (if favorable sites are selected), and those near its western margin are more likely to fail. Some experimental plantings in the best sites near the western margin and even well beyond it show, however, that local success is possible on that margin.

The rainfall records on which the location of the western margin of the shelterbelt is based have been insufficiently analyzed. Zon refers to the close coincidence of the belt to the 15-inch average rainfall line on the north and a 22-inch line on the south. But the incidence of semiarid years for half the time raises the question as to how the wet years and dry years are grouped, subregion by subregion, and how such groupings affect the risk to the life of plantings. Five dry years in succession are a far different thing from five dry years in regular alternation with five wet years.

There are many ways of stating the rainfall of a region, and detailed research upon variabilities of amount, intensity, frequency, growing season water requirements by stages, insolation, slope, and the like, is required if the *effectiveness* of rainfall is to be ascertained. A generalized rainfall map tells very little about the rainfall effectiveness at any given locality. The native vegetation supplies one of the readiest guides to water effectiveness in specific environments because it is the result of interaction over a long period of time of all the factors in their varying combinations. The natural vegetation is thus an approximate indication of agricultural productivity. A noteworthy example is the line of division between the tall-grass and short-grass formations separating "the highly productive farm lands of the prairie from the less productive ranch lands of the plains. . . ."[6]

According to Zon, more than half of the shelterbelt, or 57 per cent., lends itself to tree plantings; about 39 per cent. is difficult to plant; and about 4 per cent. may be planted to forest in solid blocks, "but each planting must be adapted to the soil conditions of every farm and oriented to the damaging winds prevailing in each locality," following narrow ravines in the "breaks," as the eroded scarps are called, as windbreaks around farmsteads and schools or in narrow strips around fields. The effect, one concludes, will be as severely local as the plantings. One may be permitted to doubt that the proposed plantings will provide the part of the semiarid region where operations are contemplated with "the amenities of a higher cultural life."[7]

During the past two years the Science Advisory Board has advocated a deeper climatological study of the Great Plains as part of a land-use program in order to determine with greater assurance where economic effort of a given type should be concentrated. Climatological studies are basic to soil and water conservation measures. Through the interest of Dr. Bennett and Dr. Lowdermilk, the Soil Erosion Service (now the Soil Conservation Service) has authorized such a study. On the physical side there is no dividing line between soil-erosion problems and the remaining problems of land and water use. It is necessary to know not merely the existing degree of soil erosion but also the erosion potential before we can make sure of that "continuing wise use" which Theodore Roosevelt set up as the main general objective of conservation. Soil is an energy source that is not renewable at all in some places from which it is lost and is renewable in other places only at an uneconomic cost. Even when the loss of the surface soil is not imminent, its rate of depletion is a subject of concern if this is greater than the replacement rate. Its waste is deplorable from any standpoint: the future degrees of national self-containment and of dependence upon foreign sources of supplies of vegetable origin are unknown, and we are therefore unable to say what the future pressure may be upon our agricultural land apart from any natural increase of population. We shall always need all our best land. Some of our most devastating erosion has been on our best land.

Population can not be moved about at will, even if plenty of good land is available outside badly eroded areas. The accustomed cultivation technique is a limiting condition. Accustomed neighbors are a desideratum. Yet poverty deepens if farmers are left upon the eroded areas. The human erosion is as important as the soil erosion which it follows. "I dig my well, I plow my field," runs a Chinese poem, "what care I who rules the land if I am left in peace?" But this may be the peace of extinction of whole communities unless those who rule the land choose to care.

[6] H. L. Shantz, *Annals*, Association of American Geographers, 13: 100, 1923.

[7] *Ibid.*, p. 394.

It is not merely more or less annual rainfall that is the basis of subdivision according to "continuing wise use" of the semiarid region of the Great Plains. There are different kinds of rainfall. To determine the amount that falls in the crop-growing season is not enough. The several parts of the growing season differ markedly in the degree of response of crops to rain. In any given year the greater part of the growing-season rainfall may occur in the wrong month for good crop effect. The rise and fall of the ground-water follows only approximately the increase and decrease of rainfall; and the soil moisture (available) changes are but little better fitted to the rainfall variations. It is vital to *interpret* rainfall *in detail* in terms of plant physiology and crop potential under a wide variety of conditions. We want to know what a rain, any rain, is worth to a crop, whether of grass or grain, and what are the indices of worth. One such index is the determination of what became of the rain received up to a given date. Again, the temperatures of the growing season may be so high that the otherwise beneficial effects of a given rainfall may be almost wholly lost. Rapid transpiration in the Great Plains in part offsets the higher summer rainfall. The afternoon windiness is higher than that of any other part of the country.

