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THE INTERNATIONAL RESEARCH GROUP ON WOOD PRESERVATION

Section 2 Test methodology and assessment

CHEMICAL, PHYSICAL AND BIOLOGICAL FACTORS AFFECTING WOOD DECOMPOSITION IN FOREST SOILS

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Introduction

Organic matter (OM) decomposition is an important variable in forest productivity and determining the potential of forest soils to sequester atmospheric CO_2 (Grigal and Vance 2000; Kimble et al. 2003). Studies using OM from a particular location gives site-specific decomposition information, but differences in OM type and quality make it difficult to compare results among soils and forest ecosystems. By using a "standard" OM in decomposition studies, OM quality is held constant, and decomposition is a function of soil abiotic (moisture, temperature, O_2/CO_2, redox potential, pH, N, P, etc), and biotic (microbial biomass, functional diversity) properties. Wood is a good material to use in soil OM decomposition studies, since it is a normal soil component (woody residue, coarse roots), and a slow decomposition rate allows wood to remain in the soil for a number of years.

In 1998 a wood stake study was initiated in the U.S., Canada, and Europe to: (1) determine the effects of abiotic soil properties on wood decomposition, and (2) assess how these soil properties affect microbial activity and diversity during wood decomposition. These study sites represent a variety of climatic conditions and forest types, which are being extensively monitored for soil moisture, temperature, and CO_2/O_2 (Appendix A). Soil chemical and physical properties have also been characterized on each of these sites. Stakes of two tree species are used to contrast different lignin types present in wood: southern pine (*Pinus spp.*) and aspen (*Populus tremuloides*). Two test stakes are cut from each 2.5 x 2.5 cm x 70 cm Amother@ stake, and divided into tree ring and weight classes prior to field installation.

One problem encountered during this study was the widely different decomposition rates across our test sites. Initially we had only planned to use stake mass loss as the indicator of wood decomposition. However, decomposition rates are quite low in Finland, Switzerland (low temperatures), and British Columbia (low water) soils, so stake mass loss was not a useful parameter for comparing initial wood decomposition across our wide range of sites. A number of studies have reported that changes in wood physical properties can be a more sensitive measure of early wood decomposition than mass loss (Wilcox 1978; Smith and Graham 1983; Nicholas and Jin 1996). Consequently, the suitability of using a mechanical strength test to assess wood stake decomposition was also investigated.

Mechanical Strength Study

A 12 week study was established to determine which laboratory wood strength test would be best suited for assessing initial decay in our wood stakes: surface hardness, longitudinal shear strength, or transverse crushing strength. Sapwood boards of both aspen and southern pine (6 to 10 rings per inch) were cut into forty 2.5 x 2.5 x 30 cm (radial x tangential x longitudinal) stakes, which had growth rings oriented parallel to one longitudinal face. Thirty pine and aspen stakes were installed with the top level with the mineral soil surface in June 1996 at a test site near Hilo, Hawaii (mean annual temperature

- 74ºF, rainfall - 130"). The other ten stakes were used as unexposed controls. Five stakes of each species were removed every two weeks, and shipped immediately to Michigan Technological University for analysis. Each stake was air-dried, conditioned to equilibrium at 12% EMC, and marked into test samples (2.5 cm cubes) according to Figure 1. Sample blocks 1, 3, and 5 were used for hardness and longitudinal shear evaluations, while samples 2, 4, and 6 were subjected to the compression strength test.

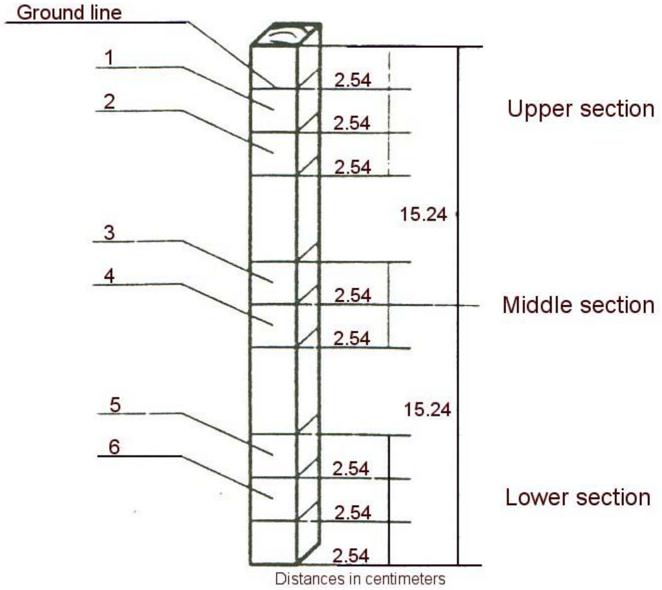
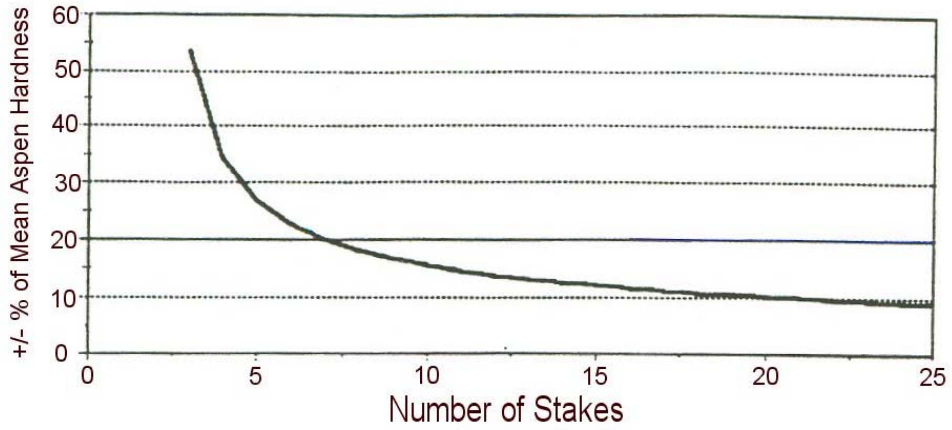


Figure 1. Position of strength properties sampling subspecimens within wood stakes.

