A Toposequence of Soils in the Karst of West-Central Florida, U.S.A

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Abstract

An abundance of information is available regarding soil horizons and their characteristics. Several methods can be used to gather and analyze this information. Through the use of qualitative analysis in the field, and laboratory and statistical analysis, a soil can be compared and analyzed with a great deal of scrutiny.

Four soil pits were excavated in Citrus County Florida and samples were collected from each master horizon. Through the use of qualitative and quantitative analysis these samples were compared and analyzed in order to identify unique, as well as homogeneous features. It was determined that the soil profile designated Old Pit was different than other profiles because of landscape position and variations in parent material. Landscape position (ie. slope position) also influenced the genesis and evolution of the soils in the other three profiles (Profile 1, 2 and 3).

Introduction

Landscape position and parent material play important roles in the formation of soils. The soils in Citrus County Florida formed in parent materials of weathered limestone residuum and quartz sands.

Gradual erosion, denudation, and the percolation of water have created a karst landscape that includes sinkholes (dolines), residual limestone hills, dry solutional valleys and caves (Reeder and Brinkmann, 1994). These processes have also created karst soils unique to the Brooksville Ridge region of the Florida Platform in West-Central Florida.

This study incorporates soil and geomorphic data collected by way of field, laboratory and quantitative analysis to assist in the description and comparison of these soils, and to qualify the relationships between area soils and the contemporary and historical physical landscape. The use of summary statistics; mean, median, standard deviation, skewness, and kurtosis, will quantify the distribution of the grain sizes which will allow soil physical characteristics to be compared to features such as landscape position and geology.

Methodology

A toposequence of four soil profiles were excavated in the Citrus Tract of the Withlacoochee State Forest in Citrus County Florida, (Figure 1). Each profile was excavated as a one cubic meter pedon. One wall of each profile was fully cleaned in the field and 500 gram composite samples were collected from the center of each soil horizon.

Laboratory analysis included air drying and grinding the soils for sieve analysis at half phi intervals. Bouyoucos texture analysis was conducted in order to determine the percentages of the sand-sized particles present in the samples (Liegal, E.A., 1980, McLaren and Cameron, 1990). Total dissolved solids (TDS) and soil solution pH were measured using a 2 to 1 water to soil mixture and solid state TDS and pH meters in order to assess the chemical environment of soil formation and evolution (Fetter, C.W., 1994, Liegal, E.A., 1980).

Statistical analyses were performed on the sieve data in order to assess the relationship between the spatial distribution of sand sized fractions, depth and landscape position. Skewness and kurtosis, mean and median, and standard deviation were calculated in order to quantify this distribution of the grain sizes.

The Study Area

The study area is in central Citrus County, Florida, in the Citrus Tract of the Withlacoochee State Forest (Figure 1). Karst topography dominates the physical landscape of this region with surface streams absent within a 20 km radius of the study area. Surface drainage enters the subsurface through sinkholes and/or by way of percolation through area sediments and soils (Brinkmann and Reeder, 1994).

The surface elevation of the study area, within a 2 km radius, varies from 6 meters to 45 meters above mean sea level. The study area itself has a relief of 39 meters above mean sea level. Minimum elevations occur where sinkholes intercept the water table at an elevation of approximately 7 meters above mean sea level. Maximum elevations are the tops of the residual interfluvial hills. The relief is the result of the denudation of the land surface as evidenced by the location of the interfluvial hills adjacent to dry valleys or sinkhole collapses (Brinkmann and Reeder, 1994).

The local bedrock is the Oligocene aged Suwannee Limestone which is a yellow to white fossiliferous limestone that is porous and crystalline. Pleistocene quartz marine sands that vary in thickness overlay the Suwannee Limestone (Brinkmann and Reeder, 1995) indicating a transgressive/regressive sequence. The weathering product of the Suwannee Limestone, as well as the quartz sands are the parent material for soils formed in the study area. The four profiles were excavated as follows: Profile 1 is at the top of a moderate slope, Profile 2 is located 30 meters away and eight meters below at midslope, Old Pit is 50 meters away and 6 meters below Profile 2 at the base of the slope directly above a cave, and Profile 3 is located 35 meters from Old Pit at the same elevation (Brinkmann and Reeder, 1994).

