Soil Organic Carbon Variability by Aspect and Slope in the High Elevation Soils of the Southwest Virginia Mountains

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ABSTRACT

Limited information is available on carbon (C) sequestered in frigid Appalachian forest soils. However, the cool moist forests of the high elevations probably hold more C than any other mineral soils in Virginia. The objectives of the study were to determine the amount and variability of soil C across aspect and slope classes in a frigid temperature regime area of Tazewell County, VA. Soils were sampled to characterize two aspect classes, N (340-90º) and S (160-270º), and three slope classes, 7-15%, 15-35%, 35-55%. Organic (L,F,H) and mineral layers and horizons (upper 5cm, A, B) were sampled at each site. Whole soil (including organic and mineral horizons) C contents on N aspects (135 Mg/ ha) were greater than on south aspects (107 Mg/ha). Average whole soil C across all sites was 112 Mg ha^{-1}. The A horizons on N aspects (13cm) were deeper than those of the S aspects (8 cm), while average leaf litter weights were greater on the S aspects (25 Mg/ ha) versus the N (17 Mg/ ha). B horizon C was greater than 1.5 % and made up more than half of the total soil C. Carbon increased with slope on N aspects, but did not increase with slope on S aspects, because estimated solar insolation potential decreases with increasing slope on N aspects and has no trend on S-facing slopes. Total C appears to be greatest on steep N-facing slopes because cooler and moister conditions promote better mixing of organic material into the mineral soil.

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Chapter 1: Introduction

Measuring carbon (C) sequestration in the soils of North America has become an important task in the wake of global warming debates. The current C content of soils and the potential for further sequestration are under scrutiny. Forest and soil maps are often used to determine global soil C and extrapolate values. Data gaps arise where C was not collected in litter and lower mineral horizons, leaving gaps in data.

Data for soil organic carbon (SOC) in the forested ridges is limited in the Southern Appalachians of Virginia. Information is scarce because Virginia's high elevations have shallow soils with low fertility, so there has been little interest in using these soils with the exception of growing timber.

The main objective of this study was to collect SOC data on soils located at high elevations in the Southern Appalachians and compare it to other forest soil C inventories in similar areas. Grouping these soils by series and examining C distribution between them can help determine the best ways to use soil data and maps to extrapolate total C in forested soils.

A second objective of this study was to observe the relationship of C between and across aspects and slopes at these elevations. There may be potential differences between aspects and across slopes because of differences in solar loading. South aspects have received more direct sunlight and are usually warmer and drier, increasing the rate at which organic C is mineralized to CO_2. North aspects are cooler and moister and promote higher sequestration of C into the mineral soil. Increasing slopes on N aspects should also have cooler temperatures, while increasing S aspects should have warmer temperatures. Aspect and slope information may also help in using series to map soil C by giving a more specific relationship between C and topography. Geographers should take soil series aspect and slope into account when determining how much C should be attached to each series and map unit.

Chapter 2: Literature Review

The purpose of this study was to (1) obtain and interpret whole soil carbon data from soils that can be correlated to cooler temperatures at high elevations, and (2) to observe any relationship of soil C by aspect and slope above 1200 m. Current information from these areas on soil organic carbon (SOC) comes largely from reconnaissance studies (Feldman et al., 1991ab) (Daniels et al., 1987ab). There are limited the amounts of soil information for the high elevations, particularly for soil C, although the southern Appalachians have been the subject of various ecological studies.

Predicting Changes in Soil Organic Carbon

Soil organic carbon storage and mass levels have become a new concern among soil scientists because public and agency demand for the information has risen. The theory of global warming follows the assumption that increases in greenhouse gases such as CO_2 prevent sunlight from escaping the earth's atmosphere and cause annual temperatures to raise steadily. It is believed that CO_2 causes an estimated 50% of greenhouse gas related warming of the atmosphere (Hoosbeek and Bryant, 1995). Atmospheric increase in CO_2 is mainly attributed to the burning of fossil fuels by modern industry, and it is from this point that the interest in soil C storage begins.

The C cycle's equilibrium dynamically moves through the following three reservoirs: the oceans, the atmosphere and terrestrial systems. The geologic reservoir is the fourth and is considered to be a permanent sink with little effect on the carbon cycle (Eswaran et al., 1993). The C released from fossil fuel burning comes from the geologic sink and contributes high amounts of C into the cycle which must subsequently go into one of the three dynamic sinks. Carbon stored in soils is nearly three times that in aboveground biomass and double that in the atmosphere (Eswaran et al., 1993). These relationships have sparked scientific interest in SOC pools. The questions include (1) how much C is currently in the world's soils, (2) how much can they hold, and (3) can current agricultural and forestry practices be improved to help increase a soil's ability to sequester C?

The net effects of conservation efforts on SOC storage are highly debated. Some projections claim that 150 Pg (1 Pg = 10^{15} g) of C could be reclaimed by terrestrial uptake in the next 50-100 years, especially by use of conservation tillage (Metting et al., 1999). Conservation tillage can increase C storage through (1) less erosion, (2) increased soil aggregation, and (3) decreasing the loss of SOC by oxidation from tillage (Metting et al., 1999). Increasing temperatures from global warming can also induce more C release from SOC stores to the atmosphere because of increased decomposition rates of organic matter. Possible feedback effects would be greatest in cooler climates, as decomposition rates are more sensitive at cooler temperatures, releasing soil C into the atmosphere. The CO_2 released could be offset by increased production and uptake by plants due to both increased temperature effects on primary production and greater CO_2 in the atmosphere (Kirschbaum, 1995).

Bohn (1976, 1982) and Eswaran et al. (1993) have discussed some projections of C sequestration potentials in soils. Estimates of global C storage in soils are not accurate because of problems with gaps in data collected and in adequate rock fragment and bulk density estimates (Eswaran et al., 1993). The Appalachian Mountains are characterized by rugged and remote terrain, where only logging and pasture are rewarding options for land use. Land use and soil mapping are less consequential than in the lower elevations of the East Coast, resulting in a gap in soil maps and data. Gaps in the C data set exist from investigators not recording amounts of surface organic materials such as leaf litter. Soils in higher elevations, however, have been found to contain thicker O and A horizons because of cooler temperatures and increased rainfall, and can therefore represent a more significant C reserve than soils at lower elevations (Lietzke and McGuire, 1987; Daniels et al., 1987a; Feldman et al., 1991ab). In current projections, most estimates of SOC extend from known values for established soil series, which can cause large errors. A second problem occurs because the more popular methods for measuring bulk density in soils have been found to have errors for horizons containing higher amounts of organic matter or coarse fragments. These rocky soils can hinder core and clod methods, so that in some cases bulk density must be estimated from regression equations (Pritchard et al., 2000).

Factors Effecting Carbon Levels in Soils

Soil organic C is highly variable in soils and is affected by many factors. Jenny (1949) related the loss constant "k" (decomposition rate) as being a function of all five soil forming factors (SFF), that is, parent material, time, topography, organisms (plant and animal), and climate.

Climate (temperature and precipitation) can affect SOC specifically due to influences on production and turnover rates. Jenny et al. (1949) looked closely at climate, comparing tropical, subtropical, and temperate environments. In the warmer, more humid tropical environments, Jenny observed increased litter production and increased rates of decomposition compared to areas in California. Annual loss of litter was therefore highest in the tropics. Observations of bare ground versus cover (forest and grass sites) in all climatic regions showed no differences in alfalfa decomposition rates, hence Jenny concluded that macroclimate (temperature and precipitation) had stronger effects on decomposition of plant tissues than solar insolation (solar radiation and angle of incidence). While this relationship may be true on a larger scale, solar insolation plays a much larger role in the microclimate of local areas (Mowbray and Oosting, 1969).

Differences arise from variability induced by topography. Microclimate variability may be pronounced, such as with elevation and aspect differences, or arise from undulating mounds and depressions over a small area. Increases in elevation are generally accompanied by decreasing temperatures and increasing precipitation created by orographic effects (Jenny et al. 1949; Sims and Nielsen, 1986; Shanks, 1954; Smallshaw, 1953). In California, Jenny (1949) observed that decomposition of organic matter increased from 90 to 900 m elevations because of increasing precipitation. In the elevation range of 900 to 2100 m, precipitation stayed constant while temperature and decomposition rates decreased. Between 2100 and 2700 m, precipitation increased again and so did decomposition even though temperature decreased. Jenny therefore concluded that precipitation had a greater effect on decomposition rates than temperature. Sims and Nielsen (1986) also correlated organic matter to elevation and precipitation. Daniels et al. (1987a) observed that A horizons in the Southern Appalachians deepened with increasing elevation, relating to incorporation of organic matter into the mineral soil. Biomass was found to decrease as elevations increased in the Smoky Mountains (Whittaker, 1966). However, A horizon depths increased with elevation because of low temperatures and decreasing decomposition rates of organic litter.

Differences in aspect and slope can affect soil organic matter content because of moisture and temperature variability. Solar insolation is the main contributor to microclimate variability on aspects and slopes (Franzmeier et al., 1969; Mowbray and Oosting, 1968). Differential warming because of topographic exposure (aspect) generate similar effects on climate as a change in latitude (Frank and Lee, 1966). Solar beam irradiation (the solar energy that affects a slope) is controlled by many factors, the most important of which is direct radiation from the sun. Potential solar irradiation is estimated because of possible day-to-day variations in atmospheric and other factors. The intensity of irradiation on the surface is proportional to the cosine of the angle of incidence, which is a product of (1) terrestrial latitude, (2) time of day (hour angle), (3) time of year (solar declination), (4) slope, and (5) surface orientation (Frank and Lee, 1966). Radiation from the sun progresses to higher angles as it approaches the earth's poles. In the Northern Hemisphere S aspects would receive more hours of direct sunlight than N aspects. Soil and air temperatures were found to be higher on S aspects than on N aspects in the Southern Appalachians (Mowbray and Oosting, 1968; Losche et al., 1970). Soil moisture was also observed to be greater on N aspects (Franzmeier et al., 1969; Mowbray and Oosting, 1968). Precipitation was also higher on N aspects (Mowbray and Oosting, 1968). Franzmeier et al. (1969) also observed that direct radiation varied on N aspects, being near zero in the winter because of low angles, but remaining more uniform throughout the year on S aspects. Calculations for latitudes between 30º and 50º have shown that S aspects do not vary drastically with increasing angle, but N aspects do receive decreasing solar insolation with increasing slope angle (Frank and Lee, 1966). Mowbray and Oosting (1968) also reported that N aspects had their lowest angles in winter, but S aspects did vary in sun inclination throughout the year. Lower slope angles on N aspects during the winter produced the greatest differences in temperature between the aspects during that season (Franzmeier et al., 1969; Mowbray and Oosting, 1968). Angles of incidence increase from high position (summit) to low position slopes (toeslope), with the greatest differences between aspects being at the lower slope positions. Lower slope positions may receive more shading from surrounding summits, making slope angle less important. Air temperature differences were observed to be highest at midslope positions even with the most pronounced contrasts lying at the lower positions, (Mowbray and Oosting, 1968). Suppression of these differences was found in rainy seasons and years with high cloud cover. Moisture from rainfall and cloud cover help evenly distribute heat more, dispersing temperature differences (Mowbray and Oosting, 1968).

Higher moisture levels and cooler temperatures on N aspects have similar effects on decomposition of litter to elevation changes. More total SOC and darker colors were reported in soils on N aspects in many different studies (Daniels et al., 1987a; Sartz and Huttinger, 1950; Finney et al., 1961; Franzmeier et al., 1969). Slope angle would also have a strong effect on C in soils as more level slopes will not drain as well giving way to more saturated conditions. Saturation can decrease oxygen levels and organic matter breakdown rates. Swamps and bogs are examples of where organic matter accumulates because of saturated conditions.

Temperature and moisture differences associated with topography directly affect the organisms SFF. Organisms include fauna (animal), flora (plants) and even anthropogenic sources of influence. Plant tissue and litter would not be decomposed or incorporated into the soil as efficiently as they are if it were not for the micro and macro-organisms in soils (geophages).

Organisms have been found to follow trends correlating with moisture gradients (Whittaker, 1952). On drier, more xeric sites, smaller insect samples were collected and fewer scavengers were found, probably because their food supply decreased. Diversity of species peaked at intermediate temperature and moisture conditions, where high biomass productivity also exists. Areas of stress (dry, cold, etc.), such as heath balds and fir stands, produced less diversity, but more advanced (adapted to extreme conditions) species, (Whittaker, 1952).

Microbial populations decrease as elevation increases (Witkamp, 1963). Jenny et al. (1949) observed that increased precipitation also led to increased decomposition in California, where precipitation increased with elevation. In contrast, Witkamp (1963) observed that in the Great Smoky Mountains temperature was the dominant controlling factor in microbial populations (not respiration). Less litter weight loss was seen with increasing elevation, even with the increased precipitation occurring with higher elevations. This indicates that in humid areas moisture is not as strong of a limiting factor. Moisture became a factor in this same study at lower elevations and precipitation.

Geophages that effect litter consumption and incorporation include squirrels and other macrofauna, insects, earthworms, bacteria and fungi (Brady and Weil, 2000). Invertebrates themselves have been shown to be involved in almost every level of decomposition. They affect soil processes and horizonation directly by incorporation and redistribution of organics and indirectly by shaping microbial populations (Wolters, 2000).

Organic matter has a low concentration of nutrients, so a lot must be ingested by invertebrates. Positive correlation with Ca, N, H_2O, and carbohydrates has been found for invertebrate populations (Wolters, 2000). Earthworms are one of the most important fauna in the soil. They eat only detritus and entrained organisms, preferring moist upland soils and fresh tissues. Earthworms ingest soil as well as organic tissue increasing aggregation as well as increasing nutrient availability to microbes (Brady and Weil, 2000). All organic matter can be oxidized eventually, no matter how recalcitrant or non-labile the fraction. Organic matter be protected from oxidation only by binding to soil particles can (Wolters, 2000).

Bioturbation, is the bulk mixing of litter and C done by earthworms, arthropods, and macrofauna. Incorporation of organic matter to greater depths increases stability and chances of organic matter binding with mineral matter (Johnson, 1990; Wolters, 2000). Mixing organic matter into the soil creates conditions favorable to microbial activity (Wolters, 2000).

Microbial activity (that of bacteria, algae, protozoan, and fungi) is very important to breakdown of detritus. Microbial breakdown of leaf litter begins on the tree, removing portions of waxy coatings, and continues after leaf fall. Microbes remove aromatic compounds and increase nutrient quality of litter, increasing litter palatability for earthworms and insects. The attraction geophages have to litter is positively correlated with the Ca, N, moisture, and carbohydrate content (Wolters, 2000). Temperature and moisture, stages of decay, and litter type control the organism type that exists in a given area and their strength in numbers (Witkamp 1963, 1966).

Vegetation distributions follows moisture gradient (Day and Monk, 1974; Whittaker, 1952; Mowbray and Oosting, 1968), where mixed mesophytic species give way to oaks, conifers, and then grassy balds along the transition from mesic to xeric sites. Whitaker (1952) reported that litter production was greater on xeric S aspects in the Smoky Mountains. Litter type has a strong influence on what organisms dominate the local decomposers (Witkamp, 1963,1966; Manuserva, 1970; Whittaker, 1952; Bal, 1970). The C:N ratio is the strongest controller of microbe type in the litter. Both bacterial and fungal counts decrease with increasing C:N (Witkamp, 1966). Bacterial counts were observed to be significantly higher in the deciduous stand versus coniferous stand for five different leaf species placed in bags. This was attributed to the low C:N ratio, moderate pH, high protein and high mineral content of the deciduous leaves, while pine needles had the opposite effect on microbial populations and breakdown (Witkamp, 1963). Bal (1970) reported that fir stand litter would be unsuitable for earthworm habitat. High C:N ratios are found in litter with lignin and more complex and difficult to digest compounds. Fungi and slower decomposers are the dominant decomposers under conifers because of the high C:N ratios. Fungi are also more versatile decomposers than bacteria and will be active long after bacteria decline (Brady and Weil, 2000). Within deciduous trees, differences can also be found between oak (*Quercus*) and beech (*Fagus*) leaves. Oak leaves have lower moisture than beech, favoring fungi populations (Witkamp, 1963). Earthworms have also been shown to prefer red maple (*Acer rubrum*) leafs over oak when in the presence of both (Shanks and Olson, 1961). Litter type will therefore strongly affect detritus breakdown and incorporation into the pedon. Bacteria and earthworms can break down and incorporate litter deeper into the soil under hardwoods, while soil profiles under conifers had increased pine needle buildup and less C incorporation into mineral horizons (Bal, 1970).

Canopy cover causes differences on C sequestration, particularly open fields versus forest canopy. Soil temperatures of meadows and pastures are higher than those of forests because they receive more direct radiation (Shanks, 1956). These differences in vegetative cover generate greater variation in summer versus winter temperatures (Munn et al., 1978). Forest canopy and litter deposits over the soil have strong insulation and buffering on freeze/thaw effects and soil temperature regimes (Daniels et al., 1983). Litter buffering also tends to give forest soils a more delayed warm up in the spring as well (Munn et al., 1978; Shanks, 1956). Daniels et al.

(1983) observed that major changes between forest and pasture were moisture relationships, bulk density of the A horizon, and the deeper location of the clay bulge in the pasture soil. No significant differences were reported between pasture and forest A horizon depths, which can reflect differences in geophage populations. Homann et al. (1995) and Pritchard et al. (2000) both found higher organic C in meadow/pasture than forest soils. Homann concluded this was from higher bulk densities and lower rock contents, while Pritchard et al. noted that meadows had a more extensive root system that would decompose beneath the surface. Total ecosystem C was reported to be greater in forest systems by Pritchard et al., because it had greater above ground biomass than pasture. Humans also affect C in soils through logging and cultivation activities.

Time and parent material are the last SFF that can affect C sequestration in soils. A study in the former Soviet Union by Manuseva (1970) observed that soils over limestone contained more organic C in the humus horizon of the soil over limestone than the soil developed from quartz sandstone. More organic matter was also found in brown limestone soils because of aggregation with clay mineral matter. Soils over limestone are also deeper, and usually more productive for forest soils. Parent material can affect bulk density, nutrient composition and depth to bedrock. These can all have strong effects on C sequestration. Time affects all of the other factors, usually via increased weathering with age. All factors and processes of weathering occur over time, such as litter accumulation, breakdown and incorporation into soils.

Separating Litter Layers

Classification and naming of forest organic layers can come with some difficulty. Changes in microclimate can alter tree species and geophages that feed on deposited detritus, which in turn can determine what type of litter layer forms.

Separation of organic layers can be done with the L, F, and H as system as litter layer designations (Hoover and Lunt, 1952). The L-layer stands for leaf, and is the unaltered dead remains of plants and animals (Federer, 1982). Bal (1970) considers the L as only a layer and not a horizon, while the F and H may be considered horizons since they have undergone changes. The F-layer is the fragmented or fermented layer, where litter is partly decomposed. The H-layer is the humus layer and is well-decomposed, amorphous organic material made from the fecal matter of geophages, so that determining what type of tissue is present is impossible (Wolters, 2000; Federer, 1982). The F and H-layers have been worked on by processes and may be considered organic parent material (Bal, 1970).

Separation of the L, F and H-layers is semi-qualitative and subject to interpretation. One individual observing the same forest litter over a number of different instances may find that their own separations between layers may differ. Care must be taken in this qualitative judgement (Federer, 1982).

Bal (1970) studied organic horizon genesis under red oak (*Quercus rubra*) and Douglas fir (*Pseudotsuga menziesii*) and the influence of soil fauna in the Netherlands. Under red oak, Bal reported a thin L-layer, where the highest concentration of microbes were present because of availability of leaf fragments. Red oak leaves decomposed faster than Douglas fir needles. Earthworms were found concentrated between the F and H-layer boundary. Water holding was also higher under the red oak versus the Douglas fir, where the H-layer was thicker. These fecal materials have higher water absorption than undecomposed needles. In comparison, the litter under Douglas fir contained a thicker L-layer of needles, attributed to the higher C:N ratio and reduced palatability. This also led to a thinner H-layer but with more sturdy excrements. Earthworms were absent within the fir stand.

Sartz and Huttinger (1950) listed stand age, stocking, logging, fires, grazing and topographic factors as other controls of humus development. Fires have significant impact on soil genesis and forest recovery because they can completely remove H-layers, taking away microbial habitat and exposing mineral soil to more extreme conditions.

The Frigid Temperature Regime

The frigid temperature regime is described in Soil Taxonomy (1999) as having a mean annual temperature of < 8^{o}C and a greater than 5^{o}C difference between the summer and winter months. The mesic soil regime is the next warmer regime (8º-15ºC) and an attempt at predicting a line between these two regimes is still being debated. This line is abstract, and attempts to represent a discrete boundary for simplified purposes. Soil temperature changes as a continuous function and can have local variances within a regional trend (Edmonds and Campbell, 1984). Therefore the term "frigid line" is also a weak characterization, as the separation between the mesic and frigid regimes would be more of a transitional zone rather than a distinct or abrupt line on a map. Certainty of accuracy increases as distance from the proposed line increases.

Determining where the frigid/mesic line may exist is difficult. Soil temperature data is normally taken at a 50 cm depth, which represents the average temperature for the upper 1 m in the pedon, and should not vary with daily temperature fluctuations (Soil Survey Staff, 1999). This temperature is commonly averaged over a one-year period and designated as the Mean Annual Soil Temperature (MAST). This depth may not always be accurate because of variations in slope, aspect, vegetation, soil wetness, and snow cover, which can alter the temperature by insulating to different degrees (Carter and Ciolkosz, 1980). Soil temperature has not been commonly recorded in the past and so has been averaged from the Mean Annual Air Temperature (MAAT). The MAST has been estimated by adding 1ºC to the MAAT, but local deviations may need as much as 3ºC added to the MAAT (Soil Survey Staff, 1999). Carter and Ciolkosz (1980) found that MAAT was 0.2ºC to 2ºC cooler (average of 1.2ºC) than the MAST due to differences in natural insulating effects.

Temperatures decrease with rise in elevation and latitude, affecting location of the frigid/mesic. Linear regression equations by Mount et al. (1999) and Carter and Ciolkosz (1980) have shown this relationship across the Central and Southern Appalachians. Around 37ºN latitude, Mount et al. (1999) predict the frigid/mesic line to be approximately 1200 m in the southern Appalachians. The Carter and Ciolkosz (1980) regression only projected north of Davis, WV and used relative latitude from that point, but Lietzke and McGuire (1987) extrapolated the line into Tennessee and correlated it with data from Roan Mountain and Unaka Mountain. With this projection it can be estimated that at 37ºN latitude the frigid/mesic boundary is around 1350m.

Forests of the Higher Elevations in the Southeastern U.S.

The Southeastern United States experiences a humid temperate climate. Orographic effects cause more precipitation to fall at higher elevations (Shanks, 1954; Jenny et al., 1949; Smallshaw, 1953). Shanks (1954) reported that rainfall above 600-800 m in the Great Smoky Mountains fell into Thornthwaite’s rain forest or perhumid class. Precipitation ranges in southwestern Virginia range from 100 cm in valleys to 240 cm on ridges, but steep slopes could also contain updrafts that can carry moisture off of ridges (Smallshaw, 1953). Extreme conditions like this can have positive effects on production, but also cause debris avalanching and mass wasting on steeper slopes in the Appalachians (Neary et al., 1986).