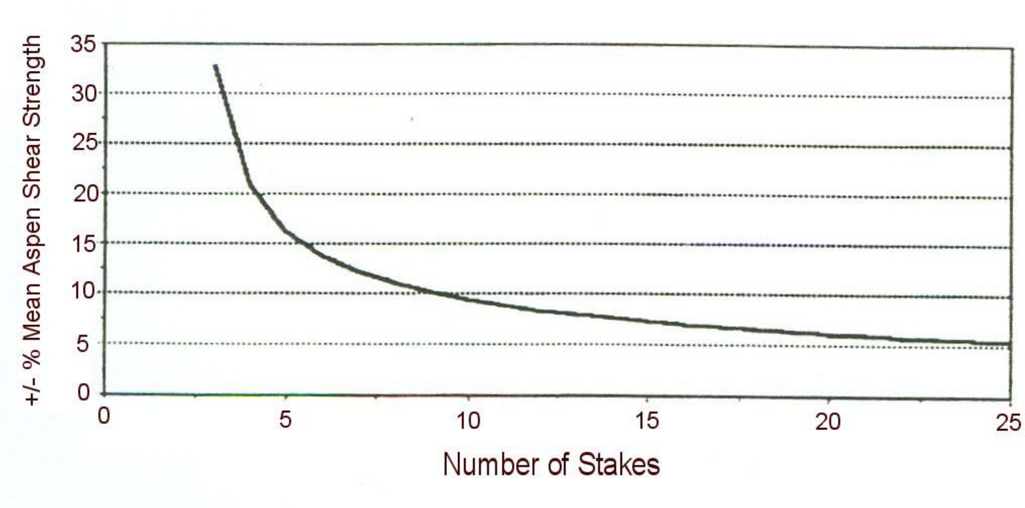
Surface hardness, shear, and transverse compression test procedures followed ASTM D-143 procedures. The hardness test was conducted before the test specimen cubes were cut from the stakes so that boundary effects could be minimized. A steel ball (1.13 cm in diameter) was used to determine hardness. The load was applied at a rate of 0.64 cm per minute, and recorded when the ball penetrated to one half its diameter on a tangential surface. Shear strength tests were carried out on notched specimens, which had the shearing surface measured before testing. Maximum load was recorded using a crosshead speed of 0.061 cm per minute. Transverse compression strength was determined by measuring the stress at 5 % compression strain in the radial direction applied at a rate of 0.03 cm per minute.

The variability observed in each of the wood strength property was used to estimate 95% confidence intervals as a function of sample size (Figure 2). Crushing strength had the lowest variability, and was also the most sensitive property to initial decay. Average crushing strength for aspen and southern pine sapwood stakes over the 12-week field exposure is shown in Figure 3. Wood strength values after twelve weeks exposure indicated that decay rates were highest near the soil surface, presumably due to more favorable soil temperature and moisture conditions (Donnelly et al. 1990; Zabel and Morrell 1992). Previous samplings showed no evident decay patterns, which may have been masked by density variations among individual stakes. To minimize this density effect, crushing strength values for the middle and upper stake sections were normalized to the lower section crushing strength (Figure 4).

a)



b)



c)

