

# Changes in growth rates and wood anatomy of broad-leaved and coniferous tree species after a landslide event in the Remstal Valley (southern Germany)

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## Introduction

On April 7<sup>th</sup> 2001, a landslide with a volume of 70.000m<sup>3</sup> occurred in the Rems valley nearby Stuttgart (southern Germany), resulting in a vertical sandstone cliff with a width of 240m and a height of 17m. The geological underground consists of marls and sandstones of the middle Keuper formation (upper Trias). The rapid mass movement started in the marls at the slope foot and caused a trench collapse at the middle slope, which points to a high content of pore water. Since the area had been used as garden land, many fruit trees and other planted trees were affected and tilted or even killed. For this study, the area was divided into the landslide area including the affected trees, and a neighbouring reference area carrying undisturbed trees.

The aim of this study was the documentation and examination of typical tree-ring structures like growth changes and wood-anatomical features triggered by the landslide event. Furthermore, the trees were examined for traces of former geomorphic activities, to test whether trees can be used as monitoring organisms for hazard assessment in a potentially endangered area.

The dendrogeomorphological investigation focused on *Picea abies* and *Betula pendula*, since these species are widely available in all parts of the study area. In total, 24 spruces and 18 birches were examined. From each tree, 4 cores were taken in the directions parallel with and perpendicular to the inclination of the slope. In order to be able to distinguish between changes in growth rates that were triggered by either climatic or geomorphological events, climate-growth analyses were carried out on the trees from the reference site to determine the general growth-controlling factors. Reference chronologies from unaffected trees from nearby sites included 9 spruces and 10 birches.

## Methods

The surface of the increment cores was smoothed with razor blades, the visual contrast was enhanced by white chalk and ring width was measured to a precision of 0.01mm with a LINTAB II measuring system.

Climate-growth relationships between ring width and climate data were calculated for the trees in the unaffected reference site as Pearson correlation coefficients between ring width chronologies and climate data from the nearest meteorological station of Stuttgart-Echterdingen, which is located about 30km south-west. Abrupt growth changes and pointer

years were determined according to Schweingruber et al. 1990. The decreasing sample size in the older parts of the developed tree-ring chronologies was accounted for by weighting the number of observed abrupt growth changes with the logarithm of the sample size.

The degree of eccentricity of the trunks caused by reaction wood formation was quantified by calculating the ratio of ring width along two different radii which were cored parallel with and perpendicular to the slope (Alestalo 1971). An index of eccentricity was calculated according to the formula given by Braam, Weiss & Burrough (1987):

$$E_i = (RA_i - RC_i) / (RA_i + RC_i) * 100 \quad (1)$$

where  $E_i$  is the eccentricity in year  $i$ ,  $RA_i$  is the ring width in year  $i$  of radius A and  $RC_i$  is the ring width in year  $i$  of radius C, respectively.

In addition, cores of *Picea abies* were investigated for the occurrence of qualitative wood anatomical features like intra-annual density fluctuations, tangential rows of resin ducts and compression wood. Their annual frequency was documented by skeleton plots.

## Results

### Climate-growth relationships

As shown in Fig. 1, the correlation functions for birch and spruce are similar. Precipitation during the summer season (May to August) has a positive influence on ring width, whereas temperature during this period and during late summer of the year prior to growth is negatively correlated with tree growth. The influence of moisture availability on growth is most noticeable in negative pointer years. The most prominent growth reduction occurred in the well known regional drought year 1976, when the amount of rainfall in June was 82 mm below the mean of 1970-2002. Further growth reductions occurred in 1989, 1991/92, 1998 and 2001. Characteristic release reactions after growth suppressions occurred in 1977, 1993 and 2002.

