T H E S I S

MANAGEMENT OF SOILS TO CONSERVE MOISTURE.

by

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upon graduation from the

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OUTLINE.

Title:

The Management of Soils to Conserve Moisture.

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The necessity of understanding the meaning of soil water.

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Conclusions:

MANAGEMENT OF SOILS TO CONSERVE MOISTURE.

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No other phase of modern farming, unless it be the ever pressing problem of how to keep up the fertility of the soil, is receiving the attention that is given to the problem of conserving the soil moisture. Even in the districts where rainfall is sufficient and where some of the moisture has to be drained away by artificial means there are dry periods which will prevent a maximum yield of any crop unless some measures are adopted to save the water not so removed. It is impossible to estimate the loss, in reduced yield of crops, due to the lack of sufficient moisture at the right time. This refers not only to the great droughts in our semiarid regions and to the local droughts which are likely to occur in any region but also to the unnoticed dryness which comes at a critical time during the growing period of a crop and reduces the yield more or less. When we consider the fact that on a large portion of the cultivated land in the United States there is sufficient moisture precipitated to mature double the average yield of most of the main crops, we see the importance of attempting to save it.

Irrigation problems will not be discussed in this production although it might be well to mention that in dry regions where irrigation is practiced, large crops are raised with much less water than is supplied in humis climates for the same yield. This is because there is less loss by evaporation. Water is run on the field when most needed so that the greater part of it is absorbed by the plants. Of course there is no way of controlling nature so as to get all of the rainfall just at the right time, but the soil can be so handled that it will receive and retain a large percent of the moisture that falls upon it.

In order to obtain maximum results from farming it is necessary to use brains as well as muscle in the work. A knowledge of the movements of water in the soil and of how water is held, the capacity of different soils to hold water and how this may be affected, and the ways in which moisture is lost, is necessary before the farmer can intelligently manage the soil to save moisture and secure the largest yield for his work. Each one of these subjects will be taken up and discussed separately.

Movements of Moisture in the Soil.

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The greater part of the water that falls as rain passes into the soil. The portion that runs off the surface varies with the compactness and nature of the soil, the slope, and character of the rainfall. The moisture which enters the soil is subjected to three types of movement: 1. Gravitational, the flow of water through spaces and crevices in the soil due to gravity. 2. Capillary, due to surface tention, and 3. Hydroscopic or thermal movement, due to the action of heat.

1. Gravitational movement:

The gravitational flow of moisture takes place through cracks and crevices and holes left by decayed roots and animals, and also through the capillary pores between the coarser grains of soil and granuels made up of finer grains. The condition of the soil as to moisture content has a decided influence on the rate of percolation. When ground has become so dry that the films of water surrounding the soil grains are very thin and there is a large volume of air in the soil, the downward flow of water is very slow except where there are shrinkage cracks and holes. For this reason light rains are not so effective in the summer when the soil is dry, as in the spring when moisture is plentiful. The water is retained near the surface where it is soon lost by evaporation.

A comparison of the rate of percolation through different kinds of soil at different texture is given in the table below. In working out this experiment six soil tubes, eighteen inches high and two inches in diameter, with overflow tubes at the top and drain tubes at the bottom, were filled with three types of soil; sandy loam, sand, and clay. The soil was poured loosely into one set of tubes while in the other tubes it was compacted. Almost a half inch of gravel was placed on the surface of each tube to prevent the flowing water from disturbing the soil. The overflow tubes were connected by short pieces of hose and water turned on so as to keep it about 3-4 inch deep on the surface. Time was noted until percolation began from each tube and when it became constant the water which percolated through each tube in thirty minutes was collected and carefully measured.

Table I.

Kind of soil.	Loose		Compacted	
	Time for percolation	C.C. Water percolated in 30 min.	Time for percola-tion.	C.C. Water percolated in 30 min.
Sandy loam	49 min.	75 C.C.	125 min.	35 C.C.
Sand	6 min.	600 C.C.	9 "	435 C.C.
Clay	155 min.	15 C.C.	10 "	6 C.C.