Higher peaks in the Southern Appalachians have regionally unique vegetation because of cooler temperatures. Common forests of the Appalachians resemble those of the Northeastern region, particularly where they lie in the frigid temperature regime (Shanks, 1954; Korstian, 1937). Climate in the higher elevations of the Smokie Mountains is suggested as similar to the lower and middle elevation Appalachians of Maine (Oosting and Billings, 1951).

In Virginia, frigid areas are restricted to higher elevations and are very small in total area (Lietzke and McGuire, 1987). The higher elevations in Virginia are typically made up of resistant geologic materials, so they have not weathered and eroded away (and they continue to be this way) as fast as their valley counterparts. The north slope of Appalachians ridges receive less sunlight than the south, so they remain cooler and wetter in comparison. These conditions presumably favor accumulation of organic C by limiting microbial decomposition.

In lower elevations of the Southern Appalachians, northern hardwoods come in at elevations above 600m and running up the slope to the lower edge of the northern evergreens forest (Strasbaugh and Core, 1977). In most forests, tree biomass overshadows that of herbaceous and shrub species (Whittaker, 1966). Sugar maple (*Acer saccharum*), beech and yellow birch (*Betula alleghaniensis*) are the dominant types of trees in the northern hardwood forest.

The northern evergreens come in at higher elevations. The most common conifer in this forest is the red spruce (*Picea rubens*). Logging of this species in the early 1900's completely removed most of this forest where it once dominated the pre-settlement Appalachian landscape (Strasbaugh and Core, 1977; Clarkson, 1964; Korstian, 1937). The spruce forests that once existed were remnants of the Pleistocene climates. During this period, the Southeastern climate was cooler and possibly periglacial (Clark, 1959; Core, 1929) and northern and southern forests were interconnected and similar in composition (Oosting and Billings, 1951). Pollen records from the Wisconsinan epoch suggest an oak-pine gradient that is similar to those of present-day northern Minnesota (Buell, 1945). In current conditions, these northern species can only survive at the higher elevations where temperatures are cool enough (Lietzke and McGuire, 1987). Spruce-fir stands were reported as absent from the southeast half of the Great Smoky Mountain range because peaks there were not high enough to encourage survival during xerothermic periods. On the north half of the range, the spruce-fir persisted where elevations are higher (Whittaker, 1952). Red spruce has now become stranded across a few peaks in the southeast, and cannot easily revegetate areas it formerly dominated (Lietzke and McGuire, 1987).

Spruce stands have still been reported in the southeastern states. The largest existing stand is in the Great Smoky Mountains National Park of Tennessee and North Carolina (McCracken et al., 1962; Feldman et al., 1991;

Buchanan, 1982; Lietzke and McGuire, 1987; Oosting and Billings, 1951). Although vegetative similarities exist between the southeastern and northeastern forest, more persistent snowfalls and more frequent low temperatures are found in the northeast, creating dissimilarities between climates (Shanks, 1954; Oosting and Billings, 1951).

Lowland forests of the southern Appalachians are dominantly oak-hickory. Composition varies with aspect and altitude (Braun, 1942). Mixed mesophytic species are found in coves and envronments with higher moisture, grading into oaks and then pines as sites become more xeric (Mowbray and Oosting, 1968; Whittaker, 1952). North slopes are moister and contain more mixed mesophytic species, while oak-hickory associations are found on drier south facing slopes (Braun, 1942). Conifers dominate the most xeric sites, possibly because most growth of these species occurs during spring and fall, and therefore evergreens can survive drier summers. This would limit competition for conifers on these sites, as deciduous trees could not maximize productivity on more stressful sites (Mowbray and Oosting, 1968).

Many mesic forests of the Appalachians were formerly oak-chestnut associations. In 1906, the chestnut blight caused by the parasitic fungus *endothia parisitica* was discovered in New York City (Keever, 1953; Woods and Shanks, 1959). By 1930, 90% of the chestnut trees in North Carolina forests were infected. Changes in forest composition occurred with the loss of forty percent of the canopy from chestnut death. (Keever, 1953). After the chestnut died, existing canopy species spread and then were replaced by other species. The majority of the replacement species were oaks, maples, and hickory (Woods and Shanks, 1959).

Soils of the Appalachians

A variety of studies have investigated the Appalachian soils. Parent material and precipitation were usually the only cited differences between soils along the Southern Appalachians from Virginia through North Carolina and Tennessee (Losche et. al., 1970). The Appalachians are commonly comprised of folded sedimentary rocks in the South and run parallel and west of a dominantly metamorphic range, the Blue Ridge Mountains. A majority of these regional soil studies have focused in the Great Smoky Mountains area, which is predominantly metamorphic. McCracken et al. (1962) reported that the soils in the Smoky Mountains were acidic soils with thick granular A horizons, and B horizons that had very little clay or Fe accumulation. The soils were described as the product of extreme weathering conditions, with nearly all feldspars from the parent material being absent from the B horizons. A horizons also contained low amounts of bases and higher amounts of Al than most typical A horizons. This would support a belief that if there were enough accumulation of organic materials, the horizons would most likely be umbric and ochric.

A study done by Daniels et al. (1987b) in the southern Appalachian Mountains found similar results to McCracken et al. (1962). The soils contained morphological characteristics of Inceptisols (young soils), but the mineralogy of highly weathered soils. Gibbsite, an Al oxide usually present in weathered soils, was found to increase in concentration with depth, possibly formed from the rapid dissolution of feldspars and desilication. The intense desilication that occurs here can be attributed to the high rainfall and leaching that accompanies it. These Al oxides can coat clay minerals, causing the loss of cation exchange sites from the subsoil. Kaolinite, a 1:1 clay mineral, was not found in high quantities, especially on N facing slopes, because of the rapid desilication occurring in these soils, producing more gibbsite. Higher amounts of kaolinite on the S slopes may be due to wet/dry cycles that help flocculate clays and produce argillic horizons (Feldman et al., 1991b). Unlike McCracken, Daniels et al. did find feldspars, which indicates either that the soil is young or is rapidly weathering into saprolite.

Exchangeable Ca and Mg in the soils studied by Daniels were undetectable below the organic layer, indicating the importance of nutrient cycling in forest soils and how the loss of this horizon could affect site productivity. Litter weights of the organic horizons were similar for all soils sampled. Total litter production and total litter weights did not vary by aspect. North facing slopes contained higher amounts of organic C in mineral horizons and whole soil organic matter content was also higher which is directly related to A horizon depths being greater on north aspects (Daniels, 1987a). This should be expected because of their cooler, moister microclimates existing on N slopes.

Losche et al. (1970) also sampled some metamorphic soils in North Carolina and obeserved less gibbsite on north aspects, in contrast to Daniels et al. (1987b). Losche et al. explained this as being due to Al bound in kaolinite and mica intergrades. Losche et al. suggested that higher temperatures that existed on south aspects caused them to have deeper, redder pedons, which contained more Fe and illuviated clay than N slope pedons. A second study area in Virginia weathering from sedimentary rocks was also observed by Losche et al. (1970). Aspect differences over siliceous sandstone were not as pronounced as the ones on a North Carolina biotite. No gibbsite was found, as there was no Al source in the siliceous material and or HIV intergrade present that could produce an “anti-gibbsite” effect.

Another study comparing parent materials was reported by Feldman et al. (1991ab) in the southern Appalachians (the Smoky Mountains and Black Mountains) and the Virginia Blue Ride province (Mount Rogers area). Different parent materials, namely sedimentary and metamorphic, underlie these three areas. Soils across all three regions were similar morphologically and in clay mineral suite, despite differences in parent material, because of the effects of a intense weathering by a humid climate and mixing of the soil. Feldman (1991b) believes that current frost churning and windthrow of these soils, and past peri glacial activities in the region have kept these soils young morphologically, with younger materials overlying older. Podzolization was the dominant soil process in this area, as Feldman also reported increasing Al and Fe saturation with depth, giving the soils chemical properties of spodic horizons, but not the classical A-E-Bhs morphology. Intense rainfall combined with organic accumulations help leach the Fe and Al through the profile. Podzolization is an important process when considering C sequestration since the chelation occurring between metals and organic matter creates stable substances that are hard to remove over time.

Coile (1938) worked on the properties of podzols (Spodosols) that formed in the Southern Appalachian Mountains. He found that they were characteristic of latitudes that are more northerly because they formed under spruce forests with cool moist climate over sandstone and shale. A majority of the sites in his study were located in West Virginia, where there were more siliceous parent materials. Some were located in the Tazewell County, Virginia were under virgin red spruce forest, possibly near or at the site for this study. In general, he found these soils to be poorly drained, and that the Spodosols were less likely to found under birch-maple forests rather than red spruce, possibly because of the higher amounts of cations in deciduous litter.

Logging in the Appalachians

Forests throughout the Southern Appalachians all share the history of being logged at least once. Logging practices can cause compaction of the soil, but more importantly they remove vegetation and litter cover that prevented erosion of well developed A and organic horizons (Johnson et al., 1991; Korstian, 1937). Average bulk density has been found to be 11% higher in the upper 50 cm of cultivated soils as compared to nearby forest soils (Kingsbury et al., 1993).

Clear-cutting of forests removes biomass and sources of litter for the forest floor. Losses of organic matter occur in the organic horizon, predominantly in the H-layer (Mattson and Smith, 1993; Covington, 1981), due to increased biotic respiration and loss of inputs (Johnson et al., 1991). The L and F-layers are lost first because their canopy sources are gone (Covington, 1981). The H-layer loss is most important because it takes a longer time to recover. Large increases in litter organic matter can come from woody debris left with cutting (Boring et al., 1981). Edwards and Ross-Todd (1983) stated that there was no detectable direct impact from logging on CO_2 concentrations in the atmosphere besides the release from decay of root masses and the reduced photosynthesis due to lower soil fertility.

In New Hampshire, during forest recovery from logging, it is reported that forests become a net sink for nutrients, while woody debris becomes a source (Covington, 1981). The forest floor degrades for about fifteen years, after which it will begin to recover, approaching its original litter weight sixty years after clear cutting (Covington, 1981). Decomposition rates can change with increased temperatures and loss of nutrient sources (Covington, 1981; Boring et al., 1981; Mattson and Swank; 1989). Mixing and shredding mesofauna have been observed to be largely absent from clear-cut lands (Abbott and Crossley, 1982). However, no significant changes have been reported in soil organic matter unless a complete loss of forest litter occurs with burning or herbicide use (Mattson and Smith, 1993).

Fires occurring after logging are the most destructive force effecting site quality for regrowth, and were common after logging operations in the Southeast (Clarkson, 1964). Complete loss of all litter occurs with fire, removing nutrients, microorganisms and the protective layer that kept moisture available for sprouting plants (Korstian, 1937). Humus has strong adsorption capacity for rainfall, and helps deter erosion in an environment with heavy precipitation (Korstian, 1937; Sartz and Huttinger, 1950; Bal, 1970). Heavy rainfall, after the loss of the protective litter layer to fire can remove soil all the way to bare rock (Korstian, 1937). A study conducted by Jones (2000) investigated disturbed and undisturbed forest soils in the Joyce Kilmer-Slickrock Wilderness and found that the major differences between the two soils were solum depths and coarse fragments. The A horizon depths were shallower and solum depths were deeper on the disturbed site, as well as the coarse fragments being located higher in the soil profile (Jones, 2000). Differences in litter layers between disturbed and undisturbed soils reported by Jones, indicated disturbed sites as lacking H horizons, which were possibly removed by forest fires.

The red spruce stands in the Appalachians are estimated to have populated over one million acres prior to logging (Karstian, 1937). Softwoods like spruce were highly valuable for construction purposes and paper (Clarkson, 1964; Korstian, 1937). Red spruce grew to heights of 27 m and could have diameters up to 1 m, and understory rhododendron usually made impassable undergrowth (Clarkson, 1964). Spruce stand litter holds high amounts of moisture. Forest floors were usually wet enough to stop fires that approached their stands, except during a dry season or if they had been logged (Korstian, 1937). Careless fires of local inhabitants rather than logging operations destroyed stands of red spruce once located on Spruce Mountain, West Virginia. The knob had burned almost a century before and was still in heath bald, because extreme conditions, such as high winds, at the high elevation prevented the growth of trees (Core, 1929).

Soils in the Appalachians are effected by many different factors, all of which can have direct effects on how much C is currently sequestered in the forests. Close attention should be paid to topography and vegetation when trying to uncover C relationships. Past land use history should be uncovered and examined to determine what effects it may have had on present C levels. Care in sampling and laboratory analysis should be done to insure the proper variability is uncovered.

Chapter 3: Materials and Methods

Study Area

The study area is located on Clinch, Garden and Beartown Mountains near Burkes Garden, in Tazewell County, Virginia (Fig 3.1). This area is a broad ridge and saddle plateau that is representative of high elevation peaks in the Southern Appalachians. The study area is located on the Hutchinson Rock USGS quadrangle (Fig. 3.2). Silurian aged Tuscarora sandstone-conglomerate, and acid sandstones, siltstones and shales of the Juniata formation hold up the ridges. The approximate boundary of the frigid and mesic soil temperature regimes is projected at around 1200 m at this latitude (Mount et al., 1999). The study area ranges from 1200 to 1450 m. Evidence of a cold climate can be seen in the vegetation of Beartown, which resembles vegetation of northern New York. The native vegetation consists dominantly of deciduous trees, such as sugar maple, beech and yellow birch (Strasbaugh and Core, 1977), with red spruce appearing at the highest elevations (Strasbaugh and Core, 1977; Kinser, 1982). Other cool climate plant species (relative to Virginia) also grow on the higher elevations, such as the spreading shielding fern (*Dryopteris campyloptera*) and at least four species of club moss (Kinser, 1982). Five birds common to northern climates are also found in the spruce stand (Kinser, 1982). A recent color infrared image of the Beartown area (Fig. 3.3) shows the rhododendron (*Rhododendron maximus*) as red, with spruce as darker points mixed into light brown areas of deciduous trees, and black areas that may be shaded.

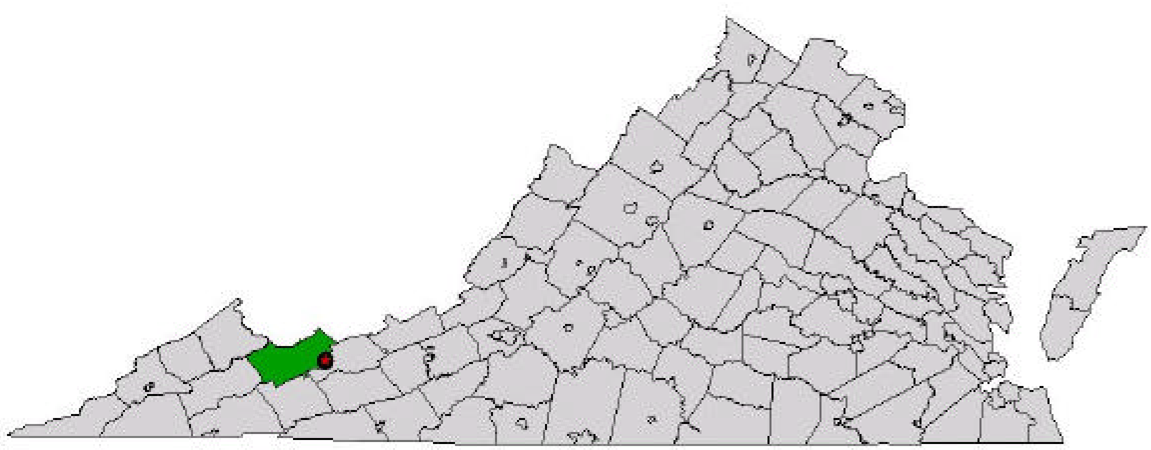

Figure 3.1: The state of Virginia with Tazewell County shown in green and a star to indicate the study area location.

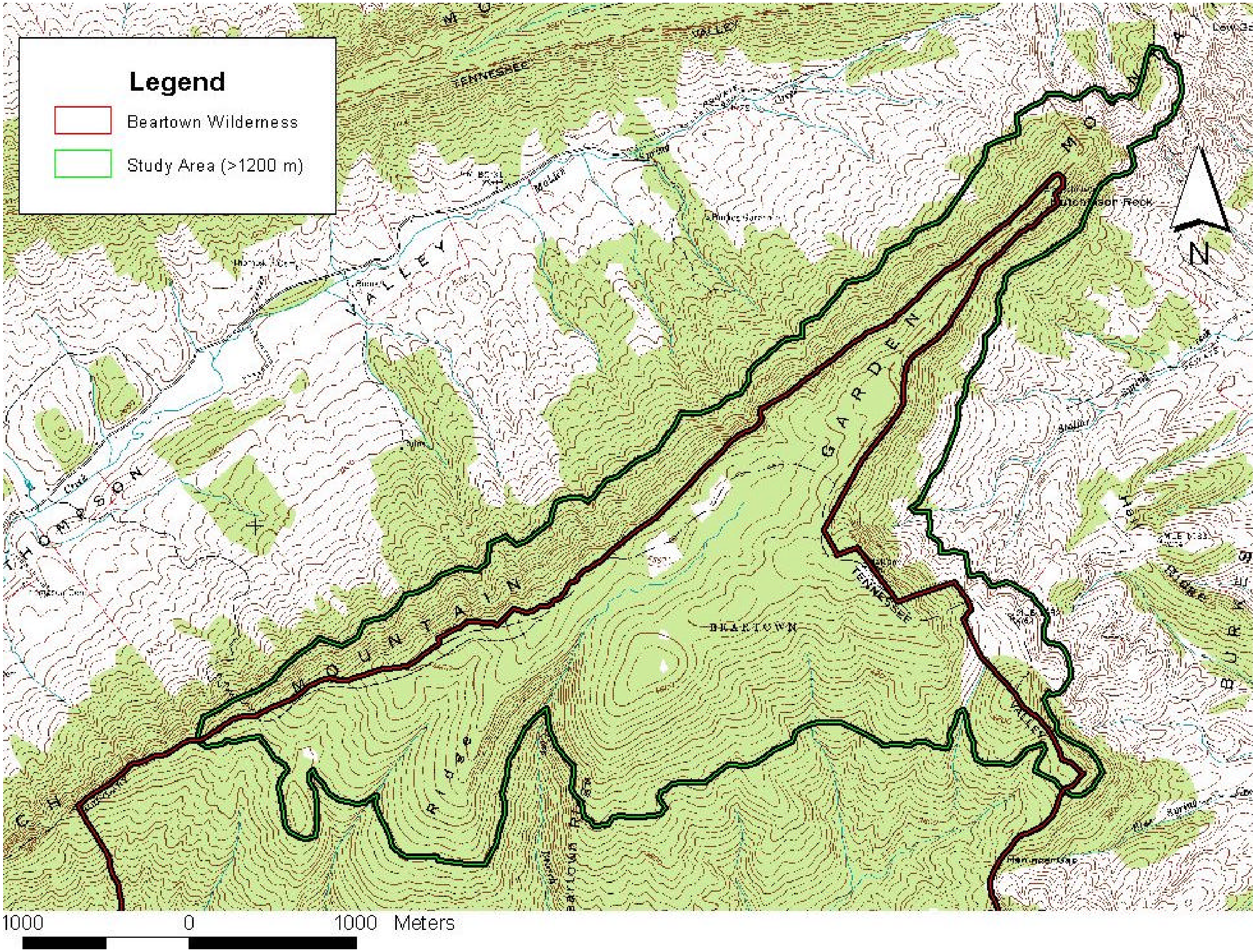

Figure 3.2: A portion of the USGS Hutchinson Rock quadrangle with the study area boundary in green and the Beartown Wilderness area boundary in red.

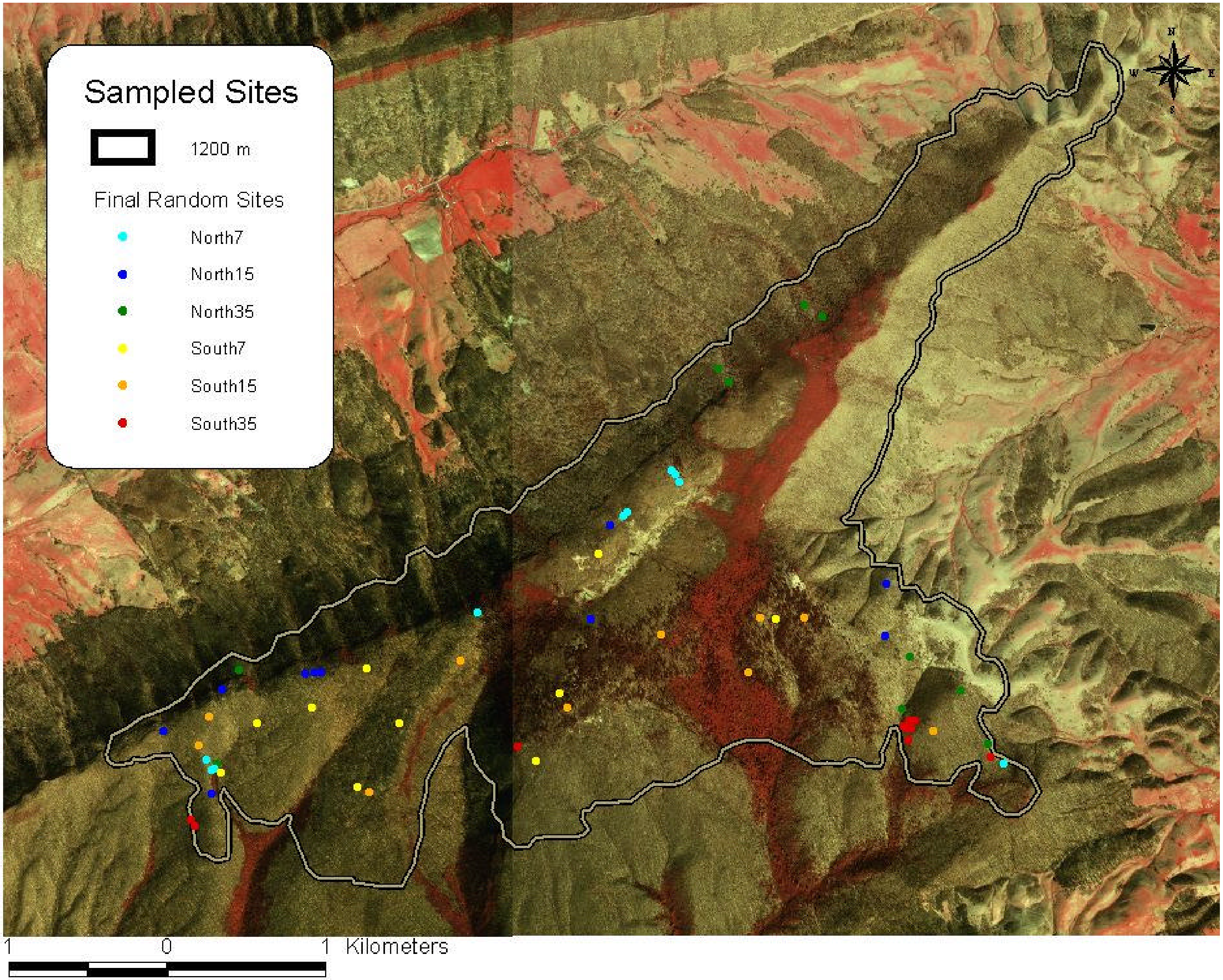

Figure 3.3: Color Infrared of the Hutchinson Rock quadrangle with the sample points shown and the study area boundary in brown.

