THE BULK DENSITY OF SOME OKLAHOMA SOILS AND THEIR MINERALOGICAL COMPOSITION

By

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CHAPTER I

INTRODUCTION

In the past two decades, investigators have contributed enormous amounts of knowledge dealing with the effect of soil factors on plant growth. Such factors as nutrient availability, root growth, moisture, and soil texture have been the topics of some of the most intricate studies.

Near Stillwater, Oklahoma some of the stratified alluvial soils were suspected of having a high bulk density layer present in their profiles. The objective of this research was to examine the bulk density of these soils as it may, or may not, be related to the implied flow of fluids and the movement of plant roots through the soil. A general study of factors contributing to high bulk density was made, and a correlation of these factors to the soils in question was completed.

The research reported in this study is an attempt to explain the relationship of major factors contributing to high bulk density. It does not, however, take into account the entire scope of those factors.

CHAPTER II

LITERATURE REVIEW

Bulk density of soil is readily accepted as an important factor in root development and plant growth. It has been pointed out by Tisdale and Nelson (1975) that high bulk densities offer increased mechanical resistance to root penetration and seedling emergence. It is also pointed out that the reduction of pore space, caused by high bulk densities, reduces the diffusion of oxygen in the soil and retards the infiltration of water (Rosenberg and Willits, 1962).

Factors Affecting Bulk Density

Many postulations have been made regarding soil characteristics and bulk density. Gerard et al. (1961) and Gerard et al. (1962) postulated that cyclic wetting and drying, in cooperation with surface applied forces, could promote the formation of high bulk density layers in virgin, as well as cultivated soils. Their laboratory investigations have shown that moisture loss by evaporation appears to be an important factor in the formation of "hard-pans". Results indicate that tillage practices promote surface drying, which may influence the depth and density of hardpan formation. Further information in these studies showed that a slow drying process greatly increased soil strength. Later work by Camp and Gill (1969) and Laase (1968) supported these findings.

Perhaps organic matter is the most easily recognized factor affecting bulk density. Fritton and Olsen (1972) studied the bulk density of a "fragipan soil", in both natural and disturbed profiles. In an 11-year study, they found that organic matter prevented the compaction of buried top soil. However, the soil containing portions of the fragipan reverted back to its previous state, and once again became a compacted fragipan.

A two cropping system was used by Davidson _et al_. (1967) to show the changes in organic matter and bulk density with depth. Over a 24-year period, results showed that continuous lespedeza cropping increased bulk density with depth. Continuous cotton cropping followed the same trend, however, at 15 centimeters depth, the bulk density had a tendency to reduce and stabilize. It was also reported in this study that an increase in organic matter additions definitely decreased the bulk density of soils. Other research by Curtis and Post (1946) and Klute and Jacob (1949) supported these findings.

Waldron and Constantin (1968) studied the effect of sodium saturated soils on bulk volume. It was apparent that sodium saturated soils had a tendency to increase in bulk volume. High sodium content tends to break down the soil aggregates and the smaller particles are dispersed into the micropore and macropores. It was also illustrated by Gerard (1965) that kinds and amounts of exchangeable cations influence the soil strength.

It was found, by Rice and Levick (1953), that individual particles of soil generally form aggregates by being cemented together by free iron oxides, organic matter, and silicates. Earlier work by Nikiforoff and Alexander (1942) with San Joaquin, California soil substantiated these findings. They also found that cementation factors, consisting of iron and aluminum, contributed heavily to the formation of these "hard-pans".

How Bulk Density Affects Plant Growth

Plant growth is probably the single most important reason that soil is researched so intensively. Soil properties such as pore space, oxygen supply, structure, nutrient availability, and moisture supply all influence the growth of plants and their ability to produce maximum yields. Many times it has been shown that bulk density affects one or more of these factors. Gumes and Warkentin (1972) evaluated the effect of bulk density and initial water content on infiltration in clay soils. Small increases of bulk density, from 1.1 gm/cc to 1.25 gm/cc, markedly decreased the rate of water infiltration. The initial water content played an important role in the water movement. Other scientists who have studied water infiltration include Eagleman and Jamison (1962), Miller and Gardener (1962), and Hanks and Bowers (1962). They have shown that textural layering definitely affects water movement and that infiltration, as a whole, is controlled by the least permeable layer.

