Soil Carbon and Other Quality Indicators in Managed Northern Forests

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Key Findings: Carbon storage in managed forest soils varied greatly with soil depth, elevation, wetness, and time since disturbance and land-use change. Because of this i) effects of harvesting on carbon storage will also likely vary and ii) some sites have a higher potential for future carbon sequestration.

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service.
http://www.nsrcforest.org

Project Summary

Soil carbon serves as a major reservoir for carbon storage in forests. Yet there is much unknown about how soil carbon varies with different soil and forest types, and much less known about how managing forests influences positive or negative changes in soil carbon. We have established eighteen reference plots on sites that have sustainable harvesting plans. The sites will serve as pre-harvest references; after re-sampling post-harvest, data can then be analyzed as an aggregate of all sites, or by forest community type, to monitor the overall impact of harvesting on forest soil carbon. These plots will provide the necessary link between the many atmospherically derived forest changes, and those created through forest management.

At each plot location, six subplots were established and soils sampled by depth. Soils were analyzed for carbon, nitrogen, and total mercury. Additional vegetation and physical site characteristics were measured and plots were permanently monumented for future use. Results from pre-harvest sampling showed that more carbon was stored in the soil (59-234 Mg C ha^{-1}) than in live trees (62-180 Mg C ha^{-1}). Carbon storage in the soil appeared to depend on multiple factors, including soil depth, elevation, wetness, and time since disturbance and land-use change. Sites where bedrock was close to the surface stored much less carbon than deeper soils. Higher elevation plots had thicker forest floors, likely as a result of colder temperatures and slower decomposition. Prior land use effects were visible at many sites; remnant stone walls were present and several sites showed evidence of a plow layer, where the organic soil horizons had been mixed with the mineral soil. At the sites with a plow layer (Ap horizon), the forest floor was thinner and earthworms were often found. Coniferous sites had generally, but not consistently, thicker forest floors than deciduous sites. Forest floor carbon had a wider relative range (1.5-34.9 Mg C ha^{-1}) than mineral soil carbon (48-226 Mg C ha^{-1}). The highest mercury concentration (225 ng g^{-1}) was found in the Oe horizons (fermentation layer in the forest floor). However, the highest mercury pools were found in the mineral A horizon because of its higher density.

Harvesting impacts will be most likely strongest on the near-surface soil horizons from physical disturbance and increased light penetration. Because of the intensive baseline sampling, these monitoring plots will be able to detect relatively small changes in forest floor carbon and mercury. Harvesting has already occurred on two of the plots and support will be sought for resampling. Results have been presented at regional meetings and disseminated to cooperators and forestry professionals. A publicly-accessible website (http://www.uvm.edu/~soilcrbn/) was created and summarizes key results.

