Climate of the Great Plains Region of The United States

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The climate of the Great Plains is extreme and variable. A wide range of weather conditions can occur within the period of a day, from one day to the next, from season to season, and from year to year. There are two key reasons for this situation: (1) the greatest portion of the Plains is remote from any major body of water and (2) air masses of differing characteristics alternate frequently in their dominance of the region.

A Continental Climate

Water bodies are the great buffers in the exchange of energy between earth and atmosphere and exert a modifying and moderating influence on adjacent land areas as well. Water will absorb five times as much heat as will soil with the same attendant change in temperature. Thus a soil surface will heat quickly when exposed to the midday sun but water temperature rises only slowly. Conversely, at night, the soil cools rapidly as it loses heat to the atmosphere but water cools slowly. The presence of large quantities of water vapor in the air over maritime regions provides yet another buffering effect, since water vapor absorbs thermal radiation and creates a greenhouse type of condition by trapping energy emitted at the surface. Where water vapor content is great the heat emitted by earth is effectively absorbed and the rate of cooling is slowed.

Much of the Great Plains region is remote from the one major body of water that influences it—the Gulf of Mexico. The fact of its remoteness is the reason that the climate is described as *continental*. Continentality dictates that the diurnal range of temperature (night to day) and the annual range of temperature (winter to summer) will be great. The Great Plains (particularly the northern portion) has the most distinctly continental climate in the United States.

Continentality and Temperature in the Great Plains

The map in Figure 1a shows the normal

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daily minimum temperature in January for the United States. Note the daily minimum in Amarillo in the Texas Panhandle is the same as it is near Detroit, Michigan, five hundred miles to the north. Settlers who moved westward onto the plains encountered climates that were considerably colder in the winter. Figure 1b, on the other hand, shows that maximum temperatures in the northern Great Plains are as high in summer as they are in the southeastern United States. The normal daily maximum temperature in north central South Dakota is about 90° F in July—the same as it is in Jacksonville, Florida.

Winters in the northern Great Plains are the coldest in the contiguous forty-eight states. The southern Great Plains are as hot as the southeastern part of the United States in summer. The northern Great Plains are hotter than the northeastern part of the country. At Steele, North Dakota, for example, the maximum summer temperature recorded is 121° F. The lowest temperature recorded is −50° F, for an annual range of 171° F. In many parts of the northern Great Plains an annual temperature range of 140° F is common.

Air Masses

Large bodies of air are conditioned continually by the surfaces over which the air moves. Air that has been in contact with tropical seas will be warm and moist; air over polar or near-polar regions will be cool and dry, since the capacity of air to hold water vapor is small at low temperatures. Further, little evaporation

