T H E S I S.

Soil Moisture and its Conservation
As Applied to Western Kansas.

Presented for the Degree of

Bachelor of Science

in Agriculture

By

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THESIS OUTLINE.

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SOIL, ITS MOISTURE AND ITS CONSERVATION AS RELATED TO WESTERN KANSAS

To almost every agricultural section of the world the subject of soil moisture is important. At no place do we at all times find the water supply perfectly suited to the greatest crop production. True in some localities the yearly rainfall is almost exactly that required for maximum crops. But does it come just when needed and never when not needed? Are there no times when the crops suffer for want of a rain?

In some sections the problem is to drain off rather than to to conserve the soil moisture. When this is the problem, it is as important as is the problem of conservation of moisture in dry sections. In our own state, in the greater portion of it at least, we have the drouth problem confronting us and it is this phase of the subject that we intend to consider.

The reason why soil moisture is important to man is that it is essential to plant growth. A certain amount is necessary before any growth will take place and a certain larger amount is required for maximum growth. This amount varies with the plant life, some requiring an enormous amount of water while others require but comparatively little. To give an idea as to the amount of water required by our Kansas crops for fair yeilds, I will insert the following table taken from Bailey's Principals of Agriculture:-

Crop	Yield per Acre	Required Water.
Corn	50 bushels	1500,000lbs.
Oats	29 bushels	1192,000 lbs.
Potatoes	200 bushels	1268,000 lbs.

This makes the amount required seem enormous but when we take into consideration the amount of rain that falls on an acre of land in a year we see at once that in Kansas the growing of maximum crops is dependent on the problem of conserving our rain falls. In Eastern Kansas the average rain fall is about forty inches per year and in Western Kansas fifteen inches. This gives us in Western Kansas 4,394,000 lbs. per acre water; almost three times the amount required to raise fifty bushels of corn per acre. Before studying means of conserving this moisture let us first understand the nature of this moisture.

We find that moisture is held in the soil in three forms; viz. Free water, capillary water and hygorscopic water.

Free water is supplied in the form of rain. It is this water which sparkles from our springs, flows in our streams and is drawn clear and refreshing from our wells. Forty inches of free water fall in the Eastern half of the State while in the Western part of the State only ninteen fall. Free water is useless to our crops except as it is the source of capillary water. Not only is free water useless to the plant but an over abundance of it in the soil is injurious; most plants suffer as readily, if not more so, from too much as from too little moisture.

Capillary water is held around and between the particles of soil. It comes from the free water of the soil being drawn from it by capillary attraction. It moves freely from one place to another keeping the soil moisture in equilibrium. It is this water which is evaporated from the surface of the earth and is utilized by the plants. Our whole problem then is the conservation of this particular kind of moisture.

Hygroscopic water is held as a very thin film of water around each minute soil particle. This moisture is present in all kinds of soil even the dryest dust of the road has a thin film of this kind of water around each particle of dust. It is not removed at ordinary temperature requiring the boiling temerature for its evaporation. Only a very small amount of this water is available to plants at all, and then only when no capillary water is left in the soil. This small amount of water may be sufficient to sustain a plant for a few hours but not for a much longer time.

Having touched upon the forms of water in the soil and its movement it will be well to consider soil as related to its moisture. To the casual observer soil is a very common place substance, alike in all forms except that to some extent it differs in color and sticking capacity, but is worthy of but little investigation. We see its importance however when we stop to consider that all life is dependent upon the soil. Man depends upon vegetables and animals to supply his bodily wants; the plants depend upon plant food in the soil and the animal depends upon the plants. Man's dependence is upon both; and his final dependence for food supply is upon the earth. This has led to scientific study and investigation of this,one of the essential elements in the development of all forms of life.

Taking the soil from where you will; a sandy soil, a clay soil, or a loam we may say in general that we find it to be composed of fragments of various kinds. In general it is composed of fragments of various kinds of rocks which may be regarded as the basis of all soils. Mixed with the rock fragments we find orgainic matter in varying amounts dependent upon location as regards rain fall, climate, drainage and so forth. This organic matter is derived from decaying vegetable and animal reamins. Scattered among the fragments or adhering to them we find various substances which have been deposited from solutions of soil moisture. This far all

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soils may be regarded as alike except as to the proportions of these elements. In clay soil among its fine silt like particles a small quanity of silicate of aluminum is present. This gives the soil its sticky plastic character when combined with water. This is but a very small per cent (1.5%) of the total weight of the soil. In some soils we find stones of various kinds varying in size from pebbles to rock weighing tons. These however are not parts of the soil but rather the primary sources of the soil.

Before going further let us take up the relation of the subsoil to the soil proper. In humid regions where the rainfall is sufficiently abundant to insure good crops the surface six to twelve inches is spoken of as the soil and below that it is referred to as subsoil. This distinction came about presumably in two wyas; first, there is a noticeable difference in color and second, the subsoil being brought to the surface is unproductive for a time.

