OKLAHOMA
AGRICULTURAL AND MECHANICAL COLLEGE
AGRICULTURAL EXPERIMENT STATION
C. P. Blackwell, Director
Stillwater, Oklahoma

Moisture and Fertility Relations of Subsoil Variations in Heavy Silt Loam Soil at Goodwell, Oklahoma

H. H. FINNELL
Associate Agronomist
OKLAHOMA AGRICULTURAL EXPERIMENT STATION

Experiment Station Bulletin No. 214 November, 1933

MOISTURE AND FERTILITY RELATIONS OF SUBSOIL VARIATIONS IN HEAVY SILT LOAM SOIL AT GOODWELL, OKLAHOMA

H. H. Finnell

Introduction

It has been generally observed that the heavy silt loam soil typical of large areas in the High Plains of Oklahoma, the northern part of the Texas Panhandle and adjoining states presents conditions of marked variation in the subsoil. Although the surface soils may be very uniform in color, texture, vegetation and topography, similar conditions can not be expected within the subsoil area, particularly 24 to 72 inches deep. This spotted condition is persistent throughout the area and results in many puzzling crop reactions in seasons of scant moisture. In some places the areas are large enough to warrant separate treatment. These soils overlie at various depths the whitish colored unweathered tertiary material consisting of calcareous sand, silt and clay in various proportions with occasional formations of caliche.

The surface, subsurface and subsoil layers are relatively uniform in character and continuous within a soil area of the same type. They vary principally in depth, and the greatest variation observed is in the subsoil. The subsoil normally consists of a reddish brown silty to sandy clay and is marked with an increasing amount of whitish material until it merges, sometimes rather abruptly, into a pure white or pinkish white formation. This unweathered substratum may be first encountered at points from two and one-half feet to more than ten feet deep.

Character of Soils

Variation in thickness of soil section which has developed from the substratum appears to be due to the nature of materials in some cases and to quaternary changes in others. Topography of the original surface undoubtedly exercised a considerable relation to the factors of erosion by wind and water and the penetration of surface water. The horizon of excessive lime content largely corresponds with the depth developed in the formation of subsoil and appears to agree also with the state of diffusion of colloids from the subsurface area. Marked accumulations of colloidal substance near the surface accompanied by a shallow subsoil development seem to indicate relatively smaller amounts of moisture penetration and consequently a less rapid maturity of the soil. The uneven leaching of lime and the dispersion of colloids were probably brought about by those features of topography which encourage runoff at one point and the accumulation of water at another. These irregularities, not being severe enough to bring about marked surface erosion, have permitted the formation of uniform topsoils overlying a wide variety of subsoil combinations.

Scope of Investigation

Since the soil experiments at Panhandle Agricultural Experiment Station carry moisture records to a depth of six feet and a survey of the nitrogen information has also recently been completed, the data of hygroscopic coefficient and the subclassification of soils were all that were needed to show some important relations of subsoil depth to the utilization of the land.

The moisture records available extend over the period 1924 to 1931, inclusive, and provide 26 samplings which have been averaged for purposes of this study. Plots devoted to three types of wheat culture were sampled. For a comparison of six-foot and four-foot subsoils under continuous wheat culture only one plot representing each condition was available. However, in the case of wheat-fallow culture and wheat-fallow-fallow culture, two and three plots were averaged, respectively, for each date reading. The moisture percentages—excepting hygroscopic, which was determined from an average of two separate composite samples—represent 26, 52 and 78 determinations, respectively. Total moisture and hygroscopic moisture were determined in the conventional ways, the data of total moisture being adapted for purposes of this study from that used in Oklahoma Bulletin No. 190 and the nitrogen data taken from a paper entitled "The Economy of Soil Nitrogen Under Semiarid Conditions," to be published as Oklahoma Experiment Station Bulletin No. 215.

The subsoil depths present in the plot series on which moisture and nitrogen data are available range from four feet, the shallowest, to more than six feet, the depth of sampling. Hygroscopic moisture, the lowest moisture content observed under field conditions, and the average total moisture content for the 8-year period are shown in Tables 1, 2 and 3.

