Ecosystem Responses to High-severity Wildfire

August 22, 2005 Final Report submitted by Steven Overby, RMRS, Flagstaff, AZ.

Vegetation Analysis

PI: John D. Bailey, Professor of Ecosystem Ecology, NAU

Pre-treatment (pre-burn) data from 2002, first year post-fire understory measurements in 2003 and second year post-fire measurements for 2004. We are still awaiting the remote sensing imagery for post-burn for comparison to pre-burn imagery. August of 2005 will be the last field exam of overstory mortality. We will be summarizing this winter (2005-2006), and plan to publish this data along with the soils data in spring of 2006.

Data and maps were furnished to the Regional Office (R-3) in support of planned salvage, which included a field trip for Region staff.

Soils Analysis

PI: Stephen C. Hart, Professor of Ecosystem Ecology, NAU

<u>Objectives</u>: The purpose of this agreement is to measure the direct effects of wildfire on soil properties from the Lake Fork site included in the Fire/Fire Surrogate study on the Jemez District. Pre-treatment soils data (2001) was collected at this site according to the FFS study plans. This gives us the chance to investigate wildfire effects on soil properties and microbial populations in a ponderosa pine ecosystem, given that we have pre-fire data from the same sites sampled after the fire. Therefore, the ecological consequences of large-scale wildfire can be contrasted to the ecological consequences of the fuels reduction programs that are planned for the FFS project.

<u>Methods</u>: Soil samples were collected following the wildfire in October, 2002 at the Jemez Mountains FFS sites as part of the ongoing plan to monitor ecosystem recovery and response following wildfire at the Lake Fork Site. Ion exchange resin cores were installed and soil samples were also collected in July, 2003. Resin cores and soil samples were collected again in October, 2003, June and October, 2004, and July of 2005 at the Jemez Mountains sites. Soil nutrient availability will be measured using ion exchange resin cores. Soil microbial functional diversity and biomass will be determined using the 0-5cm soil samples collected. The Virgin Mesa and Tusa Tank control and burn only blocks are used as controls since they have not been treated.

Soil microbial biodiversity and biomass: Laboratory assays on the ability of the soil microflora to utilize various carbon substrates and on soil enzyme activity were performed on mineral soil samples to determine the functional capabilities and diversity of the soil microbial community (Garland and Mills 1991, Sinsabaugh 2000). Biolog ECO plates are used to assess bacterial and actinomycete (prokaryote) diversity, while Biolog SF-N2 plates are used to assess fungal (eukaryote) diversity. Soil microbial biomass will be determined using the chloroform fumigation method on the soils collected in June and October, 2004, and July of 2005.

Soil nutrient availability: Post-wildfire annual rates of soil net N mineralization and nitrification are being assessed at the Lake Fork (post-wildfire), Virgin Mesa (control),and Tusa Tank (control) sites using the resin core method (Hart and Perry 1999), consisting of intact mineral soil cores capped at both ends by ion exchange resin (IER) bags (n = 20 per site). The top IER bag captures ions originating from the forest floor and/or atmosphere above the mineral soil core, while the bottom IER bag captures ions leached from the mineral soil contained within the intact soil core. The IER bags contain 30 mL of cation + anion exchange resin beads in a nylon stocking with a latex rubber tubing ring. The resulting bag fits tightly inside the top and bottom of a PVC pipe that contains the intact soil core. At each sampling point the forest floor is removed and a soil core is taken. The soil core is then placed inside the PVC pipe with an IER bag sealed on the bottom using silicone glue. Another IER bag is then placed on top of the soil core, and the forest floor that was removed is placed on top of the IER bag. At the same time another soil core and forest floor sample are collected and returned to the laboratory for determination of initial values of ammonium and nitrate. The PVC pipe containing the IER bags, the soil core and the forest floor is placed inside the hole left from removing the soil core. After a six-month incubation, the resin core is collected and returned to the laboratory for processing where the soil, forest floor and resins are extracted using 2 M potassium chloride. Three incubation periods have been completed (July, 2003 – October, 2003, October, 2003 – June, 2004, and July, 2004 – October 2004), and a fourth was initiated October 2004 and was terminated in July 2005.

A one-month laboratory incubation was also conducted on the Lake Fork and Virgin Mesa soil samples collected in October of 2002, 2003 and 2004. The purpose of the laboratory incubation is to verify that any differences in biological activity that we observe are indeed due to wildfire and not to differences in other environmental factors that occurred at this site between years (e.g., differences in precipitation). We also determined the size of the autotrophic nitrifier population using the Belser and Mays method (Hart et al. 1994) in these soils.