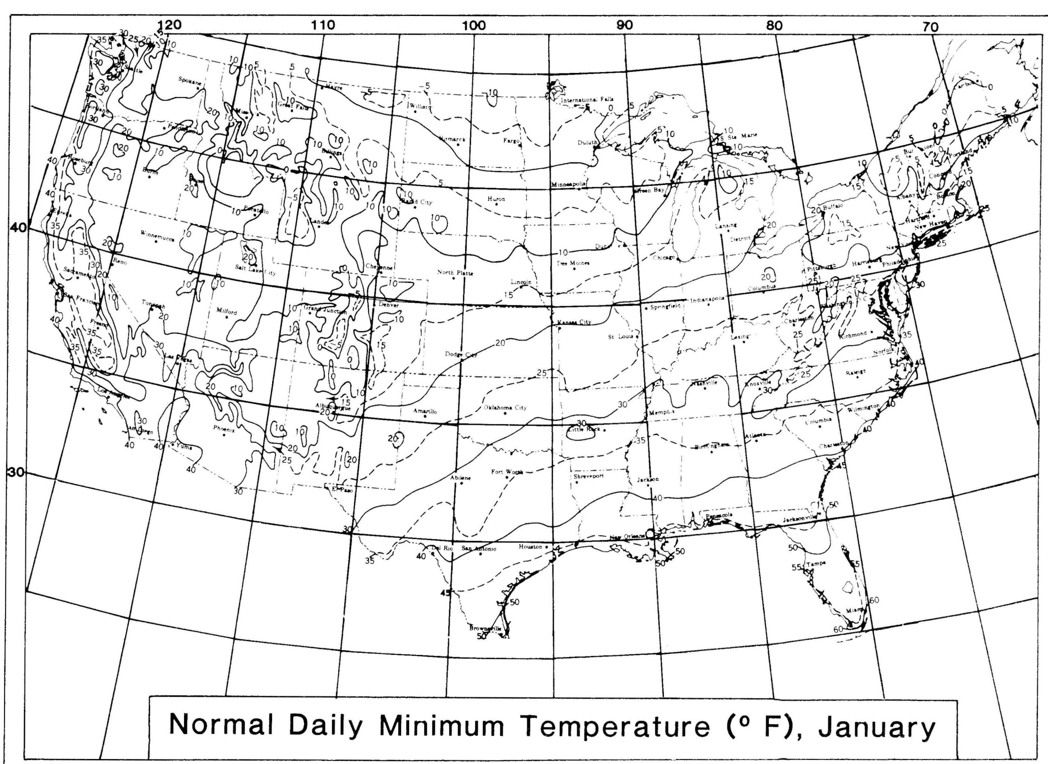

FIG. 1a. *Normal daily minimum temperature (°F) January.* (Climatic Atlas of U.S. *lower half of p. 12)*

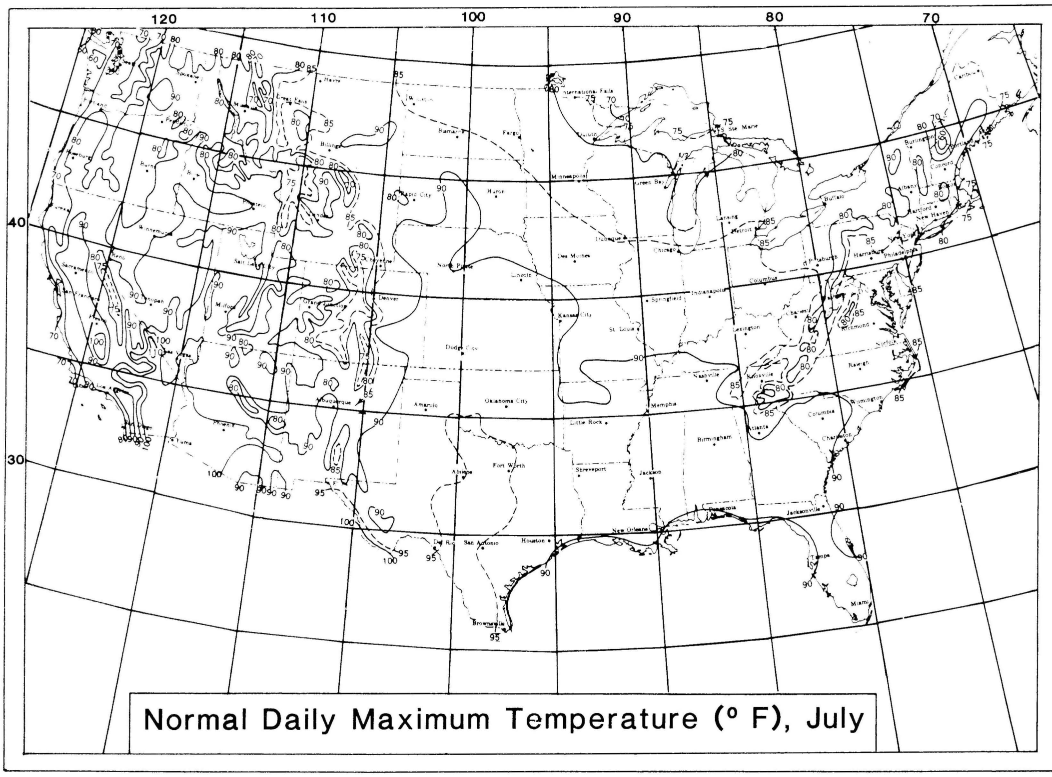

FIG. 1b. *Normal daily maximum temperature* (°F) *July*. (Climatic Atlas of U.S. *upper half of p. 13*)

occurs where the sun provides little energy to convert liquid or frozen water to vapor.