The hygroscopic capacity of a soil, because it depends upon the fineness of division and somewhat on the character of the material, reflects in a measure the development of that particular soil. It will be noted from Table 1 that no significant differences in hygroscopic moisture are shown where the depth of subsoil reaches or exceeds six feet. Comparing plots which have been cropped alike but which vary in subsoil depth shows a similar trend in each case. The shallower soil exhibits a slight tendency to hold a larger quantity of unavailable water in the surface and subsurface soils but this decreases sharply at about the point in the lower subsoil where the color change is apparent. The amount of organic matter as indicated by total nitrogen content falls to a very low figure in the substratum and is accompanied by a small hygroscopic capacity. If hygroscopic moisture be taken as a guide to colloidal concentrations, these then appear to be highest in the second foot of shallow soils; while there is no marked accumulation at any point in the deeper soils. This correlation is indicated by the observation of physical characteristics of these horizons.

While it is not certain that an opportunity was afforded during the 8-year period for each plot and depth to exhibit its lowest possible field moisture content, the minima are recorded in Table 2. These low points almost without exception occurred during the latter part of the wheat growing season or soon after harvest when the crop had reduced the moisture content of the soil to a point which in some cases was the actual wilting point. These figures should represent the physical properties of the soil regardless of the temporary effects of variable cropping programs, though systems employing summer fallowing would have fewer opportunities during the same period of time to reach a minimum moisture content.

The spread of difference between minima of total moisture found under field conditions in deep and shallow soils was greater in the upper soil section than would be indicated by hygroscopic capacity but less below the root zone as indicated by the margin shown between hygroscopic moisture and lowest observed total moisture in Tables 1 and 2. This would mean that the crops are able to exhaust the deeper types of soil to a lower point in moisture content than the shallower types of soil. When calculated on the basis of four feet, the approximate root zone, and six feet, the depth of observation, the spread of margin between subtypes is greater in the latter comparison.

TABLE 1.—Hygroscopic Moisture as Determined by Absorption of Oven-Dry Soils in Saturated Chamber

No. of Plots	Depth of Subsoil (feet)	Culture	PERCENT HYGROSCOPIC MOISTURE, BASIS DRY SOIL BY ONE-FOOT SECTIONS						
			1st	2nd	3rd	4th	5th	6th	Av.
1	6	Continuous Wheat	6.58	5.84	6.47	6.15	5.97	5.77	6.13
1	4	Continuous Wheat	6.67	6.70	5.16	4.41	3.16	2.47	4.76
2	6	Wheat-Fallow	5.60	5.89	7.09	6.44	5.87	5.92	6.13
2	4	Wheat-Fallow	6.89	7.84	5.36	5.57	4.33	3.20	5.53
3	6	Wheat-Fallow-Fallow	5.97	5.87	6.47	6.92	6.59	6.77	6.43
3	5	Wheat-Fallow-Fallow	7.08	6.67	6.49	5.74	4.42	2.48	5.48

TABLE 2.—Lowest Total Moisture Observed During Period 1924-31, Averaged by Plot Groups

No. of Plots	Depth of Subsoil (feet)	Culture	LOWEST OBSERVED PERCENT TOTAL MOISTURE, BASIS DRY SOIL BY ONE-FOOT SECTIONS						
			1st	2nd	3rd	4th	5th	6th	Av.
1	6	Continuous Wheat	6.53	7.50	9.86	8.10	8.66	7.02	7.94
1	4	Continuous Wheat	10.15	9.20	6.54	7.10	7.67	9.20	8.31
2	6	Wheat-Fallow	6.28	7.54	8.16	9.74	7.82	8.67	8.03
2	4	Wheat-Fallow	10.99	10.53	6.67	6.26	8.48	6.77	8.28
3	6	Wheat-Fallow-Fallow	7.49	6.14	7.83	7.54	8.24	7.55	7.46
3	5	Wheat-Fallow-Fallow	10.59	8.71	6.99	6.98	7.30	8.72	8.21

TABLE 3.—Amount and Distribution of Soil Moisture in Heavy Silt Loam Soils of Varying Subsoil Depths and Same Culture, Goodwell, Oklahoma; Average of 26 Dates, 1924-31, Inclusive

No. Plots	Depth of Subsoil (feet)	Culture	PERCENT TOTAL MOISTURE, BASIS DRY SOIL BY ONE-FOOT SECTIONS						
			1st	2nd	3rd	4th	5th	6th	Av.
1	6	Continuous Wheat	13.36	12.23	13.52	11.85	11.65	11.22	12.33
1	4	Continuous Wheat	15.34	14.08	10.41	10.29	11.89	12.51	12.40
2	6	Wheat-Fallow	15.24	14.91	16.07	14.79	12.93	12.88	14.45
2	4	Wheat-Fallow	18.23	16.87	13.31	11.41	12.18	13.36	14.25
3	6	Wheat-Fallow-Fallow	15.78	14.86	16.37	15.57	13.40	13.66	14.94
3	5	Wheat-Fallow-Fallow	18.64	17.77	15.40	12.79	11.40	12.77	14.80

