tremes and improvements in management of water and conservation of soil moisture. In the drier parts of the Plains, that would necessitate a shift toward a grazing economy with larger units and, where possible, an integration of cropland farming and ranching.

Improved water management through irrigation projects, the development of many small watersheds and reservoirs, and improved water-spreading techniques on rangeland offer opportunities for improved and sustained agricultural production. To make the most effective use of this water, increased emphasis on soil and water conservation research will be essential.

The potentialities from improved moisture conservation and efficiency present a challenge. Many improvements have been made in methods of summer fallowing and residue management from the standpoint of erosion control and conservation. This and stripcropping, strip fallowing, and other practices have made great strides toward stabilizing the dry-farming economy. No great advance has been made in the moisture conservation aspect of fallowing since 1915, however. Only 15 to 25 percent of the rainfall during the fallow period is conserved and stored as soil moisture for subsequent crops. If the moisture storage could be increased even 10 to 20 percent, crop yields would be substantially increased and production would be stabilized greatly. Basic research is needed for a better understanding of soil moisture movement and evaporation.

Chemicals to control weeds are good possibilities for improving conservation of moisture under both crop and fallow conditions.

There are great potentialities for improvement of crops in the Northern Great Plains through improved plant nutrition. A large part of this improvement will depend on the wise use of commercial fertilizers.

The present use of fertilizer is but a small fraction of that which could be used with profit to farmers of the area.

The Winter Wheat and Grazing Region

J. A. Hobbs

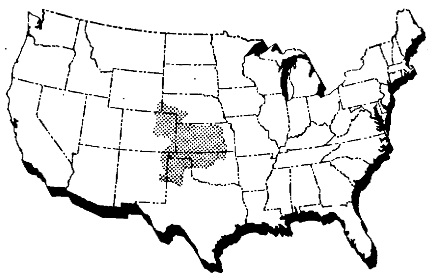
The winter wheat and grazing region of the Great Plains includes the subhumid and eastern semiarid sections of the central and southern Great Plains. The rainfall is irregular. The soils mostly are fertile. Winter wheat is the main crop. Considerable land remains in native grass, which is grazed.

The average annual precipitation is more than 38 inches in the southeast and less than 14 inches along the western edge. That is enough moisture for satisfactory growth of adapted crops if one uses recommended practices.

Precipitation has been as low as 50 percent of average and higher than 200 percent of average in almost all parts of the region. Generally the number of years with below-average rainfall slightly exceeds the number with above-average precipitation. Seasonal as well as annual irregularities are common.

Considerable variation in temperature also occurs. The average growing season—the period without a killing frost—is closely related to the mean temperature for the different sections. The average growing season ranges from more than 210 days in the southeastern part to fewer than 140 days in the northwestern section.

The wide variations in climate would lead us to expect a wide variation in



native vegetation. The variation does occur, but the native vegetation over the whole region is grass. Some small favored sites support trees. Bluestems, both big and little, and associated tall and mid grasses grow in the eastern parts. Farther west where it is drier, short grasses come into the native sward, until in the western section the short grasses, such as buffalograss and the gramagrasses, are the most common species on the uplands. Taller grasses tend to dominate on the sandier soils and on bottom lands.

A diversity of soils developed under this climate and native vegetation. The soils include the deep, dark Prairie and Reddish Prairie soils of the eastern sections; Chernozem soils in the central parts; and the shallower and lighter colored Chestnut, Reddish Chestnut, and Brown soils of the west.

Scattered through these zonal soils are some shallow soils on bedrock and some sandy soils and sand dunes. These soils and the fine-textured, tight, impermeable soils pose problems of management, but the areas are too small to designate and discuss here. The narrow belts of highly productive, alluvial soils along the many stream channels also are too small to delineate.

This winter wheat and grazing region can be divided into four subregions: The Flint Hills subregion, the Dakota Sandstone subregion, the subhumid wheat subregion, and the summer fallow subregion.

THE FLINT HILLS subregion is a rough, dissected section of shallow soils on shale and limestone bedrock. Mostly it is uncultivated and is used primarily for summer grazing. The bluestems and the associated grasses still prevail, and they and the climate and fertile soils have given to the Flint Hills a reputation of being one of the most productive native grass pasture areas in the United States.

