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Chapter 6

SOILS, HYDROLOGY, AND GEOMORPHOLOGY OF THE LISA MATTHEWS MEMORIAL BAY, BAMBERG, SOUTH CAROLINA

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ABSTRACT

The Lisa Matthews Memorial Bay contains a population of the federally endangered Canby's Dropwort (*Oxypolis canbyi*). The wetland depression is similar to a Carolina bay, but lacks the classic elliptical shape of Carolina bays. Canby's Dropwort is found in the shallow portion of the bay. The 21-hectare preserve is located on the Coastal Plain in Bamberg County, South Carolina, and is owned by the South Carolina Native Plant Society. We undertook a study of the soils, hydrology, and geomorphology of the Lisa Matthews Memorial Bay to aid in the management of the Canby's Dropwort habitat in the bay and to assist in

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the restoration of the uplands to longleaf pine (*Pinus palustris*). Twelve pedons were described and sampled for determination of soil texture, pH, carbon, nitrogen, phosphorus, potassium, calcium, magnesium, manganese, and iron. The upland soils were sampled to a depth of 250 cm, and the soils near and in the bay sampled to shallower depths (100-180 cm). The bay has a sandy clay loam/sandy clay bottom and the uplands are sandy. The pedons sampled were Typic Dystrudepts (3 sites), a Grossarenic Hapludult, an Aeric Albaquult, an Umbric Endoaquod, Typic Albaquults (5 sites), and an Umbric Paleaquult. The elevation of each pedon was determined using conventional land surveying procedures and water level in the bay measured 36 times in the 30 months from March, 2004, to September, 2006. Water level in the bay ranged from a high of 55.10 m elevation to a low of 54.07 m elevation. One pedon sampled was located in the Canby's Dropwort habitat and was classified as a Typic Albaquult with the ground elevation at 54.58 m. The deepest portion of the bay never dried out. Distribution of sand, clay and phosphorus showed the uplands and the bay margin/shallow part of the bay represented two distinct episodes of deposition.

INTRODUCTION

Canby's Dropwort (*Oxypolis canbyi)* is a federally endangered plant found in 25 locations in the southeastern United States (Murdock and Rayner, 1989). One population is in Maryland, one in North Carolina, 15 in South Carolina, and 8 in Georgia. Canby's Dropwort is a perennial herb which grows 0.8 to 1.2 m tall. Stems arise from rhizomes and the first, second and third nodes. Flowers of Canby's Dropwort appear from May through early August (Murdock and Rayner, 1989). One population of Canby's Dropwort is located in the Lisa Matthews Memorial Bay, a 21-hectare preserve on the Coastal Plain in Bamberg County, South Carolina. The wetland depression is 7.5 ha in size, but lacks the classic elliptical shape of Carolina bays (Grant et al., 1998). Approximately 2.5 ha are in a deep Pond Cypress Pond and 5 ha in shallow Pond Cypress Savanna (Sharitz, 2003). There are also small areas of Pocosin at the edge of the bay (at Site 9), and Depression Meadow in the shallow part of the bay (at Site 6). The Lisa Matthews Memorial Bay is owned by the South Carolina Native Plant Society which is attempting to promote Canby's Dropwort in the shallow portion of the bay, and restore the surrounding 13.5-ha uplands to longleaf pine (*Pinus palustris)*. We undertook a study of the soils, hydrology and geomorphology of the Lisa Matthews Memorial Bay to

aid in the management of Canby's Dropwort and to assist in the restoration of the uplands.

METHODS

The Lisa Matthews Memorial Bay is bounded by dirt roads on the north, west and south sides and by a four-lane highway (US 301) on the east side. Three transects were established perpendicular to the north boundary road at 152-m (500-ft) intervals. Ten sites were located along these transects (30 m from the nearest road and 92 m apart). Two extra sites were chosen, one in the shallow part of the bay near a population of Canby's Dropwort (Site 6) and one on the south-side upland (Site 7). Each site was augured to 100-250 cm depth and soil placed in plastic trays for description and collection of samples by horizon. The elevation of each site was also obtained using land surveying procedures. Soil samples were analyzed at Virginia Tech. Particle size analysis was done by sand sieving and the pipette method. Carbon and nitrogen concentrations were determined using an Elementar Vario Max CNS analyzer. Soil pH was measured using a 1:1 soil/water solution. Acid-extractable P, K, Ca, Mg, Mn and Fe were quantified by ICPES (Donohue and Heckendorn, 1994). The soil at each site was classified using "Keys to Soil Taxonomy" (Soil Survey Staff, 2003).

