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Characterizing the Variability of Physical and Chemical Properties across the Soil Individuals Mapped as Amy Silt Loam Soils in Southeastern Arkansas

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Abstract

Knowledge of physical and chemical properties of soil is relevant for landowners, researchers, and foresters, so that appropriate crop species and management practices to maximize site productivity can be selected. In addition to issues of plant productivity, the need for assessing soil properties has been expanded due to public interest in determining the consequences of management practices on soil quality relative to sustainability of crop ecosystem functions. The USDA-Natural Resources Conservation Service (NRCS) delineated soil mapping units to provide information about physical and chemical properties of soil in each soil series. However, soil mapping units do not provide details about the variability of soil properties within a single soil series. To determine the variability of physical and chemical properties within Amy soil series, 200 soil samples were collected to a depth of 0–15cm and 15–30cm from soil individuals mapped as the Amy silt loam soils in five different locations in southeastern Arkansas. Comparisons of soil texture, bulk density, carbon, nitrogen, Mehlich III extractable macronutrients, and micronutrients revealed significant differences among soil individuals/ locations for both depth increments. Additionally, all nutrients except potassium, magnesium, and copper differed between the two soil depths. The results suggest inherent variation in biogeochemical and geochemical cycling in the surface horizons of soils mapped as the Amy series.

Introduction

In the absence of an existing forest stand, knowledge of physical and chemical properties of soil is relevant for landowners, foresters, and researchers, to assess the potential productivity of sites, to select the appropriate forest tree species and management practices to maximize forest productivity (Baker and Broadfoot 1979). In addition to issues of plant productivity, the need for assessing soil properties has been expanded due to public interest in determining the consequences of management practices on soil quality relative to the sustainability of forest ecosystem functions (Schoenholtz et al. 2000). Physical properties of soil, such as soil texture, structure, bulk density, and soil porosity, determine nutrient and water holding capacity, root growth and development, gas exchange, biological activities, and carbon budget in the soil (Kelting et al. 1999). Soil chemical properties determine the availability of nutrients for plant growth as well as influence soil microbial activities, and these properties along with soil biogeochemical processes determine the availability of nutrients, water, and their respective cycles. Since soil is a natural dynamic body, physical and chemical properties of soil across regions change over space and time. Information about the variability of physical and chemical properties of soil across a landscape over time is valuable for precision farming, environmental monitoring, soil quality assessment, and forest management (Viscarra Rossel et al. 2006, Cohen et al. 2007).

The USDA-Natural Resource Conservation Service (NRCS) delineated soil mapping units based on the soil-landscape paradigm and modal to demonstrate physical and chemical properties of soils in a region (Soil Survey Staff 2006). The soil-landscape paradigm holds that soil properties are predictable in a particular landscape because of the distinct sets of observable properties such as climate, living organism, parent materials, topography, and time (Hartung et al. 1991). Based on these distinct soil characteristics across a region, soil scientists delineated the individual soil series on aerial photographs. However, soil maps published in the county soil surveys are not sufficient for describing patterns in variation of soil properties that occur within fields or parcels of land and across a region. The recognition of soil diversity and variability can be a valuable contribution toward the evaluation and beneficial use of soil resources in the future. Additionally, characterizing spatial variability and distribution of chemical properties within a single soil unit, including climate, land use, landscape position, and other variables, is critical for predicting rates of ecosystem processes, understanding how ecosystems function (Wang et al. 2001), and assessing the effects of future land use change on nutrients (Kosmas et al. 2000).

In southeastern Arkansas, the Amy soil series is one of the prominent soils extending from the Western Gulf Coastal Plain of Arkansas, Louisiana, Oklahoma, and Texas and to the Southern Gulf Coastal Plain of Alabama and Mississippi (Soil Survey Staff 2006). The Amy soil series was first established in Ouachita County, AR, 1969. This series was formed in loamy coastal plain sediments, which were originally covered by mostly mixed pine and hardwoods on the upland flats and hardwoods on the flood plains. The surface soils have fine texture, granular structure, many fine roots, acidic, and clear smooth boundaries, while subsurface soils are fine, distinct, yellowish brown mottles, subangular blocky structures, and wavy boundaries. Some areas of these soils commonly flood a few times each year, usually during winter and early spring. In most years, a seasonally high water table is within 12 inches of the soil surface from December through April (Soil Survey Staff 2006).