TABLE 4.—Moisture Factors Averaged for Four-Foot Soil Section Roughly Equivalent to Root Zone

Depth of Subsoil (feet)	Culture	Hygroscopic Moisture	Lowest Percent Total Moisture Observed	Margin Between Hygroscopic and Lowest Field	Average Total Moisture	AVERAGE AVAILABLE MOISTURE, FOUR-FOOT ZONE	
						Estimated	Actual
6	Continuous Wheat	6.26	7.99	1.73	12.74	6.48	4.75
4	Continuous Wheat	5.73	8.25	2.52	12.53	6.80	4.28
6	Wheat-Fallow	6.25	7.93	1.68	15.25	9.00	7.32
4	Wheat-Fallow	6.41	8.61	2.20	14.95	8.54	6.34
6	Wheat-Fallow-Fallow	6.31	7.25	.94	15.64	9.33	8.39
5	Wheat-Fallow-Fallow	6.49	8.32	1.83	16.15	9.66	7.83

No root systems have been observed beyond the subsoil of shallow soils. Root systems probably are inhibited by high salinity of the substratum, although it is usually pervious and well supplied with moisture. It therefore seems probable that the deeper soils permit a more efficient use of moisture which may be present to the depth of potential root zone. It should be kept in mind, however, that the factors which encouraged deeper penetration of surface waters permitting a leaching of the lime to lower levels, the diffusion of colloids and the deepening of the fertile zone are still operative to create a difference between the utility of the deep soil and that of the shallow soil where the movement of soil water is impeded.

A further contribution to the understanding of contrasting moisture relations is the record of total average soil moisture on the subtypes under different systems of cropping. These figures are presented in Table 3.

The extension of rest interval between harvest and sowing of crops provides an opportunity for the soil to become saturated to capacity which results in higher average total moisture percentages at all depths. However, as shown in Table 3, alternate wheat and fallow culture afforded all the rest period necessary to maintain a maximum soil moisture content. The addition of a second fallow year in the cycle did not significantly increase the soil moisture.

An indication of the limits of the root zone, particularly in the shallower type of soil, may be taken from the ratios of increase in average moisture content for the different levels as a result of increasing the fallow period. The moisture increase due to fallowing does not follow a definite trend beyond the fourth foot in shallow soils and the rate of increase was greatly decreased beyond the fourth foot in deep soils. Other observations, both of moisture utilization by the growing crop and the identification of root fragments in soil samples, have established the normal depth of root penetration for the wheat crop at approximately four feet.

Moisture factors from the preceding data have been averaged for the four-foot soil section, which roughly approximates the root zone, as shown in Table 4. In each comparison of similar cropping on different depths of soil, the margin between the indicated hygroscopic moisture content and the actual minimum percentage observed at any time during the period of observation was consistently smaller on the deep soils. The average available moisture in the four-foot zone, estimated from the difference between total and hygroscopic, did not vary significantly but the deep soil showed an advantage in the actual availability observed.

TABLE 5.—Relation of Subsoil Depth to Point of Exhaustion of Moisture Observed Under Field Conditions

No. Plots	Depth of Subsoil (feet)	Culture	AVERAGE OF SIX-FOOT SOIL SECTION		
			Lowest Percent Total Moisture Observed	Percent Hygroscopic Moisture	Margin of Difference
1	6	Continuous Wheat	7.94	6.13	1.81
1	4	Continuous Wheat	8.31	4.76	3.55
2	6	Wheat-Fallow	8.03	6.13	1.90
2	4	Wheat-Fallow	8.28	5.53	2.75
3	6	Wheat-Fallow-Fallow	7.46	6.43	1.03
3	5	Wheat-Fallow-Fallow	8.21	5.48	2.73

TABLE 6.—Amount and Distribution of Available Soil Moisture (Average Total Moisture Observed Minus Hygroscopic Moisture) in Heavy Silt Loam Soils, Goodwell, Oklahoma, 1924-31, Inclusive

