Quantifying rockfall hazards through injury counting on the bark of trees

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Motivation: classic tree-ring analyses are very time consuming

Rockfall is very common in mountains but data on past events is only sparsely available. Tree-ring analysis of conifers (e.g. Norway spruce) has been used repeatedly to date historic events with (sub-) annual resolution. However, while being very precise, this "classic" approach is also labor-intensive and time-consuming. It includes fieldwork a n d laboratory analysis of wood samples as injuries are usually masked within a few years and can no longer be detected on the bark (Fig. 1B). In contrast, injuries stay clearly visible on the bark of Common beech (*Fagus sylvatica*). The purpose of this study was to check whether rockfall activity could be quantified by counting injuries on the bark of beech trees (Fig. 3).

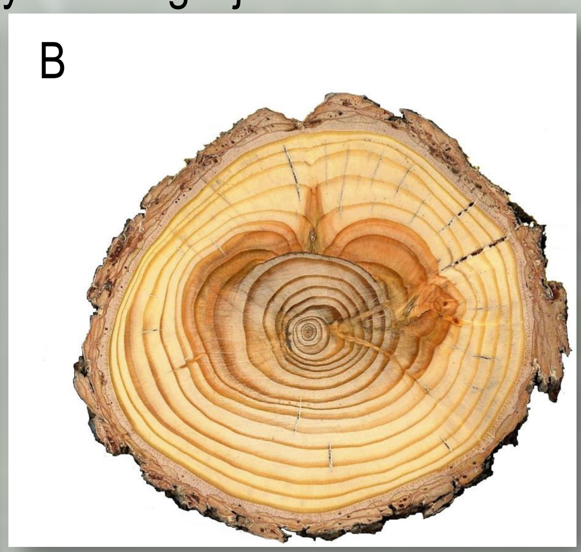

Fig 1. Fresh rockfall impacts are visible on conifers (A) but tend to become masked within a few years (B).

Aim of the study

Development a method which allows quantification of rockfall processes on forested slopes while being:

- simple,
- requiring less time and efforts,
- based on visible scars on the bark of a broadleaved species.

Fig 3. Scar count on a beech: old injuries are clearly visible - but do we overestimate „real" activity as a result of multiple scars inflicted by the same event/rock (as e.g. in event 2)?

Methods: different techniques for different species

We report from the Hechenberg in the Inn valley (Austria) where smaller rocks are frequently detached from a roughly 200 m high limestone cliff. Within the study perimeter, we applied different techniques: (i) analysis of growth disturbances in tree-ring series of Norway spruce ("classic" approach) and (ii) scar count approach on beech.

