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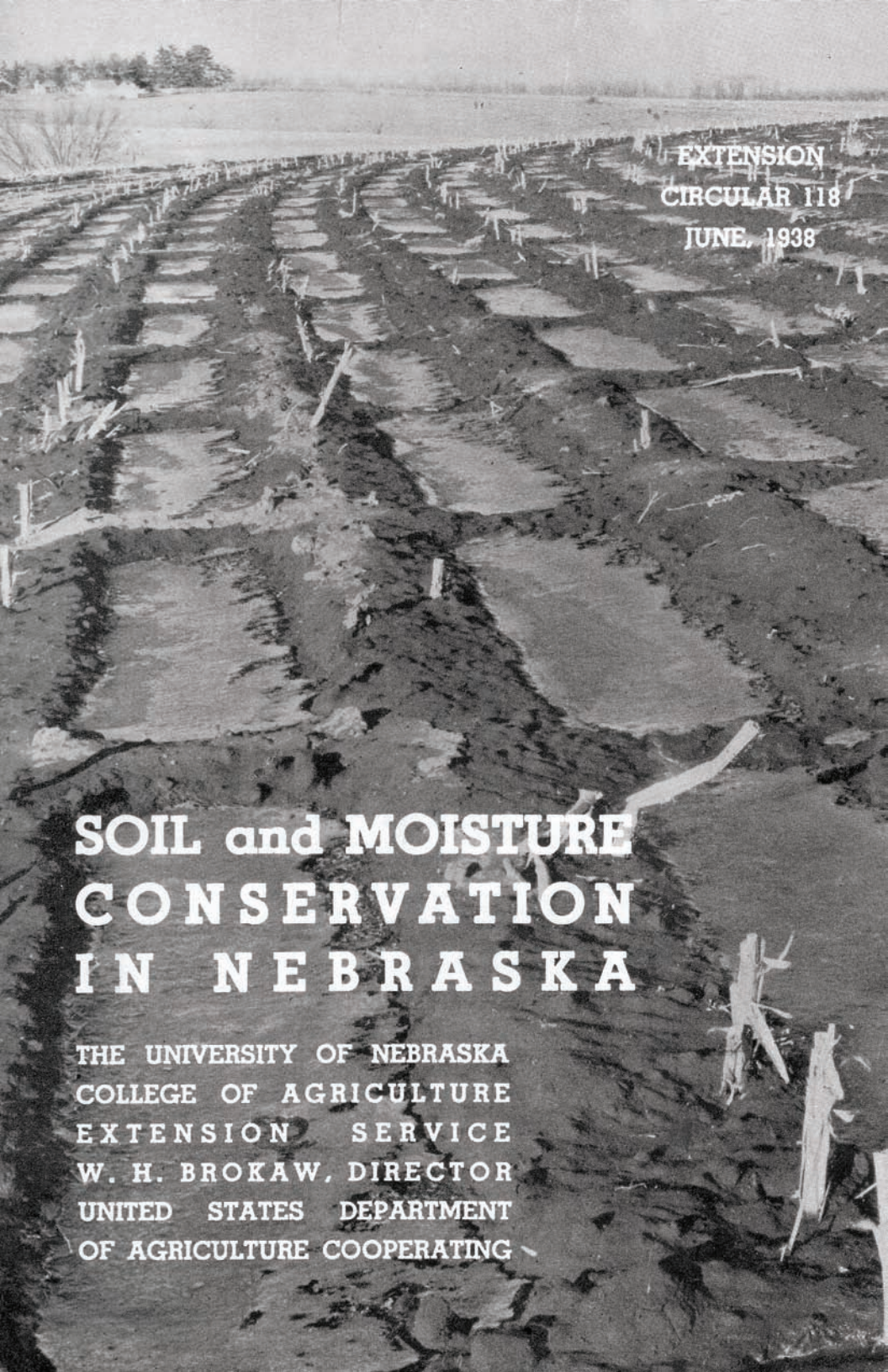

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SOIL and MOISTURE CONSERVATION IN NEBRASKA

THE UNIVERSITY OF NEBRASKA
COLLEGE OF AGRICULTURE
EXTENSION SERVICE
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CONTENTS

	Page
Factors Which Influence Erosion	5
Climate	5
Nature of the soil	6
Land use	8
Erosion Control Practices	10
Crop rotations	10
Manure	11
Basin listing	14
Strip cropping	15
Terracing	16
Pasture terracing	18
Pasture contour furrowing	19
Control of field draws	20
Gully control	22
Pasture management	24
Regrassing	25
Fire prevention	27
Storage of Soil Moisture	29

Soil and Moisture Conservation in Nebraska

D. L. GROSS AND E. H. DOLL

WHEN the white men first explored Nebraska, they found little erosion taking place. They found the hills, particularly in eastern Nebraska, covered with a dense growth of grass, underlain with a thick mat of decaying debris. The valleys were even more densely covered with the water-loving grasses and sedges. The soil underneath the prairie was black and spongy, the result of centuries of accumulating humus. The valleys bordering the streams were boggy and abounded with springs. Clear water flowed constantly in the streams. The upland draws in the more favorable parts of the state were heavily covered with the big bluestem and slough grass. Springs occurred in many of these.

This abundance of water, of springs, and of marshy flat lands was the natural result of the prairie cover. The tall grass with its underlying debris provided a condition of utmost effectiveness for rapid absorption of rainfall and for holding winter snows. Under these conditions, runoff could occur only from extremely heavy rains of more than usual duration. As a consequence, the deep subsoils of eastern Nebraska were filled to capacity with water throughout their entire depth. Excess water in the upper profile drained toward the draws and the valley land, thus creating springs and providing a constant and even source of water for streams.

FIG. 1.—The native prairie contained both grasses and legumes. The dense growth retarded runoff.

After 40 to 60 years of tillage, road building, and drainage, these conditions have changed. Scarcely anywhere in Nebraska can the original type of prairie be found. It has been destroyed entirely by the plow, or has been changed by grazing and by the inroads of introduced species. Because the prairie is not present to catch and hold rainfall and snow, because man, by drainage, has sought to remove runoff water from the land as quickly as possible, and because the highly absorbent top soil has been eroded from sloping land, springs have disappeared, streams no longer have a constant flow of clear water, water tables are lowered, the tall grass is gone from the upland draws, and the boggy flat lands are replaced by weedy unproductive pastures, or by cultivated fields. Streams that are still active are now laden with silt. Deep gullies have formed in many of the once heavily grassed draws. Wind erosion is becoming an increasing problem.

These changes are the result of more rapid and greater runoff of water from rain and snow and of gradual loss of humus from the top soil. Bare fields cause the snow to drift into gullies and draws where upon melting it quickly reaches the streams. When the prairie was first broken, the soil, because of its high humus content, absorbed rainfall at a rapid rate. As cultivation continued, the proportion of humus and the rate of water intake declined. The resulting greater runoff carried away increasing quantities of top soil. Rainfall beating upon eroded and exposed soil puddles its surface, seals its pores, and creates a condition conducive to maximum runoff.