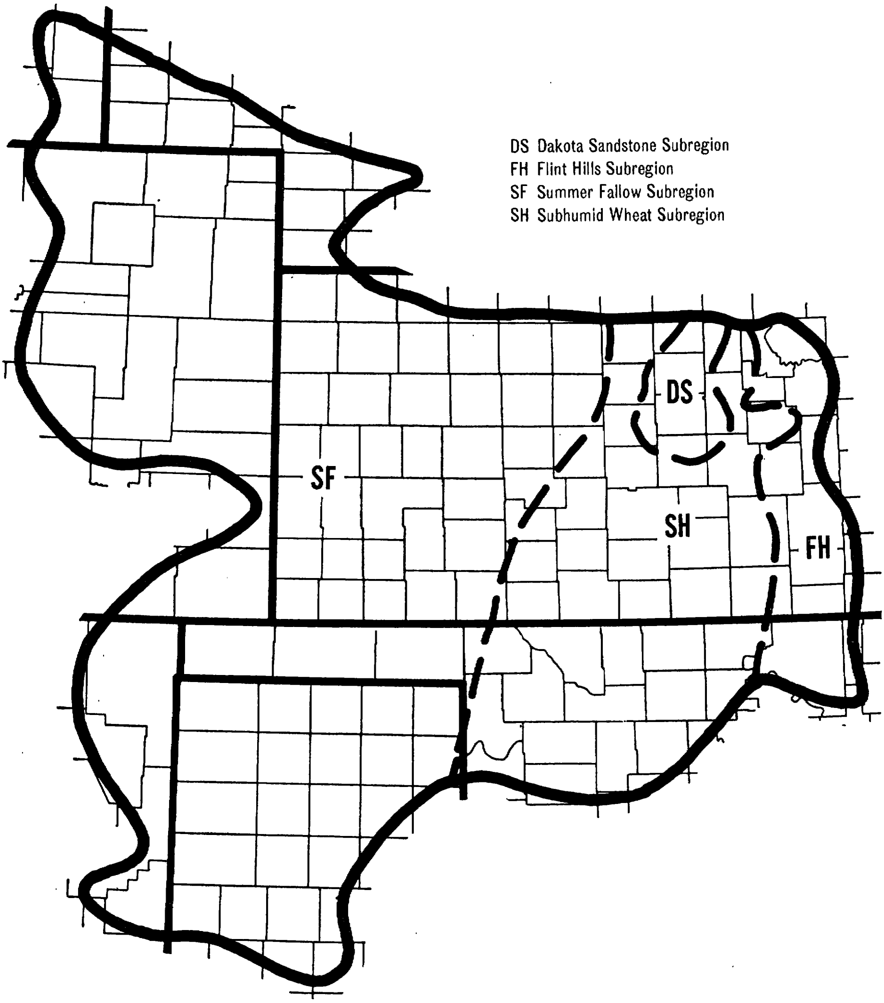
Some breeding herds are maintained, but much of the land is leased to western or Texas cattlemen at a cash rent per animal for the season. The cattle are shipped in to pasture in April and May and are shipped east to market when they are in finished condition or when the pasture is no longer useful.

Areas of soils suited to cultivation are scattered over the relatively level ridgetops. They tend to be fine textured and have tight, impermeable subsoils. Colluvial and alluvial soils at the base of slopes and on the small bottom land areas also may be tillable. These level upland soils and the colluvial and alluvial soils are limited in extent, but they are highly important to farmers—winter feed and forage for stock come from them.

Good management of the soils of the Flint Hills is nearly synonymous with good management of pastures.

Management of grazing on range pastures usually involves the maximum utilization of grass, with efficient livestock production and maintenance of the range. The large numbers of transient cattle in the Flint Hills have meant that emphasis has been put on rapid gains during the early part of the pasturing season. That places a premium on the "early bite." To gain that end, annual burning of pastures has been practiced since the early 1880's, and the practice has been written into many leases.

That the range has been maintained under such conditions is due mainly to other features of the leasing agreements. Cattlemen have demanded adequate acreage allowances per animal to promote good gains. That and the fact that many animals attain market finish in midsummer permit the grasses to make a good growth in late summer.



