Does Soil Moisture and Soil Texture Predict the Distribution of Sugar Maple and Beech in a Western Vermont Old Growth Forest?

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Abstract

The goal of this research was to understand how Sugar Maple and Beech segment themselves in different soil environments on small scale Understanding this is important to our understanding of northern hardwood forests and allows us to better model their dynamics. Data on soil moisture and soil texture were collected in 25 subplots within a 1ha plot. Sugar Maple generally dominates in wetter environments than Beech. Meanwhile Beech dominates where soils are courser and drier. Microtopography may further influence soil moisture, as there was a positive trend between slope and moisture. My findings suggest we reevaluate the assumptions in forest dynamics models that single abiotic variables, like light availability, are adequate for explaining and predicating forest dynamics in hardwood forests.

Introduction

Forest ecologists have long tried to develop models to better understand the forest succession patterns that occur on centuries-scale (Pacala et al. 1996, Prentice 1992, Schenk 1996, Acevedo 1995). Many of these models assume that competition for light is the primary process structuring forest dynamics (Bugman 2001). The goal of this study is to see whether two co-dominant species in a forest have microscale soil characteristic differences. This would suggest light competition is not enough to explain patterns in the forest.

This work is done in a northern hardwood forest dominated by Beech and Sugar Maple. The effects of subtle, fine scale differences in soil characteristics have been poorly studied in northern hardwood forests (van Breeman et al 1997).

However, based on anecdotal observations of how beech and sugar maple have segmented themselves in this 1 ha forest, I hypothesize that soil characteristics such as soil moisture and soil texture are strong predictors of the distribution of these two co-occurring species, suggesting that the light environment is not adequate on its own in predicting forest dynamics in some systems.

Methods

Summary: This work was conducted in the Battell Research Forest, Middlebury, VT, USA. Tree census data was taken from a 1 ha forest plot. All stems larger than 5 cm DBH have been tagged, identified and mapped. 25 sites were opportunistically placed in Beech-dominated, Sugar Maple-dominated, and mixed portions of the plot. At each sample point the basal area of both species was calculated within a 10 m radius. Soil moisture and soil texture samples were taken within 1 m of the each point.

I. Soil Moisture Data

- Volumetric soil moisture was measured using an Aquatterr M-350 probe (Aquatterr Insturments and Automation LLC.)
- After seven rain events that between August 8 and September 7, 2018 soil moisture values were obtained within a 1m radius of each site.
- During each sampling period, three values of soil moisture were taken within the 1m radius of each rain gauge site and at an approximate depth of 15cm.
- For each location the soil moisture at each site was taken as the average over the three samples and seven rain events.

II Soil Texture Analysis

- Soil cores were collected on October 19th, 2018 at each site, using an AMS soil core extractor at an approximate 15cm depth. Soil texture was measured in triplicates
- Soil was oxidized with 35% laboratory-grade hydrogen peroxide for approximately 3 weeks in order to remove all organic matter. After three weeks, the samples were then treated with 20ml of a dispersing agent made of 3% sodium hexametaphosphate to ensure the clay particles didn't stick to other larger particles.
- The conical tube samples were then placed in a centrifuge and spun for two minutes at 2500 rpm. The samples were then vortexed for 5 seconds. .
- The glass vials were sonified for 90 seconds and then loaded into a Horiba LA960 Laser Particle Size Analyzer (Horiba, Ltd., Kyoto, Japan), where the liquid solution for each sample was homogenized and sent through laser particle size analysis, which measures the size of particle based on light diffraction.
- Particle size distributions for each sample were obtained and categorized into 10 micron-size categories. The values were then simplified into sand, silt, and clay proportions and median grain size for statistical analysis.