This trial shows that water percolates most rapidly through the coarse grained soils, or those which, although they do not have as much total pore space, have larger pores and offer less frictional resistance. In the compacted soil percolation was much slower than in the same soil when loose. In the compacted soil the particles were brought closer together and the pore space reduced. The relative difference in time required to start percolation in the loose and compacted soil was greatest in the clay, next greatest in the sandy loam and least in the sand. This is because there is a larger number of pores in the finer soils, and these pores are reduced more in proportion to their size than the larger pores. The more or less floculent condition of the clay, and slight sponginess of the sandy loam, due to humus, caused these soils to pack more than the sand.

2. Capillary Movement:

This movement is due to surface tention which tends to keep the film of water around each soil particle the same thickness. The general tendency of capillary attraction is to bring water from below up to the surface, but it may be in any direction, the movement always being from the wetter to dryer soil, or from the thicker to the thinner films of water. It is by this action that water is carried from any direction to the roots of plants when the soil which immediately surrounds them has been made by root absorption. In irrigation the water is spread out from the ditch by capillarity and in the lamp wick this same action supplies the flame with oil.

This movement is slower than percolation and like the latter is slower in dry soil than in wet soil. When soils are stirred up so as to break the pores, capillarity is reduced and when the loosened portion becomes so depleted of its moisture as to look dry, it makes an effective mulch. The rate of capillary rise in different soils was determined by the writer by filling glass tubes thirty-eight inches high and one inch bore, with different soils and standing them upright with the lower ends, which were covered with cheese cloth caps to prevent the soil from running out, immersed in water. The soil in each tube was packed by tapping on the side of the tube while it was being filled. The kind of soils used and data obtained from the experiment is indicated in table II.

Table II.

Showing height and rate of Capillarity in different soils.

Kind of soil	Height of water in inches.								
Hours	1-2	1	2	3	6	21	45	70	94
Sandy loam	7	9	12 3-8	14 5-8	18 1-4	24 1-2	28 1-2	30 1-8	31 3-8
Sand	8 5-8	10	11 1-2	12	13	14 1-4	14 3-4	15	15 1-4
Clay	3	4 1-4	6 5-8	8 3-8	11 3-4	20 3-4	27 1-2	32 3-8	35 1-4
Humus loam	3 7-8	4 5-8	6 6	7	8 5-8	12 1-4	14 1-2	15 7-8	16 3-4
Peat	1	1 3-4	2 1-2	3 1-8	4 1-8	6 1-4	7 3-4	8 7-8	9 3-8

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The table shows that sand took up water the fastest at first the moisture raising in the first half hour over half as high as it did in the whole week's time. The rise in the sandy loam was not so fast at first but caught up with the sand between the first and second hours and the water ha had raised to twice the height of the water in the sand at the the end of the experiment. Although not so fast at first as in other soils, capillarity was strongest in clay, the water raising to the top of the soil (37 inches) before the end of the week. The weak and slow capillary action in peat is accounted for by the character of the substance. This is not really a soil; Instead of being made up of small grains it has more or a fibrous character and takes up water more like a similar column of small wood chips than like soil. The humus loam contained enough peat to have much the same character. Besides, these soils were somewhat spongy and did not pack in the tubes as closely as the other soils. Organic matter that is well rotted and properly mixed in a soil will strengthen capillarity, where too coarse the organic matter is likely to hinder capillarity.

The height to which water will raise in a soil is influenced by the size of the pore spaces and these in turn are influenced by the size of the soil grains and the compactness of the soil. Water will rise higher in a fine grained than in a coarser grained soil and higher also in a compact than in a loose soil.

Capillarity may be strengthened so as to bring up a larger per cent of the water from the deeper soil by mixing barnyard manure with the surface soil or producing a good soil mulch over the surface to prevent evaporation. As has been stated before the moist soil has stronger capillary action than the dry soil so any condition which will keep the upper foot or so supplied with a fair amount of water will enable it to bring up moisture from lower down, for the use of crops.

It is capillary water of the soil that is used by plants and that carries the plant food. It is through capillarity also that water is carried to the surface and taken up by evaporation. It is necessary, therefore, that there should be some way of controlling this movement, and this will be discussed later on.

Hydroscopic moisture and its movements:

Hydroscopic moisture is the thin film which remains on the surface of air dried particles of soil. It is impossible to make a distinct dividing line between hydrosocpic and capillary moisture; one blends gradually into the other. It is safe to say, however, that when no plant can obtain water from a soil, only hydroscopic moisture is left. It probably never happens, even in the dryest air, that soil grains or any solid surface is not covered by a film of this moisture of greater or less thickness.