The Amy soil series is a deep, frequently flooded, poorly drained soil with a low natural fertility and high available water. Although this soil series has low natural fertility, high seedling mortality and erodibility, it has high potential productivity for some forest trees, e.g. site index for loblolly pine, sweet gum, and water oak is 90. Additionally, this soil also favors the growing of cottonwood, green ash, sycamore, and oak forests (Larance et al. 1976). The frequency with which these soils occur along streamside management zones (SMZs) also makes their management important for preserving or improving water quality (Soil Staff Survey 2006). These soils are often disturbed with less frequency and intensity during forest management activities in comparison with other Amy series phases due to the implementation of Best Management Practices (BMPs) for water quality protection. The NRCS provides general information about physical, chemical, and hydrological properties of this soil series, but it does not provide enough information about the variability of physical and chemical properties across the soil individuals mapped as Amy silt loam associated with their best management. This research was initiated to determine the variability of the physical and chemical properties of soil individuals mapped as Amy series so that foresters, researchers, and landowners can apply best management practices to maximize forest production with the minimal disturbance as well as preserve water quality in SMZs.

Materials and Methods

The study sites were located on University of Arkansas-Monticello (UAM) Forest in Drew County, Arkansas. Plot boundaries were defined as by the area mapped as Amy series soils. Two soil research plots were located in the “East Block” tract of UAM forest: one plot/map unit was 2.5 hectares in size, while the second was 14.6 hectares in size. Similarly, one 3.3 hectares research plot was located on the “West Block” tract of UAM forest and on the “North Block” tract of the UAM forest, a 7.7 hectares research plot was established. The fifth research plot was a 19.4 hectares area located on the UAM forest known as “POW camp”. The NRCS web soil survey 2.0 (USDA-NRCS, 2006) was used to identify the Amy silt loam soils in the five different sites.

Sampling Techniques

Soil Sampling

Forty soil samples were collected for both the 0-15 cm and the 15-30 cm soil depths from each sites/soil individuals, using 2 cm diameter fixed volume core samplers resulting in a total of 400 soil samples. Because of the hard pan in sub-surface soil due to high clay contents, it was very difficult to take soil samples with full soil volume in sampler cores for bulk density at the depth of 15-30 cm accurately. Additionally, small change in soil volume in fixed core samplers largely influences bulk density. So, bulk density was determined only for the depth of 0-15 cm from each plot. Prior to collecting the soil samples, organic litter was removed from the soil surface to minimize the contamination of mineral soil because compounds/elements in organic litter are not mineralized yet and unavailable for the plant. Systematic transect sampling was followed to collect the soil samples. A Trimble GPS unit with soil map unit data preloaded was used to establish sampling locations and plot boundaries. Distances between samples along a transect were also adjusted based on the size of soil map unit. To avoid boundary effects, soil samples were collected at least 5m away from the boundaries. To minimize the temporal variation of soil properties among the different locations, soil sampling was completed within a two-week period (May 22 – June 4, 2008). Furthermore, soil samples from each depth were handled independently to eliminate contamination with each other. Roots, twigs, rocks, debris, and unmineralized organic matter were also removed from the soil samples. Finally, soil samples were kept in clean and tightly sealed plastic bags. Soil samples were stored in a cooler at 10 ^{0}C to reduce microbial activity and soil respiration because these activities alter the chemical composition of soil through various biological and physiochemical processes (Fisher and Binkley, 2000).

Sample Preparation and Analysis

Soil Nutrient Analysis

Soil mineral samples for nutrient analyses from each soil individuals were air-dried in clean aluminum pans for 72 hr or until the sample was sufficiently dried. The large pieces of soil samples were broken thoroughly so as to pass through a 2 mm sieve by using a Ro-Tap sieve shaker. At the same time, the remaining roots, twigs, branches or other organic litters were also removed from the samples. The percent carbon, percent nitrogen and C:N ratios for each sample were determined by catalytic tube combustion using an Elementar VarioMax CN Elemental Analyzer. For other macro- and micro-nutrients such as N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, and B concentrations in the soil samples, Mehlich III extractions (1:10) and Spectro Ciros Inductively Coupled Plasma spectrophotometric analyses (ICP) were used.

Soil pH

Soil pH was measured with a pH meter using a 1:2 soil-to-water ratio. Ten grams of air-dried, grounded and sieved soil samples were mixed with 20 ml of deionized water. Suspension was stirred thoroughly and allowing the mixture to settle for 30 minutes. The pH meter was calibrated with buffer solutions of pH 4.0 and 7.0. After calibration, the pH for each soil sample was recorded when the reading was constant for 15 seconds.

