EFFECTS OF ROCK-DERIVED NUTRIENTS ON NITROGEN CYCLIING IN NORTHERN HARDWOOD FORESTS

by

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Abstract

Y. Dong. Effects of Rock-derived Nutrients on Nitrogen Cycling in Northern Hardwood Forests, 59 pages, 5 tables, 8 figures, 2014.

The weathering of parent material is the primary source of Ca, Mg, K, and P in soils and ecosystems. The influence of rock-derived nutrients on N cycling is less often investigated. Here, we investigated the geochemical compositions of soil mineral nutrients of mineral horizon in 20 sites in the White Mountains of New Hampshire, United States. Total soil N content, foliar N concentration, and N mineralization were compared among sites located on different types of bedrock. Total soil N content was significantly higher in sites located on Rangeley schist than sites located on the Conway, Mt. Osceola, and Kinsman granites. Foliar N and N mineralization were not related to bedrock types. Nitrogen mineralization was closely related to foliar N concentration, soil C/N ratio and soil exchangeable Ca. Nitrogen mineralization rate was higher when foliar N concentration increased, but was inhibited by the soil C/N and soil exchangeable Ca. Rock-derived nutrients may deserve more attention as a control on N accumulation in ecosystem development.

Keywords: parent material nutrient; soil nutrient availability; foliar nitrogen concentration; temperate forest

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Chapter 1

I. Context of the study

Nitrogen (N) is a critical limiting nutrient that regulates plant productivity, existing in both inorganic and organic forms as well as many different oxidation states. There are typically five main processes that cycle N through the biosphere, atmosphere, and geosphere, namely N fixation, N-uptake, N mineralization, denitrification, and leaching. Within those five processes, N-uptake and mineralization are the two critical processes in the forest ecosystem that link soil and plants together (Aber, 1992). Nitrogen uptake and nitrogen mineralization can be driven by soil nutrients, particularly the rock-derived nutrients (Vitousek et al., 1995).

Rock-derived nutrients such as calcium (Ca), magnesium (Mg), potassium (K), and phosphorus (P) may limit N accumulation during primary succession (Walker and Syers, 1976). In young soils, N is in short supply and N-fixing organisms may have a substantial competitive advantage. As N quantity increases in the system, it comes into equilibrium with rock-derived nutrients, generally P (Walker and Syers, 1976). Therefore, P will become the nutrient that limits the accumulation of N in the system. Co-limitation of N and P is common in freshwater, marine, and terrestrial environments, according to an analysis across 1069 sites (Elser et al., 2007).

Understanding the effects of rock-derived soil nutrients on N cycling may be essential from a forest management perspective. Increased demands for timber resources have raised the concern of forest sustainability, especially the depletion of soil nutrients. Vadeboncoeur et al. (2014) suggested that current soil nutrient pools can only sustain a few rotations under a 100-year whole-tree harvesting rotation for northern hardwood forest. The regrowth of forest may be immediately constrained by Ca supply after first 100-year whole-tree harvest. However, the stock of P in the soil could sustain the growth of forest for about 2000 years if we conduct whole-tree harvesting every 100 years (Vadeboncoeur et al., 2014).

II. Sources of rock-derived soil nutrients

The soils in northeastern United States are relatively young (~10, 000 years), and are largely derived from glacial till (Brady and Weil, 1996). The weathering of parent material provides the constituents for the soil nutrient pool. Soil P is mainly derived from apatite, $Ca_5(PO_4)_3(F, Cl, OH)$, which is also a potential source of soil Ca (Nezat et al., 2008). But the soil Ca pool may be more variable than P due to the presence of other minerals. In northeastern United States, glacial till developed from carbonate bedrock had significantly higher Ca concentration than tills derived from crystalline silicate and clastic sedimentary rock (Nezat et al., 2008). Soil Mg developed from crystalline-silicate parent materials mainly comes from the weathering of biotite, chlorite, and hornblende (Nezat et al., 2008).

III. Effects of rock-derived soil nutrients on N accumulation

A. Soil total N

Walker and Syers (1976) proposed a theory that addresses why N accumulation in the soils could be controlled by other mineral nutrients. They pointed out that in the later stages of soil development, P and other rock-derived elements are gradually lost and/or bound in insoluble or physically protected form, while N can continue to enter the system by biological fixation. The inputs of nitrogen in the soil are greater than the weathering of rock-derived elements. Thus, P and other mineral elements will limit the N accumulation in the soils. Chadwick et al. (1999) compared soil-extractable N and P across a chronosequence of soils in Hawaii. They suggested that N is continuously accumulated in the soils after millions of years, while P and other minerals steadily declined after peaking at a substrate age of 10 kyrs.

Nitrogen accumulation in temperate forest ecosystems is slow, where soils are relatively young and little N is retained in the ecosystem (Vitousek et al., 1993). However, recent evidence indicates that N accumulation in young temperate soils may be also controlled by other mineral nutrients (Berger et al., 2002; Gradowski and Thomas, 2006; Vadeboncoeur et al., 2010). In the Northern Limestone Alps from west to east throughout Austria, the storage of total N in the soils was best explained by base cations in the soil, which indicated that base cations are key factors controlling nitrogen retention in the forest ecosystems (Berger et al., 2002). In central Ontario, P availability in the soils was the main factor controlling N retention in sugar maple stands (Gradowski and Thomas, 2006). However, most of the results from previous research were based on nutrient manipulations such as fertilization treatment. It is rarely reported whether N accumulation in the temperate forest ecosystem could be affected by the mineral nutrient in a natural environment.

B. Foliar N

Nitrogen accumulation in soils may be limited by the supply of mineral nutrients such as Ca, Mg, K, and P (Walker and Syers, 1976). Phosphorus was the element most often thought to limit foliar N concentration (Vitousek and Farrington, 1997; Chadwick et al., 1999). In a Hawaiian chronosequence, foliar N of *Metrosideros* was constrained by the depletion of P from the forest ecosystem in an old-age stand (Chadwick et al., 1999), while foliar N concentration increased by increasing the soil N and P together (Vitousek and Farrington, 1997).

Higher foliar N concentration of sugar maple seedlings was found in base-rich soils with higher soil Ca concentration. Finzi (2009) suggested that the base status of parent material may also exert a significant influence on N availability. N availability remained limited in sugar maple and white ash stands with soils derived from glacial till overlying dolomitic bedrock (Finzi, 2009). Hence, the foliar N accumulation may be influenced through combining effects from both soil P and base cations. However, the combining effects of P and base cations on N accumulation is less investigated.

C. Foliar Ca, Mg, and P

Measurements of mineral nutrient in the foliage are commonly treated as indication of the availability of rock-derived nutrients (Aerts and Chapin III, 2000). At the Hubbard Brook Experimental forest, foliar Ca concentration was substantially lower in sugar maple located on higher elevation sites, where soil base cations were generally lower (Likens et al., 1996; Johnson et al., 2000). Meier et al. (2005) compared the nutrient concentration of fresh fallen leaf litter across a soil fertility gradient, and found Ca concentration in the foliage was higher in limestone sites than sandstone sites, while P and Mg in the foliage was lowest in the limestone sites. Increasing soil P was associated with higher foliar P concentration in bigleaf maple and hemlock in Pacific Northwest forests (Cross and Perakis, 2010).

IV. Effects of rock-derived soil nutrients on N mineralization

A. Parent material types

Given the importance of parent material to soil formation, previous research associated N mineralization to the parent material types (Yavitt and Wieder, 1988; Lamarche et al., 2004; Finzi, 2009). Lamarche et al. (2009) found that forest floor properties might be regulated by soil parent material in mixed-wood boreal forests. N mineralization was higher in sites derived from clay than sites from till (Lamarche et al., 2009). Yavitt and Wieder (1988) found a difference in N mineralization in soils derived from an igneous andesite versus sedimentary rock formation on Barro Colorado Island. Finzi (2009) suggested N mineralization was significantly higher in sugar maple-white ash stands than oak-beech-hemlock stands, which may be attributed to underlying parent material. However, less information has been reported to describe chemistry of soil nutrients from rock-derived minerals.

B. Soil nutrient type

Sites with high base cations in soils have been reported to have high net N mineralization McGee et al. (2007) compared N mineralization and nitrification rates in four Adirondack northern hardwood forests, and found that net nitrification rates in the organic soil horizons at the base-rich sites were twice as high as other sites. In another study conducted in two common types of forest across New England, net N mineralization was significantly higher in sites characterized by greater base cations availability (Finzi 2009). However, several studies suggest that N cycling may be inhibited by soil cations such as Ca (Groffman et al., 2006; Groffman and Fisk, 2011). At the Hubbard Brook Experimental Forest, soil net N mineralization rates were reduced after a Ca-silicate addition to a watershed (Groffman et al., 2006). A decrease of net N mineralization rates was also found in a smaller-scale Ca addition experiment at Hubbard Brook. Inorganic level of N, net N mineralization, and microbial biomass N decreased after three years (Groffman and Fisk, 2011).

Soil P was positively correlated with N mineralization in Blackhawk Island (Pastor et al., 1984). Al was reported to be toxic and may impair forest growth, and demonstrated a negative impact on mineralization (De Boer and Kowalchuk, 2001; Gilliam et al., 2005).

V. Effects of other factors on N cycling

A. Canopy characteristics

The canopy is an important source of nutrients in mature forests because it determines the amount and composition of leaf litter produced, and therefore the amount of nutrients to be recycled. In Rocky Mountain forests, up to 88% of aboveground litter was produced by canopy litter (foliage, reproductive tissues, and fine woody debris). Litter contains up to 90% of the N and P that cycled in the forest floor (Laiho and Prescott, 1999). Higher decay rates were found to be related to the greater concentration of N and P in the litter by several studies (MacLean and Wein, 1978; Edmonds, 1980; Yavitt and Fahey, 1986). Positive relationships between N content of litter and N availability in the forest floor and soil have been reported (Pastor et al., 1984; Reich et al., 1997).

B. Soil C:N

The soil C:N ratio has been found to be a significant explanatory variable for N mineralization around the world (Dise et al., 1998; Gundersen et al., 1998; Lovett et al., 2002), though sometimes insignificant (Falkengren-Grerup, et al., 1998; Gilliam, et al., 2001; Templer, et al., 2003). Lovett et al. (2002) reported that nitrate export from forested watersheds is greatly influenced by C:N of the soils. This relationship may be driven by the litter quality of sugar maple (Ross, et al., 2004). Litter with higher C and C:N ratio tended to decompose more slowly, particularly in coniferous species (Campbell et al., 2000; Jefts et al., 2004; Vesterdal et al., 2008). However, N mineralization was not correlated with the soil C:N in Catskill Mountains, New York, which was attributed to the small range of C and N in the organic horizon (Templer et al., 2003).

C. Soil physical factors

Nitrogen mineralization rates have been related to numerous environmental physical characteristics in the forest, including topography (Zak et al., 1991; Fisk et al., 1998; Ohrui et al., 1999), elevation (Knoepp and Swank, 1998; Bohlen et al., 2001), moisture and temperature variation (Gilliam et al., 2001), tree species (Finzi et al., 1998; Lovett et al., 2004), stand age (Piatek and Allen, 1999; Fisk et al., 2002), and land-use or disturbance history (Zak et al., 1991; Goodale and Aber, 2001). Topographic soil moisture gradient is a fundamental control of the patterns of N mineralization in the Colorado Front Range (Fisk et al., 1998). Total N mineralization significantly increased with increasing elevation in an elevation gradient (525-75m) at Hubbard Brook Experimental Forest (Bohlen et al., 2001). Lovett et al. (2004) measured the N mineralization in small single-species plots of five dominant species in Catskill mountains, NY. Hemlock plots showed consistently lower N mineralization rates than sugar maple stands. Old growth stands in northern hardwood forest tended to have a higher gross N mineralization rates than second-growth forest (Fisk et al., 2002).