The amount of hydroscopic water held by a soil depends on the total soil surface to be covered. A fine grained soil has more surface for a given volume than a coarse soil and will hold correspondingly more hydroscopic moisture.

Thus plants are apparently able to feed closer on the coarse soils, reducing the moisture to a lower percentage in coarse then in fine grained soil. The amount of hydroscopic moisture in a given soil varies from day to day according to the condition of the surrounding air, being greater as the moisture in the air increases. The amount of moisture in air dry sand, clay, sandy loam and peat, under the same atmospheric conditions was determined in the Laboratory and is shown in the following table.

Table III.

Kind of soil.	Amt. of soil + hydroscopic moisture.	Weight of dried soil.	Wt. of hydroscopic water.	Per cent of hydroscopic water.
	gms.	gms.	gms.	
Sand	10.8014	10.7878	.0136	.126
Sandy loam	10.2328	10.1378	.0955	.928
Clay	10.1664	9.9566	.2098	2.064
Peat	8.1116	7.8153	.2963	3.5295

In obtaining this data, samples of each soil were carefully weighed and placed in an oven and heated to ° C. for two hours to drive out all the moisture. They were then placed in a desiccator and cooled and then weighed again and the percent of hydroscopic moisture computed from the loss in weight between the first and last weighings. A glance at the table will show which soil contained the larger percentage of moisture.

The amount of moisture a soil may absorb from the air depends upon the temperature of the soil and of the air, and the degree of saturation of the air. Evaporation and condensation between the air and the soil is continually going on tending to keep an equilibrium between the two. When the soil is cooler than the surrounding air, in a partly saturated atmospheric condition, condensation takes place unitl an equal temperature and degree of saturation is reached; then evaporation takes place as fast as condensation. If the soil could be kept at a constanly lower temperature than a saturated atmosphere, water enough might be condensed to cause percolation. An example of this is the water which collects and drops off of a cold water pipe on a warm or damp day.

The movement of the hydroscopic moisture whithin the soil takes place by evaporation similar to that between the air and the soil. When the moisture films become very thin, so that capillarity no longer has any effect, and the percentage of air in the soil is measurable increased, the thermal movement may cause considerable change in the position of the moisture. In parts of the soil where the temperature is not the same, if one part is at a higher degree of saturation than another, diffusion will take place more rapidly from the wetter to the drier soil. In a very dry soil if the surface becomes cooler than the lower soil, water vapor may come up from quite a depth, depending upon the nature of the soil, and be condensed on or near the surface. During a dry season enough moisture may be carried up in this manner to be of some benefit to plants. This internal evaporation also has a dooling effect and probably aids, to quite an extent, in keeping the soil from becoming overheated during dry, hot times.

On account of its juxtaposition with the soil particles, hydroscopic moisture should also be given the credit of dissolving plant food from the soil and in aiding in the disintegration of soil forming rocks. This form of moisture does not, however, transport any of the plant food through the soil.

Water Holding Capacity of Soils.

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The forms in which water is held in the soil have been described. The form of moisture which is most valuable to plants is that which is held by capillary attraction. Soils vary widely in their ability to hold this kind of moisture, and although this ability may be influenced to a great extent by artificial means, it is always wise in considering the value of a piece of land to look to this particularly. A soil rich in plant food may produce no larger crops than a comparatively poor soil, if it has little capacity to store up moisture for future needs.

1. The capacity of a soil to hold water:

The capacity of a soil to hold water depends upon its composition and texture. A light sandy soil will hold less

less than a fine grained soil, as clay or loess, which is rich in humus. The increased number of soil particles gives more surface for the water to cling to and the humus gives papacity by its spongy action in opening up a soil. According to Fletcher, the amount of capillary water held by different soils under field conditions is as follows: Coarse sand 12 to 15 per cent by weight, sandy loam 20 to 30 per cent, clay loam 30 to 40 per cent, and a heavy clay or a soil very rich in humus may hold from 40 to 50 percent of moisture. The fact that a sandy soil holds less moisture than the finer soils, as clay or loam, is offset to a certain extent by the fact that plants are able to use a larger percentage of the moisture from the coarser soils. A heavy soil may hold 25 per cent more moisture than a light coarse soil, but the latter will probably give up three-fourths of its moisture while the former will part with only one-half of what it contains. The reason for this is on account of the larger per cent of hydroscopic moisture in the finer soils.