Results and Discussion

Texture Analysis

The results of the Bouyoucos textural analysis are presented in Table 1. In general, all of the "A" soil horizons contain a considerable amount of sand, ranging between 90.32 percent (Profile 1) and 89.32 percent (Profile 3). The percentage of clay increased in the lowest horizon for all four of the soil pits. Old Pit textural values were slightly different from Profiles 1, 2, and 3 in that the clay contents in the "B" and "Bt" horizons were significantly higher at 40.00 and 41.00 percents respectively. These higher amounts of clay are the result of this profile's close proximity to its' parent material, the Suwannee Limestone (Brinkmann and Reeder, 1994). A large amount of clay minerals are forming at this contact and account for an increased amount of clay in Old Pit's lower horizons. This clay is not likely being translocated from upper horizons.

The sandy upper horizons are the product of the quartz sands that were deposited as a result of a regressive facies that possibly took place during the Miocene, and were reworked as a result of erosional processes lowering the landscape and creating interfluvial features (Brinkmann and Reeder, 1994). The textural classification for these soils, based on the results of the Bouyoucos textural analysis, indicate that the "A" horizons are all sand, the "E1" horizon of Profiles 1, 2, and 3 are also classified as sand. The "E2" horizons of Profiles 1, 2, and 3 are loamy sands. The textural horizons in Profiles 1 and 3 are sandy loams, while Profile 2's "B" horizon is a sandy loam and hence not a textural horizon. Old Pit's soils are slightly different from the other profiles. Old Pit's "A" horizon is sand, the "E" horizon is a loamy sand, the "B" horizon is a loam, and the "Bt" horizon is a clay loam. As stated before, this increase in clay content is probably due to the "Bt" contact with the parent material which has undergone complicated chemical reactions producing clay minerals.

pH Analysis

The results of the pH analysis are presented in Table 2. White (1987) states that in percolating rain water that is naturally dilute, cations will be in low concentration and exchanges will occur. Na will gradually be lost, followed by K as the exchange surfaces become dominated with Ca and Mg, and ultimately Al. Butler (1979) states that soils tend to become more acidic in humid areas due to weathering and leaching of bases. These statements probably indicate the processes that are occurring in the soils of Citrus county Florida because of the rapid percolation of precipitation through the sandy surface soils.

The pH of the soil horizons range from a high of 6.57 in the "E1" horizon of Profile 1, to a low of 4.45 in the "A" horizon of Old Pit. Profile 1 displays slightly higher pH values than Profile 2 possibly because of slope erosion removing the base cations and thus lowering the pH of the soil. Old Pit contains a chemical environment unlike the other three profiles. The pH value increases with depth from 4.45 at the surface to 6.16 in the "Bt" horizon. The increase in the lower horizon is most likely due to its close proximity to the soil/rock interface at the Suwannee Limestone parent material contact (Reeder and Brinkmann, 1995). The lower pH values in the bottom horizons of Profiles 1, 2, and 3 result from percolating water leaching the base nutrients thus lowering the pH of the soil. The lower pH values (4.5 to 5.8) possibly represent soils in which the removal of basic cations by leaching has lowered the base saturation (McLaren and Cameron, 1990).

Total Dissolved Solids (Soluble Salts)

The Total Dissolved Solids (TDS) were measured for each soil horizon and the results are presented in Table 2. Total Dissolved Solids are a measure of the total amount of dissolved solids, in milligrams per liter or parts per million, present in a soil/water solution (Fetter, 1994, Bohn, McNeal, and O'Connor, 1985). These solids can consist of different dissolved inorganic constituents including calcium, magnesium, sodium, potassium, and silica (Fetter, 1994). The major constituent of the dissolved solids present is the soil samples from the study area are possibly silica because of the large amounts of quartz present in the soils sandy parent material. Profiles 1, 2, and 3 display their highest Total Dissolved Solids concentrations in the "A" horizon and decrease significantly with depth. Profile 3 displays a complete lack of TDS in the "E2" horizon and an accumulation of 20 ppm in the "Bt" horizon. This is consistent with the literature in that the "E" horizon is a zone of eluviation where dissolved solids are leached into the "B" horizon or zone of illuviation. Old Pit contains an unusually high amount of TDS in comparison to the other pits. The "A" has a TDS value of 90 ppm, 30 ppm in the "E", 80 ppm in the "B", and 120 ppm in the "Bt" horizon. Again, the "E" horizon is deficient in TDS with the accumulation taking place in the "B" and "Bt" horizon. Pits 1 and 2 indicate the highest amount of TDS in the "A" horizon with decreasing values down through the profile. All of the TDS are most likely being translocated via the percolation of water through the profile. The greatest accumulation of TDS occurred in the clay-rich textural horizons of Old Pit because the clay inhibits deeper percolation and holds a portion of the dissolved solids in an available state on the clay mineral surfaces. The "A" horizons tend to be high in TDS because they are closest to the litter which is the source of the humus which contains chemical elements in available form.