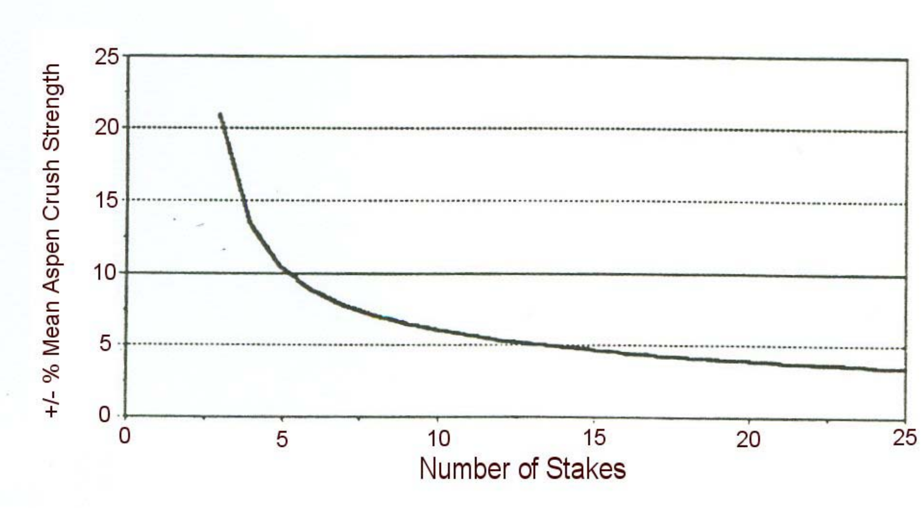
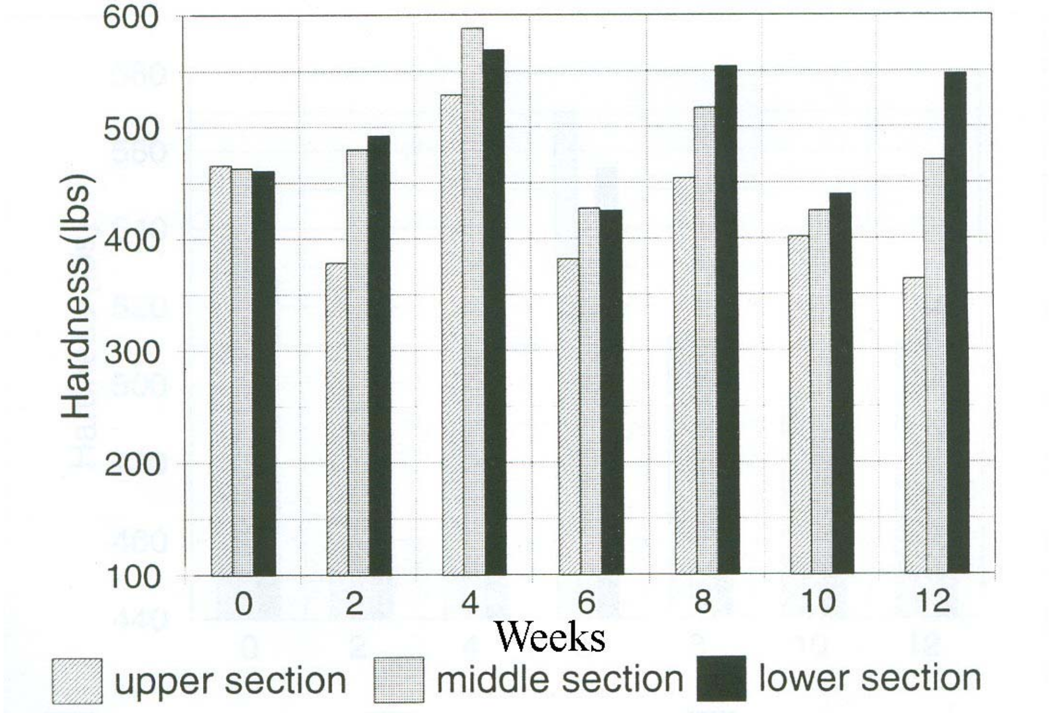


Figure 2. Estimated 95% confidence intervals expressed as a percent of the mean **a)** hardness, **b)** shear strength, and **c)** crushing strength for the upper sections of aspen stakes exposed for 12 weeks in Hawaii as a function of the number of sample stakes installed in the field.

a)



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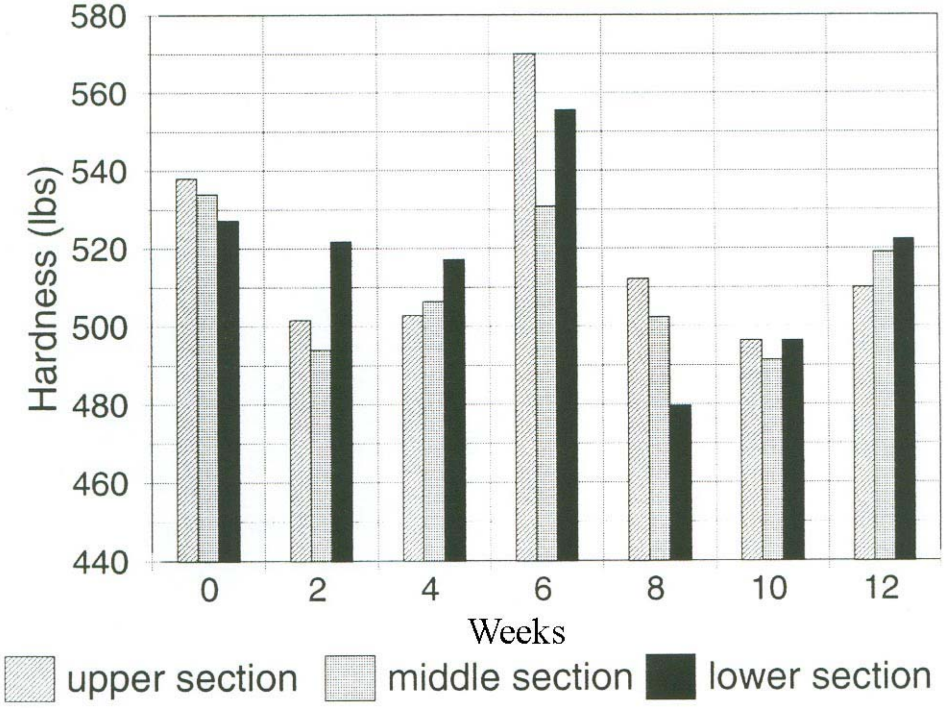


Figure 3. Average hardness of wood stakes at three soil depths over a 12-week period for: **a)** aspen, and **b)** southern pine.

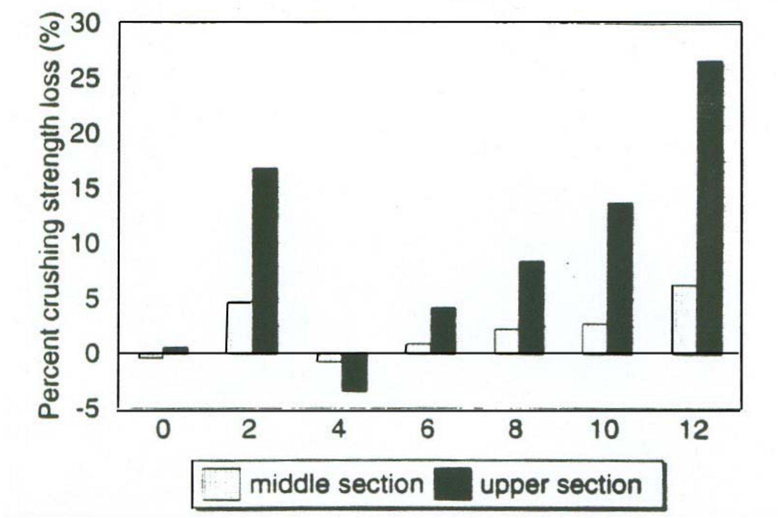


Figure 4. Mean crushing strength of upper and middle sections of aspen stakes normalized to the crushing strength of the lower section.