Sampling Design: Measurements taken have involved destructive sampling. Mineral soil samples (0-5 cm) for soil microbial biodiversity assessments are collected at the same location as the initial intact cores for the covered-core method. These measurements have been focused around the 10 vegetation-sampling modified Whittaker subplots (20 x 50 m) located systematically within each treatment plot. All measurements have been conducted within a 5-m zone surrounding the perimeter of the subplot (the exact point determined at random), with a 1-m buffer strip between this sampling zone and the vegetation subplots. This design minimizes the impacts of the destructive sampling on the treatment plots, as well allowing these measurements to be coupled with the aboveground vegetation measurements.

Status overview of Data: Data from one month following the wildfire (2002) has been analyzed and compared to the pre-fire data. These results have been reported in the presentations listed below. Data from 2003, 2004, and 2005 are being analyzed and compared to the pre-fire data in preparation for final manuscripts.

- Non-metric multidimensional scaling (NMDS) was used to analyze the carbon substrate utilization data, while standard ANOVAs were used to compare soil enzyme activity pre- and post-wildfire. We plan to also use NMDS to evaluate enzyme data.

- The eight enzyme activity levels that were measured using fluorimetry have been analyzed for the post-fire, Lake Fork site (2002). Only one enzyme, beta-1, 4-glucosidase, showed a decrease in activity after the wildfire (Fig. 1). N-acetyl-glucosaminidase and alpha-1, 4-glucosidase showed no change, while all other enzymes showed an increase in activity. Note that enzyme activity generally increased following wildfire.
- NMDS plots were produced from the carbon substrate utilization profiles obtained by the Biolog ECO and SF-N2 plates (Figs. 2 and 3). The data were analyzed using a multi-response permutation procedure (MRPP). The MRPP showed highly significant differences ($p < 0.0001$) between the pre-fire and post-fire data for both the ECO and SF-N2 substrate utilization patterns. Note that the substrate utilization patterns of the prokaryotes simplified following wildfire, while the eukaryote pattern diversified.