Water level in the bay was measured 36 times in 30 months beginning March 21, 2004 and ending September 2, 2006. Water level was determined using a surveyor's level and rod to find the difference in elevation between the open water and a benchmark at Site 5. Water level was also measured at a shallow well near Site 6 on several occasions and these water level measurements were similar to those obtained at Site 5. Water level at the end of each month was determined by interpolation. Mean monthly temperature from 1952 to 2002 at a weather station in the town of Bamberg, SC, was used to calculate potential evapotranspiration (PET) using the Thornthwaite (1948) method. Lu et al. (2005) recommended using the Hamon (1963) method with a calibration coefficient (1.2) rather than the Thornthwaite (1948) method without any calibration. However, the two methods were highly correlated ($r=1.00$) and we chose to calculate a coefficient for the Thornthwaite (1948) method PET. The prior month's water level, monthly rainfall (at the weather station in Bamberg, SC), and the Thornthwaite (1948) method calculated PET were used to predict the current water level (at the end of the month). The

regression equation computed was then used to estimate monthly water level at Site 6 over 47 years (1960-2006).

Results

Soils

The position, elevation, and classification of each site are listed in Table 1. The four upland sites were classified as either Typic Dystrudepts (3 sites) with cambic B horizons, or as a Grossarenic Hapludult (1 site) with an argillic B horizon overlain by a thick sandy surface. At an intermediate elevation an Aeric Albaquult (1 site) with aquic moisture regime and argillic B horizon was found. At lower elevations in the bay margin and shallow part of the bay there were Typic Albaquults (5 sites) all having aquic moisture regimes and argillic B horizons. Also at lower elevations, a Spodosol with substantial organic matter in the surface was classified as an Umbric Endoaquod (1 site), and an Ultisol with substantial organic matter in the surface was classified as an Umbric Paleaquult (1 site).

Field and laboratory data for each horizon sampled are shown in Appendices 1-12. Weighted average sand, silt, clay, and phosphorus to a depth of 100 cm are reported in Table 2, along with weighted average carbon to a depth of 20 cm. Percent sand, silt and clay by horizon to a depth of 100 cm is shown graphically in Figure 1.

Table 1. Characteristics of the 12 sites studied.

Site	Transect	Position	Elevation (m)	Depth to Gley (cm)	Classification
8	2	North-Side Upland	57.61	250+	Typic Dystrudept
3	3	North-Side Upland	56.46	162	Typic Dystrudept
12	1	South-Side Upland	56.40	90	Grossarenic Hapludult
7	Extra	South-Side Upland	56.10	150	Typic Dystrudept
1	3	Intermediate Elevation	55.63	31	Aeric Albaquult
9	2	Bay Margin	55.27	18	Umbric Endoaquod
4	2	Bay Margin	55.14	41	Typic Albaquult
10	1	Bay Margin	55.13	11	Typic Albaquult
11	1	Bay Margin	55.11	12	Typic Albaquult
2	3	Bay Margin	54.95	18	Typic Albaquult
5	1	Shallow Part of Bay	54.60	62	Umbric Paleaquult
6	Extra	Shallow Part of Bay	54.58	15	Typic Albaquult

Table 2. Weighted average sand, silt, clay, carbon and phosphorus at the 12 sites studied.

Site	Elevation (m)	Sand[1] (%)	Silt[1] (%)	Clay[1] (%)	Carbon[2] (%)	Phosphorus[1] (mg/kg)
8	57.61	93.3	3.6	3.2	0.90	39.0
3	56.46	94.0	3.9	2.1	0.75	59.8
12	56.40	90.6	3.8	5.6	2.42	49.9
7	56.10	88.9	5.5	5.6	0.17	59.9
1	55.63	79.0	9.0	12.0	1.48	10.7
9	55.27	93.8	3.7	2.4	4.48	9.3
4	55.14	75.4	8.8	15.8	3.41	2.5
10	55.13	64.6	11.8	23.7	4.75	2.0
11	55.11	69.1	17.3	13.5	3.82	2.0
2	54.95	72.5	10.7	16.7	1.79	2.0
5	54.60	61.5	17.0	21.5	6.12	2.0
6	54.58	65.6	10.8	23.6	2.30	2.0

[1]Weighted average for 0 to 100 cm depth.
[2]Weighted average for 0 to 20 cm depth.

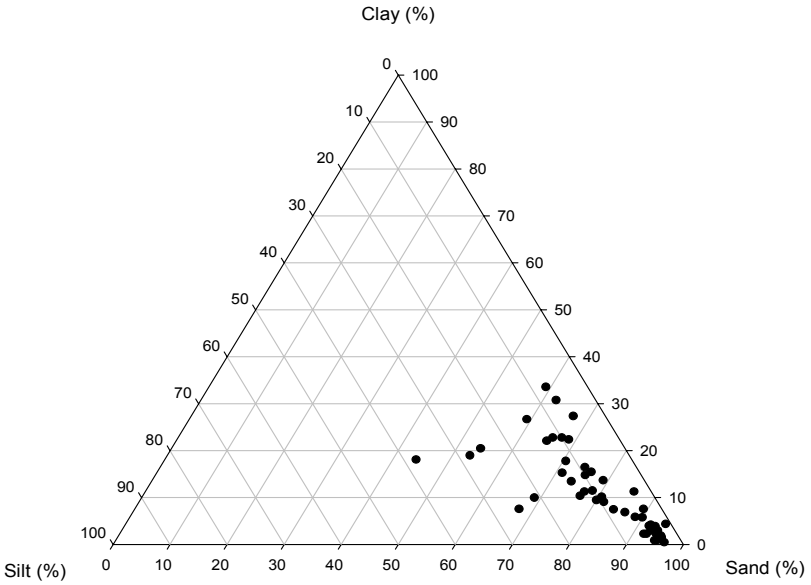

Figure 1. Distribution of sand, silt and clay by horizon (for horizons within 100 cm of the surface) at the 12 sites studied.