Soil erosion in Nebraska has not progressed to as great an extent as in states to the east and to the south. This is because of the comparatively lower rainfall in Nebraska, because the land has been farmed for fewer years in this state, and because some Nebraska soils are comparatively less erosive. The history of erosion in Nebraska for the past forty to fifty years, however, indicates that unless control measures are used many now fertile fields will sooner or later be unfit for tillage. The history of farming has been that little attention is paid to erosion control until damage is so great that the original productiveness of the soil cannot be reclaimed. This has already happened on some fields in Nebraska and, since erosion accelerates itself, the rate of destruction can be expected to increase year by year.

I--Factors Which Influence Erosion

CLIMATE

The average annual precipitation in Nebraska varies from 15 inches along the western edge to 33 inches in the extreme southeastern part. (See Figure 2.) Approximately 70 per cent of this precipitation occurs between March 1 and October 1. The greater part of the rainfall occurs in the form of torrential showers which favor maximum runoff and erosion. This is particularly true during the spring months when cultivated fields are especially vulnerable to erosion because of fresh tillage operations incident to seedbed preparation.

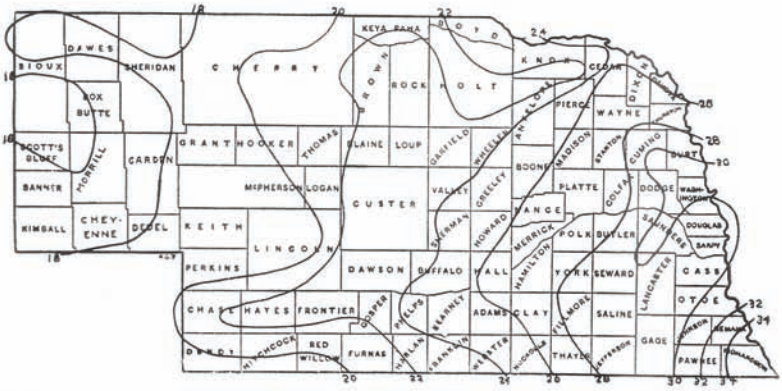

FIG. 2.—The average annual precipitation in Nebraska for the 35-year period 1898-1932.

Strong winds are common in Nebraska, particularly during the spring months when the soil has the least vegetative protection, and when it is otherwise most susceptible to blowing. The intensity, frequency, and duration of strong winds increase westward in the state. For this reason, and because of the type of farming practices, the decreased luxuriance of vegetative cover, and the scarcity of trees in western Nebraska, the extent of damage from soil blowing is greatest in this region. In addition to its direct effect, wind erosion may contribute to the seriousness of water erosion by the destruction of new vegetative growth, and by causing increased runoff as a consequence of the deposition of dust layers which resist the absorption of rainfall.

Although wind and rainfall are the direct agents of soil erosion, there are certain other climatic factors which influence the degree of erosion. These are the action of frost and the effects of heat and drouth. Freezing and thawing cause a breaking down of the exposed surface soil into small, light, open-textured granules. These are easily lifted by the wind or taken into suspension by running water. Freezing may also contribute to soil erosion by the premature destruction of vegetation which would otherwise serve as a protective cover to the soil.

FIG. 3.—The effects of a heavy rain immediately after seedbed preparation.

The destruction of vegetation or the preventing or retarding of its growth by heat and drouth may in some instances be an important factor in soil erosion. This is particularly true when prolonged drouth periods are followed by strong winds or by normal or excessive rainfall.

The denudation of pastures, resulting from drouth and overgrazing, promotes maximum runoff. Under these circumstances, gully formation and development may be very great, resulting in destruction of much bordering farm land.

NATURE OF THE SOIL

In general, damage from wind erosion is greatest in regions or on fields where the topography is level or gently sloping and where the wind has a long, clear sweep unchecked by natural or artificial barriers. The extent of water erosion, however, varies greatly with the degree and length of slope. Although the percentage of runoff is less on long slopes than on short ones, the degree of erosion is greater on the former because of increased volume and velocity of runoff on the lower segments. Even slopes present less serious erosion problems than uneven ones. The latter are often interspersed with draws where runoff water concentrates and where gully formation is apt to occur. In general, sheet erosion can be said to vary in proportion to the slope of the land. When extremely steep slopes are tilled, the loss of the entire top soil can be expected in but a few years, even with good management. It should be borne in mind, however, that equal slopes do not necessarily erode to the same degree even under identical conditions of cover, tillage methods, and rainfall. Soil

FIG. 4.—Trees may be used effectively and profitably for the control of wind erosion, especially on the lighter soils.

type, structure, and condition may often have greater influence than slope in determining the degree of erosion.

The character of soil has a tremendous influence on the rate of rainfall absorption and consequent runoff. Certain soils are naturally open in structure and have a high infiltration rate, while others resist absorption to a remarkable degree. A comparison of Marshall silt loam of northeastern Nebraska with Shelby silt loam of southeastern Nebraska, shows that the Marshall under certain conditions may have an infiltration rate nine times greater than Shelby. The percentage of runoff varies inversely with the infiltration rate.

Soils which absorb water rapidly may, in some instances, be protected from serious erosion damage merely by a well planned cropping system and by the grassing of draws, while those of the opposite character may need terraces to reduce the concentration and velocity of runoff. This would be particularly true on land having a shallow top soil and underlain with an impervious, clayey, and unproductive subsoil.

The loss of top soil on land having a very deep, absorptive, and friable subsoil is much less serious than on land having subsoils of the opposite character. Soils of the former type are typified by the loess hills. Much of this land is steeply rolling and has lost all of its top soil, yet in the eastern region productivity may be maintained at a high level by careful rotation with sweet clover. Although serious erosion damage in the Nebraska loess-hill regions is at present largely confined to gully formation and deepening of field draws, it is important that sheet erosion be reduced by careful conservation practices if productivity is to be maintained over a long period of time. In the central and southern loess hill areas, the maintenance of an adequate supply of available nitrogen is more difficult since in these regions legume rotations are more likely to cause overstimulated crop growth and consequent drouth damage.

LAND USE

Crops such as grass, which completely cover the soil and which are of sufficient height to reduce the velocity of runoff water, provide the most effective means of erosion control. Under these circumstances, soils may actually be built up by wind-blown or water-carried soil particles. Thickly sown crops such as legumes, small grain, and annual hay, approach this condition and reduce soil losses to a minimum. Clean-tilled row crops tend to promote extensive erosion where the rows follow the same general direction as the slope.

In regions such as south-central and western Nebraska where winter wheat is grown extensively, fields planted to this crop are often subject to damage from wind erosion because of insufficient cover during the late-winter and early-spring months. Much of the land in these regions is nearly level in topography, fields are large, and wind barriers are scarce. Strip planting to reduce soil blowing is not generally practiced, but where used is very effective.