Although limited work has been recorded regarding the effects of bulk density on nutrient uptake, Flocker and Nielsen (1962) reported that bulk density has an indirect effect on nutrient uptake. It was shown that total nutrient uptake decreased significantly with increases in bulk density. However, as the bulk density increased, the plants contained higher concentrations of nutrients. Both results were explained in being due to lack of available moisture. Apparently low moisture in high bulk density soils does allow for the diffusion of ions into the soil solutions for uptake by plants. It was presumed that there were enough nutrients present in the plant for sufficient growth, however, lack of moisture in the meristematic regions did not allow growth to take place.

Perhaps the most obvious effect of high bulk density on plant growth is observed when examining plant roots. High bulk density layers, claypans, and hardpans can easily distort, reduce, and otherwise destroy the rooting system of plants. Phillips and Kirkham (1962) illustrated that mechanical compaction not only reduced pore space, but it also reduced root growth. A very small increase in bulk density, from .94 gm/cc to 1.3 gm/cc, reduced corn root growth by 75 percent. Later work on cotton roots by Taylor and Gardener (1963) substantiated the fact that the bulk density of a soil could alter the penetration of plant roots.

CHAPTER III

METHODS AND MATERIALS

Three profile samples, consisting of two Teller series, as described in U.S.D.A. Handbook No. 436 (1975), and one Port series, were studied in Payne County for physical, chemical, and mineralogical analysis. Two bulk samples were taken from each profile at two inch depths with a flat point spade. One sample was used for bulk density determinations, and the other sample was oven dried, ground, and screened to pass through a 20-mesh sieve, for use in physical, chemical, and mineralogical analysis.

Physical Analyses

Both particle size distribution and mechanical analysis were determined by the hydrometer method (Day, 1956). Fifty grams of soil were weighed and transferred to a 1000 ml sedimentation cylinder. Sodium carbonate was then added for dispersion. The cylinder was then placed in a constant temperature room so as to avoid correction errors.

When the temperature became stabilized, a plunger was inserted to mix the suspension thoroughly and the amount of material in suspension was then determined with a hydrometer. For particle size distribution, the hydrometer was read at .5 minutes, 1 minute, 3 minutes, 10 minutes, 30 minutes, 60 minutes, 90 minutes, 4 hours, 8 hours, and 12 hours. Other intervals can be read if desired. To find the sand percentage, the hydrometer reading at .67 minutes was used and for the clay percentage, the one hour hydrometer reading was used. Percent silt may then be found by difference.

Bulk density was determined in the laboratory using the method presented by Brasher et al. (1966). An air dry bulk sample of soil was weighed, coated with saran resin several times, and then reweighed in order to compute the saran coating volume. The saran coated sample was submerged in water to determine volume. The volume of the saran was subtracted from the total volume for accurate bulk density determinations.

Chemical Analyses

Chemical analysis consisted of organic matter, cation exchange capacity, exchangeable cations, and free iron oxide determination. Cation exchange capacity (CEC) was determined as described by Reed (1975). A 10 gram sample of oven dry soil was saturated with calcium chloride. The chlorides were then removed with distilled water washings and the ion complex was saturated with sodium nitrate. The resulting leachate was placed in a 100 ml volumetric flask and brought to volume. Calcium determination was determined by the (ethylenedinitrilo)-tetraacetic acid tetrasodium salt (EDTA) method. The chlorides were determined and m.e. of chloride subtracted from the m.e. of calcium to give the total CEC in milliequivalents (m.e.).

Organic matter was determined by using a modified Schollenberger (1974) procedure. A half gram of soil was weighed and placed in a beaker. Pottasium dichromate and sulfuric acid were added to the sample, and then heated to 165°C on a hotplate. Cold water and orthophenanthroline color indicator were added. The sample was then titrated with 0.2 N ferrous ammonium sulfate to find the percent of organic matter.

Free iron oxides were determined by using a method obtained from Jackson (1958). The procedure employed the use of two grams of soil mixed with sodium citrate, sodium bicarbonate, and sodium dithionite heated to 80°C in a water bath. The mixture was centrifuged and the decant saved. This procedure was repeated, and the soil was then washed twice with sodium chloride. The decanted liquids were mixed together, and one milliliter of 30 percent hydrogen peroxide was added. Standard solutions were then mixed, as well as the sample solutions, using Tiron as the iron reagent. When the samples were completed, the amount of iron was determined using a chlorimeter.

The exchangeable cations were determined with the atomic absorption spectrophotometer, as described in U.S.D.A. Handbook No. 60 (1954). A 25 gram sample of soil was leached with 200 ml of ammonium acetate in 25 ml aliquots. Subsequent determination of calcium, potassium, sodium, and magnesium ions were then completed with the spectrophotometer.