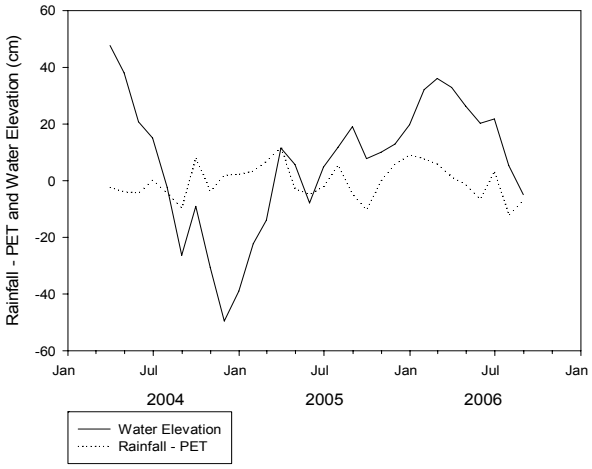

Figure 2. Water elevation at Site 6, and rainfall minus potential evapotranspiration (PET) over 30 months from March 21, 2004 to September 2, 2006.

Table 3. Modeled water level at Site 6 over 47 years (1960-2006). Percent of time (and number of years) the water is at each level.

	Below Ground (<54.58 m)	Above Ground but not at Maximum (54.58-55.09 m)	At Maximum Elevation (55.10 m)
January	8.51% (4y)	72.34% (34y)	19.15% (9y)
February	0% (0y)	76.60% (36y)	23.40% (11y)
March	0% (0y)	63.83% (30y)	36.17% (17y)
April	2.13% (1y)	76.60% (36y)	21.28% (10y)
May	6.38% (3y)	80.85% (38y)	12.77% (6y)
June	8.51% (4y)	80.85% (38y)	10.64% (5y)
July	21.28% (10y)	72.34% (34y)	6.38% (3y)
August	38.30% (18y)	51.06% (24y)	10.64% (5y)
September	34.04% (16y)	63.83% (30y)	2.13% (1y)
October	27.66% (13y)	70.21% (33y)	2.13% (1y)
November	29.79% (14y)	68.09% (32y)	2.13% (1y)
December	21.28% (10y)	70.21% (33y)	8.51% (4y)

Hydrology

Rainfall at Bamberg ranged from a low of 70.8 cm to a high of 173.4 cm for the calendar years 1952 to 2006, with median precipitation being 118.5 cm. Annual potential evapotranspiration (PET) was estimated by the Thornthwaite

(1948) method to be 94.9 cm. The year proceeding initiation of our study from March, 2003 to February, 2004 had a total of 182.5 cm precipitation. Our first measurement of the water level in March 21, 2004 was at an elevation above sea level of 55.10 m. Given the high rainfall from March, 2003 to February, 2004, and the difference in vegetation above and below the 55.10 m elevation, we consider 55.10 m to be the maximum water level possible in this bay. Figure 2 shows the change in water level observed at Site 6 along with the net precipitation (rainfall minus PET) from March, 2004 to August, 2006. Water level declined from March 21, 2004 to December 18, 2004, followed by a rise until March 11, 2006 and then declined to the last measurement on September 2, 2006. We modeled the water level with the following equation:

$$\text{Water Elevation (m)} = 3.57 + 0.934*A + 0.0164*B - 0.0137*C \quad R^2=0.88 \quad (1)$$

Where A=Previous Month's Water Elevation (m), B=Monthly Rainfall (cm), and C=Monthly PET (cm). We used this equation to model the water level from 1960 to 2006 (Table 3). We began in January, 1960, because 1959 had the fourth highest calendar year precipitation (161.1 cm) on record, and we could assume water level was at 55.10 m in December, 1959. The shallow part of the bay is likely to be covered with water in February and March, every year. When the Canby's Dropwort is in flower, in July and August, there is a 21% and 38% chance, respectively, that the ground surface in the shallow part of the bay will be dry. Pyzoha et al. (2008) proposed a four step cycle where precipitation, evapotranspiration and flow into or out of the bay are linked. Our model is a quantitative alternative to their conceptual characterization of the hydrological cycle in a Carolina bay.

Geomorphology

Inspection of a USGS topographic map of the vicinity around the Lisa Matthews Memorial Bay shows two large Carolina bays nearby. One Carolina bay is to the north and the other to the west. The "north-side upland" of the Lisa Matthews Memorial Bay appears to be the southern rim of the Carolina bay to the north. Similarly, the west side of the Lisa Matthews Memorial Bay appears to be the eastern rim of a Carolina bay to the west. The Lisa Matthews Memorial Bay seems to be sandwiched between these two Carolina bays and somewhat higher ground of the "south-side upland" and immediately to the east across US Highway 301. Sites 5, 6, 10 and 11 indicate the bay has a sandy clay loam and sandy clay texture bottom (Note that the Btg horizon of Site 11 has 21.4% fine silt, 0.002-0.005 mm, which feels like clay in the field.). Zones

of sandy clay loam texture were also found beginning at elevations of 54.13-54.54 m at the Grossarenic Hapludult (Site 12), the Aeric Albaquult (Site 1), and one of the Typic Albaquults (Site 4).