The absence of vegetation on tilled land allows runoff water to attain a maximum velocity with the resultant increase in carrying and scouring capacity. This, together with the absence of plant roots and other organic materials which tend to bind the soil particles together, provides a condition favorable to maximum erosion.

Farm land in Nebraska was laid out in square sections and, in general, fences follow the quarter, half mile, and section lines. As a consequence, cropping is generally carried out in an east-west or north-south direction parallel to these guide lines regardless of the slopes. This practice has favored maximum runoff and erosion.

Whereas runoff from land thickly covered with a tall growth of grass may be extremely little, that from closely grazed pastures may be greater than under any other soil conditions, not excepting clean-tilled land. The packing of the soil in wet weather by tramping and the formation of a non-absorbent dust mulch in dry weather accounts for this condition. It is partly for this reason and partly because of the formation of paths which tend to concentrate rain water, that extensive gully formation occurs more often in pastures than in cultivated fields. Actual soil loss is no doubt greater from cultivated fields, yet gullies may not appear as such because the side walls and overfalls are constantly broken down by the tillage machinery. Deep overfalls which advance from pastures into cultivated fields cannot be arrested, however, by ordinary tillage methods. It is for this reason that overgrazing and careless pasture management have in many instances resulted not only in damage to the pasture itself, but adjacent cultivated fields have been cut in two or even made entirely unfit for tillage by the advance of deep impassable gullies originating in pastures.

The grading of roads and the building of artificial water channels has resulted in the formation of many new gullies in cultivated land, or in

FIG. 5.—Much steep land has been broken that is not fit for tillage. Such land should be returned to grass.

the flooding of land which would otherwise be free of this menace. Little attention has been paid to this problem by road overseers. Corrective measures such as drop inlets are now being used to a limited extent, but a more general study of this problem is needed.

Much land in Nebraska which at one time was subject to seepage and to intermittent overflow has been drained. This has been accomplished partly by the use of tile but largely by the use of drainage ditches. Many streams have been straightened in order to provide a more rapid disposal of flood waters thus to protect adjacent land. Road building is designed also to provide efficient drainage. While these practices accomplish the end desired and in many instances were and are essential to the comfort and well being of the people, they have introduced new problems. Water tables have been lowered, causing a complete change in the vegetative cover of the drained land. Artificially drained land once marshy and covered with a dense growth of slough grass is now in many instances cut by deep canyon-like gullies which are sending out fingers and destroying highly productive adjacent farm land.

II--Erosion Control Practices

CROP ROTATIONS

Crop rotations which include legumes and grasses tend to add organic matter or humus to the soil and increase crop yields. Experiments have shown that when a good rotation is used there is less runoff and less erosion. This is because the organic matter in the soil makes it more absorbent of water, and the soil particles are held together in such a way that they resist erosion. In one six-year experiment, land of glacial origin rotated with corn, wheat, and a clover-grass mixture lost 233 fewer tons of soil per acre and had 55 per cent less runoff than plots in continuous corn. Corn on rotated land lost 29 per cent less water by runoff and 41 fewer tons of soil per acre than did land in continuous corn.

FIG. 6.—Sweet clover in oats in eastern Nebraska. Frequent use of legumes in the rotation is an accepted practice in the eastern one-third of the state.

In Nebraska, sweet clover is the most satisfactory legume to use in the rotation. Its seed is usually low in price, stands are easy to obtain on most soils, it adds organic matter to the soil rapidly and it has a wider adaptation than most other legumes. Sweet clover does not do well on soils low in lime such as are found in parts of eastern Nebraska, and under this condition, unless the soil is well manured or limed, red clover is more satisfactory.

A very common rotation in northeastern Nebraska consists of two years of corn followed by sweet clover with oats as a nurse crop. The sweet clover is plowed under at the beginning of its second year's growth and the land planted again to corn. This type of rotation will maintain

soil fertility fairly satisfactorily on land which does not erode badly. Where erosion is a problem, it is advisable to allow the sweet clover to complete its second year's growth, thus making a four-year instead of a three-year rotation. When this is done, the second year's growth may be pastured, used for early hay, or it may be allowed to stand for a seed crop. (See Nebraska Agricultural College Extension Circular 134 on "Sweet Clover Management".)

In Nebraska, a legume is used less and less often in the rotation as the distance westward from the eastern border of the state increases. This is because rainfall decreases likewise, and as soil moisture decreases the danger of overstimulation of succeeding crops increases. On central-Nebraska upland, therefore, the above-described rotations could not be used safely. Instead of sweet clover every third or fourth year, it is safer to plant it only every seventh or eighth year. Whereas corn usually follows sweet clover in eastern Nebraska, experience indicates that wheat is a safer following crop in central and western Nebraska. This is because wheat matures before most of the hot weather arrives, whereas corn on sweet-clover ground would make a very luxurient growth early in the season, use the greater part of the stored soil moisture, and then succumb easily should hot, dry weather prevail later.

Alfalfa may also be used in the rotation. This crop has several features, however, which make it rather unsatisfactory for this purpose. Alfalfa seed is usually high in price, stands are not always easy to obtain, and usually it is advisable to let good stands remain as long as they are productive.

Under irrigation and elsewhere where moisture is plentiful, it is advisable to use legumes very frequently in the rotation. Under these conditions, crop yields are limited chiefly by soil fertility and thus it is profitable to build up fertility to the highest point possible.

In western Nebraska where a legume rotation is impractical, a rotation which includes "wild fallow" should be of material benefit in restoring organic matter. This involves abandonment of the land to weeds for a period of from two to five years, and the eventual return of all growth to the soil.

MANURE

Barnyard and green manures or other organic materials increase the absorptive and water-holding capacity of the soil, and its resistance to erosion. They also return nitrogen and mineral elements to the soil, which have been removed by the crops. Experiments indicate that 8 to 9 tons of barnyard or green manure will reduce soil loss through erosion as much as 13 tons per acre annually, and the runoff approximately 50 per cent. For the eastern third of Nebraska, an 8-to-10-ton application of manure can be expected to increase crop yields in normal years. In dry seasons and generally throughout the western two-thirds of the state, the application of manure, except in very light amounts, often results in overstimulation and drouth injury to the following crops.

On most farms there is usually not enough manure produced for wide general use. The amount available can be increased by the more general adoption of a livestock rather than a grain type of farming, and the use of all straw and other waste organic materials as bedding for livestock in barns or corrals. Light applications of manure in any part of the state return greater value per ton of manure used than heavy applications.

Manure varies much in quality. That which is well decomposed has the highest value per ton. That made from materials high in nitrogen will add more organic matter to the soil than such low-nitrogen materials as straw or cornstalks. Low-nitrogen materials are increased in value for this purpose, however, if they are used as bedding for livestock where they will absorb nitrogenous material from the excrement. Manure made from leguminous crops such as alfalfa and the clovers is of exceptional value for building soil organic matter. Plowing under heavy crops of green sweet clover is especially effective in the restoration of organic matter. Under drouthy conditions this practice may result in reduced yields if grain crops are planted on the land immediately after the clover is turned under.