Effects of plowing and subsoiling:

These two operation will be discussed together here because they have practically the same influence on the water holding capacity of soils. The object in both cases is to loosen up the soil so as to increase the pore space and make a larger reservoir for soil water. The depth to which the plowing should be done depends on the nature of the soil. A fine heavy soil should be loosened up deep and plowed at a different depth from time to time. If plowed at the same depth every year a sort of hard-pan or "plow-sole" as it is sometimes called, will form at the bottom of the furrows; caused by the trampling of the horses and sliding of the plow. This prevents capillary connection from being formed between the upper and lower strata and has a puddling effect on the soil so that it will not take in water so readily, permitting more of it to be lost by the surface drainage. It may be of advantage, however, on a light sandy soil, to plow more shallow and about the same depth every year as such plowing packs the soil so as to hold the water from leaching away so rapidly.

Subsoiling on heavy soils increases the capacity for holding water by leaving the ground in a more or less granular condition. It also aids in percolation. Water is allowed to flow through the soil more freely. The pore spaces are enlarged so that the soil air can easily escape and let the water pass. Care should be taken not to use the subsoil plow when the ground is too wet as there is danger of puddling. It is safer on this account to subsoil in the fall when the deeper soil is usually dried out more than in the spring time.

Commercial fertilizers:

In table IV. are given the results of an experiment carried on to determine the effect of different commercial fertilizers on the capacity of a black loam soil to hold water and the ability to retain it against gravity. Four different kinds of fertilizers were used; Sulphate of potash, Sodium nitrate, Phosphoric acid and Sulphate of iron. The rate per acre at which they were used is shown in the first column of the table referred to. The soil for each sample was weighed out an the fertilizer thoroughly mixed in, after which the soil was compacted into soil tubes twelve inches high and two inches in diameter, with perforated bottoms, and the tubes were placed in a jar of water until the soil was thoroughly saturated. Each tube was weighed at saturation, and each day afterward for seven days. Covers were placed on the tubes while they were draining to prevent loss by evaporation. On account of insufficient tubes this experiment had to be run in three divisions. Two tubes of soil, into which no fertilizer was added, were run in each division to act as a check.

Table IV.

m Effect of Fertilizers on the Water Holding and Retaining Capacity of Humus Loam.

Fertilizer	No. of tubes.	Wt. of dry soil.	Wt. at saturation.	Wt. after seven days drying.	% of H^2O at saturation.	% H^2O at end of 7 days.	% loss in 7 days.
Nitrate of soda at the rate	1	471.	666.4	646.8	41.48	37.75	3.73
of 100# per acre.	2	470.8	670.	647.3	42.31	37.50	4.81
Nitrate of soda	3	457	653.8	631.	43.06	38.07	4.99
at the rate of 150# per acre.	4	499.2	700.3	682.2	40.28	36.65	3.63

Nitrate of soda at the rate of 200# per acre.	5	485.5	684.8	664.2	41.05	36.84	4.21
	6	484.9	682.8	666.2	40.81	36.97	3.84
Sulphate of potash at rate of 100# per acre.	7	471.4	680.	654.	44.25	38.73	5.52
	8	462.3	669.3	647	44.77	39.97	4.8
Check.	9	427	646.9	621.7	51.49	45.59	5.9
	10	408.7	616.5	691.1	50.84	44.62	6.22
Second division.							
Sulphate of potash, 150# per acre.	1	444.	646.4	627	44.28	39.97	4.31
	2	442	635.4	612.2	43.75	38.50	5.25
Sulphate of potash at rate of 200# per acre.	3	435	634.8	608.5	45.93	39.88	6.05
	4	453	659.2	629.8	45.73	39.00	6.73
Phosphoric acid at the rate of 200# per acre.	5	440	643.2	615.2	46.18	39.81	6.37
	6	450	656.4	631.2	45.86	40.27	5.59
Phosphoric acid at the rate of 300# per acre.	7	452	654.9	633.2	44.88	40.09	4.79
	8	444	645.6	623.3	45.40	40.38	5.02
Check	9	452.5	670.9	644.9	48.26	42.52	5.74
	10	435	643.6	618.	47.95	42.07	5.88
Third division.							
Phosphoric acid at the rate of 400# per acre.	1	450.	638	624.	41.77	37.77	4.
	2	447	640	620	43.17	38.68	4.49
Sulphate of iron at the rate of 50#per acre.	3	457	640.1	624.5	40.06	36.65	3.41
	4	471	662	646	40.55	37.15	3.45
Sulphate of iron at the rate of 100# per acre.	5	469	654.2	636.5	39.48	35.72	3.74
	6	479	664.8	647	38.79	35.07	3.72