Roughly 600 ha (1400 acres) of a virgin red spruce stand was estimated to exist in the area prior to the logging efforts, removed primarily from the bowl shaped valley on the summit of Clinch Mountain, between 1938 and 1942 (Fig. 3.2). Over twenty million board feet of lumber were transported off of the study area during this time. Following logging, an intense fire removed the humus layer, leaving bare earth and white rock (Buchanan, 1982). The severe burn coupled with the high altitude has slowed regeneration of Beartown such that in 1981 only a few pockets of spruce regenerated (Fig. 3.3). In 1985 the summit and bowl were placed into the "Beartown Wilderness Area" (Fig. 3.2) by act of Congress (Buchanan, 1982).

A current but uncorrelated USDA-NRCS soil survey map shows several soil series within the study area (Fig 3.4). Lily (Fine-loamy, siliceous, semiactive, mesic Typic Hapludults) and its frigid taxajunct were the dominant soil series along with Drypond (Loamy-skeletal, siliceous, mesic Lithic Dystrudepts), Jefferson (Fine-loamy, siliceous, semiactive, mesic Typic Hapludults) and Calvin (Loamy-skeletal, mixed, active, mesic Typic Dystrudepts). Frigid taxajunct of Calvin and Dekalb were also mapped in the wilderness area. All of the above soils are well drained and formed in acid sandstones, shales, and siltstones. All series have ochric epipedons. Drypond is the only shallow series, while Lily, Calvin, and Dekalb are moderately deep, and Jefferson is deep.

Selection of Sites

There were six treatments defined, including northerly (340-90º) and southerly (160-270º) aspects with three slope classes, 7-15%, 15-35% and 35-55% on each aspect (Fig 3.5). There were 10 sites described and sampled within each treatment area. Possible sample sites were identified using a level one 30 m Digital Elevation Model (DEM) of the Hutchinson Rock quadrangle. Both aspect and slope maps were extracted from the DEM using ESRI Arc View™ 3.2a analysis tools. Arc View™ can extract an aspect overlay from a DEM with the Spatial Analysis™ module. The slope angle overlay was derived using the DEMAT extension (downloaded from the ESRI website http://www.esri.com) using the Horn method for rough surfaces. Both aspect and slope maps were then reclassified to the treatment area categories of this study and subsequently combined through the map calculator function to identify areas for the six treatment combinations. Each pixel on this combined map represented approximately 30 x 30 m ground area, and for each treatment, only pixels lying above 1200 m were selected (Fig 3.6).

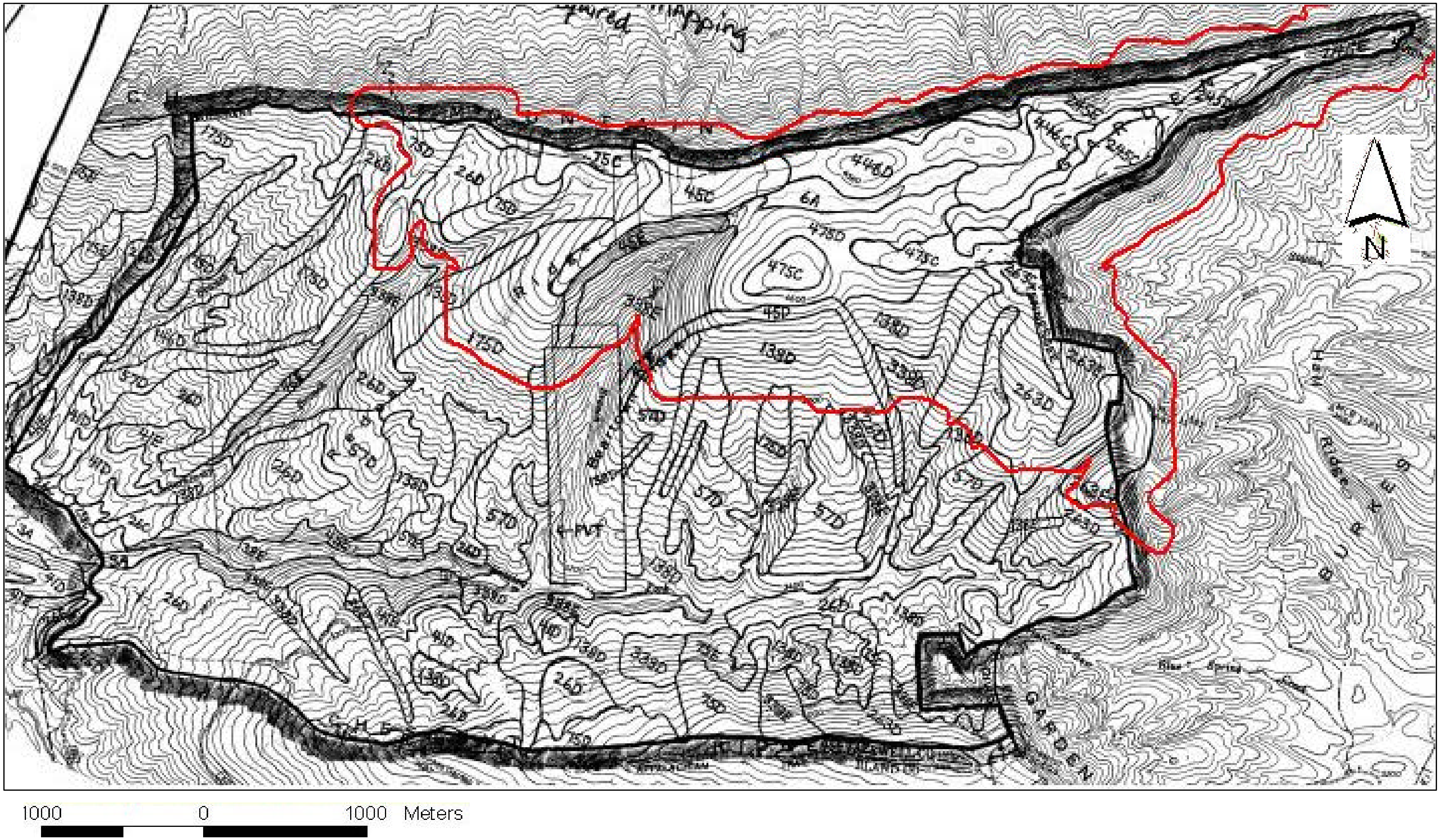

Figure 3.4: Soil Survey map of the Beartown Wilderness with the study area boundary in red.

Survey Key:	26	Jefferson loam	175	Lily-Oriskany complex	475	Lily frigid variant
	45	Drypond-Rock Outcrop complex	263	Calvin frigid variant		
	75	Lily Sandy Loam	338	Oriskany very cobbly loam, rubbly		
	138	Oriskany very cobbly loam, very stony	446	Dekalb frigid variant		

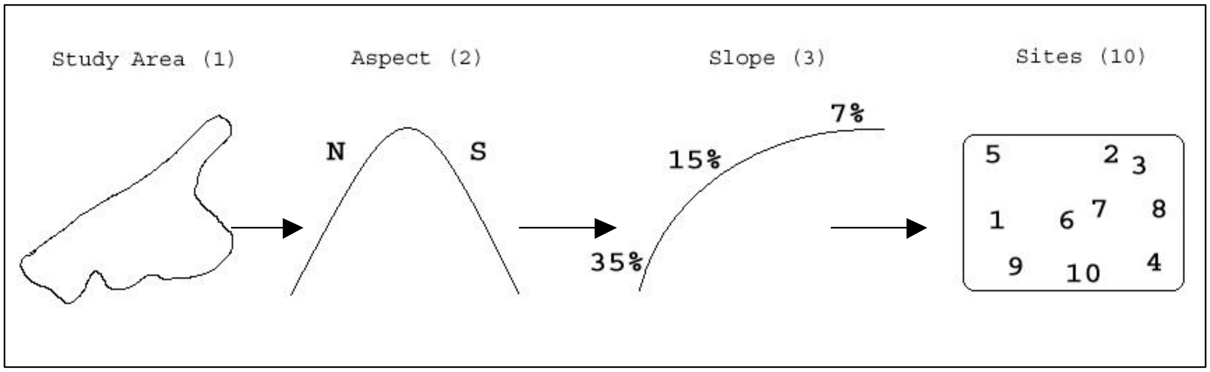

Figure 3.5: Diagram of sampling design for the 2 x 3 factorial. The study area contained two aspect classes, with three slope classes per aspect, and ten random sample sites per aspect x slope treatment combination. Each of the ten aspect x slope sites was 30 x 30m, and one representative pedon was sampled from Each site.

The centroid of all pixels was assigned an (X, Y) coordinate in decimal degrees, and any pixels not directly adjacent to at least 2 other pixels of the same treatment were removed from the table of possible sites. A random number generator was used to select 40 potential sampling sites per treatment. Selection criteria were used to eliminate sites that were not suitable. The selection criteria were set up to make sure that any variability within organic C was due to aspect and slope and not due to other confounding factors. Initial reconnaissance was done using digital ortho color infrared aerial photography, geologic maps, topographic maps, soil maps and pre-sampling within the study area to observe soil properties. Areas with limestone as an underlying parent material were avoided because of the errors $CaCO_3$ can cause in SOC estimation. Soils with sandy textures were not sampled because of differences in drainage and organomineral complexing. Spruce was not the dominant vegetation in the study area, so only mixed and deciduous stands were sampled because of the difference in breakdown rates between coniferous and deciduous litter. Areas that appeared highly disturbed, whether by anthropogenic, faunal, or floral (windthrows) activity were also avoided. The (X,Y) coordinates for the center of each 30x30 site located using the Garmin eMAP Global Positioning Systems (GPS) unit. The first 10 sites per treatment that met all selection criterions were selected for field sampling.

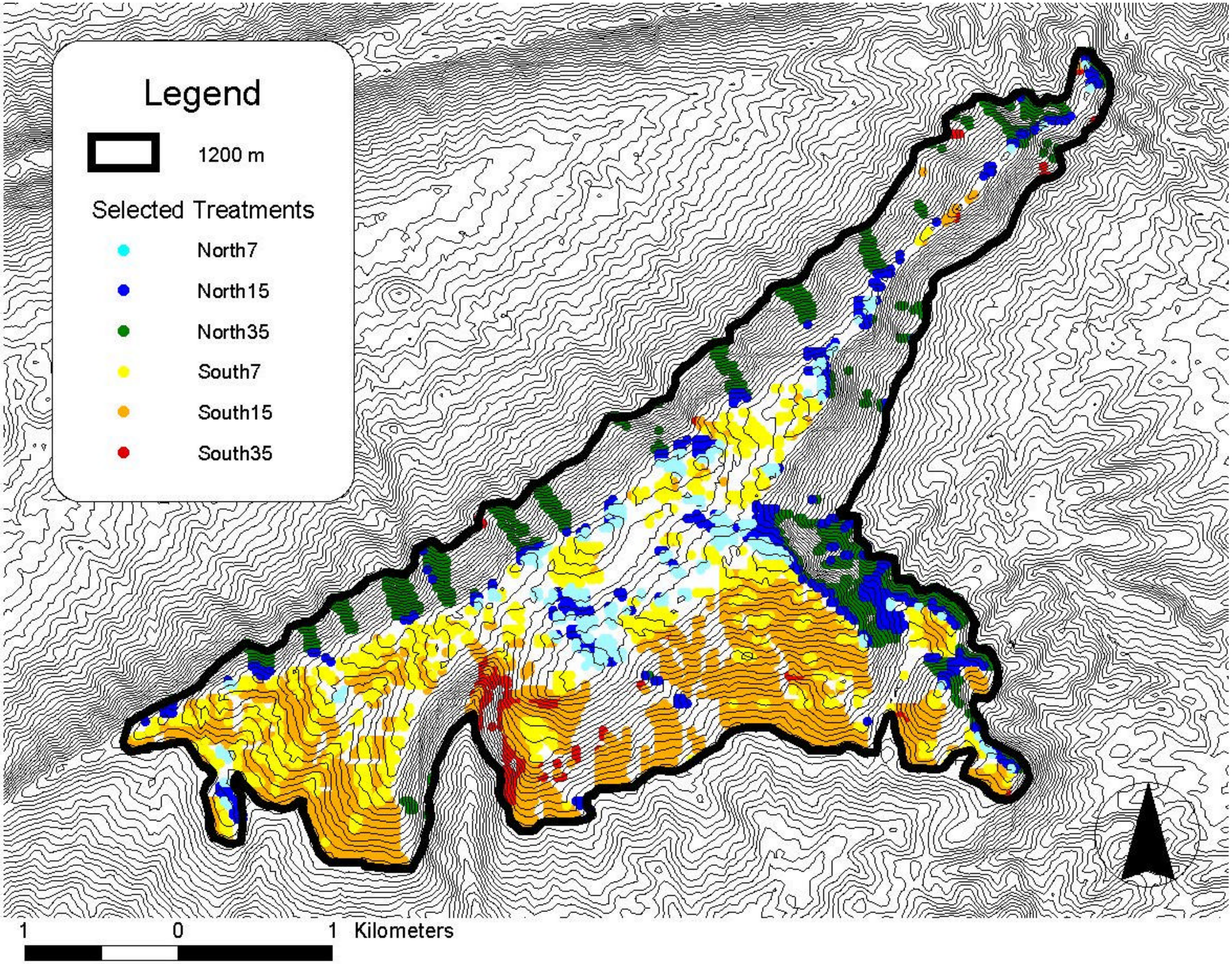

Figure 3.6: Selected treatments within the study area with each colored point representing a 30x30 m ground area.

Sampling Sites

Soil sampling took place between June and July 2001. Subsamples were taken in the (1) litter layer, (2) A horizon, and (3) B horizons to a depth of 1 meter or bedrock contact. The upper 5 cm of the A horizon was sampled separately from the lower portion if the A horizon was more than 7 cm thick.

Soil and site descriptions were made at each sample site. The litter layer was collected within a 0.25 m^2 quadrat by removing the L, F, and H-layers in succession. A 300 g sample of the top 5 cm of the mineral soil of each pedon was then removed. The rest of the mineral soil profile was sampled by auger and a mixed sample of 300 g of soil was taken from the auger sample of the A horizon below 5 cm and from the B horizon directly below. Rock fragment volume was estimated in each horizon. Bulk density was collected on all mineral horizons at two selected sites per treatment using the core method, and corrected for rock fragments in the lab (Blake and Hartage, 1986). Bulk density can be found with the following equation:

$$BD = \frac{ODS}{((V - (RW/RD)} \qquad \text{Eq. [1]}$$

where BD is bulk density (g/cm^3), ODS is the oven dry soil weight (g), V is the volume of the cylinder (cm^3), RW is the rock weight (g), and RD is the rock density (g/cm^3). Bulk density can be obtained for the litter layer data by dividing the dry weight by the .25 m^2, which is the area of the quadrat, and the layer thickness.

Solar irradiation and insolation of sites were estimated from tables for latitudes between 30º and 50º using latitude, slope angle, and aspect direction (Frank and Lee, 1966).

Laboratory Analyses

Soil and leaf samples were air-dried at room temperature. Soils were manually ground with mortar and pestle and passed through a 2 mm sieve. Leaf litter was ground into particles < 5 mm. Total C (g kg^{-1}) and total N (g kg^{-1}) were measured by combustion with a Elementar CNS analyzer (Nelson and Sommers, 1996).
SOC (Mg ha^{-1}) for mineral horizons was calculated by the summing C values from surface O horizons and mineral samples using the following formula:

$$SOC = OC * BD * UCF * T*(1-R) \qquad \text{Eq [2]}$$

where OC is organic C (%) for the samples, BD is the bulk density (g/cm^3), T is the sampled thickness of the horizon (cm), UCF is a unit conversion factor (100 Mg cm^2 ha^{-1} m^{-2}), and R is the decimal percent rock fragments.

The presence of inorganic forms of C was tested for using 10% HCl acid. The pH was measured with a pH meter in a 1:1 soil to H_2O mixture (Thomas, 1996).

Statistical Analyses

Normality was tested on data sets to examine any skewing of values. Statistical analyses were preformed using an analysis of variance (ANOVA) approach for differences in slope and aspect levels. The error control design used was the completely randomized design (CRD), structured by a factorial (Lentner and Bishop, 1993). The first factor was aspect, with two levels (north and south). The second factor was slope, with three levels (7-15%, 15-35% and 35-55%). The six total treatments were identified as, N7, N15, N35, S7, S15, and S35. SAS (Statistical Analysis Systems) was used to analyze the factorial and test for interactions and Fisher's LSD test (Lentner and Bishop, 1993) was used to separate differences across aspects and slopes. LSD were only preformed when F tests were found significant at $p = 0.05$. Pairwise comparisons were ran in SAS using the “pdiff” function to examine differences between treatments.

Chapter 4: Results

Aspect Comparisons

Forest Litter Layers

Average L-layer thicknesses (Table 4.1) were 0.4 cm and 0.5 cm on N and S aspects. F-layer thicknesses were greater on N aspects (2.0 cm) than on S aspects (1.5 cm). Total thickness of litter layers (L+F+H) was similar between aspects with 2.4 cm on N aspects and 2.8 cm on S aspects.

Weights of L and F-layers (Table 4.2) were similar between aspects. A complete set of H-layers was not found, and so they could not be analyzed as a separate litter layer. Only 13 of 60 sites had H-layers, with only one described on a N aspect. Average combined litter weights (L+F+H) were greater on S aspects (25 Mg ha^{-1}) than N aspects (17 Mg ha^{-1}).

Percent C of the litter layers did not vary by aspect (Table 4.3). The mass/area, (Mg ha^{-1}C) of the L and F-layers still did not vary by aspect (Table 4.4). Total litter C (Table 4.4) was greater on S aspects, with 8.7 Mg ha^{-1} on S slopes and 6.3 Mg ha^{-1} on N slopes.

Table 4.1. Descriptive statistics for layer and horizon thickness tested for combined aspect and slope effects.

	Litter Layers				Mineral Horizons		
	L	F	H	Total Litter	A	B	Total Soil
	---------- cm ----------						
<u>Overall Aspect Effects</u>	NS	*	†	NS	***	NS	**
North (n = 30)	0.4	2.0 a ‡	0.03	2.4	13 a	40	55 a
South (n = 30)	0.5	1.5 b	0.9	2.8	8 b	36	44 b
<u>Overall Slope Effects</u>	NS	NS	†	NS	NS	NS	NS
7-15% (n = 20)	0.4	1.8	0.05	2.3	10	37	48
15-35% (n =20)	0.6	1.7	0.2	2.5	12	35	49
35-55% (n = 20)	0.3	1.7	1.0	3.0	10	40	52

*,**,*** Significant at the 0.05, 0.01, and 0.001 probability levels respectively,
NS = Not Significant
† Only 13 sites had H horizons; no ANOVA was performed
‡ Within columns, means followed by the same letter are not significantly different by LSD (0.05)

Average L-layer nitrogen (N) was 1.78% on the N aspect and 1.74% on the S aspect (Table 4.5). The F-layer N contents were 1.69% on the N aspect and 1.62% on the S aspect. The C:N ratios also did not vary by aspect for L or F-layers. However, in both layers S aspects did have slightly higher values. The C:N ratio of L-layers on S aspects was 27.6 and. 26.2 on N aspects. The C:N ratios of F-layers averaged 24.1 on S aspects and 23.0 on N aspects.

Table 4.2: Descriptive statistics for litter weights (Mg ha^{-1}) by layer for combined aspect and slope effects.

	Litter Weights			
	L-Layer	F-Layer	H-Layer	Total Litter
	-------------------------------- Mg ha^{-1}	-------------------------------		
Overall Aspect Effects	NS	NS	†	**
North (n = 30)	0.8	15.7	16.8	17.1 a ‡
South (n = 30)	0.9	16.8	19.1	25.0 a
Overall Slope Effects	NS	NS	†	NS
7-15% (n = 20)	0.8	16.2	3.7	17.6
15-35% (n =20)	1.0	16.8	17.8	22.2
35-55% (n = 20)	0.8	15.8	22.4	23.3

** Significant at the 0.01 probability level
NS = Not Significant
† Only 13 sites had H horizons, no ANOVA was produced
‡ Within columns, means followed by the same letter are not significantly different by LSD (0.05)

Table 4.3. Descriptive statistics of organic and mineral C% tested for combined aspect and slope effects.

	Organic Layers			Mineral Horizons		
	L	F	H	Upper 5 cm	A	B
	-- %	--				
Overall Aspect Effects	NS	NS	†	NS	NS	NS
North (n = 30)	46.1	38.1	13.1 ‡	8.1	6.7	1.7
South (n = 30)	46.2	38.6	23.8	7.8	7.2	1.6
Overall Slope Effects	NS	NS	†	NS	NS	NS
7-15% (n = 20)	45.8	39.1	21.2	7.9	6.9	1.5
15-35% (n =20)	46.4	38.2	18.7	8.3	7.2	1.7
35-55% (n = 20)	46.4	37.9	24.9	7.6	6.8	1.7

NS = Not Significant
† Only 13 sites had H horizons, no ANOVA was produced
‡ Only one north site had an H horizon

Table 4.4: Descriptive statistics for organic and mineral soil carbon (Mg ha^{-1}) for combined aspect and slope effects.

	Organic Layers				Mineral Horizons				
	L	F	H	Total Litter	Upp. 5 cm	A	B	Total Soil	Whole Soil
	Mg ha^{-1}								
Overall Aspect Effects	NS	NS	†	*	NS	***	NS	**	*
North (n = 30)	0.4	5.9	2.2	6.3 a‡	28.7	56.1 a	62.3	118.3 a	124.7 a
South (n = 30)	0.4	6.5	4.3	8.7 b	26.9	35.0 b	55.0	90.0 b	98.8 b
Overall Slope Effects	NS	NS	†	NS	NS	NS	NS	NS	NS
7-15% (n = 20)	0.4	6.2	1.4	6.7	27.2	40.2	53.7	93.8	100.6
15-35% (n =20)	0.5	6.4	4.2	7.9	31.5	53.2	58.4	111.5	119.4
35-55% (n = 20)	0.4	6.0	5.6	8.0	24.7	43.3	63.9	107.1	115.1

*,**,*** Significant at the 0.05, 0.01 and 0.001 probability levels respectively,
NS = Not Significant
† Only 13 sites had H horizons, no ANOVA was produced
‡ Within columns, means followed by the same letter are not significantly different by LSD (0.05)

Table 4.5: Descriptive statistics for N% and C:N ratios of litter layers for combined aspect and slope effects.

	Nitrogen		Carbon and Nitrogen	
	L-Layer	F-Layer	L-Layer	F-Layer
	%		C:N	
Overall Aspect Effects	NS	NS	NS	NS
North (n = 30)	1.78	1.68	26.2	23.0
South (n = 30)	1.74	1.62	27.6	24.1
Overall Slope Effects	NS	NS	NS	NS
7-15% (n = 20)	1.83	1.63	25.2	24.2
15-35% (n =20)	1.78	1.76	26.2	22.4
35-55% (n = 20)	1.66	1.56	29.4	24.1

NS = Not Significant

Mineral Soil Horizons

Average thickness of A horizons (Table 4.1) were greater on N aspects (13 cm) than on S aspects (8cm), but there were no differences in B horizon thickness by aspect. Total mineral soil thicknesses (A+ B horizons) were also greater on N aspects (55 cm) versus S aspects (44 cm).