CONTOUR FARMING

Contour farming is the practice of conducting farming operations on a level or near level, and therefore across, rather than up and down the slopes. Farm implements such as grain drills, planters, cultivators, plows, and listers, leave depressions and ridges in the soil which, when on the contour, tend to hold back runoff water and permit it to soak into the ground. This is especially true of the lister, since it leaves deep furrows which may hold as much as a three-inch rainfall without allowing runoff. While contour farming thus promotes greater water absorption and consequently less runoff and soil erosion, it has other advantages such as lower power cost and less washing away of seed and young plants.

When starting field operations from contour lines, it is important that such operations, particularly with the lister, be downward from each contour line. Listing upward from the contour line tends to cause water to flow toward the crests of knolls should successive furrows tend to deviate from the true contour. This may cause the water to break over at these points and cause damage to the field. On the other hand, listing downward from the contour line tends to lead excess water slowly toward the natural field draws, where it may be carried away without damage if such drainage ways are kept in thick-growing vegetation.

The number of contour lines necessary on a given field depends upon the nature of the slope. One line may be sufficient if the slope is even. On uneven slopes additional lines should be run wherever rows begin to deviate too far from the true contour. Odd-shaped areas between the contoured rows may be planted to grass or to small grain if it seems impractical to list them out with point rows. Field rearrangement will help to eliminate part of these small odd-shaped areas.

The first contour line is placed near the top of the slope. On steep slopes this distance should be less than 100 feet, and on more gentle slopes up to 150 feet. Contour lines are surveyed on the true level.

The practical use of the contour method of farming requires that in parts of most fields, the operation of farm machinery will need to be slightly away from the contour. In many fields, this will involve crossing small depressions or draws in a direction that is not on the true contour. Runoff water may concentrate in these low places and thus cause erosion. Such water courses need to be protected by planting them to grass or allowing other vegetation to grow which will hold the soil but permit the water to flow without damage. Many fields have been severely damaged

FIG. 7.—Field rearrangement for contour operations helps to eliminate point rows.

by planting row crops across the slope and paying no attention to the depressions. Plows, listers, and cultivators should be lifted from the ground when crossing depressions, and the disk should be set straight. This will permit weeds and grass to gain a foothold. By this means, silting will be encouraged in the low places and thus they may eventually be eliminated.

In many fields, it may be advisable to plant row crops on a very slight gradient toward protected drainage ways. This may be accomplished by making the first row slightly below the contour line when crossing drainage ways and slightly above the contour line on the higher land between the draws. Laying out rows in this manner also tends to reduce the sharpness of the curves.

Land that is excessively steep or has extremely irregular slopes does not lend itself well to contour farming, particularly with the type of farm machinery commonly used at present. The general type of farming and the size of farm units are also factors which are not favorable to contour farming under these conditions. Where slopes are long, reason-

ably uniform, and not too steep, contour farming is entirely practical under both extensive and intensive types of farming. Where these conditions do not prevail, it may be necessary to reduce the size of operating units, change the general type of farming, use smaller machinery, and return part of the land to grass if contour operations are to be carried out successfully.

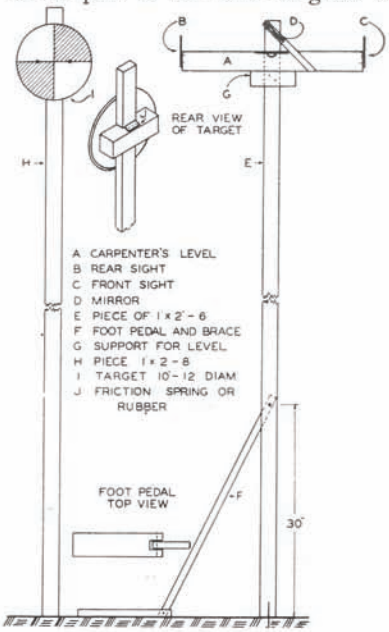

FIG. 8.—Home-made level and target rod.

The engineer's level and the farm level are the usual instruments used to run contour lines, although the home-made level shown in Figure 8 can be used very successfully. Aside from the carpenter's level and the level sights, this device can be made out of material found about the farm. (See Extension Circular 704 for instructions on how to make a farm level.)

BASIN LISTING

Basin listing is one of the more recent developments in soil and moisture conserving practices. The implement used for this purpose consists of an ordinary lister to which a mechanism is attached which builds dams in the lister furrows at intervals, thus converting the furrows into a series of basins. The basins catch the falling rains and permit the moisture to soak slowly into the ground. The basin lister may thus provide one means of replenishing the moisture content of the deeper subsoils. In addition to storing the moisture, the hazards of soil erosion caused by water running down the slopes are also reduced to a minimum.

When used on hillsides with slopes in excess of two or three per cent, the basin lister may become a most destructive implement. When listing is done straight up and down the hill, the capacity of the basins decreases as the slope increases. The water collects at the lower end of a sloping basin and in heavy rains breaks over the top of the dams. When any one of the dams in a furrow gives way, the additional load placed upon the dams below causes them to fail also. The water would thus rush down the slope, carrying with it an excessively large amount of soil. The damage done by erosion would be much greater than were no dams built, and the purpose of the basins, that of conserving moisture, would be destroyed. It is therefore important that basin listing be done as nearly on the contour as possible.

The basin lister has perhaps its greatest possibility as a summer tillage implement. Land to be fallowed during the following summer can be listed with this machine in early fall. Fall rains are held in the basins and stored in the soil. Snow is caught in the lister furrows and will remain there until spring. When the snow melts in the spring before the frost has left the ground, the dams will keep the water from running off the field and hold it until the soil is in condition to absorb it.

When weed growth starts in the spring, the ridges may be split, again using the basin attachment. In combatting weeds, basin-listed fallow land may be handled in much the same manner as that listed to row crops, although any practice which leaves the dams intact is preferred. A spiketooth harrow can be used successfully to kill weeds before they get well started. If the ordinary listed-corn cultivator or go-devil is used, a small shovel mounted in front of each bell wheel to cut through the dam will permit the machine to operate more smoothly.

FIG. 9.—Strip cropping reduces runoff and soil losses. Note the grassed draws where excess water can escape without damage to the project.

STRIP CROPPING

Strip cropping means the planting in alternate strips of different kinds of crops. For the control of wind erosion on land where water erosion is not a problem, the strips usually run east and west, or across the direction of the prevailing winds. These strips are commonly 15 to 20 rods in width and consist of alternate planting of row crops or fallow with thick-sown crops such as small grain or weed fallow. Trees may be planted in rows across the field as permanent wind barriers.