Color

Soil color is one of the most easily observed features of a soil. It can relate a number of characteristics of the soil such as chemical, physical, and biological properties (Buol, Hole, and McCracken, 1989). The soils present in Citrus County Florida are summarized in Table 3. Profile 1 exhibits a dark grayish brown in the "A", light yellowish brown in the "E1", yellowish brown in the "E2", and brownish yellow in the "EBt". These colors indicate a soil with some organic material accumulation in the upper horizon and well aerated soils with air moving freely through pore spaces (Huddleston and Kling, 1984, Bridges and Davidson, 1982).

Profile 2 exhibits a color sequence similar to Old Pit and Profile

3. Some of the brown colors are due to iron oxide coatings present on the mineral grains which is typical of "B" horizons (Huddleston and Kling, 1984). For the most part the soils of Citrus County Florida are well aerated, and hence rich in pore space, because the major textural constituent of these soils is sand. This grain size would allow an abundance of air and water solutions to move through the soil depending upon moisture conditions.

Sieve Analysis

The results of the sieve analysis are presented in Table 4 and Figures 2 and 3. Sieve analysis was conducted at half phi increments for each of the sixteen soil samples collected. This type of analysis is useful as an indicator of grain size when a large percentage of the sample is sand sized particles or larger (Leeder, 1992). Coarse-textured soils that have a high percentage of sand are characterized by large pore spaces and good permeability and aeration but poor water retention (Butler, 1979). This is important in the study area because a large portion of the drainage in this area is by direct infiltration (Brinkmann and Reeder, 1994).

The results of the textural analysis indicate that sand is the major constituent of these soils. Only small percentages of silt and clay are present. Profile 1 has 2.62 percent clay and silt in the "A" horizon, 2.50 percent in the "E1" horizon, 0.78 percent in the "E2" horizon, and 4.80 percent in the "EBt" horizon. Profile 2 contains 2.40 percent in the "A" horizon, 0.98 percent in the "E1" horizon, 3.82 percent in the "E2" horizon, and 0.67 percent in the "B" horizon. Profile 3 contains 4.29 percent in the "A" horizon, 4.25 percent in the "E1" horizon, 3.73 percent in the "E2" horizon, and 5.56 percent in the "Bt" horizon. Profiles 1 and 3 each display higher concentrations of silt and clay in their textural horizons. However, profile 2 displays an unusually small amount of silt and clay in its' lowest subsoil horizon when compared to pits 1 and 3. Perhaps this small percentage is due to the position of profile 2 in the toposequence. It is located midslope and may lose a larger fraction of silt and clay to erosional processes.

Old Pit contains larger percentages of silt and clay than the other 3 profiles. Old Pit "A" horizon contains 9.29 percent, the "E" horizon contains 9.04 percent, the "B" horizon contains 13.89 percent, and the "Bt" horizon contains 14.93 percent. These results support the findings of the textural analysis in that this site contains larger amounts of clay when compared to the other 3 pits, mainly due to its contact with the parent material and formation of clay in situ. However, Old Pit's "A" and "E" horizons display slightly higher percentages than the results of the textural analysis, and the "B" and "Bt" horizons display a significantly lower percentage than the textural analysis results. This disparity is the result of incomplete breakdown of the individual peds during soil grinding which would yield a larger sand size percentage. In this instance, the results of the Bouyoucos textural analysis proved to be more reliable.

Sieve Data Statistical Analysis

Table 5 contains the results of the summary statistics that were performed on the sieve data. Soil samples show a range of grain sizes and this variation must be characterized statistically so that samples can be interpreted and compared (Leeder, 1982). These statistics include the mean, median, standard deviation, skewness, and kurtosis. It is important to keep in mind that all particles in this sieve analysis are classified as "sand", excluding the soil that passes into the pan which are the silt and clay fraction of the sample. The mean is the most common measure of central tendency which divides the sum of the values by the number of values to yield a point about which a distribution of numbers is centered (Earickson and Harlin, 1994).

The median is the midpoint of the values with half positioned above the median and half positioned below the median. The standard deviation measures the spread of the values around the mean, or the sorting or variability of the values (McBride, date unknown). Because in this study all samples have the same number of observations (12 phi percentages) and the sum of the 12 phi percentages is approximately 99% in each sample (percent recovery), the mean and the standard deviation based upon the mean are not useful statistics. Because of the nature of the data base, median is also not a useful statistic.

More useful in these type analyses are skewness and kurtosis. Skewness is a measure of symmetry of the distribution around the mean and kurtosis is a clustering or dispersion of the values, or grain sizes in this situation, in the distribution (McBride). Skewness and kurtosis can answer one very important question; which location has the greatest variability? (Earickson and Harlin, 1994). In this study, the horizons with positive skewness have an excess of fine grains and those with negative skewness have excess of coarse grains (Leeder, 1982).