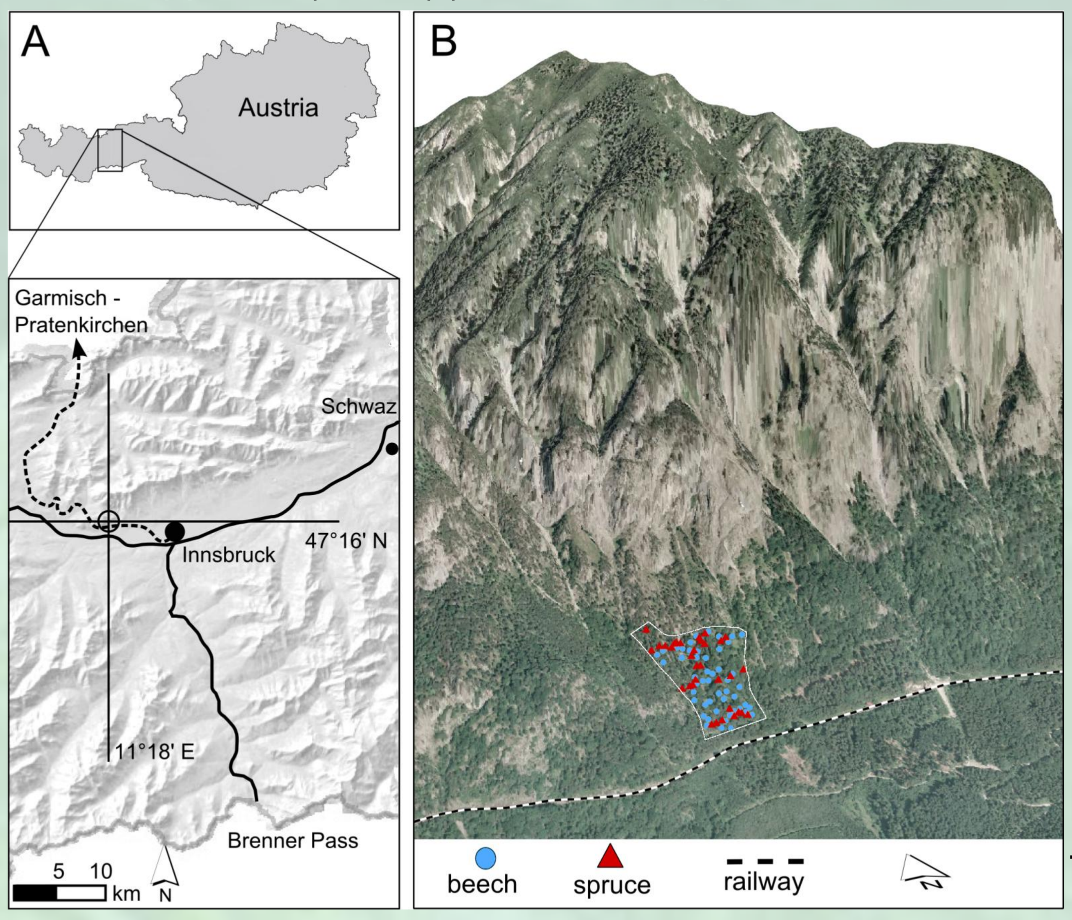

Fig 2. Study site in Austria: different techniques were applied at the site.

In total, 33 spruces and 50 beeches were selected for sampling. Return periods were calculated for each individual tree by dividing its age by the number of impacts.

For the **scar count approach on *F. sylvatica***, only 50 cores from 50 trees (1 core per tree) were extracted so as to assess tree age. Rockfall events were determined by counting visible impacts on the stem surface.

For the **"classic" approach on *P. abies***, 144 increment cores were extracted from 33 trees (3-4 cores per tree). All cores were analyzed under a microscope. Events were dated via the identification of growth anomalies in tree-ring series such as injuries, resin ducts, callus tissue, growth decrease or reaction wood.

Higher activity derived from scar count

Analysis of the spruce samples allowed reconstruction of 277 rockfalls, whereas 1140 rockfall scars were detected on the bark of beech trees (Fig. 4). As a consequence, the mean number of impacts per tree differs strongly with 8.4 for *P. abies* and 22.8 for *F. sylvatica*.

Although absolute numbers of impacts differ, spatial patterns on the slope clearly demonstrate areas of similar degrees of activity: Both methods show more impacts in the upper part of the study area and a decline towards the lower part.

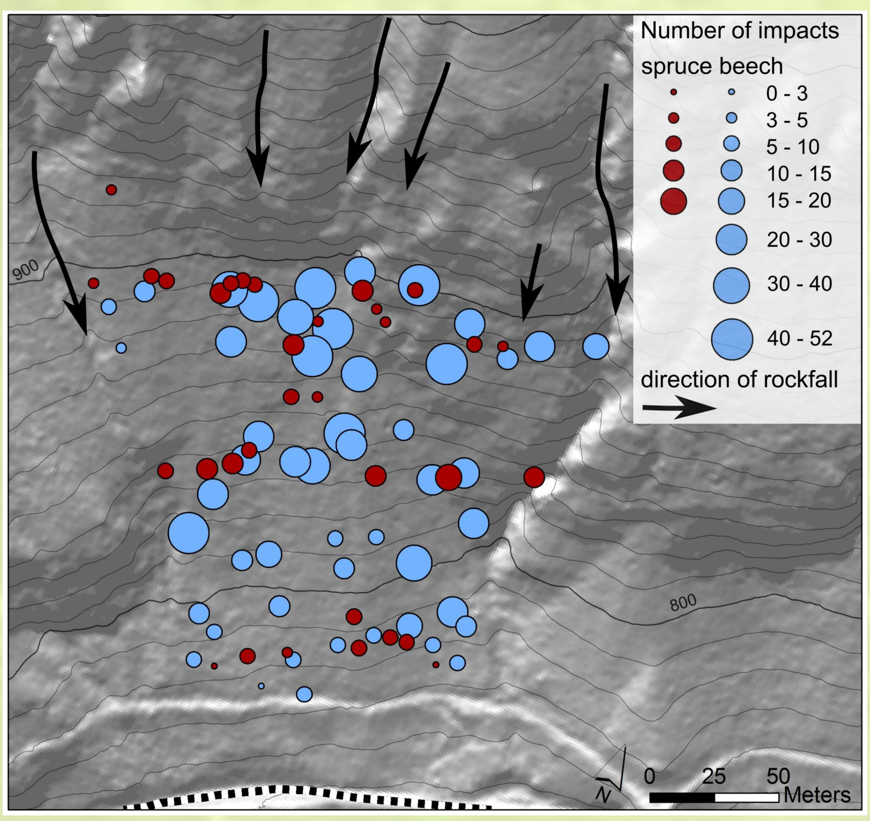

Fig 4. More impacts recorded by scar count on beech trunks (blue) – spatial pattern is reliable.