Necessary reserves of carbohydrate thus are replenished in the grass roots and crowns.

Some deterioration has been noted, especially in pastures grazed the full season without reduction in stocking load and in smaller pastures, which almost always are overstocked.

The adjustment of acreage allowance to the productive capacity of the grass is highly important. Not all cattlemen realize that when range is "fully utilized" about half of the current year's growth should remain at the end of the pasture season.

Additional practices needed in these pasture areas include a reduction or complete prevention of burning and the provision of adequate and properly spaced watering and salting sites. Because wells are often inadequate in the long, dry seasons, ponds and other structures should be made to supplement the water supply. Places that have started to gully because of overgrazing should be fenced off and allowed to recover.

Danger of erosion is great on the sloping cultivated fields on the uplands. Many of the cultivated lands are underlain by slowly permeable subsoil. Runoff and the likelihood of soil loss are greater on them. These lands should be cultivated on the contour. Terraces should be used when they are needed to control erosion. Applications of fertilizer will increase production of crops. The denser stands and heavier residues resulting from fertilization help reduce erosion losses. Little benefit from deep chiseling has been seen in carefully controlled experiments.

The Dakota sandstone subregion, another grazing area, is just west of the Flint Hills. Its soils are strongly acid and very low in available phosphorus. Originally the grass cover was like that of the Flint Hills. Because of the lower annual rainfall and poorer soils, this section succumbed more quickly to overgrazing. Now it is much more depleted, and it does not have the reputation as a grazing area that the Flint Hills region has.

The cattle usually are raised locally and retained until they are shipped to the market.

Steep slopes and overgrazing have permitted some water erosion. The cultivated soils are highly erosive. Frequently they are shallow over bedrock and are infertile. Wind erosion has been serious when dry weather or low fertility has reduced the vegetative cover to any sizable extent.

The management practices required on the grazing lands in the Dakota Sandstone subregion resemble those that should be used in the Flint Hills, but the use of the pastures should be more restricted because of lower productivity and lower rainfall. Larger acreages are required to carry the stock because the soils are less productive.

Some lands are cultivated on most farms to supplement the production of the range. Only soils that are reasonably level and relatively deep over bedrock should be cultivated.

Nitrogenous and phosphatic fertilizers generally are needed in the production of small grains and sorghum. Phosphatic fertilizers and frequent applications of limestone are needed for alfalfa.

Contour cultivation should be employed. Because of erosiveness of the soils, the lands steep enough to require terracing probably should not be cultivated. Terraces are not needed on native grass that is in good condition, regardless of slope.

The subhumid wheat subregion comprises parts of the eastern half of Kansas and of Oklahoma east of the Panhandle.

Some pasture and rangelands are included, but the area consistently produces more wheat per acre of total farmland than any other subregion. Corn is raised in the northern and eastern parts. Sorghum is grown over the whole subregion. The availability of seed of adapted, high-yielding, hybrid sorghums undoubtedly will mean an increase in the acreage devoted to sorghum. Alfalfa also is an important crop on many soils in the north and east and on bottom lands elsewhere.

Many problem soils exist in this subregion, but the soils generally are productive and respond well to good management. The main problems are the irregularity of precipitation, the need for supplemental fertilization, and water erosion and wind erosion in some years.

Every effort should be made to reduce unnecessary losses of moisture from the soil—to lessen runoff to a practical minimum, control weeds, and cut evaporation losses.

Management practices that aid in reducing runoff losses are the ones that are also recommended for controlling water erosion. Contour cultivation, ridging on the contour, terrace construction, contour stripcropping, and reseeding steep areas to grass or trees will help to cut down moisture losses by runoff. On deep, permeable soils, the use of those practices may increase materially the moisture available for crop growth. On less permeable soils or on soils with limited moisture storage capacity, the gains in moisture may be smaller.

Stubble-mulch tillage is not adapted to medium- or fine-textured soils of this subregion in years of average or above-average precipitation. Some effort should be made nevertheless to keep some of the crop residues at or near the surface so as to increase or maintain soil permeability and reduce loss of soil by erosion. Stubble-mulch tillage should be used on sandy soils and may be used in drier than average seasons on the medium- and fine-textured soils.