No. Plots	Depth of Subsoil (feet)	Culture	PERCENT AVAILABLE MOISTURE, BASIS DRY SOIL BY ONE-FOOT SECTIONS						
			1st	2nd	3rd	4th	5th	6th	Av.
1	6	Continuous Wheat	6.78	6.39	7.05	5.70	5.68	5.45	6.20
1	4	Continuous Wheat	8.67	7.38	5.25	5.88	8.73	10.04	7.64
2	6	Wheat-Fallow	9.64	9.02	8.98	8.35	7.06	6.96	8.32
2	4	Wheat-Fallow	11.34	9.03	7.95	5.84	7.85	10.16	8.72
3	6	Wheat-Fallow-Fallow	9.81	8.99	9.90	8.65	6.81	6.89	8.51
3	5	Wheat-Fallow-Fallow	11.56	11.10	8.91	7.05	6.98	10.29	9.32

TABLE 7.—Amount and Distribution of Available Soil Moisture (Average Total Moisture Observed Minus Lowest Field Observation) in Heavy Silt Loam Soils, Goodwell, Oklahoma, 1924-31, Inclusive

No. Plots	Depth of Subsoil (feet)	Culture	PERCENT AVAILABLE MOISTURE, BASIS DRY SOIL BY ONE-FOOT SECTIONS						
			1st	2nd	3rd	4th	5th	6th	Av.
1	6	Continuous Wheat	6.83	4.73	3.66	3.75	2.99	4.20	4.39
1	4	Continuous Wheat	5.19	4.88	3.87	3.19	4.22	3.31	4.09
2	6	Wheat-Fallow	8.96	7.37	7.91	5.05	5.11	4.21	6.22
2	4	Wheat-Fallow	7.24	6.34	6.64	5.15	3.70	6.59	5.97
3	6	Wheat-Fallow-Fallow	8.29	8.72	8.54	8.03	5.16	6.11	7.48
3	5	Wheat-Fallow-Fallow	8.05	9.06	8.41	5.81	4.10	4.05	6.59

When the six-foot soil section was considered as a whole, including portions of the substratum in cases of shallow subsoils as shown in Table 5 this margin between the determined hygroscopic percentage and actually observed minimum was found to widen. This relation agrees with other observations to the effect that very little, if any, root penetration takes place in the white substratum.

If the amount of available moisture be calculated by foot depths as in Table 6 on the assumption that the average total moisture of the soil above the hygroscopic capacity was useful to crop plants, the superior moisture utilization would appear to rest in the shallow type of soil; but in view of the wide difference in marginal water just discussed this would be a questionable assumption.

The field minima would appear to be a more practicable basis for estimating approximate quantities of useful soil water. In Table 7 available moisture has been calculated on this basis and the situation relative to deep and shallow soils is reversed. When the root zone (four-foot soil section) is considered alone the advantage of deep soils appears to be further increased. It would seem that approximately 7 percent more water was available to the crop on six-foot soils than on five-foot soils, where wheat was grown in fallow rotation once every three years. The advantage of a six-foot soil over a four-foot soil was 15 percent, wheat alternating with fallow, and 23 percent where wheat was grown in continuous culture. Crop yields[1] as well as studies of moisture utilization[2] show a better economy of soil resources through the elimination of subsoil drainage losses[3], therefore, the narrowing of deep soil advantage under increasing degrees of summer fallowing indicates an efficiency loss which almost eliminates the soil advantage. This comparison further emphasizes the weakness of summer fallowing as an economic practice under the soil and climatic conditions prevailing in this area.[4]

The differences in total moisture content in the six-foot soil section shown in Table 3 and in the four-foot soil section shown in Table 5 are insignificant; but the differences in availability indicate a greater reception of moisture by the deeper soils, probably due to the greater penetrability of the surface and subsurface layers where collodial concentrations have been dispersed.

Distribution of Soil Nitrogen in Deep and Shallow Soils

The amount and distribution of nitrogen in soils of various depths, both cropped and native sod, shown in Table 8 corresponds in a measure to the hygroscopic capacity indicated in Table 1 showing the distribution of organic matter in the soil to be an important factor in determining the moisture relations. Thus it would appear that the penetration of moisture has much to do with the depth of fertile area developed in a particular phase of soil type. At the same time the deepening of the fertile area beyond the depth of potential root zone of crops commonly grown would place a considerable amount of the soil resources in an unavailable position. The shallow soil in its native conditions shows the same marked concentration of nitrogen in the surface soils, compared to native soils of greater depths, as has been brought about on cultivated soils by continuous cropping compared to fallow.[4] Cultivated soils show the same relationship by the marked depletion of soil nitrogen extending to a depth of five feet on deep soils, whereas it extends only to a depth of about four feet on the shallower soils.