Figure 1 indicates most horizons in the surface 100 cm are sandy (sand, loamy sand, and sandy loam texture). The four upland sites (Sites 8, 3, 12, and 7) averaged 88.9-94.0% sand and 2.1-5.6% clay in the 0-100 cm depth. The Umbric Endoaquod (Site 9) was also sandy (93.8% sand and 2.4% clay in the 0-100 cm depth). Site 9 was close to the deep part of the bay and the sand appeared to have sloughed from the bay rim to this position. Also, the spodic horizons at Site 9 were formed by fluctuations of the ground water associated with rise and fall of the water level in the bay. The Aeric Albaquult (Site 1) was intermediate in elevation and had 79.0% sand and 12.0% clay in the 0-100 cm depth. The Typic Albaquults (Sites 4, 10, 11, 2, and 6) and the Umbric Paleaquult (Site 5) averaged 13.5-23.7% clay in the 0-100 cm depth, considerably more clay than the uplands.

Besides textural differences between the uplands and the bay margin/shallow part of the bay, there were differences in phosphorus concentrations. The four upland sites (Sites 8, 3, 12, and 7) had 39.0-59.9 mg/kg P in 0-100 cm depth, whereas the five Typic Albaquults (Sites 4, 10, 11, 2, and 6) and the Umbric Paleaquult (Site 5) averaged 2.0-2.5 mg/kg P in 0-100 cm depth. Sites 1 (Aeric Albaquult) and 9 (Umbric Endoaquod) had intermediate P concentrations, 10.7 and 9.3 mg/kg P, respectively. Phosphorus concentrations were a good indicator of the overlaying sand which forms the uplands at the Lisa Matthews Memorial Bay.

The uppermost gleyed horizons throughout the preserve had few bright-colored mottles, indicating the ground water level did not fluctuate greatly. The water level measurements in the bay showed the level could range from a high of 55.10 m to a low of 54.07 m. Similarly, the spodic horizons at Site 9 began at 54.72 m and 54.44 m indicating ground water levels were bimodal.

CONCLUSION

Soils at twelve sites at the Lisa Matthews Memorial Bay were examined, described, and sampled to determine geomorphologic relationships. In addition, elevation of each site and water level in the bay over a 30-month period was measured.

The Lisa Matthews Memorial Bay appears to be sandwiched between two Carolina bays and somewhat higher ground on the south side and east side.

The bay has a sandy clay loam (and sandy clay) bottom, while the uplands are sandy (sand, loamy sand, and sandy loam). High phosphorus concentrations were found to be associated with the upland sand deposits, and there was little P in the Typic Albaquults (5 sites) and the Umbric Paleaquult (1 site) on the bay margin and in the shallow part of the bay.

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APPENDIX 1. TYPIC DYSTRUDEPT, SITE 8, ELEVATION 57.61 M.

Site	8	8	8	8	8	8
Horizon	Ap	Bw1	Bw2	Bw3	Bw4	Bt
Depth (cm)	0-20	20-75	75-125	125-175	175-205	205-250
Matrix Color	10YR5/4	10YR5/6	10YR5/6	10YR5/6	10YR5/6	7.5YR5/6
Mottles						
Very Coarse Sand (%)	1.2	0.7	1.4	2.8	2.4	2.2
Coarse Sand (%)	26.7	16.8	24.1	20.6	14.6	15.2
Medium Sand (%)	48.4	49.6	53.2	41.5	35.6	36.3
Fine Sand (%)	14.3	20.0	14.8	22.4	29.2	27.8
Very Fine Sand (%)	2.7	5.0	2.1	6.8	8.2	8.8
Total Sand (%)	93.3	92.2	95.6	94.1	90.0	90.4
Silt (%)	2.9	4.0	3.1	3.5	5.4	4.8
Clay (%)	3.7	3.8	1.3	2.4	4.6	4.8
Textural Class (USDA)	S	S	S	S	S	S
Carbon (%)	0.898	0.216	0.075	0.054	0.091	0.290
Nitrogen (%)	0.045	0.014	0.010	0.009	0.016	0.029
C:N Ratio	20.15	15.19	7.33	6.08	5.88	10.04
pH	5.01	5.07	5.23	5.48	5.37	5.39
Phosphorus (mg/kg)	73	38	14	11	31	15
Potassium (mg/kg)	15	11	8	19	15	15
Calcium (mg/kg)	92	72	77	125	125	305
Magnesium (mg/kg)	16	15	12	16	14	28
Manganese (mg/kg)	16.1	4.6	1.8	3.6	0.8	0.5
Iron (mg/kg)	42.0	19.1	10.1	15.0	26.3	18.5

APPENDIX 2. TYPIC DYSTRUDEPT, SITE 3, ELEVATION 56.46 M.