On sloping land where water erosion is serious, the strips follow the contour of the land as nearly as possible, and intertilled crops such as corn are alternated with thickly-sown crops such as small grain or grass. The advantage of the latter type of stripping is that the speed of runoff water from the intertilled crops is checked as it reaches the thickly sown strips. When the speed of running water is reduced, it not only drops part of its soil load, but it is given more time to soak into the soil.

A modified form of strip cropping adapted to certain slopes is one in which a series of cultivated fields having parallel sides are laid out on a

slope as nearly on the contour and as close together as possible. The uneven strips lying between these fields are then planted to permanent grass which may be profitably used for hay and seed production, and pastured during the early spring and late fall months. The advantage of this type of strip cropping is that it provides regular-shaped cultivated fields, field borders are permanently marked, and point rows are eliminated. A mixture of brome grass and alfalfa is a good one to use for permanent strips in eastern and parts of central Nebraska. Blue grama grass or other native grasses are suggested for central and western Nebraska.

FIG. 10—Contour plowing with a six horse team on a gang plow in a terraced field.

Under adverse climatic conditions field borders may yield less than the centers because of damage from hot winds or insects. Strip cropping increases the length of border. The use of wide strips may reduce this damage to a minimum. Narrow strips may also enhance gully formation in natural draws. This, however, may be prevented by keeping drains well grassed, thus using them to carry away surplus water without serious damage.

TERRACING

Fields that have small rills or gullies a foot or two deep cannot be contoured satisfactorily. Strip cropping with grassing of gullies is not a practical solution of the erosion problem if the gullies are too numerous. Terracing will control erosion more effectively on such fields. Terracing has proved to be a very effective measure for the control of soil erosion. A terrace system consists of a series of ridges and drainage channels constructed at intervals across a hillside. Each terrace intercepts any water that may run from the area between it and the next higher-lying one. This water is led very slowly from the field to a well protected

outlet. Terracing on some fields may be rather expensive, and where land values are low, it may be more profitable to seed a very badly eroded slope to grasses and legumes.

Terraces cut long slopes into numerous short ones, thus reducing soil losses greatly. Slopes that do not exceed 10 per cent and are long and smooth are best adapted to terracing. Irregular slopes, which require terraces far from parallel, are difficult to handle as cultivated fields. Medium-sized gullies that require sharp turns in ordinary contour opera-

FIG. 11.—A terrace outlet discharging water on a pasture. This is a profitable way to use surplus water.

tions can be practically eliminated by terraces. By making fills where the terraces intersect gullies, sharp curves in field operations may be reduced. Since the details of construction of a terrace system are rather exacting it is not advisable to proceed without the aid of technical experience.

In planning a terrace system the first consideration should be given to adequate outlets for excess water. A pasture or meadow is an ideal place to outlet terraces. Where these are not available it is often advisable to provide them by special seeding. Should it be necessary to construct special outlet channels experienced engineers should be consulted.

A terrace system will rapidly deteriorate in effectiveness unless it is properly maintained. Field operations should be as near parallel to the terraces as possible. Breaks must be repaired promptly. The height of the terrace should be maintained with a blade or by the use of other adapted machinery. The use of the two-way plow on the entire field, which facilitates throwing the soil toward the top of the hill, is recom-

mended. This tends to counteract the natural movement of soil down hill and reduces the tendency to the eventual formation of bench-like terraces.

PASTURE TERRACING

Pasture terraces provide an excellent means of preventing excessive runoff, not only while the grass is attempting to reestablish itself, but also later when the closely grazed grasses are unable to hold back dashing rains.

FIG. 12.—Pasture terraces built before the grass is seeded provide permanent erosion control and permit practically no runoff.

Pasture terraces are usually built on the contour and consist of earth ridges thrown up at intervals of about 30 feet across the slope. The ridges are made sufficiently high to intercept all of the moisture that would otherwise run down the slope.

A small blade grader, which can be pulled by power available on the farm, is a satisfactory implement for building pasture terraces. Either horses or a tractor may be used to supply the power. Pasture terraces are built by moving dirt down hill. The leading end of the blade is started in the line previously marked off with the plow and the dirt is rolled down hill. At the end of the line, the blade is reversed and a fresh cut is taken from the upper side. On the next trip, the dirt loosened is moved against and on top of that of the first cut. This process is repeated until the terrace is completed.

Pasture ridges can be built by backfurrowing with a plow on the contour line. When it is advisable to summer-fallow a sloping field before seeding it for a pasture, the terraces may be built with very little additional work. The ridges can be back-furrowed once a month to control the weeds and three or four plowings will build a satisfactory terrace ridge. Low places should be built up with a fresno. Dams built at intervals in the terrace channels will reduce the chances of overtopping at possible low points.

The purpose of the pasture terrace is to hold all moisture on the side hill. The ends of each terrace should therefore be closed. This is most easily accomplished by slightly turning up the ends. At fence lines, it may be necessary to use a spade or slip scraper to extend the ridge.

PASTURE CONTOUR FURROWING

Pasture contour furrowing consists of a series of plow furrows constructed on the contour at a horizontal spacing as close as 10 feet on a very steep slope and as far apart as 25 feet on a very gentle slope.

FIG. 13.—Pasture furrows help to reduce runoff and thus stabilize pasture gullies. The conserved moisture increases the growth of grass.

This practice adapts itself particularly to areas where the pasture vegetation contains grasses that spread rapidly. The furrows, if properly spaced, can be expected to prevent practically all runoff. To make the stored moisture benefit the greatest number of plants, the spacing of the furrows should be close. The usual procedure is to plow single furrows from 20 to 30 feet apart across the slope. When these furrows have become grassed over, others may be constructed between the existing ones.

Since the capacity of a single contour furrow is small, it is essential that the top contour be started very near the top of the slope. If a one-bottom plow is used for the work, it is desirable to drive the team or tractor slowly. To increase the capacity and strengthen the ridge, a second slice may be plowed out of the bottom of each furrow.

The ends of the pasture furrows should be turned slightly uphill to prevent water from escaping. It is advisable to throw up small dams across each furrow where it gets slightly off the contour. Places in the furrows that will need dams can be located by the breaking over of water during the first heavy shower following the construction of the furrows.

It is possible to irrigate a pasture where there is water running down a draw from a higher field. By giving the furrows a slight down grade

from the points where they cross the upper end of the draw, such runoff water can be led onto the knolls at a slightly lower elevation.

CONTROL OF FIELD DRAWS

The lowering by erosion of natural field draws or depressions has caused permanent damage to many fields through the steepening of the side slopes which lead into them and the loss of the top soil. This process has been hastened by the practice of plowing or working in the depressions each season, only to have this loosened soil wash away soon after. Fields damaged by the lowering of these depressions become more difficult to cultivate each year. Finally large fields are divided into many smaller ones because of the depth of the depressions. Contour tillage of fields damaged in this manner becomes impractical.

FIG. 14.—Field draws, if unprotected, can readily become impassable gullies.