Mineralogical Analyses

The clay fraction of soil was separated using the method proposed by Jackson (1969). The clay was then separated into the fine clay and coarse clay using a Sharples high speed steam centrifuge. X-ray examination of the clay fractions was completed using samples that had been saturated with (1) calcium, (2) calcium saturated and ethylene glycole solvated, and (3) potassium saturated and heated to 550°C for four hours. These procedures attempted to identify the clay minerals present as follows: (1) identify all of the clay minerals which may be present, (2) differentiate between expanding and non-expanding 2:1 clay minerals and (3) differentiate between kaolinite and other minerals with similar diffraction characteristics.

CHAPTER IV

RESULTS AND DISCUSSION

Locations of samples occur as follows. Location one is a Teller soil, as described in U.S.D.A. Handbook No. 436 (1975), taken from the NW corner, NW1/4, SW1/4, Section 36, T18N, R2E, Indian Meridian. Location two was taken from the Port series at the SW corner, SE1/4, SW1/4, SW1/4, SW1/4, Section 4, T19N, R1W, Indian Meridian. Location three was taken from the Teller series at the NW corner, NW1/4, SW1/4, SE1/4, SW1/4, Section 27, T18N, R1E, Indian Meridian.

Physical Analyses

The mechanical analysis data are shown in Figures 1 through 3. The relative percentage of sand, silt, and clay are plotted against depth for each location. Similar trends are shown for the two Teller soils (Figures 1 and 3). In both soils the sand percentages tend to decrease and then sharply increase with depth. The percentage of sand for the Port soil in Figure 2 shows a somewhat different trend. Stratification is very apparent in this soil. The sand has an increase-decrease tendency as soil depth increases and at a depth of 26 inches, the amount of sand starts to decrease rapidly.

The percentages of the silt fraction which occur in profiles 1 and 3 are also very similar in pattern. In both cases, an increase in silt is apparent through the middle depths. In the lower depths, silt began