Sulphate of iron

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Sulphate of iron at the rate of 150# per acre.	7	455	646	629.8	41.97	38.41	3.56
	8	452	643.2	626.8	42.30	38.67	3.63
Check	9	437.5	646.3	629.3	47.68	43.84	3.84
	10	441.5	644.3	627.2	45.93	42.06	3.87

The results of the experiment are not very satisfactory, In some cases duplicate samples show a greater difference in the percent held or lost than samples with different fertilizers or different amounts of the same fertilizer. This difference may be caused, however, by a difference in compactness of the soil, which would make a variation in its capacity to held water and also partly to errors in weighing. It will be seen that in every case the capacity of the soil to hold water seemed to be reduced by the application of the fertilizer, although the percentage lost during the seven days was less, with three exceptions, in the fertilized soil. These exceptions were when potash was used at the rate of 200# per acre, and where phosphoric acid was used at the rate of 200 and 400 pounds per acre. The difference in per cent of water held is not so great as is shown by the table, because the fertilizers were dissolved in water sufficient to make a tenth normal solution and this was added to the dry soil before its weight as given in the table was taken. As the per cent of water held by the soil was calculated from the weight of the dry soil, this would make the fertilized soils show from five to two per cent less moisture than they really contained. No variation in daily loss was caused by the fertilizers and they did not seem to cause any difference in the texture of the soil.

Lime applied to the soil properly, is claimed to be beneficial as far as the moisture problem is concerned, to both heavy and light soils. In the heavy soil, especially clay, it collects the fine particles into granules, causing the floculent condition. This aids percolation, makes more room for film moisture, and lessens the tendency for puddling. On light soils it has a binding effect which retards leaching.

4.Effect of Humus:

Humus increases the water holding capacity of a soil. It opens up a heavy clay soil and acts as a sponge in absorbing the water. It gives body to light sandy soils and fills up the pores so that water will not leach out so readily. Table V. shows the effect of different amounts of humus on the water holding capacity of a sandy soil:

Table V.

Soil.	Wt. of dry s soil grams.	Wt. of soil at saturation. grams.	Wt. of soil and water held after five days. grams.	Wt.of water retained. grams.	Per cent of water held after five days. per cent.
Sand	600	754	731	131	17.92
	600	752	730	130	17.9
520 gms sand	545	692	675	130	19,25
+ 25 gms. peat.	545	681	668	123	18.4
490 gms sand +	540	689	662	122	19.03
50 gms. peat.	540	685	657	117	18

430 gms. sand+	530	697	661	128	19.45
100 gms. peat.	530	694	663	133	20.
Peat	360	526	505	145	28.7
	335	505	486	151	31

Very little explanation is needed for this table. The soil tubes used were the same as in table IV. The soil in each tube was saturated then drained for five days and the per cent of water held at that time, computed. It is evident that the capacity of sand to hold water is increased directly as ~~xxxxxxx~~ more humus is added.

5. Drainage:

It seems strange at first thought that draining a soil sould increase its amount of availabe moisture. The reason is as follows: When the subsoil is filled with water the roots of plants cannot penetrate it on account of the lack of air. They occupy only a limited amount of soil at the surface, and when this is exhausted of its moisture, capillarity is not strong enough to bring up a sufficient supply from below. In drained soils, on the other hand, there is a deep subsoil to hold moisture, into which the roots can penetrate and capillarity does not have to carry the water so far before it reaches the plant. There is also a much larger volume of soil from which plants can obtain nourishment.

How Moisture is Lost.