In the northern Great Plains, snowfall may play an important part in determining the amount of available soil moisture, and systematic snow surveys are still a novelty and in the promotional stage. The average annual snowfall of the Dakotas is 30 inches and the duration of snow-cover is 120 days; for western Oklahoma the figures are 10 inches and 20 days; in southwestern Texas, the average snowfall is but 1 inch. The average annual number of days of snow-covered ground ranges from 120 in the extreme north to about 10 in central Oklahoma.[8]

Climate, from the standpoint of a growing plant, means a number of conditions *in relationship.* That is why plant experimentation should go hand-in-hand with intensified climatological studies. Only as they are coordinately analyzed shall we be able to define regions of unlike land use, scientifically reduce the area of risk, and improve methods of use, section by section, throughout the semiarid West.

Pasture management is no less important than cropland management. One of the fundamentals of a study of land use and soil erosion (including wind erosion) in the drier Great Plains is to know more about the phenology of the region—the times of flowering and seeding (not the growing season) of range grasses. One day we shall have an analytical grass map of the range lands, according to maximum use in different types of rainfall years. We shall then sample plots of different range regions (as we now measure the trees of sample plots in the forest) and work out our range practices accordingly. When such a master grass map is produced we shall know where we can best stimulate the growth of grass, both indigenous and introduced varieties. Overgrazing on grassland is as bad as over-pulverization on fallowed fields and fields devoted to row crops. Grass, on the average, is 65 times as effective with respect to water conservation and causes 5 times as much rainfall to sink into the ground, under comparative conditions, as clean-tilled crops.[9]

Whatever we learn about land we have more to learn about the adaptation of shifts of population to our scientific findings. Writing of South Africa, Du Toit[10] quotes a line on the "ever-changing present," cautions against too-ready acceptance of constant appeals for new irrigation enterprises in view of "new and unforeseen developments . . . both here and abroad" that have altered the basis of many of the irrigation settlements, and deplores lack of study of "precise use" and the influence of politics. Are we leveling off living standards by ransoms levied on the better areas by government edict or do we recognize that the diversities of the physical environment may inevitably call for somewhat similar diversities in economic status?

The distinction between scientific agencies and planning agencies in land-use studies can not be too strongly emphasized. Our scientific agencies of the government are fact-finding agencies, and their research is directed mainly toward the better determination and improved statement of *facts.* In the early years of the century policy-making got mixed up with fact-gathering and possibly with no detriment to the use of forests and minerals. But a government ought not to allow policy-making to lower the standards of its scientific services. It is on the basis of facts that policies should be determined. To make the "facts" fit the current policies is detrimental alike to policy and to science. A politician is most dangerous when, as medicine man, he juggles facts. The citizen may want to have things "put plain," but the solutions of some problems are hard and complex, inasmuch as they deal with not yet fully ascertained or analyzed facts, intricately related forces, current views and mutually unrelated tendencies. Not all distributional facts can be readily understood by "a glance at the map."

Speaking in this place, where one almost overlooks the drought-stricken areas of the past few years, may I refer to studies[11] carried out since 1930 on the mar-

[8] J. B. Kincer, *Annals,* Association of American Geographers, 13: 73, 1923.

[9] H. H. Bennett, SCIENCE, 81: 326, April 5, 1935.

[10] Alex. Du Toit, *South African Journal of Science,* 31: 1–24, ref. on p. 5. 1934.

[11] Carried out under the auspices of the American Geo-

ginal lands and settlements of selected parts of the West and based on climatic records, tree rings and the history of lake fluctuations in the Great Basin region and on field notes made in 1930 and 1932 in the territory extending from the Texas Panhandle to the Canadian border. The questions one naturally asks in viewing the region are: (1) How long will the drought last? (2) Was the West ever as dry as it is now and will equally severe drought conditions return soon? (3) Is there a general tendency toward a permanently drier climate? (4) Has our Western land been permanently disabled, and what measures can be taken to offset the bad effects of drought?