Background and Justification

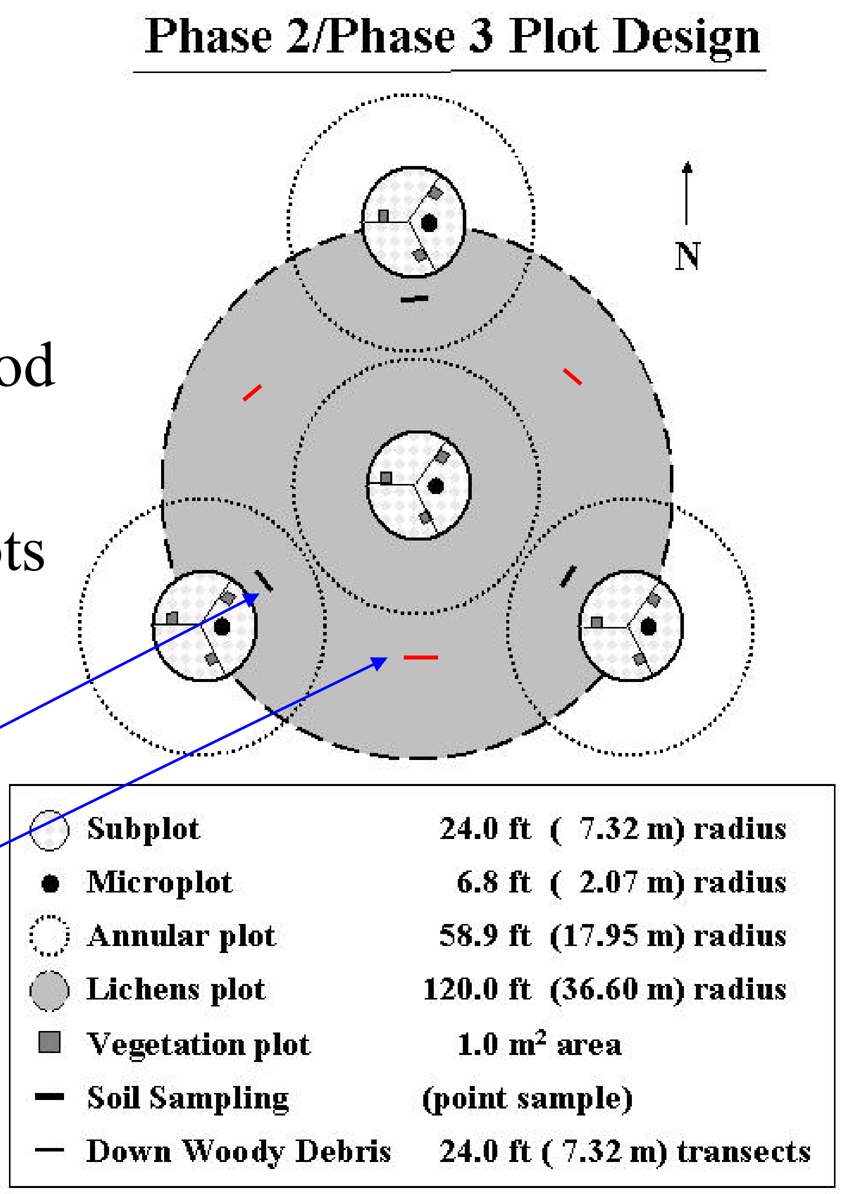
Change is occurring in the Northern Forest as a result of human activities. These activities include regional and global influences of continued acidic deposition, mercury deposition, and climate change. In addition, local forest management practices create an impact, the extent of which may accelerate as increasing pressures are put on local communities to seek alternative energy sources from forests. Science is now showing the positive role forest ecosystems can play in removing and storing excess carbon from the air.

Soil carbon serves as a major reservoir for carbon storage in forests. Yet there is much unknown about how soil carbon varies with different soil and forest types, and much less known about how managing forests influences positive or negative changes in soil carbon. Furthermore, soil quality includes other factors in addition to carbon. Soil quality has a number of definitions but all focus on the sustainability of the ecosystem. One lesson learned from research into the effects of acidic deposition is that we had insufficient baseline data against which to measure change. There are now at least two long-term soil monitoring experiments established in unmanaged forests in Vermont that will be an invaluable resource for studying the effects of regional and global change. In this project, we established soil reference plots in Vermont on actively managed forest lands.