Many of these depressions are started by the accidental concentration of runoff water or by the marks of machinery which lead directly down the slope. By careful attention new depressions can be prevented, and those that are still slight can be easily cured. The first essential to the control and cure of depressions or field draws is that of permitting them to remain in close-growing vegetation. Such growth will retard the flow of water, cause silting, and thus eventually either obliterate the depression or provide a permanent non-erosive runway for flood water. It is important, therefore, that all farm machinery which disturbs the soil be lifted when crossing depressional areas. Weed growth alone will do much to stabilize field draws.

Weeds in undisturbed water channels will do much to prevent erosion, but such channels should eventually be stabilized with a dense erosion-resistant sod. The width of the area covered by sod need be such as will eliminate the probability of runoff forming new channels on either side of the grassed strip. Where the water course is fairly narrow, and

where the slopes on either side are abrupt, a strip of a rod or so in width and having a slightly depressed center is sufficient. Where the channel is broad, however, and where side slopes are very gradual, the grassed area may need to be several rods in width. Too often, under the latter conditions, the use of narrow strips has resulted in the elevation of the channel center by less silting and the eventual formation of new eroded channels in the bordering unprotected soil.

For the eastern half of Nebraska, a brome grass and alfalfa mixture not only forms a tough non-erosive sod, but at the same time can be made to produce a profitable crop of seed or hay. This is particularly true where the water channel is broad and flat and where it is necessary to provide a wide protected channel.

FIG. 15.—Permanently grassed draws prevent gullying and at the same time produce hay and grass seed.

In order to establish a sod in a water channel that is undergoing considerable erosion, it may be necessary to first work the soil down into a firm seedbed and then construct temporary channels on either side to divert the water until the new seeding is established. The first planting may well be a quick-growing crop such as Sudan or other sorghum. When this crop is harvested, a four-to-five-inch stubble should be left, which will tend to check erosion and cause silting. In the following fall or spring, brome and alfalfa may be drilled in this stubble without seedbed preparation. In this manner the young seedlings of brome and alfalfa will have an opportunity to gain a foothold while the stubble is still present to afford protection against erosion. Where brome is not adapted, blue grama and western wheat grass are suggested.

In the establishment of vegetation in any erosive channel even under the most favorable conditions of weather, soil, and management, one

cannot expect to obtain a perfect stand by these initial efforts. In all probability there will be places in the channel where the stand is thin or where erosion has washed away the seed and formed small eroded channels or depressions. These should be filled with soil after each rain and sod pieces pressed in to help hold the soil in place.

GULLY CONTROL

A study of gully control, more than any other erosion control method, brings out the desirability and perhaps the necessity of correlating several of the established soil and moisture conserving practices. Many of the structures placed in gullies are of a temporary nature which necessitates that ultimate control be affected by means of seeding the gully to permanent grasses, by terracing, or by resorting to a more permanent type of structure.

The cause of gully erosion is the concentration of water running down a slope. At first, only a depression exists, but as the water continues to rush down in large volumes a small gully soon appears. On cultivated fields the banks of small gullies are broken down by machinery operations. With each successive rain, this loose soil is washed down the slope, with the result that the gully becomes constantly wider and deeper.

Another type of gully formation, and one which is very destructive and difficult to control, is brought about by the advancement of overfalls. Overfalls usually appear after a definite gully has already been established. They may start at any point where an obstruction in a drainage way creates a miniature water fall. At first, a small drop of a few inches seems very insignificant, but before many years this same small waterfall may have attained tremendous proportions. Many fields in Nebraska have been destroyed for productive use by gullies created by overfalls.

It is apparent that the most effective means of controlling further advancement of gullies is to remove the cause. Wherever it is possible to keep the runoff water from concentrating and running down the gully, this should be the method of attack. Terracing of higher lying areas and of the areas where gullies are being formed is perhaps the most effective means of gully control. Whenever the gullies are small, the terrace ridges can be built across the depressions and the water which would otherwise run down the gully is carried slowly away to a protected outlet. Contour farming, especially of row crops, is also an effective means of controlling gully erosion.

Overfalls are threatening to destroy many of our Nebraska pasture areas. Runoff from overgrazed pasture hillsides has been excessive. Many deep overfalls have been formed and existing ones have worked their way into the pasture with increasing rapidity. Pasture terracing and pasture contour furrowing will in many instances entirely stop the activity of the overfall. As soon as runoff is controlled, reclamation of the gully by planting it to trees, shrubs or grass can be more effectively carried out.

Trees, shrubs and grasses, if allowed to grow thickly in the gully, are very effective methods of permanent control. The thicker and taller the

vegetation the greater is the resistance offered to the velocity of the runoff water. As soon as the velocity of the water is reduced part of the silt load is deposited, causing the gully to fill gradually. To insure a thick vegetative growth, a fence should be built around the gully to keep out livestock. Frequently gullies can be controlled merely by fencing, thus permitting vegetation to gain a foothold.

It is often possible to quickly check an overfall in a pasture by means of a diversion dike. This resembles a terrace in cross-section although the ridge is usually built up considerably higher than that of a terrace. The dike is thrown up a short distance above the overfall. The channel above the dike is given a slight grade not to exceed 0.8 per cent and leads to

FIG. 16.—Diversion dikes, at the head of overfalls, carry water away and spread it on grass where it will do no damage. The gully can then be healed with grass, trees, and shrubs.

a well grassed slope where the water has an opportunity to spread. It is essential that the drainage area above the dike be very small unless it is protected by pasture terraces on contour furrows.

Overfalls or even gullies that carry runoff from small drainage areas can be stabilized by the use of sod. A series of sod dams may be built in the gully. To construct a sod dam in a ditch it is first necessary to make a dirt fill at right angles to the direction of flow. The sides of the fill should have a slope of from 15 to 25 per cent. The upstream side may be left steeper than the downstream side. The top of the fill should be level and the ends raised to form a weir notch. This will tend to prevent water from cutting around the dam. The fill of dirt must be well tamped and it is then ready for a covering of sod. It is also important to tamp the sod well in order to form a good contact with the dirt fill. A very satisfactory tool for tamping the fill and sod can be made by filling a gallon can with concrete and inserting a piece of gas pipe suit-

able for a handle. Under dry conditions it is advisable to water the fill and sod if convenient. This will give the grass a better chance to become rooted before the first heavy rain.

To remedy an overfall it must first be worked down to a 15 to 25 per cent slope. It is then well packed and sodded. Gully control with sod is more permanent than with brush or post dams since the latter soon rot out. Consequently temporary structures made of brush and wood should be supplemented with grass, shrubs and trees. Labor and materials may frequently be saved by using a sod dam in the original attempt to control the gully.

In smaller gullies on moderate slopes, brush dams can be used successfully to catch silt carried in suspension by runoff water from higher lying land. The brush dam is a temporary structure and either seeding the gully to grass as soon as it has been filled sufficiently or diverting the water by means of terraces or permanent structures should be resorted to. For detailed information on the construction of brush and wire dams, refer to Extension Circular 741, "Inexpensive Methods of Gully Control."

