Properties of forest soils across the South, 2000 – 2004

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~ Introduction ~

Soil is a key aspect of forest ecosystems and is derived from parent materials of different mineral compositions resulting in properties that influence the nature of the plant life an ecosystem will support (Pritchett and Fisher 1987). Likewise, the modification of soils, through natural or anthropogenic means has the potential to affect the associated vegetation.

Bulk density can range from 0.1 g/cm³ for histosols, to 2.2 g/cm³ for compacted glacial tills. The upper threshold for bulk density is considered 1.6 g/cm³; above this, root growth becomes impaired.

Soil pH is a major factor in determining what types of vegetation will dominate a landscape (Brady & Weil 1996). The pH of most soils is typically between 4.0 and 8.5 (Black 1957). Soil pH, base-forming cations, such as calcium, and exchangeable aluminum are intricately related. As base-forming cations are leached from the soil, aluminum concentrations increase, and pH decreases. This can lead to calcium deficiencies and aluminum toxicity.

~ Methods ~

Field Methods

Soil samples were collected by the Forest Inventory and Analysis (FIA) unit of the USDA Forest Service on forest health plots and analyzed in a laboratory for various physical and chemical properties. Using an impact-driven corer, mineral soil was collected in two layers, 0 – 10 cm (M1) and 10 – 20 cm (M2), and analyzed for bulk density, pH, carbon, and a variety of exchangeable cations (USDA 2004).

Laboratory Methods

(O'Neil, Amacher, and Perry 2005)

* pH was analyzed via a combination pH electrode in a 1:1 soil-water suspension

* Exchangeable cations were analyzed using a 1 M NH_4Cl extraction with inductively coupled plasma optical emission spectroscopy

* A combustion analyzer was used for determination of organic carbon

~ Results ~

~ Bulk Density ~

Bulk density averaged 1.14 g/cm³ (SD=0.31) (n=1364) for the M1 layer, while the M2 layer averaged 1.45 g/cm³ (SD=0.25) (n=1357). The majority (56%) of M1 samples had bulk densities < 1.20 g/cm³. Most M2 samples (65%) were ≥1.40 g/cm³ (fig. 1).

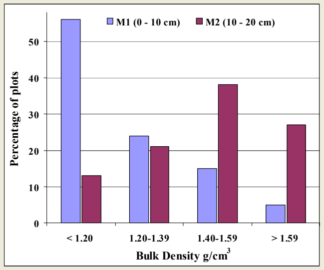

Figure 1. Distribution of bulk density of mineral soil by layer, all plots.

Table 1. Distribution of bulk density values by layer and State

State	Layer	Bulk Density g/cm³ < 1.20	1.20-1.39	1.40-1.59	> 1.59	N
		----------Percentage of Plots----------				
Alabama	M1	63	24	7	6	176
	M2	14	22	37	27	175
Arkansas	M1	53	25	17	5	87
	M2	11	20	33	36	83
Florida	M1	47	26	22	5	58
	M2	7	18	48	27	60
Georgia	M1	48	25	19	8	202
	M2	9	17	28	46	198
Kentucky	M1	61	32	7	0	122
	M2	9	24	52	16	122
Louisiana	M1	55	30	12	3	106
	M2	19	20	43	18	108
North Carolina	M1	74	12	10	3	121
	M2	24	30	33	13	123
South Carolina	M1	57	29	8	6	97
	M2	8	17	44	32	101
Tennessee	M1	81	13	4	2	106
	M2	32	27	33	9	104
Texas	M1	31	26	32	11	183
	M2	7	16	46	31	180
Virginia	M1	59	20	17	4	106
	M2	11	27	32	30	103

Texas and Georgia had the highest percentage of M1 samples with bulk densities > 1.59 g/cm³. Georgia and Arkansas had the highest percentage of M2 samples with bulk densities > 1.59 g/cm³ (Table 1).

~ Exchangeable Aluminum ~

Thirty percent of M1 and 35% of M2 samples had a high amount of aluminum (>100 mg/kg) (fig. 2). Adverse effects on vegetation are possible at these levels. Nearly all samples with high Al, had a pH ≤ 5.0.

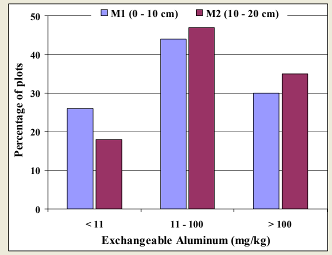

Figure 2. Distribution of aluminum in mineral soil by layer, all plots.