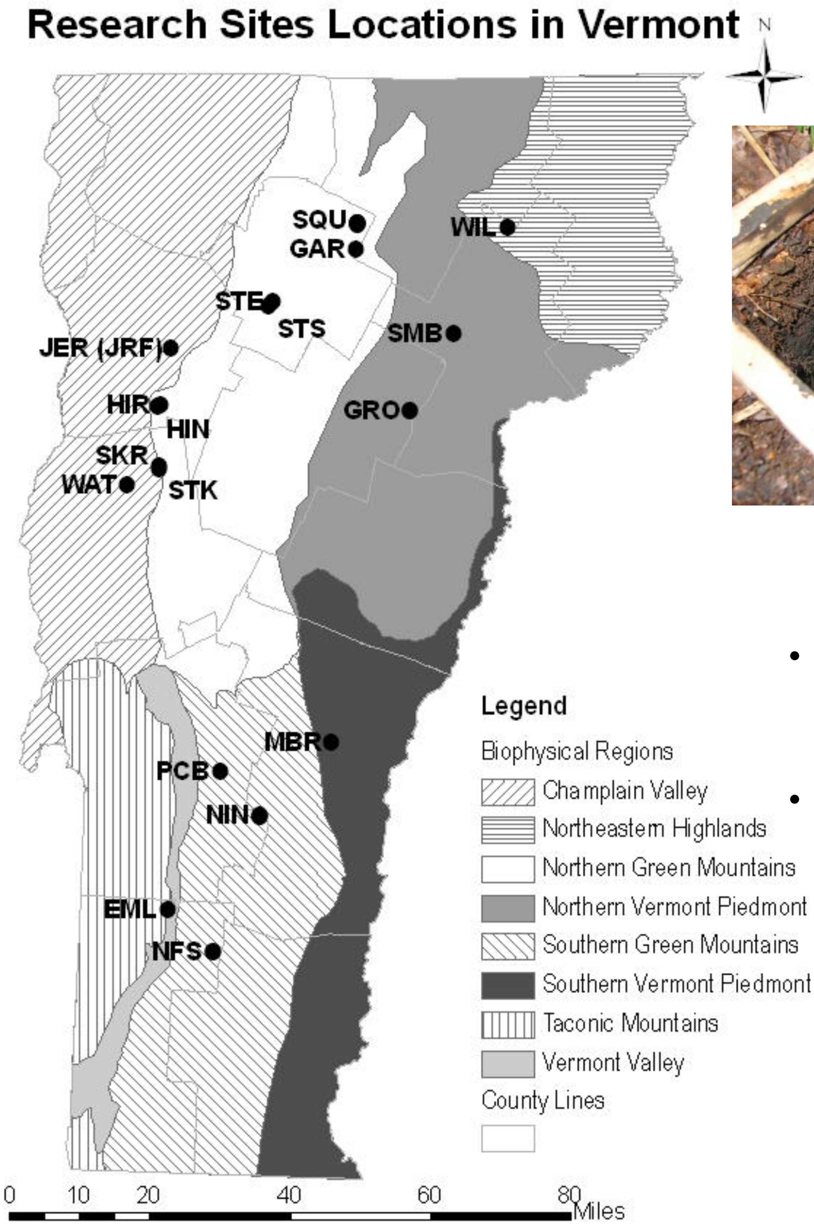
We measured soil carbon pools throughout the soil profile. Results were publicized on a website to promote awareness (http://www.uvm.edu/~soilcrbn).

Methods

- 18 plots on 3 forest types
  - 9 northern hardwood
  - 5 enriched northern hardwood
  - 4 lowland spruce/fir
- Plot design identical to FIA plots (USDA Forest Service Forest Inventory Analysis)
- 4 vegetation plots
- 3 soil sampling locations + 3 more than FIA plots, 60^0 from each original location



Methods



- Sampled the forest floor separately for each horizon (Oi, Oe, Oa) by cutting the forest floor vertically along 15 x 15 cm frames
- Described soil pits using NRCS criteria

Site abbreviation key, natural communities and simple characteristics

Plot abbr.	PLOT	Forest Community	Elevation Center [m]	Average Aspect [deg.]	Average Slope [deg.]
EML	Emerald Lake State Park	Enriched Northern Hardwood	299	142	21
GAR	Atlas Partnership 'Garfield'	Northern Hardwood	488	97	16
GRO	Groton State Forest	Spruce-Fir	425	245	3
HIN	Hinesburg Town Forest 'Poor'	Northern Hardwood	403	326	5
HIR	Hinesburg Town Forest 'Rich'	Enriched Northern Hardwood	370	349	21
JER	Jericho Research Forest (UVM)	Northern Hardwood	154	269	18
MBR	Marsh-Billings-Rockefeller National Park	Northern Hardwood	397	90	24
NFS	Green Mountain National Forest	Northern Hardwood	493	50	14
NIN	Coolidge State Forest 'Ninevah'	Spruce-Fir	552	182	7
PCB	Coolidge State Forest 'PCB'	Enriched Northern Hardwood	651	193	10
SKR	Starksboro Town Forest 'Rich'	Enriched Northern Hardwood	349	278	24
SMB	Steam Mill Brook Wildlife Management Area	Spruce-Fir	649	254	5
SQU	Atlas Partnership 'Square'	Enriched Northern Hardwood	589	100	15
STE	Sterling Town Forest (Stowe) 'Hardwoods'	Northern Hardwood	528	250	6
STK	Starksboro Town Forest	Northern Hardwood	333	215	13
STS	Sterlling Town Forest (Stowe) 'Spruce-Fir'	Spruce-Fir		94	6
WAT	Waterworks	Northern Hardwood	237	279	18
WIL	Willoughby State Forest	Northern Hardwood	465	79	7

