Soil nutrients, aboveground productivity and vegetative diversity after 10 years of experimental acidification and base cation depletion

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Abstract
Soil acidification and base cation depletion are concerns for those wishing to manage central Appalachian hardwood forests sustainably. In this research, 2 experiments were established in 1996 and 1997 in two forest types common in the central Appalachian hardwood forests, to examine how these important forests respond to depletion of nutrients such as calcium and magnesium. After 10 years of treatment, relatively few effects were detected on soil nutrients or total aboveground biomass. This research will continue to monitor effects as the stands develop and as nutrient uptake and cycling changes over time.

Key Words
Calcium depletion, vegetative diversity, liming, forest sustainability.

Introduction
Concerns have existed for many years about nutrient depletion of forest soils, either through harvesting, acidic deposition or other causal agents. In the central Appalachians, where both acidic deposition and forest harvesting have been occurring for many decades, depletion of soil calcium and magnesium is a particular concern. The forests of the central Appalachians are generally quite productive, and highly diverse, and serve many important functions including providing recreational opportunities, supporting wood-based industries and communities, providing wildlife habitat, and ensuring delivery of ecosystem services. In 1996, a study was begun to assess the effects of base cation depletion on long-term productivity of soil and forest vegetation in the central Appalachians. These studies are affiliated with the international Long Term Soil Productivity Study (Powers *et al.* 2005). Our objectives were: (1) Characterize the productivity, diversity and biogeochemistry of a forest system hypothesized to be sensitive to base cation removals. (2) Determine the response of this forest community to base cation removal, and (3) Create new and modify existing vegetation, nutrient cycling, hydrologic models to describe and simulate forest change in response to base cation removals, nitrogen and sulfur inputs and mitigating base additions. This presentation will focus on the second objective.

Site descriptions
Two sites were used in this study, the Fork Mountain study site, and the Middle Mountain study site, both located in West Virginia, within the central Appalachian mountains. The Fork Mountain site is also located within the Fernow Experimental Forest, a research area set aside in 1934 and dedicated to long-term forestry research (Adams *et al.* in press). These sites represent 2 distinct forest types (Table 1), with similar treatments and experimental designs (Adams *et al.* 2004).

Methods
To induce base cation depletion a combination of treatments was used; whole-tree harvesting was used along with removal of all down dead wood, to effect removal of aboveground nutrient pools, and minimize cycling from these pools (Whole-tree harvest, WT). Ammonium sulfate fertilizer was applied 3 times per year at 35 kg N/ha/yr, and 40 kg S/ha/yr to accelerate leaching of calcium and magnesium from the soil (WT+NS). This rate was approximately twice the ambient throughfall inputs (Adams *et al.* 2006). In addition, dolomitic lime (WT+NS+LIME) was applied at a rate of 22.5 kg Ca/ha/yr and 11 kg Mg/ha/yr (a rate twice that of export from an untreated reference watershed (Adams *et al.* 1997), to evaluate whether simple replacement of these nutrients is effective. On the Middle Mountain site, a treatment of WT plus lime additions (LIME) was added.

These experiments are designed to last for approximately 80 years. We report on soil and vegetation measurements collected prior to and during the first 10 years.

Table 1. Characteristics of the Fork Mountain and Middle Mountain long term soil productivity study sites.

	Fork Mountain	Middle Mountain
Forest type	Mixed hardwoods	Cherry- maple , some red spruce
Age of forest stand (yrs)	~80	~90
Soil type	Loamy skeletal, mixed, mesic typic Dystrochrepts	Loamy skeletal, mixed, active, frigid typic Dystrudepts
Elevation (m)	790-850	1100-1250
Experimental treatments	4 blocks of 4 treatments – Uncut control – WT only – WT+fertilizer – WT+fertilizer+lime	4 blocks of 5 treatments – Uncut control – WT only – WT+fertilizer – WT+fertilizer+lime – WT+lime

Results

Soil chemistry

Ten years after the experiments began; the only detectable treatment effects on soil nutrients appear related to the liming treatment. Changes in soil pH due to the LIME treatment were noted at the more acidic the Middle Mountain study site (Figure 1). The liming treatment increased soil magnesium (Mg) levels significantly in all 3 depths studied on the Fork Mountain site (Figure 2), but there were no statistically significant treatment effects on soil exchangeable calcium. Soil carbon in the upper soil horizons of the liming treatment also appear to have increased after 10 years, but the effect is not statistically significant.