The earth dam often adapts itself as a soil saving structure in medium sized or large gullies where the installation of concrete or masonry dams would be impractical. The subject of earth dams is so involved, however, that no attempt is made in this bulletin to go into details of design and construction.

PASTURE MANAGEMENT

Runoff from closely grazed pastures has been shown to be greater than from most other conditions of soil surface. This, no doubt, is due to excessive tramping and the creation of a non-absorbent powdery mulch. On the other hand, experiments indicate that a vigorous growth of grass provides the most efficient means for the prevention of runoff. Careful grazing is doubly important, therefore, in that it will not only prevent the destruction of grass by overgrazing and excessive tramping, but it will permit sufficient growth to retard runoff and thereby provide additional soil moisture.

Many pastures are injured by permitting stock to have access to them during the winter months. Damage also results from early spring grazing. Close early spring grazing results in the depletion of the food reserves in the grass roots, and consequently in a less vigorous growth throughout the season. Complete destruction of many pastures has resulted from continued grazing after drouth has arrested all growth. Hungry livestock have been permitted to grub and tramp the weakened turf until nothing but worthless annual weeds remained.

Where some semblance of a turf remains on damaged pastures, they may be rehabilitated by non-grazing, thus permitting the restoration of root reserves, the production of seed, and the natural spread of the sod clumps.

To reduce runoff, the use of contour pasture furrows seems to offer promise on permanent native grass pastures. Although this practice is be-

ing used experimentally on many pastures, its value from the standpoint of its effect on grazing yield has not been determined for Nebraska conditions. As a means for diverting water from pasture gullies it has proved to be very efficient.

Non-grazing of permanent pastures for the purpose of restoration requires forethought if livestock needs are to be taken care of. Where other adequate pasture is not available temporary pastures can be expected to provide a greater amount of grazing per acre than permanent pastures. Sudan, first and second year sweet clover, and fall rye are the most practical temporary pasture crops to use in the eastern half of Nebraska (see Nebraska Extension Circular 138). Sudan and rye are adapted also to the western half of the state. Provision for an adequate supply of supplemental feed, particularly silage and sweet sorghum fodder, is also a wise precaution against the probability of overgrazed permanent pastures.

Many permanent pastures are scarred with deep gullies. Most of these could have been prevented in their early stages by the diversion and spreading of water from cow paths and the breaking down or filling and regrassing of overfalls. The only practical treatment for most pasture gullies is that of diverting the water from them by means of pasture furrows and terraces or diversion dikes, and fencing them to keep out the livestock. Such treatment, together with the planting of trees and shrubs will permit the gullies to heal naturally. The actual filling of these gullies with soil is impractical unless they occur on fairly level land, and drain a sufficiently large watershed of cultivated land to supply the necessary silt deposits.

REGRASSING

Grass furnishes the most effective means of erosion control. Little or no erosion takes place on land covered with a thick sward of grass. The blades and clumps of grass act as dams which retard the flow of water, giving it more time to soak into the soil. The grass roots bind the soil together, thus making it resistant to erosion. Covering the land with grass is nature's way of preventing erosion. Grass roots not only bind the soil but they also bring about a granular structure which greatly increases the rate of water absorption and improves tilth.

Many steep slopes have been broken and farmed which should have remained in grass. Much land has been broken which has a very shallow soil and is unprofitable to farm. Quite a large acreage of land in Nebraska is so badly eroded that it is no longer fit for tillage. Natural water ways or field depressions in cropped land have been broken and are becoming gradually deeper with the consequent steepening of the slopes which lead into them. All such land will eventually need to be returned to grass.

In eastern Nebraska regrassing does not present a serious problem since seed of adapted tame grasses is readily available. Although there are several adapted species, such as orchard, meadow fescue, bluegrass, and timothy, the most satisfactory and long-lived one is brome (*Bromus*

inermis). A vigorous stand of brome can be expected to produce from 300 to 500 pounds of seed per acre under normal weather conditions and in addition, furnish much pasture and palatable dry roughage. Brome grass seed production can thus be made a profitable enterprise while at the same time the soil is undergoing improvement.

Brome grass is also fairly well adapted to most of central Nebraska. Many farmers in this area have found brome grass-alfalfa meadows to be their most profitable land from the standpoint of both pasture and seed production. Brome without a legume is likely to become "sod bound" and unproductive. The low productivity of pure brome stands is due to a shortage of available nitrogen. Legumes supply this need. Alfalfa

FIG. 17.—Brome grass is a good substitute for the prairie. It is Nebraska's best pasture grass. Production of brome grass seed can be made a profitable enterprise.

is the best legume for this purpose since it is long lived. Brome-alfalfa mixed pastures have given no trouble from bloat. Where brome does not thrive well, blue grama, side oats grama, switch grass, buffalo, and western wheat grass offer promise. The grama grasses seem particularly promising since they start easily from seed, they often produce a good crop of seed which is easily havested, and are highly palatable as pasture. Seed of native grass will usually need to be harvested locally from native meadows. Growing of pure stands of native grasses for seed production offers promise as a profitable venture for enterprising farmers.

The most important essentials of a good seedbed are: mellowness, firmness, freedom from excess weed seed, and adequate soil moisture. Either the plow or the disk may be used for the initial step in seed bed preparation. Where the field is free of an excessive amount of vegetation and where the soil is mellow double disking is preferred. Otherwise,

the land should be plowed 3 to 5 inches deep and later packed thoroughly with the disk, harrow and roller. On sloping land which is inclined to be erosive and which is not to be returned later to cultivated crops, it may be advisable to lay out level pasture terraces before seeding. This will reduce erosion and runoff to a minimum.

In western Nebraska where it is more difficult to obtain stands of grass it is often advisable to leave the land in wild fallow, permitting the weeds to grow for protection against wind and water erosion and allowing the native grasses to gradually take possession. Regrassing may be hastened by harvesting native grass seed and scattering this over the area without seedbed preparation.

March and April or late August and September are the best months of the year for seeding grasses. The choice between these months depends largely upon soil moisture and weed conditions. When the land can be fallow-tilled without serious erosion, fall seeding is ideal. This builds up soil moisture reserves and provides a weed-free seedbed. Growing conditions are usually more satisfactory during the fall months. Good stands may be obtained from April seeding, however, if the essentials of a good seedbed are provided and if weed growth is clipped often to prevent undue shading of the young grass seedlings. New stands of grass may be destroyed by mowing the weeds during the summer months after the grass seedlings have become tender because of shading.