Mineral soil horizon C% did not vary between aspects (Table 4.3). The upper 5 cm of the mineral soil contained 8.06 % C on N aspects and 7.81% on S aspects, while the total A horizon C averaged 6.74% on N aspects and 7.22% on S aspects. On both aspects, B horizon C averages were above 1%, with 1.69% on N aspects and 1.62% on S aspects.

The upper 5 cm of the mineral soil did not vary in total C. North aspect soils contained higher total C in A horizons, averaging 56 Mg ha^{-1} on the N and 35 Mg ha^{-1} on the S. Thirty two sites of the 60 sampled had A horizons deeper than 5 cm. For those 32 sites the upper 5cm of the mineral soil had greater C than the lower part of the A horizon, averaging 82.5 g/kg C and 46.0 g/kg C. There were no differences found in total C in B horizons, although total C amounts were higher than in A horizons. Total mineral soil C (A+B horizons) was greater on N aspects (118 Mg ha^{-1}) than S aspects (90 Mg ha^{-1}). Whole soil C (litter + soil) was greater on N aspects averaging 125 Mg ha^{-1} compared to 99 Mg ha^{-1} on Saspects.

The A horizons were strongly acidic, with an average pH of 3.97 on N aspects and 3.79 on S aspects. The B horizons were slightly less acidic, with pH of 4.43 and 4.41 on N and S aspects respectively. Data for pH is summarized in Appendix E.

Slope Comparisons

Factorial analysis used n = 20 for each slope class (7-15%, 15-35%, and 35-55%), averaging 10 samples from N aspect with 10 samples from S aspect sites. The factorial analysis tested for overall slope effects with both aspects averaged together per slope class. No differences were found in any litter or soil properties among the slope classes (Tables 4.1- 4.5). Some interactions between aspect and slope occurred for N, C:N ratio, upper 5 cm C, and total A horizon C. The following section contains the results from the pairwise comparisons of treatments done to examine differences for slopes between and across aspects to look for masking due to interactions, and to compare slopes on each aspect separately.

Aspect x Slope Treatment Comparisons

Forest Litter Layers

Total litter weights (Fig. 4.1) did not vary between the three slope classes on the N aspects. Average litter weights increased on S aspects as slope increased. South7 sites had lower litter weights than both S15 and S35 slope classes. South15 and S35 had higher total litter weights and had the highest litter weights than all other slope classes. South15 had high L-layer weights while S35 sites contained six sites with heavy H-layers.

Litter C (Fig. 4.2) varied in similar fashion to the litter weights. South15 and S35 were marginally higher in total litter C ($p < 0.1$) than N slopes, and also had the highest C values.

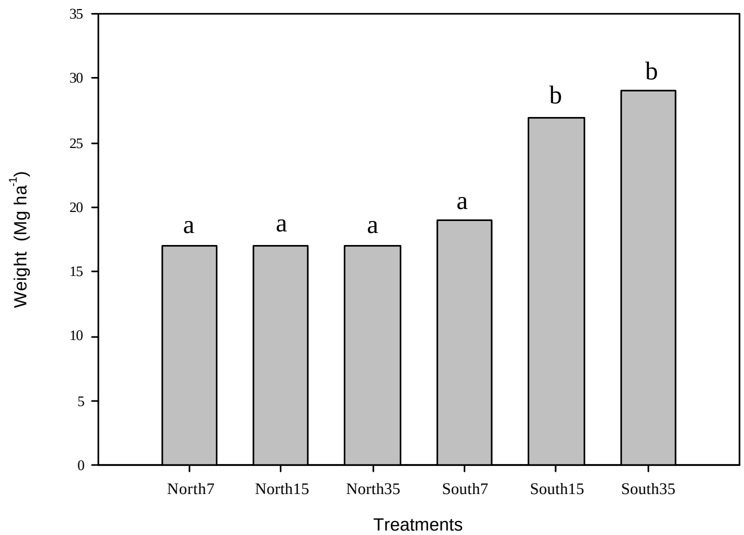

Figure 4.1. Average litter weight (Mg ha^{-1}) for aspect x slope treatments. Treatments with the same letter are not different at $p = 0.05$.

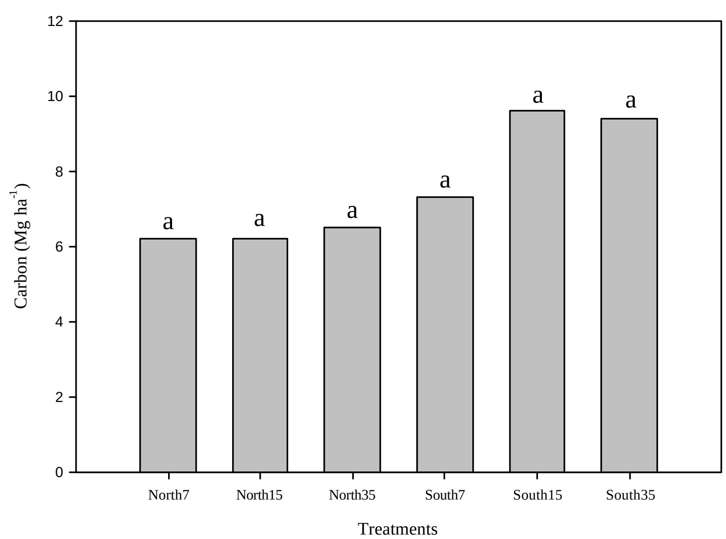

Figure 4.2. Leaf litter C (Mg ha^{-1}) comparing aspect x slope treatments. Treatments with the same letter are not different at $p = 0.05$.

Soils on S35 slopes had lower L-layer N content (Fig. 4.3) than N15 or S7 slopes. The L-layer C:N ratios (Fig. 4.4) were higher on S35 sites than all other treatments. Nitrogen concentrations in the F-layer (Fig. 4.5) were lower in S35 sites than N15, N35 and S7. However, C:N ratios in the F-layer (Fig. 4.6) were lower on N15 slopes rather than on S35 slopes.

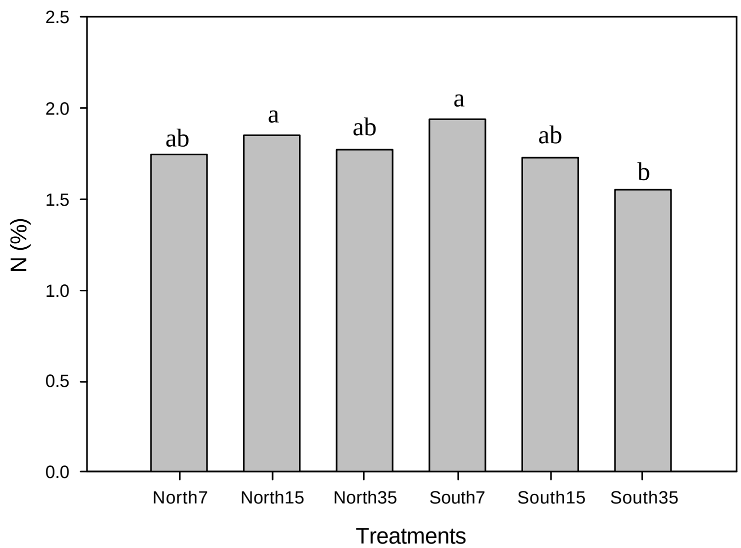

Figure 4.3. Nitrogen concentration (%) for the L layer for aspect x slope treatments. Treatments with the same letter are not different at p = 0.05.

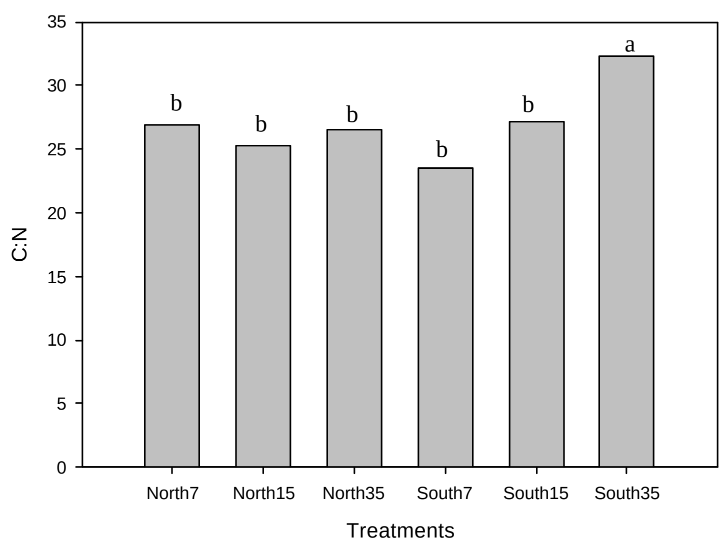

Figure 4.4: L layer C:N ratios for aspect x slope treatments. Treatments with the same letter are not different at p =0.05.

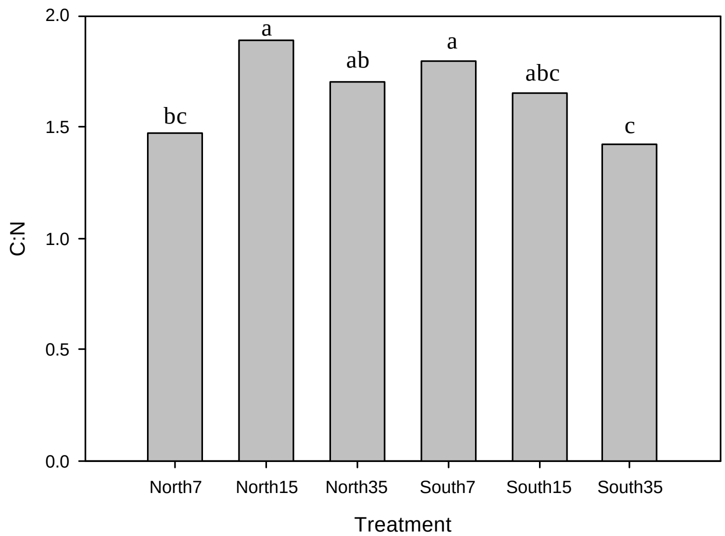

Figure 4.5: F layer N concentrations (%) for aspect x slope treatments.
Treatments with the same letter are not different at p = 0.05.

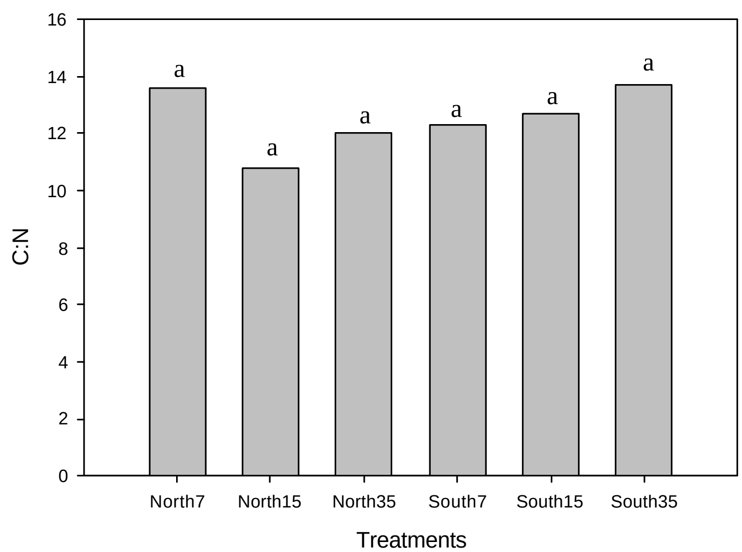

Figure 4.6. F layer C:N ratios for aspect x slope treatments.
Treatment with the same letter is not different at p = 0.05.

Mineral Soil Horizons

The A horizon thicknesses (Fig. 4.7) were similar among N slope treatments. However, A horizons on N7 slopes were marginally different than on N35 slopes. A horizon thicknesses on S aspects did not vary. The A horizon depths between aspectsx were different on S35 and N35 slopes. On N aspects a slope effect occurred, where A horizon depth increased with slope angle. No variation was seen in B horizon thickness.

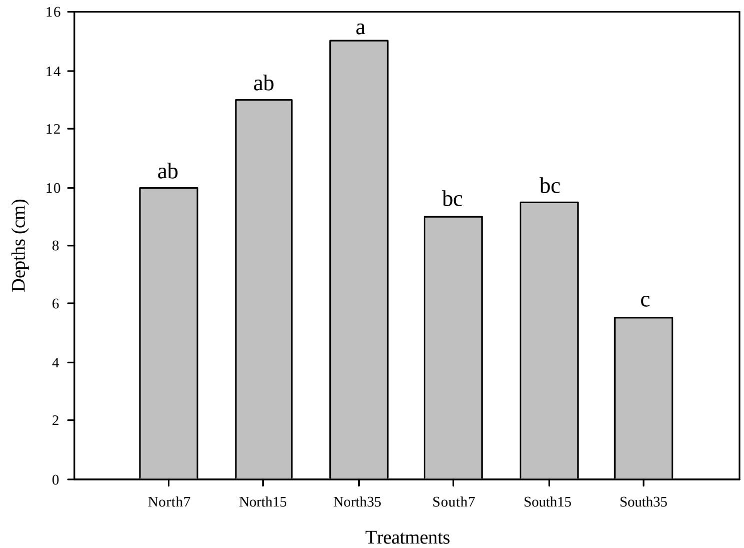

Figure 4.7. Average A horizon depths (cm) for aspect x slope treatments. Treatments with the same letter are not different at p =0.05.

Total mineral soil depths (Fig. 4.8) were shallow overall, and were similar among slope classes on S aspects. The N7 and N15 slopes, contained marginally shallower pedons than the N35 class, with p values of 0.0656 and 0.0566. Between aspects the 35-55% classes were different, with the N35 slopes (63 cm) having deeper soils than the S35 slopes (40 cm). The deepest soils were found on N35 slopes and the shallowest were on S35 slopes.

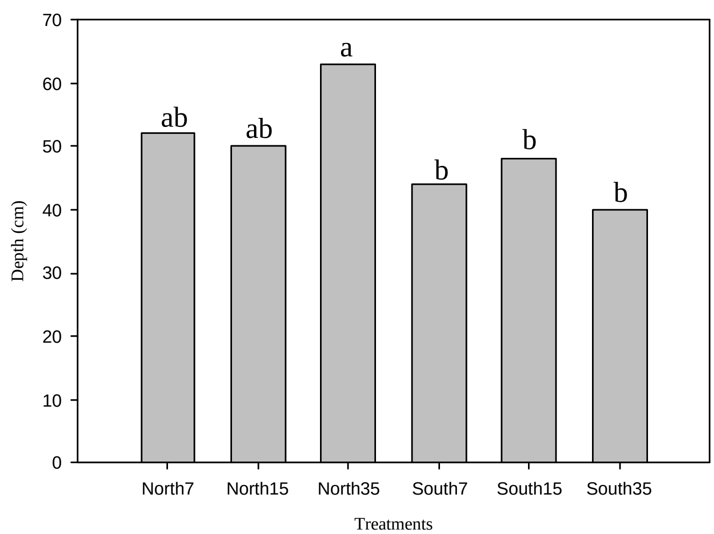

Figure 4.8. Graph of average pedon depth (cm) for aspect x slope treatmer
Treatments with the same letter are not different at p = 0.05.

Average C in the upper 5 cm of the mineral soil (Fig. 4.9) was similar among all slope classes on N aspects. S35 slopes were much lower in C than the S15 slopes. C was considerably higher on N7 and N35 slopes versus the S35 slopes in the upper 0-5 cm of the mineral soil.

Total C values in N aspect A horizons, (Fig. 4.10) were similar among N35 and N15 slopes. N35 had more C than N7 slopes. A slope effect was evident on N aspects, with A horizon mass C increasing as the slope angle increased, similar to the A horizon depths. The steeper S35 slopes were much lower in C than the S15 slopes, with 20 Mg ha^{-1} and 52 Mg ha^{-1}. S15 slopes were more similar to N slopes for A horizon C. All slopes on N aspects had higher surface horizon C than S35 slopes. North35 slopes had the highest A horizon C, with 67 Mg ha^{-1}, while S35 slopes had the lowest, with 20 Mg ha^{-1}. No variance was observed for B horizon total C among slopes on N and S aspects.

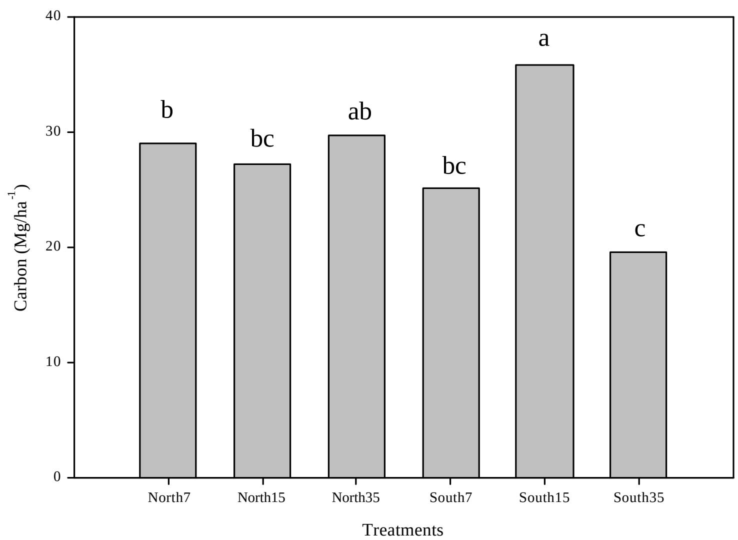

Figure 4.9. Average C in the upper 5cm (Mg ha^{-1}) for aspect x slope treatments. Treatments with the same letter are not different at p = 0.05

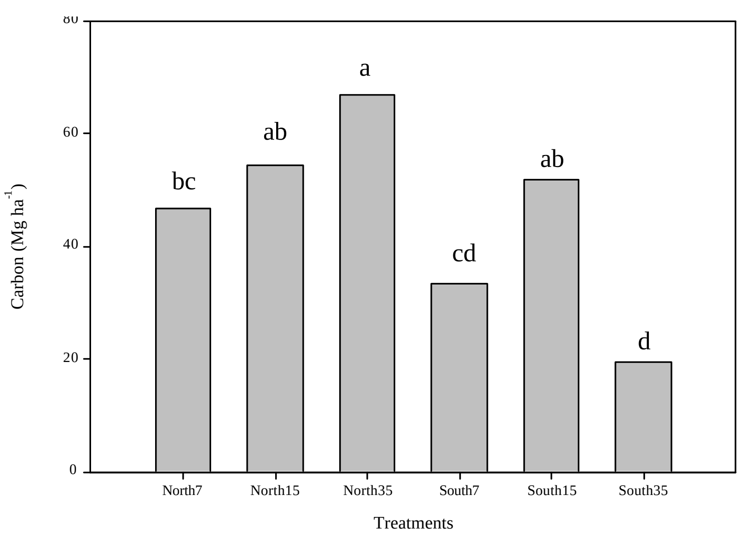

Figure 4.10. C values for the entire A horizon for the aspect x slope treatments. Treatments with the same letter are not different at p = 0.05.

Total pedon C (Fig. 4.11) was higher on N35 slopes (134 Mg ha^{-1}) than N7 slopes (99 Mg ha^{-1}). Total pedon C increased as slope angle increased on N aspects. Slope classes on S aspects were similar in total pedon C. The N15 and N35 slopes had greater total pedon C than S35 slopes. The highest average total soil C was on the N35 sites and the lowest was on the S35 sites, with 145 Mg ha^{-1} and 89 Mg ha^{-1}. Whole soil C differences (Fig. 4.12) were similar to the comparisons for total pedon C. North7 slopes had marginally lower whole soil C than N35 slopes with $p = 0.0616$. A slope effect was seen on N slopes where whole site C increased regularly with slope. None of the slope class treatments varied in whole soil C on S aspects. N15 and N35 slopes were considerably higher in whole soil C than S35 slopes. The highest average whole soil C was on N35 sites and the lowest was on S35 sites, with 140 Mg ha^{-1} and 90 Mg ha^{-1}.

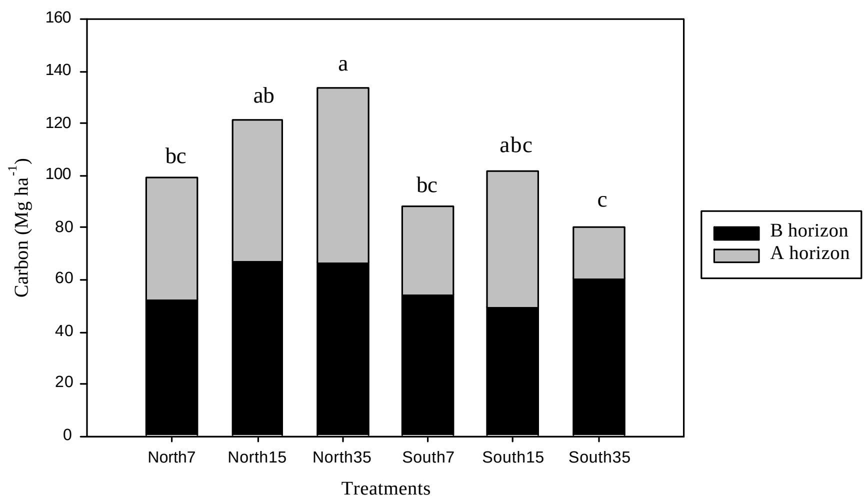

Figure 4.11. Total soil C (Mg ha^{-1}) for the aspect x slope treatments.
Treatments with the same letter are not different at $p = 0.05$.

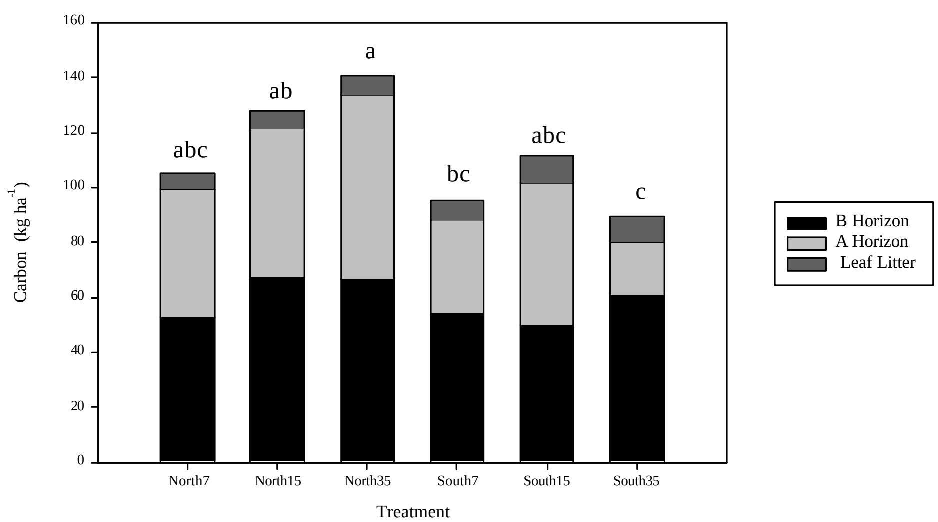

Fig. 4.12. Whole soil C, mineral soil and litter, (Mg ha^{-1}) for the aspect x slope comparisons.
Treatments with the same letter are not different at $p = 0.05$.