Except for the initial two week sampling, a progressive decay occurring in the upper section of the aspen stakes is evident. Higher lignin content in the pine stakes resulted in a slower decay rate, so that crushing strength loss was only apparent after 12 weeks, even under the high decay conditions in Hawaii.

The results of these tests showed that: 1) radial crushing strength is a better indicator of initial wood decay than surface hardness or longitudinal shear strength, 2) normalizing test results to an internal control reduces the inherent variability in wood strength properties, and 3) a minimum stake sampling interval longer than three months is needed.

Wood Stake Installation and Sampling

Fifty stakes of both southern pine and aspen are spaced 40 - 50 cm apart, and placed in the soil so that the wood stake is level with the mineral soil surface. In order to reduce soil compaction and damage to the stake during installation, each stake is placed in a hole made in the soil by a 2.5 cm square coring tool. The top of the stake is sealed to reduce moisture loss from the cut surface. Five stakes of each species are removed from test plots at periodic intervals, depending on soil temperature/moisture conditions at each study site. This sample size will allow us to estimate site mean crushing strength to within 3% (Figure 5). Over the five sampling periods, this design will provide a probability > 0.99 of detecting crushing strength reductions as low as 8% (Figure 6). The stakes are sent to the Institute of Wood Research at Michigan Technological University for compression strength testing, and to the USFS Forestry Sciences Laboratory, Moscow, Idaho and the USFS Forest Products Laboratory, Madison, Wisconsin for chemical analysis.

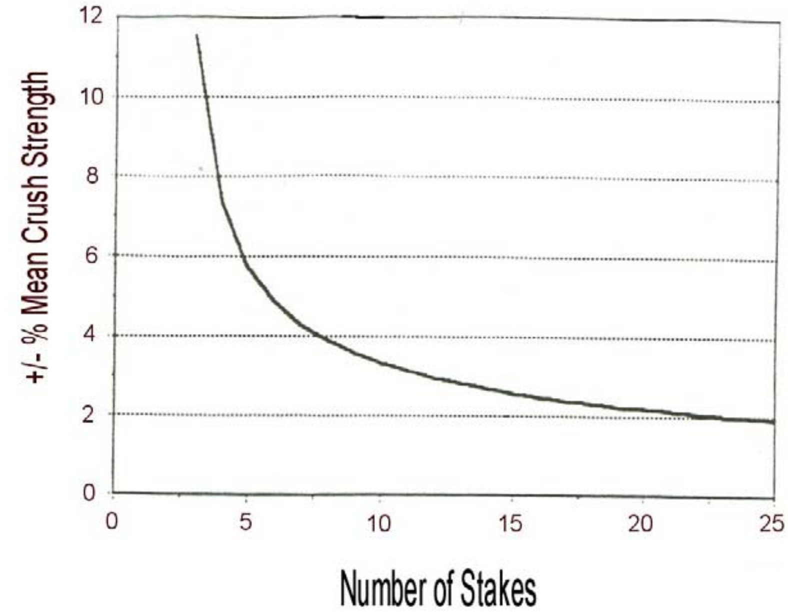


Figure 5. Predicted variability in mean compression strength for pine stakes as a function of replicate number.

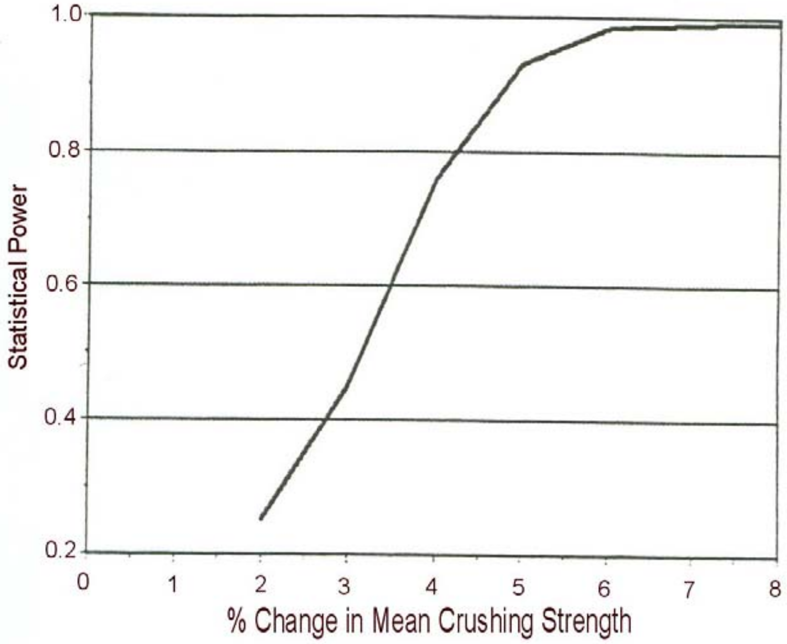


Figure 6. The statistical power (i.e., the likelihood of detecting a difference at alpha = 0.05) for different degrees of change in mean pine hardness.