*How long will the drought last?* There is no known way of predicting the end of a drought. There is no "apparent conformity to any law of succession" (Kincer) in rainfall variations. The change from a wet period to a dry period is comparatively uniform, but the time intervals between successive maxima are other dry, in a given year or period. Precipitation in the mountainous areas of the West is in closer correspondence as to amounts and times of occurrence than the lighter precipitation on the adjacent plains and basin floors.

One can safely predict for our dry West a rainfall heavier than that of the present. One can also be reasonably sure that its return is near, a matter of a few years at most, for the longer a drought lasts the surer we are (from past records of duration) that it will soon end. The less extreme rainfall departures are local, and that means locally different; the more extreme departures affect wider territory; and the most extreme affect most of the West and the Great Plains. It is the last-named type that we have been experiencing.

*Was the West ever as dry as it is now?* The rainfall records west of the 100th meridian with few exceptions cover a period but 50 to 60 years in length.

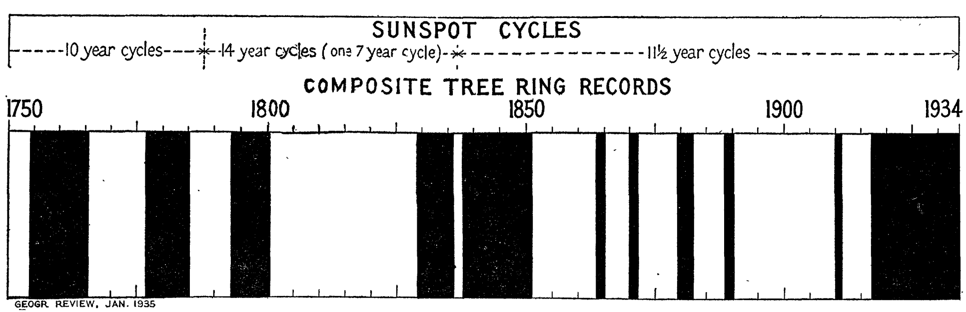


FIG. 6. Sunspot cycles and tree growth. In the upper part of the diagram are shown the dates of change in the lengths of successive sunspot cycles. The lower diagram is a composite representation of tree records in central Oregon and northeastern California. The shaded bands represent periods in which tree-rings are prevailingly thin, indicating lighter rainfall and a lower water table. Alternating blank-spaces represent periods of thicker tree-rings, greater rainfall and higher water table.

decidedly irregular. Regular cyclic changes in rainfall have not been identified in the records; there are only pseudocyclic appearances. Climatic changes appear to be inevitable and to be as yet unpredictably irregular, whatever their cause. The power of forecast may one day be ours. As yet it eludes us. The periods of protracted drought have been in general from 5 to 12 years, and periods of greater rainfall range from one to five to 60 or more years in duration. There are marked differences in cycle phase from region to region. One region may be wet, an-

graphical Society with two supplementary grants from the Carnegie Institution. The results have been published in part in the *Geographical Review*. The present résumé is based chiefly on material in "Our Expanding and Contracting 'Desert,'" *Geogr. Rev.*, January, 1935, pp. 43–65. Dr. Antevs, who participated in the study, has just completed a paper to be published jointly by the American Geographical Society and the Carnegie Institution, entitled "Rainfall Fluctuations in the Great Basin during the past 100 years."

Accounts of lake levels, reports of the condition of the grass and the record of the differences in thickness of tree rings on adjacent slopes of the Great Basin combine to tell us that the most severe drought of that region, prior to the present one, as far back as any of the evidence goes, was in the 40's, with interrupted duration of drought from 1829 to 1852. Different parts of the region later on suffered shorter droughts at intervals. The changes in level of Goose Lake, lying across the California-Oregon boundary, are instructive. From the slides you see a part of its floor exposed and wagon tracks running across it. A track also shows across its southern end on one of the sheets of the Wheeler Survey of 1877–1878.