Soil Physical Analysis

Soil Texture

Soil texture was determined by the Bouyoucos Hydrometer method (Kalra and Maynard 1991). For each sample, 50 g of soil was mixed with 50 ml of Calgon solution (10% sodium hexametaphosphate solution) and shaken overnight to disperse soil colloids prior to sedimentation analyses. After overnight shaking, each soil sample was poured into a 1-liter graduated cylinder and mixed with de-ionized water to the 1000 ml mark. Additionally, a blank sample consisting only of Calgon solution was run with each set of samples to facilitate the required temperature adjustments of suspension density readings. Hydrometer readings were taken at 40 s and 2 hr, and after adjustments for temperature, the sand, silt and clay contents were determined by standard methods (Kalra and Maynard 1991).

Bulk Density

Soil samples from each location were oven dried at 105 ^{0}C for 24 hr prior to soil mass determination. Soil bulk density was determined by dividing the mass of soil by the total volume of the soil core. No adjustments for coarse fragment contents were required.

Statistical Analysis

Shapiro-Wilk tests were conducted to test for non-normality of distributions for the variables of interest, and Levene's tests as ANOVA-based inferential statistics were used to test for heterogeneity of the variance structure of the physical and chemical properties of soil individuals mapped as Amy silt loam soils. Two-factor ANOVA was used to determine the variation of chemical and physical properties of Amy silt loams across locations and between the soil depths except for bulk density and nitrogen. For bulk density, one factor ANOVA was used to determine the variability of bulk density across the different research plots mapped as Amy silt loam soils ($\alpha = 0.05$). Tukey's HSD (Honestly Significant Difference) test was used for multiple comparisons in conjunction with the ANOVAs to distinguish which means were significantly different from one another ($\alpha = 0.05$). Since carbon followed a non-normal distribution, non-parametric Kruskal–Wallis ANOVA test was used, and a Z-approximation adjusted for the number of multiple comparisons was used to compare carbon content among soil individuals and between the soil depths.

Results and Discussion

Mean, standard deviation, minimum, and maximum values for each soil attribute at the depth of 0-15 cm and 15-30 cm are given in Table 1. The results demonstrate that nutrient concentrations in the surface soil are higher than in sub-surface soil. Additionally, calcium, magnesium, iron, and potassium exhibited greater variation as compared to other nutrients at both soil depths of 0-15 cm and 15-30 cm.

Soil physical properties revealed significantly differences among soil individuals and between soil depths (Table 2). The results showed that sand content in the West Plot (WP) and North Plot (NP) was significantly different as compared to the East Plot 1 (EP1), East Plot 2 (EP2), and POW camp, but there were no differences in sand content among EP1, EP2, and POW camp, and between WP and NP plots (Table 4). Silt content in the NP and EP2 plots were significantly different as compared to EP1, WP, and POW camp (Table 4). Similarly, it was observed that clay contents were significantly different among EP1, POW camp, and EP2 sites. However, clay content was not different between WP and NP, and EP1 and EP2 sites (Table 4). Soil bulk density did not differ between WP and EP1, EP2 and NP, and NP and POW camp (Table 4). Since this soil series occurs frequently in SMZ, variation in particle size distributions was due to natural disturbances i.e. flooding and anthropogenic activities in addition to the inherent biogeochemical processes in the soil. In the Amy soil series, soil surface is flooded at least six months in a year (Larance et al. 1976).

The transportation and deposition of soil materials by small creeks/streams in soil individuals mapped as Amy silt loam were the most influencing factors to redistribute soil particles across locations and between depths (Nearing et al. 1989). Since the variation in soil macro- and micro-nutrients across soil mapping units (Tables 2-5), it influences soil anthropogenic activities with more microbial activities in the nutrient-enriched ambient sites that influences inherent soil biogeochemical processes (Sopher and Baired 1982). The increased biogeochemical processes in soil accelerate the disintegration of mineral soil particles to fine sized particles and vice versa. Other activities like wildfire burning altered soil textures by producing a finer particle due to an increase in silt fraction resulting from the decomposition of sand grains (Ulery and Graham 1993, Ketterings et al. 2000). Variation in soil physical properties at depth increments occurs mainly due to different soil horizons in the surface and sub-surface (Larance et al. 1976). Because of different distribution of particles sizes across the sites, bulk density was also varied accordingly (Fisher and Binkley 2000). Variation in bulk density is also associated with the amount of water content in soil because it affects soil aggregations (Augeard et al. 2006). Furthermore, different tree species and management activities among soil individuals also revealed the level of soil aggregations, soil compaction, and organic matter contents within a single soil series. Intensive forest management through the use of heavy equipment at the different times increases soil strength and compaction leading to increase bulk density with reduced soil porosity. However, the rate of change However, the rate of change in bulk density, porosity, and soil strength was varied among soil textural classes (Gomez et al. 2002).