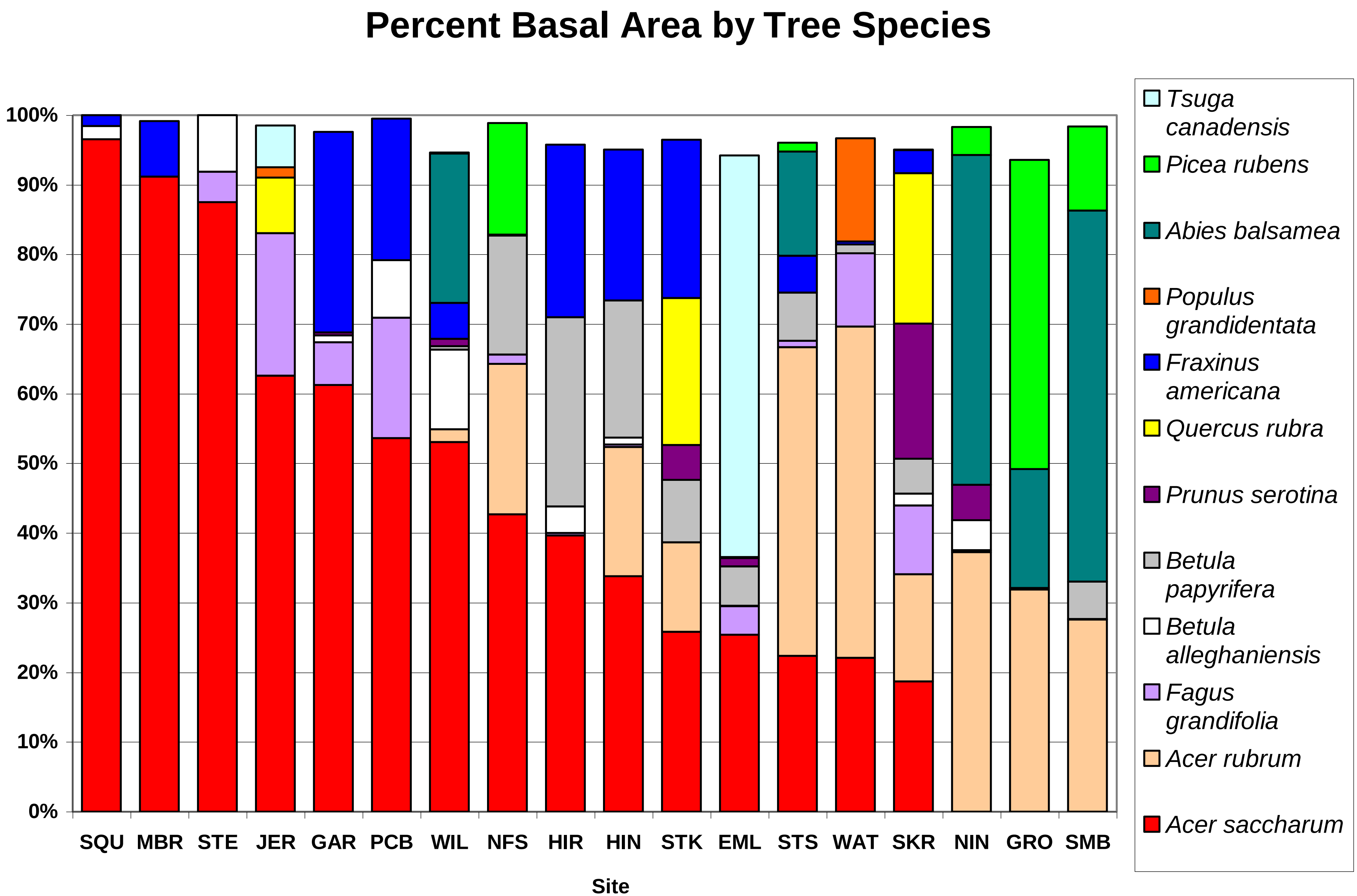
Methods

Described all vegetation within vegetation plots following the USDA Forest Inventory and Analysis protocol: tree species, diameter at breast height (DBH), tree height, crown and decay class.