Profile 1 has a large positive skew value of approximately 1.50 in each horizon. Large skew values will extend the tail to the right, indicating that one or two values of finer grained soils in each horizon is quite large. Kurtosis is also quite high for the "A" and "E1" horizons. This indicates that most values are clustered together with a few large values acting as outliers.

In Profile 2 there is a major difference in the kurtosis value of the "B" horizon compared to Profile 1. This horizon has a small negative kurtosis value of -.089. This value indicates that the values are more dispersed. In other words, fewer values are clustering together and the distribution is closer to normal. These grain sizes are more dispersed and have slightly fewer sizes that are similar.

Old Pit has "A" and "E" horizons that display characteristics similar to Profiles 1 and 2. The major difference falls within the "B" and "Bt" horizons. Old Pit has a very small negative skew value of -.018. The kurtosis value of -1.805 indicates that these grain sizes are more dispersed throughout the "B" horizon with some clustering occurring in the very fine grains and the coarse grains. Old Pit's "Bt" horizon has a skewness value of -0.110 which indicates a close to normal distribution. However, this distribution has a negative kurtosis (-1.277) because the grain sizes are more evenly dispersed over many different portions of the distribution.

But as previously reported, because sieve analysis is not accurate for clay-rich soils, these values may be in error because peds were not entirely crushed during grinding.

Profile 3 has values similar to Profiles 1 and 2. The skewness values indicate that there are several outliers of finer grains that skew the distribution. Kurtosis, however, varies somewhat between horizons. The "A" horizon has a large kurtosis value of 2.051 indicating that there are a large number of grain sizes that are clustering together. The "E1" and "E2" horizons have similar distributions but not quite as clustered. The "Bt" horizon has a smaller kurtosis value of 0.708. This indicates that the values are more evenly dispersed.

Conclusions

Many types of analysis can be conducted during the study of soils. Qualitative analysis can be done in the field and supported or rejected later by the use of more quantitative analyses. This has proven to be the case in this study. The initial field identification of a textural horizon in Pit 2 has been rejected after textural analysis was performed in the laboratory. The laboratory analysis supported the differences between the profiles, especially the uniqueness of Old Pit. The large percentage of clay in the lower horizons of Old Pit were supported by the results of sieve and textural analysis. The analysis of Total Dissolved Solids also confirmed the presence of zones of illuviation and eluviation, especially in Old Pit.

Quantitative methods incorporated laboratory data into statistical analysis and comparison. The skewness and kurtosis gave indications of the presence of outlying or extreme values and any tendency for grain sizes to cluster together as a more homogenous group or to disperse because of lack of homogeneity. This data provides information about the geomorphic processes occurring in the study area and how the landscape has changed through time. The skewness and kurtosis data indicates the clustering of grain sizes in Profile 1 at the top of the slope and that finer grains are present. This probably occurs because the topography is flat and slope wash is limited. In Profile 2, at midslope, clustering of grain sizes does not occur and grain sizes seemed more mixed in each horizon. This is due to the dynamic nature of the geomorphological processes occurring at mid slope. Old Pit is different than the other profiles with respect to skewness and kurtosis because it is located at the base of a slope, and soil genesis and geomorphic evolution is greatly influenced by the presence of residual clays in the subsoil horizons. At Profile 3 the large kurtosis indicates certain grain sizes are clustered together, and the skewness indicates that finer grains skew the distribution. These are ramifications of this profiles topographic position in that it is in a flat area at the base of a slope, hence it is greatly affected by deposition of slopewash materials.