Site	3	3	3	3	3	3
Horizon	Ap	E	Bw	C	Cg1	Cg2
Depth (cm)	0-15	15-32	32-64	64-162	162-206	206-260
Matrix Color	10YR6/4	10YR5/3	7.5YR5/4	10YR7/2	10YR5/2	10YR4/2
Mottles						
Very Coarse Sand (%)	5.7	3.7	2.8	2.5	4.1	3.5
Coarse Sand (%)	17.9	14.9	9.5	9.9	18.5	11.2
Medium Sand (%)	28.8	27.4	21.3	18.3	23.1	32.5
Fine Sand (%)	32.2	36.3	45.7	44.0	36.3	28.6
Very Fine Sand (%)	9.5	11.9	13.8	20.0	5.5	11.9
Total Sand (%)	94.2	94.2	93.1	94.7	87.5	87.7
Silt (%)	3.6	3.0	3.5	4.7	2.9	6.2

Clay (%)	2.2	2.8	3.4	0.7	9.6	6.1
Textural Class (USDA)	S	S	S	S	LS	LS/S
Carbon (%)	0.837	0.484	0.554	0.041	0.154	0.155
Nitrogen (%)	0.039	0.021	0.029	0.003	0.023	0.018
C:N Ratio	21.65	22.53	18.97	13.28	6.74	8.46
pH	4.91	4.81	4.77	5.38	4.82	4.90
Phosphorus (mg/kg)	88	95	85	9	5	5
Potassium (mg/kg)	13	12	20	25	32	31
Calcium (mg/kg)	62	48	77	42	88	55
Magnesium (mg/kg)	11	9	14	10	13	12
Manganese (mg/kg)	6.0	7.8	4.7	0.8	0.3	0.4
Iron (mg/kg)	44.3	24.2	2.6	2.2	6.9	4.6

APPENDIX 3. GROSSARENIC HAPLUDULT, SITE 12, ELEVATION 56.40 M.

Site	12	12	12	12	12	12	12
Horizon	A	Bw1	Bw2	Bwg	Eg	Btg1	Btg2
Depth (cm)	0-16	16-50	50-90	90-125	125-186	186-225	225-250
Matrix Color	10YR3/2	10YR5/4	10YR5/4	10YR6/2	10YR6/2	10YR6/2	7.5YR5/6
Mottles				Many 10YR6/4		Many 7.5YR5/6	Common 10YR6/2
Very Coarse Sand (%)	2.1	2.2	1.8	2.1	1.0	1.1	1.3
Coarse Sand (%)	24.7	25.4	24.4	25.7	11.7	10.2	10.6
Medium Sand (%)	38.6	42.4	44.6	36.9	26.0	23.0	26.4
Fine Sand (%)	15.4	16.1	17.8	21.5	29.2	28.2	27.6
Very Fine Sand (%)	5.1	3.9	3.7	6.9	15.5	10.3	8.1
Total Sand (%)	85.9	90.1	92.4	93.0	83.4	72.8	74.1
Silt (%)	3.0	4.3	3.6	4.2	9.1	6.2	4.1
Clay (%)	11.1	5.6	4.0	2.8	7.5	21.0	21.8
Textural Class (USDA)	LS	S	S	S	LS	SCL	SCL
Carbon (%)	2.928	0.412	0.154	0.072	0.070	0.100	0.117
Nitrogen (%)	0.167	0.070	0.054	0.054	0.051	0.053	0.053
C:N Ratio	17.50	5.85	2.86	1.34	1.37	1.90	2.24
pH	5.07	5.14	4.81	4.81	4.88	4.61	4.60
Phosphorus (mg/kg)	97	66	26	15	42	10	2

Appendix 3. (Continued)

Potassium (mg/kg)	52	33	30	42	59	33	27
Calcium (mg/kg)	195	72	44	33	52	64	50
Magnesium (mg/kg)	36	18	14	10	26	24	19
Manganese (mg/kg)	21.6	3.0	0.6	0.2	0.3	0.2	0.1
Iron (mg/kg)	22.4	26.3	29.1	31.7	34.0	31.5	12.9

APPENDIX 4. TYPIC DYSTRUDEPT, SITE 7, ELEVATION 56.10 M.