Upon receipt of the stakes from the field sites, they are conditioned to 12% EMC, and cut into three 2.5 cm segments corresponding to 10 cm soil depth categories. The compression parallel to grain test (ASTM D 143 Sec 55-62) is used to estimate initial wood decomposition rates. After the compression test, all wood segments are dried at 105^o C and weighed. Selected blocks are then ground and analyzed for carbohydrates, lignin, C, N, P, and cations (Ca, Mg, K). Compression tests, dry weight measurements, and chemical analyses are also made on the 10 cm center segment of the mother stakes (control) to estimate initial field stake strength, weight properties, and chemical composition.

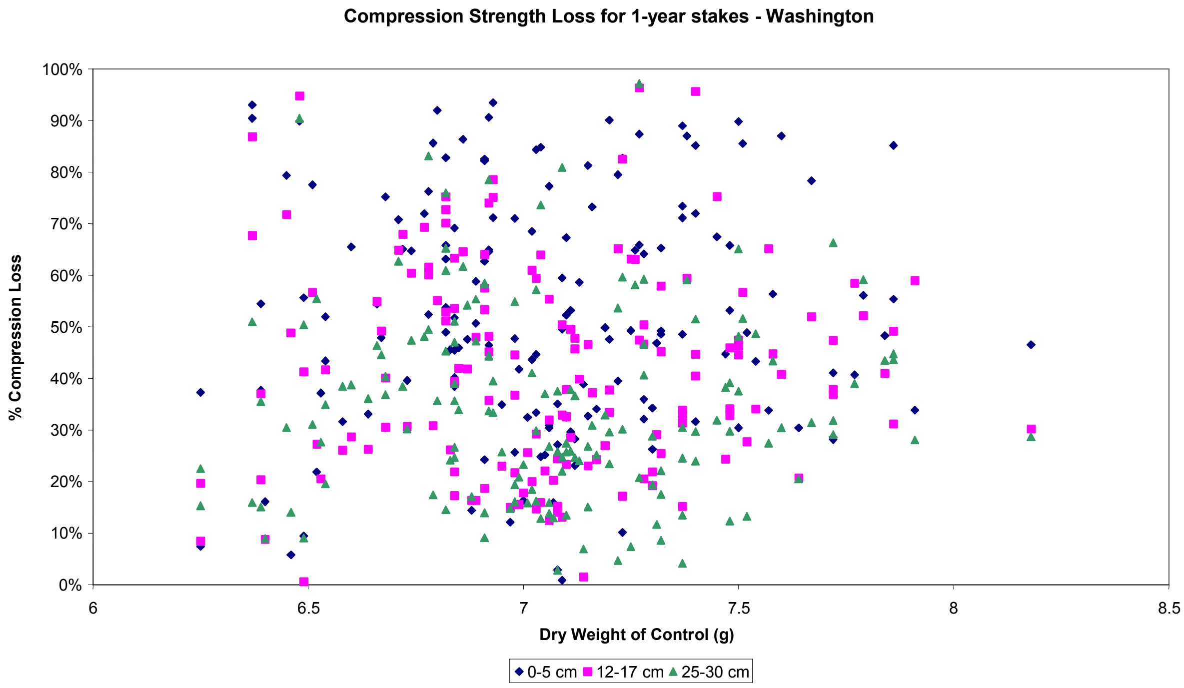
Preliminary Results

A comparison of compression strength loss to mass loss in both aspen and pine stakes showed wide variations. This poor relationship was not due to differences in initial mass of the individual test stakes (Figure 7), but may reflect differences in the microbial communities colonizing the stakes (Nicholas and Jin 1996). The radial compression test was a better indicator of early wood decomposition than mass loss. This was shown in a latitudinal gradient stake study conducted from northern Finland to southern Poland (Figure 8). Even after three years, the pine stakes in Finland show ed very little mass loss, but had significant reductions in compression strength. Wood stake mass loss generally increased as test site latitude decreased in response 'to warmer soil temperatures, but compression strength loss was still a good indicator of wood decomposition on all sites (Figure 9).

The relationship of compression strength and mass loss is shown for a study conducted in western Washington (Figure 10). Similar to pine in northern Europe, aspen stakes showed rapid compression strength loss, while mass loss was much slower. Aspen decomposition rates varied greatly, depending on their depth in the mineral soil and the forest management treatment applied. Lignin concentration in aspen stakes showed a steady increase over a two-year period, while cellulose decreased (Figure 11). Changes in pine stake lignin and cellulose composition were much less, reflecting the slower decomposition rate of softwoods.

The results presented here illustrate some of the information we are collecting from our wood stake decomposition study sites. Work is progressing on developing soil moisture and temperature decay curves for each of our soils, and how these relationships may vary according to soil chemical and physical properties. New test sites are being added to broaden the range of climatic conditions and soil properties in our database.
We are also planning to initiate studies on the effect of microbial biomass and diversity on the rate of wood decomposition under varying soil moisture, temperature, and nutrient conditions.

a)