Chapter 2

Abstract

Rock-derived nutrients such as Ca, K, Mg, and P play an important but poorly understood role in forest N cycling processes. The availability of mineral nutrients may be the limiting factors that ultimately constrain the fixation of the atmospherically derived nutrients carbon (C) and nitrogen (N). I investigated soil mineral nutrients in 20 sites in the White Mountains of New Hampshire, United States. Soil total N content, foliar N concentration, and N mineralization rate in the soil were compared across sites overlying different types of bedrock. Soil total N content was significantly higher in sites located on Rangeley schist bedrock than in the sites located on granite (Conway, Mt. Osceola and Kinsman) bedrock. Foliar N and N mineralization (p=0.50) were not related to bedrock types. Nitrogen mineralization was closely related to foliar N concentration (p=0.0002), soil C/N ratio and soil exchangeable Ca (p=0.006). Nitrogen mineralization rates were higher where foliar N concentration was higher, but were reduced when the soil C/N and soil exchangeable Ca were higher. Thus N availability in the soil may be influenced by the chemical properties of the parent material. The effects on N cycling of rock-derived elements in the parent material deserve further study.

Key words: parent material nutrient; soil nutrient availability; foliar nitrogen concentration; temperate forest

I. Introduction

Nitrogen (N) is a key element that limits plant growth in ecosystems (Vitousek and Howarth, 1991). Nitrogen dynamics such as N accumulation and N mineralization may influence the structure and function of temperate forest ecosystems (Schimel and Bennett, 2004). During the uptake process, inorganic N forms such as NH_4^+ and NO_3^- accumulated in the soil are assimilated by plants for photosynthesis and further growth. Organic N forms from the leaf litter are mineralized into inorganic form by soil microbes and stored in the soils for plant usage. Those N cycle pathways including N accumulation and mineralization are processed within upper soil horizons. The nutrients stored in those soil horizons, particularly the rock-derived nutrients, may have major impacts on the N cycle.

Rock-derived soil nutrients, such as Ca, Mg, K, and P, can affect N accumulation and cycling in the terrestrial ecosystem (Walker and Syers, 1976). Those soil chemicals include exchangeable soil nutrients that are readily available for plant uptake as well as non-exchangeable forms that can also be important for supporting plant growth (Likens et al., 1996; Likens et al., 1998). The non-exchangeable form chemicals support plant growth through replenishing soil available nutrient pool, primarily by weathering of mineral particles (e.g. apatite and hornblende) (Nezat et al., 2007; Buol et al., 2011). However, soil nutrient availability can be highly variable due to different parent material mineralogy (Nezat et al., 2008), and this heterogeneity can occur at a small landscape scale (See, 2014, Master's thesis).

Nitrogen in the northern hardwood forest ecosystem is mostly retained in the soils as organic matter (Bormann et al., 1977). This organic N is mainly a result of biological fixation, root turnover, and litterfall return. Due to short history of soil development in glaciated regions, the N accumulation process in forest ecosystem was considered mainly limited by the supply of N from soils (Vitousek, 2010). However, recent evidence suggested that other soil chemical properties such as the availability of soil P and base cations may affect the N accumulation in temperate region (Berger et al., 2002; Gradoswki et al., 2006). In the Northern Limestone Alps of Austria, nitrogen was higher in sites with high base cations (Berger et al., 2002). Soil P was considered one of the most critical elements in retaining the soil N in sugar maple stands in central Ontario (Gradoswki et al., 2006).

Foliar N is the consequence of N uptake, transport, and assimilation by plant and can be governed by various factors, such as species, stand age, and soil nutrient availability (Fahey et al., 1998; Chadwick et al., 1999). Foliar N concentration in pin cherry was generally higher than other species in northern hardwood forest (Fahey et al., 1998). Studies in Hawaiian rainforests suggested that foliar N decreased in old-age stands, although soil availability of N remained high (Chadwick et al., 1999). Other studies on sugar maple stands suggested that soil N concentration was positively related to foliar N (St. Clair and Lynch, 2005; Juice et al., 2006). Studies using fertilization revealed that the foliar N concentration was higher after increasing the soil P availability (Vitousek et al., 1993; Herbert and Fownes, 1995). However, as the source of soil nutrients, parent material may also cause the variation of foliar N and the role of parent material is less investigated.

Leaf litter is an important source of N that cycles from the plants to the soil. Once leaves are returned to the forest floor after the growing season, the leaf litter, as organic matter, is mineralized by microbes into plant-accessible forms. Nitrogen mineralization processes in the soil may also be affected by mineral nutrients, because the litterfall and soil organic matter are the main sources of organic N for mineralization in the soils. Indeed, numerous studies have demonstrated relationships between N mineralization processes and physical attributes such as slope, elevation

(Knoepp and Swank, 1998; Bohlen et al., 2001), age (Piatek and Allen, 1999; Fisk et al., 2002), soil chemistry (Ross et al., 2004; Ross et al., 2009), canopy chemistry (Ollinger et al., 2002), and land-use history (Zak et al., 1991; Goodale and Aber, 2001). However, N mineralization in relationship to the characteristics of rock-derived nutrients has been less investigated.

The primary objective of this study was to examine the effects of rock-derived nutrients on soil total N, foliar N concentration, and N mineralization rate. I expected to find that sites with higher mineral nutrient concentration would also have high N in the soil and foliage, as well as higher N mineralization rates in the soil.

II. Methods and Materials

A. Study sites

This study was conducted in 25 sites in the White Mountains of New Hampshire, USA (Figure 1). Thirteen of the sites (HB101, "M", "H", and "T" sites) were chosen by Tony Federer (Yanai et al., 2000). Another young site (CC2) was added into the thirteen sites and comprised as chronosequence stands in the year of 2003. Nine other sites ("C" sites) were established under Ca project (Fisk et al., 2014). Two additional sites (HBM, HBO) were added under the MELNHE project (Yanai et al., 2008). These sites range in age from 22 to 138 years since harvest. This study is made possible by the data previously collected in these sites. The species within these sites are typical for northern hardwood forest including sugar maple (*Acer saccharum* Marsh.; SM), American beech (*Fagus grandifolia* Ehrh.; BE), yellow birch (*Betula alleghaniensis* Britt.; YB), white birch (*Betula papyrifera* Marsh.; WB), and red maple (*Acer rubrum* L.; RM). Pin cherry (*Prunus pensylvanica*; PC) also occurred in young stands as an early-successional species (Table 1).

The climate across the sites is humid-continental with a mean annual temperature of 5 ˚C and annual precipitation of ~ 1, 400 mm (Bailey et al., 2003). The elevation ranges from 330 m to 730 m. Soils are Typic Haplorthods developed on glacial till, which is largely derived from local granitoid or high-grade metamorphic silicate rocks (Fig. 1) (Nezat et al., 2004; Nezat et al., 2007; Schaller et al., 2010).

B. Foliage collection and chemical analysis

Leaf litter was collected across different years in each site (i.e., 1994, 1995, 1996, 2003, 2004, 2005, and 2009) (Table 1). All foliar litter samples were collected before they reached the ground, using tarps, nets, or baskets. Freshly fallen litter samples were sorted by species for nutrient analyses. In 2004, samples were collected frequently in baskets with an area of 0.234 m^2 for mass until the end of fall, and a subsample collected during a rain-free period was used for chemical analysis (Table 1). For 2009 samples, baskets with an area of 0.234 m^2 were used to collect litter through the end of the fall for litter mass. The nutrient concentrations for the stand level were averaged by the contribution of the six species studied here (i.e., BE, SM, WB, YB, RM, and PC), excluding minor species.

A 20-mesh screen was used to pass the ground samples except the 2004 samples. A SPX CertiPrep 8000 Mixer/Mill (Metuchen, New Jersey) was used for grinding the 2004 samples into fine powder. Samples were ashed at 470 or 500 ºC, then digested in 6 N HNO_3 regarding the 1990s (0.7g) and 2003 (0.25g) samples. The 2004 samples (0.1g) were digested in concentrated HNO_3 using reinforced XP-1500 Teflon vessels (MARS 5) (CEM Corporation, Matthews, North Carolina) with high pressure.

For the samples from the 1990s, Ca, Mg, and P concentrations were measured on an Atomic Absorption Spectrophotometer 4000 (Perkin Elmer, Wellesley, MA). Inductively coupled plasma optical emission spectrometry (ICP-OES; PE-3300DV, Perkin Elmer, Norwalk, CT) was used to quantify the nutrient concentration for the 2000s samples. N was analyzed using total combustion on a LECO 2000 CN analyzer for the 1996 and 2004 samples (LECO Corporation, St. Joseph, MI). For the 2009 samples, N concentrations were measured on a CN elemental analyzer (Thermo Electron Corporation, EA 1112 elemental analyzer).

C. Soil collection and chemical analysis

Soil pits at each site were excavated to the C horizon in the summer of 2003 and 2004 (Table 1). Most soil pits are collected in a quantitative manner (i.e., C1, C2, C4, C6, C8, C9, H1, H4, H6, M5, M6, and T30), which means the mineral soil samples were quantitatively sampled in several depth increments (i.e., 0-10 cm, 10-30 cm, 30+, and C horizon). The soils from each depth were sieved and weighed for mass during the excavation process (Vadeboncoeur et al. 2012). In eight sites (i.e., M3, M4, H2, H3, H5, CC2, HB101, and T20), soils were sampled in a qualitative manner, which means soils were sampled by horizons (O, A, E, B, and C) and soil mass was not weighed. In 2010, power core was used to collect soil samples from another four sites (i.e., C5, C7, HBM, and HBO) (Table 1). Twenty power core samples were collected in each site. Soils were collected by depth increment (i.e. 0-10 cm, 10-20 cm, 20-30 cm, and 30-50 cm). Soils were sieved and weighed from each depth.

Soil samples collected from the field were air-dried and sieved to 2mm. A subsample of the <2mm mineral soil fraction was oven-dried for moisture content. For the soil samples excavated from both quantitative and qualitative soil pits, a sequential extraction was used to quantify exchangeable, organic, and weatherable minerals for each nutrient (Nezat et al., 2007). First, 1M NH_4Cl was used to extract cations such as Ca, Mg, and K. Then, 30% H_2O_2 was used to extract soil organic matter. (Note: This step was omitted in the soil samples from qualitative soil pits.

Therefore, the organic fraction dissolved in this extraction step was done in the third step). Third, 1M HNO_3 at room temperature was used to dissolve apatite (Ca and P) in contact with the solution, as well as some of the Mg and K contained in chlorite and biotite. Finally, Mg and K contained in biotite, chlorite, and hornblende were dissolved by a 1M HNO_3 at 150 ^{o}C (Nezat et al., 2007). Total mineral nutrient concentrations for Ca, Mg, K, and P were estimated as the sum of all the four digests (Nezat et al., 2007). Elements were measured on a PerkinElmer Optima 3300DV inductively coupled plasma-optical emission spectrometer (PerkinElmer, Norwalk, CT). Soil subsamples of each depth from quantitative soil pits and power cores were used to measure the total N concentration. The total N concentration was measured on a CE Instrument Model NC2100 elemental analyzer. Soil total N content for soils from each depth (i.e., 0-10 cm, 10-20 cm, 20-30 cm) was calculated as the product of total N concentration and soil mass. Then, I computed the soil total N content of 0-30 cm by adding soil total N content from each depth together. Since we have three soil pits or twenty power core samples per site, soil total N content of 0-30 cm from each core or pit was averaged within each site for further analysis.

D. Laboratory incubation for N mineralization and nitrification

Soil samples for lab incubation were systematically sampled from the Oe horizon along transects or subplots in 2012 or 2013 (Table 1) (Note: for the samples collected in 2012, the only one of the four plots was used here, because the rest were fertilized beginning in 2011). Samples were refrigerated (4˚C) until processing (less than 48 hrs). Samples were mixed by hand and fine roots and coarse fragments (>2mm) were removed before analysis.

