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The applicability of roots in Dendrogeomorphology

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Introduction

The possibilities to reconstruct recurrence frequencies of geomorphical processes using dendrochronological methods are limited, due to the fact that most analyses focus on growth reactions in the stems of directly influenced trees. Frequent perturbations of the root system of a tree by erosive processes in most cases only can be analysed if they cause specific growth reactions in the trees' stem (e.g., Bégin *et al.* 1991). With the exception of age determinations of adventitious roots for the purpose of reconstructing past debris-flow events (Strunk 1995), roots have hardly played a role in geomorphological studies.

Dendrochronologists have only sporadically used the total age of exposed roots to quantify soil erosion (e.g., Eardley 1967; LaMarche 1968). Efforts to determine exposure-related diagnostic anatomical features in the growth rings of roots (Fayle 1968) have shown the potential of root studies for the field of dendrogeomorphology. However, so far all attempts have failed to identify diagnostic anatomical features with which the first year of exposure can be dated accurately. The research presented here is based on Fayle (1968) and more recent studies (e.g., Carrara and Caroll 1979; Danzer 1996; Krause and Eckstein 1993; Morneau and Payette 1998). It is focused on the analysis of wood-anatomical variations in the annual growth rings of coniferous roots caused by exposure due to geomorphical processes, and explores the possibilities of determining and dating anatomical changes in exposed roots as well as their significance for the estimation of erosion rates.

Material and methods

In order to get a firm grip on the diagnostic features related to root exposure, first the so-called "common structure" of growth rings of buried roots has to be determined. For this study, root samples were used from different depths below the soil surface. The samples were derived from a wide variety of sites in Germany and Switzerland. The large size of the original data set enhanced the possibility to exclude (or include) side specific influences to the shape of structural variations. The sampling strategy involved geomorphological mapping of each study area as well as the detailed documentation of the position of the exposed and unexposed roots. In this manner it is possible to determine the process causing root exposure (Gärtner 2001). The study was restricted to conifers (*Larix decidua* Mill., *Picea abies* (L.) Karst., *Pinus cembra* spp. *sibirica*), because in most cases the growth rings in the roots of coniferous trees are clearly visible. Discs (i.e. cross sections) were taken of the exposed and buried roots at a minimum distance of ca. 50 cm from the stem, in order to exclude disturbances caused by the proximity of the stem.

After the discs were dried and sanded (using a 100 to 600 grid), their age was determined. Macroscopic features (e.g., occurrence of tangential rows of resin ducts, changes in latewood characteristics) were documented. To analyse cell-structure variations within the growth rings, thin cuts were taken using a sledge microtome. A detailed description of the preparation of cell-structure analysis can be found in Schweingruber (1978).
To visualize the cell structure, monochromes were taken from the prepared samples. These photographs were digitised for the purpose of analysing features such as the number of cells per growth ring and the ratio of earlywood (EW) and latewood (LW) cells. A LINTAP measurement device was used to measure ring width as well as the dimension of cells (length of cells in radial direction, width of cells in radial direction). Cell size was calculated by multiplying the length and width of cells (Gärtner et al. 2001).

Results

For getting a firm bases to determine diagnostic features related to root exposure, the so called "common structure" of growth rings of buried roots had to be analyzed.
This analysis concentrated on roots sampled at different depths below soil surface. The buried roots of all studied species show significant growth variations, related to their distance to the soil surface (Fig. 1). Roots growing more than 15 cm below soil surface show the "typical" root structure (Fig. 1, left). Growth-ring boundaries are indistinct (mostly one row of latewood cells only), the different growth layers are often distorted, and wedging rings are frequent.