In arid regions both these distinctions disappear. Soil taken from the bottom of wells thirty feet deep have proven as productive as surface soils. This difference in the nature of the subsoils of arid and humid regions must be due to a variation either in the abundance or the arrangement of the finer soil particles; those of humid regions of closer texture and is harder for water to penetrate.

The difference between the soil of humid and arid or semiarid regions is not confined to the subsoils. This is eveidenced by the fact that when soils of humid regions become dry they get very hard, those of arid regions remain loose.

The most satisfactory explanation of this difference between the adhesive properties of the soils of arid and humid climates is that the amount of lime contained in the two soils differs. Hilgard has shown that the soils of arid regions contain a comparatively large per cent of lime. That lime would have this effect seems to be indicated by the fact that salts of lime added to turbid water floculated the silt-like particles and left the water clear. Without this addition it would have remained turbid for a long time.

Hilgard also gives another experiment which also goes to substantiate this view. Tough clay worked into a plastic mass and then dried became very hard. To a similar mass of plastic clay was added one-half a per cent of caustic lime. On drying, the soil became very crumbly.

Although this does not prove conclusively that this is the true explanation it is proved by the fact that we have clay containing a large amount of lime which when worked becomes quite plastic and could have been used for brick or pottery but for the fact that it slacks after firing and breaks the vessel into which it has been shaped. These soils contain as high as 5% of lime and yet have not lost their plasticity, the lime for some reason not producing the flocutation it sometimes does.

The water absorbing and water retaining capacity of the soil depends upon three things; the texture, composition and kind of soil.

To give an idea of the texture of the soil so far as the size of its grains are concerned we will use a table compiled by Hilgard in his mechanical analysis of Mississippi soils. He has separated the grains of different soils as to bring those together having the same diameters, thus enabling him to tell the per centage amounts of each size entering into each kind of soil. The first table gives the size of the soil grains and percentage amounts of

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each as they occur in a sandy soil and subsoil.

Diameter in inches.	Soil Per Cent.	Sub-soil. Per Cent.
.03937 to .04724	.4	.4
.02362 to .03937	.3	.8
.01575	6.9	6.3
.01181	8.1	3.4
.00610	3.0	3.9
.00472	1.6	1.5
.00283	1.2	.6
.00185	3.6	2.6
.00142	6.8	5.4
.00098	14.6	7.6
.00059	14.8	17.0
.00031	30.7	38.3
.00004	4.6	10.9

The second table gives results from similar analysis of two other soils, one a "hogwallow" subsoil very clayey and another loess soil.

Diameter in inches	Clay subsoil %.	Loess Soil %.
.03937 to .04724	.2	(.2
.02362 to .03937	1.2	(.2
.01515	2.0	.4
.01181	1.6	.6
.00610	.9	.9
.00472	.3	1.7
.00283	.2	2.0
.00185	2.5	14.3
.00182	3.7	16.2
.00098	5.6	20.1
.00059	10.6	5.6
.00031	24.7	33.6
.00004	48.0	2.5

From these tables we can gain an idea how it is that soils act as reservoirs and hold such enormous quanities of water as are evaporated from the soils and given off through vegetation, how even though the materials of which they are composed are very difficult of solution, they may when supplied with abundance of water be dissolved in such large qunaities and how it is that roots are brought into contact with such a large surface of grains.

A marble dipped into water and taken out is surrounded by a

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film of water. In a similar way after a rain each soil grain is surrounded by a film of water. Now the finer the soil grain the greater the soil surface to which the water may adhere and the greater the soil water. To illustrate; take a marble one inch in diameter; It will just slip in a cube one inch in diameter and will hold a film of water 3.1416 square inches in area. Reducing the diameter to one tenth of an inch and at least one thousand marbles would be required to fill the cube and the total surface will be 31.416 square inches. If the diameter was one thousandth of an inch 1000,000 000 marbles would be required to fill the tube and the total surface area would be 314,59 square inches.

In the table we see that smallest soil grains have diameters of .00004 of an inch and yet a cubic foot of soil grains having a diameter of only .001 of an inch will provide a surface for holding water equal 37700 square feet. A very thin film on a fine soil will give us a very large amount of water and we need not wonder that we find in moderately fine grained soils under field conditions containing an amount of water in the surface five feet equal to twelve to twenty inches of water on the level.

In the first part of this discussion we tried to show the importance of water in the soil to plant life, the large amounts required by crops under our methods of cultivation and the large amount of water that fall and is found in the soil. Confinning our remarks now to the conditions in Western Kansas we find that the total rainfall is sufficient for maximum crop production. But the rain fall is during the whole year, while that which falls during plant growth is a very small percent of that required for growing a crop, When we take this into consideration together with the fact that considerable of this rainfall never enters the ground but flows off in ditches, creeks, and that an enormous amount of water brought to the surface by capillary action escapes directly in the air we see the importance of this question in Western Kansas. In the Western lands we have an abundance of plant food and in an available form to a depth of two hundred feet or more. We find the per cent of Nitrogenous plant food to be greater than in the Eastern soils. Our only difficulty ~~then~~ in producing enormous crops year after year then is a sufficient supply of moisture during the growing season. But sufficeint rain falls every year for the largest crops; conserve it then and we have our crops. We see at once the great problem of the West. Although we see from the tables given that the sandy soils of the west are incapable of holding as much water as the clay soils yet they will give up a larger percent of the water held and that more readily.