Soil moisture content was determined by oven-drying a subsample of soil at 60 ˚C for 48 hrs. Soil pH was measured with a glass electrode in a 1:4 soil:solution (H_2O). Inorganic N (NO_3^- and NH_4^+) concentration was determined by extraction with 2M KCl from an initial subsample and also from a second subsample after 21 d incubation in the laboratory (~ 20 ˚C) (Fisk et al., 2014). Then extracts were analyzed on an auto-analyzer (Bran+Luebbe GmbH Norderstedt, Germany). Net N mineralization rate was calculated for the difference in NH_4^+ and NO_3^- concentrations between final and initial extracts.

Exchangeable cations (Ca and Mg) in the Oe soils were determined by extracting a subsample in 1M NH_4Cl. Elements were analyzed on inductively coupled plasma optical emission spectroscopy (ICP-OES; PE-3300DV, Perkin Elmer, Norwalk, CT). P was extracted in 0.5M $NaHCO_3$ from a subset of soil samples. In order to get the P concentration, ammonium-molybdate-ascorbic acid method (Murphy and Riley, 1962) was used to analyze the P extracts on UV-1800 spectrophotometer (Shimadzu Corporation, Japan). Another subsample was dried, ground, and analyzed for C and N by dry combustion on the LECO 2000 CN analyzer (LECO Corporation, St. Joseph, MI).

E. Data analysis

In this study, I chose the soil mineral nutrients concentration from B horizon to represent the rock-derived nutrients of mineral horizon. Hierarchical cluster analysis was used to identify groups of sites with three site-level mineral nutrients concentration (Ca, Mg, and P) in B horizon. This analysis was conducted on 20 of the sites with quantitative or qualitative soil pits, excluding (Table 1). The sites with power cores were not included because the analysis of these samples was not yet complete; Jeffers Brook could also be added to this data set. For the mineral nutrient concentration from the 12 sites with quantitative soil pits, I used the mineral nutrient concentration (i.e., Ca, Mg, and P) of 10-30 cm, because most of the soils located in this depth belong to B horizon (data not shown) (Note: Part of the quantitative soil pits (i.e., H1, H4, H6, M5, M6, and T30) were sampled as depth from 0-10 cm, 10-20 cm, 20-30 cm. So the nutrient concentration from 10-20 cm and 20-30 cm was averaged to represent the nutrient concentration of 10-30 cm). Since we have three soil pits in sites excavated in a quantitative manner, soil mineral nutrient concentration (i.e, Ca, Mg, and P) of 10-30 cm were averaged across three pits to get a site-level soil mineral nutrient. For the rock-derived nutrients from the 8 sites with qualitative soil pits, soil mineral nutrients concentration within the B horizon (i.e., B1, B2, and Bh) were averaged for each soil pit. This averaged value was used to represent the site-level soil mineral nutrient concentration, because we only have one pit for sites excavated in a qualitative manner.

A one-way ANOVA model was used to compare the soil total N content among sites located on different types of bedrock. This analysis was conducted on the 16 sites that had quantitative pits or soil cores (Table 1). I used the soil N information of 0-30 cm for the analysis. The soil total N content of each depth was calculated as the product of total N concentration and soil mass (i.e., 0-10 cm, 10-20 cm, and 20-30 cm). Then, I computed the soil total N content of 0-30 cm by adding soil total N content from each depth together. Since we have three soil pits or twenty power core samples per site, soil total N content of 0-30 cm from each core or pit was averaged within each site. This analysis could have been done with 8 more sites using N concentration as the dependent variable (the sites with qualitative soil pits in Table 1). Data are also available for 2 additional sites at Jeffers Brook but these are on a different bedrock type (Ammonoosuc Volcanics).

A one-way ANOVA model was used to compare foliar nutrient concentration (i.e., Ca, Mg, N, and P) of 20 sites located on different types of bedrock. There were 22 sites at which foliar nutrients were measured; this analysis excluded HBM and HBO (Table 1). The foliar nutrient concentration in the model was the averaged foliar nutrient concentration across years. Each site was one experimental unit in the one-way ANOVA model. The one-way ANOVA model was applied for each species separately. Bonferroni correction of P-value was also used for each species and nutrient. The adjusted P-value was calculated as the product of P-value of individual species and number of species (i.e., 6 in this study).

A one-way ANOVA model was used to address the N mineralization difference between sites located on different types of bedrock. There were 25 sites for which N mineralization was measured (Table 1). Normality test of residuals was performed for each of the ANOVA models.

A multiple linear regression model was used to explore N mineralization as a function of stand age, elevation, and soil water content in those 25 sites (Table 1).

Foliar nutrients (Ca, Mg, N, and P) for each of 22 sites were weighted by mass of litter of each species (C3, C5, and C7 were not included due to issues with the quality of foliar chemistry data in 2005; data may become available from 2012). A Pearson correlation analysis was performed across those mass-weighted foliar nutrient concentrations. Only foliar Ca showed no significant correlation with foliar N. These two variables were considered in a stepwise regression to determine the best predictors of N mineralization. The normality of residuals was also checked. Type II sum squares was reported for the final model. The significance level for inclusion and exclusion for stepwise regression was set at $p<0.05$. The residuals met the tests for normal distributions.

The soil C/N ratio was measured only in the 13 sites in the Federer chronosequence. For these stands, soil chemical variables, namely soil pH, soil exchangeable Ca, soil exchangeable Mg, soil extractable P, and soil C/N ratio were considered in a stepwise multiple linear regression to identify the best soil chemical predictors of N mineralization (there were no significant correlations among these predictor variables). The model residuals were used for testing the normality of data representing both soil physical and chemical factors. Type II sum of squares was reported for the final model.

All statistical analyses above were conducted on SAS 9.3 (SAS Inc, NC).

III. Results

Of the 20 sites with soil pits, 15 of the sites were located on Conway, Mt. Osceola and Kinsman granites, and the other 5 on Rangeley schist, according to the geological survey from the USGS (Figure 1). The sites with higher soil Ca, Mg, and P concentrations were generally located on Rangeley schist bedrock (Figure 2). Cluster analyses on three soil nutrients (Ca, Mg, and P) indicated that sites located on Rangeley schist formed one cluster, while sites with granitic origin formed another (Figure 3). When soil K was included as the fourth variable in the cluster analysis, the five Rangeley schist sites still fell into the same cluster (Appendix. Figure 3).

Soil total N was significantly higher in sites located on Rangeley schist than sites located on the granite (p=0.02) (Figure 4). For foliar N, only red maple had a significantly higher N concentration in sites located on Rangeley schist than on granite before I did the Bonferroni correction of the P-value (p=0.04) (Table 2). After I adjusted the P-value, foliar N and Ca concentrations for all species were not different between sites located on Rangeley schist and granite (Table 2). Foliar Mg concentrations of American beech, red maple, white birch, and yellow birch were significantly higher in sites located on Rangeley schist than sites located on granite (Table 2). Foliar P concentrations of beech, sugar maple, white birch, yellow birch were higher at sites located on Rangeley schist than sites located on granite (Table 2). Pin cherry and birch had higher foliar N, Mg, and P concentrations than other species, while foliar N, Mg, and P concentrations were lower for sugar maple (Figure 5).

N mineralization was not different between the sites located on Rangeley schist and granite (p=0.50). The relationship between N mineralization rate and soil physical factors was not significant in multiple linear regression (p=0.09) (Figure 6; Table 3), for stand age (p=0.23), soil water content (p=0.18), or elevation (p=0.10).

Only foliar N concentration remained in the final model after stepwise regression. Foliar N concentration explained 54% of the variation in the N mineralization rate among sites (Figure 7; Table 4).

Soil exchangeable Ca and C/N ratio were the two variables related with N mineralization rate after stepwise multiple linear regression (Table 5). Soil Ca and C/N ratio together explained 79% of the variation in N mineralization rate among sites. Pearson correlation verified that there was no multicollinearity between soil Ca and C/N ratio (p=0.57).

IV. Discussion

A. Geochemistry of soil nutrients availability

Our findings of the geochemical difference between these sites suggested sites located on Rangeley schist tended to have higher rock-derived soil nutrients concentration than those sites located on granite (Conway, Mt. Osceola and Kinsman). In our sites, apatite was the main source for soil P, and potentially for soil Ca, which is one of the easily weathered minerals in northeastern United States (Nezat et al., 2008). Most of the Mg was derived from biotite, chlorite, and hornblende (Nezat et al., 2007). The nutrient concentration (Ca, Mg, and P) in the C horizon was also higher in sites located on Rangeley Schist sites than sites located on granite sites based on the cluster analysis (Appendix. Figure 2).

The variability of soil nutrient availability related to different parent material origins could be very large from a landscape scale. A comparison study of apatite across northeastern United States from New York to Maine revealed a 20 fold difference in concentration among Ca and P concentrations in apatite at a large landscape scale (Nezat et al., 2008). In our study sites, soil Ca was 5 times higher in some sites located on Rangeley schist than sites located on granite sites, and this difference was even greater for Mg and P, which could be more than 10 times (Figure 2). Since most of our sites are located within less than 50 km of each other, this difference in soil nutrient availability reveals that the heterogeneous chemical properties of parent material may be large even from a small landscape scale.

B. Effects of bedrock types on soil total N, foliar N, and N mineralization

Soil total N

I hypothesized that natural variation in soil mineral nutrients caused by parent material difference would lead to variation in soil total N content. This prediction was supported by our results (Figure 4). Unlike the theory proposed by previous studies that N accumulation is limited by the time frame of soil development (Walker and Syers, 1976; Vitousek and Farrington, 1997), the result of higher soil total N content in sites located on Rangeley schist indicated the N accumulation process in the soil may be controlled by the rock-derived nutrients. Though I am not able to unravel the relative importance of the three mineral nutrients (i.e. Ca, Mg, and P), recent evidence suggested both P and base cations may affect N in temperate soil (Berger et al., 2002; Gradowski et al., 2006; Vadeboncoeur et al., 2010). Principles of resource allocation suggest that the availability of one nutrient in the soil could be increased by increasing the availability of another nutrient, and will thereby advance the balance in availability of N and other mineral nutrients (Fisk et al., 2014). The production of N-mineralizing enzymes may be promoted by high

P availability (Olander and Vitousek, 2000). Alternatively, the fixation of N by microbes may be promoted by high P in the soil, because the stoichiometry of soil micro-organisms is thought to change little (Cleveland and Liptzin, 2007). In our sites, the soil P concentration in some of the sites located on Rangeley schist is 10 times higher in P concentration than sites located on granite (Figure 2). Therefore, the high P in these soils may promote the microbial activities and more N may be retained in a synergistic manner.

The soil N accumulation process may also be affected by base cations from two primary aspects. One is promoting the N assimilation of microbes and plant roots, the other is indirectly affecting the availability of other important ions by increasing the pH. Those important ions includes both nutrients and potentially toxic elements (e.g. the solubility of rhizotoxic Al^{3+}, sorption of PO_4^{3-}, nitrification, enzyme activities, and microbial community composition (Sparks, 2003; Paul, 2006)). In our study, the soils located on Rangeley schist did have a significantly higher pH than the granite sites (Figure 8). The high soil pH in sites located on Rangeley schist may indicate the N leaching may be less severe and thus more N could be accumulated.

Foliar N

The higher soil N concentration in the sites located on Rangeley schist may be due to greater N assimilated by the plants. However, I didn't see a higher foliar N concentration in the sites located on Rangeley schist than sites located on the granite. This results are similar with some previous studies (Yavitt, 2000; Castle and Neff, 2009). Foliar N concentrations were similar across andesite, sedimentary, and sandstone parent material in Barro Colorado Island, Panama (Yavitt, 2000). Foliar N of aspen showed no difference in sites across three parent materials (andesite, limestone, and sandstone) in the southern Rocky Mountains of Colorado (Castle and Neff, 2009). Though I found red maple had significantly higher foliar N in sites located on Rangeley schist than sites located on granite, it is still hard to conclude that this difference is caused by the difference of bedrock, not by chance from a statistical perspective.