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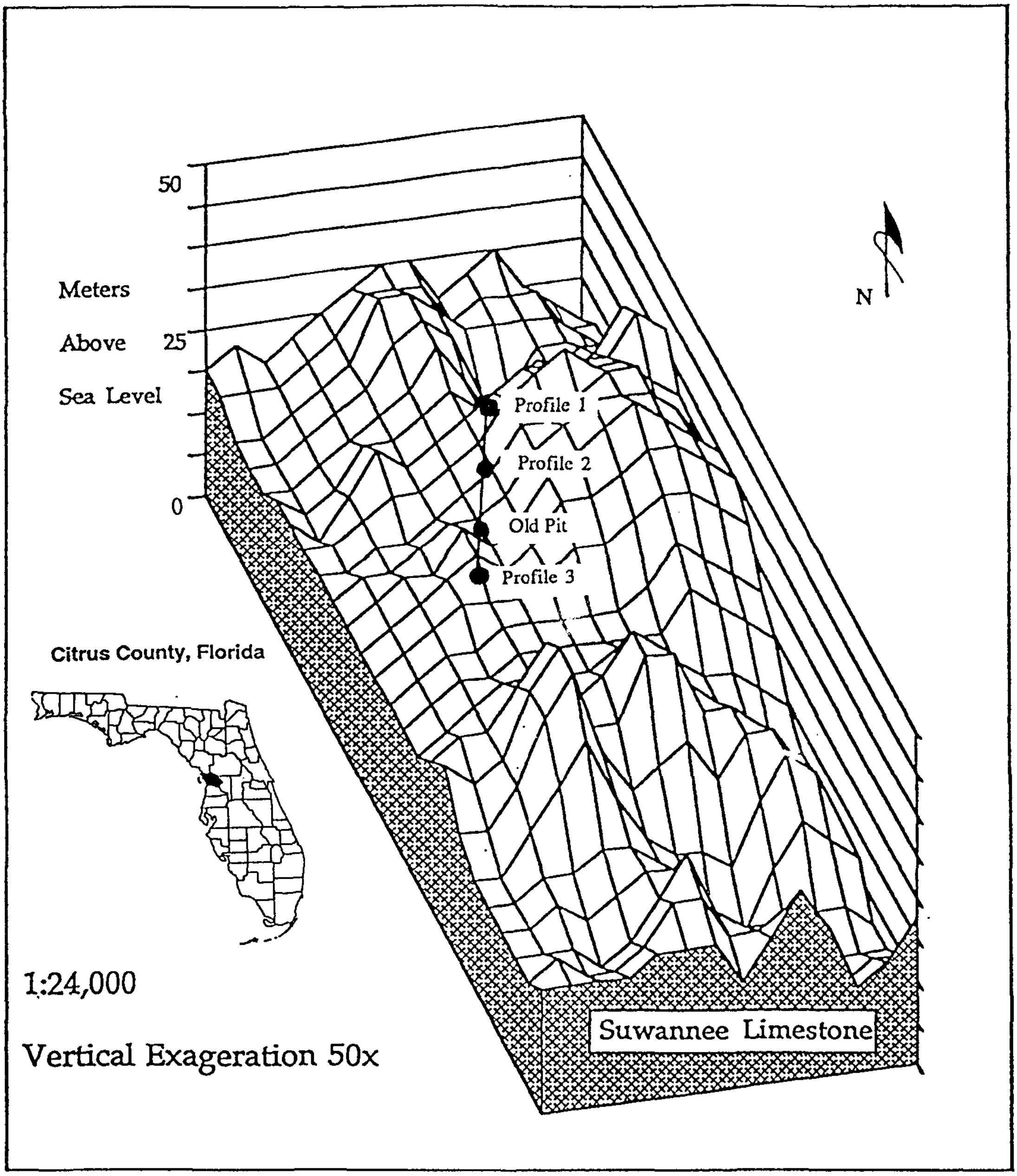