Total carbon, total nitrogen, C:N ratio, phosphorus, potassium, calcium, magnesium, and sulfur were significantly different among sites (Table 2). Similarly, these soil chemical parameters were significantly different between soil depths except for potassium and magnesium (Table 3). Total carbon and nitrogen contents in the NP were significantly different as compared to their content in other locations. However, carbon and nitrogen contents were no differences between EP2 and WP, and POW camp and EP1 sites. Similarly, C:N ratio was not significantly different between NP and EP2, and WP and EP1 sites. Phosphorus content in the NP was significantly different as compared to other locations. Similarly, calcium content was not different between NP and WP, and among WP, EP2, and POW camp (Table 4). Sulfur content was not different among NP, EP2, and POW camp, and between WP and POW camp, and between POW camp and EP1 sites. Potassium and magnesium contents in NP site were significantly different as compared to their contents in other locations (Table 5).

Additionally, other soil micronutrients, such as copper, zinc, iron, and sodium, as well as soil pH, were significantly different among soil individuals. These soil chemical properties were also significantly different across soil depth increments except for copper (Table 2 and 3). Copper, iron, and zinc contents in NP were significantly different as compared to their content in other locations. However, copper and iron concentrations in EP1, EP2, and POW camp were not significantly different. Similarly, iron content was not significantly different among WP, EP1, and POW camp. Sodium concentration was not significantly different between NP and WP, WP and EP2, and EP2 and EP1 sites. In addition to soil macro- and micronutrients, soil pH was not significantly different between EP1 and WP, WP and EP2, EP2 and POW camp, and POW camp and NP (Table 5). The physical and chemical properties of Amy soil series measured among soil individuals had interaction between sites and depths, but they were not significantly different.

Table 1: Mean, standard deviation, minimum, and maximum values physical and chemical properties of soil mapped Amy series at the depth of 0-15 cm and 15-30 cm.

Soil parameters	Surface soil (0-15 cm)				Subsurface soil (15-30 cm)			
	Mean	Standard Deviation (SD)	Minimum	Maximum	Mean	Standard Deviation (SD)	Minimum	Maximum
1. Sand (%)	30.88	10.52	3.52	59.04	27.34	12.18	6.54	66.01
2. Silt (%)	44.71	9.49	14.50	61.96	41.85	11.19	2.00	64.00
3. Clay (%)	24.41	9.88	10.98	75.98	30.94	14.09	10.00	76.00
4. Bulk density (Mg m^{-3})	1.74	0.14	1.30	2.06	-	-	-	-
5. Nitrogen (g kg^{-1})	0.80	0.40	0.10	2.40	0.70	0.40	0.20	3.60
6. Carbon (g kg^{-1})	11.70	5.40	1.10	33.90	8.40	5.10	2.60	31.20
7. C:N ratio	14.38	2.65	2.40	22.57	12.63	5.10	2.60	31.20
8. Soil pH	5.06	0.30	3.84	5.93	4.92	0.24	4.10	5.77
9. Phosphorous	5.80	4.63	2.00	37.80	3.77	4.71	0.24	55.90
10. Potassium	81.00	50.64	29.00	340.00	86.26	62.90	4.26	396.40
11. Calcium	407.00	284.72	10.00	1792.00	279.10	227.86	0.83	1897.00
12. Magnesium	188.00	539.52	19.00	7500	179.40	172.84	4.45	1382.00
13. Sulfur	15.30	24.08	4.40	215.10	23.76	42.01	1.37	475.80
14. Sodium	13.70	9.02	5.30	85.40	17.28	13.95	0.56	118.40
15. Iron	149.00	63.31	67.00	521.00	108.72	58.69	3.04	442.30
16. Zinc	3.10	2.55	0.70	14.90	2.31	1.71	0.16	12.72
17. Copper	5.30	2.94	1.10	15.90	5.72	3.18	0.11	24.11

All units are mg kg^{-1} unless otherwise noticed.