N mineralization

I expected the soil mineral nutrients may influence N cycling in the forest floor. However, the N mineralization rate in sites located on these two types of bedrock was not different (P=0.50) (Figure 6). N mineralization rate was also found not different across three types of parent material (andesite, sedimentary, and limestone) in Barro Colorado Island, Panama (Yavitt, 2000). The effects of mineral nutrients on N mineralization may be obscured by factors such as litter quality, soil micro-environmental variability (Prescott, 2002; Lovett et al., 2004; Ross et al., 2004). Sites dominated or co-dominated by sugar maple were determined to have a higher N mineralization rates in eight northeastern forested sites (Ross et al., 2004). The spatial pattern of N mineralization was influenced by soil moisture and ambient temperature in central Appalachian hardwood forest (Gilliam et al., 2001).

C. **Relationship between N mineralization and other factors**

The close relationship between N mineralization rates in the soil and foliar N concentration has been demonstrated in several studies (Binkley and Giardina, 1998; Ollinger et al., 2002; Prescott, 2002). Though I treated the N cycling process as a dependent variable in this study, the relationship between foliar nutrient and soils may be an interactive one. The foliage may have a higher N with high N availability in the soils. Then, the N mineralization rate may be further increased by having litterfall with higher N returned to the soil.

Nitrogen mineralization was also related to soil C/N ratio and exchangeable Ca. The effect of soil C/N on N mineralization has been documented by many researchers (Goodale and Aber, 2001; Lovett et al., 2002; Idol et al., 2003; Ross et al., 2004; Ross et al., 2009). Species composition may be one of the main factors that controls soil C/N. Sites with sugar maple are reported had a higher N mineralization rate and lower soil C/N (Lovett et al., 2002; Ross et al., 2004). Our results indicated that soil C:N may be a good predictor of N mineralization rate in northern hardwood forest.

Soil cations were reported to facilitate N mineralization (Mitchell et al., 2003; Christopher et al., 2006). Species such as sugar maple, birch, and aspen were associated with base-rich sites, and higher N mineralization rates were found in these sites (McGee et al., 2007). In contrast, our results indicated that the N mineralization rate may be decreased by exchangeable Ca. The inhibition of N mineralization by soil Ca has rarely been reported. The N mineralization rate was reduced in the Hubbard Brook Experiment Forest after adding Ca at both large (watershed) and small (field plots) scale (Groffman et al., 2006; Groffman and Fisk, 2011). The Ca addition experiment in Hubbard Brook showed that inorganic N decreased in the soil (Groffman and Fisk, 2011). Our results indicated that N cycling could also be inhibited even in a natural gradient of available soil Ca. Groffman and Fisk (2011) proposed that the decrease of N mineralization rate may be attributed to the immobilization of N by certain microbes when they are stimulated by higher Ca availability. Also, the uptake of NH_4^+ by roots and mycorrhizal associations may be another reason that accounts for the decline of N mineralization rates. Soil microbes considered nitrifiers may be outcompeted by plants under Ca enriched soil (Groffman and Fisk, 2011). The N mineralization process was still stimulated by the Ca additions when plants were removed from the plots, which revealed the role of plants in the N uptake process (Groffman and Fisk, 2011). In our study, I did the incubation in the lab so that the root assimilation of N was less likely to be the reason for the inhibition of N mineralization. Therefore, the immobilization of N by microbes may be the main reason that contributed to the decline of N mineralization.

V. Conclusions

Given that the parent material is the primary source of soil mineral nutrients, I expected that rock-derived nutrients in the soil would also affect N cycling. Our results indicated that soil total N content tended to be higher in the sites located on Rangeley schist sites, which generally had higher rock-derived soil nutrient availability of Ca, Mg, and P in mineral horizon, than those sites located on the granite. The variation of soil total N may be due to the higher P and base cations in the soil located on the Rangeley schist sites. However, foliar N concentration and N mineralization rates in the forest floor were not different across the sites overlying two types of bedrock. Nitrogen mineralization was closely related to foliar N, soil C/N, and soil exchangeable Ca levels. N mineralization rate increased with higher foliar N concentration, whereas it was inversely related to the soil C/N and soil exchangeable Ca. Within the northern hardwood forests, these results underscore the potential importance of parent material in forest ecosystem development. The inclusion of soil exchangeable Ca in the future modelling of N mineralization is warranted.

Chapter 3

Summary

Nitrogen dynamics such as soil total N, foliar N uptake, and N mineralization are critical for the structure and function of forest ecosystems. These dynamics were hypothesized to be determined by the availability of the rock-derived soil nutrients Ca, Mg, P, and K.

The results presented here suggest that differences in soil nutrient availability are associated with the rock-derived soil nutrients. Sites located on Rangeley schist tended to have higher extractable nutrients (Ca, Mg, and P) than that in granite sites. Soil total N may be driven by the difference in parent material. This could have major implications for the role of parent material in the development of N cycling in the northern hardwood forest.

Our results confirmed that N mineralization was more closely associated with foliar N and the soil C/N than by parent material. Contrary to the previous idea that N mineralization was promoted by soil exchangeable Ca, our results suggest that N mineralization is more likely constrained by soil exchangeable Ca. This suggests the possibility that more inorganic N is assimilated by certain microbes through immobilization when there is more Ca present.

There are some potential limitations in this study related to the merging of datasets from different sources. For example, in this study, I chose the soils from 10-30 cm from quantitative soil pits and B horizon from qualitative soil pits for analysis, but this may be biased to represent soil nutrient concentration from the mineral horizon. Also, a lack of replicates in the qualitative soil pits may reduce the credibility of representing the soil nutrient concentration at a site level. Excavation of soil pits in the field is very costly and time-consuming. Power coring method was recently recommended as an efficient approach to quantify the soil mass, in spite of artifacts introduced by grinding (Levin et al., 2012).

Future research should also include more sites located on different types of bedrock when examining the effects of rock-derived nutrients on N cycling. Future research should put more attention on the role of soil exchangeable Ca, as this could be important to reduce N saturation or leaching, and increase N sequestration.

Tables and Figures

Table 1. Summary of study sites includes information about year of harvest, elevation, species composition, and sample collection date for foliage, soil pits, and forest floor samples. Space marked with "X" means this species occurred in this site.

Site	Year of Cut	Elevation(m)	Dominant species*						Sample collection date		
			BE	SM	RM	WB	YB	PC	Foliage	Mineral soil	Forest floor (Oe)
C1	1990	570	X	X	X	X	X	X	2005, 2009	2004[#]	2012
CC2	1989	330	X		X	X	X	X	2004	2004	2013
C2	1988	340	X		X	X	X	X	2005, 2009	2004[#]	2012
C3	1985	590							NA	NA	2012
H6	1984	330	X	X	X	X	X	X	1994, 1995, 1996, 2003, 2004	2003[#]	2013
M6	1979-1980	540	X	X	X	X	X	X	1994, 1995, 1996, 2003, 2004	2003[#]	2013
C4	1979	410	X	X	X	X	X	X	2005, 2009	2004[#]	2012
C5	1976	550							NA	2010[§]	2012
C6	1975	460	X	X	X	X	X	X	2005, 2009	2004[#]	2012
H5	1967	360	X	X	X	X	X	X	1994, 1995, 1996, 2004	2004	2013
H1	1939	320	X	X	X	X	X	X	1994, 1995, 1996, 2003, 2004	2003[#]	2013
T20	1939	540	X	X	X	X	X	X	1994, 1995, 1996, 2004	2004	2013
H4	1933-1935	350	X	X	X	X	X		1994, 1995, 1996, 2003, 2004	2003[#]	2013
C7	About1890	440							NA	2010[§]	2012
C9	1890	440	X	X			X		2005, 2009	2004[#]	2012
C8	1883	330	X	X	X		X		2005, 2009	2004[#]	2012
H2	1875	320	X	X	X		X		1994, 1995, 1996, 2004	2004	2013
H3	About 1875	320	X	X	X	X	X		1994, 1995, 1996, 2004	2004	2013
M5	1976-1977	630	X	X	X	X	X	X	1994, 1995, 1996, 2003, 2004	2003[#]	2013
HB101*	1971	520	X	X	X	X	X	X	1994, 1995, 1996, 2004	2004	2013
HBM[*]	1966	500		X	X	X	X		2009	2010[§]	2012
T30	1948	550	X	X	X	X	X		1994, 1995, 1996, 2003, 2004	2003[#]	2013
M4	1933-1935	460	X	X	X	X	X		1994, 1995, 1996, 2004	2004	2013
HBO*	1911-1913	500	X	X	X		X		2009	2010[§]	2012
M3	1910	580	X	X	X	X	X		1994, 1995, 1996, 2004	2004	2013

*** HB indicates Hubbard Brook Experimental Forest. HB101 was designated as C3 in previous study (Yanai et al., 2000). BE refers American beech, PC refers to pin cherry, RM refers to red maple, SM refers to sugar maple, WB refers to white birch, YB refers to yellow birch.**

[#] Quantitative soil pits dug through an increment of depth (i.e. 0-10 cm, 10-30 cm, 30+, C horizon) and the soil mass was determined for each depth.

[§] Power core was used to sample the soils through a depth increment (i.e., 0-10 cm, 10-20 cm, 20-30 cm, 30-50 cm) and soil from each depth was weighed for mass.

Table 2. Summary of P-value and adjusted P-value from the one –way ANOVA model for each species and nutrient.

Nutrient		Species					
		BE	**PC**	**RM**	**SM**	**WB**	**YB**
N	**P-value**	0.67	0.56	0.04	0.52	0.24	0.08
	Adjusted P-value*	1.00	1.00	0.24	1.00	1.00	0.48
Ca	**P-value**	0.97	0.80	0.24	0.69	0.17	0.87
	Adjusted P-value*	1.00	1.00	1.00	1.00	1.00	1.00
Mg	**P-value**	0.007	0.16	0.007	0.04	0.0002	0.008
	Adjusted P-value*	0.042	0.96	0.04	0.24	0.001	0.05
P	**P-value**	0.002	0.36	0.02	0.004	0.0001	0.0001
	Adjusted P-value*	0.01	1.00	0.12	0.02	0.0006	0.0006

*** The p-value from the one-way ANOVA model was adjusted using the Bonferroni method. The adjusted P-value was calculated as the product of p-value of individual species and number of species (i.e., 6 in this study). BE refers American beech, PC refers to pin cherry, RM refers to red maple, SM refers to sugar maple, WB refers to white birch, YB refers to yellow birch.**

Table 3. Summary of multiple linear regression model that examined the N mineralization as a function of site physical factors.

Source	DF	Type I SS	Mean Square	F Value	Pr>F
Model	3	55.36	18.45	2.16	0.12
Elevation	1	25.49	25.49	2.98	0.10
Stand Age	1	13.03	13.03	1.52	0.23
Soil Water Content	1	16.84	16.84	1.97	0.18
Error	21	179.75	8.56		
Total (Corrected)	24	235.10			

Table 4. Summary of the final model from stepwise regression of N mineralization as a function of foliar nutrients (Ca, N, Mg, and P).

Source	DF	Type II SS	Mean Square	F Value	Pr>F
Model	1	114.97	114.97	22.5	0.0001
Foliar N concentration	1	114.97	114.97	22.5	0.0001
Error	19	97.11	5.11		
Total (Corrected)	20*	212.08			

***The foliar N concentration of site H3 was missing in this analysis.**

Table 5. Summary of the best model from stepwise multiple linear regression of N mineralization for soil chemical characteristics in Oe horizon.