Results

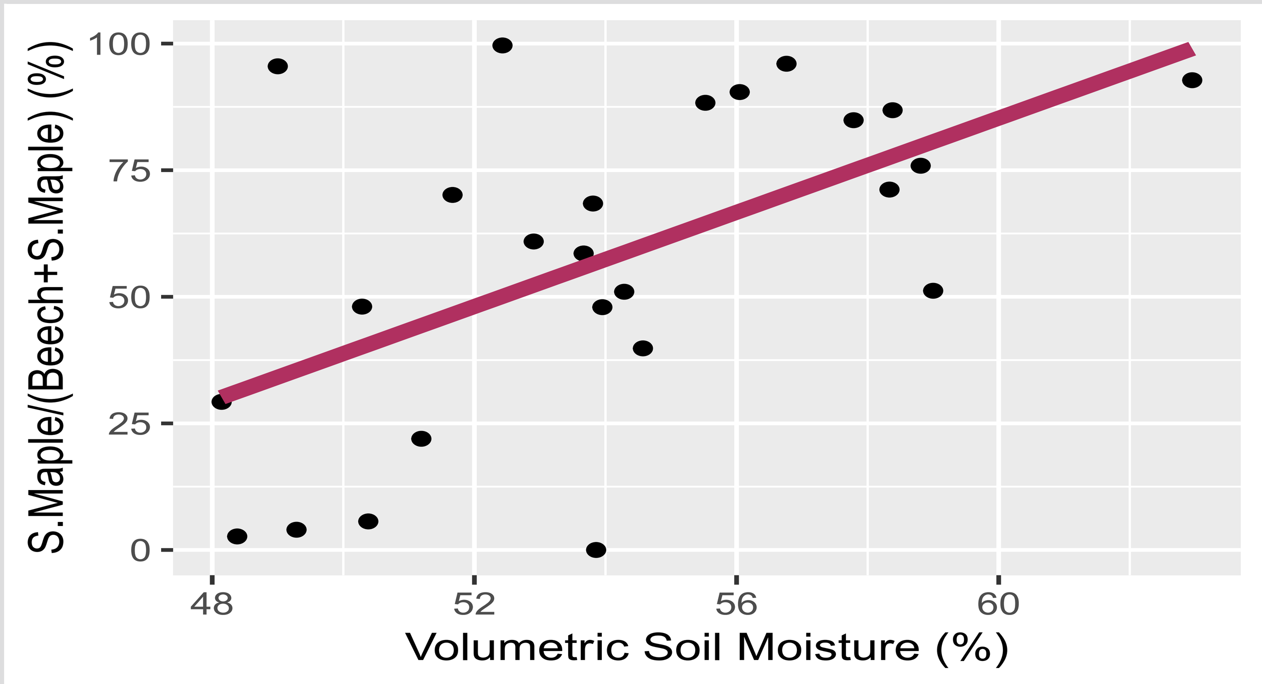

Figure 1. Linear model showing the relationship between soil moisture and the percent of the Beech and Sugar Maple total basal area that is Sugar Maple. R^2 =0.30, F=10.14, P=0.004, Slope=4.65% Sugar Maple per 1% soil moisture.