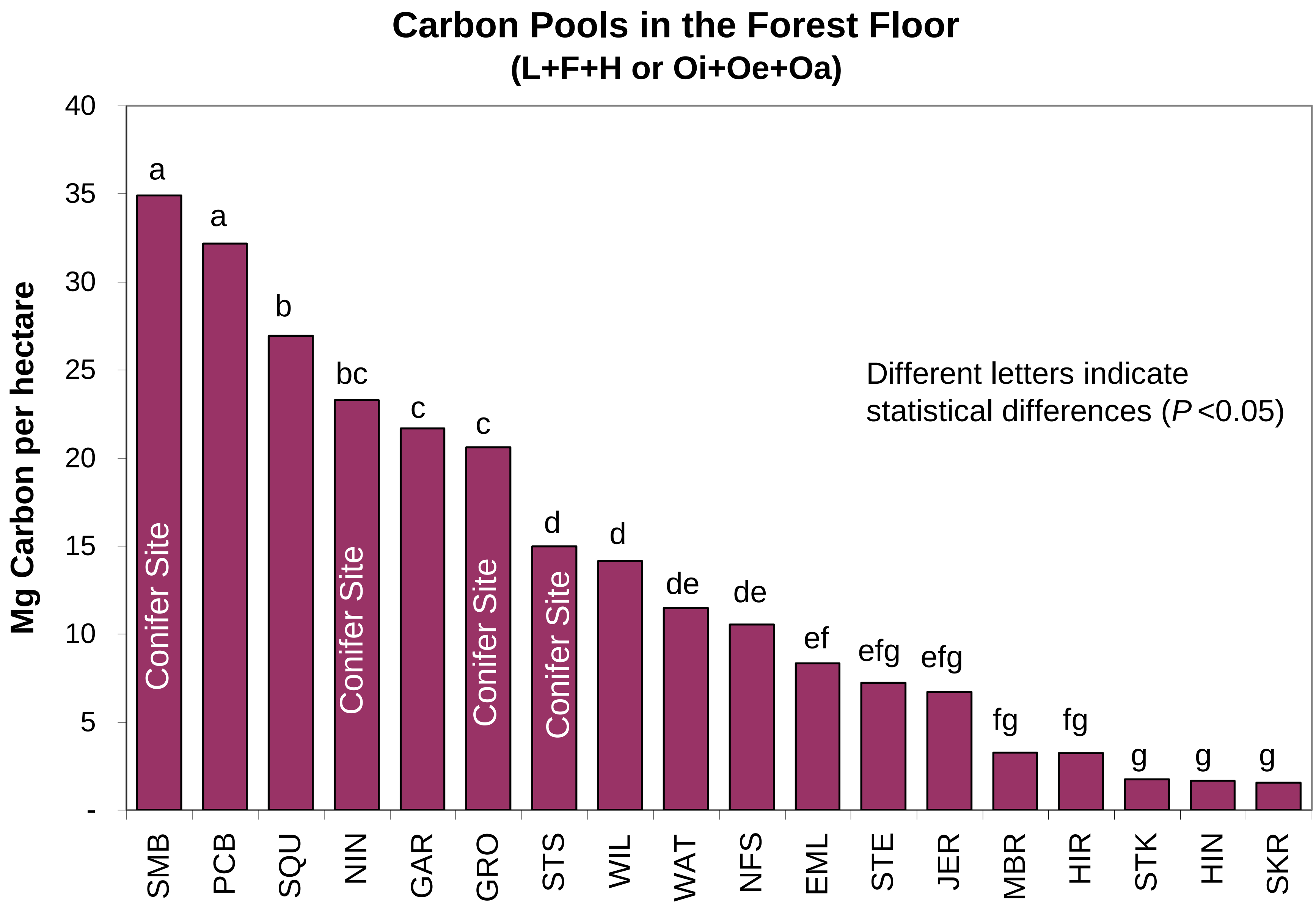
Collected soil cores for bulk density using diamond-tipped core mounted on a power auger

Analyzed soil samples for carbon and nitrogen on an elemental analyzer. Archived samples for future analyses.