Source	DF	Type II SS	Mean Square	F Value	Pr>F
Model	2	86.66	43.33	18.44	0.0004
Soil exchangeable Ca	1	27.76	27.76	11.82	0.006
C/N ratio	1	73.09	73.09	31.11	0.0002
Error	10	23.5	2.35		
Total (Corrected)	12*	110.16			

***The soil C/N ratio was only available on 13 sites (i.e., H1, H2, H3, H4, H5, H6, M3, M4, M5, M6, T20, T30, CC2, and HB101)**

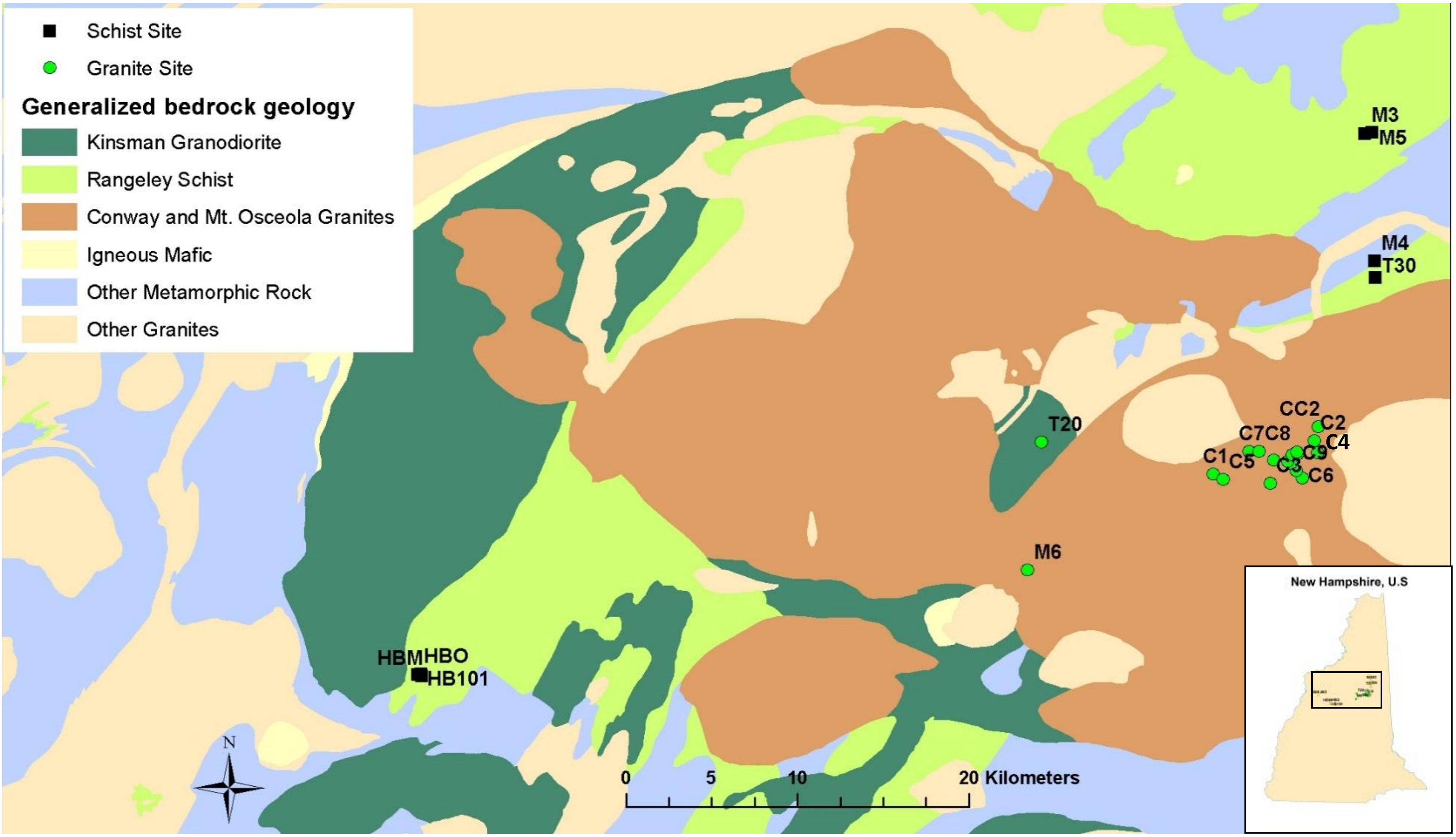

Figure 1. Location of the 25 sites in this study. Information of the geological information of lithology was also included. The small inset map showed the site location within State of New Hampshire. The bedrock information was acquired from Mineral Resources Online Spatial data ,USGS website.

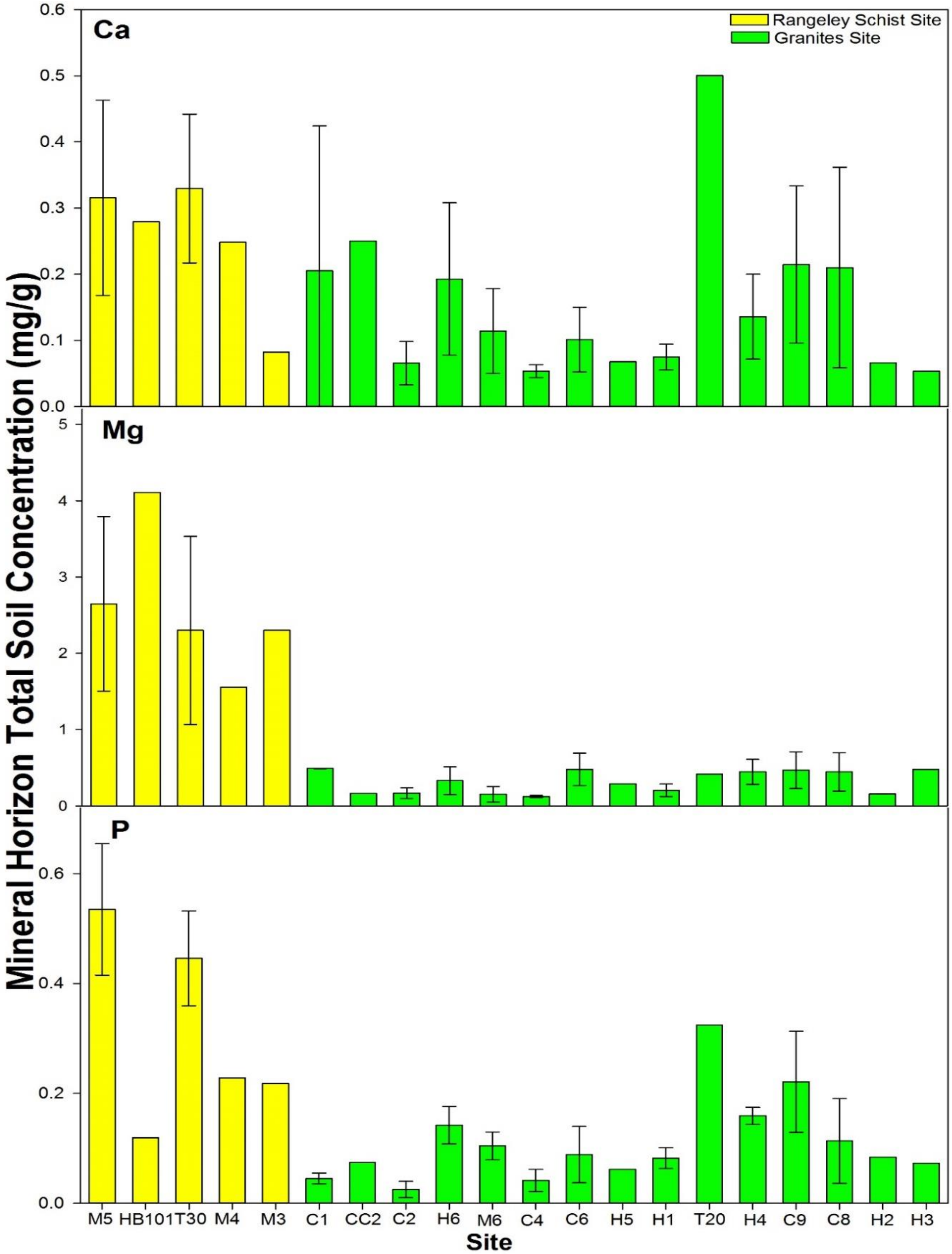

Figure 2. Total soil nutrients concentration of Ca, Mg, and P in the mineral horizon (mostly B horizon) from the sum of four extraction processes. The error bar here represents the 95% CI.

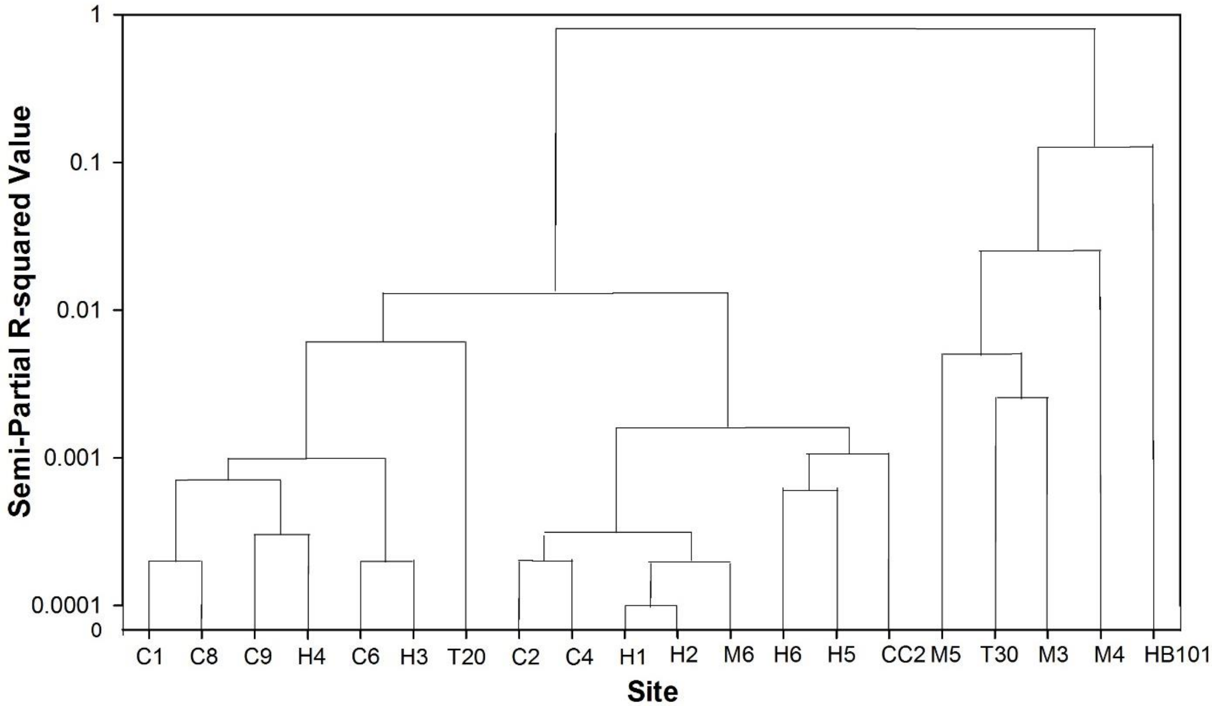

Figure 3. Results of cluster analysis using Ward method. Three soil nutrient variables including Ca, Mg, and P from the mineral horizon were included in this analyses. The Semi-partial R-squared values were added a constant (i.e. 0.0001) then showed in log-scale.