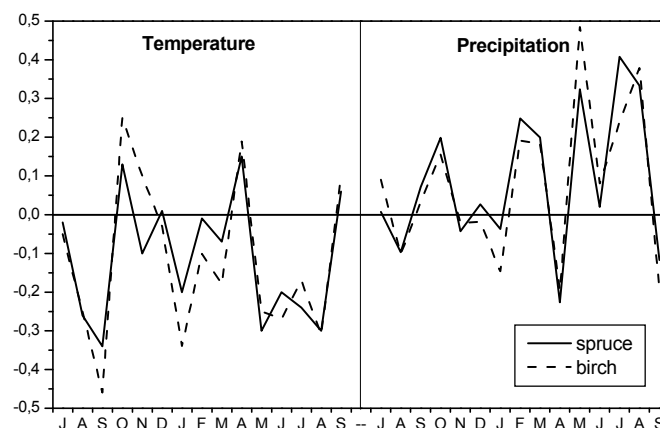
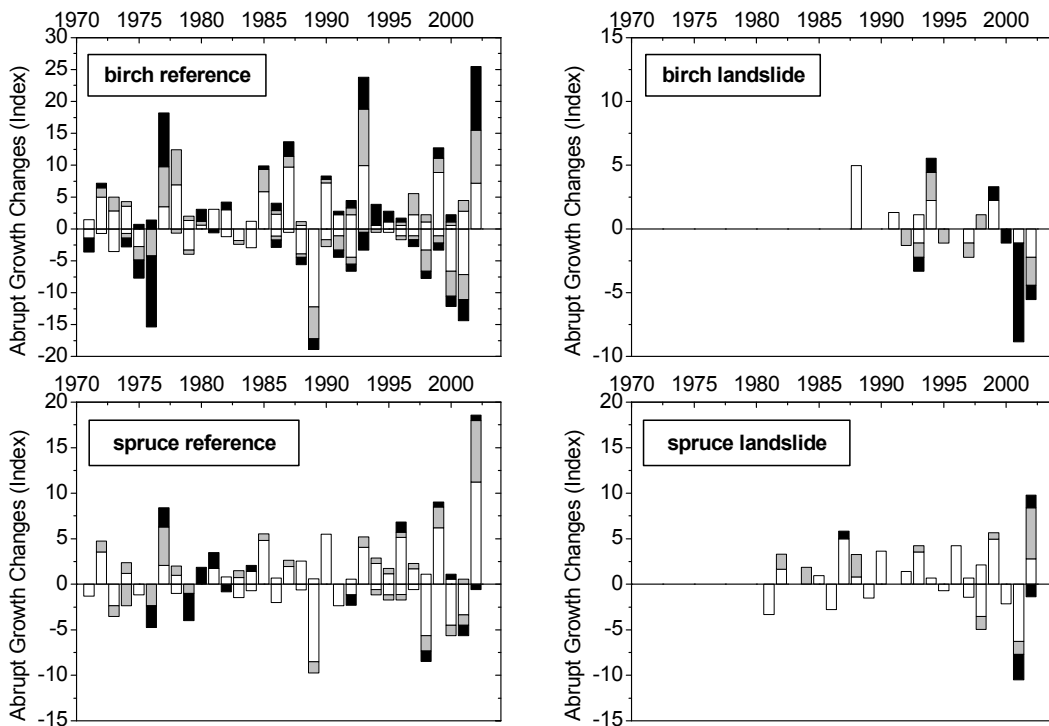


Figure 1: Correlation functions of spruce (*Picea abies* L. and birch (*Betula pendula*) ring width index chronologies with monthly means of temperature and precipitation from July of the year prior to growth until September of the year of growth for the 50-year period 1953-2002

### *Growth reductions and eccentricity of ring width*

10 trees (2 birches and 8 spruces) which were affected by the landslide could be examined. In 2001, the year of the landslide, significant reductions in ring-width occurred on the landslide area as well as on the reference plot (Fig. 2). However, whereas more pronounced growth reductions like in 2001 occurred on the reference plots several times before, the landslide caused unprecedented growth suppression in the immediate affected trees. The growth reductions in 1976 and 1989 can be assigned to climatic events (see above). In 2002, the trees on the reference plots and the spruce trees within the landslide area exhibited growth releases, whereas growth suppression still continued in the birch trees of the landslide plot. Thus, growth reductions alone can not be used as an unequivocal indicator of landslide activity.



*Figure 2: Abrupt growth changes of spruce and birch trees within the reference area and within the landslide area. White, grey and black parts of the columns refer to light, medium and severe growth changes which mean growth suppressions of 40%-55%, 56%-70% and >70% and growth releases of 50%-100%, 101%-200% and >200% in relation to the mean of the previous 5 years (after Schweingruber et al. 1990), respectively.*

Unexpectedly, the eccentricity method did not deliver definite results. Only some of the disturbed trees show a change of the eccentricity level in 2001. Before 2001, no high eccentricity indices occur, which points to the absence of comparable landslide events before 2001. One reason for the even distribution of the eccentricity level may be the continuous

process of hill creeping that occurs in the clayey soils of the study area, which causes a high “background noise” from which overlain signals caused by landslides cannot be clearly distinguished (Schmid & Schweingruber, 1995).