Wildfire Effects on Extracellular Activities

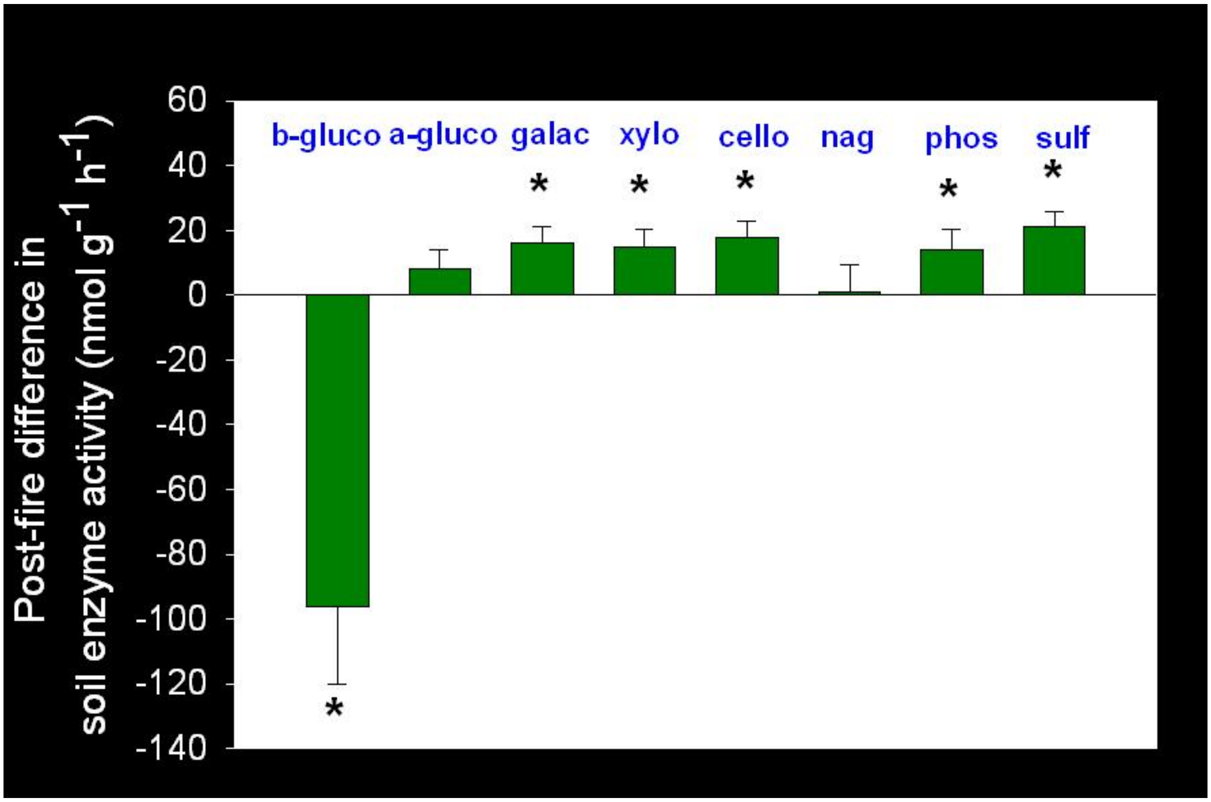

Fig. 1. Enzyme activity levels expressed on an oven-dry (105 ºC) soil mass basis for the mineral soil (0-5 cm) at the Lake Fork FFS site. Of the eight enzyme activities that were assessed, six were significantly different post-fire compared to pre-fire. Only one of these was significantly lower post-fire, B-glucosidase, which catalyzes the rate limiting step in cellulose degradation.