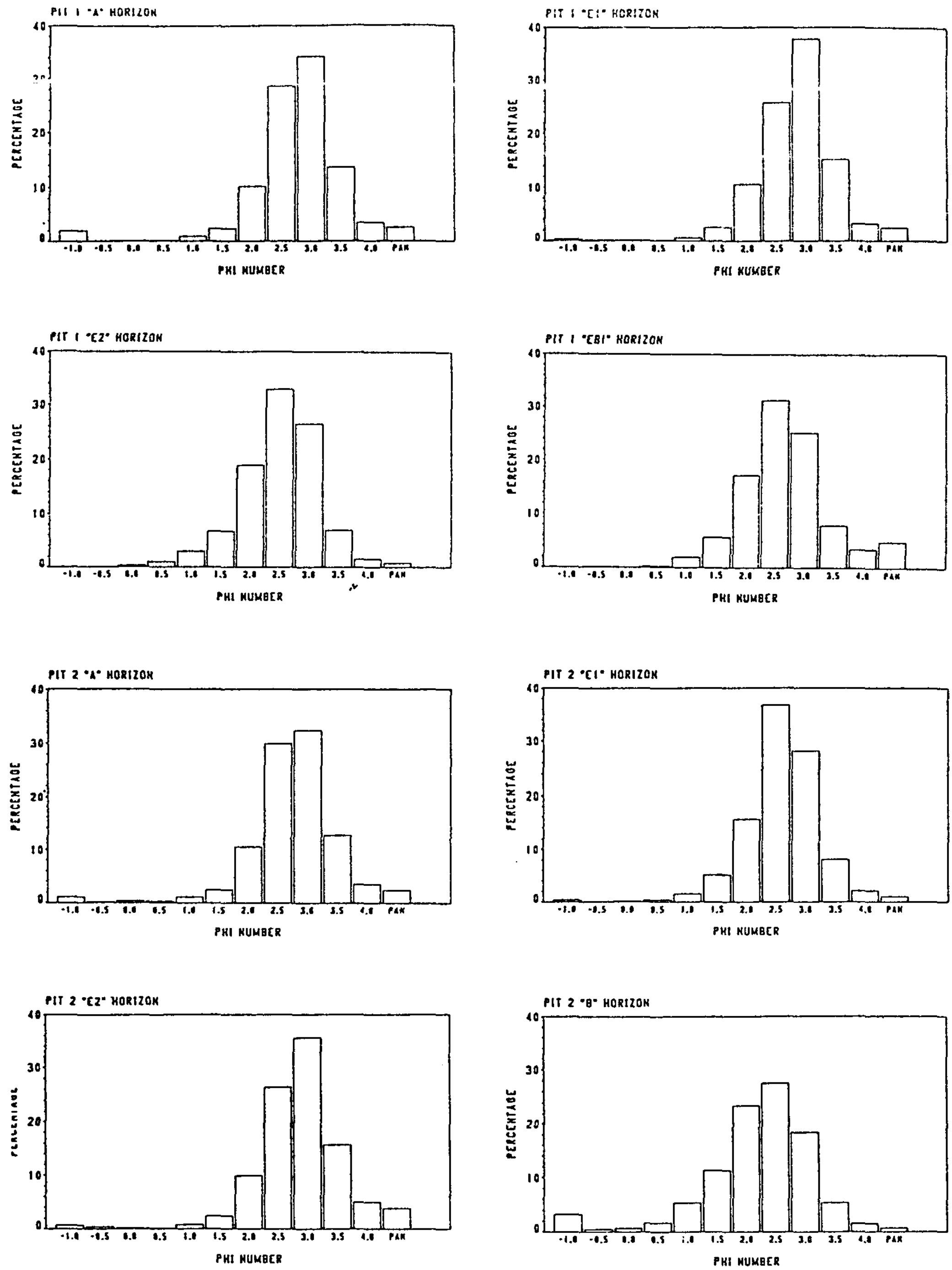
Figure Captions