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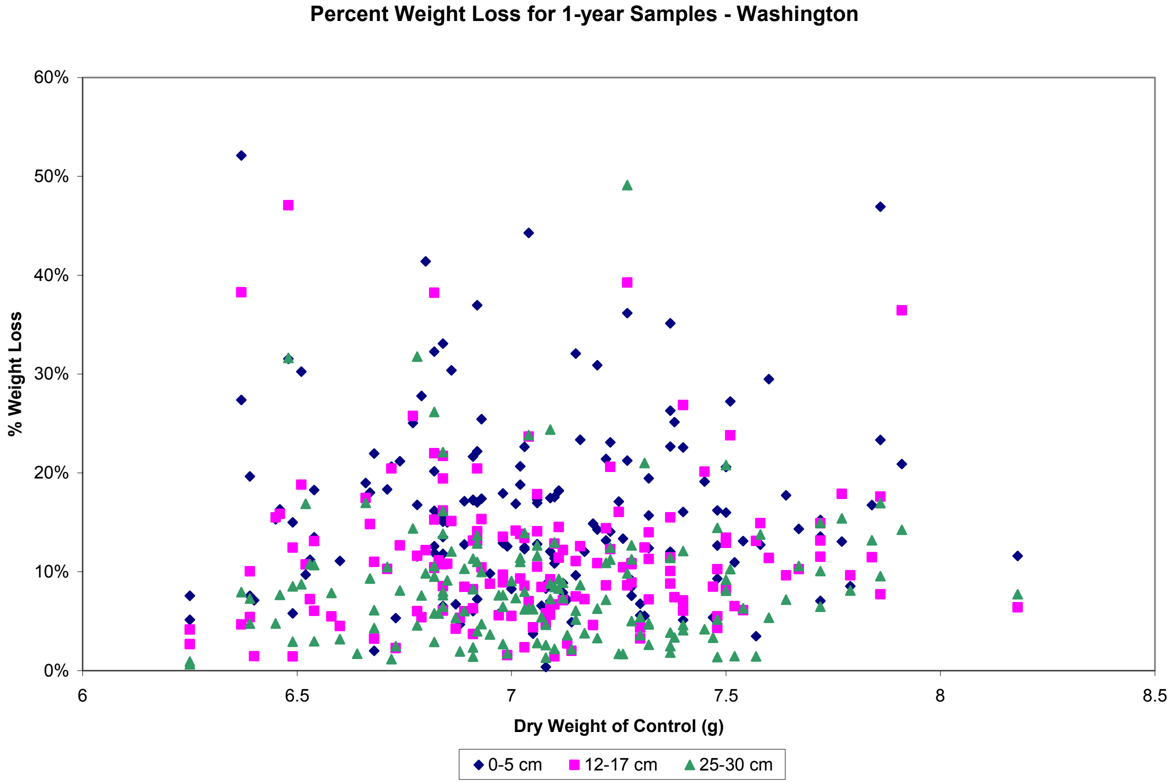

Figure 7. Percent loss of **a)** compression strength and **b)** weight by soil depth for 1-year stakes from western Washington.

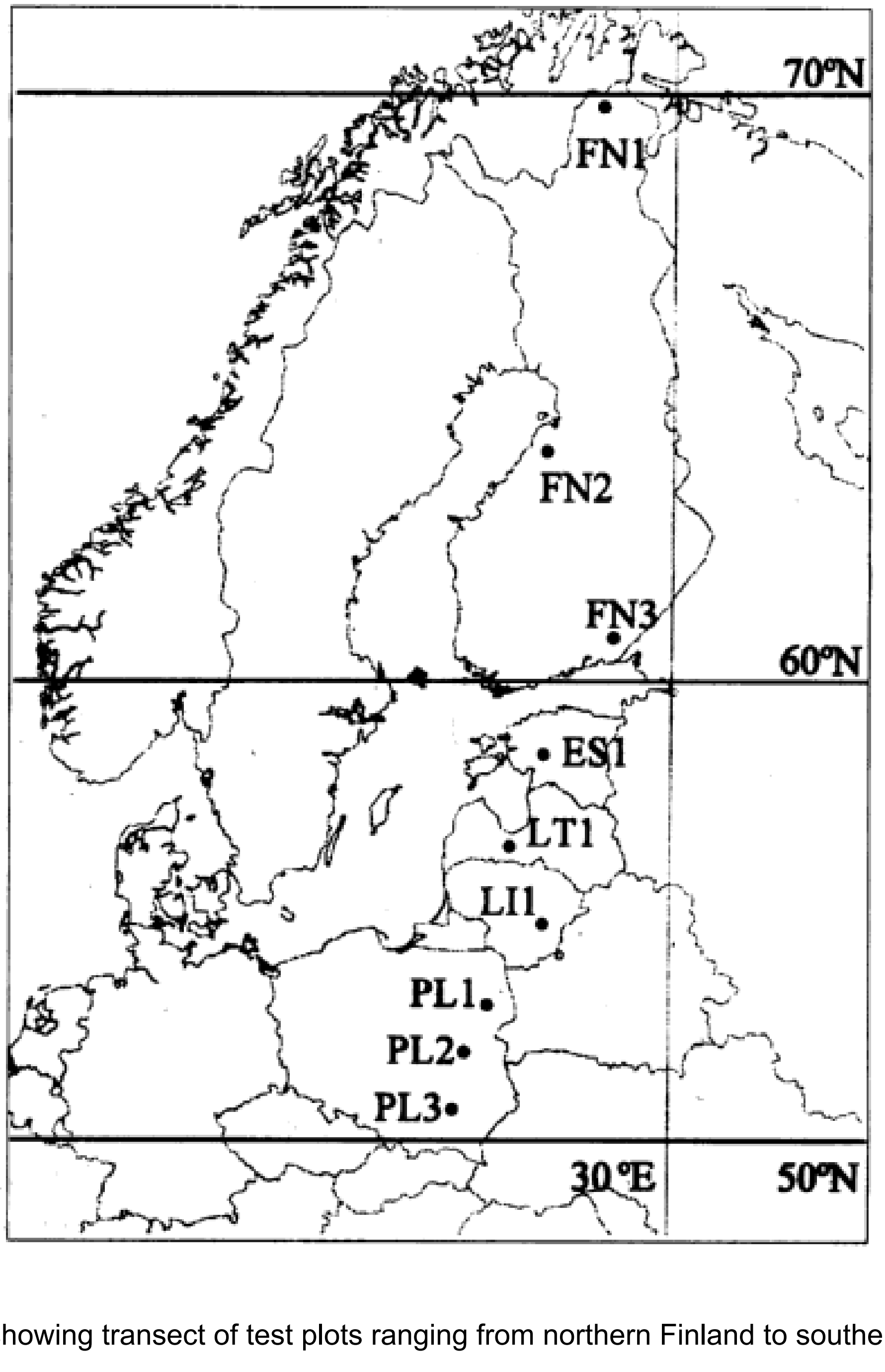

Figure 8. Map showing transect of test plots ranging from northern Finland to southern Poland