The data of Table 8 include all available analyses in addition to the twelve wheat plots studied. The average nitrogen content of the four-foot and six-foot soil sections is shown for these particular plot groups in Table 9.

TABLE 8.—Amount and Distribution of Soil Nitrogen in Heavy Silt Loam Soils of Varying Subsoil Depths, Goodwell, Okla.

Depth of Subsoil (feet)	Number Plots Averaged	Average Intensity of Cropping	TOTAL NITROGEN BY ONE-FOOT SECTIONS, P. P. M. OF DRY SOIL						
			1st	2nd	3rd	4th	5th	6th	Av.
6	20	26.40	754.9	569.8	483.3	432.4	394.6	370.6	500.9
5	32	30.45	790.6	561.3	426.1	357.7	282.1	190.9	434.8
4	18	31.41	820.3	600.7	414.3	327.9	189.3	119.6	412.0
6	Composite	Native Sod	921.3	643.5	508.6	436.7	430.7	370.0	551.8
5	Composite	Native Sod	1005.7	663.9	497.9	373.4	283.5	137.4	493.7

TABLE 9.—Summary of Wheat Yields, Available Moisture, and Total Nitrogen at Goodwell, Oklahoma, 1924-32

No. Plots	Depth of Subsoil (feet)	Culture	Yield of Grain, Lbs. per Acre	Coefficient of Variability of Yield	AV. TOTAL NITROGEN, P. P. M.		AV. PERCENT AVAILABLE MOISTURE	
					4 Foot	6 Foot	4 Foot	6 Foot
1	6	Continuous Wheat	596.4	107.6	614.4	526.7	4.75	4.39
1	4	Continuous Wheat	490.1	112.2	677.2	502.4	4.28	4.09
2	6	Wheat-Fallow	405.5	75.2	594.7	517.3	7.32	6.22
2	4	Wheat-Fallow	369.8	83.8	540.1	420.8	6.34	5.97
3	6	Wheat-Fallow-Fallow	384.6	77.4	542.1	492.0	8.39	7.48
3	5	Wheat-Fallow-Fallow	322.2	81.0	567.2	459.3	7.83	6.59

Comparable Wheat Yields on Deep and Shallow Soils

As a final evidence of the relative advantages and disadvantages of deep and shallow phases of heavy silt loam soil, the crop yields and variability for a period of nine years are shown in Table 9. The shallow phase of soil failed by one to two bushels per acre in yielding the grain produced under the same system of culture on the deep phase of soil. Although no great differences in dependability were shown as indicated by the coefficient of variability, the advantage was consistently in favor of the deep phase. There was no consistent relation between production and the relative amounts of total nitrogen in the root zone but the effects of available moisture supply on yield were apparent under every system of culture. Under the present fertility level which is approximately 90.7 percent of the original in the case of the deep phase of the soil and 88.0 percent of the original in the case of five-foot soils, efficiency of moisture utilization is of greater consequence in determining yields than the fertility resources of the soil. According to previous studies,[2] excessive surface evaporation losses previous to penetration were shown to be characteristic of this soil type under normal rainfall conditions. The more mature phases of soil appear to have distinct advantages for agricultural production over the shallower phases, mainly due to those physical developments enhancing the moisture using efficiency.

REFERENCES

(1) Finnell, H. H., "Methods of Reducing the Cost of Wheat Production," Panhandle Bulletin No. 29, (Goodwell), July, 1931.

(2) __________ "The Utilization of Moisture on Heavy Soils of the Southern Great Plains," Oklahoma Experiment Station Bulletin No. 190, (Stillwater), June, 1929.

(3) ____________ "Factors Affecting the Accumulation of Nitrate Nitrogen in High Plains Soils," Oklahoma Experiment Station Bulletin No. 203, (Stillwater), May, 1932.

(4) ____________ "The Economy of Soil Nitrogen Under Semiarid Conditions." To be published as Oklahoma Experiment Station Bulletin No. 215, (Stillwater), December, 1933.