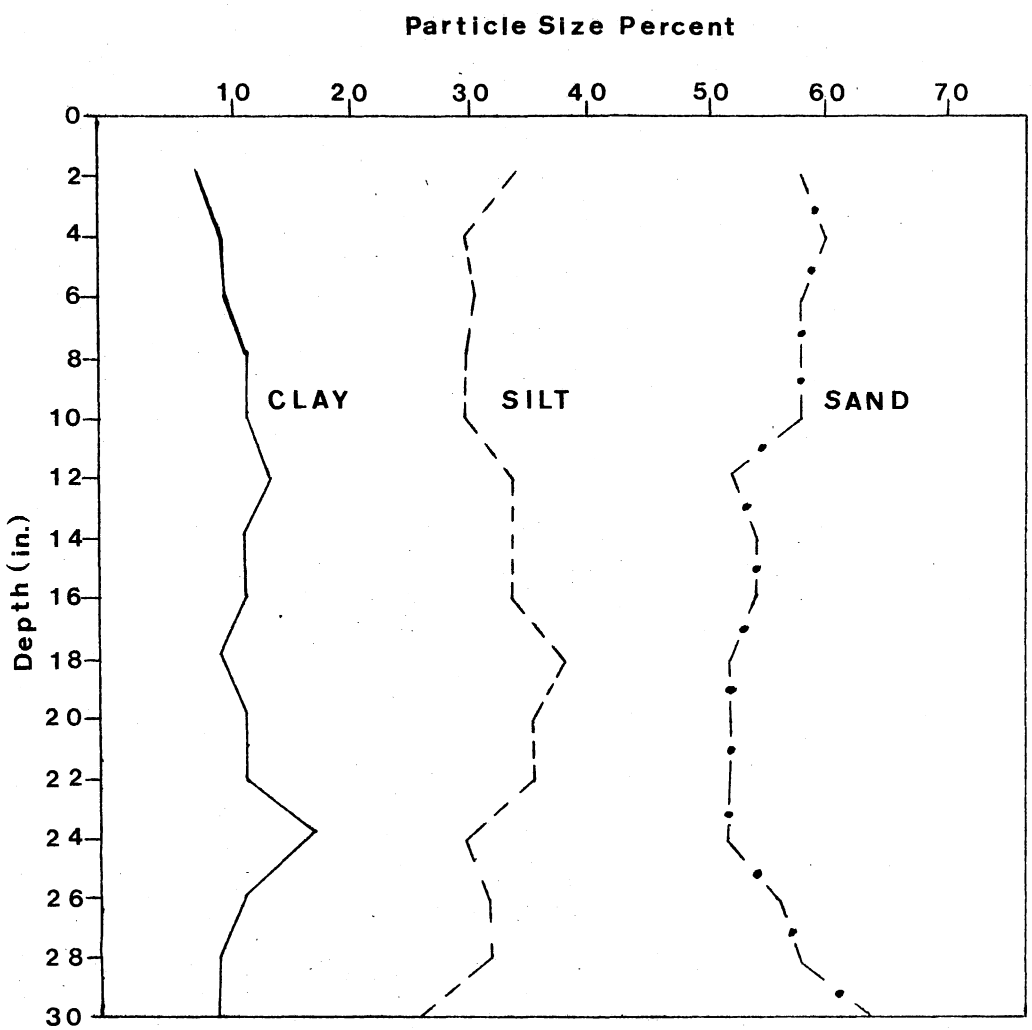

Figure 1. Mechanical Analysis for Location One

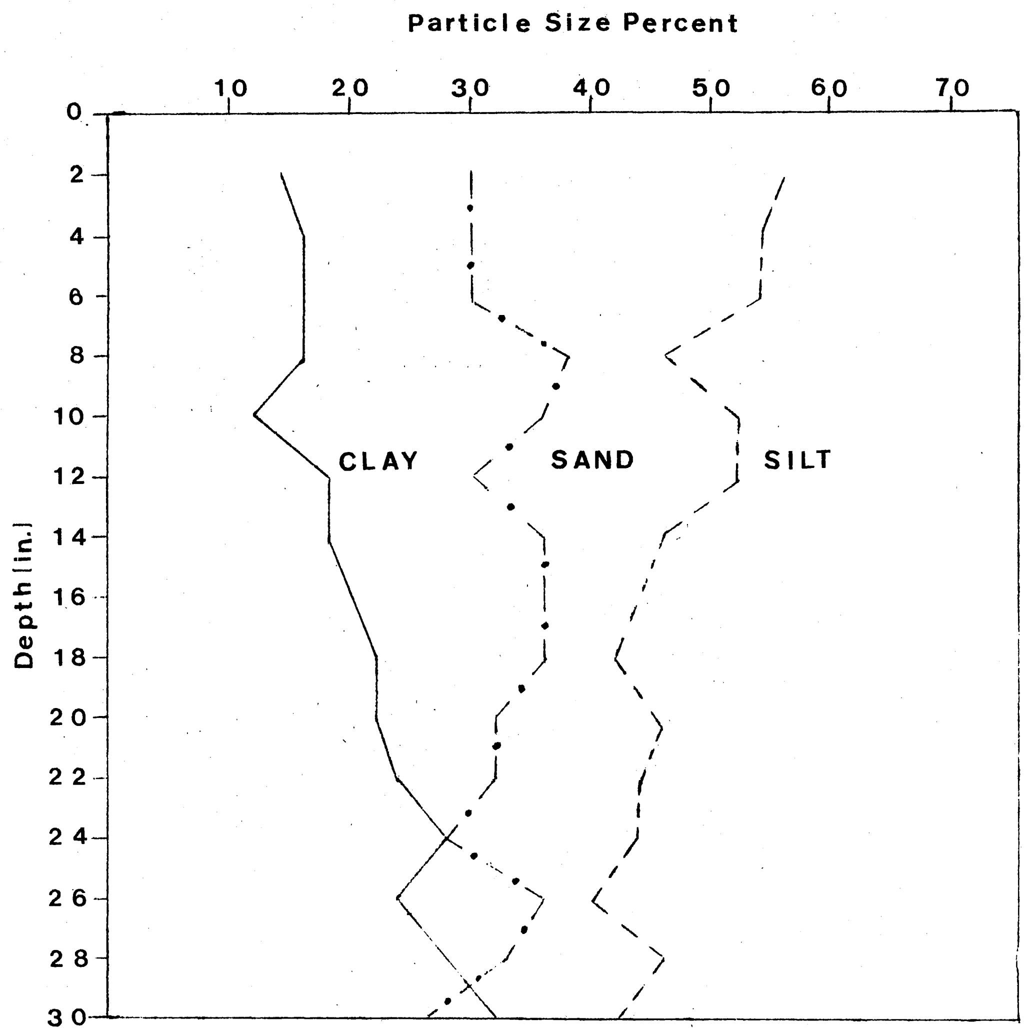

Figure 2. Mechanical Analysis for Location Two

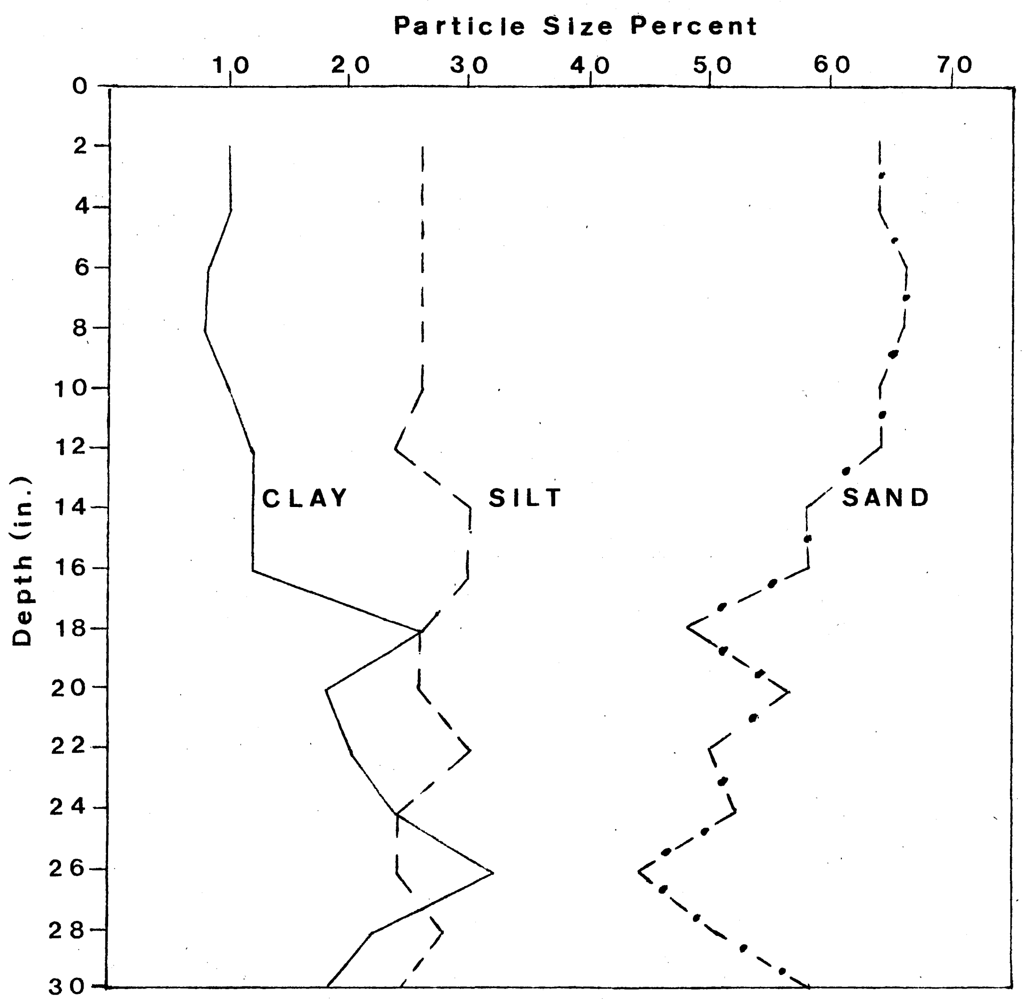

Figure 3. Mechanical Analysis for Location Three

to decline. A much higher silt content is shown in Figure 2 than is present in either of the other two profiles. Once again stratification is evident in the increase-decrease pattern which occurs with depth.

The clay fractions in all three profiles increased with depth in a linear pattern. At the 30 inch depth, both location one and location three show a declining pattern, however, a decline in clay content at location two was not evident at the 30 inch depth (76.2 cm).

Bulk density data is graphically depicted in Figure 4. Statistical analysis on bulk density shows that there is no comparable difference in these soils, nor is there a difference within these soils, due to depth. However, these samples were all taken from cultivated fields, and close examination of the graph shows compacted layers in the surface portion of each profile. It is estimated that high bulk density in these surface layers is due to mechanical compaction, resulting in data which shows no difference due to depth. If, however, the top few layers were deleted temporarily, the graphs, and perhaps the statistical analysis, would have been different and would have shown difference due to depth.