Vegetation

Total aboveground wood biomass did not differ among treatments (Johnson *et al.* in press) on the Fork Mountain site after 10 years. An analysis of treatment effects at the species level suggests, however, that some tree species, notably *Liriodendron tulipifera* and *Magnolia acuminata*, demonstrated increased diameter growth and accumulated significantly greater biomass in the WT+NS+LIME treatment than in the other treatments. These tree species are known to acquire and utilize more Ca and possibly Mg in their bolewood. Species richness declined at both sites over the 10 year period, presumably due to the changes in microclimate following the whole-tree harvesting treatment, although richness also declined in the uncut control plots on the Fork Mountain site. Vegetative species richness, which included trees, shrubs and herbaceous vegetation, declined from 75 to 57 species during the 10-year period on the Fork Mountain site, and from 40 to 32 species on the Middle Mountain site during the 10 years.

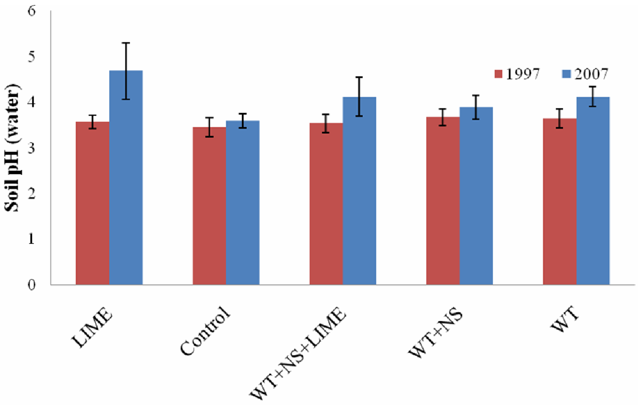

Figure 1. Mean A horizon soil pH, Middle Mountain site. N=12. Bars represent ± standard deviation.

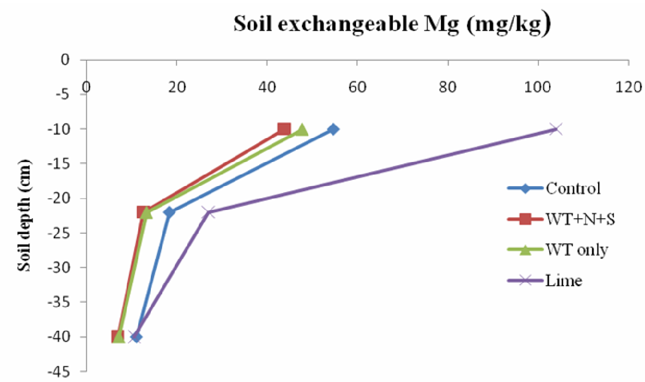

Figure 2. Mean soil Mg concentrations, Fork Mountain site, by soil depth and by treatment.

Conclusions

Ten years into these 80-year experiments, relatively few effects directly attributable to the chemical treatments have been detected. While there is clearly an effect of the whole tree harvesting on vegetative productivity and diversity, we cannot yet detect soil acidification from the fertilization treatments. Only the liming treatment appears to have had an effect on soil chemistry, and this effect appears to be due to the magnesium in the lime, rather than a calcium effect. Soil magnesium levels are so low, that even adding a small amount has resulted in a significant increase in available magnesium. We will continue to follow forest development and effects on soil and soil solution chemistry to better understand how these hardwood forests respond to changes in availability of important nutrients over time.

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