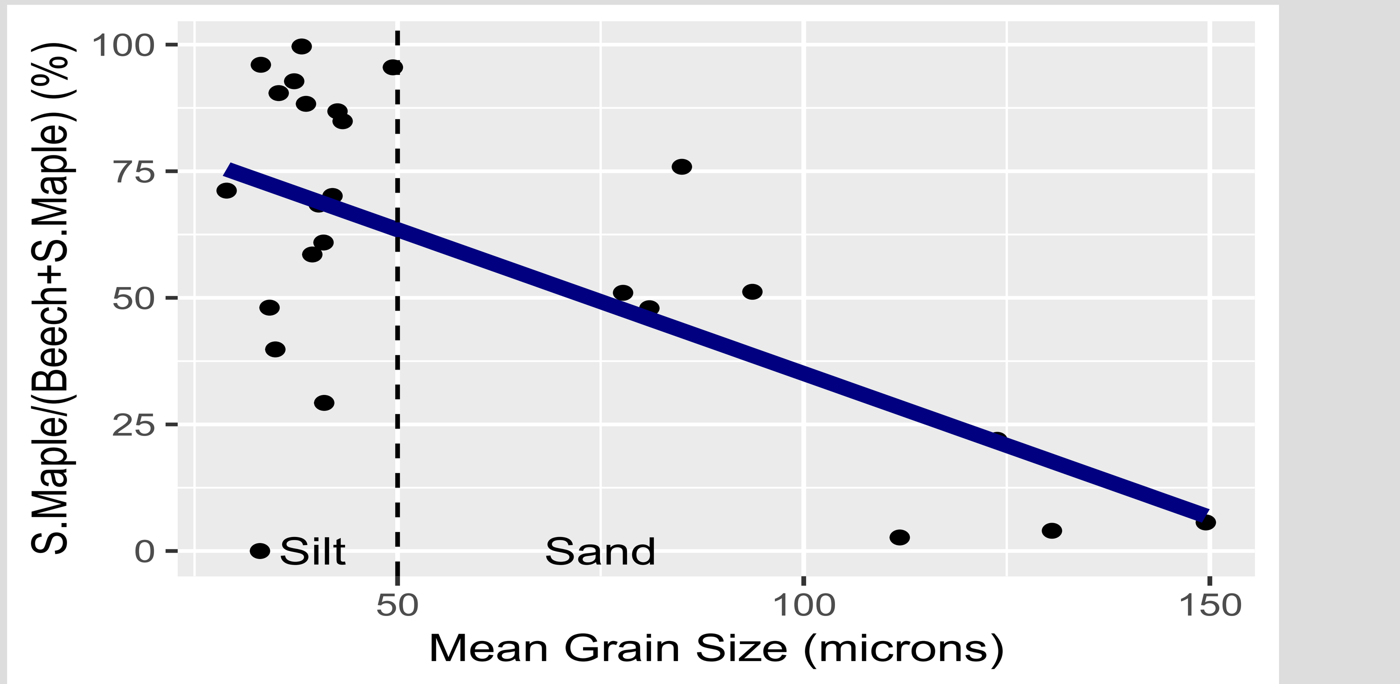

Figure 2. Linear model showing the relationship between mean grain size and the percent of the Beech and Sugar Maple total basal area that is Sugar Maple. R^2 =0.40, F=15.1, P=0.0007, Slope=-0.60% Sugar Maple per 1 micron.

