Soil Erosion and Tree Root Response Along Hiking Trails in the White Mountains of New Hampshire

A study performed during the first North American Dendroecological Fieldweek, Pinkham Notch Camp, Gorham, New Hampshire

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Introduction

The objective of this study was to evaluate the feasibility of measuring soil erosion rates along recreational trails, in the White Mountains of New Hampshire, using dendrochronological techniques. Previous studies by LaMarche (1961,1963,1968) and P.Carrara (1979) have demonstrated that root response to exposure by natural erosion processes could be successfully used in calculating rates of soil degradation. In this study comparisons were made between erosion rates found on heavily used recreational trails and the "natural" erosion rate of the surrounding landscape. Quantifying the impacts of recreational use on forest ecosystems is an important aspect of land use planning. Knowing how much material is lost by activities such as hiking and skiing, recreational planners may develop better ways to protect their recreational assets.

The original studies that measured degradation rates using tree-rings succeeded because of three key factors that we believe are a direct consequence of geography and soil characteristics in the regions where the studies were performed. These are longevity of tree species studied, the formation of eccentric rings following root exposure, and the ability to accurately determine original ground level. Working with Bristlecone pine (P.aristata), a species capable of living for thousands of years, LaMarche was able to calculate long term erosion rates. Similarly, Carrara, studying Pinyon pine (P.edulis), demonstrated how intermittent changes in erosion rates could be detected and measured over the course of half a century. In the White Mountains of New Hampshire, trees growing along trail sides were on the average 180 years old. We assumed that due to recreational use, erosion rates would be greater on trails than off trails and that this accelerated rate would permit us to make use of younger, shorter lived, trees.

Earlier studies that measured degradation relied heavily on physical changes in root growth to date the timing of exposure. The most obvious is the formation of incomplete growth rings. Ring growth after exposure continues only on the buried side of the root (LaMarche 1963, 1968, Carrara 1979, Fayle 1968). The first occurrence of eccentric ring form marks when the root's surface was initially exposed. Measuring the distance from the top of an exposed root to the present ground level and dividing that distance by the number of eccentric rings, the rate of soil removal is calculated. As the root continues to grow new rings on the buried side, the distance representing the amount of material lost due to degradation, is not affected. In all the exposed roots we examined, our findings indicate the opposite. Root morphology appears to be directly affected by exposure but in the opposite direction. Once the soil covering has been removed, root ring formation on the exposed surface increases. The wood formed after exposure above the ground level resembles stemwood more in character than root wood. The implication of this finding is that as the soil is being removed from the surface by degradational processes, the root itself is growing upwards, thus obfuscating erosion rate calculations.

The third factor enabling erosion rate calculation using tree-rings stems from the character of tree rooting habit and root initiation. LaMarche (1963, 1969) and Fayle (1968) both describe a phenomenon called "Buttress root" formation, as the establishment of major lateral roots that structurally support a tree. Such roots begin growth from root initials just under the ground surface.

The point on the stem, below the basal swell and level with the axis of a buttress root, is considered the "original" ground level at the time of root establishment. Determining the ground level at the time of root establishiment is critical in the calculation of natural erosion rates. Dividing the distance from the original ground level to the current ground level by total root age, natural degradation rate is calculated. Our examination of tree rooting habit revealed that in this region normal root development begins from an exposed condition making it very difficult to determine where the original ground level was at the time of root initiation. The implication of this finding is that "natural" degradation rates computed by the above technique in this region would be questionable due to the difficulty in locating the original ground level.