Chemical Analyses

The results of the chemical analysis of the soils used in this study are shown in Tables I through III. It is apparent that all three soils follow a similar trend. It might be noted that these soils are stratified and thus show a general increase-decrease pattern with depth.

As stated previously, Nikiforoff and Alexander (1942) showed that cementation by iron can result in the formation of high bulk density

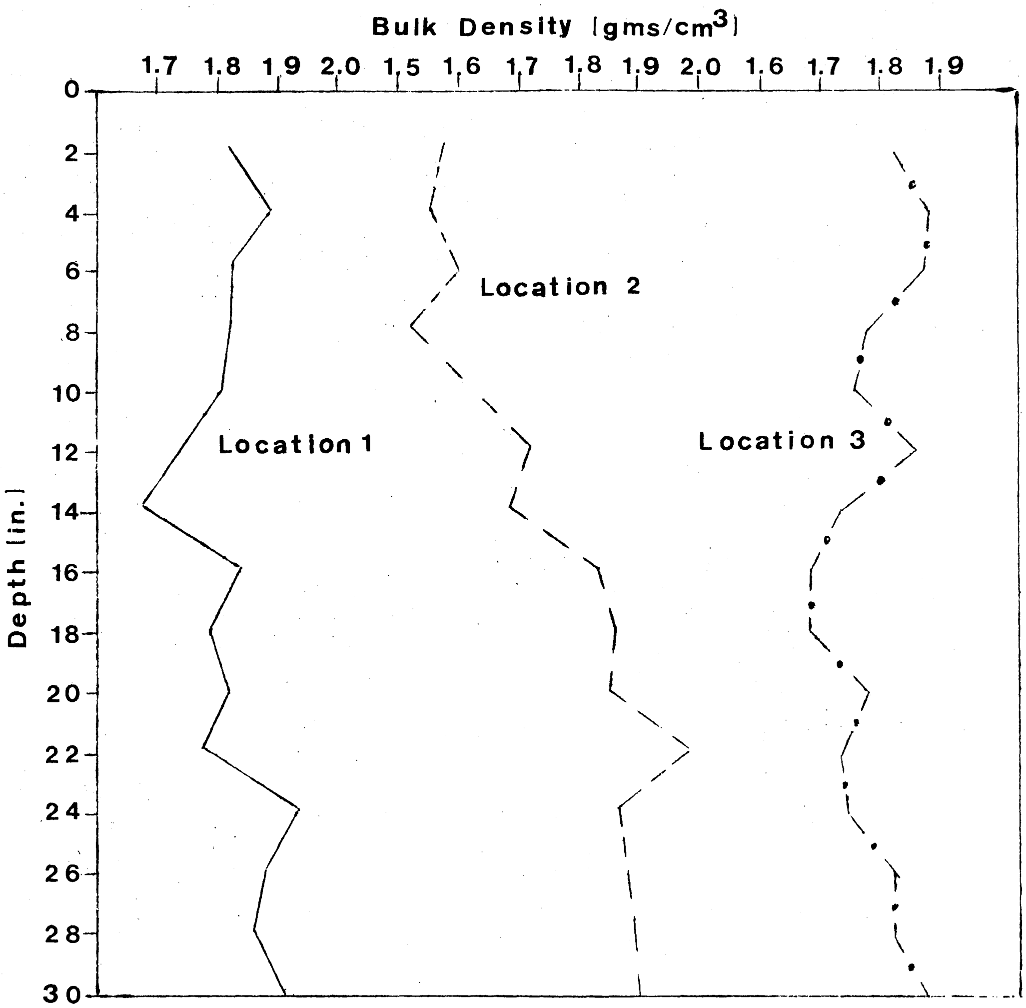

Figure 4. Graphical Interpretation of Bulk Density

TABLE I

CHEMICAL ANALYSIS OF TELLER SOIL AT LOCATION ONE

Depth	Percent		PPm				CEC	
(in.)	Fe_2O_3	O.M.	Ca	Mg	Na	K	(m.e./100 gm)	pH
0-2	0.258	1.07	1401	296	26	1391	3.38	6.5
2-4	0.075	0.95	1313	221	25	751	3.19	6.3
4-6	0.215	0.90	1462	225	34	637	5.04	5.9
6-8	0.273	0.88	1185	182	24	471	4.00	6.0
8-10	0.280	0.92	1185	186	24	479	2.97	6.1
10-12	0.496	2.28	2027	315	33	574	6.92	6.3
12-14	0.251	1.45	2179	307	33	395	8.38	6.5
14-16	0.366	1.37	2285	339	35	341	7.97	6.4
16-18	0.316	1.30	2514	422	43	397	8.78	6.6
18-20	0.287	1.30	2465	470	39	377	7.12	6.7
20-22	0.215	1.13	2292	556	41	374	9.84	6.5
22-24	0.539	1.13	1834	430	39	332	9.85	6.7
24-26	0.661	1.05	2387	879	76	444	9.02	6.8
26-28	0.309	0.95	2451	485	80	440	11.12	6.7
28-30	0.517	0.93	2096	777	85	383	10.26	6.7