In the conservation of moisture the first thing to be considered is plowing. It will be apparent at once that plowing must have the ground loose and open and that is usually the reason we plow. If the ground is loose and open the ground is capable of permiting the free percolation of water hence we may say less runs off and more is absorbed by the soil. Fall plowing then will be beneficial when the ground is at all compact in that it will absorb the water from all winter snows and rains: King has observed a difference of 2.31% of moisture between plowed and unplowed land in favor of plowing. Besides acting as a mulch and allowing the freer absorbtion of water the loose condition of the ground also leaves the land more open to the weathering action which is very beneficial. Now that all the benefits of fall plowing may not be lost let us examine the fall plowed land in the spring. We find that it has become compacted to some extent and a crust forms over the whole surface from which water is freely evaporated reaching as high as twenty tons daily per acre and extending to a depth of four feet. This crust must be pulverized at once.

With land apt to become too easily compacted, spring plowing then would be of great benefit, but when the ground has a tendency to looseness as we find it in Western Kansas another deep stiring would not be advisable. On ground that has not been plowed in the fall and on ground that has been plowed it is of the utmost importance to double disc as early in the spring as possible. ~~This~~ This loosens up the surface and establishes a surfaced mulch. Disc by lapping half as this leaves the ground even, not cutting it up in rdiges and cross ridges and leaving no undisced ground exposed when evaporation would take place very rapidly.

The subject of subsurface packing is of such importance to the semi-arid section of Kansas, that we should not pass without discussing it. It is, or at least used to be, commonly suposed by farmers that rolling the ground helped to preserve the moisture. It is easily seen how this idea originated because for a time the surface soils do contain more water. This comes about by the open and non-capillary spaces having been filled, capillary action is more rapid and the water is brought from below to the surface. The moisture being brought to the surface and nothing being provided to prevent evaporation it passes off. Then we have the lower soils, much dryer and the upper soils more moist.

The following tables taken from King's book "The Soil" which he worked out by analysis shows this to be true. These are the average results of One hundred and seventeen sets of samples:-

Surface 36-54 inches unrolled------------19.43% water.
"" "" 36-54 inches, rolled-------------18.72% water.

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Surface 24 inches, unrolled	19.35 %	Water.
"" "" " " rolled	19.45 %	" "
Difference	.10 %	water

Surface 2-18 inches unrolled	15.66	in. water
" 2-18 " rolled	15.85	" "
Difference.	.21	in. water

From the table we draw this conclusion; that at a depth greater than two feet unrolled ground contains the more moisture while at two feetand under it contains less moisture.

By subsurface packing we know that the moisture would be drawn from below, the same as the rolled ground but, it will draw it, not to the surface where it would be at once evaporated, but to the subsurface where the roots get their supply of water. The large air spaces and non-capillary spaces have been destroyed and we have capillary action bringing moisture from greater depths. Another advantage to be mentioned in subsurface packing is the providing of a finely pulverized soil for the germination of the seed.

We should always have a harrow following a subsurface packer. It is not enough that the water should be brought close to the surface but it should have over it a fine dust blanket or mulch that prevents it being exposed to evaporation.

An implement indespensable to the farmer is the disk harrow. It has often been misused and generally with detrimental results. It has been made to answer for a plow which it cannot do satisfactorily. Its use is in preventing evaporation and not preparing seed beds. The disc is preeminently the only tool for preparing a surface mulch in early spring before plowing as well as ground that cannot be plowed at all, and for preparing mulch in the fall before plowing as for example after removing a wheat crop. It alone cannot be used to prepare a field for a crop, but in connection with the plow its work is of great value. To the cultimation of an orchard it is indispensible in presefving a surface mulch and in preventing the formation of surface and subsurface crusts.

In the cultivation of cropsplanted in rows the question of shallow or deep cultivation,with many and small, or few and large shovels is an important question. As to the size of shovel to use, it is not hard to see that the smaller the shovel the finer the mulch hence the less the evaporation. As to shallow cultivation; it is not a question fully solved, but it is pretty well settled that deep cultivation is not at all times successful. Exactly at what depth to cultivate cannot be stated but the weeds should be killed and the branching side roots should not be cut by the cultivator. The time of cultivation is of more importance than the depth of cultivation. No exact time for cultivation can be set but this general rule should be followed. Always stir the ground as soon after a rain as you can work without dirt sticking to the tools. Do not wait until after the crust is formed but prevent its formation.

In conclusion let us apply the summerization to the Western semi-arid Kansas whose resources have not yet begun to be developed. We find here we have a sandy soil containing an abundance of all the essential elements of plant growth and that to a depth of two hundred feet. We have a rainfall sufficient to grow the largest crop of any kind ever taken from any piece of ground in one year.

With proper methods of cultivation then will no where be found a region richer in grain, stock and fruit than will be developed in Western Kansas.