Because of the problems found in using the techniques of others, to measure degradation rates along trails using tree-rings, our group developed an alternative technique, one that relied on dating the reaction of trees to injury. Dating the first occurrence of barrier zones in exposed roots in the trail, formed as a result of injury (Rademacher et.al 1894, Tippett, Shigo 1981), we were able to determine when the first travelers passed over a root. We assumed roots that crossed the trail and emanating from the trail walls were exposed by trail erosion. Measuring the distance from the top of such wounds to the present trail level and dividing this distance by the number of years since injury we estimated trail erosion. We did not establish an alternative technique by which natural erosion rates could be measured. For the purpose of demonstration, we tried to make some estimate of natural degradation using the technique described by LaMarche(1966). Choosing two trees growing beside the trail with roots which were damaged by hikers we strung a transect between the point on the base of each tree presumed to be the "original" ground level. The amount of material lost due to natural degradation was considered the distance from this transect line to the top of a the first wound made by hikers. The timing of this first wound had to coincide with the date the trail was established. Total natural erosion was calculated by dividing the distance from the transect line to the top of the wound by the total age of the root at the time of first wounding. Comparing the two computed rates of erosion, natural and that due to hiking, the results do reflect an increase in the rate of erosion, possibly due recreation (table 1).

Table 1.

	Natural Erosion Rate	Trail Erosion Rate
Transect # 1:	0.129 cm/yr	0.75 cm/yr
Transect # 2:	0.124 cm/yr	N/A
Transect # 3:	0.19 cm/yr	0.66 cm/yr

The last aspect of our trail study involved a Kreiging analysis of growth patterns before and after trail establishment. From a sample of 20 trees, ten growing beside the trail and ten growing off the trail, increment cores were taken at breast height. All cores were cross dated and ring-width measurements made of growth rings for years where there was no expected growth tendency. By analysis of varigrams we found that during the years 1950, 51, 52, 64, and 1965 there was no difference in growth between the trees growing off the trail and the trail bound trees. After trail construction in 1978 the varigrams computed for the years 1978, 80, 81 and 85 showed a distinct difference between the two samples. This analysis suggest that factors effecting growth for both samples changed after the trail was established.

The result of this study leads us to believe that dendrochronological techniques can be used to quantify some of the ecological impacts of recreation in New Hampshires forest, although the methods developed by others to measure erosion using tree-rings are not necessarily applicable in Northern New England. Factors pertaining to geology, micro-site topography and quite possibly lower base erosion rates, cloud clear interpretation of root ring form. Our study suggested the existence of specialized root shapes that may be a physical response to structural pressures involved in supporting a tree growing on very shallow, unstable soils.

This study involved the use of cross dating, master chronology development, ring-width measuring and computer analysis techniques which are all essential to the proper interpretation of tree ring data. There are certainly many more questions that could be asked in future experiments. For instance, the question of how root development is effected by soil structure and exposure is one which we feel needs further study. Our examination of one trees complete root system suggests that root growth in an air limited environment may be very different than growth in a moisture limited environment. Under mesic conditions, exposed roots may actually adopt a bimorphic growth form where the above ground portion takes on a morphology akin to stemwood while the remaining below ground portion maintains a true rootwood character. This would be a possible topic for future study. Our study demonstrates some merit in using dendrochronological methods to answer soil erosion questions.

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Title: Forest History group of the dendroecological fieldweek

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Project Goals: Determine the forest dynamic events in a well-developed spruce-fir forest and if possible compare with a forest with a known history of cutting. Also supplement tree-ring analyses with compositional and dead wood inventories. Finally to see if a small group could complete appropriate sampling in an field week setting.

Methods: Coring of all {28} red spruce trees on a 20 X 25 m sample plot in Tuckerman Ravine, N.H. Determination of age and major release events of all cores in the laboratory. Also a mapping and inventory of all living, dead standing and downed dead wood on the same plot. These data were brought together in map form to determine the location and date of release/cutting or gap formation events.

Results: We only sampled one plot, but found in this relatively undisturbed location evidence of minor cutting some 70 years previously. The group worked well, and despite limited time and experience completely addressed our original purpose.

Conclusion: just that. Extention of this methodology in any area should be profitable in elucidating its history as well as informative to participants on the use and limitations (can't tell all) of tree-ring analysis. It also used a low-level technical approach (only disceting scopes and tree corers needed) to use tree ring data.