TABLE II

CHEMICAL ANALYSIS OF PORT SOIL AT LOCATION TWO

Depth (in.)	Percent Fe_2O_3	Percent O.M.	PPM Ca	PPM Mg	PPM Na	PPM K	CEC (m.e./100 gm)	pH
0-2	0.115	2.25	2265	572	48	741	11.69	7.3
2-4	0.144	2.17	2143	590	78	410	10.65	7.3
4-6	0.416	1.98	2176	687	91	387	10.66	7.4
6-8	0.230	1.49	2099	642	90	364	10.43	7.6
8-10	0.101	2.42	3027	1004	151	369	13.98	7.6
10-12	0.129	2.81	3087	1215	216	348	17.93	7.5
12-14	0.488	2.85	3212	1513	303	313	20.46	7.4
14-16	0.151	2.74	3594	2000	431	349	23.98	7.4
16-18	0.431	2.53	3373	2073	547	343	24.58	7.5
18-20	0.266	2.19	3253	2231	614	367	6.49	7.5
20-22	0.108	1.87	2846	1898	627	343	13.56	7.6
22-24	0.352	1.57	3015	2299	714	388	21.47	7.6
24-26	0.445	1.30	2478	2088	742	567	19.40	7.6
26-28	0.215	1.15	2296	2045	762	394	19.38	7.6
28-30	0.596	1.04	2490	1995	815	400	19.18	7.7

TABLE III

CHEMICAL ANALYSIS OF TELLER SOIL AT LOCATION THREE

Depth (in.)	Percent Fe_2O_3	Percent O.M.	PPM Ca	PPM Mg	PPM Na	PPM K	CEC (m.e./100 gm)	pH
0-2	0.194	0.96	805	79	22	268	3.99	5.8
2-4	0.179	1.02	843	92	24	267	4.00	6.0
4-6	0.194	1.02	778	79	23	322	4.19	6.2
6-8	0.093	0.89	833	86	23	302	3.49	6.1
8-10	0.194	1.02	1053	137	23	300	4.65	6.1
10-12	0.165	1.19	1228	189	25	275	6.08	6.0
12-14	0.158	1.26	1335	173	20	191	6.06	6.1
14-16	0.122	1.20	1317	229	23	190	7.31	6.0
16-18	0.165	1.19	1325	293	23	170	6.70	6.2
18-20	0.093	1.09	1515	319	28	180	7.11	6.0
20-22	0.151	1.06	1528	333	29	164	8.15	6.1
22-24	0.309	1.06	1663	362	31	142	9.19	6.1
24-26	0.323	1.04	1102	442	31	221	8.77	5.9
26-28	0.338	0.94	1272	508	37	243	11.30	5.8
28-30	0.244	0.85	1314	529	37	183	11.90	5.9

soils. However, in the soils studied in this project, no correlation can be shown between bulk density and the free iron oxides present.

As one would expect, organic matter content in these soils has an inverse relationship to bulk density and shows a quadralinear trend. It is interesting to note that organic matter tends to accumulate in the profile near the start of the high bulk density areas. This is especially true in Table I at the 10 to 12 inch depth.

Exchangeable cations determined were calcium, magnesium, sodium, and potassium. The amount of cations present show a general linear increase as the soil depth increases in all cases. Both magnesium and sodium show significant relationships with bulk density. However, it was determined that neither cation is present in sufficient amounts to affect the soil bulk density.

The cation exchange capacity (CEC) of the three soils shows significant differences due to depth and location, especially in the Port soil. However, there appears to be no influence of CEC on the bulk density.

Mineralogical Analyses

The X-ray diffraction analysis on both the fine clay and the coarse clay fractions of each soil is shown in Tables IV through VI.

As expected, quartz was present in all samples. The coarse clays generally showed medium to high amounts of hydrous micas, and kaolin was also high in the upper horizons of locations one and two. The fine clays displayed weak amounts of well crystallized clay minerals at most depths. However, montmorillonite showed some rather strong peaks of well crystallized clay at the lower depths in the Port soil.