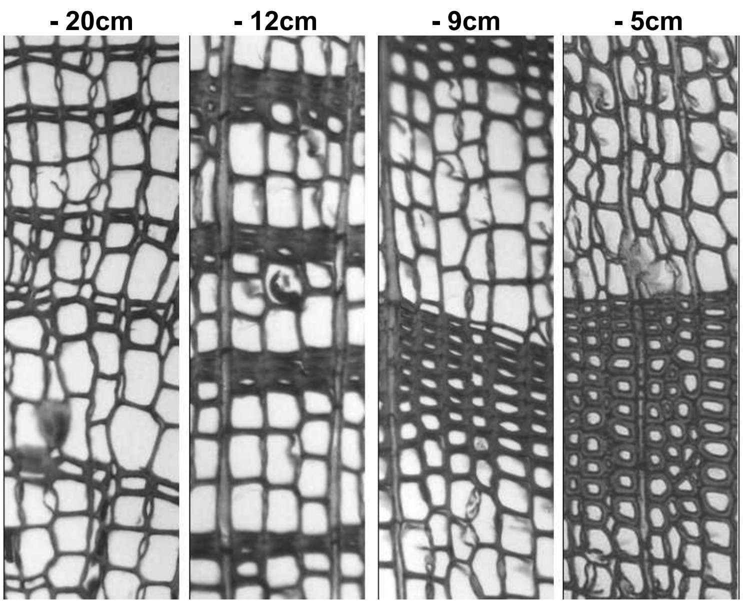

Figure 1: Differences in cell structure of buried Larix decidua roots regarding their distance to the soil surface (-20 to -5cm). Source: Gärtner 2001, p.52.

The closer the position of the root to the surface, the more distinct the growth rings become. The number of cells in EW and LW increases and cell-wall thickness (mainly in LW) increases as well.