Although 65 percent or more of the rain that falls on the land in this subregion is lost by evaporation, little progress has been made in developing methods for reducing the evaporation losses very much.

One practice that appears to hold promise in sorghum production, at least, is the use of the narrower rows. Evidence has been accumulating that on more favored sites yields of row-planted grain sorghums can be increased by spacing the rows at 20-inch intervals instead of 40 inches. Much of this increase appears to come from a reduction in evaporation from the soil surface. Even after small rains, the surface soils stay damp much longer in narrow rows than in wide rows.

Weeds are a major obstacle to putting this practice into use. Most sorghums in eastern Kansas and Oklahoma formerly were planted with row-crop machinery and cultivated 2 or 3 times after emergence. Cultivation of the growing crop is more difficult with 20-inch row spacing. The land should therefore be as free of weeds as possible at planting time in order to reduce the need for weed control. That will entail later planting of sorghums—not a serious matter, because much of the sorghum is planted too early anyway. Even with delayed planting and good weed-control measures before seeding, weeds may compete with the crop in years when conditions are not ideal for rapid, early growth of sorghum. The need for some cultivation of the narrow rows should therefore be anticipated.

Crops respond to fertilizer on most fields in this subhumid area. Usually combinations of nitrogen and phosphatic fertilizers give higher yields of small grains and sorghums. Corn requires mainly nitrogen applications, although phosphate may be beneficial on extremely early or extremely late plantings. Alfalfa requires applications of phosphate.

Because rates of application vary with the crop, soil, and cropping history, no general recommendations can be made. Nearly every county in this region has a soil-testing laboratory. Soil samples can be submitted for analysis to the laboratories, and the test results can be used as a basis for recommendation of fertilizer. Samples also can be submitted to the State soil-testing laboratories.

Many of the surface soils and some of the subsoils are acid in reaction. It would seem that these soils should be limed, especially for the production of legume crops, but in some localities where the surface soils are acid but the soils below the plow depth are neutral to alkaline, applications of lime have failed to increase yields of legumes.

Consequently one should know the soil reaction not only in the surface soil but also in the subsoil before making a recommendation for lime.

A number of studies have been made to determine the best time and method of preparing a seedbed for wheat, corn, and sorghum. The studies have not shown any one implement to be markedly superior for preparing the seedbed. A particular implement may be successful in preparing a seedbed under certain conditions, but it might be unsatisfactory under different conditions of moisture and crop residue. In the western part of this section, the initial seedbed operation on a field can be done as well by a one-way disk plow as by a moldboard plow. Since the one-way is cheaper to operate, it may replace the moldboard plow for the initial tillage wherever the one-way will do a satisfactory job.

Studies on the time of tillage showed that altering the time of the first tillage operation in seedbed preparation affected yields greatly. At Manhattan, Kans., the effect of withholding plowing after July 15 until August 15 or September 15 reduced the subsequent wheat yields by about 1 bushel an acre for each week's delay after July 15. Similar results have been obtained in other areas.

Satisfactory seedbed preparation for corn and sorghums in this section also takes time. Spring plowing generally is to be recommended over fall plowing for corn and sorghums, but the plowing should be done early in the spring. There is no evidence in this section that cultivation of the land, whether in the growing crop or in preparation of the seedbed before planting, needs to be conducted oftener than necessary to control weeds and prepare a firm seedbed.

Experiments at Stillwater, Okla., and Manhattan have shown that acre yields of cereals may be increased by growing them after alfalfa or sweetclover.

Farther south and west, where moisture is more limiting, alfalfa and other legumes are rarely grown on the uplands because of the drought hazard in establishing the crop and because of the indifferent yields of legumes.

Various crops are grown in this subregion, but the acreage in wheat—when allotments were not in effect—was more than twice as great as the total acreage devoted to all other cultivated crops. When such a situation prevails and wheat is so much better adapted to the area than nearly any other crop, one can hardly expect farmers to be interested in crop rotations. In fact, it is not surprising that they restrict the acreage of other crops to the amounts that are needed to provide feed for their own livestock.

Sweetclover can be grown in the more humid areas of this section, but there seems to be little benefit from using sweetclover solely for green manuring purposes. About as good results in soil improvement can be obtained by pasturing it or using it as a hay or seed crop, or by omitting the legume entirely (especially in the main wheat counties) and using large quantities of nitrogenous fertilizers.