TABLE IV

MINERALOGICAL ANALYSIS OF CLAYS FOR LOCATION ONE

Depth	Fine Clay	Coarse Clay
0-2	Q	Mi,K,Q
2-4	Q	Mi,K,c,Q
4-6	Q	Mi,K,Q
6-8	Q	Mi,k,Q
8-10	mi,m,Q	Mi,K,Q
10-12	Mi,Q	Mi,K,Q
12-14	mi,m,k,Q	Mi,K,Q
14-16	mi,m,Q	Mi,m,K,Q
16-18	mi,m,Q	mi,m,k,Q
18-20	mi,m,Q	Mi,m,K,Q
20-22	m,Q	mi,m,k,Q
22-24	m,Q	mi,m,k,Q
24-26	mi,Q	mi,m,k,Q
26-28	mi,m,Q	Mi,m,k,Q
28-30	mi,m,Q	mi,m,k,Q

Note: Mi = hydrous mica, M = montmorillonite, K = kaolinite, C = chlorite, Q = quartz, capital letters = medium to strong peaks, lower case letters = weak to medium peaks.

TABLE V

MINERALOGICAL ANALYSIS OF CLAYS FOR LOCATION TWO

Depth	Fine Clay	Coarse Clay
0-2	mi,m,Q	mi,m,K,Q
2-4	mi,m,k,Q	mi,m,K,Q
4-6	mi,m,k,Q	mi,m,K,Q
6-8	mi,m,Q	mi,m,K,Q
8-10	mi,m,k,Q	Mi,M,K,Q
10-12	mi,m,Q	mi,Q
12-14	mi,m,Q	mi,m,k,Q
14-16	Mi,m,Q	m,k,Q
16-18	mi,m,k,Q	mi,K,Q
18-20	mi,m,k,Q	Mi,K,Q
20-22	Mi,M,C,Q	k,c,Q
22-24	M,Q	m,k,Q
24-26	M,k,Q	m,k,Q
26-28	M,Q	m,k,Q
28-30	M,Q	m,Q

Note: Mi = hydrous mica, M = montmorillonite, K = kaolinite, C = chlorite, Q = quartz, capital letters = medium to strong peaks, lower case letters = weak to medium peaks.

TABLE VI

MINERALOGICAL ANALYSIS OF CLAYS FOR LOCATION THREE

Depth	Fine Clay	Coarse Clay
0-2	mi,k,Q	mi,k,Q
2-4	mi,m,Q	mi,m,k,Q
4-6	mi,m,k,Q	mi,k,Q
6-8	mi,m,Q	mi,k,Q
8-10	Mi,m,Q	mi,k,Q
10-12	Mi,m,k,Q	Mi,m,K,f,Q
12-14	Mi,m,Q	Mi,m,K,Q
14-16	Mi,m,k,Q	Mi,m,K,Q
16-18	Mi,m,k,f,Q	Mi,m,K,f,Q
18-20	Mi,M,k,f,Q	Mi,K,Q
20-22	Mi,M,k,Q	Mi,m,K,Q
22-24	Mi,m,k,Q	Mi,m,K,Q
24-26	mi,m,Q	Mi,K,Q
26-28	mi,m,k,Q	Mi,m,K,Q
28-30	Mi,m,k,f,Q	Mi,K,f,Q

Note: Mi = hydrous mica, M = montmorillonite, K = kaolinite, F = feldspars, Q = quartz, capital letters = medium to strong peaks, lower case letters = weak to medium peaks.

CHAPTER V

SUMMARY AND CONCLUSIONS

Statistical analysis shows there is very little affect on bulk density due to factors reported in this study. It is shown that organic matter content has an inverse relationship with bulk density in a quadralinear fashion. The percent of free iron oxides have shown no affect on the bulk densities in these samples, although iron does appear to increase with depth. It has been reported that sodium may have an influence on bulk density. However, with the exception of location two, these samples do not contain any appreciable amounts of sodium.

It is estimated that mechanical compaction, in the surface layers, has masked statistical analysis so that no difference in bulk density can be related to depth. Should this test be repeated, it is suggested that the use of cultivated fields as well as non-cultivated fields be used. If possible, the use of a virgin soil would be desirable. This would permit the investigator to compare the normal with the abnormal, making sure that high bulk densities are actually present, and that continuous cropping and cultivation are not the major contributing factors.

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