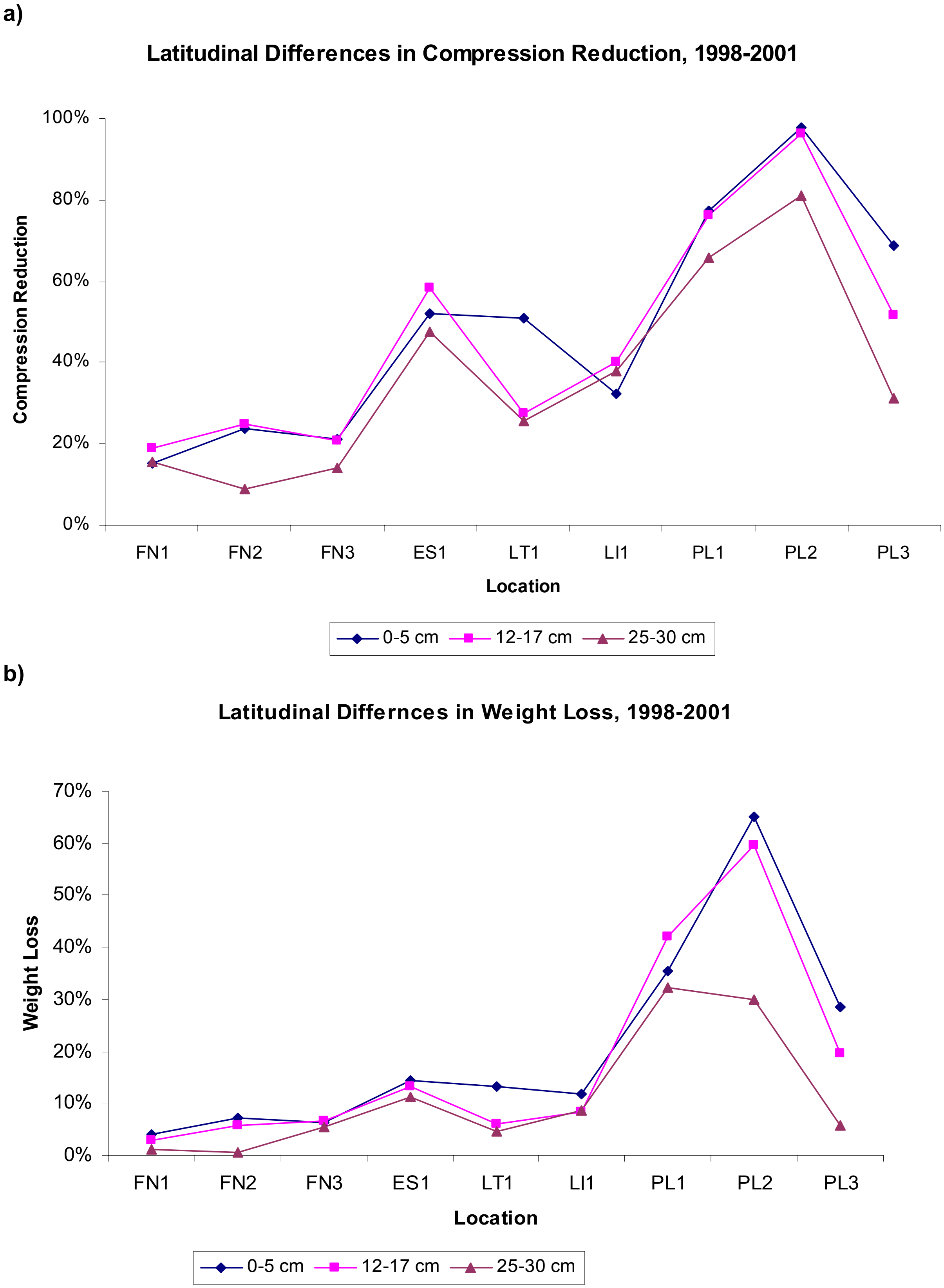

Figure 9. Loss of **a) compression** strength, and **b)** mass in pine stakes in Europe.