Results/Project outcomes



Results/Project outcomes



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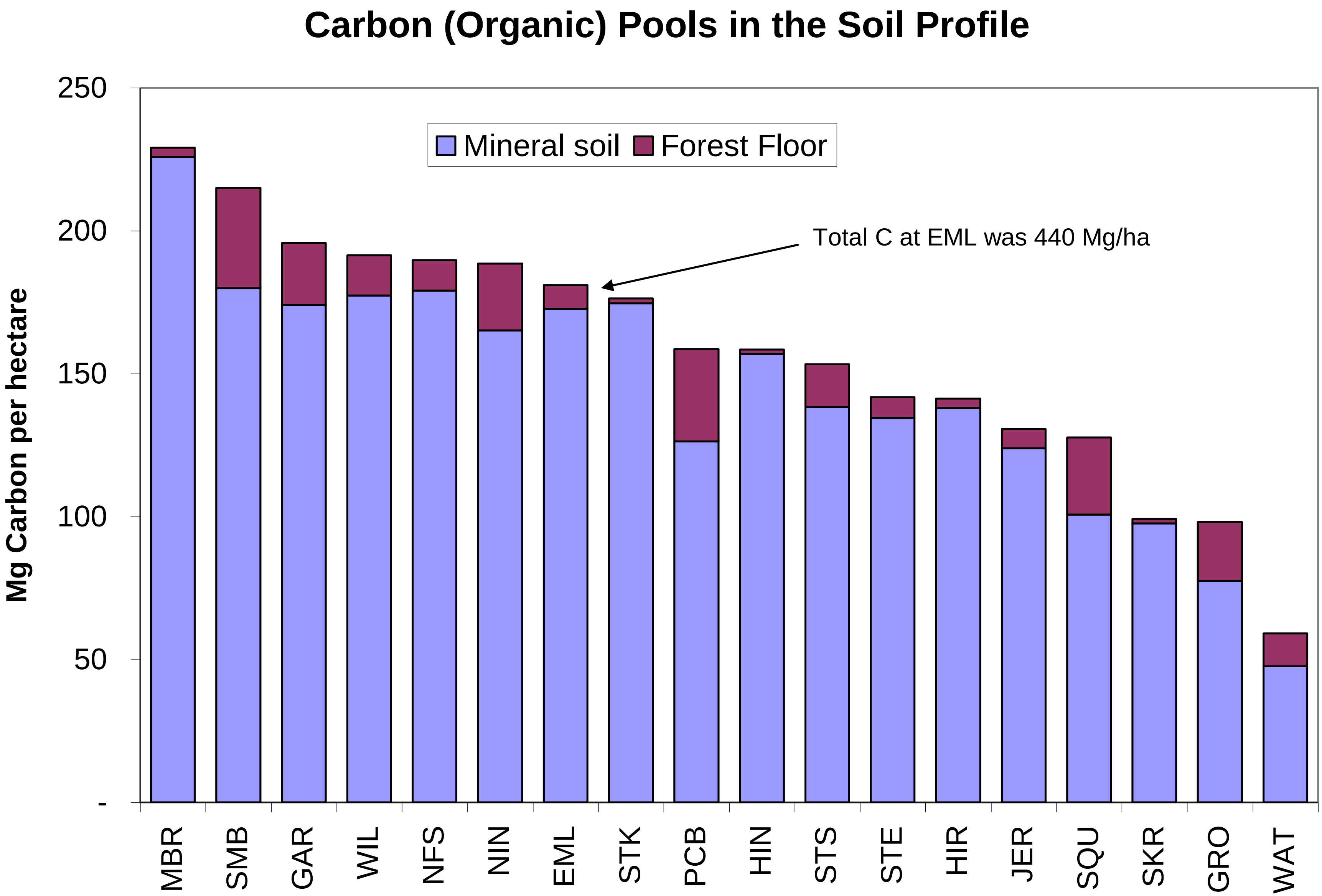

