SOIL CONDITIONS ACROSS VIRGINIA, 2000 – 2002

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~ABSTRACT~

The health and productivity of a forest ecosystem depends, to a large degree, upon the physical and chemical properties of the soil. The modification of these soils, through natural or anthropogenic means, has the potential to affect the associated vegetation. Recently, the USDA Forest Service began monitoring soil conditions across the United States. Between 2000 and 2002, soil samples were collected for laboratory analysis from the forest floor layer (litter + duff) and the upper mineral portion of the soil at two depths, 0 - 10 cm (M1) and 10 - 20 cm (M2).

Bulk density averaged 1.10 g/cm³ for all M1 samples (n=69), while the M2 layer averaged 1.45 g/cm³ (n=68). Average bulk density for both layers was highest in the Coastal Plain, and lowest in the Northern Mountains. Overall, 21 plots (31%) had bulk densities ≥ 1.6 g/cm³ for either the M1 or the M2 layer. Average pH for the M1 and M2 layers was 4.8 (n=76) and 4.9 (n=76), respectively. The majority of samples had a pH < 5.0. Exchangeable aluminum averaged 148.5 mg/kg (n=78) and 144.6 mg/kg (n=76) for the M1 and M2 layers, respectively. For both layers, aluminum was highest in the Mountains and lowest in the Southern Piedmont and was negatively correlated with pH ($p < 0.0001$). Soils with lower pH values and higher exchangeable aluminum had lower proportions of exchangeable base-forming cations. Exchangeable calcium averaged 447.4 mg/kg for the M1 layer, and 165.3 mg/kg for the M2 layer. The forest floor accounted for 11.9 Mg/ha of organic carbon, and the M1 and M2 layers accounted for 25.6 and 13.0 Mg/ha, respectively. All three layers, together, accounted for 2.4 Mg/ha of nitrogen.

Preliminary analysis showed that in Virginia high bulk densities may be cause for concern due to the potential for impaired root growth at ≥ 1.6 g/cm³. Also of potential concern are the low soil pH values and high amounts of exchangeable aluminum. This may cause the loss of base cations, such as calcium, and contribute to nutritional imbalances and ultimately to forest decline. Due to changes in methodology, this analysis represents only a portion of the data that will eventually be available. With a full set of data, these issues will be further clarified, and some may warrant further investigation.

~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. Human-related activities that affect soil properties include acidic deposition, soil compaction, (from heavy equipment), and erosion of topsoil (from harvesting or grazing activity).

Bulk density, varies by soil texture. Clay soils tend to have lower bulk densities than do sandy soils. Bulk density can range from 0.1 g/cm³ for histosols, to 2.2 g/cm³ for compacted glacial tills. The threshold value for bulk density is typically considered 1.6 g/cm³. At or above this threshold, root growth becomes impaired.

Soil pH affects all physical, chemical, and biological properties of a soil. It is a major factor in determining what types of vegetation will dominate a natural landscape (Brady and Weil 1996). The pH values of most soils are 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 replaces these much needed nutrients on the soil complex, and pH decreases.

~METHODS~

Soil samples were collected by the Forest Inventory and Analysis (FIA) unit of the USDA Forest Service on forest health (P3) plots and analyzed in a laboratory for various physical and chemical properties to further clarify the status of forest soils. The forest floor layer (litter + duff) was analyzed for percent moisture, carbon, and nitrogen. The mineral portion of the soil was collected using an impact-driven corer in two layers, 0 – 10 cm (M1), and 10 – 20 cm (M2) and analyzed for the same information as the forest floor, plus pH and a variety of exchangeable cations (USDA 2004). Due to changes in methodologies, only the data from 2000 – 2002 is included in this analysis. For a description of these changes, see O'Neil, Amacher, and Perry (2005).

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

~RESULTS~

~ pH ~

Average pH for the M1 layer was 4.8. The average for the M2 layer was slightly higher, at a pH of 4.9. The majority of the M1 and M2 samples had a pH <5.0 (fig. 1). At these levels of pH there may be sufficient amounts of exchangeable aluminum present to impact plant growth.

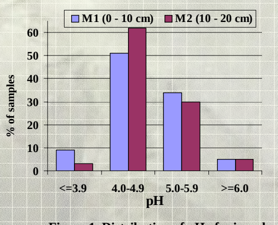
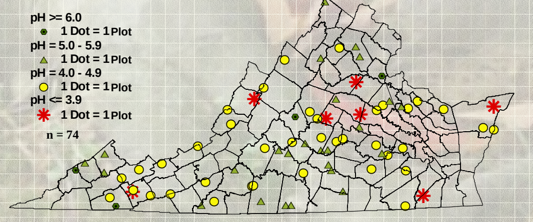


Figure 1. Distribution of pH of mineral soil by layer, Virginia.