The region between the Rocky Mountains and the Appalachian chain is open to motion of air masses that originate in the north (continental polar air masses) and over the Gulf of Mexico (maritime tropical air masses). The orientation of the North American mountain chains does not separate the air masses from one another as do the Alps in Europe and the Himalayas in Asia. Instead, the air masses meet and clash with great frequency. A third type of air mass enters the Great Plains periodically, air that is conditioned over the Pacific Ocean—moist but cooler than Gulf air because of its more northerly origin. Maritime Pacific air masses cool as they rise to cross the western mountain ranges, and the capacity of the air to hold water vapor decreases sharply. Condensation and precipitation occur and the air mass dries out. When it descends the eastern slopes of the Rocky Mountains to the western Great Plains, this maritime Pacific air is warm and quite dry. Thus we say that the western Plains lie in the "rainshade" of the Rockies. Still a fourth source of air sometimes dominates the Plains, air warmed over the dry southwestern deserts of the United States and northern Mexico. Frequent outbursts of this warm, dry air in spring and summer create strong evaporative stress on crops growing in the region.

Air Masses, Fronts, and Precipitation

Rapid changes in the temperature, humidity, cloudiness, windspeed, and wind direction that occur frequently in the Great Plains are due to the passage of air masses with different characteristics: where two or more air masses meet, fronts are formed. *Fronts* are defined as the transition zones or interfaces between two air masses of different density. The passage of fronts across the Plains is irregular. Continental polar air masses moving south encounter maritime tropical air masses advancing northward from the Gulf. The maritime air is lighter, because of its higher temperature, and more moist. It is forced aloft and, cooling as it rises, loses water by precipitation. Thus, most of the precipitation decreases with distance from the source of the vapor—the Gulf of Mexico. Figure 2 shows how sharply the total annual precipitation drops off with distance from the Gulf. Near the Gulf Coast annual precipitation is forty-eight inches. In northwestern Montana, it is twelve inches.

The advance of frontal systems may be accompanied by light general rains or by violent storms in which torrential rains fall for hours or sometimes days. Thus, it is the variability in moisture content of the maritime tropical air, the path of its movement, and the intensity of the impact with other air masses that produce the great variability in spacial and temporal distribution of precipitation in the Great Plains.

Warming of ground surfaces under unstable moist air may also lead to precipitation in isolated thunderstorms. These occur after formation of towering cumulus clouds in summer and are characteristically accompanied by thunder and lightning. The distribution of rainfall from this type of storm is more

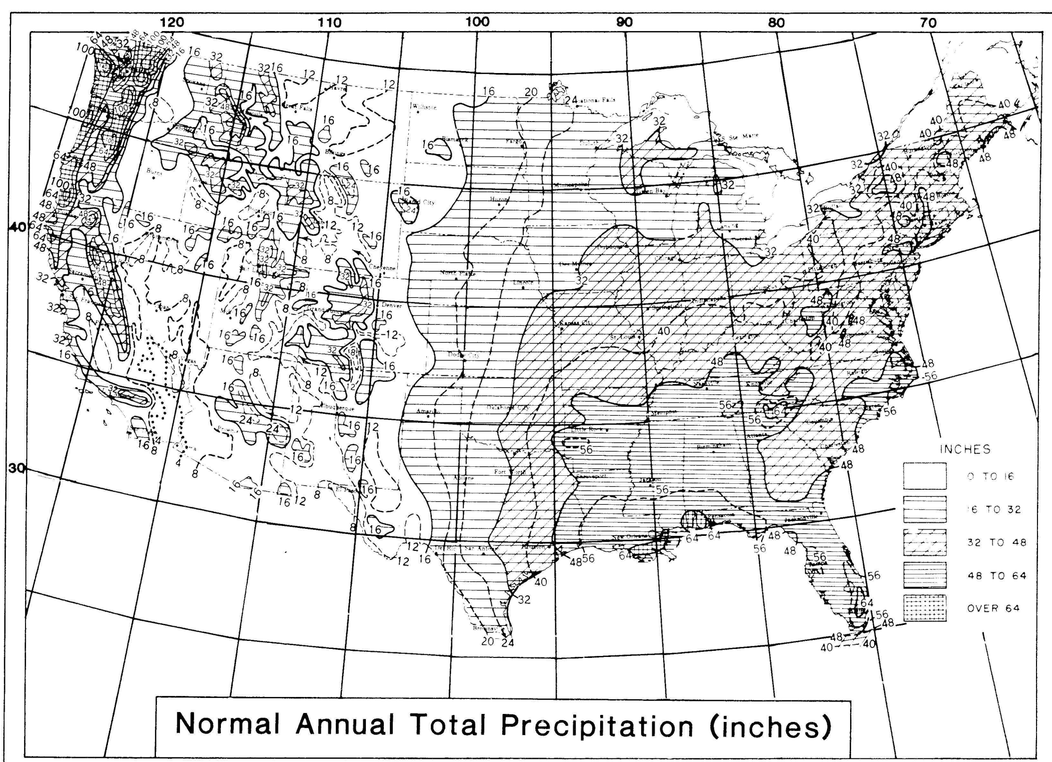

FIG. 2. *Normal annual total precipitation (inches).* (Climatic Atlas of U.S. *p. 43)*

random than that from the frontal systems.