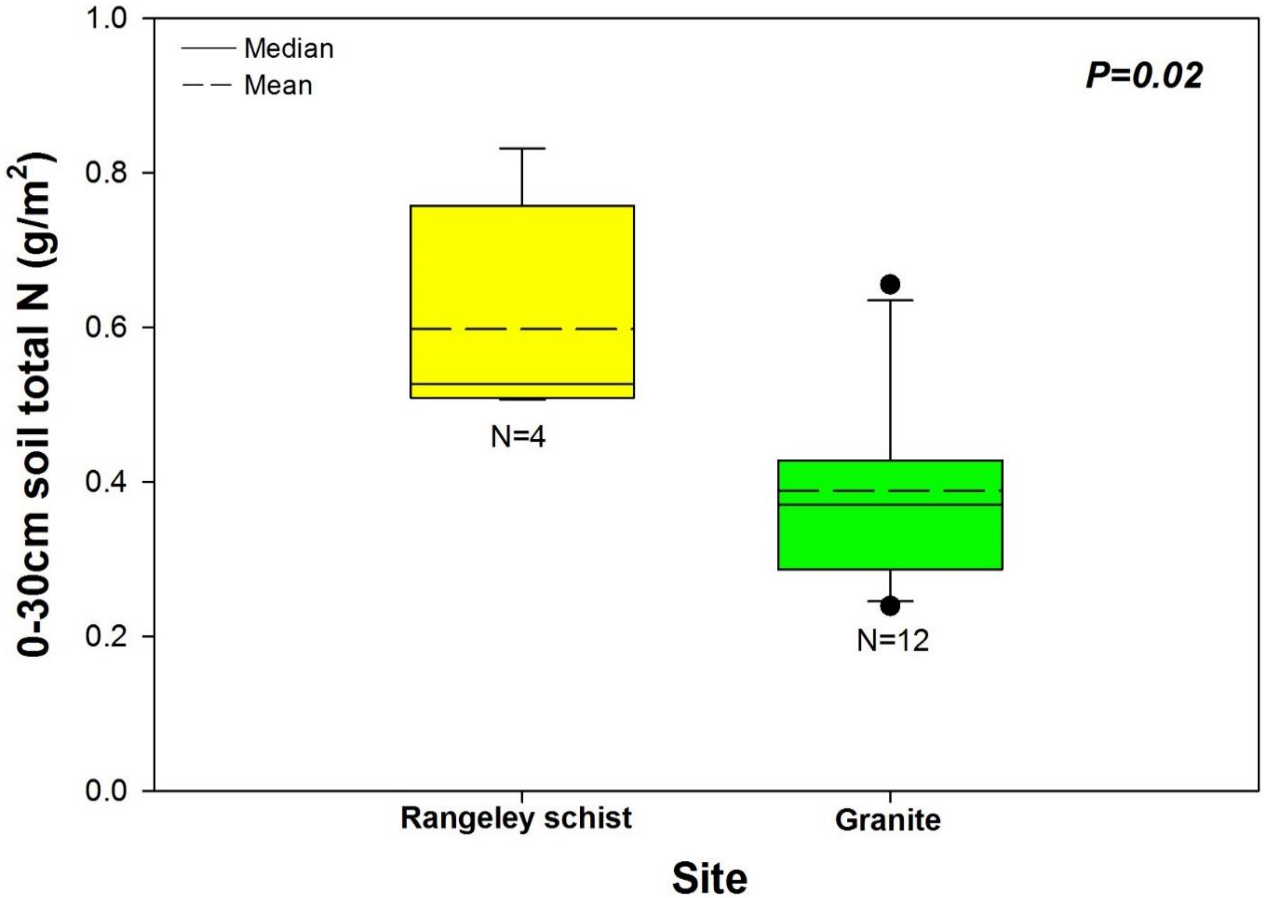

Figure 4. Soil total N content from the 0-30 cm from sites located on two types of bedrock (i.e., Rangeley schist, granite). The P-value represents the result of one-way ANOVA model used to compare the difference of soil total N content between sites located on Rangeley schist and granite.

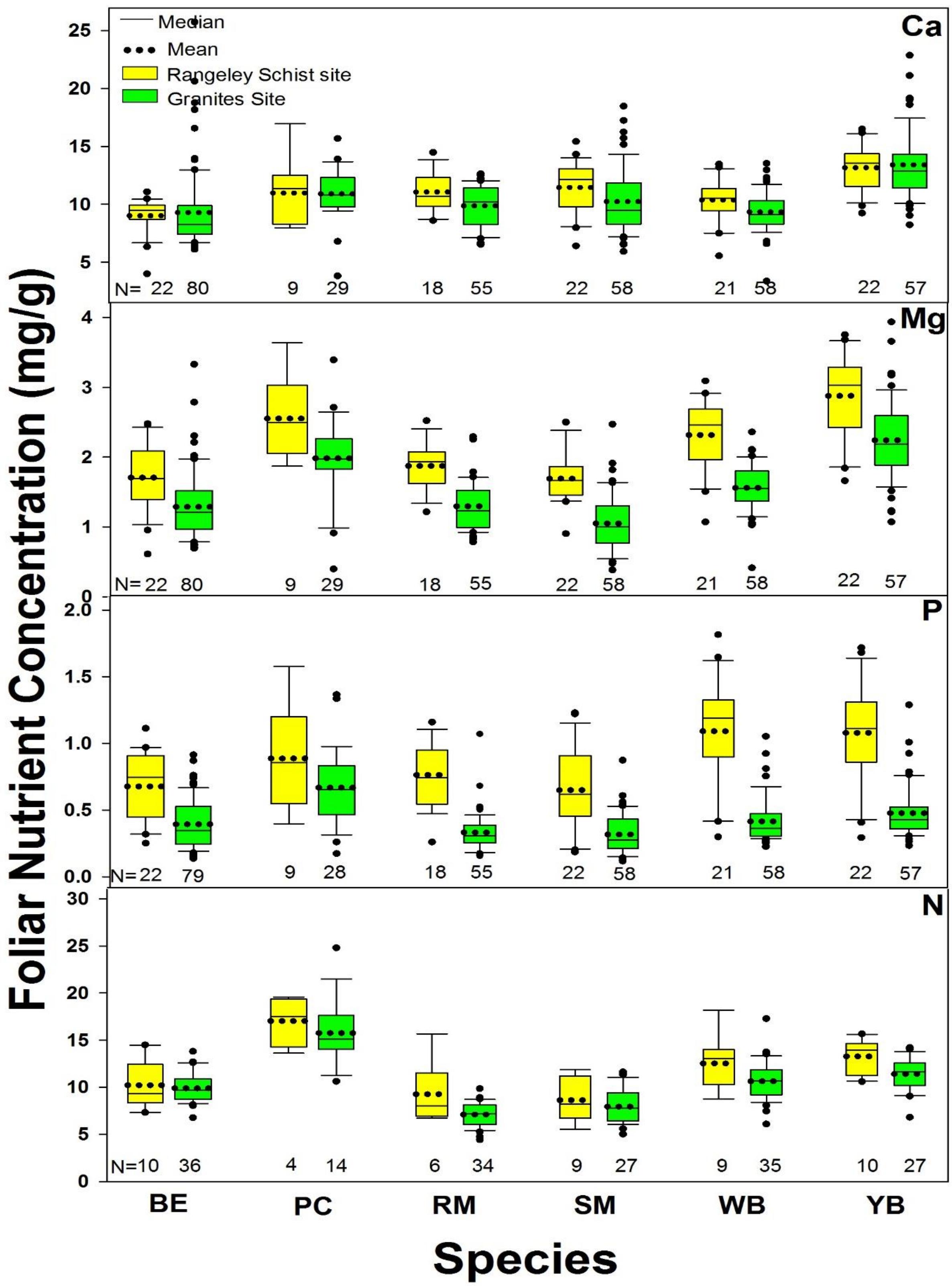

Figure 5. Foliar nutrient concentration by species comparing two bedrock types.

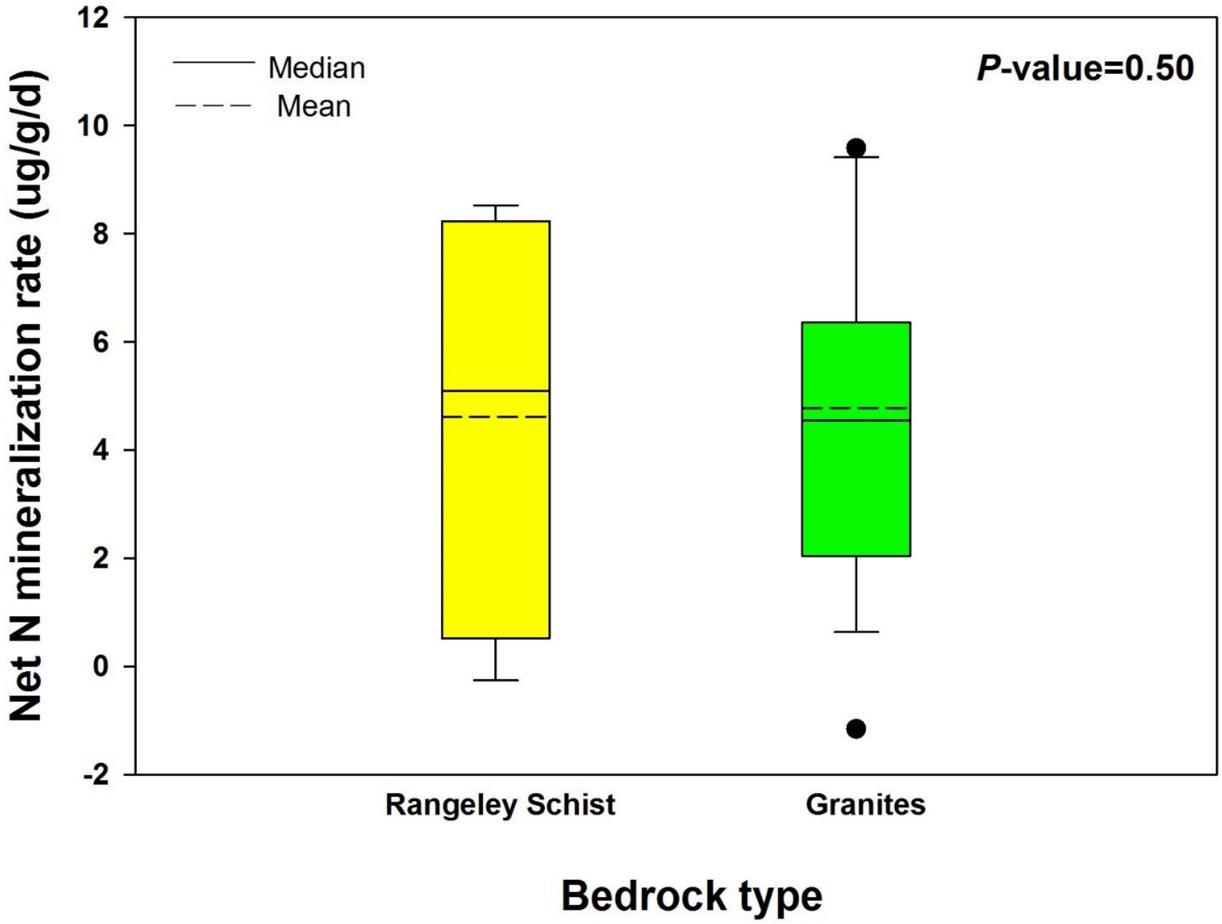

Figure 6. Net N mineralization rate of Oe soil between sites located on Rangeley schist and Granite is compared using one-way ANOVA.