Fifteen to twenty pounds of grass seed per acre is considered an adequate seeding whether for pure or mixed stands. When seed is high in price the use of as little as 12 pounds per acre may be advisable. The proportion of each grass seed used in mixtures may be influenced by the relative price and purity of the different seeds. The best tame grass mixtures are those in which brome is the dominating grass, and in which alfalfa is the principal legume. No mixture has given better pasture or has proved as long-lived as one composed of brome and alfalfa only. The proportion of three to four pounds of brome to one of alfalfa is a good one for pasture and seed production. Where the crop is to be used at first for hay and later for pasture the proportion of alfalfa seed may be increased. The rate of seeding for native grasses cannot be definitely stated because of their great variability in purity and germination. The percentage of live seed in native grass should be determined both before and after harvest. In some years and under adverse conditions, the viable seed produced by stands of native grass may be very low.

FIRE PREVENTION

Much valuable organic material is destroyed by burning. Each spring many farmers make a practice of raking and burning cornstalks, and setting fire to other dead plant materials such as straw stacks, stubble fields, or second year sweet clover stems. The continuation of this practice results in depletion of soil organic matter, lowered fertility, and increased erosivity of the soil. Nature's method of restoring or maintaining

FIG. 18.—Burning depletes soil organic matter and reduces fertility and water absorption.

the fertility and stability of soil is that of returning nearly all plant materials to the surface where they may decay and return their substance to the soil.

III--Storage of Soil Moisture

Soils vary in their capacity to absorb and to hold water. A clay soil may hold as much as three inches of available water for each foot in depth, whereas a coarse sandy soil may hold less than an inch. Most silty soils hold about two inches of available water per foot. Soils containing a high percentage of organic matter will hold more water than the same type of soil containing less organic matter.

The amount of water that a soil will absorb in a given time is affected by its texture, its general structure, and by the condition of the surface. Fine textured soils absorb water more slowly than coarse textured ones. A freshly plowed field will absorb water faster than a compact one. A soil having an open structure with large porous, granules such as the loess will absorb water more rapidly than a soil having small dense compact granules. The Marshall soil for instance, which is of loessial origin, may absorb water eight or nine times as fast as the Shelby, a glacial soil which has a compact structure. A given soil may vary greatly in the rate at which it will absorb water depending upon the amount of organic matter it contains. Organic matter not only increases the total water holding capacity of the soil, but increases also the rate of absorption.

Many other factors influence the amount of water that will be absorbed by a soil from a given rain. An inch of rain water falling on a steep slope may add little soil moisture, because of excessive runoff. An inch of rain falling in two hours will add more soil moisture than the same amount of water falling in one hour. Any condition or practice that retards runoff will increase the amount of soil moisture obtained from a given rain. Runoff may be 50 per cent or more of the rainfall on a soil having a bare surface, while at the same time, under the same conditions there may be little or no runoff from soil covered with a heavy growth of grass. Contour furrows, basin listing, and any thick-growing crop reduce the speed of runoff water and thus increase the length of time that absorption can be taking place. Contour listed furrows may prevent all runoff and thus cause the absorption of nearly all the rain water, provided it does not come in excessive downpours. Instances have been noted where such furrows on an absorbent soil have prevented all runoff from rains up to 4 inches, falling in 48 hours. Where lister furrows deviate slightly from the contour, dams such as those made by the basin lister are effective in reducing runoff.

Water stored in the first 6 inches of soil may be lost entirely by evaporation, or by vaporization when the soil becomes heated. Water stored below this depth will remain indefinitely unless removed by plant roots or pushed downward by additional water from the surface. On open-structured soils the roots of grain crops may use all of the available water to a depth of 6 to 7 feet and a part of that stored at a somewhat greater depth. The roots of sweet clover may take all of the available water from a soil to a depth of 14 feet, while old alfalfa stands may use water to a depth of 30 feet or more. Contrary to a quite common belief, soil

moisture at field carrying capacity does not move appreciably by capillarity in the absence of free water. Under these conditions, which prevail in most fields, roots must move to the water if they are to use it.

The amount of water needed by a crop for normal growth depends greatly upon weather conditions. A full-grown corn plant, for instance, may use as little as 1.5 pints of water on a cool moist day, whereas on a hot dry windy day the requirement may be as much as 10 pints. Other factors, however, such as weeds, soil fertility, and the kind of crop grown, determine the efficiency with which soil moisture is used. A sunflower plant, for example, has been shown to use twice as much soil moisture as a corn plant. Pig weeds are also very lavish users of soil moisture. Crops on rich soil use water more efficiently than on poor soil. Crops, themselves, vary in the amount of water required to produce a pound of dry matter. Calculations indicate that under average eastern Nebraska weather conditions seven inches of water if used efficiently by the different crops, will produce about 25 bushels of corn, 38 bushels of oats, 22 bushels of wheat and 0.8 ton of alfalfa per acre.

Since plant roots will not penetrate dry soil, and since on most of our land the free water table is at such depth that it is of no significance in crop production, it is important to consider the amount of water stored in the soil before crops are planted. It is also important that consideration be given to the actual location of the stored moisture with reference to its depth and intervening dry layers of soil. Although alfalfa may use water at a depth of 25 to 35 feet, its roots cannot reach this water if above it there is dry soil. For this reason soil dried to a depth of 5 to 10 feet for example, but moist below that depth, needs to be replenished before alfalfa is seeded if this crop is to reach and use this more deeply stored water. In soils where no deep subsoil moisture exists alfalfa can be expected to produce about one ton of hay for each eight inches of water stored and used by the crop. The replenishment of water in soil dried to great depths by a previous crop of alfalfa may take many years under average cropping and rainfall conditions. In one instance at the Nebraska Experiment Station a field dried to a depth of over 25 feet by alfalfa, has had no replenishment after more than 20 years under average cropping conditions. On the other hand experiments indicate that on a porous soil, special practices such as a combination of contour ridging and clean tillage may cause the replenishment of this water in a very few years depending upon the rainfall.

Wheat yields at the Nebraska and Kansas experiment stations have been shown to correlate quite closely with the amount of stored moisture at seeding time. The following table represents yields of wheat calculated from data obtained at the North Platte Experiment Substation and at three Kansas Experiment Stations. The calculations are based on the assumption of 100 seedings for each soil condition at seeding time.

An analysis of the data used in the above calculations shows that when figures from the North Platte Substation only are used, failures due to dry soil at seeding time are less frequent and that yields of 20 bushels or more

Number of times in 100 that given wheat yields can be expected under different soil moisture conditions.

Depth of moisture at seeding time	Number of seedings	Failures less than 4 bu.	4-9 bu.	10-19 bu.	10-29 bu.	30 bu. or more
Dry	100	66	17	17	0	0
1 foot.....	100	30	27	15	16	12
2 feet.....	100	24	11	16	20	29
3 feet or more..	100	10	3	14	42	31

are more frequent when only the top foot of soil is wet, than is the case at the Kansas stations. This would indicate that dry soil at seeding time under the more favorable climatic conditions of the North Platte station is less serious than under the conditions represented by the Kansas station. It would indicate also that a dry soil in eastern Nebraska at seeding time would be less serious than at North Platte because of the probability of greater precipitation during the spring months in eastern Nebraska.

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