Figure 1. Terrain model and location of the study area, and location of the four soil profiles excavated during this study.

Figure 2. Sieve data from each designated horizon in soil profiles 1 and 2.

Figure 3. Sieve data from each designated horizon in the soil profile Old Pit and Profile 3.


50
Meters
Above 25
Sea Level
0
Profile 1
Profile 2
Old Pit
Profile 3
N
Citrus County, Florida
1:24,000
Vertical Exageration 50x
Suwannee Limestone


PIT 1 "A" HORIZON
PIT 1 "E1" HORIZON
PIT 1 "E2" HORIZON
PIT 1 "EB1" HORIZON
PIT 2 "A" HORIZON
PIT 2 "E1" HORIZON
PIT 2 "E2" HORIZON
PIT 2 "B" HORIZON
PERCENTAGE
PHI NUMBER
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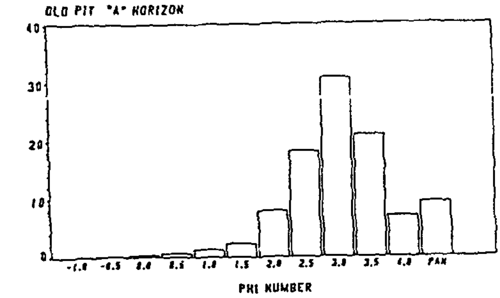
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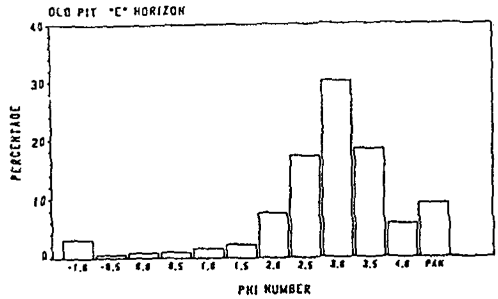
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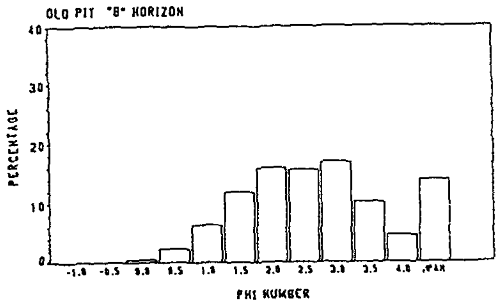
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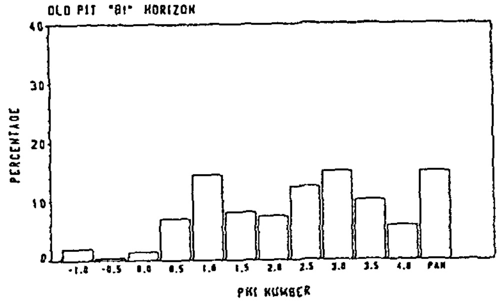
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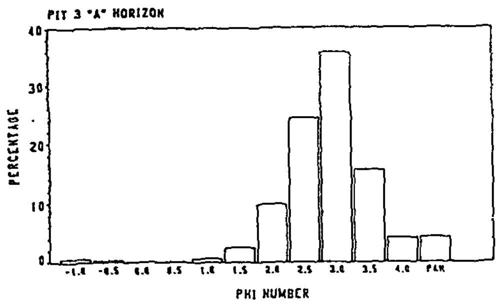
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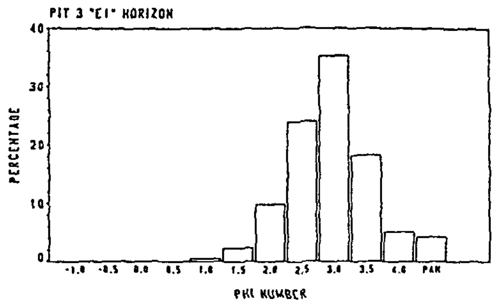
PHI NUMBER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PERCENTAGE
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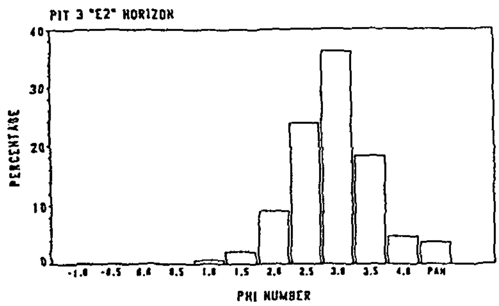
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PERCENTAGE
PHI NUMBER

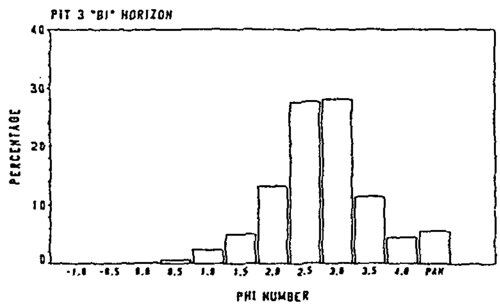
PIT 3 "B1" HORIZON
PERCENTAGE
PHI NUMBER

Table 1. Results of Bouyoucos textural analysis completed on soil samples collected from Citrus County Florida.

Horizon	Percent Sand	Percent Silt	Percent Clay	Texture
PIT 1				
"A"	90.32	3.96	5.72	Sand
"E1"	92.32	3.96	3.72	Sand
"E2"	87.32	4.96	7.72	Loamy Sand
"EBt"	65.32	6.96	27.72	Sandy Clay Loam
PIT 2				
"A"	90.32	7.96	1.72	Sand
"E1"	89.32	4.96	5.72	Loamy Sand
"E2"	88.32	5.96	5.72	Loamy Sand
"Bt"	83.32	6.96	9.72	Loamy Sand
OLD PIT				
"A"	90.00	4.00	6.00	Sand
"E"	88.00	8.00	4.00	Loamy Sand
"B"	46.00	14.00	40.00	Sandy Clay
"Bt"	23.00	36.00	41.00	Clay
PIT 3				
"A"	89.32	6.96	3.72	Loamy Sand
"E1"	90.32	5.96	3.72	Sand
"E2"	88.32	5.96	5.72	Loamy Sand
"Bt"	69.32	4.96	25.72	Sandy Clay Loam

Table 2. Results of pH analysis and Total Dissolved Solids analysis for samples collected from profiles in Citrus County Florida.