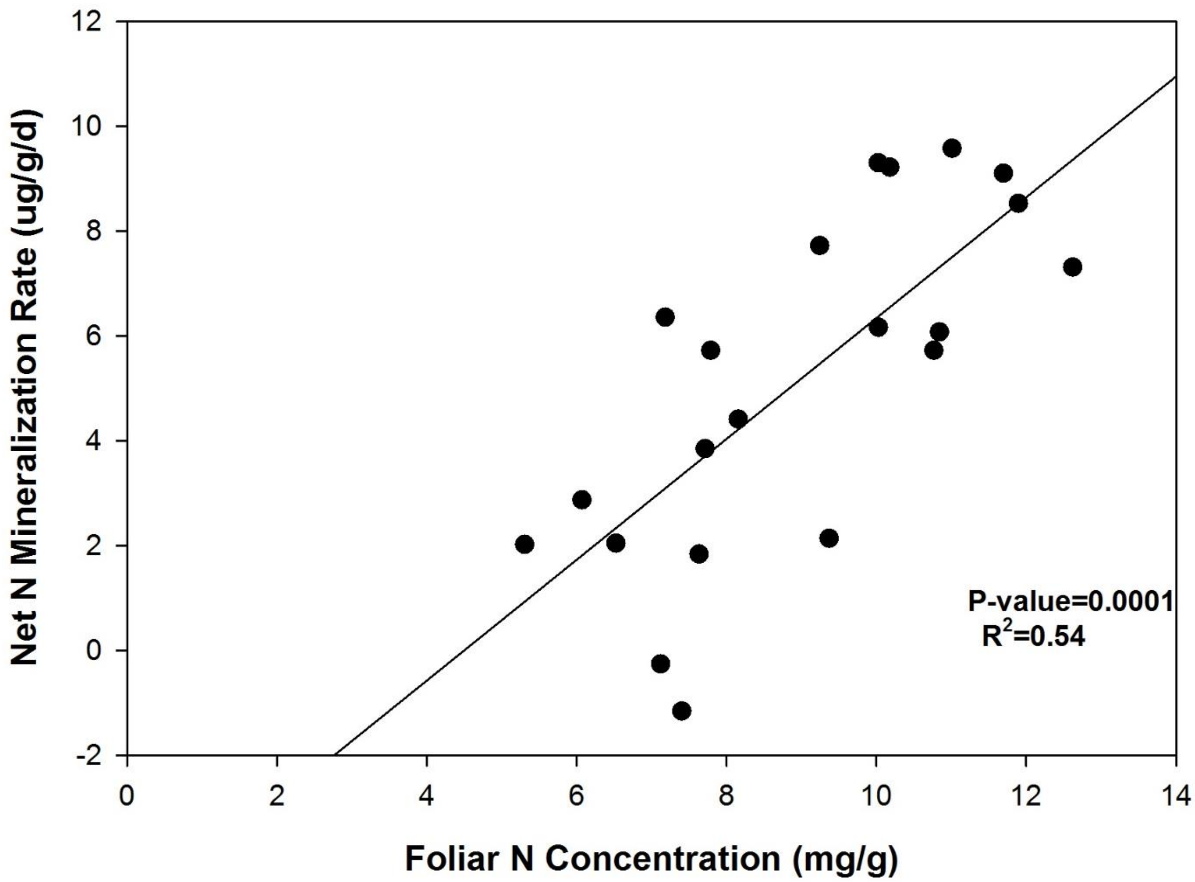

Figure 7. Linear regression for net N mineralization rates as a function of foliar N concentration. Each observation is a site (n=21).

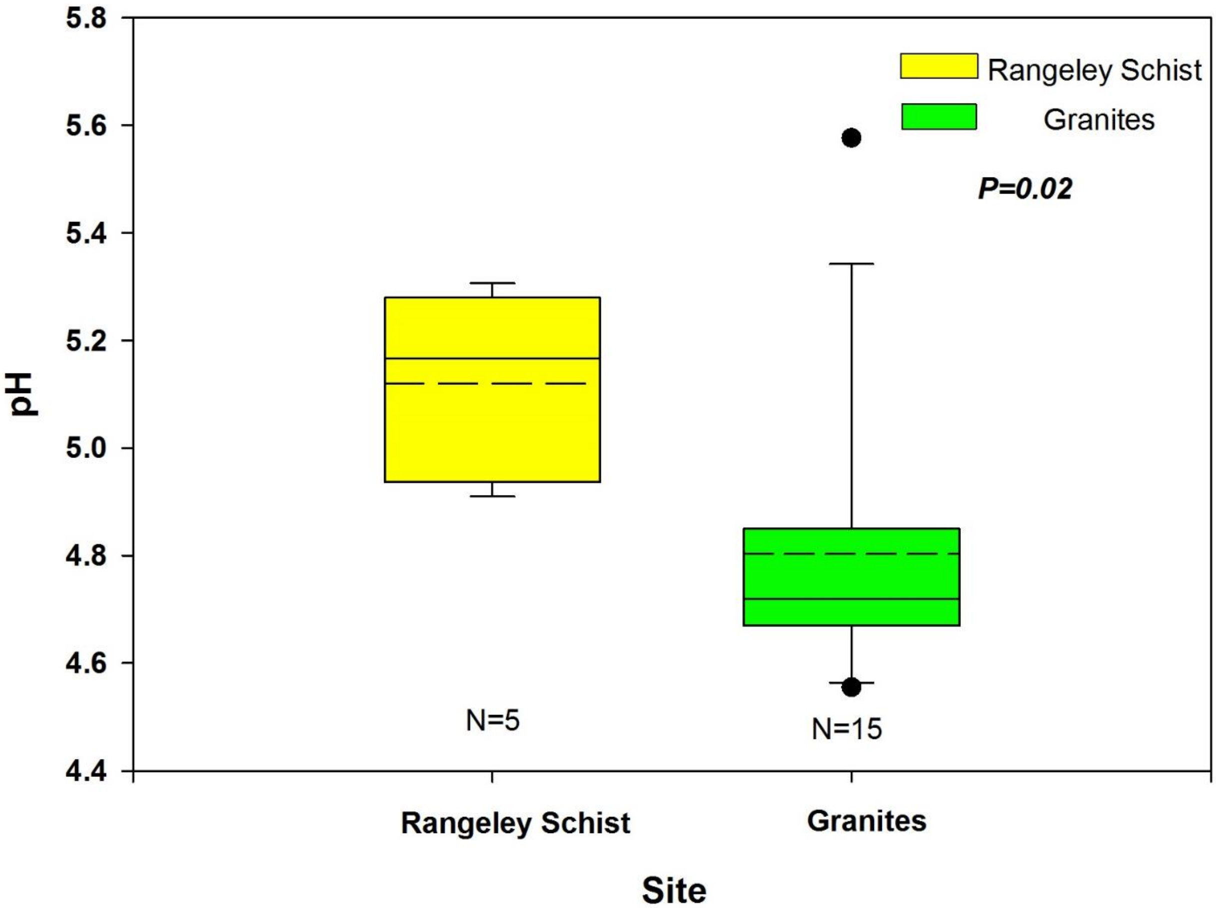

Figure 8. Soil pH of the Oe horizon from sites located on two types of bedrock (i.e. Rangeley schist, granite). The P-value represents the result of one-way ANOVA model that used to compare the difference of soil pH between sites located on Rangeley schist and sites located on granite.

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Appendices

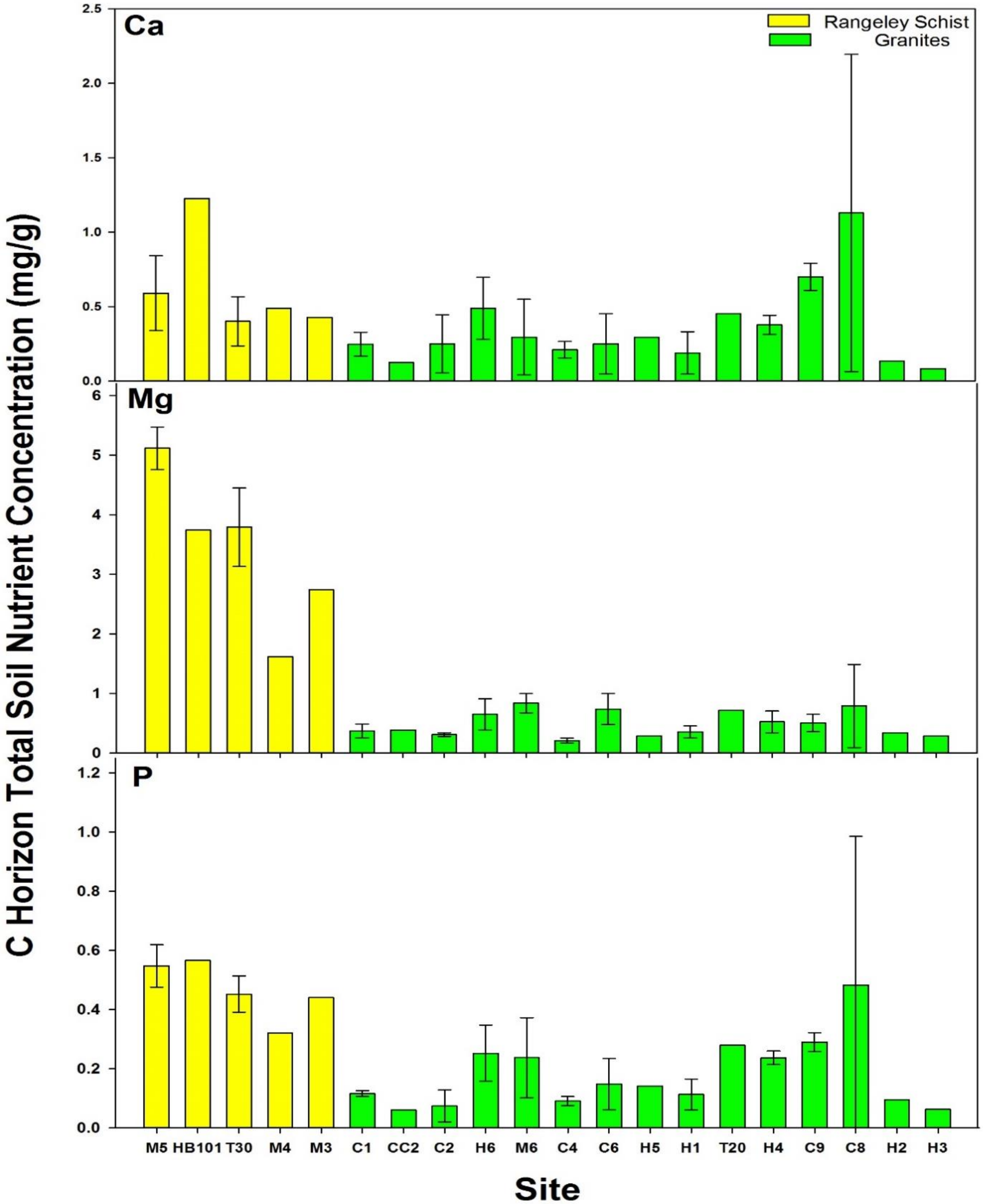

Figure 1. Total soil nutrients concentration in C horizon from the sum of four extraction processes. The error bar here represents the 95% CI.

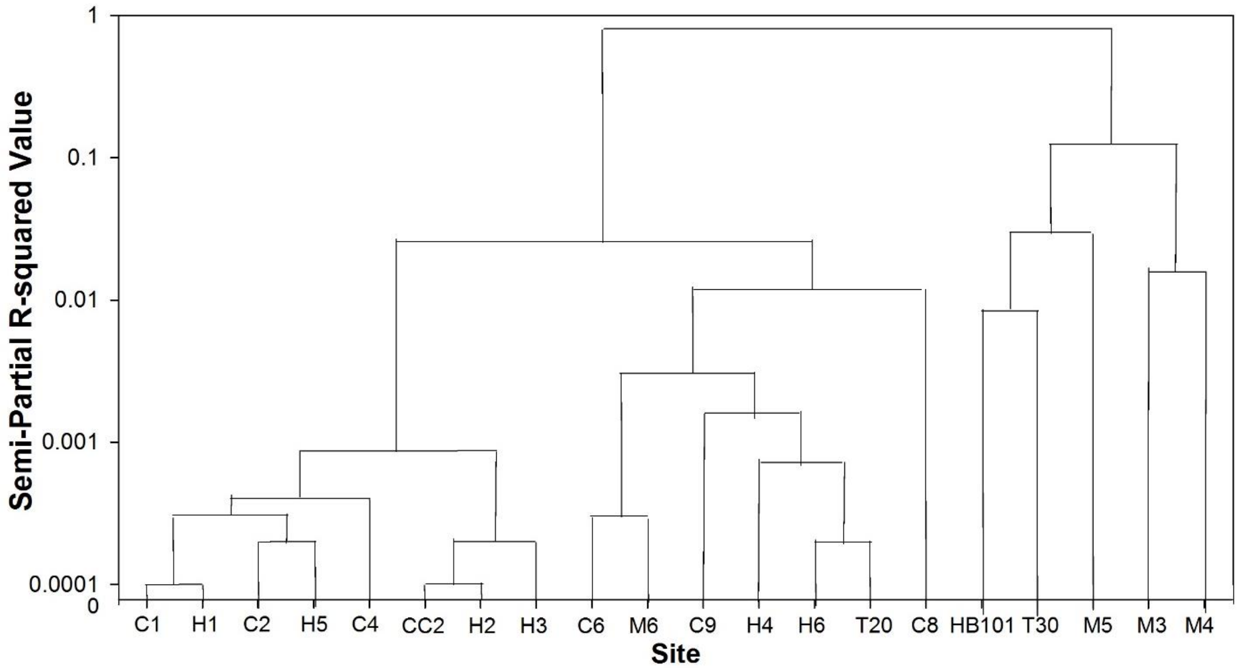

Figure 2. Results of cluster analysis using Ward method. Three soil nutrient variables, namely Ca, Mg, and P in the C horizon, were used in this analyses. The Semi-partial R-squared values were added a constant (i.e. 0.0001) then showed in log-scale.