The disappearance of these tracks, made by the forty-niners and others, soon after progressive exposure in the period about 1920–1927, supports the presumption that they were quickly covered with water soon after the lake level rose (1852 +) and were not again exposed until the 1920's. Since diversion of the tributary water for irrigation would exaggerate the effects of diminished rainfall on lake level, it is safe to say that the period between 1852 and 1918 was at no time so dry as in the late 1840's and since 1918. This conclusion requires checking, region by region, to determine the extent of its application to the West generally and to the Great Plains. The Goose Lake records are supported by the record of ring thicknesses in junipers in the Harney Lake region.[12]

*Is there a general tendency toward increasing dryness?* The present drought appears to be the *longest* that is recorded in the tree rings of the past two centuries, though such rings tell us almost nothing about proportional amounts of rainfall. It is, however, roughly like the drought of the 1840's in duration and possibly in intensity. We have no specific evidence that protracted droughts are now more frequent or severe than they were a century or two centuries ago. Glacier retreat may or may not indicate progressive desiccation. Much depends upon the seasonal distribution and kind of precipitation that affects glacier alimentation. There is no direct correlation between rate and amount of ice retreat on the one hand and precipitation on the other.[13] Highly important is the fact that mountains and plains may differ markedly in precipitation trends in the same period of time, and as yet we lack "normals" sufficiently reliable to use in determining the value of departures, in our search for a basis of forecast. The longest continuous rainfall record in the United States is 121 years (New Bedford, Mass.), too short to give us satisfactory evidence on secular changes in rainfall. Only uninformed boldness, not science, would venture long-range prediction as to future occurrence, duration and intensities of drought upon so short a record. One may safely predict a wetter future period than we have had for the past five years. In any event, we can not hurry the seasons. A closer spacing of rain gauges is possible and a further analysis of tree rings based on contemporaneous studies of tree growth in relation to local factors of insolation, rainfall pattern, etc.

*Has our western land been permanently disabled?* The "forces of life" have a curious way of offsetting or ridiculing our prophecies. Nature surprises us with her hardships and disasters but also with her beneficences. Her time schedule in many categories of action seems to be made up only a little way ahead. There is in preparation an "Atlas of Calamities." An essay should accompany it entitled "Calamities that never happened." A major query for the wind-eroded risk areas in the grasslands of the Great Plains is, "Under what conditions can a sod cover be restored?" With the breaking-up of the sod cover there is a tremendous increase in the action of rainwater, not in the way of direct erosion on flat surfaces, but in decreasing the crumb structure and porosity of the soil and destroying the humus content which acts as a binder. Repeated cultivation of the surface mulch on a fallow field—part of the process of dry-farming —hastens these processes and gives the wind a chance to carry the whole surface layer away. Thus thousands of farmers become "subsoil farmers."[14] If we change our cultivation habits, allow the land to remain idle, sow suitable grass seed and prohibit all grazing for a time, we shall find out how far and how fast a sod cover can be restored. These things are also likely to show whether or not irreparable damage to the soil has been done because of a lack of favorable rainfall in our present phase of rainfall change and how far we may expect early replacement of a grass cover.

The list of inquiries might be greatly extended. I have chosen to limit myself to four of the main or immediate questions: much might be added on water resources and wild life conservation, and on economic questions in their regional framework. The adaptable techniques of science that will aid in the wiser use of our drier lands are not difficult to apply: it *is* difficult to get short-term administrators to see their importance. Government is now so large and complicated that small and temporarily powerful groups may control decisions on grave issues, scientific and administrative, and the heads apparently have to be too much occupied politically to give attention to well-coordinated scientific programs. Scientific research is too often left to the mercy of rival bureaus and to the decisions of ambitious men who are engrossed in personal advancement.

Four leading desiderata in a land-use program for the semiarid areas of pronounced risk may be mentioned in closing: (1) soil erosion techniques should be tested by research upon the present widely developed field projects; (2) the principal wind-erosion districts of the Great Plains should be withdrawn from cultivation, and experiments and studies instituted looking toward the restoration of a sod cover to be followed by grazing under strict regulations; (3) tree and shrub plantings should be limited to the better parts of the shelterbelt, the expected beneficial effects being in the longer future, while cultivation practices both in and out of the shelterbelt need immediate improvement from the wind-erosion and agricultural-risk standpoints; (4) a thoroughgoing analysis of climatological records should be made to help determine and define the areas and grades of serious agricultural risk.

[12] L. T. Jessup, *Geog. Rev.*, 25: 310–312, April, 1935.

[13] The Committee on Glaciers of the American Geophysical Union has found that the glaciers of the United States have been in retreat since a time before 1850. If the retreat continues, most of the glaciers of our western ranges will have disappeared, as they are believed, on physiographic evidence, to have done a few centuries ago.

[14] H. H. Bennett, SCIENCE, April 5, 1935, p. 322.