The annual patterns of precipitation in the Great Plains change with the seasons. The distribution of snow in the north and rain in the south is fairly uniform from east to west in winter, but winter precipitation contributes only a small portion of the annual total. The bulk of the annual precipitation falls during the growing season from April to September. Autumn weather is usually drier in most of the Great Plains than it is farther east—a definite advantage in the harvest.

It is important to realize that the foregoing describes a normal or average annual pattern of rainfall distribution. Rainfall may be scant during one season and excessive in the next. Drought may occur one year and floods the next. This irregular distribution of rainfall over space and time in the Great Plains is one of the major constraints to the development of the region.

Evaporation—an Indicator of Climatic Variability

Rapid frontal movements through the plains region account for the rapid and frequent changes in cloudiness, air temperature, humidity, windspeed, and wind direction. In turn, each of these factors determines rate of evaporation. Thus, study of the evaporation rates gives an indication of the variability in the overall climatic condition. Table 1 gives data on the annual amount of evaporation from special pans maintained throughout the country by the National Weather Service. Four locations are compared in the table. On an annual basis, evaporation at Mead in eastern Nebraska is less than at Phoenix, Arizona, or at Davis, California, but is more than at Coshocton, Ohio. The western locations have longer growing seasons, and Phoenix is essentially a desert location. Coshocton is a bit farther south than Mead and in a more humid region. Of the four locations, the standard deviation of the annual evaporation (a measure of variability) is greatest at Mead. This is due to the high degree of day-to-day and year-to-year variability in Great Plains weather caused by the continual interchange of air masses.

Another interesting feature of Table 1 is the data on maximum reported daily evapotranspiration (ET). *Evapotranspiration* is the sum of water evaporated directly from the soil surface and water evaporated at the leaves of plants through which the water has passed from the soil (transpiration). Evapotranspiration rates are as high in the east central Great Plains as in the southwestern desert location. The rate at Mead, Nebraska, is also greater than it is in the Mediterranean climate of Davis or the inland climate of Coshocton. Thus, we see that, at least at times, the integrated effect of the Great Plains climate—high temperatures, low humidity, strong winds, and clear skies—leads to a very rapid consumption of water by growing plants.

Figure 3 shows the mean annual evaporation from lakes in the United States. The lines

TABLE 1

PREDICTED EVAPORATION FROM CLASS A PANS AND REPORTED MAXIMUM ET AT FOUR LOCATIONS IN THE CONTINENTAL UNITED STATES (mm) (AFTER ROSENBERG, 1969)

Location:	Mead (Nebr.)	Coshocton (Ohio)	Davis (Calif.)	Phoenix (Ariz.)
Annual pan evaporation	1,524	1,117	1,778	2,267
Stand. deviation (annual)	264	86	107	173
May–October evaporation	1,173	861	1,333	1,840
Daily mean May–October	6.41	4.70	7.28	10.05
Maximum reported daily ET	12.02	9.14	11.56	12.20