Shorter return periods derived from scar count

Using the classic approach on *P. abies*, we obtain a mean return period of 18.4 years. In contrast, the scar count approach applied to *F. sylvatica* results in a mean return period of 8.7 years. While these values differ, spatial patterns (Fig. 5) show again similarities. Both methods show more frequent rockfall in the upper part of the study are as well as in its eastern part.

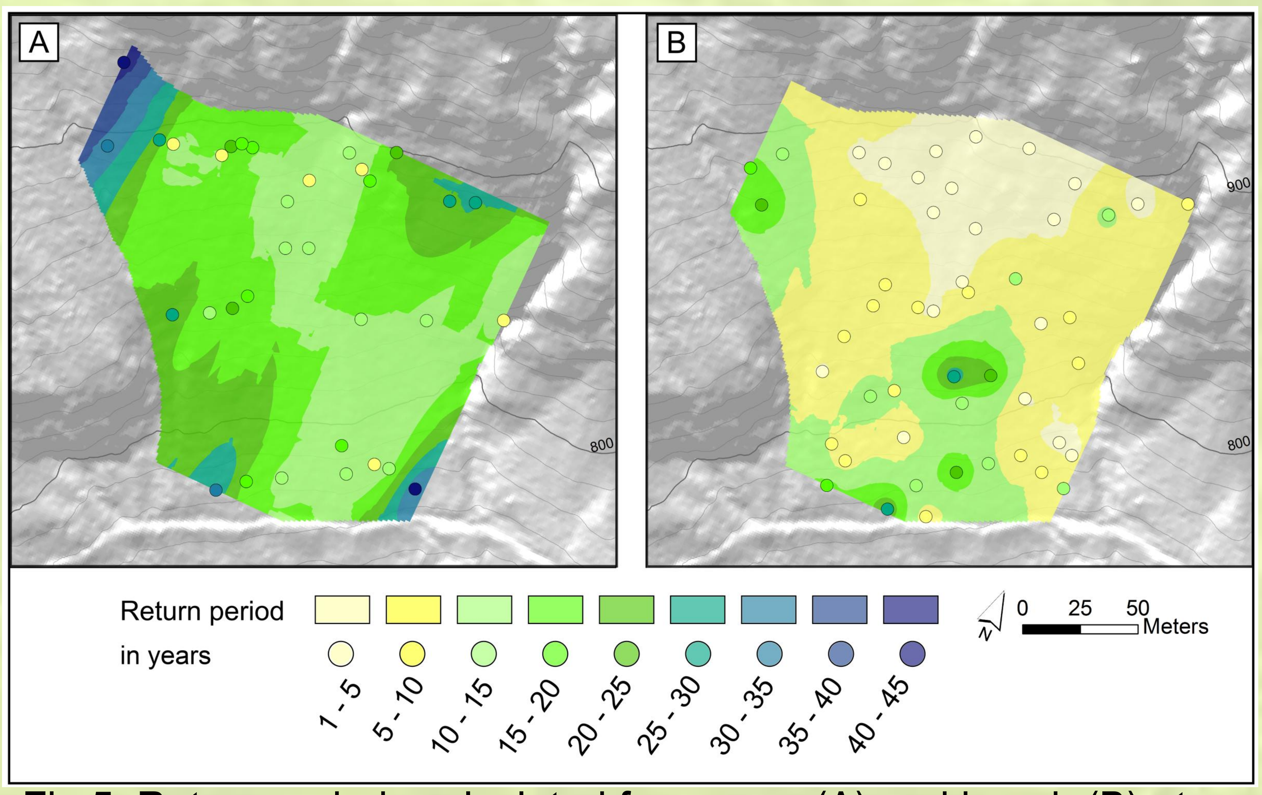

Fig 5. Return periods calculated for spruce (A) and beech (B) at individual tree locations and interpolated (ordinary kriging): Both methods show lower return periods in the upper part – absolute values are lower for scar count approach (B).

Conclusion: Scar count method reliable (beech) – an overestimation of activity is possible

- Scar count approach on beech results in much lower return periods (higher frequency) of rockfall events than the classical tree-ring approach applied to Norway spruce.
- Reasons for different values are likely due to the masking of scars in conifers, multiple impacts of one rock on broadleaved trees, and the greater vulnerability of beech bark to mechanical disturbance.
- Reconstruction by classic dendrogeomorphic techniques on conifers may underestimate - scar count on *F. sylvatica* may overestimate "real" rockfall activity.
- Counting scars on beech trees can yield reliable data on the spatial distribution of rockfall activity.

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