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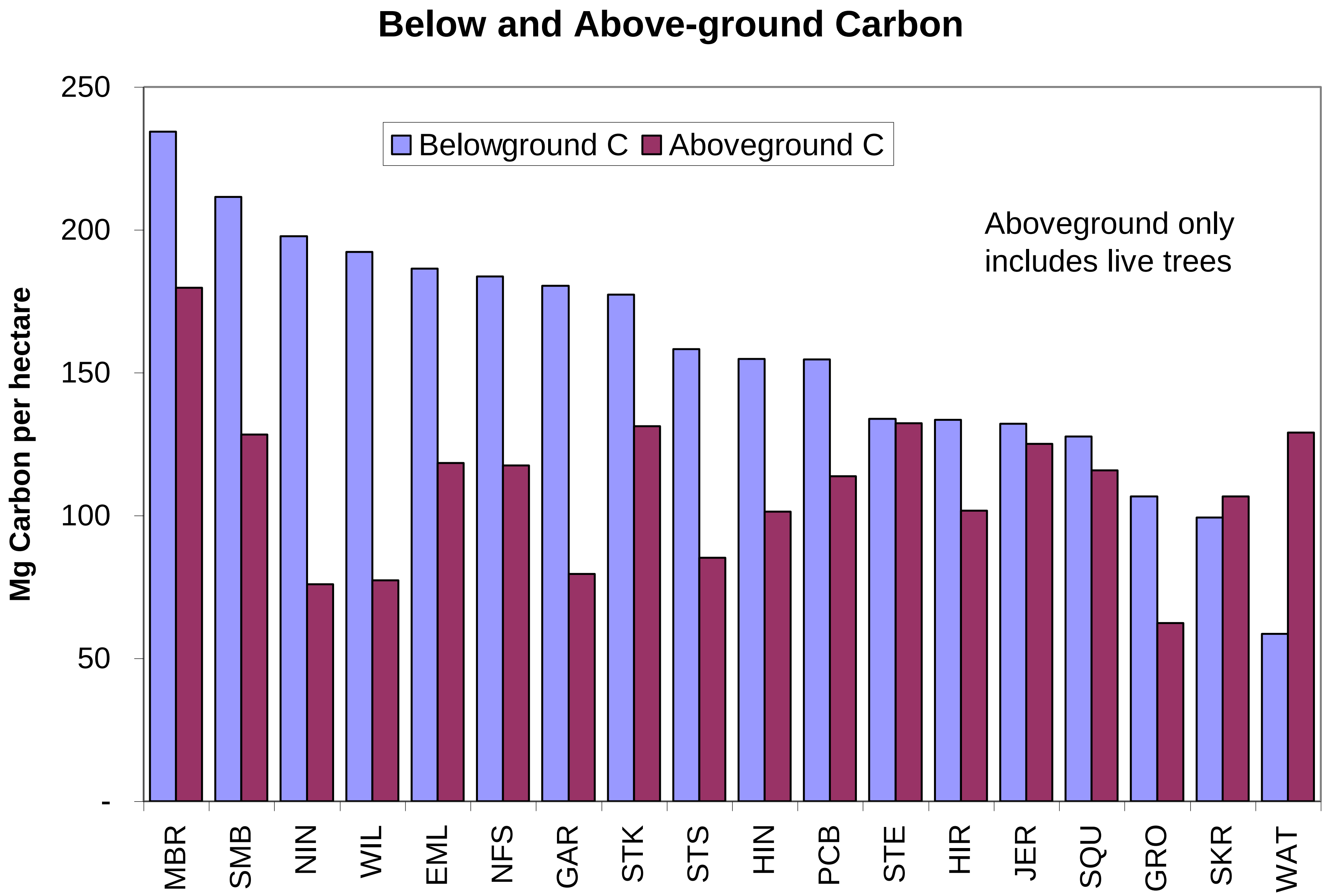

Results/Project outcomes

Factors affecting soil C accumulation

- Soil depth
- Elevation
  - Lower soil temperature at higher elevation
  - Decomposition slowed more than production
- Wetness (drainage)
- Time since disturbance
- **Time since land-use change** (farm to forest)

Stone Wall at NIN Coolidge State Forest

Outreach

Plant and Soil Science Department Newsletter: *The Tiller*, Volume 4, Issue 1, 2009