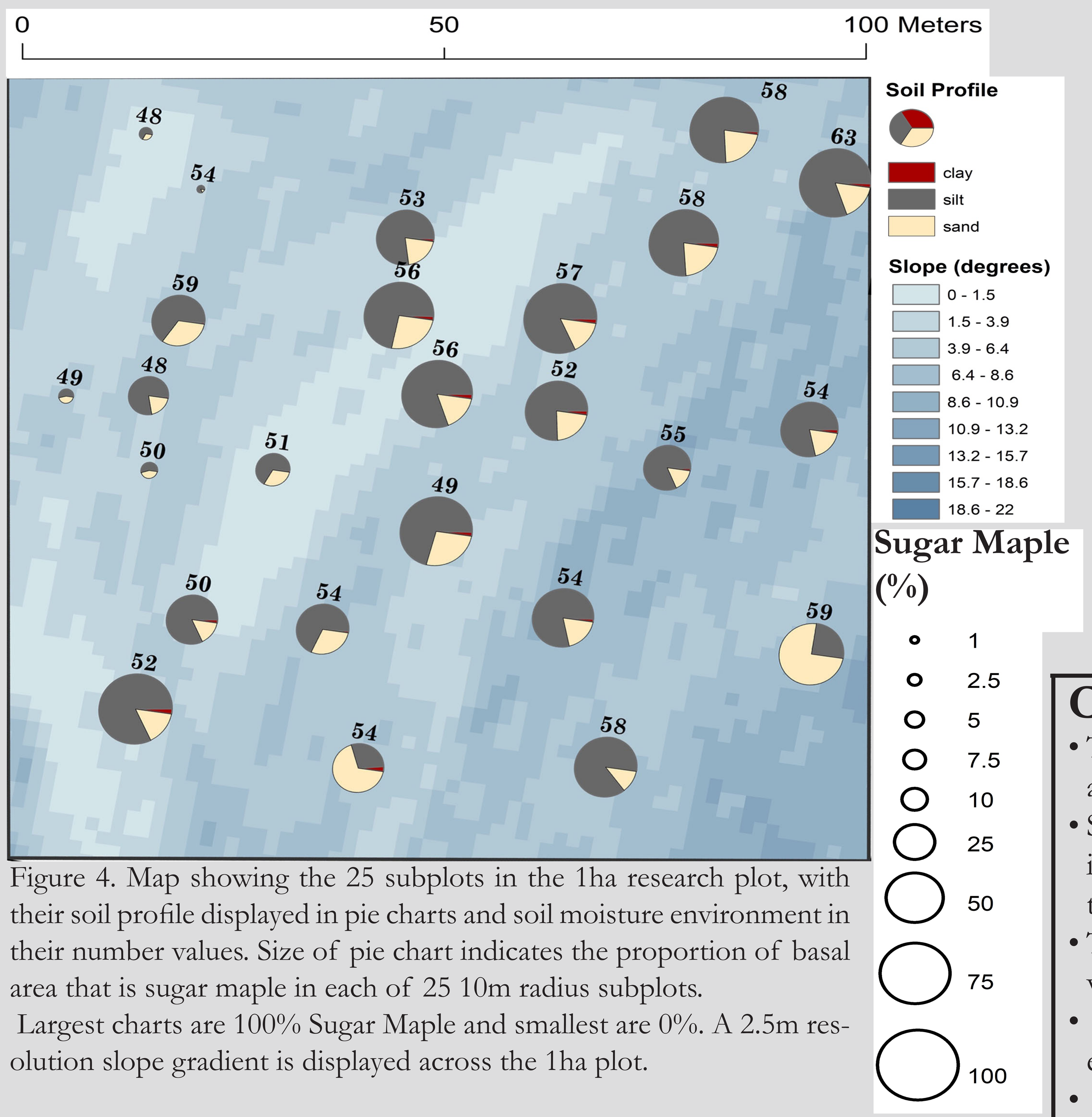

Figure 4. Map showing the 25 subplots in the 1ha research plot, with their soil profile displayed in pie charts and soil moisture environment in their number values. Size of pie chart indicates the proportion of basal area that is sugar maple in each of 25 10m radius subplots.
Largest charts are 100% Sugar Maple and smallest are 0%. A 2.5m resolution slope gradient is displayed across the 1ha plot.

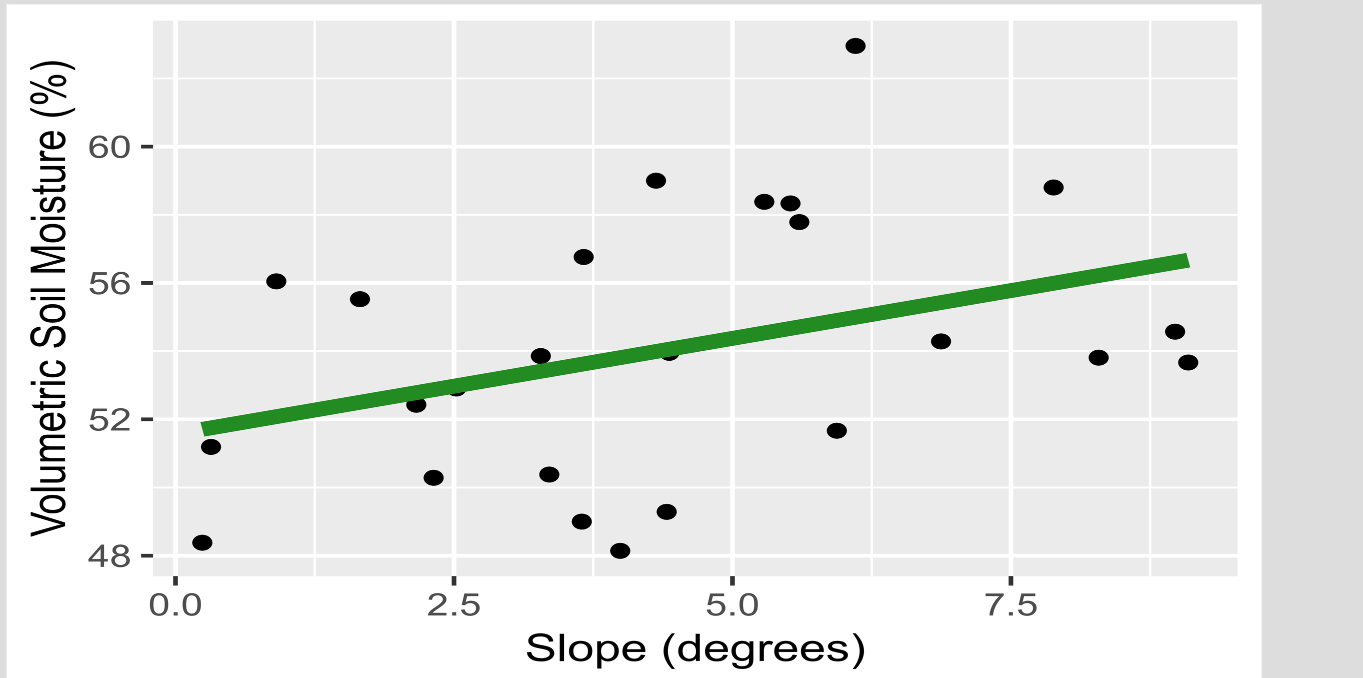

Figure 3. Linear model showing the relationship between slope and soil moisture. Slope data was derived from 2.5m resolution LIDAR remote sensing data. R^2 =0.13, F=3.7, P=0.067, Slope=0.56% soil moisture per 1 degree slope. Because P>0.05 this is just a trend in the data and is not a significant result.