Bulk Density

Bulk density values are listed in Table 3. There were no outliers among the data set so all values were used to calculate the total C for mineral horizons. Densities ranged from 0.29 to 1.12 g cm^{-3} for A horizons, and 0.99 to 1.27 g cm^{-3} for B horizons. South35 treatment sites had the lowest average A horizon and B horizon bulk densities, although they were not statistically compared.

Table 4.6: Bulk density values (corrected for coarse fragments) for selected sites (done by the core method).

Site #	A Horizon	B Horizon ‡
	------------------------------------ g cm^{-3}	---------------------------------
N7-228	0.76	1.11
N7-229	0.72	1.09
N15-400	0.76	1.27
N15-440	0.57	1.27
N35-320	0.64	1.22
N35-324	1.12	1.04
S7-432	0.29	1.08
S7-587	0.85	1.22
S15-1307	0.72	1.05
S15-2393	0.81	1.28
S35-101	0.43	0.99
S35-114	0.63	1.07

‡ Values for the B horizon represent an average of multiple horizons

Soil Classification

The soils of the study area are frigid, but do not fit any existing frigid soils series. The closest matching mesic soil series are: Dekalb very channery loam, Ramsey silt loam, Lily silt loam, Ungers silt loam, Klinesville silt loam and Muskingum silt loam. Table 4.7 lists nine taxajuncts of those series, their classifications and their site frequency. The non-skeletal Ramsey taxajunct, and the shallow and moderately deep Lily taxajuncts made up 77% of the 60 soils sampled. All soils are well drained and complete descriptions are found in Appendix F. Fifty two percent of the soils are taxajuncts of the Lily series because they have enough C to be in the Humults suborder instead of the lower C Udults suborder.

Table 4.7: Classification of soils and closest matching taxajuncts, frequency in the study area, B horizon color, and depth class.

Soil Series	Series Classification †	# sites	Color	Depth ‡
Dekalb taxajunct	Loamy-skeletal, siliceous, active, frigid Lithic Dystrudepts	1	10YR	Shallow
Ramsey taxajunct^{1}	Loamy-skeletal, siliceous, subactive, frigid Lithic Dystrudepts	2	10YR	Shallow
Lily taxajunct^{1}	Loamy, siliceous, semiactive, frigid Lithic Haplohumults	18	10YR	Shallow
Lily taxajunct^{2}	Fine-loamy, siliceous, semiactive, frigid Typic Haplohumults	10	10YR	M. Deep
Lily taxajunct^{3}	Loamy, siliceous, semiactive, frigid Lithic Hapludults	1	10YR	Shallow
Lily taxajunct^{4}	Fine-loamy, siliceous, semiactive, frigid Typic Hapludults	2	10YR	M. Deep
Ungers taxajunct^{1}	Fine-loamy, mixed, semiactive, frigid Typic Haplohumults	1	5YR	M. Deep
Ungers taxajunct^{2}	Fine-loamy, mixed, semiactive, frigid Typic Hapludults	1	5YR	M. Deep
Ramsey taxajunct^{2}	Loamy, siliceous, semiactive, frigid Lithic Dystrudepts	15	10YR	Shallow
Klinesville taxajunct^{1}	Loamy, mixed, active, frigid Lithic Dystrudepts	2	5YR	Shallow
Muskingum taxajunct	Fine-loamy, mixed, semiactive, frigid Typic Dystrudepts	5	10YR	M. Deep
Klinesville taxajunct^{2}	Fine-loamy, mixed, active, frigid Typic Dystrudepts	2	5YR	M. Deep

† Differences with the official series are underlined
‡ M. Deep stands for moderately deep

All sampled soils formed in colluvium. The soils contained at least two different rock types, some with subrounded edges, in the subsurface horizons. Evidence of some recent soil movement was indicated by bowing of trees on steeper slopes (Fig 4.13).

The color of the A horizons ranged from very dark brown (10YR 2/2) to dark brown (7.5YR 3/4). Surface textures were loam or silt loam, with rock fragments commonly <10% in volume. Only, three sites had surface textures with a gravelly modifier and one site had a very channery modifier. Average C in the A horizon was 6.98%. Three soils out of the 60 sampled had epipedons deep enough to be classified as umbric, while the rest were ochric epipedons. Subsurface horizons ranged from dark yellowish brown (10YR 3/4) to dark reddish brown (5YR 3/4) in color. Colors of 10YR and 7.5YR are considered brown soils and 5YR are considered red. Subsoil textures were commonly silt loam or clay loam. Rock fragments were commonly <10% in the subsurface, but three pedons were classified as skeletal (>35% rocks). Clay loam subsoils under loam or silt loam surfaces were classified as argillic horizons because of the clay increase. Loam subsoils under loam or silt loam surfaces were classified as cambic horizons. Sampled soils were either in shallow (<50 cm) or moderately deep (50-100 cm). Thirty nine (65%) of the 60 soils were shallow. Examples of a moderately deep Lily taxajunct^{1} silt loam are shown below (Fig 4.14). Three soils were removed from analysis because they were too sandy. Several sites on the summit of Beartown were not sampled at all because of textures that were sandier than previously selected.

Figure 4.13: Some bowing (indicating downhill soil movement) can be seen in the trunk near the center of the picture at site S35-118

Figure 4.14: Moderately deep Lily silt loam at site N7-25

Whole soil C averaged by aspect and slope classes can be seen in Table 4.8 for each soil series described in the study area. The S aspect had pedons from each series, while the N aspect had only had five of the nine series present. On N aspects shallow and moderately deep Lily taxajunct[2] silt loam made up 66% of the soils sampled. Pedons were more evenly distributed through the nine series on S aspects, with the largest amount described as shallow Lily taxajunct[1] silt loams.

Average whole soil C amounts were highest in the shallow Dekalb taxajunct very channery loam, but were only based on one sample. With the exception of the moderately deep Lily taxajunct[2] silt loam, C was higher on north aspects for series with pedons on both aspects. Soil C increased with slope angle for all soil series except the moderately deep Lily taxajunct[2].

Table 4.8: Average whole soil C (Mg ha^{-1}) by aspect and slope, with frequency in parenthesis.

Soil Series	Aspect †		Slope			Series Average
	North	South	7-15%	15-35%	35-55%	
	-----------	-----------	-----------	Mg ha^{-1}	-----------	-----------
Dekalb taxajunct	- §	189.9 (1)	189.9 (1)	-	-	189.9
Ramsey taxajunct[1]	-	59.0 (2)	-	-	59.0 (1)	59.0
Lily taxajunct[1]	157.0 (9)	94.9 (9)	91.3 (6)	136.5 (8)	191.2 (6)	125.5
Lily taxajunct[2]	140.8 (8)	147.6 (2)	172.3 (4)	115.8 (2)	149.6 (4)	144.2
Lily taxajunct[3]	87.2 (1)	-	-	87.2 (1)	-	87.2
Lily taxajunct[4]	105.4 (2)	-	-	-	105.4 (2)	105.4
Ungers taxajunct[1]	-	81.9 (1)	-	-	81.9 (1)	81.9 (1)
Ungers taxajunct[2]	101.9 (1)	81.9 (1)	-	-	91.9 (2)	91.9
Ramsey taxajunct[2]	115.7 (7)	107.4 (2)	87.2 (6)	121.2 (7)	139.1 (2)	111.5
Klinesville taxajunct[1]	-	110.1 (2)	106.4 (1)	113.7 (1)	-	110.1
Muskingum taxajunct	137.9 (3)	98.7 (2)	89.9 (2)	104.2 (1)	163.4 (2)	118.3
Klinesville taxajunct[2]	-	147.7 (2)	-	147.7 (2)	-	147.7

§ If no value was recorded, there was no series sampled on that aspect or slope

Soil series classifications were dependent on SOC. The Lily and Ungers series were split into Haplohumults and Hapludults based on classification criteria. Many soils made the criteria for humults in the Lily soils because they had greater than 0.9% OC in the upper 15 cm of the argillic. The Ungers[1] made the criteria for humults, even though it has less whole soil C (Table 4.8) than the Ungers[2] because of B horizon % OC.

Chapter 5: Discussion

Aspect Effects

Forest Litter Layers

Litter weights were sampled in June and July 2001, and therefore are greatly reduced in weight from the original 2000 leaf fall. Average leaf (L) weights were the same on N and S aspects (1 Mg ha^{-1}). These L-layer weights were much lower than those reported by Jones (2000) in either disturbed (logged) or undisturbed (virgin) watersheds in the Southern Appalachians. Jones reported higher L-layer weights in the disturbed forest, attributing this to the greater production of a younger stand. The study site was disturbed and a documented fire removed the entire organic layer to bare rock in some places after logging in 1942, and therefore this was also a relatively young stand. However, litter production is much lower than levels reported by Jones or Daniels et al. (1987a), possibly due to site location differences; Jones and Daniels et al. studied sites in higher rainfall watersheds where production rates were higher. Extreme conditions at high elevations can also slow regeneration of the forest. Regeneration of a spruce stand had not occurred a century after being burned on Spruce Mountain in West Virginia, possibly because of extreme weather and strong winds at the high elevations (Core, 1929). In the study area significant regeneration of the forest had not occurred as late as 1980, 40 years after the fire (Graham Buchanan, personal communication).

Fermentation (F) layer weights were 16 Mg ha^{-1} on N aspects and 17 Mg ha^{-1} on S aspects, similar to the total litter weights reported by Daniels et al. (1987a), but much higher than F-layer weights reported by Jones in the same undisturbed watershed. F-layer weights ranged from 4 to 6 Mg ha^{-1} in Jones' study, where most of the total litter weight was found in H-layers. Jones' disturbed watershed had much higher F-layer weights, ranging from 28 to 40 Mg ha$^{-1,}$ while this study ranged from 7 to 36 Mg ha^{-1} , and averaged 16 Mg ha^{-1}. The similarity of the F-layer weights with those reported by Daniels et al. may mean that much of the L-layer has been incorporated into the F-layer of this study by mid-summer. It is also possible that annual forest production is lower for L-layers at the high elevations of this study, while cooler temperatures slow decomposition of the litter, helping total surface accumulation match that in more productive areas. Only 13 sites had H-layers, and 12 of those were found on S aspects. Total litter weights were much greater on S aspects (25 Mg ha^{-1}) than on N aspects (17 Mg ha^{-1}) when all litter layers were combined. These values were similar to weights on N aspects of Daniels et al., but higher than theirs for average total litter weights on the S aspects. Both aspects in this study contained lower total litter weights than either the disturbed or undisturbed watersheds of Jones (2000). Accidental inclusion of heavier mineral matter with organic materials may be the reason for the greater weights reported by Jones.

Percentage C in the L, F, and H-layers were similar to amounts in the corresponding litter layers of the Jones (2000) study. There were no differences between any separate litter layers across aspects in % C or total C. Greater organic layer C was found on the N aspect, which should be expected since there were also higher total litter weights there.

There were no differences in N content or C:N ratios for L or F-layers, although C:N ratios were marginally higher on the N aspect for both layers. The C:N values were similar for F-layers reported by Jones (2000), but L-layer C:N ratios were lower in this study (27:1) and Jones' undisturbed sites (60:1).

Separation of litter layers was difficult. An indistinct L-layer of about four or five recognizable leaves was found on a site. The majority of the organic litter (by weight) was in the fragmented F-layer. Comparing total weights between studies is difficult because of possible differences in the subjective separation of litter layers. Even the differences in total litter should be scrutinized because H-layers may contain significant mineral matter increasing total weight. The slightly higher C:N ratios decrease litter palatability and may be the reason why H layers were found on S aspects. The H-layers may also be are remnants of the spruce forest or just exist because of the drier conditions on S aspects. The fire that burned the organic layers off the surface may not have reached sites were most H-layers were presently found.

Mineral Soil Horizons

A horizon depths were greater on N aspects, averaging 13 cm on N and 8 cm on S aspects. These depths are much shallower than those reported by Jones (2000) and Daniels et al. (1987a) in an undisturbed watershed. The A horizon thicknesses in this study are much closer to the disturbed watershed averages reported by Jones. A horizon depths in Beartown are also similar to other studies reported for the Appalachians by Franzmeier et al. (1969), Finney et al. (1961), McCracken et al. (1962), and Feldman et al. (1991b). The greater depths of A horizons on N aspects may be due to higher soil moisture contents (Finney et al., 1961; Franzmeier et al., 1969; Mowbray and Oosting, 1968), producing more palatable litter from mixed mesophytic species or more suitable conditions for detritivores that mix litter and soil materials together. Moister soils are also reported to be more productive sites for vegetation (Mowbray and Oosting, 1968). Increased litter production will also increase microbial populations and activity at the sites, which may be another reason for deeper A horizons.

Total soil depths were greater on N aspects (55 cm) than S aspects (45 cm). These depths are shallow compared to other studies in the Appalachians by Franzmeier et al. (1969), Finney et al. (1961), McCracken et al. (1962), Feldman et al. (1991b), Daniels et al. (1987a), and the undisturbed sites of Jones (2000). Average solum depths of 90 cm were reported by Daniels et al. (1987a), while depths to rock were > 1.3 m. The Beartown soils are closer to in solum depth to the disturbed sites reported by Jones (2000). This relationship may support that logging and extremely hot fires help increase the erosion of mineral soil matter with the loss of protective litter layers. However, a more likely reason for the shallow soils is the extremely resistant iron and silica cemented sandstones that form these soils parent materials, relative to the highly weatherable carbonate cemented sandstones in the Jones (2000) and Daniels et al. (1987a) studies.

Carbon % was similar in the upper 5 cm of the mineral soil to the upper 7.5 cm of the mineral soil reported by Daniels et al. (1987a). Sampling the upper 5 cm and the lower portion of the A horizon separately was justified because a higher C% was observed here in the upper 5 cm of the mineral soil, probably because H-layer material is difficult to separate out of the surface of the soil when sampled in the field. The total A horizon C% was not different between aspects, but was much greater than other reported values in the Appalachians (Jones, 2000; Franzmeier et al., 1969; Finney et al., 1961; McCracken et al., 1962; Feldman et al., 1991b; Losche et al., 1970). Of those studies, only Feldman et al. observed soils in the frigid temperature regime, so the higher values in this study may be because higher elevations. Cooler temperatures at higher elevations can decreaseddecomposition rates so that turnover and loss of C to CO_2 is much lower, and more C is retained. The B horizon C% was very high for subsurface horizons, with values greater than 1.0 % on both aspects. These C% were similar to those reported by Jones (2000) and greater than values reported by Finney et al. (1961) and Franzmeier et al. (1969) in the Southern Appalachians. The C values may be higher in the B horizon in this study because of cooler temperatures increasing C sequestration. Pritchard et al. (2000) reported C% to be 1.6 in the northeastern part of the Olympic Mountain range and 4.1% in the southwestern portion of the range with cryic and frigid soil temperature regimes, the higher values come from B horizons with spodic properties.

Complexation with Fe and Al may also have strong effects on C sequestration in the subsurface, making podzolization an important process in these soils. Carbon levels in subsurface horizons are more similar to spodic horizon values than in other studies. The pH values for this study were 4.0 in A horizons and 4.5 in B horizons and did not differ between the aspects. These values are strongly acidic, but agree with other reports on forested soils in the Appalachians (Jones, 2000; Daniels et al., 1987a; Finney et al., 1962; Franzmeier et al., 1969; Losche et al., 1970). These strongly acidic values may be caused by acid deposition from the atmosphere and have been documented in other Appalachian systems (Feldman et al, 1991a). The low average pH seen in surface and subsurface horizons will also have a lot of free Al to complex with organic matter. Veldkamp (1994) reported that strong stabilization occurred with Al-organic matter complexes in soils with volcanic parent materials. After deforestation, SOC levels remained high in subsurface horizons, which Veldkamp credits to the stabiliztion of the complexes because of allophane and other sources of Al. Daniels et al. (1987b) reported mineralogy for a southeastern watershed to have high amounts of gibbsite, because high rainfall leached much of the Si from the system. The same situation could be occurring in this study area, providing soils with high amounts of Al to form complexes with organic matter. The high C% observed in B horizons could also be a result of vegetation. Higher elevations have lower biomass and production rates (Mowbray and Oosting, 1968; Jenny et al., 1949), so higher C does not come from increased production. When the study area was in spruce this would have protected the soils from fire, as the litter is moist enough inhibit fires. The spruce litter that existed here previously may be the cause of higher C being leached into the B horizon. Existing root channels may receive sluff from A horizons, and extensive root systems may contribute much C to the mineral soil. Root channels were not observed in this study, although all samples were augered and pit sampling may uncover more evidence. Vegetation can also cause mixing of the soil by windthrow, which can mix organic rich A horizons with subsurface horizons. Tree tipover was frequently observed in this study, and is common in the shallow soils of the Appalachians. Lietzke and Mcguire (1987) observed that for soils with shallow organic layers, vegetation had more roots in the mineral soil, making it more likely to be mixed when windthrow occurred. Periglacial activity is another possible mixing event that could have occurred on these slopes. Feldman et al. (1991b) reported extensive soil mixing that might have occurred due to freeze/thaw and mass flow of the soil, which in turn can mix surface and subsurface horizons.

Total C was higher on N aspects than S aspects in the A horizons with 56 Mg ha^{-1} and 35 Mg ha^{-1}. The differences are directly related to the greater A horizon depths on the north slopes increasing total C. Total A horizon C was less than that reported by Daniels et al. (1987a), due to the much greater A horizon depths that occurred in their study. Total C in B horizons was not different between N and S aspects, but there was more total C in B horizons than A horizons. Carbon percentages were lower in B horizons than A horizons, but thicknesses were four times greater. More C was stored in B horizons than litter and mineral surfaces combined because of the greater thicknesses of the subsurface horizons. Total soil C amounts were also greater on N aspects, even though there were no differences found in B horizon total C. Total soil C was also less than values reported by Daniels et al., but if solum depths in this study were doubled to match those in Daniels et al., total C values would become very close. More C was stored in surface horizons in their study, because thicknesses of A horizons were sometimes 50 cm. Carbon is still greater on N aspects even when litter C is added to mineral C (whole soil). Most of the total C differences between aspects can be attributed to the A horizon and its higher C values and greater depths.

Bulk densities were lower in the A horizon than the B horizon, which was expected because of greater organic matter in the A horizon. Bulk density values in this study were similar to Daniels et al. (1987a) for the A horizon but slightly lower in the B horizon. The bulk densities of 0.29 and 0.43 g/m^3 in the A horizon are very low compared to any other studies in the Appalachians. If these A horizons were removed by erosion after the fire in 1940's, this would represent a regeneration of surface epipedons in about 60 years. Very high amounts of organic matter and low disturbance of the surface are the reason for the very low densities seen in A horizons. The fire was documented to have been confined to the summit of Clinch and Garden Mountains, though, and it is possible that not all of these A horizons were affected by that recorded fire.

Aspect x Slope Treatment Comparisons

Forest Litter Layers

There were no strong effects for litter layer weights or carbon detected between slope classes, but interactions occurred which can mask differences. Most studies in the Appalachians have not sampled or separated slopes classes. Reported slopes were usually steeper than the sites that were observed for this study, so no direct comparisons of slope effects can be made between this and other studies.

The S15 and S35 slopes had the highest total litter weights and total litter C of all sampled slope classes. Directly related to this was total N content and C:N ratio, where S35 slopes had the lowest N content of all L-layers. On S35 slopes, L-layer C:N ratios were highest and different from all other slopes on N or S aspects. H-layers were present on seven of the ten sampled pedons on S35 slopes. The high C:N ratios in the leaves on S35 sites probably reduced the palatability of the litter, reducing decomposition rates and perpetuating the formation of the H-layers also. The H-layers on S35 may be remnants of the spruce stand, but are also likely to exist because of the drier conditions usually found on S aspects supporting vegetation such as oak and rhododendron, with higher C:N ratio in their leaves.

Mineral Soil Horizons

The A horizon thickness increased with slope angle on N aspects, but there was no such trend on S slopes. Mowbray and Oosting (1969) reported the same relationship in a Blue Ridge gorge. The S35 slopes were found to have shallower A horizons than all N slopes. These shallow A horizons may also be related to the high C:N ratios and H-layers that occurred on S35 sites, where less mixing may have occurred. The deepest soils were on N35 sites and shallowest were on S35 sites, similar to the results for A horizon thickness. This could be due to more hydrolysis occurring on N aspects because of a moister climate, rather than from vegetation and microbial activity.

Carbon was lower in S35 pedons when compared to other slope classes on N or S aspects in the upper 5cm of the mineral soil, because of the low bulk density or low C%. The lowest average bulk density values were reported for S35 sites, but not by much. Similarly, the average C% was lowest on S35 treatments, but not enough to be different from any other slope treatment class on S or N aspects. However, when these two factors are combined with depths, they apparently are low enough to make total C in the upper 5cm to be lowest on S35 slopes. Total C in the A horizon exhibited a strong slope effect on N aspects, where C increased with increasing slope angle. No slope effect on C was observed on S aspects. The lowest C amounts were observed on S35 sites because average depths for A horizons were also the shallowest. Total soil C also followed the same slope effect on north aspects, where total C increased with slope angle. The S35 sites still had the lowest total C in the soil, but the addition of B horizon C made S35 slopes similar to the N7 and S15 slopes. Whole soil C also exhibited slope effect on N aspects, where N35 had the highest total C and S35 had the lowest. Overall, only the 35-55% slope treatment classes were different for each C by horizon subset. The N15 sites had high enough C to be marginally different from the S15 slopes when total soil C and whole soil C were calculated, but most of the difference between aspects resides in the steeper slopes. These differences in C between N35 and S35 slope treatments can be related to site-specific properties that reduce litter breakdown and incorporation on S35 slopes. However when whole C values are presented, S35 sites are not much lower than any other S slope treatment class.

These site-specific differences do not explain why there is an apparent effect that causes N35 slopes to have the highest C. An explanation that may satisfy this comes from potential solar insolation that affects each slope. Insolation decreases with slope angle on N aspects based on estimated values for the 38º N parallel from tables by Frank and Lee (1966). On S aspects potential insolation increases from S7 to S15 slopes, but then decreases for S35 slopes towards S7 values. Therefore N aspects should receive less direct sunlight on steeper slopes, while south aspects will not have any noticeable pattern with increasing slope. This can produce changes in moisture, vegetation and microfauna on north aspects as cooler temperatures are experienced on steeper N-facing slopes. South aspects also are estimated to have higher average insolation values overall, meaning that they should be drier and support more xeric species, such as oak and rhododendron, have less micro-faunal activity to incorporate organic matter, and have higher total litter weights. These drier sites should have lower production of litter as well, leaving less to incorporate. Since litter weights are higher on the S aspect though, it is better to assume that geophages activity is slowed by the drier conditions.

Soil Classification and Series C Distribution

All soil series mapped are frigid taxajuncts of mesic series. Many of the other taxajuncts are due to shallow depths to bedrock. Very resistant parent materials underlie the area and so most soils sampled are shallow (<50 cm).

The shallow and moderately deep Lily taxajuncts made up 50% of the pedons sampled, while overall 59% of the pedons were classified as Ultisols and the rest as Inceptisols. Only three pedons had thick enough A horizons to be classified as umbric epipedons. However 29 of 32 Ultisols had high enough C to be Humults because of B horizon OC%. The other three that classified as udults are probably humults as well because C was averaged over the whole thickness of the B because the sample was collected in that manner. The upper 15 cm of those other three Ultisols may very well have greater than 0.9% OC. The fire and erosion that have occurred here in the past following logging may be the reason for the shallow A horizons, compared to other studies in the Appalachians (Finney et al, 1961; Daniels et al., 1987a).