Website: http://www.uvm.edu/~soilcrbn/


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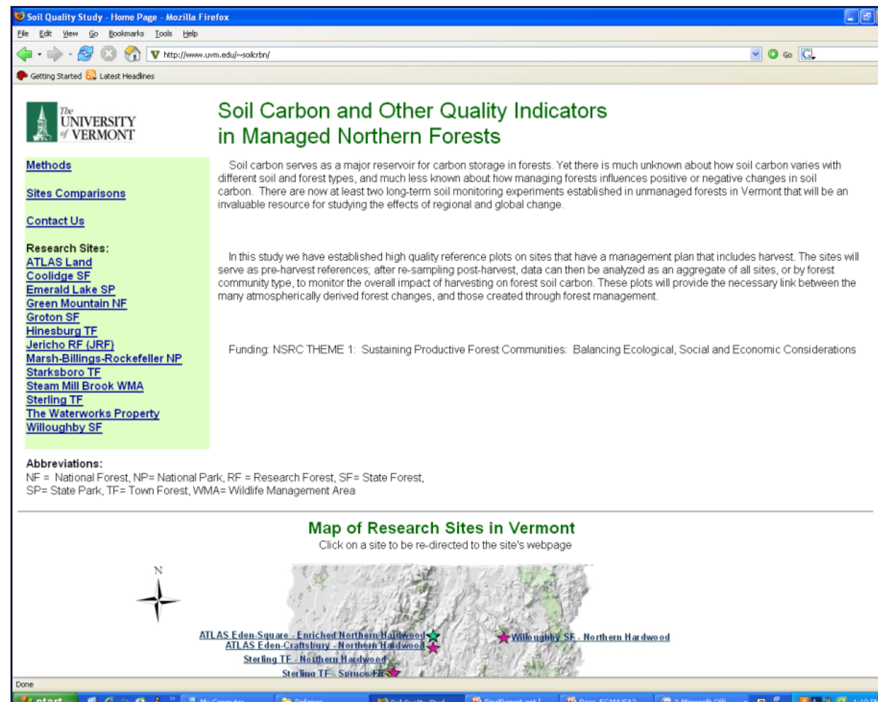
The Carbon Beneath Your Footprints

Juliette Juillerat and Don Ross preparing a sampling site

Soils around the world contain a vast store of carbon— more than currently in the atmosphere or tied up in living plants and animals. While not a cure for global climate change, enhancing and protecting soil carbon can partially offset atmospheric increases while also increasing soil quality. Vermont's forests cover about 80% of the state and a better understanding of forest soil carbon dynamics is needed. How much carbon is contained in a typical forest soil profile? How is it distributed with depth? What are the effects of timber harvesting on soil carbon stores? These questions are being addressed in a study conducted by Don Ross, PSS faculty, and Juliette Juillerat, PSS graduate student, along with Sandy Wilmot of the Vermont Department of Forests, Parks and Recreation. The focus has been put on state lands, federal lands, town forests, UVM's Jericho forest and parcels owned jointly by the Vermont Land Trust and the Nature Conservancy. Early results are interesting in that it appears that 'poor' sites that are wet may have more carbon than nutrient-rich sites that may be more productive for timber. A website (http://www.uvm.edu/~soilcrbn/) details the study and is being updated with results as they are tabulated. The plan is to revisit and resample the sites after timber harvest and examine any changes in soil carbon. A number of other soil quality indicators are being measured, including mercury, which is the focus of Juliette's thesis research. Mercury is an air-borne toxin that, while low in concentration, appears to accumulate in forest surface soils (associated with soil carbon). Several undergraduate

Jerome Barner, Chauncey Smith and Emily West arrive with edible reinforcements



Implications and applications in the Northern Forest region

- Some lower elevation sites, such at the Waterworks property, are relatively low in soil carbon and thus have a high potential for future carbon sequestration.
- The wide variation in carbon in the upper soil horizons (the zone most susceptible to harvesting impacts) suggests that management activities could have a wide range in impact.

Future directions

- Re-sample after harvest
  - Changes in carbon storage in soils depending on intensity of harvest
  - Changes in mercury deposition and concentration in the forest floor
- Influence of earthworms on forest floor depth

List of products

- Publications
  - Juillerat J. I., in preparation expected ready 12/2010
- Theses
  - Juillerat J. I., *Influence of Forest Composition on Mercury Deposition in Litterfall and Subsequent Accumulation in Soils, December 2010*
- Conference Presentations
  - ECANUSA, 2010
- Poster Presentations
  - Vermont Monitoring Cooperative, 2008
  - University of Vermont Student Day, 2009
  - American Geophysical Union, 2009, 2010
  - Goldschmidt, 2010
- Newsletter
  - Plant and Soil Science Department Newsletter, The Tiller, Volume 4, Issue 1, 2009
- Website
  - http://www.uvm.edu/~soilcrbn/