The summer fallow subregion is across the boundary between the western subhumid and eastern semiarid sections of the Great Plains. Its eastern boundary approximates the 25-inch rainfall line. Although this boundary marks the approximate eastern edge of summer fallowing in this region, the frequency of fallow varies within the subregion. Fallow is used on any particular field in the eastern part only about once in 4 or 5 years. Fields in the west usually are fallowed every other year.

The soils of this subregion usually are productive in years of average or above-average precipitation. On the breaks along the North Platte, South Platte, Republican, and Smoky Hill Rivers in Kansas and Nebraska, on the sand dune areas along the Arkansas River in eastern Colorado and western Kansas, and along the Cimarron and Canadian Rivers in Oklahoma and Texas, much of the land is not suited to cultivation.

A major problem in this subregion is the shortage of available moisture, which is evidenced by the great interest in (and response to) moisture-conservation practices and moisture storage. Another phase of this problem sometimes is overlooked: The importance of efficient utilization of stored moisture and current rainfall by crops. Even though wind erosion is more spectacular and causes severe crop losses, water erosion may cause even larger losses of soil from sloping fields in this section.

Crop responses to fertilization have been erratic and usually unprofitable on most soils. With continued grain production, the soils may become sufficiently depleted of fertility to respond regularly and profitably to fertilization.

Extensive tracts of grasslands could be found in all western counties in this region before the First World War.

Some of them were broken during and after the war. Still more land was broken from sod during and after the Second World War. The breakout continued until drought, beginning in 1952, and acreage allotments reduced the possibilities of quick profit from wheat production. The remaining grassland areas are covered mainly with the short grasses, but some mid grasses grow on the uplands in the west. Mid grasses and even tall grasses are found in addition to short grasses in the more humid areas on the uplands and on the sandy and bottom land soils.

Some rather large cattle enterprises flourish in localities where sodland occurs in large blocks. Elsewhere the size of the cattle venture is restricted by the acreage of grass. To maintain production on these grasslands, grazing pressure has to be reduced to that which will not destroy or damage the native species. That is not easy. Alternating periods of drought and adequate rainfall complicate the task of matching the stocking rate with the conditions of the range. Often the range is overgrazed.

Particularly on the sand dune areas great care should be taken in grazing. The soil is highly erosive. If even one knoll starts to erode in the wind, active erosion will spread to the surrounding dunelands or even to the sandy soils next to the dunes.

In places where overgrazing has depleted the cover to the point where wind erosion is active, it is hard to reestablish a cover. Perhaps the best way to reestablish native grass on these soils is to drill sorghums or Sudangrass on the land as protection for grass seedlings. To prevent later competition, the sorghum or Sudan stand should be mowed high if there is any danger of seed production. Adapted native or other grass species should then be drilled into the undisturbed cover. Species of tall and mid grasses are best adapted to reestablishment on sandy soils because their roots penetrate the soils quickly. This may be a critical factor in years of unfavorable moisture.

Drilling the grass seed one-half to three-fourths inch deep usually gives better results than broadcasting. Broadcasting pelleted grass seed from airplanes has not been entirely satisfactory in many places.

It will continue to be necessary to adjust stocking rates to range conditions in this subregion. To do so with a minimum of adjustment in the livestock enterprises, temporary pastures will have to be provided on cultivated parts of the farms. These pastures may have to be planted on fallow land. Reserve feed supplies will need to be stored in favorable years for use in periods of drought. Reserves for 2 to 4 years are not too much to have on hand.

Most of the land suited to cultivation (and some not suited) has been broken from sod and used for cultivated crops. Wheat is a still more predominant crop here than in the subhumid section. In this subregion, more than 75 percent of all land planted regularly to cereal and forage crops in the period before acreage allotments was seeded to wheat or was fallowed in preparation for wheat. Sorghums and a limited acreage of small grains, other than wheat, are raised here.

The problem of first importance on the cultivated lands, as in the range areas, is moisture conservation. All the known moisture conservation practices that can be applied practically to cultivated lands should be employed. These include contour cultivation and terracing on sloping lands. Weed control, including the control of volunteer grain, is important in the conservation of moisture. Weedy crops use as much soil moisture as weed-free crops, and the weeds may reduce yields as much as 50 percent.