There was a significant amount of clay in the soil for the resistant sandstone parent material present. High clay amounts may be a result of the mixed colluvium soils formed in, and the high amounts of rainfall at these elevations may increase hydrolysis and solution weathering. Weathering was not enough to increase total depths in the siliceous parent material.

Average whole soil C within each soil series varied widely, from 59.0 to 189.9 Mg ha^{-1}. There was also a large difference observed between C values for series that had pedons on both N and S aspects. Carbon increased with slope within the same series as well. All of these results for soil series C variability mean that extreme caution should be taken in modeling C by soil series or medium intensity maps. Slope and aspect should be taken into account when using soil series to model global C sequestration. If only one value is used for a given series when mapping regional or ecosystem C levels disregarding what aspect or slope it may occur on large errors may be generated. These errors will either over or underestimating C amounts in the soil. Carbon values for mesic series should not be used for their frigid taxajuncts, there is a higher C% in the higher elevation soils compared to studies done at lower elevations. Carbon values for series should be chosen with due attention paid to N slopes. GIS was used to identify the slope and aspect classes in this study and could be used to create more accurate regional soil C maps. More accurate C values can be applied for each series by identifying aspect and slopes using a DEM and then overlaying this on soil maps.

Comparisons between series were unbalanced in sample size, so C comparisons between series may not be thorough. There were general differences in C found between aspects and slopes regardless of series, so those effects should still be taken into account.

Overall soil C values in the study area, regardless of aspect, slope or series, averaged 112 Mg ha^{-1}. That value would have been slightly lower had we reduced the total by rock fragment volume. Mattson and Smith (1993) found roughly half of that in a West Virginia forest and Daniels et al. (1987a) found more than twice the whole soil C in a Southern Appalachian watershed, with 74 and 280 Mg ha^{-1} respectively. Mattson and Smith's study area was at a lower elevation, where faster decomposition may be the reason for lower C amounts. The higher soil C reported by Daniels et al. is probably because it was a virgin stand, where deeper A horizons and deeper solum contributed to higher C amounts.

Eswaran et al. (1993) estimated temperate Alfisols and Mollisols to contain 55 and 91 Mg C ha^{-1}. The soils in this study were either Inceptisols or Ultisols. Kern (1994) averaged SOC by suborders and orders and found Ultisols (70 Mg ha^{-1}) to have less C than Mollisols (121 Mg ha^{-1}) and Inceptisols (117 Mg ha^{-1}), while being similar to Alfisols (70 Mg ha^{-1}). The C in Ultisols in this study is more similar to the Inceptisols and Mollisols of Kern. Humults were found to have the highest average C of Ultisols by Kern, averaging 126 Mg ha^{-1}, which is probably the reason why C in this study was so high, since all of the most of the Ultisols classified as humults. Inceptisols in this study also average higher C than those Inceptisols reported by Kern (1994). Two studies of forested soils in Oregon by Homann et al. (1995) and Boone et al. (1988) reported C amounts of 150 and 58.3 Mg ha^{-1}, while a third study in the Olympic Mountains of Washington state reported average C levels of 86 Mg ha^{-1} (Pritchard et al., 2000). These studies done in the northwestern United States show similar ranges to those soils in the southwest.

Post et al. (1982) estimated a mean soil C density of 121 Mg ha^{-1} for overall cool temperate moist forests, so the average for this study is just slightly below average for moist forest soils. The soils in this study appear to be average in the amount of C they currently sequester for a cool temperate forest. Rock fragment content of most soils was low. Most pedons (43 of 60) had less than 10% rock fragments throughout. However, a few (17 of 60) contained 10- 60% rock fragments, with the highest content in the B horizon. Rock fragment volume of each horizon is reported in Appendix F. Many factors control C in forested soils, and projecting C amounts for forested soils in North America should not be mapped without concise application of as many known parameters controlling soil C as possible. Soils in this study have also sequestered higher amounts of C compared to other studies, and if the forest fully recovers from logging may sequester values closer to those reported by Daniels et al (1987a).

Chapter 6: Conclusions

Soils in the study area are shallow, with high amounts of clay relative to the resistant sandstone material they are derived from. Most soils should classify as Inceptisols, but the increase in clay in the subsurface may be enough that these soils could be Ultisols. The A horizons were very dark and contain higher levels of C% than has been reported by others in the Southern Appalachians. However, most pedons observed did not have A horizons deep enough to be considered umbric epipedons, possibly because of the potential erosion after the forest fire. It is possible that recovery of these soils and regeneration of the forest has been slow, as a direct result of higher elevations, and a large amount of erosion may have removed the A horizons and some of the subsurface. The intense burn that removed the protective organic layer and some of the mineral horizon would have significantly delayed recovery of this forest after logging. Overall, soils in the study area were similar to other logged Appalachian forest soils reported in the literature.

Sixty years after the fire, some recovery in litter accumulation has occurred, with litter layers probably being close to what they once were. The spruce forest that once dominated the upper slopes will probably not reclaim its former density and productivity very rapidly. The isolation of the stand makes it hard to pollinate with other spruce stands. Although it was not directly measured, litter production in the study area appears to be lower than other similar Appalachian forests, which may also be because of the higher elevations and cooler temperatures.

North aspects contained higher amounts of total C, due to deeper A horizons. These deeper A horizons are most likely caused by cooler temperatures prevailing where there is less solar insolation and more geophage activity. Production rates may also be higher on the moister N aspects, with more litter on the soil surface for geophages to mix into the soil. On N aspects there is also an obvious slope angle effect where soil C increases with slope as solar insolation decreases.

South aspects, being warmer, should have faster decomposition rates than N aspects. However, higher litter weights were observed. This may be because S aspects are drier and lower moisture would reduce decomposition rates, even though temperatures were higher. Another reason for higher litter weights are the H-layers found on S aspects, on slopes above 35%, which probably formed because of the higher C:N ratios in the L-layer. The majority of the differences were observed at slopes >35% for slope differences between N and S aspects. South35 sites were equal to all other S slopes, when whole soil C amounts were calculated. The litter that is not mixed into the soil retains C in the H-layer, making whole soil C similar to all other S slopes. The N35 slopes had the highest C in every horizon and combination of horizons, and are therefore where the most important slope class treatment exhibiting differences between slopes and aspects.

Carbon percentages were very high in the subsurface horizons. This may be due to many factors, such as soil mixing and Al complexation. The high SOC percentages observed in the study area were also common in frigid soils in the northwest United States. If these soils were deeper, much larger amounts of SOC would be stored there. Most Ultisols were classified as humults on the suborder level because of the high OC% found in the B horizons. Classification as humults helps make sense of why average C in this study area is similar to that of Mollisols. Even Inceptisols in this study have higher C than is reported by Kern (1994), but there is no current classification in taxonomy to describe this fact.

Soil C in the study area averaged 112 Mg ha^{-1}, higher levels than found in most studies within the Southern Appalachians, but similar to the predicted value for cool moist temperate forests by Post et al. (1982) of 121 Mg ha^{-1}. Percent C was similar, but total C was lower than in the study done by Daniels et al. (1987a), because of shallower A horizons in this study. The study area soils were severely damaged by fire and possibly erosion, and in the future may recover soil C values closer to those reported by Daniels et al.

Total C is higher in the frigid temperature regime of Virginia's Southern Appalachians where the highest C values are found on slopes >35%. Extrapolation of C from soil series to estimate global C sequestration that ignores aspect effects may cause factors of over or underestimation. Differences between series, slopes and aspects were observed when whole soil C was grouped by soil series. Specific factors such as elevation, slope and aspect should be examined to make more accurate regional C predictions since many types of modeling done to predict C levels and future sequestration use soil and forestry maps.

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Appendix A

Leaf litter weights (kg/ha)

Site ID	"L" Weight (kg/ha)	"F" Weight (kg/ha)	"H" Weight (kg/ha)	Total Litter Weight (kg/ha)
N7-158	553.6	24,921.6	NP †	25,475.2
N7-224	392.0	8,854.4	NP	9,246.4
N7-227	1,112.0	12,977.6	NP	14,089.6
N7-228	1,043.2	26,542.4	NP	27,585.6
N7-229	696.0	16,380.8	NP	17,076.8
N7-25	974.4	16,353.6	NP	17,328.0
N7-34	1,100.8	12,748.8	NP	13,849.6
N7-36	768.0	12,915.2	NP	13,683.2
N7-51	470.4	11,436.8	NP	11,907.2
N7-53	532.8	16,236.8	NP	16,769.6
N15-000	424.0	9,059.2	NP	9,483.2
N15-131	185.6	7,491.2	NP	7,676.8
N15-225	1,617.6	28,224.0	NP	29,841.6
N15-316	310.4	20,523.2	NP	20,833.6
N15-333	1,345.6	14,348.8	NP	15,694.4
N15-362	187.2	18,768.0	NP	18,955.2
N15-374	473.6	11,012.8	NP	11,486.4
N15-400	1,331.2	16,390.4	NP	17,721.6
N15-408	440.0	8,916.8	NP	9,356.8
N15-440	1,067.2	13,776.0	16,889.6	31,732.8
N35-124	1,155.2	11,425.6	NP	12,580.8
N35-129	747.2	12,422.4	NP	13,169.6
N35-172	1,635.2	13,129.6	NP	14,764.8
N35-225	1,219.2	17,792.0	NP	19,011.2
N35-282	1,024.0	11,713.6	NP	12,737.6
N35-320	627.2	14,739.2	NP	15,366.4
N35-324	296.0	36,347.2	NP	36,643.2
N35-411	830.4	26,232.0	NP	27,062.4
N35-640	540.8	9,464.0	NP	10,004.8
N35-722	476.8	10,678.4	NP	11,155.2
S7-148	920.0	11,667.2	NP	12,587.2
S7-291	1,251.2	21,110.4	NP	22,361.6
S7-432	603.2	36,168.0	NP	36,771.2
S7-499	523.2	11,824.0	3,752.0	16,099.2
S7-573	332.8	23,795.2	NP	24,128.0
S7-582	1,489.6	11,308.8	NP	12,798.4
S7-587	380.8	14,166.4	NP	14,547.2
S7-732	700.8	17,350.4	NP	18,051.2
S7-739	536.0	8,540.8	NP	9,076.8
S7-751	718.4	8,286.4	10,144.0	19,148.8
S15-1091	923.2	20,664.0	NP	21,587.2

Site ID	"L" Weight (kg/ha)	"F" Weight (kg/ha)	"H" Weight (kg/ha)	Total Litter Weight (kg/ha)
S15-1307	664.0	16,006.4	30,001.6	46,672.0
S15-153	451.2	14,675.2	NP	15,126.4
S15-163	2,788.8	23,387.2	NP	26,176.0
S15-1748	344.0	20,766.4	7,721.6	28,832.0
S15-2393	1,268.8	17,225.6	NP	18,494.4
S15-272	2,667.2	33,932.8	11,356.8	47,956.8
S15-383	2,507.2	11,912.0	NP	14,419.2
S15-604	508.8	13,787.2	NP	14,296.0
S15-954	825.6	14,220.8	22,539.2	37,585.6
S35-101	651.2	8,505.6	16,232.0	25,388.8
S35-102	900.8	24,524.8	20,796.8	46,222.4
S35-102	900.8	24,524.8	20,796.8	46,222.4
S35-113	478.4	14,865.6	18,771.2	34,115.2
S35-114	582.4	26,124.8	43,731.2	70,438.4
S35-118	518.4	12,785.6	10,598.4	23,902.4
S35-119	654.4	11,716.8	24,222.4	36,593.6
S35-175	816.0	10,504.0	NP	11,320.0
S35-182	788.8	17,881.6	NP	18,670.4
S35-184	822.4	11,612.8	NP	12,435.2
S35-65	515.2	14,500.8	NP	15,016.0
Spruce ‡	NP	NP	84,179.2	84,179.2
Mean	845.0	16,261.0	18,212.0	21,052.0
Min	185.6	7,491.2	3,752.0	7,677.0
Max	2,788.8	36,341.2	43,731.2	70,438.0
SD	543.9	6,841.2	10,594.5	11,831.0

† NP = not present

‡ Spruce is a sample taken under conifers for comparison, not used in any analyses

Appendix B

Leaf litter carbon (kg/ha)

Site ID	"L" Carbon (kg/ha)	"F" Carbon (kg/ha)	"H" Carbon (kg/ha)	Total Litter Carbon (kg/ha)
N7-158	259.7	7,482.2	NP †	7,741.9
N7-224	183.1	3,585.9	NP	3,769.0
N7-227	514.2	5,571.5	NP	6,085.6
N7-228	480.2	8,633.1	NP	9,113.3
N7-229	322.5	4,853.7	NP	5,176.2
N7-25	452.5	7,567.5	NP	8,020.0
N7-34	517.6	5,844.5	NP	6,362.1
N7-36	347.6	5,975.2	NP	6,322.8
N7-51	213.1	2,786.0	NP	2,999.0
N7-53	247.2	6,249.6	NP	6,496.8
N15-000	199.7	4,002.5	NP	4,202.2
N15-131	85.7	3,447.0	NP	3,532.6
N15-225	724.2	11,537.7	NP	12,261.9
N15-316	146.5	9,354.3	NP	9,500.8
N15-333	613.0	5,925.4	NP	6,538.4
N15-362	89.6	4,061.3	NP	4,150.9
N15-374	222.0	4,012.9	NP	4,235.0
N15-400	618.2	6,342.3	NP	6,960.5
N15-408	206.3	4,090.9	NP	4,297.2
N15-440	494.9	3,878.0	2,220.0	6,593.0
N35-124	536.0	4,924.2	NP	5,460.2
N35-129	345.6	5,368.7	NP	5,714.3
N35-172	728.5	4,897.9	NP	5,626.5
N35-225	552.1	6,970.7	NP	7,522.8
N35-282	449.9	4,201.4	NP	4,651.3
N35-320	288.1	4,996.7	NP	5,284.8
N35-324	136.2	12,149.8	NP	12,286.0
N35-411	375.9	10,752.9	NP	11,128.8
N35-640	243.3	2,748.1	NP	2,991.4
N35-722	226.2	4,561.8	NP	4,788.0
S7-148	431.1	5,305.3	NP	5,736.4
S7-291	432.8	7,430.4	NP	7,863.2
S7-432	274.4	16,310.6	NP	16,585.0
S7-499	239.4	5,277.9	1,130.1	6,647.4
S7-573	155.6	8,023.9	NP	8,179.5
S7-582	704.4	4,372.2	NP	5,076.6
S7-587	176.3	5,602.9	NP	5,779.2
S7-732	328.8	7,402.4	NP	7,731.2
S7-739	247.3	2,890.3	NP	3,137.6
S7-751	337.3	3,755.2	1,936.3	6,028.8
S15-1091	435.7	4,948.1	NP	5,383.9
S15-1307	305.7	7,511.0	11,848.6	19,665.4

Soil ID	"L" Carbon (kg/ha)	"F" Carbon (kg/ha)	"H" Carbon (kg/ha)	Total Litter Carbon (kg/ha)
S15-153	206.9	6,268.0	NP	6,474.9
S15-163	1,291.8	10,421.5	NP	11,713.3
S15-1748	161.3	6,922.7	1,638.3	8,722.3
S15-2393	600.4	7,474.0	NP	8,074.4
S15-272	1,228.7	14,312.3	3,029.1	18,570.1
S15-383	1,138.9	3,877.6	NP	5,016.5
S15-604	235.9	5,059.9	NP	5,295.7
S15-954	365.3	4,067.9	2,153.1	6,586.3
S35-101	307.8	3,913.5	2,500.2	6,721.5
S35-102	431.3	9,804.1	4,970.8	15,206.2
S35-113	229.0	6,381.4	4,072.3	10,682.7
S35-114	273.0	9,801.5	8,587.7	18,662.2
S35-118	248.0	4,427.5	2,579.6	7,255.1
S35-119	306.5	5,443.3	10,766.0	16,515.7
S35-175	380.7	3,112.9	NP	3,493.6
S35-182	371.2	5,147.5	NP	5,518.7
S35-184	384.4	3,760.5	NP	4,144.9
S35-65	241.6	5,957.0	NP	6,198.6
Spruce ‡	NP	NP	36,352.4	36,352.4
Mean	388.2	6,195.9	4,417.9	8,013.7
Min	85.1	2,748.1	1,130.1	2,991.4
Max	1,291.8	16,310.6	11,848.6	19,665.4
SD	247.8	2,804.1	3,616.7	4,026.9

† NP = not present
‡ Spruce is a sample taken under conifers for comparison, not used in any analysis

Appendix C

Mineral horizon carbon (kg/ha)

Soil ID	Upper 0-5cm Carbon (kg/ha)	Lower A Carbon (kg/ha)	Total 'A' Carbon (kg/ha)	B Carbon (kg/ha)	Total Soil Carbon (kg/ ha)
N7-158	32,019.7	74,623.0	106,642.7	29,875.8	136,518.5
N7-224	29,585.9	15,293.0	44,878.8	33,484.9	78,363.7
N7-227	25,798.2	17,881.9	43,680.2	41,313.5	84,993.7
N7-228	22,770.4	10,015.4	32,785.8	40,045.7	72,831.5
N7-229	39,837.9	25,699.5	65,537.4	50,677.9	116,215.3
N7-25	32,802.3	NP †	32,802.3	109,796.0	142,598.3
N7-34	24,155.5	11,197.7	35,353.1	66,411.3	101,764.4
N7-36	34,365.2	NP	34,365.2	70,632.7	104,997.9
N7-51	28,344.5	NP	28,344.5	102,905.0	131,249.5
N7-53	25,931.8	27,986.4	53,918.1	26,293.0	80,211.2
N15-000	25,325.5	41,870.9	67,196.5	12,648.6	79,845.1
N15-131	31,608.6	NP	31,608.6	107,325.6	138,934.1
N15-225	27,107.1	49,215.5	76,322.6	46,256.7	122,579.3
N15-316	22,898.9	NP	22,898.9	81,243.6	104,142.4
N15-333	38,114.6	39,859.7	77,974.3	73,212.1	151,186.4
N15-362	22,927.5	33,012.6	55,940.1	27,115.1	83,055.2
N15-374	36,905.9	73,221.9	110,127.8	31,445.8	141,573.6
N15-400	30,550.3	41,952.7	72,503.0	63,971.9	136,474.9
N15-408	34,470.9	NP	34,470.9	238,388.7	272,859.6
N15-440	18,440.6	NP	18,440.6	103,906.2	122,346.8
N35-124	26,265.9	25,661.5	51,927.4	44,484.2	96,411.6
N35-129	41,073.9	62,078.2	103,152.1	80,754.2	183,906.3
N35-172	19,868.5	17,634.3	37,502.8	73,070.2	110,573.0
N35-225	45,617.1	39,137.6	84,754.7	44,980.4	129,735.1
N35-282	18,272.5	21,549.9	39,822.4	71,820.3	111,642.7
N35-320	21,677.1	41,109.2	62,786.2	20,642.1	83,428.3
N35-324	35,381.0	57,102.3	92,483.3	42,559.1	135,042.4
N35-411	30,751.4	59,370.1	90,121.4	117,160.1	207,281.5
N35-640	25,324.1	61,013.2	86,337.3	32,680.6	119,017.9
N35-722	43,379.3	NP	43,379.3	233,293.0	276,672.4
S7-148	53,558.1	31,581.3	85,139.4	99,000.1	184,139.5
S7-291	43,138.0	NP	43,138.0	55,479.7	98,617.7
S7-432	14,981.6	NP	14,981.6	189,712.5	204,694.0
S7-499	30,070.5	NP	30,070.5	57,085.9	87,156.4
S7-573	36,638.3	23,656.8	60,295.2	39,665.0	99,960.1
S7-582	25,486.2	NP	25,486.2	56,273.6	81,759.8
S7-587	27,466.1	18,958.8	46,424.9	22,736.2	69,161.2
S7-732	11,098.5	10,494.1	21,592.6	19,872.6	41,465.2
S7-739	17,952.9	17,035.5	34,988.4	24,806.1	59,794.5
S7-751	28,597.8	NP	28,597.8	58,483.5	87,081.2
S15-1307	41,034.2	NP	41,034.2	27,505.6	68,539.7
S15-153	42,100.3	73,923.8	116,024.1	35,424.3	151,448.3
S15-163	60,927.8	32,687.1	93,614.9	24,222.5	117,837.4
S15-1748	31,111.4	39,474.1	70,585.4	45,683.5	116,268.9

Soil ID	Upper 0-5cm Carbon (kg/ha)	Lower A Carbon (kg/ha)	Total 'A' Carbon (kg/ha))	B Carbon (kg/ha)	Total Soil Carbon (kg/ ha)
S15-1901	28,844.7	NP	28,844.7	42,011.1	70,855.8
S15-2393	22,881.6	15,890.0	38,771.5	46,280.8	85,052.3
S15-272	31,625.4	NP	31,625.4	60,696.6	92,322.0
S15-383	25,558.5	NP	25,558.5	115,559.5	141,118.0
S15-604	57,393.8	NP	57,393.8	51,078.6	108,472.5
S15-954	21,240.2	NP	21,240.2	76,387.7	97,627.8
S35-101	20,808.0	NP	20,808.0	50,766.4	71,574.4
S35-102	25,071.1	NP	25,071.1	41,642.4	66,713.5
S35-113	12,780.5	NP	12,780.5	124,389.5	137,170.1
S35-114	26,397.1	NP	26,397.1	65,407.1	91,804.2
S35-118	21,146.3	NP	21,146.3	78,029.9	99,176.2
S35-119	18,935.2	NP	18,935.2	31,269.6	50,204.8
S35-175	14,320.9	NP	14,320.9	84,009.2	98,330.1
S35-182	9,758.6	NP	9,758.6	42,007.9	51,766.5
S35-184	10,743.4	NP	10,743.4	45,876.7	56,620.2
S35-65	43,209.0	NP	43,209.0	122,327.6	165,536.6
Mean	29,107.5	35,812.5	47,610.6	65,868.1	113,478.7
Min	9,758.6	10,015.4	9,758.6	12,648.6	41,465.2
Max	60,927.8	74,623.0	116,024.1	238,388.7	276,672.4
SD	10,892.6	19,737.0	27,967.9	46,014.1	47,492.3

† NP = not present

Appendix D

Carbon totals (kg/ha)