How Moisture is Lost.

There are four ways by which the moisture which falls on a soil may be lost: 1. Surface Run off, 2. Leaching through soils, 3. Through plants, 4. By evaporation.

The per cent of water which runs off without entering the soil varies with the soil, slope, and nature of the rain. In a heavy dashing rain, it is neccssarily greater than in a slow, gentle rain. The soil can take in water only so fast and what falls in excess of this amount in a given time is lost. In fields that have been put in the best shape to receive and retain moisture, the loss is much reduced. In case of heavy rains the damage done by washing and cutting a field may amount to considerably more than merely the loss of the water, if precautions are not taken against it.

In loose, sandy soils and soil filled with shrinkage cracks, much water may escape by leaching. Such water carries more or less plant food along with it and may rob a soil of a large percentage of its fertility. Such a loss of water can be largely corrected by adding humus to the soil in the form of manure or cover crops, and the the proper methods of tillage.

It seems impossible that plants should take as much water from the soil as experiments show. Hellriegel, in Germany, found that wheat uses about 450 pounds of water for each pound of dry matter formed. Corn has been found to use about 275 pounds, and clover 605 pounds of water per pound of dry matter. Investigations with trees show that during the growing period, Birch and Linden transpired from 600 to 700 pounds of water per pound of dry leaves; Oaks from 200 to 300 pounds of and Spruce and Pines only 30 to 70 pounds. The thickness of the leaf and number of stomata per square inch influences the rate of transpiration.

Transpiration is much slower in the thick, fleshy cactus of the arid regions than in the thin leafed plants of the humid climates.

The drying effect of plants on the soil can be seen by comparing the moisture content of a soil which is growing a heavy crop with one which has been kept cultivated without a crop. The latter will be found moist during the entire season, while the former will show signs of drought within two or three weeks of a good rain.

Evaporation is caused by the sun's rays setting the molecules of water in such rapid vibration that the force of cohesion is overcome and they are thrown out into the air in the form of vapor. The amount of water evaporated either from a water surface or the soil, varies according to the climatic conditions and weather. Also to the condition of the soil surface. There are days when the air is nearly saturated that evaporation even from a water surface cannot be detected, while on a hot, windy day, when the air is dry, an enormous qualtity of water is evaporated. Hilgard states that the evaporation from reservoirs and ditches in the arid regions may , in many cases, exceed the rainfall of the year; and that from 40 to 50 inches was evaporated from the resorvoir that supplies San Francisco with water in a year, while the annual rainfall is less than 24 inches. Evaporation is not only greater as the temperature of the air increases, other things being equal, but increases directly as the temperature of the water is raised where the air temperature is unchanged.

Evaporation from the soil depends largely on the conditions of the surface and the rate at which moisture is brought from below as the surface dries. A field which has been plowed and kept rough and more or less cloddy, will loose more by evaporation when harrowed on account of the greater amount of surface exposed. A thoroughly compacted surface may not loose water as fast at first as a newly plowed and harrowed field, but will loose water for a longer period on account of its stronger capillarity. On the plowed ground capillarity is broken up more or less and the loose surface soon dries out and forms a mulch preventing further loss.

Methods of Conserving Moisture.

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Often water has once been stored in the soil the principal way it is lost, which gives no benefit to crops is by evaporation. Capillarity and evaporation have already been described and it has been stated that they may be largely controlled by handling the soil in the right way. The chief means of preventing evaporation is by mulches which stop or retard the capillary rise of the water. These mulches may be of soil or some organic material as straw, sawdust, or leaves. Windbreaks are effective by checking the rate at which the air moves over a field.

Effect of Mulches:

The effectiveness of a mulch depends on the degree to which it hinders capillary action, and this, with soil mulches, is influenced by the fineness of the soil and the depth and frequency or cultivation. Fine soils in which capillarity is strong suffer a greater loss of moisture through the soil mulch than coarse-grained soils. As to the depth of a mulch, three inches is generally considered the best. It is in most cases more effective than the deeper mulches and cheaper to produce. The frequency of cultivation depends upon the weather conditions. It should be often enough to keep a dividing line bbetween the stirred and the lower soil particles. As long as the mulch is well loosened and separated from the firm soil beneath nothing is gained by cultivation and may be an added expense and cause injury to the crop, expecially near the end of the growing season, when the soil is dry, by cutting off plant roots which have come close to the surface to obtain moisture from showers. The relative effectiveness of mulches on sandy loam and humus loam soils in cylinders four inches in diameter and eighteen inches high is given in table VI.