Site	7	7	7	7	7
Horizon	Ap	Bw1	Bw2	Cg1	Cg2
Depth (cm)	0-25	25-83	83-150	150-190	190-250
Matrix Color	10YR4/3	10YR5/6	10YR6/4 and 7.5YR5/6	10YR5/2	10YR5/2
Mottles					
Very Coarse Sand (%)	3.3	1.1	1.1	1.6	2.9
Coarse Sand (%)	26.6	21.3	22.7	27.6	17.5
Medium Sand (%)	42.7	47.2	45.0	45.1	27.8
Fine Sand (%)	11.9	16.5	19.4	13.3	22.5
Very Fine Sand (%)	1.9	2.7	4.7	2.2	6.6
Total Sand (%)	86.5	88.8	92.9	89.9	77.4
Silt (%)	6.9	5.4	3.6	5.1	6.3
Clay (%)	6.7	5.7	3.5	5.1	16.3
Textural Class (USDA)	LS	S	S	S	SL
Carbon (%)	0.167	0.143	0.147	0.537	0.164
Nitrogen (%)	0.029	0.018	0.017	0.032	0.024
C:N Ratio	5.71	7.90	8.43	16.94	6.69
pH	4.83	4.84	4.85	4.72	4.63
Phosphorus (mg/kg)	25	82	36	30	20
Potassium (mg/kg)	26	12	14	36	34
Calcium (mg/kg)	296	71	36	35	43
Magnesium (mg/kg)	25	11	10	11	26
Manganese (mg/kg)	54.1	11.4	1.6	0.6	0.4
Iron (mg/kg)	42.6	50.8	71.8	39.3	53.1

APPENDIX 5. AERIC ALBAQUULT, SITE 1, ELEVATION 55.63 M.

Site	1	1	1	1	1	1
Horizon	A	E	Eg	EBg	Bg	Btg
Depth (cm)	0-6	6-31	31-56	56-118	118-150	150-175
Matrix Color	10YR3/2	10YR4/4	10YR5/2	10YR5/2	10YR6/1	7.5YR5/6
Mottles						Many 10YR6/1
Very Coarse Sand (%)	2.2	2.7	1.9	1.6	3.2	2.7
Coarse Sand (%)	12.1	10.4	9.4	10.1	11.7	12.0
Medium Sand (%)	28.7	25.0	21.9	21.7	23.1	20.7
Fine Sand (%)	30.7	33.5	35.4	30.2	27.6	20.4
Very Fine Sand (%)	8.0	12.6	12.2	11.1	9.3	5.6
Total Sand (%)	81.7	84.2	80.8	74.7	74.9	61.3
Silt (%)	9.4	8.6	9.3	9.0	8.5	3.5
Clay (%)	8.9	7.3	10.0	16.3	16.6	35.2
Textural Class (USDA)	LS	LS	LS	SL	SL	SCL
Carbon (%)	3.148	0.764	0.354	0.166	0.129	0.285
Nitrogen (%)	0.148	0.030	0.024	0.021	0.019	0.027
C:N Ratio	21.30	25.20	14.71	7.84	6.71	10.36
pH	4.14	4.84	4.82	4.79	4.68	4.54
Phosphorus (mg/kg)	14	28	6	3	5	2
Potassium (mg/kg)	66	44	31	26	38	31
Calcium (mg/kg)	236	57	40	143	99	116
Magnesium (mg/kg)	22	12	11	18	17	23
Manganese (mg/kg)	2.9	4.4	2.0	0.4	0.2	0.2
Iron (mg/kg)	40.1	19.8	19.2	30.3	45.1	21.9

APPENDIX 6. UMBRIC ENDOAQUOD, SITE 9, ELEVATION 55.27 M.

Site	9	9	9	9	9	9	9
Horizon	A1	A2	Eg1	Bhs1	Eg2	Bhs2	Cg
Depth (cm)	0-8	8-18	18-55	55-72	72-83	83-90	90-100
Matrix Color	10YR2/1	10YR3/2	10YR6/2	10YR2/1	10YR4/2	10YR2/1	10YR4/2
Mottles							
Very Coarse Sand (%)	3.5	1.3	1.7	1.7	1.6	2.1	1.2
Coarse Sand (%)	37.3	29.2	22.3	20.3	31.4	26.1	21.6
Medium Sand (%)	39.2	50.2	47.3	45.7	49.2	47.7	48.9
Fine Sand (%)	10.9	11.6	21.9	19.8	12.3	17.2	22.0
Very Fine Sand (%)	1.3	0.4	2.0	2.0	0.7	1.8	2.8
Total Sand (%)	92.1	92.6	95.2	89.4	95.3	94.9	96.6
Silt (%)	5.7	5.3	4.0	3.2	3.0	0.9	3.1
Clay (%)	2.1	2.1	0.8	7.4	1.7	4.2	0.3
Textural Class (USDA)	S	S	S	S	S	S	S
Carbon (%)	6.986	3.343	0.095	1.028	0.367	0.872	0.277
Nitrogen (%)	0.332	0.158	0.002	0.068	0.011	0.085	0.071
C:N Ratio	21.07	21.15	47.44	15.07	32.40	10.26	3.92
pH	4.26	4.38	6.43	4.40	4.98	4.88	5.21
Phosphorus (mg/kg)	12	6	2	18	12	27	7
Potassium (mg/kg)	189	110	43	37	41	72	34
Calcium (mg/kg)	311	125	44	51	41	46	38
Magnesium (mg/kg)	74	30	13	13	11	14	11
Manganese (mg/kg)	8.8	1.7	0.2	0.2	0.2	0.2	0.2
Iron (mg/kg)	19.1	15.3	2.5	5.1	3.3	3.8	2.7

APPENDIX 7. TYPIC ALBAQUULT, SITE 4, ELEVATION 55.14 M.