Table 2: Different parameters of soil measured across the soil individuals mapped as Amy series

Parameters	Data Transformation	F-value	pr>F
1. Sand	Square Root	26.72	<0.001
2. Silt	Square Root	13.98	<0.001
3. Clay	Square Root	61.01	<0.001
4. Bulk Density	Logarithmic	25.68	<0.001
5. Nitrogen	Square Root	69.17	<0.001
6. C:N ratio	Logarithmic	11.72	<0.001
7. Phosphorus	Logarithmic	43.92	<0.001
8. Potassium	Logarithmic	67.39	<0.001
9. Calcium	Square root	38.77	<0.001
10. Magnesium	Logarithmic	59.68	<0.001
11. Sulfur	Logarithmic	11.15	<0.001
12. Soil pH	Logarithmic	8.31	<0.001
13. Zinc	Logarithmic	81.17	<0.001
14. Iron	Logarithmic	27.44	<0.001
15. Copper	Logarithmic	17.92	<0.001

Table 3: Different parameters of soil measured between the soil depths mapped as Amy series

Parameters	Data Transformation	F-value	pr>F
1. Sand	Square Root	18.70	<0.001
2. Silt	Square Root	8.78	<0.001
3. Clay	Logarithmic	51.87	<0.001
4. Nitrogen	Square Root	48.81	<0.001
5. C:N ratio	Logarithmic	65.46	<0.001
6. Phosphorus	Logarithmic	179.87	<0.001
7. Potassium	Logarithmic	0.00	0.982
8. Calcium	Square Root	46.11	<0.001
9. Magnesium	Logarithmic	1.86	0.173
10. Sulfur	Logarithmic	17.27	<0.001
11. Soil pH	Logarithmic	31.15	<0.001
12. Zinc	Logarithmic	30.03	<0.001
13. Iron	Logarithmic	113.18	<0.001
14. Copper	Logarithmic	2.76	0.098
15. Sodium	Logarithmic	8.56	0.004

Table 4: Comparison of soil parameters measured across the soil individuals mapped as Amy series

Sites	Sand (%)	Silt (%)	Clay (%)	Bulk Density ($Mg\ m^{-3}$)	Total Carbon ($g\ kg^{-1}$)	Total Nitrogen ($g\ kg^{-1}$)	C:N ratio	Phosphorus ($mg\ kg^{-1}$)	Calcium ($mg\ kg^{-1}$)
POW camp	34^{a}	36^{c}	30^{b}	1.64^{c}	7.33^{c}	0.57^{cd}	12.85^{c}	2.93^{c}	115.20^{c}
East plot 2 (EP2)	32^{a}	45^{a}	23^{c}	1.71^{b}	9.65^{b}	0.67^{b}	14.40^{b}	3.61^{b}	312.20^{b}
East Plot 1 (EP1)	30^{a}	47^{a}	23^{c}	1.80^{a}	7.74^{c}	0.51^{d}	12.85^{c}	2.62^{c}	115.20^{c}
West Plot (WP)	23^{b}	43^{ab}	34^{a}	1.85^{a}	9.16^{b}	0.61^{bc}	12.85^{c}	3.77^{b}	363.20^{ab}
North Plot (NP)	21^{b}	40^{bc}	39^{a}	1.66^{bc}	15.83^{a}	1.09^{a}	14.52^{b}	6.47^{a}	450.80^{a}

Values with same superscript within column are not significantly different.

Table 5: Comparison of soil parameters measured across the soil individuals mapped as Amy series (continued)

Sites	Sulfur ($mg\ kg^{-1}$)	Potassium ($mg\ kg^{-1}$)	Magnesium ($mg\ kg^{-1}$)	Copper ($mg\ kg^{-1}$)	Sodium ($mg\ kg^{-1}$)	Iron ($mg\ kg^{-1}$)	Zinc ($mg\ kg^{-1}$)	Soil pH
North Plot (NP)	16.38^{a}	118.8^{a}	251.24^{a}	6.84^{a}	17.50^{a}	160.65^{a}	4.68^{a}	4.86^{c}
West Plot (WP)	9.41^{c}	76.33^{b}	120.88^{b}	4.80^{b}	15.75^{ab}	81.85^{c}	1.59^{c}	5.02^{ab}
East Plot 2 (EP2)	14.78^{a}	90.50^{b}	150.98^{b}	4.95^{b}	13.00^{bc}	112.16^{b}	2.31^{b}	4.97^{b}
East Plot 1 (EP1)	14.16^{ab}	52.67^{c}	90.50^{c}	4.41^{b}	12.00^{c}	105.10^{b}	1.69^{c}	5.09^{a}
POW Camp	11.09^{bc}	41.26^{c}	56.10^{d}	3.50^{c}	8.52^{d}	120.86^{b}	1.43^{c}	4.95^{bc}

Values with same superscript within column are not significantly different.