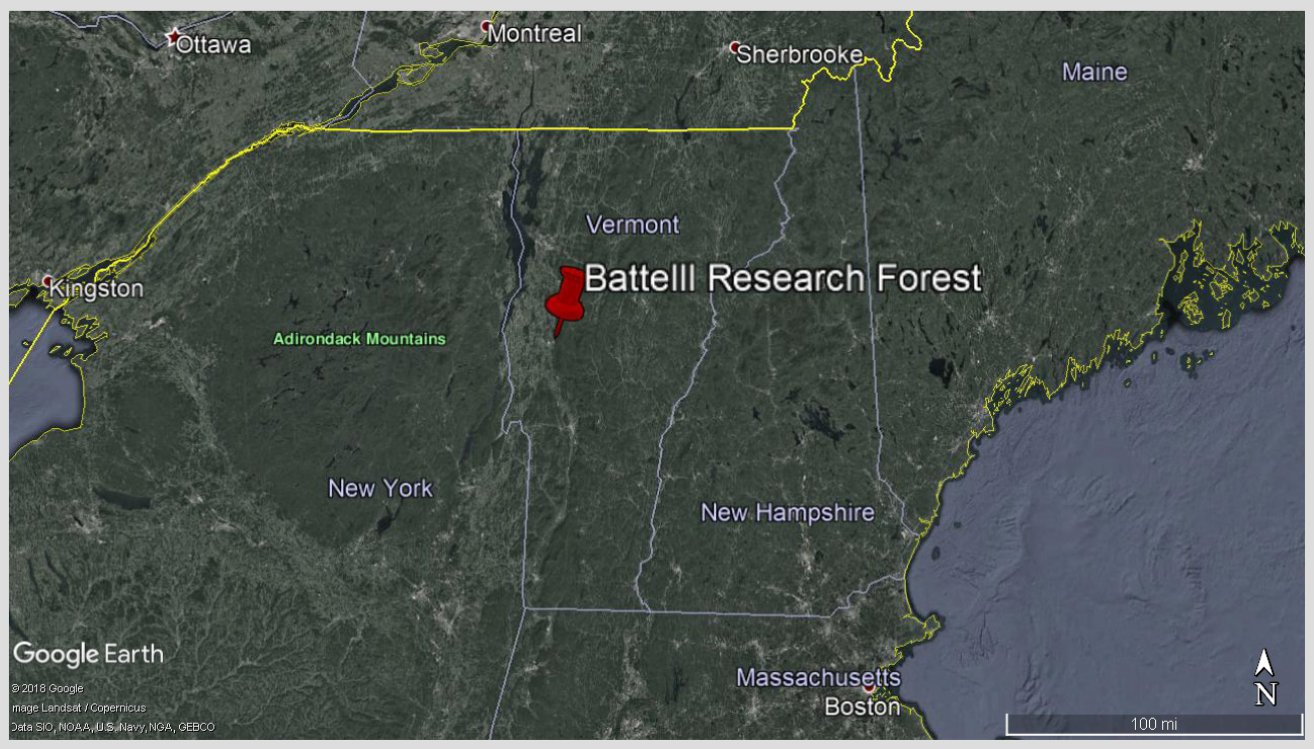

Figure 5. Map showing the location of the 42ha Battell Research Forest, located between 180m and 365m in elevation, 6 miles Northeast of Middlebury, Vermont on the western escarpment ridge of the Green Mountains. It is sourounded by Green Mountain National Forest land to its North, South

Conclusion

- The findings here suggest that Sugar Maple and American Beech may show niche differentiation on microscales in northern hardwood forests, explained by soil moisture and texture.
- Sugar Maple generally dominates in a soil environment that is >56% volumetric soil moisture in this 1 ha hardwood forest. Meanwhile, American Beech was shown to dominate in a moisture environment that is <56%.
- The segmentation of these two co-dominant species is impressive because it occurs across a very fine gradient of soil moisture, just 48% to 60%.
- Sugar Maple dominates in finer silty soils, while American Beech is most dominant in courser, sandy soils.
- Soil texture is a significant predictor of their microscale distribution, which is interesting in the context of soil moisture because there was no significant relationship found between texture and soil moisture, which would be expected based on the intuition of declining soil water holding capacity with increasing grain size.
- Grain size and soil moisture may be acting in somewhat independent, albeit synergistic ways, forming two slightly different ecological niches of these two species.
- Furthermore, microtopography is suggested to play another complex role here, as there is a trend in the data that shows a positive relationship between slope and soil moisture.
- Findings here suggest that assuming the light environment is the primary limiting abiotic resource is inadequate for parameterizing forest dynamic models.

Acknowledgments

I am forever grateful to my professor David Allen for all he has taught me as both a friend and teacher. I also am very thankful for geology professor Jeff Munroe for helping me analyze soil samples and providing state of the art laboratory facilities and equipment to do it. I am grateful for Middlebury College for providing all the funding and the remarkable research forest that made all this possible!

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