Even when all possible moisture-conservation practices are used in the production of crops in this region, only 30 to 35 percent of the precipitation that falls during the growing period can be used by the crop. The rest is lost in a variety of ways. As the amount of rain during the growing season usually is insufficient for optimum yields, moisture from periods when no crop is growing must be stored in the soil for the use of subsequent crops. Methods of seedbed preparation thus are highly important.

The tillage implements used in the seedbed preparation for continuous wheat include plows, cultivators (both stiff and spring shanked), subsurface sweeps, disk-type equipment, and rodweeders. Experiments show that the moldboard plow can be replaced readily by other tillage tools. In fact, the use of the moldboard plow and other implements that incorporate crop residues with the soil should be discouraged because of their effects on susceptibility to wind erosion. The lister is rarely used for preparing a seedbed for wheat.

It is generally true that no one implement should be used to the exclusion of all others. For example, a one-way disk plow can be used profitably to incorporate some of the plant residues with the soil and thus reduce the difficulties that sometimes are encountered in drilling wheat through large amounts of stubble. If the one-way is used too frequently, however, all of the crop residues will be placed below the surface of the soil, and a serious wind erosion hazard will be produced. Other implements, such as the rodweeder and subsurface sweeps, should be used instead after an initial operation with the one-way.

Stubble-mulch tillage, which involves the use of undercutting equipment alone or with other tools, such as the one-way, probably is not so well adapted to continuous wheat production as it is to alternate fallow and wheat production. That does not mean that crop residues should not be left at or near the surface on continuous wheat land. Some residues should be left on the surface to maintain the infiltration capacity of the soil and to reduce the susceptibility of the soil to erosion. In the drier parts, where alternate fallow and wheat production is the common cropping system, and elsewhere on fallow land, stubble-mulch tillage is one of the best methods of seedbed preparation. Yields will be as high or higher on this type of seedbed preparation as on more conventionally prepared land, and the danger of water and wind erosion will be reduced markedly.

There is little evidence that newer methods of seedbed preparation, such as chiseling and subsoiling, are more effective moisture conservers than those that employ more conventional tillage tools. Little difference in moisture storage in the soil has been brought about by the use of other implements. There is a good deal of evidence, however, that moisture conservation is greatly affected by timeliness of seedbed preparation.

Studies at the dryland stations in this section show that the moisture stored in the soil at seeding time may be increased 100 percent or more by starting the preparation of a wheat seedbed in early or mid-July instead of in late August or September. This extra moisture storage is accompanied by the release of larger supplies of nitrates. Both the moisture and the nitrates are needed for high crop yields.

Seedbed preparation in June or early July is possible in the southern part of this subregion. As seeding is done here quite late in the fall, a long time for moisture storage is permitted even under continuous wheat production. There is not much benefit here from the inclusion of a fallow period between wheat crops.

Farther north, however, where the time between wheat harvest and wheat seeding is shorter, yields of wheat even on seedbeds prepared as early as possible may not be satisfactory, and some other method of preparation may be necessary.

Over much of this dryland section, sufficient moisture cannot be stored in the soil from harvest to seeding time to supplement rainfall. There are only two practical ways by which greater supplies of moisture can be provided for crop use in this area—irrigation and summer fallow.

Irrigation is a practical solution to the moisture problem where water of good quality is available and the soils are suitable for irrigation. Although an expansion of irrigation in this region is assured, it can be used only on a limited number of farms.

Summer fallow therefore will have to be used to provide for the moisture needs of crops on most farms. Fallow is the practice of keeping the land free of live vegetation throughout a crop-growing period before the one in which a crop is normally produced.

The efficiency of moisture storage by fallow is relatively low. The efficiency of moisture storage during fallow for wheat averaged only about 16 percent at two places in Kansas. At Goodwell, Okla., the efficiency was estimated at 18 percent. Other studies show up to 20 percent efficiency. In other words, only 1 out of 5 or 6 inches of precipitation that fall during the fallow period is stored in the soil. It appears that fallow will store only about 3 to 5 more inches of water than early seedbed preparation will. That does not seem to be very much. Studies have shown, however, that each inch of water used by a wheat crop (water used equals stored water in soil plus precipitation from seeding to harvest) above a certain minimum produces an additional 2 bushels of wheat. Thus, these extra 3 to 5 inches of water stored during a fallow period may mean the production of 6 to 10 extra bushels of grain.