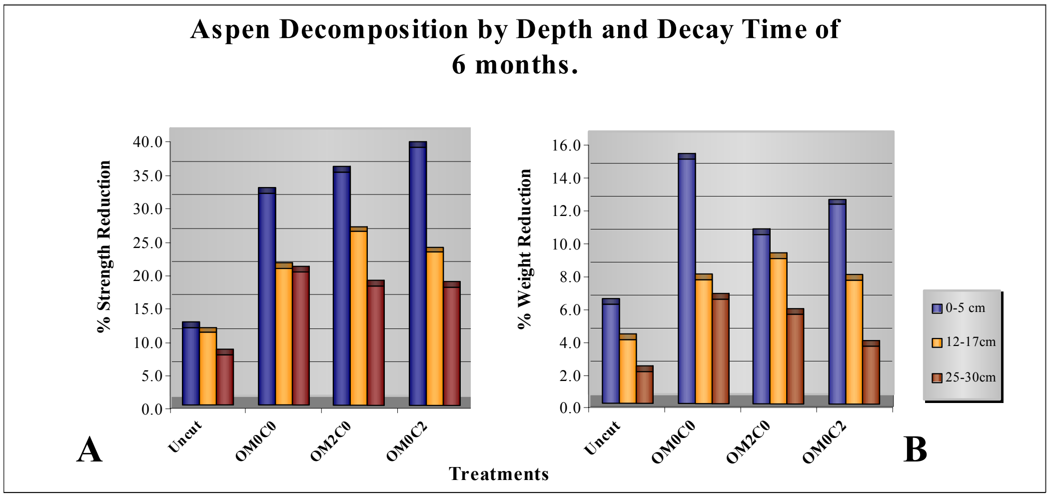

Figure 10 Aspen stake decomposition by soil depth and profile after 6 months, western Washington. (treatments: OM_0C_0 - no organic matter removal, no soil compaction; OM_2C_0 organic matter removal, no soil compaction; OM_0C_2 - no organic matter removal, soil compaction)

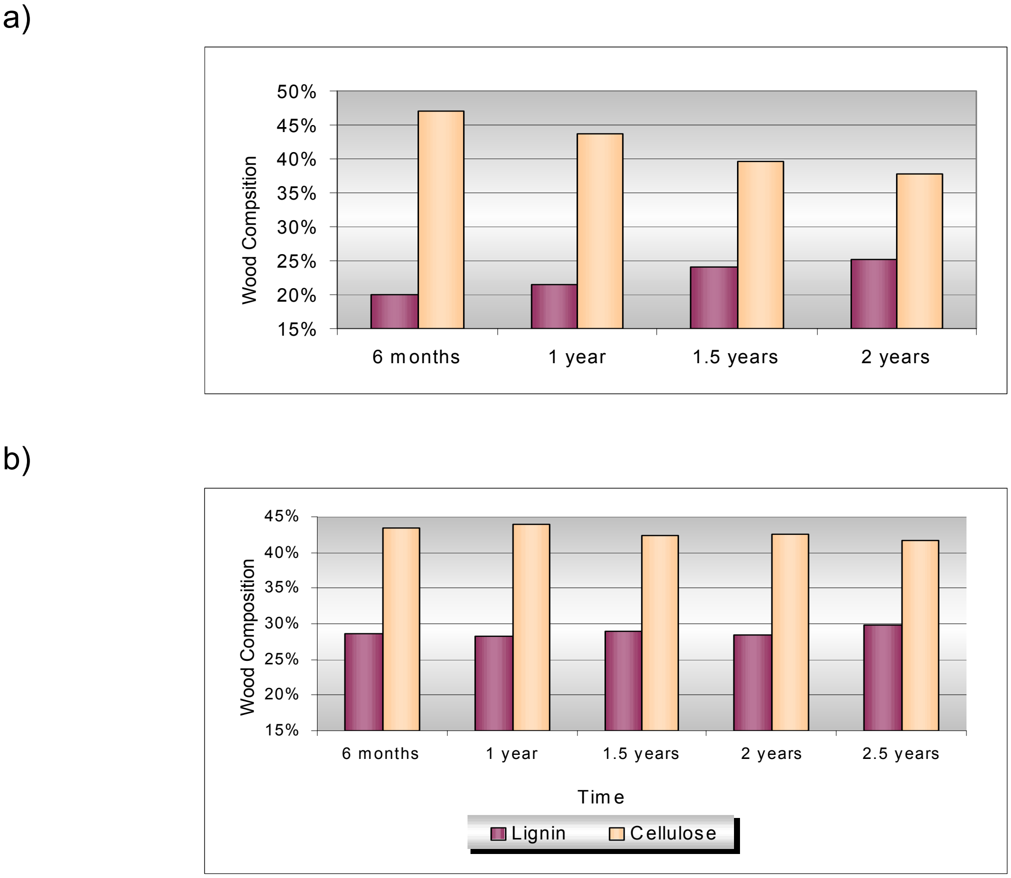

Figure 11. Lignin and Cellulose percent change in a) aspen and b) pine stakes from northern Idaho over time.

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Appendix A: Wood stake decomposition locations and principal cooperating investigator

United States
Arizona - Dan Neary, Rocky Mountain Station, USFS, Flagstaff, Arizona

California - Matt Busse, Pacific Southwest Station, USFS, Redding, California

Hawaii - Jack Jeffers, USFWS, Hilo, Hawaii

Idaho - Deborah Page-Dumroese, Rocky Mountain Station, USFS, Moscow, Idaho

Montana - Peter Robichaud, Rocky Mountain Station, USFS, Moscow, Idaho

Oregon - Deborah Page-Dumroese, Rocky Mountain Station, USFS, Moscow, Idaho

South Carolina - Phil Daugherty, Meadwestvaco, Summerville, South Carolina

Washington - Tom Terry, Weyerhaeuser Corporation, Centralia, Washington

Washington/Idaho - Jim Moore, Intermountain Fertilization Coop, Moscow, Idaho

Canada
British Columbia - Mike Curran, B.C. Ministry of Forests, Nelson, B.C., Canada

Ontario - Jim McLaughlin, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, Canada

Finland - Leena Finer, Finnish Forest Research Institute, Joensuu, Finland

New Zealand - Peter Clinton, Forest Research Institute, Rotorua, New Zealand

Switzerland - Martin Schütz, Federal Research Institute (WSL), Birmensdorf, Switzerland

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