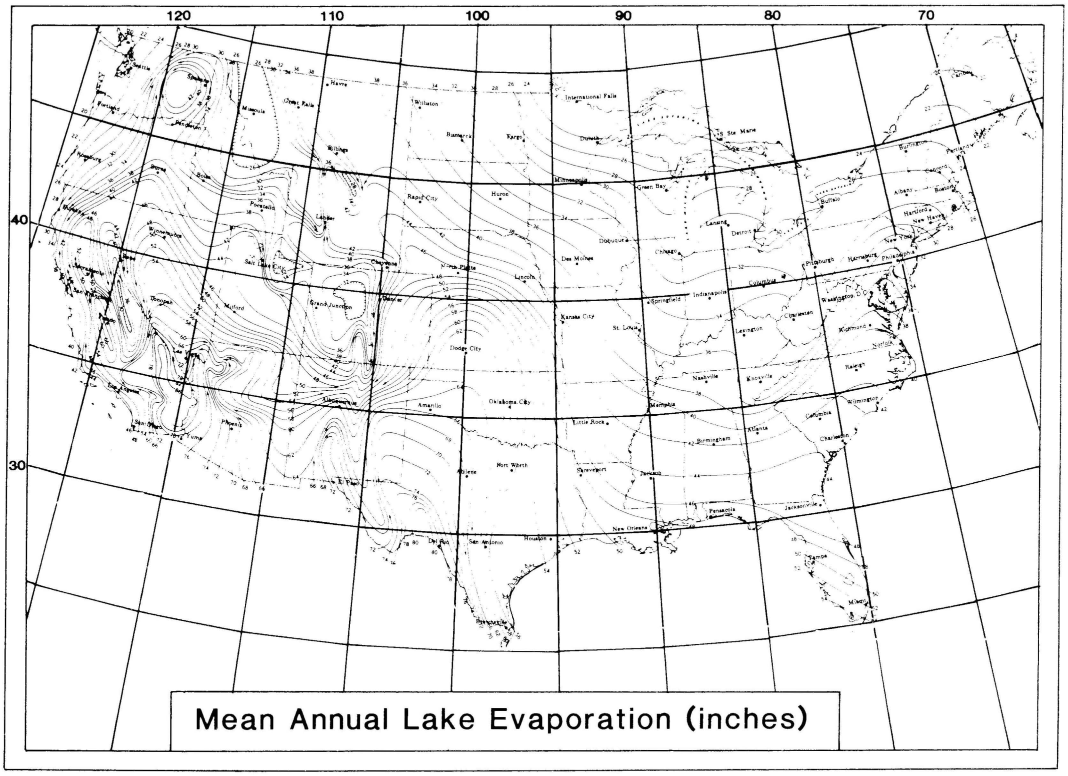

FIG. 3. *Mean annual lake evaporation (inches).* (Climatic Atlas of U.S. *p. 63—plate 2*)

representing areas of equal evaporation have a northwest to southeast orientation in the northern Great Plains from Montana through Nebraska. South of Nebraska, the evaporation increases sharply but in a different regional pattern. By comparing this figure with Figure 2, we may see how, on an annual basis, the evaporative demand exceeds the rainfall almost everywhere in the Great Plains region. At Lincoln, Nebraska, for example, the average annual rainfall is about thirty-four inches. The annual evaporation from free water is about forty-two inches. Therefore, if water were always available, evaporation would exceed rainfall by eight inches. At Scottsbluff, Nebraska, the annual rainfall is about sixteen inches. The annual evaporation from free water is estimated at forty-four inches. In western Nebraska, as in the western portion of most of the Great Plains, the atmospheric demand for water vapor far exceeds the amount of water available through precipitation.

All of these factors point out that the Great Plains is a region of deficit water supply. The atmospheric demand for water from growing plants is strong snd generally exceeds the supply of natural precipitation. It is for this reason that irrigation has been of such major importance in the Great Plains region. Only through the development of irrigation can farmers have a reasonable degree of confidence in their ability to produce consistently high yields of crops and to survive periodic drought.

Climatic Hazards and Adaptations in the Plains

Thus one can readily see that the Great Plains posed for settlers severe climatic problems that to this day restrict the economic and social development of the region.

Extreme Temperatures

The frequency with which very hot days occur in all parts of the plains is considerably greater than it is at the same latitudes in the eastern portion of the United States. Forty days a year of temperatures higher than 90° F occur at Lincoln, Nebraska. At New York City (about the same latitude) only five to ten such days occur each year. Great heat imposes a strong evaporative demand on growing crops, which not even irrigation can fully alleviate. Human comfort is affected by high temperatures and domestic animals are also sensitive. Large losses of livestock are reported in the Plains each year during hot spells, particularly when humidity is also high.

The polar climate of the Great Plains winter creates other hazards to human and animal life. Good shelter and fuel for heating have always been necessary in the northern Plains. Even in southern Texas, occasional northers drop temperatures to below freezing for a few days at a time, damaging sensitive subtropical crops such as grapefruit. Blizzards, although infrequent, create other dangers. People caught out-of-doors can lose all sense of direction during a blizzard and some have frozen to death only yards away from shelter. Herds of cattle drift aimlessly in blizzards and serious losses occur as the animals wander into dangerous terrain.