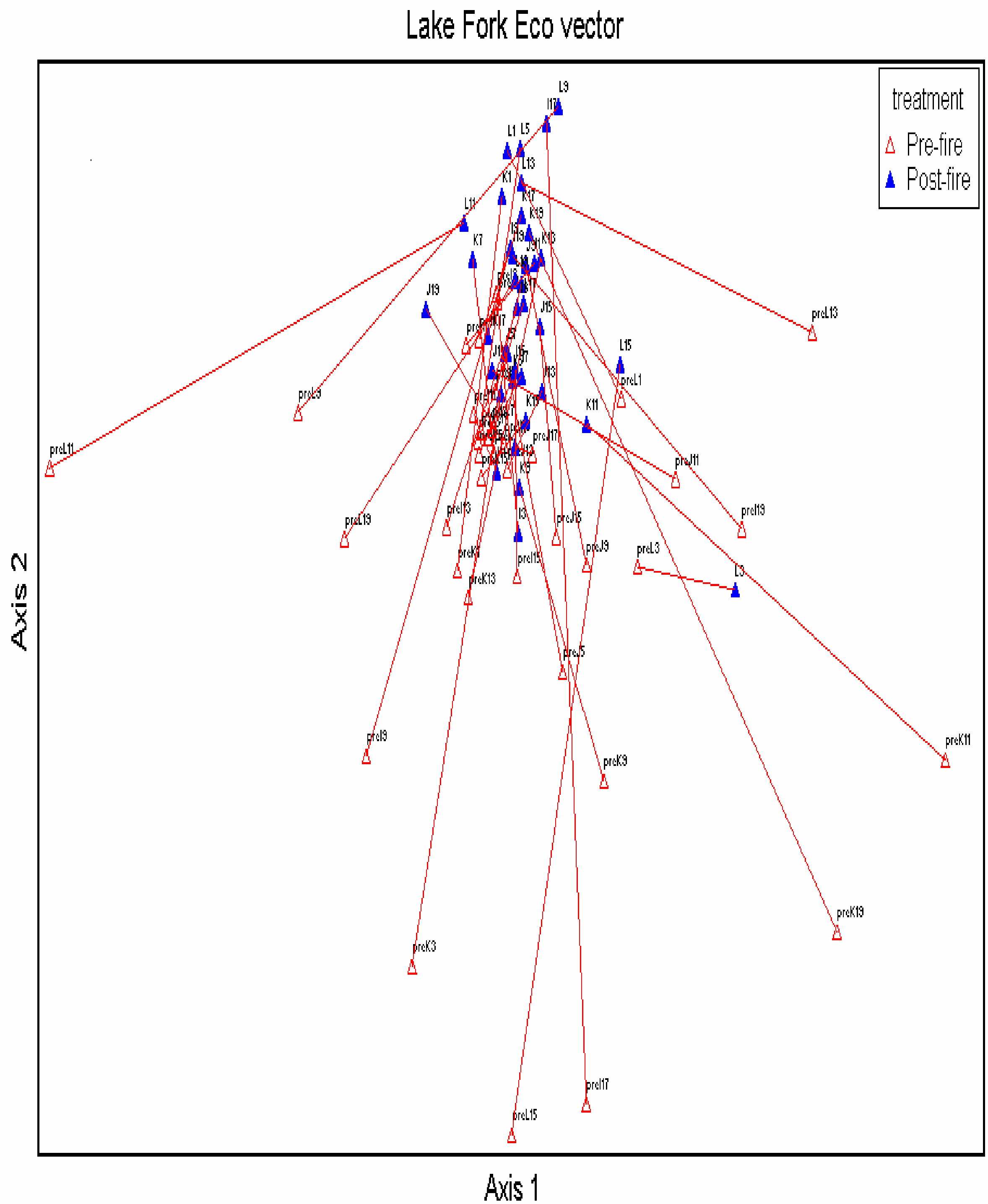

Fig. 2. Non-metric multidimensional ordination of carbon substrate utilization by prokaryotes (bacteria and actinomycetes) in soil from the Southwest Plateau Fire and Fire Surrogate Lake Fork site. There was a highly significant difference ($P < 0.0001$) between pre-fire and post-fire utilization patterns.

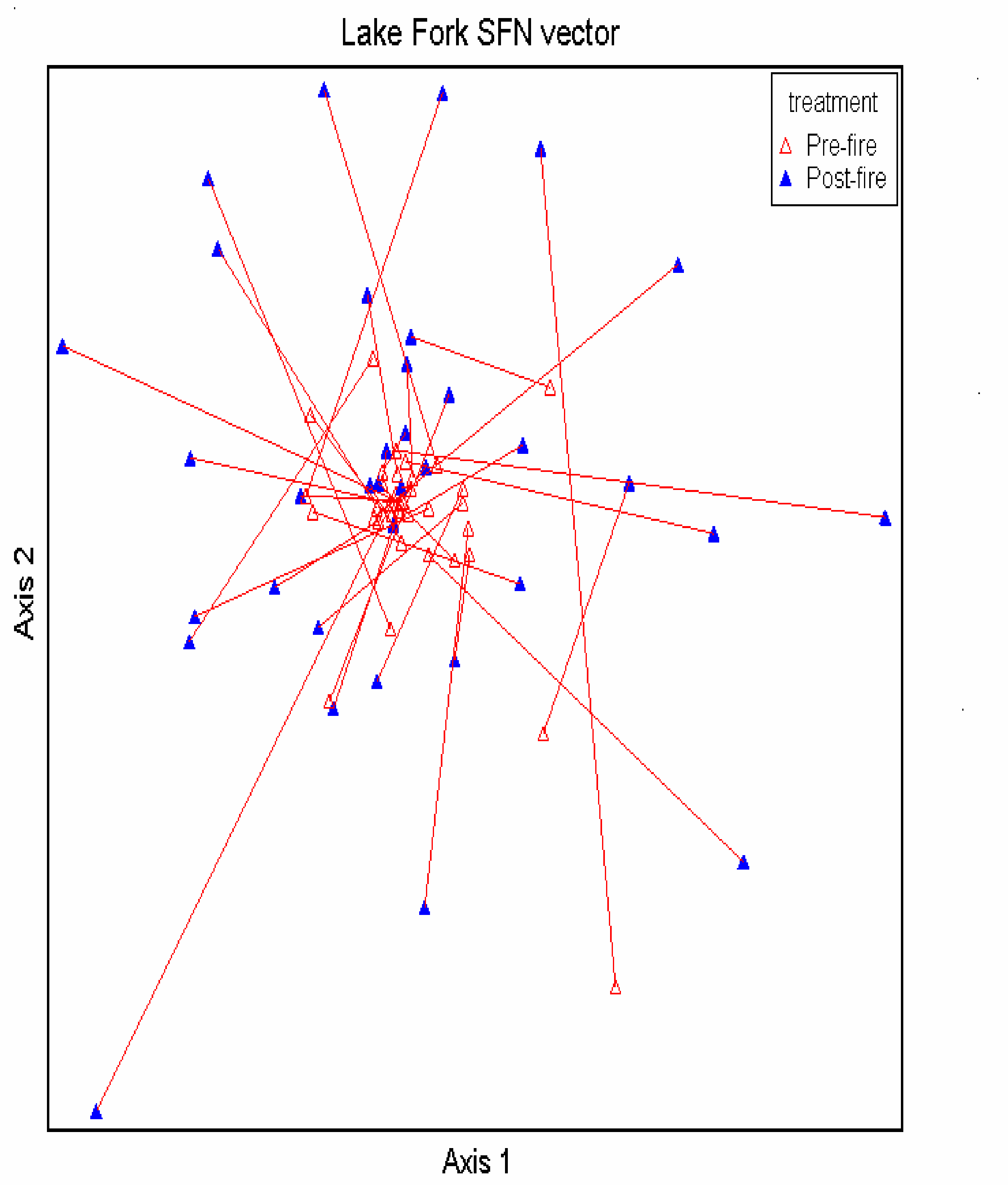

Fig. 3. Non-metric multidimensional ordination of carbon substrate utilization by eukaryotes (fungi) in soil from the Southwest Plateau Fire and Fire Surrogate Lake Fork site. There was a highly significant difference ($P < 0.0001$) between pre-fire and post-fire utilization patterns.