Since soil forming factors within a single soil series are common, it is assumed that the physical and chemical properties of soil mapped as a single soil series are more homogenous than the properties across soil series. Variation in soil properties is driven by natural disturbances such as flooding and anthropogenic activities as well as human driven management activities i.e. site preparation, plant cultivars and species, tree composition, total tree species per unit area, intercultural practices and harvesting techniques (Nyland 2002). Tree species composition and past management activities in different sites are the important driving factors affecting soil nutrient composition. The POW camp composed of sweetgum, bottomlands and mixed hardwood species without management activities e.g. nutrient management, thinning, weed control, herbicide and pesticide management. Pine, white oak and southern red oak were predominately found in EP2. This site was thinned in 1996, but others management activities were not conducted. EP1 consists of entirely pine tree species and thinned in 1996 and 2004. NP consists of mainly mixed hardwood and bottomland species and has no management activities. Pine and mixed hardwood species were predominant in the WP. However, no management activities conducted in this site. Forest management activities, species composition, and canopy characteristics within a soil series are the prevalent factors that not only influence soil properties but also modify the physical and chemical properties of soils accordingly to be suitable for the growth of a particular species (Kiser et al. 2008).

Soil macronutrients originating from organic sources are important for the healthy functioning of forest ecosystems as well as for environmental concerns such as climate change and global warming. Organic sources such as biological N-fixation, atmospheric deposition, decayed roots, twigs, leaves, stems, root exudates, and other detritus are the storehouse for carbon, nitrogen, and sulfur (Sopher and Baired 1982). Depending upon plant species, soil organic matter contains a large amount of carbon, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur as compared to other micronutrients. Decomposition of soil organic matter is governed by site conditions such as soil temperature, moisture, texture, microbial activity, as well as physical and chemical composition of organic litter (Giardina et al. 2001). In addition to site factors, forest canopy architectures influence the rates of key soil processes involved in nutrient cycling by altering physical environment in forest stands (Prescott 2002). Forest canopy architecture also alters the hydrological properties in soil by removing water through transpiration and reducing the direct impact of precipitation on the soil surface that influences the magnitude of nutrient losses through leaching or overland flow in soils (Nyland 2002). Because of different species composition within a single map unit, variation in tree canopy structures induces localized/microclimatic variations among each forest composition. The latter can then influence soil biogeochemical and geochemical processes resulting in nutrient compositions in forest soils. Soil temperature and moisture are important factors that influence soil microbial activities, resulting in rapid mineralization of organic matter and weathering of minerals under high soil temperature and humid conditions that lead to the release of soil nutrients (Fisher and Binkley 2000, Prescott 2002). Furthermore, different types of forest species within a soil series influence rate of soil respiration by altering soil microclimate and structures, quality and quantity of detritus supply, and overall rate of root respiration because it affects the microbial activities that ultimately influence the overall soil biogeochemical processes (Raich and Tufekcioglu 2000).

On the other hand, uptake and accumulation of soil nutrients in tree biomass can be significant factors for driving soil nutrient variation within a single mapping unit (Johnson and Todd 1990). Since soil-plant transfer of nutrients is important in nutrient cycling, absorption of soil nutrients by tree species should be accounted for because each tree species has distinct physiological function and rooting behavior. Hardwood species have extensive root systems that exploit more nutrients and space as compared to that of conifers (Whittakar et al. 1974, Bockheim 1997). The nutrient demands for hardwood species far exceed those of conifers, with deciduous trees often containing twice as much Ca, Mg, and K in their aboveground biomass (Whittakar et al. 1974, Bockheim 1997). Additionally, plant roots exude some organic compounds that are also responsible for weathering of minerals by providing the essential nutrients for soil flora and fauna. Furthermore, soil nitrogen fixation and mycorrhizal association with plant roots are the potential sources of nutrients for some of forest species like conifers, mixed hardwood and bottomland species (Fisher and Binkley 2000). All of these factors are directly or indirectly responsible for the variation in physical and chemical compositions within a soil series.