Soil ID	Total Litter Carbon (kg / ha)	Total Soil Carbon (kg/ ha)	Whole Site Carbon (kg/ha)	Whole Soil Carbon (kg/m^2)
N7-158	7,741.9	136,518.5	144,260.4	14.4
N7-224	3,769.0	78,363.7	82,132.8	8.2
N7-227	6,085.6	84,993.7	91,079.3	9.1
N7-228	9,113.3	72,831.5	81,944.8	8.2
N7-229	5,176.2	116,215.3	121,391.5	12.1
N7-25	8,020.0	142,598.3	150,618.3	15.1
N7-34	6,362.1	101,764.4	108,126.5	10.8
N7-36	6,322.8	104,997.9	111,320.7	11.1
N7-51	2,999.0	131,249.5	134,248.5	13.4
N7-53	6,496.8	80,211.2	86,707.9	8.7
N15-000	6,422.2	79,845.1	86,267.3	8.6
N15-131	3,532.6	138,934.1	142,466.8	14.2
N15-225	12,261.9	122,579.3	134,841.3	13.5
N15-316	9,500.8	104,142.4	113,643.3	11.4
N15-333	6,538.4	151,186.4	157,724.8	15.8
N15-362	4,150.9	83,055.2	87,206.1	8.7
N15-374	4,235.0	141,573.6	145,808.6	14.6
N15-400	6,960.5	136,474.9	143,435.4	14.3
N15-408	4,297.2	272,859.6	277,156.8	27.7
N15-440	4,373.0	122,346.8	126,719.8	12.7
N35-124	5,460.2	96,411.6	101,871.8	10.2
N35-129	5,714.3	183,906.3	189,620.6	19.0
N35-172	5,626.5	110,573.0	116,199.5	11.6
N35-225	7,522.8	129,735.1	137,257.9	13.7
N35-282	4,651.3	111,642.7	116,294.0	11.6
N35-320	5,284.8	83,428.3	88,713.1	8.9
N35-324	12,286.0	135,042.4	147,328.4	14.7
N35-411	11,128.8	207,281.5	218,410.3	21.8
N35-640	2,991.4	119,017.9	122,009.3	12.2
N35-722	4,788.0	276,672.4	281,460.4	28.1
S7-148	5,736.4	184,139.5	189,875.9	19.0
S7-291	7,863.2	98,617.7	106,480.8	10.6
S7-432	16,585.0	204,694.0	221,279.0	22.1
S7-499	6,647.4	87,156.4	93,803.8	9.4
S7-573	8,179.5	99,960.1	108,139.7	10.8
S7-582	5,076.6	81,759.8	86,836.5	8.7
S7-587	5,779.2	69,161.2	74,940.4	7.5
S7-732	7,731.2	41,465.2	49,196.5	4.9
S7-739	3,137.6	59,794.5	62,932.1	6.3
S7-751	6,028.8	87,081.2	93,110.0	9.3
S15-1307	5,383.9	68,539.7	73,923.6	7.4
S15-153	19,665.4	151,448.3	171,113.7	17.1

Soil ID	Total Litter Carbon (kg / ha)	Total Soil Carbon (kg/ ha)	Whole Site Carbon (kg/ha)	Whole Soil (kg/m^2)
S15-163	6,474.9	117,837.4	124,312.3	12.4
S15-1748	11,713.3	116,268.9	127,982.2	12.8
S15-1091	8,722.3	70,855.8	79,578.1	8.0
S15-2393	8,074.4	85,052.3	93,126.8	9.3
S15-272	18,570.1	92,322.0	110,892.1	11.1
S15-383	5,016.5	141,118.0	146,134.5	14.6
S15-604	5,295.7	108,472.5	113,768.2	11.4
S15-954	6,586.3	97,627.8	104,214.1	10.4
S35-101	6,721.5	71,574.4	78,295.8	7.8
S35-102	15,206.2	66,713.5	81,919.7	8.2
S35-113	10,682.7	137,170.1	147,852.8	14.8
S35-114	18,662.2	91,804.2	110,466.4	11.0
S35-118	7,255.1	99,176.2	106,431.2	10.6
S35-119	16,515.7	50,204.8	66,720.5	6.7
S35-175	3,493.6	98,330.1	101,823.7	10.2
S35-182	5,518.7	51,766.5	57,285.2	5.7
S35-184	4,144.9	56,620.2	60,765.1	6.1
S35-65	6,198.6	165,536.6	171,735.2	17.2
Mean	7,451.3	113,478.7	121,020.0	12.1
Min	2,991.4	41,465.2	49,196.5	4.9
Max	19,665.4	276,672.4	281,460.4	28.1
SD	4,025.3	47,492.3	47,672.3	4.8

Appendix E

pH Data

Site ID	A horizon	B horizon
N15-000	3.9	4.09
N15-131	3.26	4.3
N15-225	4.19	4.74
N15-316	3.71	4.13
N15-333	4.105	4.83
N15-362	3.945	4.16
N15-374	3.95	4.34
N15-400	3.995	4.38
N15-408	3.55	4.26
N15-440	4.06	4.53
N35-124	4.485	4.64
N35-129	3.99	4.53
N35-172	4.41	4.61
N35-225	3.91	4.63
N35-282	4.445	4.59
N35-320	4.36	4.59
N35-324	4.08	4.86
N35-411	3.685	4.21
N35-640	4.39	4.64
N35-722	3.93	4.13
N7-158	3.935	4.39
N7-224	4.325	4.65
N7-227	4.315	4.53
N7-228	4.385	4.57
N7-229	3.925	4.53
N7-25	3.34	4.13
N7-34	3.62	4.18
N7-36	3.36	4.18
N7-51	3.65	4.18
N7-53	3.9	4.39
S15-1091	4.4	4.66
S15-1307	3.82	4.48
S15-153	3.645	4.2
S15-163	3.455	4.45
S15-1748	3.805	4.28
S15-2393	4.44	4.51
S15-272	3.37	4.13
S15-383	3.99	4.38
S15-604	3.43	4.25
S15-954	3.72	4.36

Site ID	A horizon	B horizon
S35-101	3.99	4.49
S35-102	3.9	4.53
S35-113	3.89	4.32
S35-114	3.94	4.52
S35-118	3.93	4.61
S35-119	5.01	4.57
S35-175	4.24	4.66
S35-182	4.39	4.52
S35-184	4.15	4.42
S35-65	3.45	4.2
S7-148	3.23	3.72
S7-291	3.55	4.44
S7-432	4.045	4.54
S7-499	3.8	4.27
S7-573	4.015	4.37
S7-582	4.1	4.43
S7-587	4.18	4.48
S7-732	4.04	4.46
S7-739	4.22	4.53
S7-751	3.83	4.57
Mean	3.95	4.42
Min	3.23	3.72
Max	5.01	4.86
SD	.355	0.208

Appendix F

Soil pedon site descriptions

N7-158

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 15, 2001
Latitude: 37.07904
Longitude 81.43614
Elevation: 4460 ft **Aspect:** 41° **Slope%:** 12
Vegetation: Striped maple, beech, red spruce

L 0-0.1cm, leaves

F 0.1-1.0 cm, partially decomposed leaves

A 1-27 cm, dark yellowish brown (10YR 3/4), loam, moderate medium granular structure, 4 % rocks, clear smooth boundary

Bt 27-41 cm, dark yellowish brown (10YR 4/6), clay loam, weak medium subangular blocky structure

R 41+ cm, highly weathered sandstone

N7-224

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 29, 2001
Latitude: 37.07060
Longitude 81.45525
Elevation: 4065 ft **Aspect:** 50° **Slope%:** 10
Vegetation: Red maple, northern red oak, beech, ferns

L 0-0.5 cm, leaves

F 0.5-3.5 cm, partially decomposed leaves

A 3.5-14.5 cm, dark yellowish brown (10YR 3/4), silt loam, moderate fine granular structure, clear smooth boundary

Bt 29.5-43.5 cm, dark yellowish brown (10YR 4/6), clay loam, weak medium subangular blocky structure

R 43.5+ cm, hard sandstone

N7-227

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 16, 2001
Latitude: 37.07006
Longitude 81.45494
Elevation: 4061 ft **Aspect:** 61º **Slope%:** 8
Vegetation: Chestnut (oak?), northern red oak, sugar maple

L 0-0.5 cm, leaves

F 0.5-2.5 cm, partially decomposed leaves

A 2.5-14.5 cm, brown (10YR 4/3), silt loam, moderate fine granular structure, 2 % rocks, abrupt smooth boundary

Bw 14.5-43.5 cm, yellowish brown (10YR 5/6), silt loam, weak medium subangular blocky structure, 5% rocks

R 43.5 cm, hard sandstone

N7-228

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 16, 2001
Latitude: 37.07013
Longitude 81.45470
Elevation: 4060 ft **Aspect:** 64º **Slope%:** 9
Vegetation: Chestnut, northern red oak, sugar maple

L 0-0.5 cm, leaves

F 0-2.3 cm, partially decomposed leaves

A 2.3-11.3 cm, dark yellowish brown (10YR 4/4), silt loam, moderate fine granular structure, 2% rocks, abrupt smooth boundary

Bw 11.3-42.3 cm, yellowish brown (10YR 5/6), silt loam, weak medium subangular blocky structure

R 42.3+ cm, hard sandstone

N7-229

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 12, 2001
Latitude: 37.07064
Longitude 81.3988
Elevation: 4030 ft **Aspect:** 58º **Slope%:** 10
Vegetation: Striped maple, yellow birch

L 0-0.2 cm, leaves

F 0.2-2.0 cm, partially decomposed leaves

A 2 -12 cm, dark brown (7.5YR 3/2), silt loam, moderate fine granular structure, 3% rocks, gradual smooth boundary

Bt 12-35 cm, dark yellowish brown (10YR 4/4), clay loam, weak medium subangular blocky structure, 7% rocks

R 35+ cm, hard sandstone

N7-25

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: July 2, 2001
Latitude: 37.08654
Longitude 81.42186
Elevation: 4633 ft **Aspect:** 44º **Slope%:** 8
Vegetation: Yellow birch, beech

L 0-0.5 cm, leaves

F 0.5-4.0 cm, partially decomposed leaves

A 4-9 cm, dark brown (7.5YR 3/2), loam, moderate fine granular structure, abrupt smooth boundary

Bt 9-77 cm, strong brown (7.5YR 4/6), clay loam, weak medium subangular blocky structure

Cr 77-85 cm, soft sandstone

R 85+ cm, hard sandstone

N7-34

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: July 2, 2001
Latitude: 37.08715
Longitude 81.42240
Elevation: 4551 ft **Aspect:** 358º **Slope%:** 11
Vegetation: Beech, hawthorne, striped maple, yellow birch

L 0-0.5 cm, leaves

F 0.5-4.0 cm, partially decomposed leaves

A 4-20 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, clear smooth boundary

Bt1 20-31 cm, yellowish brown (10YR 5/4), silt loam, weak medium subangular blocky structure, 5% rocks, clear smooth boundary

Bt2 31-82 cm, yellowish brown (10YR 5/4), gravelly clay loam, weak medium subangular blocky structure, 25% rocks, clear smooth boundary

Cr 82-87 cm, soft bedrock

R 87+ cm, thinly bedded siltstone and shale

N7-36

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: July 2, 2001
Latitude: 37.08696
Longitude 81.42216
Elevation: 4620 ft **Aspect:** 12º **Slope%:** 10
Vegetation: Beech, red spruce

L 0-0.5 cm, leaves

F 0.5-3.0 cm, partially decomposed leaves

A 3-8 cm, brown (10YR 4/3), silt loam, moderate fine granular structure, abrupt smooth boundary

Bt1 8-23 cm, strong brown (7.5YR 4/6), silt loam, weak medium subangular blocky structure, clear smooth boundary

Bt2 23-68 cm, strong brown (7.5YR 5/6), silty clay loam, weak medium subangular blocky structure, 4% rocks, clear smooth boundary

Cr 68+ cm, siltstone

N7-51

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: July 2, 2001
Latitude: 37.08482
Longitude 81.42554
Elevation: 4564 ft **Aspect:** 352º **Slope%:** 12
Vegetation: Beech, witch hazel, northern red oak

L 0-0.2 cm, leaves

F 0.2-1.0 cm, partially decomposed leaves

A 1-6 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, abrupt smooth boundary

Bt1 6-15 cm, dark yellowish brown (10YR 4/4), silt loam, weak medium subangular blocky structure, 5% rocks, clear smooth boundary

Bt2 15-27 cm, dark brown (10YR 5/4), clay loam, weak medium subangular blocky structure, 10% rocks, clear smooth boundary

BC 27-48 cm, dark brown (10YR 5/4), gravelly loam, weak medium subangular blocky structure, 23% rocks, abrupt smooth boundary

2Cr 48+ cm, tuscarora sandstone

N7-53

Series: Muskingum taxajunct
Classification: Fine-loamy, mixed, semiactive, frigid Typic Dystrudepts

Date: July 2, 2001
Latitude: 37.08461
Longitude 81.42577
Elevation: 4581 ft **Aspect:** 2º **Slope%:** 10
Vegetation: Beech, witch hazel, sugar maple

L 0-0.2 cm, leaves

F 0.2-1.0 cm, partially decomposed leaves

A 1-15 cm, dark brown (7.5YR 3/2), silt loam, moderate fine granular structure, abrupt smooth boundary

Bw1 15-37 cm, strong brown (7.5YR 4/6), gravelly loam, weak medium subangular blocky structure, 18% rocks, clear smooth boundary

Bw2 37-54 cm, strong brown (7.5YR 4/6), gravelly loam, weak medium subangular blocky structure, 22% rocks,

R 54+ cm, sandstone

N15-225

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 14, 2001
Latitude: 37.08076
Longitude 81.40713
Elevation: 4109 ft **Aspect:** 59º **Slope%:** 31
Vegetation: None listed

L 0-0.5 cm, leaves

F 0.5-3 cm, partially decomposed leaves

A 3-33 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, clear smooth boundary

Bw 33-50 cm, dark yellowish brown (10YR 3/4), silt loam, weak medium subangular blocky structure

R 50+ cm, sandstone

N15-440

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 16, 2001
Latitude: 37.06874
Longitude 81.45490
Elevation: 4045 ft **Aspect:** 42º **Slope%:** 33
Vegetation: Rhododendron, Striped maple, N. Red Oak

L 0-0.5 cm, leaves

F 0.5-1 cm, partially decomposed leaves

H 1-2 cm, amorphous material

A 2-6 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, 2% rocks, abrupt smooth boundary

Bw1 6-43 cm, yellowish brown (10YR 5/4), silt loam, weak medium subangular blocky structure, 10% rocks

R 43+ cm, sandstone

N15-316

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 23, 2001
Latitude: 37.07874
Longitude 81.42807
Elevation: 4634 ft **Aspect:** 345º **Slope%:** 20
Vegetation: Beech, red spruce, magnolia

L 0-0.2 cm, leaves

F 0.2-2.0 cm, partially decomposed leaves

A 2-9 cm, dark yellowish brown (10YR 4/4), silt loam, moderate fine granular structure, gradual smooth boundary

Bw1 9-33 cm, yellowish brown (10YR 5/4), silt loam, weak medium subangular blocky structure, 2% rocks

R 33+ cm, sandstone

N15-400

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 25, 2001
Latitude: 37.07466
Longitude 81.45415
Elevation: 4191 ft **Aspect:** 6º **Slope%:** 26
Vegetation: Red maple, beech, striped maple

L 0-0.5 cm, leaves

F 0.5-2.0 cm, partially decomposed leaves

A 2-19 cm, very dark grayish brown (10YR 3/2), silt loam, moderate fine granular structure, 10% rocks abrupt smooth boundary

Bw1 19-43 cm, brown (10YR 4/3), silt loam, weak medium subangular blocky structure, 10% rocks,

R 43+ cm, sandstone

N15-408

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 25, 2001
Latitude: 37.07222
Longitude 81.45837
Elevation: 4085 ft **Aspect:** 20º **Slope%:** 31
Vegetation: Beech, striped maple, red maple

L 0-0.5 cm, leaves

F 0.5-1.7 cm, partially decomposed leaves

A 2-8 cm, very dark grayish brown (10YR 3/2), silt loam, moderate fine granular structure, 10 % rocks, abrupt smooth boundary

Bt 8-16 cm, dark yellowish brown (10YR 4/4), silty clay loam, weak medium subangular blocky structure, 15% rocks

R 16+ cm, Tuscarora sandstone

N15-362

Series: Lily taxajunct
Classification: Loamy, mixed, semiactive, frigid Lithic Hapludults

Date: June 28, 2001
Latitude: 37.07562
Longitude 81.44721
Elevation: 4391 ft **Aspect:** 356º **Slope%:** 25
Vegetation: American beech, chestnut oak, red maple, striped maple

L 0-0.2 cm, leaves

F 0.2-1.3 cm, partially decomposed leaves

A 1-15 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, abrupt smooth boundary

AB 15-21 cm, dark yellowish brown (10YR 4/4), silt loam, weak medium subangular blocky structure, clear smooth boundary

Bt 21-48 cm, dark yellowish brown (10YR 4/6), gravelly loam, weak medium subangular blocky structure, 15% rocks,

R 48+ cm, sandstone

N15-374
Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 28, 2001
Latitude: 37.07561
Longitude 81.44766
Elevation: 4387 ft **Aspect:** 0º **Slope%:** 31
Vegetation: Beech, striped maple, red maple

L 0-0.5 cm, leaves

F 0-2.1 cm, partially decomposed leaves

A 2-20 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, abrupt smooth boundary

BA 20-26 cm, dark yellowish brown (10YR 4/3), clay loam, weak medium subangular blocky structure, clear smooth boundary

Bt 26-48 cm, dark brown (10YR 5/4), gravelly clay loam, weak medium subangular blocky structure, 18% rocks, clear smooth boundary

R 48+ cm, sandstone

N15-000
Series: Lily taxajunct
Classification: Loamy, mixed, semiactive, frigid Lithic Haplohumults

Date: June 24, 2001
Latitude: 37.07551
Longitude 81.44830
Elevation: 4380 ft **Aspect:** 2º **Slope%:** 32
Vegetation: Beech, striped maple, red maple, chestnut oak

L 0-0.5 cm, leaves

F 0-2.3 cm, partially decomposed leaves

A 2-19 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, abrupt smooth boundary

Bt1 19-40 cm, dark yellowish brown (10YR 4/6), clay loam, weak medium subangular blocky structure, 5% rocks, clear smooth boundary

Bt2 40-47 cm, dark yellowish brown (10YR 4/6), clay loam, weak medium subangular blocky structure, 10% rocks

R 47+ cm, sandstone

N15-131

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: July 2, 2001
Latitude: 37.08406
Longitude 81.42671
Elevation: 4600 ft **Aspect:** 38º **Slope%:** 19
Vegetation: Yellow birch, sugar maple, N. red oak

L 0-0.2 cm, leaves

F 0.2-1 cm, partially decomposed leaves

A 1-8 cm, dark brown (10YR 3/3), channery silt loam, moderate fine granular structure, 25% rocks, abrupt smooth boundary

Bt 8-21 cm, dark yellowish brown (10YR 3/4), channery silt loam, weak medium subangular blocky structure, 25% rocks, clear smooth boundary

BC 21-53 cm, dark yellowish brown (10YR 4/4), chnnery clay loam, weak medium subangular blocky structure, 32% rocks, clear smooth boundary

R 53+ cm, sandstone

N15-333

Series: Muskingum taxajunct
Classification: Fine-loamy, mixed, semiactive, frigid Typic Dystrudepts

Date: July 27, 2001
Latitude: 37.07787
Longitude 81.40719
Elevation: 4100 ft **Aspect:** 62º **Slope%:** 28
Vegetation: Sugar maple

L 0-0.5 cm, leaves

F 0.5-2.0 cm, partially decomposed leaves

A 2-17 cm, very dark grayish brown (10YR 3/2), silt loam, moderate fine granular structure, 5 % rocks, abrupt smooth boundary

BA 17-29 cm, dark brown (10YR 3/3), silt loam, weak medium subangular blocky structure, 5% rocks, clear smooth boundary

Bt1 29-68 cm, dark yellowish brown (10YR 4/6), gravelly clay loam, weak medium subangular blocky structure, 15% rocks

Bt2 68-99 cm, dark yellowish brown (10YR 4/6), very gravelly clay loam, weak medium subangular blocky structure, 40% rocks

R 99+ cm, siltstone

N35-124

Series: Ungers taxajunct
Classification: Fine-loamy, mixed, semiactive, frigid Typic Hapludults

Date: July 2, 2001
Latitude: 37.07373
Longitude 81.40602
Elevation: 4220 ft **Aspect:** 80º **Slope%:** 38
Vegetation: Ohio buckeye, sugar maple

L 0-0.2 cm, leaves

F 0-2 cm, partially decomposed leaves

A 2-22 cm, brown (7.5YR 3/2), silt loam, moderate fine granular structure, abrupt smooth boundary

Bt1 22-54 cm, reddish brown (5YR 4/4), clay loam, weak medium subangular blocky structure, 5% rocks, clear smooth boundary

Bt2 54-74 cm, reddish brown (5YR 4/4), channery clay loam, weak medium subangular blocky structure, 32% rocks, clear smooth boundary

R 74+ cm, sandstone

N35-722

Series: Lily taxajunct
Classification: Loamy, mixed, semiactive, frigid Lithic Haplohumults

Date: June 12, 2001
Latitude: 37.07173
Longitude 81.3999
Elevation: 4030 ft **Aspect:** 62º **Slope%:** 47
Vegetation: Sugar maple, striped maple, elm

L 0-0.2 cm, leaves

F 0.2-1.0 cm, partially decomposed leaves

A 1-7 cm, dark brown (7.5YR 3/2), silt loam, moderate fine granular structure, gradual smooth boundary

Bt1 7-31 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 4% rocks, clear smooth boundary

Bt2 31-43 cm, dark yellowish brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 11% rocks

R 43+ cm, sandstone

N35-324

Series: Lily taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: June 12, 2001
Latitude: 37.07471
Longitude 81.40186
Elevation: 4194 ft **Aspect:** 70º **Slope%:** 37
Vegetation: Ohio buckeye, sugar maple

L 0-1.0 cm, leaves

F 1-4.0 cm, partially decomposed leaves

A 4-15 cm, brown (7.5YR 3/2), silt loam, moderate fine granular structure, 2% rocks, abrupt smooth boundary

BA 15-24 cm, dark brown (7.5YR 3/4), silt loam, weak medium subangular blocky structure, 4% rocks, gradual smooth boundary

Bt 24-76 cm, dark brown (7.5YR 4/4), cahnnery clay loam, weak medium subangular blocky structure, 7% rocks

R 76+ cm, sandstone

N35-129

Series: Muskingum taxajunct
Classification: Fine-loamy, mixed, semiactive, frigid Typic Dystrochrepts

Date: June 13, 2001
Latitude: 37.09662
Longitude 81.41304
Elevation: 4155 ft **Aspect:** 12º **Slope%:** 52
Vegetation: Sugar maple, striped maple, ohio buckeye

L 0-0.2 cm, leaves

F 0.2-2.3 cm, partially decomposed leaves

A 2-19 cm, dark brown (7.5YR 3/2), silt loam, moderate fine granular structure, 10% rocks, gradual smooth boundary

Bw 19-70 cm, dark brown (7.5YR 3/4), loam, weak medium subangular blocky structure, 10% rocks

R 70+ cm, sandstone

N35-225

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dydtrudepts

Date: June 13, 2001
Latitude: 37.09591
Longitude 81.41176
Elevation: 4380 ft **Aspect:** 15º **Slope%:** 53
Vegetation: Striped maple, sugar maple

L 0-0.3 cm, leaves

F 0.3-2.0 cm, partially decomposed leaves

A 2-14 cm, brown (7.5YR 3/2), silt loam, moderate fine granular structure, 7% rocks, abrupt smooth boundary

Bw 14-54 cm, dark brown (7.5YR 3/4), loam, weak medium subangular blocky structure, 10% rocks, gradual smooth boundary

R 54+ cm, sandstone

N35-282

Series: Lily taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: June 13, 2001
Latitude: 37.09224
Longitude 81.41840
Elevation: 4330 ft **Aspect:** 20º **Slope%:** 50
Vegetation: Sugar maple, striped maple, ohio buckeye