A good summer fallow must permit the storage of moisture and the release of nitrates and still must permit the control of erosion. To achieve these objectives, three main conditions must prevail: The surface soil should be cloddy and open; plant residues should be kept on the surface of the soil to facilitate water movement and prevent wind erosion; and weeds and volunteer grain must not be permitted to grow.

The least cultivation that will control weeds and volunteer grain and prepare an adequate seedbed is the cheapest and also the most effective.

Studies at all dryland experiment stations to determine the best method of fallowing for wheat and other crops show no large differences between yields resulting from different tillage treatments. At Hays, Kans., for instance, the use of a chisel to depths of 6 to 12 inches in August preceding the fallow year did not increase yields of the fallow crop over those on land where preparation was started in May by plowing. Many farmers nevertheless use the chisel for the first tillage operation in preparing the wheat seedbed. There seems to be little to recommend this practice, except for emergency erosion control.

Similarly, no large differences in yields have been obtained by preparing the fallow by sweep-type or disk-type equipment or by the moldboard plow. In spite of this, the use of implements that leave much of the crop residue on the surface is recommended because of the effect on erosiveness. No increase in crop yields could be demonstrated for the use of a lister or basin lister as a first tillage operation at Hays. Farther west, there appears to be some advantage to fall listing before fallowing.

Although there seems to be no marked superiority for any particular implement for seedbed preparation as measured by crop yields on experimental areas, studies have shown that the time of starting the fallowing operation may cause marked differences in yield. By and large, no advantage has been obtained by initiating tillage before May. In fact, there appears to be marked advantages to allowing the stubble to stand over winter to trap snow.

Large losses in yield result from delaying the first tillage operation into June. With the increase in fireweed (*Kochia* species) and Russian-thistle (*Salsola pestifer*) in summer fallow areas, there may be need to change the date for starting the fallowing operation. If these weeds grow up on the wheat stubble in profusion and threaten to remove all the moisture that might otherwise be stored, the land may need

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to be cultivated shortly after harvest to prevent this loss of moisture.

Even if every care is taken to insure the conservation and storage of all possible moisture, many occasions arise when moisture may not be sufficient. Thus every effort must be made to utilize the stored water efficiently.

The prospective yield of a wheat crop can be estimated with fair accuracy if the amount of moisture stored in the soil at seeding time is known. If a silt loam soil is moist to 3 feet, the prospect for high yields of wheat are good and chances of a failure are low. With smaller amounts of stored water, the chances for high yields become less and the possibilities of failures become increasingly great. Accordingly, if the amount of moisture available at wheat seeding time is determined, the chances of a good crop can be ascertained.

If it appears better not to seed wheat, the land can be held over for spring seeding of another crop in the hope that more water will be stored over winter, or the land can be fallowed to prevent dissipation of the stored water by an unprofitable crop.

Similarly, sometimes a wheat crop can be abandoned in early spring when the moisture condition in the soil is low enough to preclude the possibility of successful production. Land thus abandoned can store almost as much moisture during a fallow period as land not seeded to wheat subsequent to wheat harvest the year previously. Wheatland abandoned in April because of poor moisture reserves will produce more wheat after a fallow period than similar land allowed to remain in wheat and reseeded to wheat the same fall. Accordingly, abandonment in many instances may actually be a method of increasing crop production. It is advisable nevertheless to plant a spring-seeded crop on abandoned wheatland, fallowed the previous summer, because land should not be fallowed for two consecutive years.

A second serious problem in this section is erosion. Water erosion is most severe on bare, sloping lands. When adequate steps are taken to conserve all possible moisture for crop use, water erosion rarely should be a serious problem because the methods used to conserve moisture help control erosion.

The occurrence of wind erosion usually is associated with consecutive drought years, although other factors may influence the amount of soil drifting that will occur.

Nearly every farmer in the dryland section knows the principles of the control of wind erosion.