For soil nutrients from mineral sources, microclimatic variation is the primary driving agent that influences biogeochemical processes within a single map unit. Variations in particle distributions were observed across different locations and depths. Nutrient concentrations across a soil series were found to be different by altering soil water availability, porosity and surface area (Scott et al. 1996). Soil dominated by higher clay content has a higher amount of carbon and nitrogen than soil dominated by silt and sand content (Stevenson 1986). Since the Amy soil series is wet more than 6 months, different rates of wetting and drying of soil throughout the year within a single soil series influences the flushes of nutrients in soil (Stevenson 1986). Wetting and drying of soil influence oxidation and reduction reaction (redox reaction) in soil that ultimately affects soil biogeochemistry, pedogenesis, and ecological functioning of ecosystem. The major reactions that occur in hydrated soil are nitrification, denitrification, Mn reduction, Fe reduction, SO_4 reduction, and methanogenesis (Yu et al. 2007). Direction of drainage and mass flow of nutrients from or into this soil series due to flooding and surface runoff are other potential driving forces that affects soil nutrient composition. Furthermore, different rates of nutrient leaching from the surface and subsurface at different soil sites and depth increments within a single mapping unit influence soil macro- and micro-nutrient concentrations. Calcium concentration in soil is largely influenced by its accumulation and sequestration in forest biomass and detritus, while magnesium content is varied by leaching from the soil surface (Johnson et al 2007). Potassium is such a mobile element that it is easily leached from soil surface or taken up by plants. Due to leaching from soil surface, magnesium, potassium and copper were not significantly varied as soil depth increments (Stevenson 1986).

The results revealed that the variation in physical and chemical properties of soil across a single mapping unit because the behavior of soil chemical properties i.e. both macro and micronutrients is very complex because numerous processes operate simultaneously and vary continuously over time period (Hesterberg 1998). The “hot spots” and “hot moments” at a landscape over time are also common processes that expedite the biogeochemical process in soil resulting in soil heterogeneity (McClain et al. 2003). Additionally, the change in nutrient concentration and their distribution is the great concern because it not only affects the plant nutrition but also influences the environmental quality. However, based on information about tree species and management activities in each soil individuals, it is very difficult to tract out nutrient cycles for each nutrient and particular factors influencing for soil macro and micronutrients. Variation in soil nutrients across a single series is the result of combined factors of natural and human driven activities. It is difficult to point out one factor is responsible for a particular nutrient at the particular location that makes significantly different as compared to their content in the other sites. However, nutrient dynamics at each site is the main driven force for determining physical and chemical properties of soil within a soil mapping unit at the different locations and depth increments.

Conclusion

The USDA-NRCS conducts soil surveys and develops soil maps for the United States with the aim of providing information about the physical, chemical, and biological properties of soils. Based on these maps, researchers, landowners, agronomists, and foresters can better apply management practices to maximize crop production while minimizing both input costs and loss of ecosystem services. Since the stage of pedogenetic development is the same for a single soil series, much of the variability of physical and chemical properties in surface horizons within a single series is a function of land management activities such as site preparation, plant species composition and density, nutrient and fertilizer management, harvesting techniques, and other cultural activities. In addition to appropriate management activities for maximizing crop production, anthropogenic activities may influence the biogeochemical processes in soil that can result in changes in physical characteristics, nutrient composition and other soil properties across soil mapping units. The variability found in this study of surface physical and chemical properties of soils mapped as Amy silt loam suggests site-specific management can be expected to improve forest production and maintain or improve soil quality for environmental concerns.

However, effective site-specific management that incorporates intra- map-unit variability will require intensive and expensive georeferenced soil sampling and analyses that are cost prohibitive for many silvicultural and some agricultural systems. Through the use of new soil analytical procedures, costs may be reduced, and with greater demands for both production and environmental protection, precision agriculture and silviculture become more economically viable.

While the USDA-NRCS soil survey provides good data on the general properties of soil individuals/ map units, the "modal pedon" concept underlying map unit delineation does not provide information about the variation among soil individuals within a soil series. Recognition of this variation becomes more important as the intensity of management increases. Accordingly, when silvicultural prescriptions include high inputs for production, the results of this study suggest that relying upon the published soil survey data alone will neither facilitate production maximization nor ecosystem services protection.

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