*Wood anatomical features*

Compression wood was formed in 25% of all affected spruce trees in 2001 and in more than 50% of all spruce trees in 2002 as an unequivocal reaction to the impact of the landslide (Fig. 3). However, an increase of compression wood in 2002 is also found in the reference area. This means that the site was not stable and was also affected by geomorphic activity, even though to a smaller degree than the landslide area proper. This could be caused by the high amount of precipitation in the years 2001 and 2002, when annual rainfall was 180 mm and 390 mm above the long term mean, respectively. The abundant moisture could have caused an intensification of soil creeping activity which may have led to an increased formation of compression wood. Although a significant statistical correlation between higher precipitation rates and the occurrence of compression wood can not be observed, an influence of the higher rainfall amounts in the preceding years on the increase of the pore water content in the affected slopes must be assumed. No significant periods of reaction-wood formation can be found in the tilted trees before 2001.

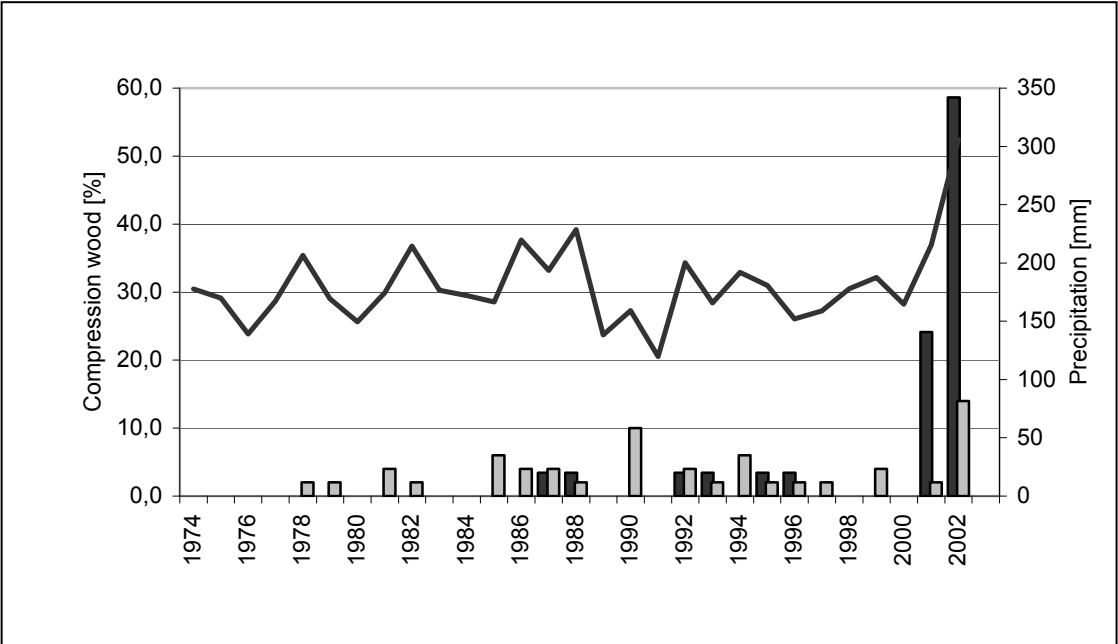


Figure 3: Annual frequency of compression wood formation in spruce trees of the sites that were affected (black bars) and unaffected (grey bars) by the landslide of 2001. The black line shows means of summer rainfall (May-August).

The annual portion of trees that show the formation of tangential resin ducts usually amounts to 10% to 15% in the landslide area as well as in the reference area (without graph). This shows that both areas are affected by continuous geomorphic activity. In 2001, however,

40% of all trees in the landslide area and 25% of all trees in the reference area exhibit this feature. In the years 1990 and 1993, 30% of the trees in the landslide area produced tangential resin ducts, compared to about 10% of the trees in the control plot. However, this finding could not be clearly assigned to a certain triggering event, since annual rainfall was not enhanced in one of these years (Fig. 3).

## **Conclusions**

It was not possible to detect former landslide activities in the study area. Since landslides of the amplitude like the one that occurred in April 2001 are rare events in the study region, it is very likely that prior to 2001 no such event had ever taken place during the lifetime of the investigated trees, which only covered the past 30 years.

The landslide event of 2001 is clearly documented in qualitative and quantitative features of the disturbed trees. Thus, the possibility to use trees as monitoring organisms for geomorphological processes (Schweingruber 1996) can be confirmed. However, due to the continuous slope activity on the clayey soils in the study area which forms a continuous background signal influencing the formation of reaction wood, a combination of wood anatomical features and abrupt growth changes is needed to verify unambiguously the nature of the triggering factors. Since the reference plot is situated on the same geological situation in the vicinity of the landslide, the trees on the reference plot are also affected by geomorphic activity which reduces the suitability of the plot to act as a true reference in the proper sense. To distinguish between growth reductions caused by geomorphologic activity and climatic singularities, a thorough study of climate-growth relationships with trees from a neighbouring, unaffected control site is necessary. The reconstruction of the frequency of landslides in a certain area could allow an improved estimation of hazard risks.

## **References**

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