Short Growing Season

Figure 4 maps the average length of the

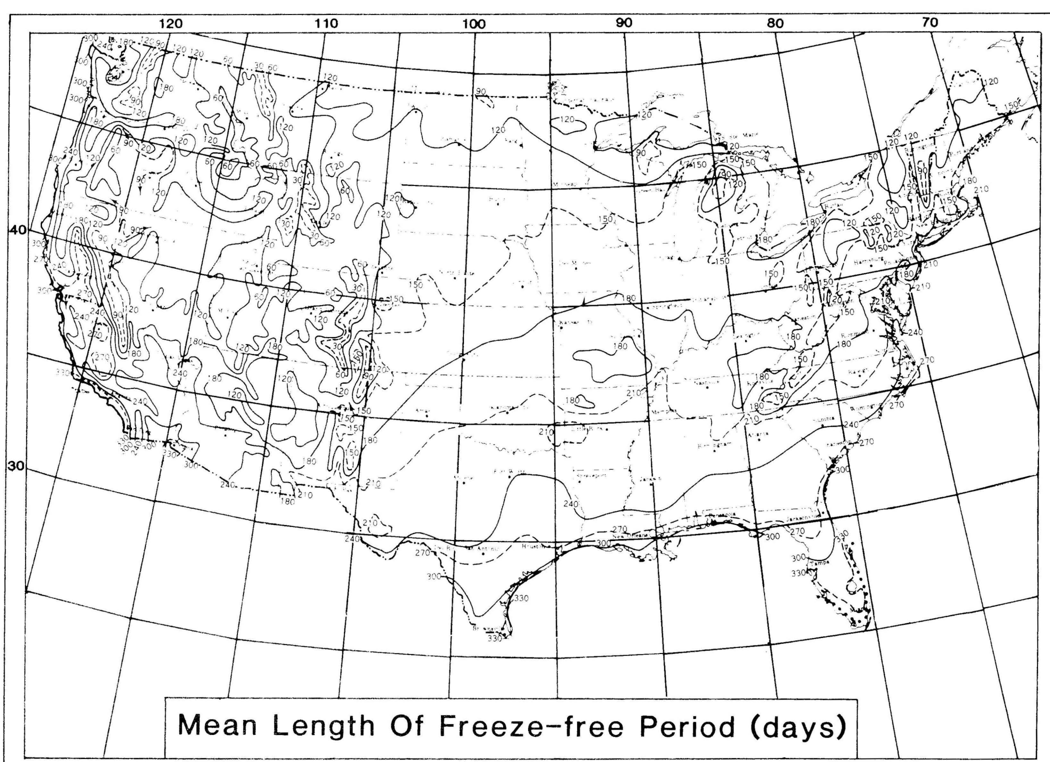

FIG. 4. *Mean length of the freeze-free period. Days between last 32°F temperature in spring and first 32°F temperature in autumn.* (Climatic Atlas of U.S. *p. 31)*

freeze-free period in the continental United States. This is the number of days between the last occurrence of 32° F temperatures in spring and the first such occurrence in fall. Growing season in the northernmost part of the Great Plains is limited to between three and four months. The choice of crops is necessarily very restricted. In the southern plains, the growing season may last eleven months each year. Except for the area adjacent to the Gulf and except for the mountainous areas in the Appalachian chain, it is correct to say that the growing season is shorter anywhere in the Plains than it is at the same latitude in the eastern United States. Crops adapted to shorter growing seasons were needed by the settlers to succeed on the Plains and crop research is still devoted, in large measure, to finding the species and varieties of crops adapted to the shorter growing season.

Even after crops have been planted in spring and before the harvest in fall, frosts may occur and cause considerable damage. The extensive cropping systems (large areas, low capital input) of the Plains region do not generally justify expensive measures for frost protection, so frost is just one more hazard with which the farmer must learn to live.

Recurrent Drought

Drought can be defined in various ways. Any extended period of dry weather that leads to a measurable loss of crop production can correctly be called *drought*. When such periods become so long and the shortage of soil moisture so critical as to cause abandonment of fields already sown, or when crop cover becomes so sparse, because of lack of moisture, as to permit the erosion of the soil surface by wind, drought can be catastrophic in the Great Plains region.