Several States in the region have laws that permit county commissioners to order emergency tillage conducted on farmland that is menacing neighboring lands by its erosiveness. The cost of this tillage is added to the taxes of the farm.

Conditions beyond a farmer's control sometimes may reduce vegetative cover enough that wind erosion may occur during the windy spring months. On the medium- to fine-textured soils, it may be possible to roughen the surface of the soil so that its erosiveness is greatly reduced. This is necessary in emergencies even in the growing crop. Sandier soils need plant material, either living or dead, to reduce their erosiveness to manageable proportions. That is one reason why sorghums, whose residues may be left undisturbed on the land until after the spring winds are past, are better adapted to sandier soils than small grains.

The stubble-mulch tillage has been highly recommended as a means of reducing water and wind erosion. This practice, particularly during the fallowing operation, has much to commend it. The residues are not completely destroyed by the tillage and remain mixed with the surface soil to help resist soil movement. Yet the residues are not sufficiently bulky after the fallow period to interfere with seeding even if the ordinary disk-type grain drill is used.

In the northern and central areas of this subregion, the prevailing direction of the winds that cause erosion is south-north. Planting crops in strips (east-west) across this prevailing direction will help to reduce erosion by cutting down the width of bare or fallowed fields. The alternate strips, to be effective, must provide protection against erosion in all seasons, but particularly in early spring. The destructive winds are not predominantly in any one direction in southern areas. Here stripcropping has much less to recommend it.

Areas of sandy soils are extensive in southwestern Kansas, the Panhandles of Oklahoma and Texas, southeastern Colorado, and northeastern New Mexico. Many have a low content of clay in the surface layers (2 to 5 percent) and are particularly erosive when they are cultivated. Deep plowing of certain of these soils will help control wind erosion. Where the erosive surface layers are underlain by subsoils with 12 to 25 percent of clay at depths that can be reached by large plows, deep plowing can be used successfully. If fine material cannot be brought to the surface by plowing, no improvement in wind erosion control is obtained.

Deep plowing is not a cure-all on sandy lands. Continued sifting by wind can cause deep-plowed land to lose its increased clay content and become as erosive as ever. The deep-plowed land can trap flying sand particles from neighboring farms. That will dilute the fine surface texture prepared by plowing. Deep-plowed land should be handled with a cropping system that will reduce to a minimum the loss of fine material from the soil. Deep plowing should be undertaken on a community basis.

Although low fertility is not usually considered a problem in most dryland areas, some crops on specific soils may respond to fertilization. In tests in most States in the region, only the sandy soils seemed to respond consistently enough to warrant the use of fertilizer. Since crop growth and fertilizer response in this section are tied so closely to situations of moisture and temperature, recommendations as to fertilization have to take them into consideration. No areas in this subregion are known where response is obtained to applications of potash. Some areas are deficient in phosphorus, but most soils seem to have enough phosphate.

Nitrogen seems to be the element most likely to limit production. Sufficient nitrogen usually is present in dry years for the growth of the crop the moisture can produce. In fact, more than ample nitrogen supplies seem to be produced in dry seasons, because symptoms of nitrogen deficiency are rarely noticed in a wet year immediately following a dry year. Perhaps it takes several consecutive humid years to demonstrate nitrogen deficiency symptoms on noneroded dryland soils.

Crops on noneroded, productive, hard-land soils have not responded to applications of manure. Crops on sandy lands may respond to manure applications. Usually manure neither increases nor decreases crop growth. In several instances, however, lower yields have followed applications of manure. Applications of manure on poorly drained or eroded soils or on saline or alkali spots have improved soil properties and plant growth in many instances.

As wheat and sorghums and possibly corn in the northern areas are the cultivated crops best adapted to the dryland soils of this subregion, there appears to be little chance for crop rotations. In fact, many farmers who grow both wheat and sorghum on their farms as a regular practice tend to produce the wheat continuously, or alternately with fallow, on specific fields and to produce the sorghums on entirely different fields. A number of farmers alternate wheat and sorghums on individual fields, but the sorghums are planted only if the soils are too dry for wheat seeding in the fall or if the wheat crop fails to become established over winter. On the other hand, some farmers follow a sequence on their land of fallow, wheat, sorghum. Others use a cropping sequence of fallow, wheat, fallow, sorghum.