Table VI.

Showing effectiveness of different mulches on sandy loam and humus loam soils.

	Kind of mulch	Lbs. lost the first week.	Lbs. lost the second week.	Lbs. lost third week.	Total lbs. lost.	Acre in evaporated.	T. per acre.
Sandy loam.	(No treatment.	.33	.26	.37	.96	2.1	239.6
	(Stirred 1 in.	.27	.23	.31	.81	1.77	202.1
	(" 3 in.	.32	.31	.38	1.01	2.22	252.1
	(1 in. sawdust.	.10	.04	.04	.18	.39	44.9
	(1 inl sand.	114	.11	.20	.45	.99	112.3
Humus loam.	(No treatment	.29	.21	.28	.78	1.68	191.8
	(Stirred 1 in.	.20	.16	.25	.61	1.34	152.2
	(" 3 inl	.20	.14	.21	.55	1.2	137.3
	(1.in sawdust.	.08	.04	.06	.18	.39	44.9
	(1.in sand.	.09	.05	.06	.20	.439	49.9

The soil mulches in this experiment were stirred every day. It will be seen that in each case the loss was less in the humus loam. Granulation was good in this soil and capillarity not so strong. With the soil mulches the sandy loam did not dry out so as to separate from the undisturbed soil as the humus soil much[1] did. The three inches of mulch of the sandy loam remained muddy during the entire three weeks. This accounts for its excessive loss. The table shows that for the second week there was less loss from all the mulches than in either of the other weeks. This may be due to the cool cloudy days during that week. It will be seen that sawdust made the most effective mulch, the sand ranking second.

Nature's way:

Examples of nature's way of saving the soil water from evaporation are the thick mulch of leaves which is spread over the soil in a forest and on the prairie grounds the mat of dead grass. The soil under these natural mulches when undisturbed is usually found moist and mellow. In pastures, certain patches which have been allowed to be closely grased off will dry out much quicker than other spots where the grass is allowed to grow up and shade the ground. The closely grazed patches not only receive more of the direct rays of the sun, but are exposed more to the wind and the soil is packed more by the tramping of stock, strengthening capillarity.

In the forest also, land covered with a good mulch of leaves will be in a moist condition when ground from which the leaves have been removed is dry and hard. Evaporation here id due more to the action of the wind as the soil is more or less shaded from the sun by the trees.

Cover crops:

The practice of growing a catch crop in the spring or fall of the year is quite common where moisture enough is present to permit. Such crops are beneficial, by improving the texture of the soil when turned under, by preventing the soil from washing where there is such a tendency, and by saving soluble nitrates and other plant food from being leached out. The danger in growing cover crops are, leaving the soil too dry for crops that are to follow, sapping all the available nitrates from the soil so that following crops are impeded in their growth, and cutting off capillary connection when plowed under, preventing the surface soil from being supplied from below. None of these dangers are so great when the cover crops are grown in the fall and where rainfall is sufficient such crops are nearly always beneficial, but in arid and semiarid regions, where there is little danger of leaching and washing, more moisture may be conserved by early plowing and it is afasafer practice in the growing of the main crops.

Plowing:

The effects of plowing have already been mentioned in discussion evaporation and the water holding capacity of soil. However, nothing has been said yet as to the time of plowing or how it improves the physical condition of the soil. It is generally conceded that stubble fields should be plowed as soon in the fall as possible, and soil for spring crops, if not fall plowed and kept in condition by disking, should be plowed as early as the weather will permit. The moisture condition of the soil at the time of plowing must always be considered. If too dry when plowed, it will break up into hard clods and lay loose, allowing too free a circulation of air. If too wet, the turned up surface, expecially in clay soils, is apt to bake and become so hard that it cannot be pulverized. When in the right condition and a plow which has a mouldboard with a steep upward curve is used, the soil is not only inverted but is thoroughly pulverized by the shearing action within the furrow slice.