Site	4	4	4	4	4
Horizon	A1	A2	Eg	Btg1	Btg2
Depth (cm)	0-25	25-41	41-80	80-150	150-180
Matrix Color	10YR3/1	10YR4/1	10YR5/1	10YR6/1	10YR6/1
Mottles				Common 10YR5/6	Common 10YR5/6
Very Coarse Sand (%)	3.4	3.2	2.2	1.6	2.0
Coarse Sand (%)	16.2	13.3	12.0	10.0	8.2
Medium Sand (%)	28.3	26.6	26.1	20.7	18.6
Fine Sand (%)	25.0	26.0	30.1	23.3	24.0
Very Fine Sand (%)	5.7	7.8	9.0	6.9	8.5
Total Sand (%)	78.5	76.9	79.3	62.5	61.3
Silt (%)	10.2	13.0	7.3	6.9	4.3
Clay (%)	11.3	10.2	13.5	30.6	34.4
Textural Class (USDA)	SL	SL	SL	SCL	SCL
Carbon (%)	3.413	1.817	0.468	0.311	0.311
Nitrogen (%)	0.198	0.086	0.034	0.029	0.025
C:N Ratio	17.24	21.01	13.82	10.66	12.41
pH	4.20	4.60	4.80	4.49	4.41
Phosphorus (mg/kg)	4	2	2	2	2
Potassium (mg/kg)	66	44	50	27	23
Calcium (mg/kg)	42	44	52	63	63
Magnesium (mg/kg)	20	16	21	26	28
Manganese (mg/kg)	0.7	0.9	0.9	1.3	1.7
Iron (mg/kg)	57.2	48.2	84.5	93.6	73.1

APPENDIX 8. TYPIC ALBAQUULT, SITE 10, ELEVATION 55.13 M.

Site	10	10	10	10
Horizon	A	Eg	BEg	Btg
Depth (cm)	0-11	11-40	40-55	55-100
Matrix Color	10YR2/1	10YR4/1	10YR5/1	10YR6/1
Mottles				
Very Coarse Sand (%)	4.0	1.3	1.6	1.7
Coarse Sand (%)	10.3	9.3	10.5	8.7
Medium Sand (%)	20.0	22.4	24.9	19.1
Fine Sand (%)	15.0	28.0	28.8	22.6
Very Fine Sand (%)	4.0	10.3	9.8	7.2
Total Sand (%)	53.3	71.3	75.6	59.3
Silt (%)	27.9	13.6	9.8	7.3
Clay (%)	18.8	15.1	14.6	33.4
Textural Class (USDA)	SL	SL	SL	SCL
Carbon (%)	8.106	0.657	0.277	0.236
Nitrogen (%)	0.370	0.123	0.116	0.096
C:N Ratio	21.94	5.32	2.40	2.46
pH	4.03	4.55	4.62	4.47
Phosphorus (mg/kg)	2	2	2	2
Potassium (mg/kg)	72	59	49	23
Calcium (mg/kg)	61	38	41	92
Magnesium (mg/kg)	26	14	13	14
Manganese (mg/kg)	1.5	0.3	0.2	0.7
Iron (mg/kg)	60.5	31.2	45.9	56.6

APPENDIX 9. TYPIC ALBAQUULT, SITE 11, ELEVATION 55.11 M.

Site	11	11	11	11
Horizon	A	Eg	BEg	Btg
Depth (cm)	0-12	12-37	37-56	56-100
Matrix Color	10YR2/1	10YR5/2	10YR5/2	10YR6/2
Mottles				Many 2.5YR4/8 10YR5/6
Very Coarse Sand (%)	1.6	1.3	1.1	1.3
Coarse Sand (%)	12.0	11.5	10.4	8.5
Medium Sand (%)	27.3	25.4	22.5	23.3
Fine Sand (%)	26.4	25.4	26.1	27.0
Very Fine Sand (%)	6.5	7.1	7.4	7.5
Total Sand (%)	73.8	70.7	67.5	67.6
Silt (%)	12.9	11.6	9.9	25.0
Clay (%)	13.3	17.6	22.6	7.4
Textural Class (USDA)	SL	SL	SCL	SL
Carbon (%)	5.998	0.555	0.342	0.169
Nitrogen (%)	0.344	0.104	0.088	0.071
C:N Ratio	17.45	5.35	3.88	2.37
pH	3.99	4.71	4.65	4.56
Phosphorus (mg/kg)	2	2	2	2
Potassium (mg/kg)	61	41	32	19
Calcium (mg/kg)	54	39	41	43
Magnesium (mg/kg)	20	14	16	14
Manganese (mg/kg)	0.7	0.3	0.3	0.2
Iron (mg/kg)	91.7	64.0	79.9	19.0

APPENDIX 10. TYPIC ALBAQUULT, SITE 2, ELEVATION 54.95 M.