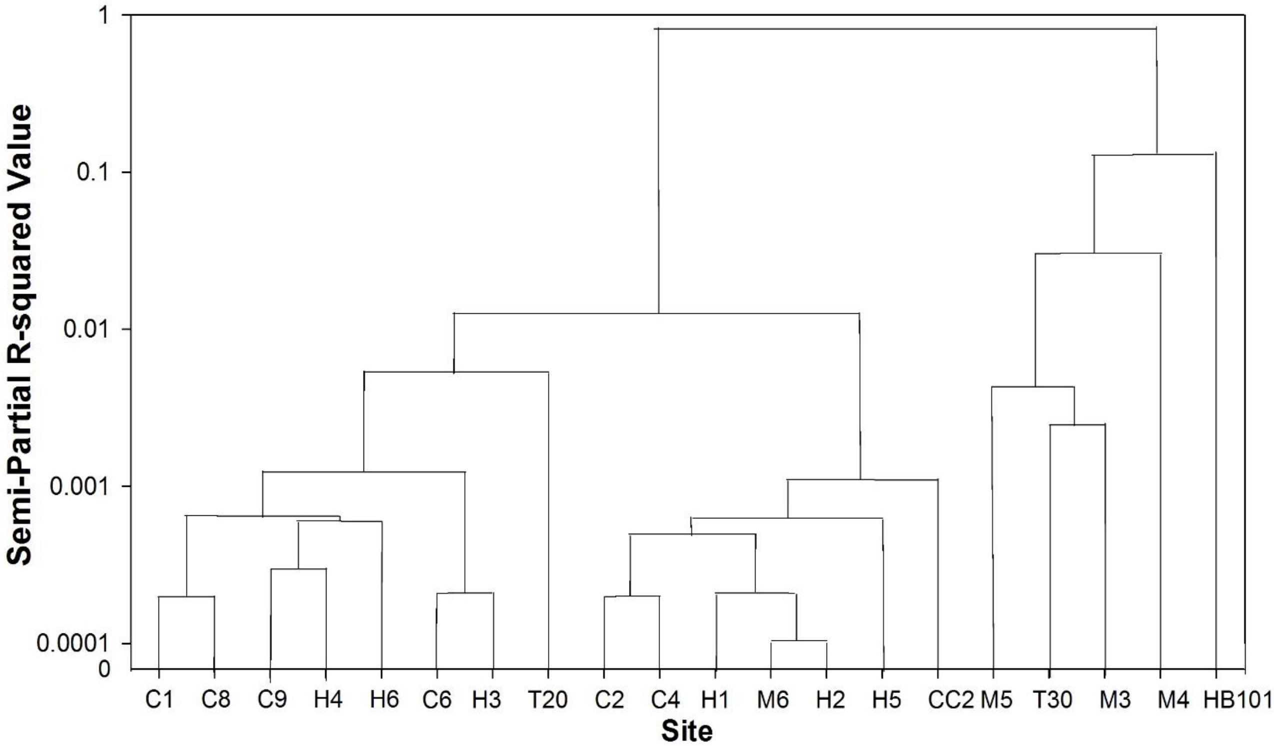

Figure 3. Results of cluster analysis using Ward method. Four soil nutrient variables, namely Ca, Mg, K, and P from the B horizon, were used in this analysis. The Semi-partial R-squared values were added a constant (i.e. 0.0001) then showed in log-scale.

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EDUCATION

State University of New York ***May 2014***
College of Environmental Science and Forestry
Syracuse, NY
Master of Science
Area of Study: Forest and Natural Resources Management
Research: Parent material, N cycling, and foliar chemistry in a northern hardwood forest

Chinese Academy of Forestry, China ***2012***
Master of Science
Area of Study: Forest and Ecological Engineering
Research: Numerical simulation of wind reduction effect of coastal shelter forest

Central South University of Forestry & Technology (China) ***2010***
Bachelor of Science
Area of Study: Forestry
Research: Assessment of sustainable forest certification in Huangfengqiao Forest Farm, Hunan

PROFESSIONAL EXPERIENCE

State University of New York College of Environmental Science and Forestry
Graduate Teaching Assistant ***Spring 2013, 2014***
Course: Meteorology

- ***Coordinate the teaching resources with instructors and insure the resources delivered properly***
- ***Oversee homework grading and providing tutoring to students***
- ***Manage communication regarding announcements from instructor to students***

State University of New York College of Environmental Science and Forestry
Research Assistant (Ruth Yanai Lab) ***Fall 2012, 2013***

- ***Coordinated work of volunteers and REU students in the field work***
- ***Trained the new students on using multiple types of research equipment***
- ***Designed experiments, collected and analyzed the data from the field***
- ***Organized group meetings with members from multiple professional fields (P.Is, scientists, graduate students, undergraduate students, volunteers, teachers)***
- ***Wrote lab documents including proposals, analysis report, summaries, etc.***

Chinese Academy of Forestry
Research Assistant (Coastal forestry engineering lab) ***Summer 2010***

●***Communicated with local foresters to conduct field experiments***
●***Assisted with field and lab work in various national and provincial funded projects***
●***Designed experiments, collected and analyzed the data from the field***
●***Wrote summary reports of lab and field work***

PROJECTS

State University of New York, College of Environmental Science and Forestry, Syracuse, New York, 2012-2014

●***Long-term investigation of nutrient cycling in a northern hardwood forest*** **(**Funded by NSF, US**)**
Communicate with previous project investigators, Assemble and organize archived data, perform statistical analysis, write professional report

●***Multiple element limitation in northern hardwood forest*** (Funded by NSF, U.S, 2010-2014)
Field work coordination, forest inventory, fertilization, Minirhizotron image analysis, Soil respiration measurements, roots classification, multiple data management and analysis

●***Quantifying uncertainty in ecosystem studies (QUEST)*** (Funded by NSF, U.S, 2013-2017)
Organize and summarize large datasets, perform model selection analysis, model validation, write summary report.

Institute of Subtropical Forestry, Chinese Academy of Forestry, Fuyang, 2010-2012

●***Research on the systematic mechanism of hurricane-resistance shelter forest in the coastal land*** (Funded by the National Ministry of Science, China, 2009-2013)
Tree and forest measurements, tree ring analysis, applied statistics, use the 3S software to process data, quantify the relationship between the hurricane and costal forest eco-structure, investigate the soil respiration rate, soil temperature, and soil moisture

●***Research on the systematic construction technique of shelter forest in the coastal land*** (Funded by the National Ministry of Science, China, 2006-2010)
Seedlings breeding, salt and alkaline soil analysis, tree and forest measurements, collect specific tree leaves to test certain related physiological indices.

●***Research on the restoration technique of vegetation in the ecological degraded hills along the lower Yangtze River*** (Funded by the national ministry of science, China, 2006-2010).
Investigate the biotic factors (roots, litter-falls), collect the soil sample and analyze the nutrient content, tree and forest measurements

●***Importation of the technique of silviculture on high carbon forest*** (National Research Project"948", 2008-2011)
Investigate the biotic factors (roots, litter-falls), collecting the soil sample and analyzing the nutrient content, tree and forest measurements.

●***Research on the technique of cultivating Catalpa bungei C. A. Mey.*** (Funded by the National Ministry of Science, China, 2007-2011)
Seedling breeding, cuttage, field measurement of transplanted seedlings

●***Research on the crucial techniques on the cultivation and effective usage of sawtooth oak*** (Funded by National Non-Profit Research Fund, 2007-2011)
Fertilize the trees in a controlled manner, investigate the biotic factors (roots, litter-falls), collect the soil sample and analyze the nutrient content, tree and forest measurements.

●***Research on the technique and systematic construction model of vegetation along the coastal land in Shanghai*** (Funded by the Municipal Government of Shanghai,2008-2010)
Investigate the productivity of *Ascendens mucronatum*, tree and forest measurements, investigate the biotic factors(roots, litter falls), collect the soil sample and analyze the nutrient content, measure the soil respiration rate, moisture and so forth using soil respiration detector.

●***Research on the responsive mechanism of Hibiscus hamabo and Myrica cerifera in the artificial coastal land*** (Funded by the Municipal Government of Shanghai, 2008-2010)
Detect the morphological indices of tree leaves, investigate the biotic factors (roots, litter falls, seedling height, basal diameter, the ratio of root to canopy), detect the photosynthetic ability by using the chlorophyll fluorescence spectrum, test the root vigor, soluble protein content, soluble sugar content, soluble starch content, activity of ethanol acid oxidase.

PRESENTATION

Dong, Y., Effects of parent material on foliage nutrient in northern hardwood forest (poster). New York Society of American Foresters (SAF) Annual meeting, Syracuse, NY, 2014

Dong, Y., A comprehensive strategy for analyzing beech scale population density (poster). Research show case, Syracuse University, Syracuse, NY, 2013

Dong, Y., Do soil nutrients affect foliage nutrients in a northern hardwood forest. Hubbard Brook Cooperators Annual Meeting, North Woodstock, NH, 2013

Dong, Y., Do foliage nutrients indicate soil nitrogen mineralization in a northern hardwood forest. Rochester Academy of Science annual meeting, Nazareth College, Rochester, NY, 2013

PUBLICATIONS

1. **Dong, Y.**, T., Wu, J., Gu, M., Yu, X., Cheng, X., Duan, C., Wang. 2012. Response of photosynthesis and chlorophyll fluorescence characteristics of *Nerium idicum* to distance from coastline. *Journal of Northeast Forestry University*. 40(12): 60-62, 70.

2. **Dong, Y.**, Z., Wang, T., Wu, M., Yu, X., Cheng, X., Duan. 2013. Temporal and spatial distribution of wind in coastal area, Shanghai. *Resources and Environment in the Yangtze Basin*. 22(1): 40-45.

3. Wu, T., **Y., Dong**, M., Yu, G. G., Wang, D., Zeng. 2012. Leaf nitrogen and phosphorus stoichiometry of *Quercus* Species across China. *Forest Ecology and Management*. 284: 116-123.

4. Wu, T., M., Yu, G.G., Wang, **Y., Dong**, X., Cheng. 2012. Leaf nitrogen and phosphorus stoichiometry across forty-two woody species in southeast China. *Biochemical Systematics and Ecology*. 44: 255-263.

5. Wu, T., M., Yu, G., Wang, Z., Wang, X., Duan, **Y., Dong**, X., Cheng. 2012. Effects of stand structure on wind speed reduction in a *Metasequoia glyptostroboides* shelterbelt. *Agroforest Syst*. Online publication.

AWARDS/HONOR SOCIETIES

- Travel grant from Graduate Student Association, ***SUNY College of Environmental Science and Forestry 2013***
- Outstanding speaker of English address contest, ***Central South University of Forestry& Technology*** **2007**
- Students community leader, ***Central South University of Forestry & Technology*** **2008**