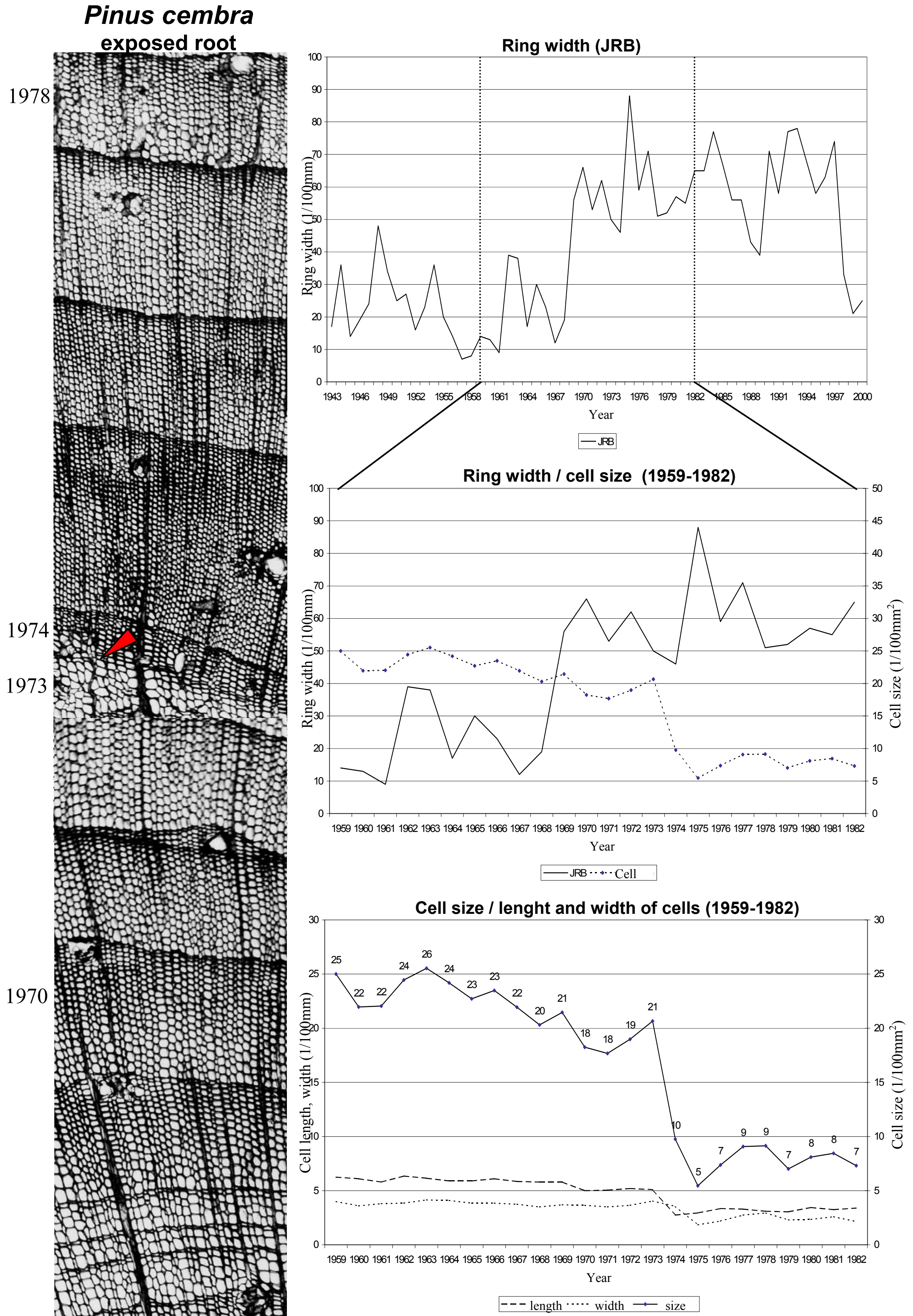

Figure 2: Cross section of an exposed Pinus cembra root and related diagrams of ring width (1), cell size changes (3) and a comparison of ring width and cell size changes (2). The root was exposed in 1974. The arrow indicates callous tissue that leads to a resin pocket (not visible) on the left. Source: Gärtner, 2001, p. 77.

The cell structure of roots growing near the soil surface closely resembles the structure of stem wood. Given the fact that the studied roots have never been exposed, this shows that such a structure should not be interpreted as a sign of exposure. In addition, it means that we can exclude the influence of light as a main cause of similar changes in the cellular structure of exposed roots.

The analyses of exposed and buried roots shows that there is no fixed time interval required for a change of the structure of exposed roots; I noted a wide variety of gradual and rapid changes. However, I did find a feature in the cell-size variations of exposed roots that can be used to diagnose the time of first exposure. This feature, occurring in the exposed roots of all studied tree species, consists of a size reduction of EW cells of ca. 50% or more (Fig. 2). This striking, enduring change in cell size only appears in exposed roots and is restricted to the exposed parts of the roots only. Buried parts of the same roots do not show this feature. Although a species such as *Pinus cembra* in general develops a rather low content of latewood cells, meaning that the stem-like structure in general is not as distinct as it is for other tree species, even the exposed roots of this species show this 50% reduction (Fig. 2).

Discussion and conclusion

There are significant differences in root anatomy, caused by different kinds of erosive processes. Taking into account that root structure also differs according to the distance to the surface, the study of roots is not limited to determining the date of their initial exposure. A combination of the variations and additional features present in root structures, such as the appearance of reaction wood, enables the reconstruction of the changing conditions over time that resulted in root exposure.

In general, specific anatomical features can be related to (i) sudden erosive events causing an immediate and complete change of the size and shape of EW and LW cells, and (ii) continuous denudation causing a gradual change of LW cells first. Although the causal factors are still in part uncertain, these changes are not randomly distributed in the growth rings. We are even able to discern the type of exposure from the root structure.

At about 5 cm beneath the soil surface, growth rings appear “stem like”. This implies that a stem-like shape of the growth rings in roots can no longer be interpreted as a sign of exposure. Furthermore, the notion that light is the main factor causing anatomical changes in roots has become questionable.

Many uncertainties still exist concerning the degree of influence of some environmental factors on the growth of roots. However, the analysis of root structure in relation to the distance to the soil surface offers new and exiting possibilities for the reconstruction of e.g. soil erosion.

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