We did not find a statistically significant increase in net N transformation rates determined in situ one month following a high-severity burn. However, laboratory estimates of net N transformation rates did show increases, and these higher rates may be due to lower N immobilization owing to reduced C availability following the fire.

The difference in results between these two methods may be due, in part, to the fact that in situ estimates were made over the upper 15 cm of mineral soil while the direct effects from the fire were likely restricted to the upper few cm.

Soil extracellular enzyme analyses, community level physiological profiles, and laboratory estimates of C and N transformations suggest that there was a large change in the function of the soil microflora following a high-severity burn. Particularly surprising is the rapid apparent increase in the size of the autotrophic nitrifier population, a group of organisms that have been characterized as highly sensitive to heating and slow growing.

We plan to monitor changes in microbial function in this wildfire site relative to the unburned areas over time in the hope that we will gain additional insight of how wildfires alter the biology of forest soils.

Presentations

Title	**Location**	**Date**
Newman, G. S., S.C. Hart, D.R. Guido, and S.T. Overby. 2003. Wildfire effects on soil microbial activity and community-level physiological profiles in a ponderosa pine ecosystem. Presented at the Southwest Fire Initiative Conference.	Flagstaff, AZ	4/29/03
Newman, G. S., S.C. Hart, D.R. Guido, and S.T. Overby. 2003. Wildfire effects on soil microbial activity and community-level physiological profiles in a ponderosa pine ecosystem. Presented at the Soil Ecology Society Ninth Biannual International Conference	Palm Springs, CA	5/13/03
Newman, G.S., S.C. Hart, D.R. Guido, and S.T. Overby. 2003. Wildfire effects on soil microbial activity and community-level physiological profiles in a ponderosa pine ecosystem. Presented at the annual meetings of the Ecological Society of America.	Savannah, GA	8/03
Newman, G.S., S.C. Hart, D.R. Guido, and S.T. Overby. 2003. The impact of wildfire on soil microbial function. Presented at the annual meetings of the Soil Science Society of America.	Seattle, WA	11/01//04

Manuscripts

Hart, S.C., T.H. DeLuca, G.S. Newman, D.M. MacKenzie, and S.I. Boyle. *In press*. Post-fire vegetative dynamics as drivers of microbial community structure and function in forest soils. *Forest Ecology and Management*.

Newman, G.S., S.C. Hart, D.R. Guido, and S.T. Overby. *In prep. for September, 2005 submission*. Wildfire effects on soil microbial activity and community-level physiological profiles in a ponderosa pine ecosystem. *Soil Biology and Biochemistry*.

*note: The above manuscripts and any future manuscripts that pertain to the JFSP Lake Fork Wildfire study will be made available at http://www.rmrs.nau.edu/publications/.

Other Products

In progress: Presentation for the 8th Biennial Conference of Research on the Colorado Plateau at Northern Arizona University, Flagstaff, AZ   November 7 - 10, 2005. This conference provides an interdisciplinary forum for research and land management issues related to the biological, cultural, and economic resources of the Colorado Plateau. The theme of this year's conference is "Preservation and Restoration of Colorado Plateau Natural and Cultural Landscapes."

Literature Cited

Garland J and Mills A. 1991. Classification and characterization of heterotrophic microbial communities on the basis of patterns of community-level sole-carbon-source-utilization. *Applied and Environmental Microbiology* 57: 2351-2359.

Hart, S.C., J.M. Stark, E.A. Davidson, and M.K. Firestone. 1994. Nitrogen Mineralization, Immobilization, and Nitrification. pp. 985-1018 in Methods of Soil Analysis, Part 2 - Microbiological and Biochemical Properties - SSSA Book Series, no. 5, Madison, WI.

Hart, S.C. and Perry, D. 1999. Transferring soils from high- to low-elevation forests increases nitrogen cycling rates: climate change implications. *Global Change Biology* 5: 23-32.

Sinsabaugh S, Reynolds H, and Long T. 2000. Rapid assay for amidohydrolase (urease) activity in environmental samples. *Soil Biology and Biochemistry* 32: 2095-2097.