Soil pH did not vary significantly by physiographic province (fig. 2).



* Plot locations are accurate to the county.

Figure 2. pH of mineral soil (0-10 cm) on each plot, Virginia.

~ Bulk Density ~

Bulk density averaged 1.10 g/cm³ for all M1 samples, while the M2 layer averaged 1.45 g/cm³. The majority (57%) of M1 samples had bulk densities in the range of 0.88 – 1.37 g/cm³. M2 samples (68%) were mostly in the range of 1.12 – 1.62 g/cm³ (Fig. 3).

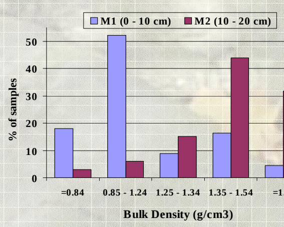


Figure 3. Distribution of bulk density of mineral soil by layer, Virginia.

~ Carbon and Nitrogen ~

The forest floor accounted for 12.0 Mg/ha of organic carbon, and the M1 and M2 layers together accounted for 37.9 Mg/ha. Total nitrogen averaged 0.4 Mg/ha for the forest floor, and 2.0Mg/ha for the mineral soil (table 1).

Table 1. Average tons/acre of carbon and nitrogen for the forest floor and mineral soil

	n	Organic Carbon	Total Nitrogen
		-------- Mg/ha	----------
Forest Floor	87	12.0 (18.7)[a]	0.4 (0.7)
Mineral soil (0-20 cm)	66	37.9 (35.4)	2.0 (1.0)

[a] Standard Deviation

~ Exchangeable Cations ~

Exchangeable aluminum averaged 148.5 and 144.6 mg/kg for the M1 and M2 layers, respectively. Exchangeable calcium averaged 447.4 mg/kg for the M1 layer, and 165.3 mg/kg for the M2 layer (table 2).

Table 2. Exchangeable cations in mineral soil, Virginia.

		Exchangeable Cations				
		AL	CA	MG	K	NA
Layer	n	---------- mg/kg				------------
M1 (0 – 10 cm)	76	148.5	447.4	94.6	90.0	7.7
M2 (10 – 20 cm)	74	144.6	165.3	54.5	57.7	5.7

Both Ca and Al were significantly correlated ($p < 0.0001$) with pH (fig. 4).

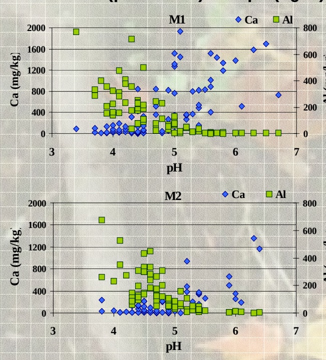


Figure 4. Relationship between cation concentrations and soil pH in mineral samples, Virginia.

Soil Ca : Al ratios were highly correlated with pH ($p < 0.0001$) (fig. 5). Between 39 – 47 % of samples (depending on layer) had a ratio of less than 1.0.

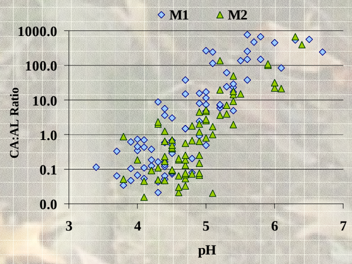


Figure 5. Relationship between Ca:Al ratios and soil pH in mineral samples, Virginia.

~CONCLUSIONS~

Overall, 21 plots (31%) had bulk densities at or above 1.6 g/cm³ for either the M1 or the M2 layer. Over one-half of these were on the Coastal Plain.

More than 50 % of samples had a pH of < 5.0. At these levels of pH there may be sufficient amounts of exchangeable aluminum present to impact plant growth. Additionally, a low percentage of base saturation would be expected (Buol et al. 1980). Low soil pH may occur naturally, or may be related to acidic deposition created from the combustion of fossil fuels.

Given the low pH values and high proportion of exchangeable aluminum in about 30 percent of the samples, very low calcium to aluminum ratios in the soil solution are very possible. Typically, calcium to aluminum ratios of < 1.0 in soil solution are considered the threshold below which plant growth is reduced.

The status of soil on P3 plots in Virginia varied by region and by the parameter considered. High bulk densities may be cause for concern. Likewise, low soil pH and high amounts of exchangeable aluminum are potential issues. Losses of base cations, such as calcium, from soils and the immobilization of soil 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).

The complexity due to the interconnectedness of soil properties and the fact that soil properties are intrinsically tied to deposition and site history makes it difficult to focus on just one variable and relate it to forest health. Furthermore, due to changes in methodology, this analysis represents only a portion of the data that will eventually be available. With a full set of data, some issues will be further clarified, while some may warrant further investigation.

~LITERATURE CITED~

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~ CITATION ~

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