Drought in the Plains is not just a modern phenomenon. H. E. Weakly's dendrochronological studies (tree-ring measurement and interpretation) on specimens of red cedar and ponderosa pine have identified short periods of dry years and, less frequently, droughts lasting for more than five years. Weakly found tree-ring patterns that indicated the occurrence of one drought period of thirty-eight years.

Long-term records of annual precipitation virtually anywhere in the Plains show extreme year to year variability. Such records also show that dry years have tended to occur very often in series of two, three or more years—although these series are often interspersed with occasional wet years. Thus, for example, in the period since systematic weather records have been kept in the Great Plains, a number of drought periods of greater and lesser severity have been experienced. W. C. Palmer has, through weather records research and the study of newspapers and other historical documents, described the drought history of a number of locations in the Plains. His history of western Kansas is typical. Drought that had major impact on the agricultural production in western Kansas occurred in 1894, when as many as 90 percent of the settlers abandoned their farms in some areas. Drought occurred again in 1913, following the dry years of 1910 and 1911 and the abnormally wet year of 1912. Between August 1932 and October 1940, thirty-four months of extreme drought occurred in western Kansas. In 1952 and 1953, all thirty-one counties in western Kansas were declared a drought disaster area by the federal government, and the dry conditions extended through 1955. Similar histories can be recited for other parts of the Great Plains during these same periods. Recurrent drought is part of the Great Plains environment and its inevitability is, unfortunately, forgotten when the weather is good.

Strong and Persistent Wind

The Great Plains is the windiest region of the country—open as it is to the free sweep of air masses from north and south. Because the terrain is relatively flat and smooth and the land is largely cropped or in pasture grass, the frictional forces that reduce wind speed in other regions are less active in the Great Plains. In winter, northerly winds predominate as far south as Texas. In summer, southerly winds predominate as far north as Montana. Hot southerly winds during the growing season create stress on plants and the low humidity of southwest winds increases the evaporative demand on crops still more.

Strong winds from any direction can cause mechanical damage to crops such as breakage or blowing over (lodging). In winter, northerly winds increase the loss of heat from buildings. Animals also seek shelter from the strong northerly winds during winter. For these reasons, early settlers used European techniques of windbreak plantations to protect their farmsteads, animals, and fields. In the 1930s and early 1940s, the Shelterbelt Project was initiated by the federal government to protect the entire Great Plains region by the planting of thousands of miles of tree windbreaks. It was thought at the time that, as well as providing immediate protection for fields and farms, this extensive network of trees might beneficially change the climate of the Plains. The Shelterbelt Project was abandoned during World War II for lack of funds and labor to complete it, although windbreak plantings continue less systematically today.

Wind erosion has been a serious problem on the Plains, probably from times well before settlement. During the drought of the 1930s, particularly, farming methods that left the soil bare at certain times of the year led to serious wind erosion and dust storms. The periodic plowing of marginal lands in the semiarid belts of the western Great Plains also contributed to the problem. Modern methods of soil erosion control (strip-cropping, stubble-mulching, increasing surface roughness) have been effective in minimizing wind erosion damage, but these improved practices are not used universally.

The Great Plains settler treated the wind as an enemy, but it is also a source of power. Windmills once dotted the Plains to pump water, and, before rural electrification, to drive simple generators. With the energy shortage before us and with engineering improvements in windmill design, a windmill renaissance may be coming on the plains. Wind is also the sweeper of the atmosphere. The Great Plains owes the relative cleanliness of its air to the fact that manmade and natural pollutants are moved out of the region with great rapidity because of the almost continual action of the winds.

Other Hazards

Frontal storms over the Great Plains as well as other regions of the country frequently trigger severe wind and, occasionally, tornadoes. The region of most intense tornadic activity is centered in east central Kansas and north central Oklahoma. The frequency of hailstorms is greatest in an area centered in the southwestern corner of the Nebraska Panhandle and in adjacent parts of Wyoming and Colorado. As many as nine days with hailstorms occur each year, on the average. The frequency of hailstorm days drops to about five per year in the Wyoming, Kansas, Colorado, and Nebraska areas surrounding the "hail center." The eastern edge of the Great Plains commonly has three to four days with hailstorms each year. The high frequency of hail in the western plains region explains the fact that hail insurance rates in that region are the highest in the United States. Hail can be particularly devastating to wheat growers in the western High Plains because the storms are common during late spring and early summer when the crop is ripening and the impact of a hailstorm will shatter heads of wheat, making harvesting virtually impossible. Cultivation of the sugar beet is one means of adaptation to the great hail hazard in western Nebraska, eastern Colorado, and Wyoming. Sugar beets recover remarkably well from hailstorms, which sometimes strip the plant of virtually all its leaves.