~ Carbon ~

Organic carbon (M1 + M2) averaged 32.7 Mg/ha (SD=22.7). Seventy-five percent of all plots had > 20.0 Mg/ha of organic carbon (Table 2). Florida and Louisiana had the highest percentage of plots with < 10.0 Mg/ha of organic carbon.

Table 2. Distribution of organic carbon for mineral soil (M1+M2) by State

State	Organic Carbon (Mg/ha) < 10.0	10.0-20.0	20.1-40.0	> 40.0	N
	---------- Percentage of plots ----------				
Alabama	4	18	55	23	171
Arkansas	5	16	66	13	82
Florida	14	24	33	29	51
Georgia	5	19	52	24	197
Kentucky	4	9	66	21	76
Louisiana	12	22	53	12	98
North Carolina	5	15	39	41	124
South Carolina	8	25	40	26	99
Tennessee	5	10	63	23	105
Texas	8	30	46	16	178
Virginia	3	10	64	24	105
All	6	19	52	23	1286

~ pH ~

Average pH was 5.1 (SD=0.96) (n=1506) for the M1 layer, and 5.2 (SD=0.86) (n=1477) for the M2 layer. Sixty percent of M1 samples and 57% of M2 samples had a pH ≤ 5.0 (fig. 3). At these levels of pH there may be sufficient amounts of exchangeable aluminum present to impact plant growth.

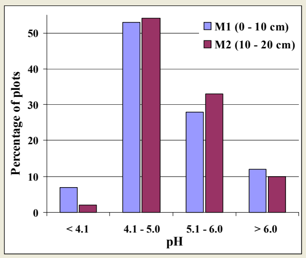

Figure 3. Distribution of pH of mineral soil by layer, all plots.

North Carolina and South Carolina had the highest percentage of M1 samples with pH ≤ 5.0, 79% and 76%, respectively (fig. 4). The majority of very low pH values (< 4.1) were from the coastal plain across the South. Nearly all M1 samples from West Texas had a pH > 6.0.

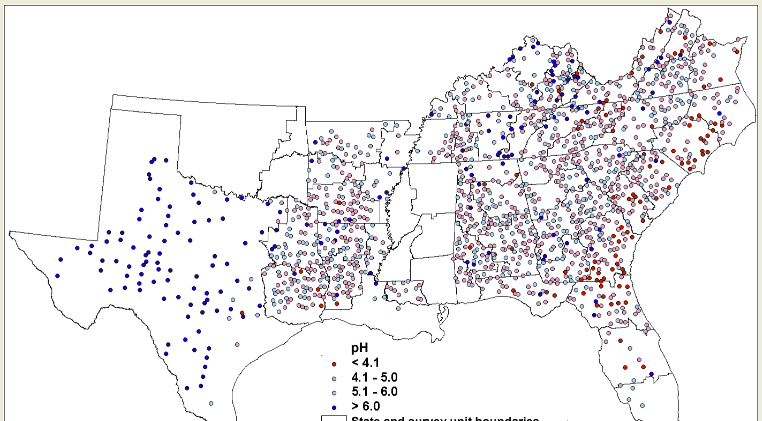

Figure 4. pH of mineral soil (0-10 cm) on each plot*

*Plot locations are approximate

~ Conclusions ~

In the South, high bulk densities may be a cause for concern due to the potential for impaired root growth at ≥ 1.6 g/cm³. Overall, 5% of M1 and 27% of M2 samples had bulk densities ≥ 1.6 g/cm³.

Low soil pH and high concentrations of aluminum are also potential issues. More than 50 % of samples had a pH of < 5.0, and about 30% of samples had > 100 mg/kg of aluminum. Given the low pH and high amounts of aluminum, low Ca:Al ratios in the soil solution are possible. Typically, Ca:Al ratios of < 1.0 in soil solution are considered the threshold below which plant growth is reduced.

Losses of base cations, such as calcium, from soils and the mobilization of aluminum may contribute to nutritional imbalances and ultimately to forest decline as well as to water quality degradation (Agren and Bosatta 1988; Garten and Van Miegroet 1994). On a more positive note, the majority of samples had fairly high amounts of organic carbon, which is a result of high amounts of organic matter. This can result in increased buffering capacity, better retention of calcium, and a more stable pH.

~ Literature Cited ~

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~ CITATION ~

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