Where the surface is uneven and hard or is covered with considerable trash, it should be well disked before plowing. This will even up and pulverize the surface and scatter the trash so that the turned furrow will lay close to the undisturbed soil beneath and establish better capillary connection. If the soil is not plowed early, disking is beneficial by making a mulch which preserves the moisture.

The subsurface packer is an implement which should be used more on plowed ground, especially in dry districts. It should follow the plow the same day the plowing is done. Its effect is to firm the lower portion of the furrow slice establishing a connection with the subsoil and retarding the circulation of air. It leaves a loose layer on the surface to act as a mulch and when this is smoothed and pulverized by a harrow, ideal surface conditions are produced.

Listing:

The theory that the more surface exposed the greater will be the loss by evaporation does not always hold where the lister is used. In the wheat belt of the great plains, many of the fields, especially the sandier ones, are prepared by listing first, then leveling down with a disk-cultivator and harrow. The listed ridges seem to hold moisture better than the plowed ground and frequently the larger crops are secured on the soil so prepared. One reason given for less moisture being lost from the listed ground is that much of the surface is protected from the wind, only the tops of the ridges being exposed.

Cultivation:

No set rule can be given for the depth and frequency of cultivation. This depends upon the crop, weather, and physical condition of the soil. Cultivation should commence as soon as the weed seed has sprouted, or a crust has begun to form on the surface, and conintue often enough to keep the mulch established. After a rain the field should be cultivated as soon as it is dried out so the soil will not stick to the cultivator shovels.

In the early cultivation of corn the harrow may be used the first couple of times over. It has the advantage of enabling the farmer to get over a larger area of ground in a day and it keeps the surface crust broken up and destroys weeds that are just sprouting. Spring harrowing of wheat fields is so often practiced and probably saves no small amount of moisture where the soil has become crusted over by the packing of heavy rains. Where heavy rains have formed a crust over the field before the planted crop had come up, the harrow is also an indespensable article.

As to the depth of cultivation it is usually mecessary to keep a deeper mulch in a dry, windy climate than where the air is more humis and does not circulate so freely. The depth may also vary with the season. Less harm is done by deep cultivation in the spring when crops are small, than in the late summer when the roots are spread out nearer the surface. In the cultivation of corn, listed corn can be cultivated deeper than surface planted corn because of its roots being deeper in the soil. It is better to use a cultvator with three small shovels on each side than with the two large one, as the smaller shovels will not dig in so deeply at the point and will leave the soil pulverized better and leave less surface exposed.

The effect of wind-breaks and forests:

Evaporation is much faster on soils which are exposed to the full action of the wind than on theos which are protected by some form of a wind-break. Prof. King, in "Irrigation & Drainage", states that when the rate of evaporation at 20, 40, and 20 feet to the leeward of a grove of Black Oak 15 to 20 feet high was 11.5, 11.6, and 11.9 cc respectively, from a wet surface of 27 square inches, it was 14,5, 14.2, and 14.7, cc at 280, 300, and 320 feet distance, or 24 per cent greater at the three outer stations than at the nearer ones. A growing crop along the edge of a strip of land checks the rate of evaporation by impeding the velocity of the wind and by the moisture it gives off to the air. Forest are of great benefit also by the amount of water evaporated brom their leaves, making the air that passes over surrounding fields more humid.

The wind not only dries out the soil, but often, especially in light soils where large fields are exposed, drifts the soil into great heaps, cutting down to the ground in some places and taring the crops out by the roots. Windbreaks and trees along the fields and roads exert a great influence in lessening these re sults. The point is sometimes argued that trees sap the soil and cause a wide strip of land on the border of fields to be unprofitable for crops, but this may be more than overcome by the benefit derived from savind moisture farther out.

Conclusions.

There is no reul which will act as a guide in the management of soil under all conditions. Soil that on account of its position is naturally too wet, must be drained while soil that is dry and receives little rainfall must be kept in condition to conserve all of its moisture. Putting the soil in the best physical condition to store and conserve water also produces the best seed-bed, hastens nutrification and causes more plant food to become available.

Evaporation is lessened by covering the soil with a mulch. A soil mulch is the most practicable for the ordinary farmer and it must be kept loose to be most effective. Coarse grained and floculent soils make the most effective mulches as capillarity is not so strong in loose, coarse grained soil.

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