Site	2	2	2	2	2	2
Horizon	A	Eg	Btg1	Btg2	Btg3	C
Depth (cm)	0-18	18-30	30-57	57-108	108-170	170-190
Matrix Color	10YR3/1	10YR5/2	10YR4/1	10YR5/6	10YR5/6	10YR5/2
Mottles				Common 10YR5/2	Many 10YR5/2	
Very Coarse Sand (%)	2.7	1.2	0.9	2.5	1.6	2.8
Coarse Sand (%)	14.6	10.9	7.5	13.1	11.4	19.7
Medium Sand (%)	29.2	24.6	19.3	25.1	25.7	32.4
Fine Sand (%)	26.7	28.2	22.6	25.5	29.0	23.0
Very Fine Sand (%)	7.0	12.3	9.0	10.1	8.5	6.3
Total Sand (%)	80.2	77.2	59.4	76.3	76.2	84.2
Silt (%)	10.5	11.7	14.2	8.3	5.2	1.9
Clay (%)	9.3	11.1	26.5	15.3	18.6	13.8
Textural Class (USDA)	LS	SL	SCL	SL	SL	LS
Carbon (%)	1.950	0.331	0.435	0.232	0.167	0.130
Nitrogen (%)	0.118	0.026	0.056	0.028	0.023	0.022
C:N Ratio	16.51	12.89	7.73	8.43	7.32	5.97
pH	4.47	4.76	4.55	4.51	4.48	4.65
Phosphorus (mg/kg)	2	2	2	2	2	4
Potassium (mg/kg)	35	19	11	25	31	29
Calcium (mg/kg)	95	58	133	61	54	76
Magnesium (mg/kg)	19	12	18	14	18	27
Manganese (mg/kg)	0.9	0.3	0.5	0.1	0.2	0.2
Iron (mg/kg)	65.8	108.4	130.9	48.1	30.4	36.7

APPENDIX 11. UMBRIC PALEAQUULT, SITE 5, ELEVATION 54.60 M.

Site	5	5	5	5	5
Horizon	A1	A2	EBg	Btg1	Btg2
Depth (cm)	0-36	36-62	62-117	117-160	160-175
Matrix Color	10YR3/1	10YR4/1	10YR4/1	10YR5/2	10YR5/2
Mottles					
Very Coarse Sand (%)	2.0	1.4	2.0	2.4	1.6
Coarse Sand (%)	13.5	16.9	15.4	10.9	7.9
Medium Sand (%)	23.9	31.5	26.7	23.3	16.8
Fine Sand (%)	10.7	11.4	14.7	24.3	18.5
Very Fine Sand (%)	4.4	4.7	6.4	8.3	5.6
Total Sand (%)	54.4	65.9	65.2	69.2	50.4
Silt (%)	25.3	11.4	12.9	10.5	10.0
Clay (%)	20.3	22.6	21.9	20.3	39.7
Textural Class (USDA)	SCL/SL	SCL	SCL	SCL/SL	C/SC
Carbon (%)	6.119	1.136	0.688	0.303	0.338
Nitrogen (%)	0.378	0.088	0.055	0.031	0.040
C:N Ratio	16.20	12.94	12.47	9.88	8.40
pH	4.58	4.82	4.82	4.58	4.36
Phosphorus (mg/kg)	2	2	2	2	2
Potassium (mg/kg)	64	59	64	33	21
Calcium (mg/kg)	112	157	212	109	129
Magnesium (mg/kg)	24	35	49	34	68
Manganese (mg/kg)	2.2	2.7	4.3	1.1	0.7
Iron (mg/kg)	37.0	30.3	27.6	15.1	24.5

APPENDIX 12. TYPIC ALBAQUULT, SITE 6, ELEVATION 54.58 M.

Site	6	6	6	6	6
Horizon	A	E	BEg	Btg1	Btg2
Depth (cm)	0-10	10-15	15-50	50-105	105-150
Matrix Color	10YR3/1	10YR6/2	10YR4/1	10YR6/1	10YR7/1
Mottles				Many 7.5YR5/6	
Very Coarse Sand (%)	1.2	1.5	1.7	2.1	2.1
Coarse Sand (%)	7.1	10.4	9.9	10.2	8.9
Medium Sand (%)	14.7	19.6	20.8	20.5	19.6
Fine Sand (%)	15.7	26.0	27.0	23.9	27.5
Very Fine Sand (%)	5.6	11.6	9.5	10.5	10.3
Total Sand (%)	44.3	69.1	68.9	67.2	68.4
Silt (%)	37.8	21.1	8.9	5.7	8.0
Clay (%)	17.9	9.8	22.2	27.2	23.6
Textural Class (USDA)	L	SL	SCL	SCL	SCL
Carbon (%)	4.173	0.638	0.239	3.295	0.143
Nitrogen (%)	0.291	0.044	0.034	0.139	0.010
C:N Ratio	14.34	14.64	7.05	23.69	13.88
pH	4.52	4.81	4.61	4.47	4.50
Phosphorus (mg/kg)	2	2	2	2	2
Potassium (mg/kg)	49	48	24	22	27
Calcium (mg/kg)	94	52	82	73	95
Magnesium (mg/kg)	22	14	30	41	56
Manganese (mg/kg)	1.1	0.8	0.6	0.4	5.8
Iron (mg/kg)	50.8	27.7	15.7	6.4	4.1