ADVANTAGES OF THE GREAT PLAINS CLIMATE

While it is true that drought, severe weather, strong winds, and extreme heat and cold impose serious restrictions on the developmental possibilities of the Great Plains region, it is also true that the region enjoys distinct climatic advantages. The intensity of solar radiation at any given latitude increases from the East Coast to the Rocky Mountains. This trend occurs most clearly across the plains region because of the increasing elevation of the land and the reduced frequency of cloud cover. The air in the Great Plains regions, because of a generally low humidity content, is also less turbid (opaque). Thus, crops that require intense illumination for development are well adapted to the western Great Plains.

Another advantage of the Great Plains climate is the relatively dry autumn season. The probability of significant rainfall drops off rapidly in September and October in most parts of the Plains. This makes the use of mechanized harvesting equipment more efficient than it is, generally, in the more humid East. There are times, of course, when rain and early snowfall make harvesting very difficult, but generally the harvest progresses easily.

Humidity decreases from east to west across the United States to the Great Plains and decreases with distance from the Gulf. The low relative humidity suppresses many types of plant fungal diseases that are common in the East. The potato crop in western Nebraska, for example, is more easily protected against "late-blight" (a fungal disease) than it is in more easterly locations.

SUMMARY

The climate of the Great Plains is characterized by: (a) a great range in daily, seasonal, and annual temperature; (b) strong atmospheric potential for evaporation because of the ample solar radiation; (c) strong windiness and usual dryness of the air; (d) wide difference in the annual totals of precipitation received from the east to the west, and (e) frequent severe weather including damaging winds, hailstorms, and tornadoes.

Limited length of the growing season and irregularity of the precipitation are the major constraints to the stability of the agricultural production in the region. Late spring and early fall frosts are frequent but unpredictable. There is a significant risk that crops will not have a long enough season for optimum growth. Droughts of greater or lesser severity are a regular feature of the plains climate. The history of the region and its flow of population in and out are closely linked to the incidence of drought.

Adaptation to the plains climate has required ingenuity, persistence, and fortitude on the part of the peoples who have ventured into it. Earthen shelters and sod houses for protection from the cold; shelterbelts for protection of homes, animals, and fields from the damaging effects of severe wind; use of windmills for power to pump water; introduction of short season crop varieties or varieties that extend the season by overwintering; soil terracing, stubble-mulching and minimum tillage practices to minimize water and soil erosion; the introduction of irrigation—all are important adaptations that have been made.

Optimists in the past have proposed that man's works would alter the plains climate—but rainfall does not "follow the plow" as Dr. Samuel Aughey of the University of Nebraska proposed in the early 1870s, nor do shelterbelts modify and moderate the climate as President Franklin D. Roosevelt's Committee on the Future of the Great Plains suggested in 1936. Neither does it seem reasonable to expect that the influence of large-scale irrigation projects will extend very much beyond the irrigated region. Some believe that cloud seeding for rainfall augmentation will have a significant effect on the climate of the region. Others (myself included) doubt that this will be the case.

The climate of the Plains will be in the foreseeable future what it has been in the past, although the possibility of its becoming warmer and drier as a result of increasing the carbon dioxide concentration in the atmosphere (the greenhouse effect) seems more and more likely as new scientific evidence on this question accumulates. Man's works are too puny in scale to modify the weather, but improved crop varieties, better irrigation and dryland farming techniques, and modifications of the environment of individual fields will all contribute to increased stability of agricultural production in the region.

The Great Plains has been, in modern times, a major producer of food and feed grains, fodder, and livestock products for the nation and the world. Critical shortages in the world's food supply, experienced during the 1970s, have been alleviated and the economics of food production in the Great Plains is at best confused in the late 1980s. It seems likely that, with continuing growth in world population, demands for Great Plains food production will again increase, but the economic success of production agriculture will require, more than ever before, a degree of management skill that minimizes the stresses imposed by the climate of the region and makes the best possible use of its beneficent features.

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