L 0-0.3 cm, leaves

F 0.3-4.0 cm, partially decomposed leaves

A 4-18 cm, dark brown (7.5YR 3/4), silt loam, moderate fine granular structure, 2% rocks, gradual smooth boundary

Bt 18-72 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 7% rocks

R 72+ cm, sandstone

N35-172

Series: Lily taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: June 13, 2001
Latitude: 37.09297
Longitude 81.41910
Elevation: 4180 ft **Aspect:** 20º **Slope%:** 50
Vegetation: Striped maple, sugar maple, ohio buckeye

L 0-0.2 cm, leaves

F 0.2-4.0 cm, partially decomposed leaves

A 4-17 cm, dark brown (7.5YR 3/4), silt loam, moderate fine granular structure, 2% rocks, clear smooth boundary

Bt 17-69 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 10% rocks,

R 69+ cm, sandstone

N35-320

Series: Lily taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Hapludults

Date: June 16, 2001
Latitude: 37.07045
Longitude 81.45451
Elevation: 4072 ft **Aspect:** 65º **Slope%:** 31
Vegetation: Sugar maple, striped maple, ohio buckeye

L 0-0.5 cm, leaves

F 0.5-2.0 cm, partially decomposed leaves

A 2-11 cm, dark brown (10YR 4/3), silt loam, moderate fine granular structure, clear smooth boundary

BA 11-22 cm, dark yellowish brown (10YR 4/6), silt loam, weak medium subangular blocky structure, 2% rocks

Bt 22-69 cm, dark brown (10YR 5/8), clay loam, weak medium subangular blocky structure, 5% rocks

R 69+ cm, sandstone

N35-411

Series: Lily taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: June 25, 2001
Latitude: 37.09297
Longitude 81.41910
Elevation: 4120 ft **Aspect:** 10º **Slope%:** 50
Vegetation: Striped maple, beech, red maple

L 0-0.5 cm, leaves

F 0.5-2.0 cm, partially decomposed leaves

A 2-24 cm, dark brown (7.5YR 3/2), silt loam, moderate fine granular structure, 2% rocks, clear smooth boundary

Bt 24-58 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 25% rocks,

R 58+ cm, sandstone

N35-640

Series: Lily taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Hapludults

Date: June 27, 2001
Latitude: 37.07669
Longitude 81.40546
Elevation: 4067 ft **Aspect:** 64º **Slope%:** 42
Vegetation: Red maple, ohio buckeye

L 0-0.2 cm, leaves

F 0-1.0 cm, partially decomposed leaves

A 1-31 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, clear smooth boundary

Bt 31-71 cm, dark yellowish brown (10YR 4/4), gravelly clay loam, weak medium subangular blocky structure, 20% rocks

R 71+ cm, sandstone

S7-291

Series: Klinesville taxajunct
Classification: Loamy, mixed, active, frigid Lithic Dystrudepts

Date: May 30, 2001
Latitude: 37.07876
Longitude 81.41500
Elevation: 4576 ft **Aspect:** 180º **Slope%:** 14
Vegetation: chestnut

L 0-1.0 cm, leaves

F 1-4.0 cm, partially decomposed leaves

A 4-9 cm, dark brown (7.5YR 3/4), silt loam, moderate fine granular structure, 2% rocks, clear smooth boundary

Bw 9-41 cm, dark brown (7.5YR 4/4), loam, weak medium subangular blocky structure, 3% rocks,

R 41+ cm, sandstone

S7-739

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 16, 2001
Latitude: 37.06989
Longitude 81.45424
Elevation: 4030 ft **Aspect:** 212º **Slope%:** 8
Vegetation: Striped maple, yellow birch, sugar maple

L 0-0.1 cm, leaves

F 0-2.0 cm, partially decomposed leaves

A 2-15 cm, dark brown (10YR 3/4), silt loam, moderate fine granular structure, gradual smooth boundary

Bw 15-42 cm, yellowish brown (10YR 5/6), silt loam, weak medium subangular blocky structure, clear smooth

C 42-48, dark yellowish brown (10YR 5/4), silt loam, weak medium subangular blocky structure, 4% rocks

R 48+ cm, sandstone

S7-732

Series: Lily taxajunct
Classification: Loamy, mixed, active, frigid Lithic Haplohumults

Date: June 18, 2001
Latitude: 37.06911
Longitude 81.4446
Elevation: 4209 ft **Aspect:** 260º **Slope%:** 10
Vegetation: Striped maple, N. red oak, sugar maple, yellow birch

L 0-0.1 cm, leaves

F 0.1-1.7 cm, partially decomposed leaves

A 2-17 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, clear smooth boundary

Bt 17-48 cm, strong brown (7.5YR 4/6), silty clay loam, weak medium subangular blocky structure,

R 48+ cm, sandstone

S7-573

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 18, 2001
Latitude: 37.07278
Longitude 81.44161
Elevation: 4575 ft **Aspect:** 260º **Slope%:** 13
Vegetation: Striped maple, yellow birch, sugar maple

L 0-0.1 cm, leaves

F 0.1-2.0 cm, partially decomposed leaves

A 2-13 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, 2% rocks, gradual smooth boundary

Bw 13-43 cm, yellowish brown (10YR 5/6), silt loam, weak medium subangular blocky structure, clear smooth

R 43+ cm, sandstone

S7-582

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 18, 2001
Latitude: 37.07270
Longitude 81.45172
Elevation: 4180 ft **Aspect:** 256º **Slope%:** 9
Vegetation: Striped maple, N. red oak, sugar maple, yellow birch

L 0-1.0 cm, leaves

F 0-2.0 cm, partially decomposed leaves

A 2-7 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, clear smooth boundary

Bw 7-34 cm, dark yellowish brown (10YR 4/6), silt loam, weak medium subangular blocky structure,

R 34+ cm, sandstone

S7-751

Series: Muskingum taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Dystrudepts

Date: June 23, 2001
Latitude: 37.07063
Longitude 81.43195
Elevation: 4448 ft **Aspect:** 170º **Slope%:** 13
Vegetation: Red maple, red oak, red spruce, fraser magnolia, striped maple

L 0-0.1 cm, leaves

F 0.1-0.5 cm, partially decomposed leaves

H 0.5-1 cm, amorphous organic material

A 1-8 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, 2% rocks, gradual smooth boundary

BA 8-31 cm, yellowish brown (10YR 4/3), gravelly silt loam, weak medium subangular blocky structure, 15% rocks, clear smooth boundary

Bw 31-82 cm, yellowish brown (10YR 5/6), gravelly silt loam, weak medium subangular blocky structure, 20% rocks

R 82+ cm, sandstone

S7-499
Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 23, 2001
Latitude: 37.07453
Longitude 81.43024
Elevation: 4699 ft **Aspect:** 240º **Slope%:** 10
Vegetation: Red spruce, beech, yellow birch

L 0-0.1 cm, leaves

F 0.1-0.5 cm, partially decomposed leaves

H 0.5-1 cm, amorphous organic material

A 1-8 cm, dark brown (10YR 4/4), silt loam, moderate fine granular structure, clear smooth boundary

Bw 8-33 cm, yellowish brown (10YR 5/6), silt loam, weak medium subangular blocky structure, 5% rocks

R 33+ cm, sandstone

S7-587
Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 28, 2001
Latitude: 37.07359
Longitude 81.44786
Elevation: 4363 ft **Aspect:** 210º **Slope%:** 10
Vegetation: Beech, striped maple, red maple

L 0-0.1 cm, leaves

F 0.1-1.0 cm, partially decomposed leaves

A 1-13 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, 2% rocks, gradual smooth boundary

Bt 13-41 cm, yellowish brown (10YR 5/6), silty clay loam, weak medium subangular blocky structure, 2% rocks

R 41+ cm, sandstone

S7-148

Series: Dekalb taxajunct
Classification: Loamy-skeletal, siliceous, active, frigid Lithic Dystrudepts

Date: June 2, 2001
Latitude: 37.08242
Longitude 81.42760
Elevation: 4615 ft **Aspect:** 182° **Slope%:** 10
Vegetation: Red spruce, beech, yellow birch, witch hazel

L 0-0.2 cm, leaves

F 0.2-1.2 cm, partially decomposed leaves

A 1-10 cm, dark brown (10YR 3/2),very channery loam, moderate fine granular structure, 60% rocks, clear smooth boundary

Bw 10-33 cm, dark brown (7.5YR 3/4), silt loam, weak medium subangular blocky structure, 40% rocks

R 33+ cm, purple sandstone

S7-432

Series: Lily taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: June 25, 2001
Latitude: 37.07585
Longitude 81.44397
Elevation: 4532 ft **Aspect:** 210° **Slope%:** 10
Vegetation: Witch hazel, sugar maple, red oak

L 0-0.2 cm, leaves

F 0.2-2.1 cm, partially decomposed leaves

A 2-8 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, 2% rocks, gradual smooth boundary

BA 8-22 cm, yellowish brown (10YR 5/6), silt loam, weak medium subangular blocky structure, 2% rocks, clear smooth boundary

Bt1 22-47 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 7% rocks, clear smooth boundary

Bt2 47-62 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 13% rocks

R 62+ cm, sandstone

S15-383

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 19, 2001
Latitude: 37.07632
Longitude 81.43733
Elevation: 4544 ft **Aspect:** 179º **Slope%:** 31
Vegetation: Beech, chestnut, sugar maple

L 0-1.0 cm, leaves

F 0-2.0 cm, partially decomposed leaves

A 2-6 cm, very dark grayish brown (10YR 3/2), loam, moderate fine granular structure, clear smooth boundary

Bw 6-32 cm, dark yellowish brown (10YR 3/4), silt loam, weak medium subangular blocky structure

R 32+ cm, sandstone

S15-2393

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 25, 2001
Latitude: 37.07585
Longitude 81.44397
Elevation: 4100 ft **Aspect:** 220º **Slope%:** 28
Vegetation: Northern red oak, red maple, beech, striped maple

L 0-0.5 cm, leaves

F 0.5-3.0 cm, partially decomposed leaves

A 3-13 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, gradual smooth boundary

Bt 13-49 cm, yellowish brown (7.YR 5/6), clay loam, weak medium subangular blocky structure, 5% rocks,

R 49+ cm, sandstone

S15-1091

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 18, 2001
Latitude: 37.07310
Longitude 81.45512
Elevation: 4168 ft **Aspect:** 220º **Slope%:** 17
Vegetation: Red maple, ohio buckeye, beech, N. red oak

L 0-0.5 cm, leaves

F 0.5-1.0 cm, partially decomposed leaves

A 1-7 cm, dark yellowish brown (10YR 4/4), silt loam, moderate fine granular structure, abrupt smooth boundary

Bw 7-46 cm, dark yellowish brown (10YR 5/6), silt loam, weak medium subangular blocky structure, 5% rocks

R 46+ cm, sandstone

S15-604

Series: Klinesville taxajunct
Classification: Loamy, mixed, active, frigid Lithic Dystrudepts

Date: May 30, 2001
Latitude: 37.07575
Longitude 81.41687
Elevation: 4318 ft **Aspect:** 208º **Slope%:** 26
Vegetation: Chestnut, striped maple, yellow birch, spruce

L 0-0.5 cm, leaves

F 0.5-2.0 cm, partially decomposed leaves

A 2-9 cm, very dark grayish brown (10YR 3/2), silt loam, moderate fine granular structure, abrupt smooth boundary

Bw 9-43 cm, reddish brown (5YR 5/4), loam, weak medium subangular blocky structure, 10% rocks

R 43+ cm, sandstone

S15-163
Series: Klinesville taxajunct
Classification: Fine-loamy, mixed, active, frigid Typic Dystrudepts

Date: May 30, 2001
Latitude: 37.07883
Longitude 81.41298
Elevation: 4608 ft **Aspect:** 194º **Slope%:** 25
Vegetation: Striped maple, red spruce

L 0-2.0 cm, leaves

F 2.0-3.0 cm, partially decomposed leaves

A 3-13 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, gradual smooth boundary

Bw 13-43 cm, yellowish red (5YR 4/6), silt loam, weak medium subangular blocky structure, 10% rocks, gradual smooth boundary

Bw 43-63 cm, dark reddish brown (5YR 3/4), silt loam, weak medium subangular blocky structure, 15% rocks

R 63+ cm, sandstone

S15-153
Series: Klinesville taxajunct
Classification: Fine-loamy, mixed, active, frigid Typic Dystrudepts

Date: May 30, 2001
Latitude: 37.07887
Longitude 81.41605
Elevation: 4590 ft **Aspect:** 200º **Slope%:** 25
Vegetation: Chestnut, striped maple, yellow birch, spruce

L 0-0.5 cm, leaves

F 0.5-2.0 cm, partially decomposed leaves

A 2-4 cm, very dark brown (10YR 2/2), silt loam, moderate fine granular structure, abrupt smooth boundary

Bw1 4-25 cm, yellowish red (5YR 4/6), loam, moderate fine granular structure, 5% rocks, abrupt smooth boundary

Bw2 25-59 cm, reddish brown (5YR 5/4), loam, weak medium subangular blocky structure, 5% rocks

R 59+ cm, sandstone

<u>S15-1307</u>
Series: Lily taxajunct
Classification: Fine-loamy, siliceous, semiactive, frigid Typic Haplohumults

Date: June 12, 2001
Latitude: 37.07244
Longitude 81.40377
Elevation: 4134 ft **Aspect:** 232° **Slope%:** 22
Vegetation: Northern red oak, red maple, chestnut, red spruce

L 0-0.2 cm, leaves

F 0.2-1.5 cm, partially decomposed leaves

H 1.5-3.0 cm, amorphous organic material

A 3-10 cm, dark brown (7.5YR 3/4), silt loam, moderate fine granular structure, 2% rocks, clear smooth boundary

Bt 10-63 cm, brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 5% rocks, gradual smooth boundary

R 63+ cm, sandstone

<u>S15-1748</u>
Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: May 30, 2001
Latitude: 37.07887
Longitude 81.41605
Elevation: 4377 ft **Aspect:** 250° **Slope%:** 31
Vegetation: Yellow birch, striped maple, N. red oak, chestnut

L 0-0.1 cm, leaves

F 0.1-1.5 cm, partially decomposed leaves

H 1.5-2.0 cm, amorphous organic material

A 2-18 cm, dark brown (10YR 3/3), silt loam, moderate fine granular structure, 5% rocks abrupt smooth boundary

Bt 18-40 cm, yellowish brown (10YR 5/4), gravelly silty clay loam, moderate fine granular structure, 15% rocks, abrupt smooth boundary

R 40+ cm, sandstone

S15-272

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts
Date: June 23, 2001
Latitude: 37.07782
Longitude 81.42313
Elevation: 4634 ft **Aspect:** 180° **Slope%:** 32
Vegetation: Northern red oak, red maple, chestnut, red spruce

L 0-0.2 cm, leaves

F 0.2-2.0 cm, partially decomposed leaves

A 2-7 cm, very dark grayish brown (10YR 3/2), loam, moderate fine granular structure, clear smooth boundary

BA 7-32 cm, dark yellowish brown (10YR 4/4), silt loam, weak medium subangular blocky structure, 5% rocks, gradual smooth boundary

Bw 32-47 cm, dark yellowish brownbrown (10YR 4/4), silt loam, weak medium subangular blocky structure, 5% rocks

R 62+ cm, sandstone

S15-954

Series: Muskingum taxajunct
Classification: Fine-loamy, mixed, semiactive, frigid Typic Dystrudepts

Date: June 23, 2001
Latitude: 37.07371
Longitude 81.42973
Elevation: 4596 ft **Aspect:** 179° **Slope%:** 18
Vegetation: Yellow birch, striped maple, red spruce

L 0-0.1 cm, leaves

F 0.1-0.5 cm, partially decomposed leaves

H 0.5-2.0 cm, amorphous organic material

A 2-9 cm, dark yellowish brown (10YR 3/4), silt loam, moderate fine granular structure, abrupt smooth boundary

Bw 9-62 cm, yellowish brown (10YR 5/6), silt loam, moderate fine granular structure, 5% rocks,

R 62+ cm, sandstone

S35-101

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults
Date: June 9, 2001
Latitude: 37.07304
Longitude 81.40546
Elevation: 4005 ft **Aspect:** 260° **Slope%:** 37
Vegetation: Spruce, beech, maple

L 0-0.2 cm, leaves

F 2-1 cm, partially decomposed leaves

H 1-6 cm, amorphous organic material

A 6-12 cm, very dark grayish brown (10YR 3/2), silt loam, moderate fine granular structure, clear smooth boundary

Bt 12-48 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 5% rocks,

R 48+ cm, sandstone

S35-102

Series: Ungers taxajunct
Classification: Fine-loamy, mixed, semiactive, frigid Typic Haplohumults

Date: June 9, 2001
Latitude: 37.07303
Longitude 81.40504
Elevation: 4105 ft **Aspect:** 260° **Slope%:** 44
Vegetation: Red spruce, chalk maple, N. red oak, beech

L 0-0.1 cm, leaves

F 0.1-2.0 cm, partially decomposed leaves

H 2-7 cm, amorphous organic material

A 7-14 cm, dark brown (7.5YR 3/4), silt loam, moderate fine granular structure, abrupt smooth boundary

Bt 14-58 cm, yellowish red (5YR 5/6), clay loam, moderate fine granular structure, 5% rocks,

R 58+ cm, sandstone

S35-119

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults
Date: June 12, 2001
Latitude: 37.07190
Longitude 81.40556
Elevation: 4118 ft **Aspect:** 260° **Slope%:** 38
Vegetation: Spruce, beech, maple

L 0-0.2 cm, leaves

F 0.2-1.0 cm, partially decomposed leaves

H 1.0-3.0 cm, amorphous organic material

A 1-9 cm, very dark grayish brown (10YR 3/2), silt loam, moderate fine granular structure, clear smooth boundary

Bt 9-32 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 2% rocks,

R 32+ cm, sandstone

S35-65

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 23, 2001
Latitude: 37.07143
Longitude 81.43324
Elevation: 4464 ft **Aspect:** 220° **Slope%:** 37
Vegetation: Red spruce, red oak, red maple, striped maple

L 0-0.5 cm, leaves

F 0.5-1.0 cm, partially decomposed leaves

A 1-8 cm, dark brown (10YR 3/2), silt loam, moderate fine granular structure, abrupt smooth boundary

Bw 8-45 cm, yellowish brown (10YR 5/4), loam, moderate fine granular structure, 2% rocks,

R 45+ cm, sandstone

S35-175

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 27, 2001
Latitude: 37.07095
Longitude 81.39974
Elevation: 4020 ft **Aspect:** 208º **Slope%:** 38
Vegetation: Spruce, beech, maple

L 0-0.2 cm, leaves

F 0.2-1.3 cm, partially decomposed leaves

A 1-7 cm, very dark grayish brown (10YR 4/4), silt loam, moderate fine granular structure, abrupt smooth boundary

BA 7-16 cm, dark brown (7.5YR 4/4), silt loam, weak medium subangular blocky structure, clear smooth boundary, 3% rocks,

Bt 16-49 cm, dark brown (7.5YR 4/4), clay loam, weak medium subangular blocky structure, 5% rocks,

R 49+ cm, sandstone

S35-114

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 27, 2001
Latitude: 37.07257
Longitude 81.40534
Elevation: 4117 ft **Aspect:** 258º **Slope%:** 42
Vegetation: Red spruce, red oak, red maple, striped maple

L 0-0.2 cm, leaves

F 0.2-1.1 cm, partially decomposed leaves

A 1-8 cm, dark brown (7.5YR 4/4), silt loam, moderate fine granular structure, 2% rocks, abrupt smooth boundary

Bt 8-36 cm, dark brown (7.5YR 4/6), silty clay loam, moderate fine granular structure, 7% rocks,

R 36+ cm, sandstone

S35-118

Series: Ramsey taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 27, 2001
Latitude: 37.07257
Longitude 81.40568
Elevation: 4107 ft **Aspect:** 250º **Slope%:** 43
Vegetation: Spruce, beech, red maple, n. red oak

L 0-0.1 cm, leaves

F 0.1-0.5 cm, partially decomposed leaves

A 1-5 cm, dark brown (7.5YR 3/4), silt loam, moderate fine granular structure, 5% rocks, clear smooth boundary

Bw 5-41 cm, dark brown (7.5YR 4/4), silt loam, weak medium subangular blocky structure, 7% rocks,

R 41+ cm , sandstone

S35-113

Series: Lily taxajunct
Classification: Loamy, siliceous, semiactive, frigid Lithic Haplohumults

Date: June 27, 2001
Latitude: 37.07275
Longitude 81.40586
Elevation: 4034 ft **Aspect:** 260º **Slope%:** 43
Vegetation: Red spruce, red oak, red maple, chestnut

L 0-0.2 cm, leaves

F 0.2-1.0 cm, partially decomposed leaves

H 1.0-2.0 cm, amorphous organic material

A 2-6 cm, dark brown (7.5YR 4/4), silt loam, moderate fine granular structure, 5% rocks, abrupt smooth boundary

BA 6-22 cm, dark brown (7.5YR 4/2), clay loam, moderate fine granular structure, 5% rocks, clear smooth boundary

Bt 22-48 cm, dark brown (7.5YR 4/4), clay loam, moderate fine granular structure, 10% rocks,

R 48+ cm, sandstone

S35-182

Series: Ramsey taxajunct
Classification: Loamy-skeletal, siliceous, semiactive, frigid Lithic Dystrudepts

Date: June 29, 2001
Latitude: 37.06720
Longitude 81.45633
Elevation: 4020 ft **Aspect:** 242º **Slope%:** 38
Vegetation: Striped maple, red maple, n. red oak

L 0-0.5 cm, leaves

F 0.5-2.2 cm, partially decomposed leaves

A 2-6 cm, dark brown (7.5YR 3/2), channery silt loam, moderate fine granular structure, 20% rocks, clear smooth boundary

Bw 6-32 cm, brown (7.5YR 4/2), very channery silt loam, weak medium subangular blocky structure, 50% rocks,

R 32+ cm, sandstone

S35-184

Series: Ramsey taxajunct
Classification: Loamy-skeletal, siliceous, semiactive, frigid Lithic Dystrudepts

Date: July 26, 2001
Latitude: 37.06688
Longitude 81.45607
Elevation: 4050 ft **Aspect:** 240º **Slope%:** 38
Vegetation: Striped maple, sugar maple, N. red oak

L 0-0.5cm, leaves

F 0.5-2.3 cm partially decomposed leaves

A 2-7 cm, dark brown (7.5YR 3/2), cahnnery silt loam, moderate fine granular structure, 20% rocks, abrupt smooth boundary

Bw 7-35 cm, dark brown (7.5YR 4/2), very channery clay loam, moderate fine granular structure, 50% rocks,

R 35+ cm, sandstone

VITA

Jarrod Ottis Miller was born in 1977 in Havre de Grace, Maryland to Jimmie and Jerry Miller. Primary and secondary education was obtained at Darlington Elementary School, Havre de Grace Middle School, and Havre de Grace High School. Jarrod graduated from Havre de Grace High School in 1995. Following high school Jarrod obtained his bachelors degree in Environmental Science at Virginia Polytechnic Institute and State University in 1995. Jarrod is a member of the Soil Science Society of America and the Huckleberry Trail Photography Club.