Horizon	pH	TDS in PPM
PIT 1		
"A"	5.71	30
"E1"	6.57	10
"E2"	6.40	10
"EBt"	5.77	10
PIT 2		
"A"	5.67	60
"E1"	6.01	10
"E2"	5.56	10
"Bt"	5.28	10
OLD PIT		
"A"	4.45	90
"E"	5.83	30
"B"	5.99	80
"Bt"	6.14	120
PIT 3		
"A"	5.03	20
"E1"	5.31	10
"E2"	5.44	0
"Bt"	4.74	20

Table 3. **Dry Munsell color for soil collected from pits in Citrus County Florida.**

Horizon	Munsell Color	Description
PIT 1		
"A"	2.5Y4/2	dark grayish brown
"E1"	2.5Y6/3	light yellowish brown
"E2"	10YR5/6	yellowish brown
"EBt"	10YR6/6	brownish yellow
PIT 2		
"A"	10YR4/2	dark grayish brown
"E1"	10YR5/6	yellowish brown
"E2"	10YR6/6	brownish yellow
"Bt"	10YR5/8	yellowish brown
OLD PIT		
"A"	10YR5/2	grayish brown
"E"	10YR6/4	light yellowish brown
"B"	10YR4/6	dark yellowish brown
"Bt"	10YR5/6	yellowish brown
PIT 3		
"A"	2.5Y5/2	grayish brown
"E1"	2.5Y6/3	light yellowish brown
"E2"	2.5Y7/4	pale yellow
"Bt"	10YR5/6	yellowish brown

Table 4. Results of sieve analysis completed on soil samples collected from Citrus County Florida (size in micrometers).

Abundance by size (weight percent)

Phi	Pit1 "A"	Pit1 "E1"	Pit1 "E2"	Pit1 "EBt"
-1.0	1.96	.31	.06	.02
-0.5	.06	.08	.06	.13
0.0	.11	.10	.34	.07
0.5	.19	.11	.96	.25
1.0	.91	.61	2.96	1.91
1.5	2.39	2.62	6.70	5.66
2.0	10.08	10.57	18.84	17.19
2.5	28.57	25.77	32.91	31.22
3.0	34.13	37.87	26.41	25.14
3.5	13.53	5.20	6.91	7.86
4.0	3.45	3.26	1.54	3.48
Pan	2.62	2.50	.78	4.80

Phi	Pit2 "A"	Pit2 "E1"	Pit2 "E2"	Pit2 "B"
-1.0	1.08	.40	.73	3.24
-0.5	.24	.09	.40	.48
0.0	.39	.23	.24	.66
0.5	.34	.41	.19	1.65
1.0	1.10	1.52	.81	5.28
1.5	2.47	5.14	2.39	11.22
2.0	10.50	15.53	9.85	23.43
2.5	29.96	36.79	26.31	27.49
3.0	32.40	28.11	35.61	18.37
3.5	12.70	8.10	15.66	5.32
4.0	3.53	2.12	4.94	1.52
Pan	2.40	.98	3.82	.67

Phi	Old Pit "A"	Old Pit "E"	Old Pit "B"	Old Pit "Bt"
-1.0	.17	3.16	.00	2.02
-0.5	.22	.58	.02	.42
0.0	.41	.96	.50	1.45
0.5	.69	1.02	2.37	7.02
1.0	1.30	1.67	6.43	14.38
1.5	2.31	2.29	11.93	8.09
2.0	7.87	7.53	15.92	7.45
2.5	18.06	17.08	15.57	12.28
3.0	30.70	29.95	16.87	14.90
3.5	20.90	18.20	10.26	10.07
4.0	6.95	5.61	4.63	5.78
Pan	9.29	9.04	13.89	14.93

Table 4 - Continued

Phi	Pit3 "A"	Pit3 "E1"	Pit3 "E2"	Pit3 "Bt"
-1.0	.64	.04	.23	.08
-0.5	.35	.07	.12	.00
0.0	.22	.05	.22	.14
0.5	.16	.04	.04	.59
1.0	.69	.52	.67	2.39
1.5	2.54	2.34	2.16	5.02
2.0	9.82	9.85	9.09	13.19
2.5	24.38	23.94	23.78	27.62
3.0	35.74	35.30	36.15	28.07
3.5	15.57	18.16	18.26	11.38
4.0	4.18	5.14	4.71	4.51
Pan	4.29	4.25	3.73	5.56

Table 5. Summary statistics calculated for the soils collected from profiles excavated in Citrus County Florida.

	Skewness	Kurtosis
Pit 1		
"A"	1.619	1.497
"E1"	1.704	2.209
"E2"	1.432	0.761
"EBt"	1.412	0.841
Pit2		
"A"	1.597	1.302
"E1"	1.664	1.772
"E2"	1.602	1.686
"B"	1.162	-0.089
Old Pit		
"A"	1.298	0.871
"E"	1.484	1.703
"B"	-0.018	-1.805
"Bt"	-0.110	-1.277
Pit 3		
"A"	1.653	2.051
"E1"	1.515	1.486
"E2"	1.592	1.779
"Bt"	1.360	0.708