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Changes in stem growth rates and root wood anatomy of oriental beech after a landslide event in Hanyeri, Bartın, Turkey

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Abstract: On 19 May 1998, a small-scale landslide occurred near Hanyeri, Bartın, in the western Black Sea region. The purpose of the study is to investigate the changes in stem growth rates and root wood anatomy of oriental beech (*Fagus orientalis* Lipsky). According to results from 8 years before and after the event year, growth variation in the affected trees is significantly high. In the control trees, growth increases after the event year, and the growth variation is 116.22%; this value is 69.59% in the affected trees. However, the growth variation values for ±11 years are 107.69% and 81.36% in control and affected trees, respectively. Root wood anatomy also revealed a clear response in affected trees after the event year, and ring width on one side of the root showed an abrupt increase.

Key words: Landslide, oriental beech, tree rings, wood anatomy

1. Introduction

Landslides are one of the most important natural disasters affecting human life in many countries (EM-DAT 2011). Landslides are generally described as the movement of a mass of rock, sediment, soil, or artificial fill on an oversteepened slope under the effects of gravity (Highland and Bobrowsky 2008; Clague 2010). There are many factors triggering landslides, such as gravity, heavy rains, snowmelt, earthquakes, and man-made structures, as well as erosion by rivers, glaciers, or ocean waves (Highland and Bobrowsky 2008).

Landslides are a serious geologic hazard common to almost every region in Turkey (Ercanoglu 2005). However, due to heavy precipitation, mountainous topography, and proximity to the North Anatolian Fault, the Black Sea region of Turkey is more sensitive to small- and large-scale landslides (Ercanoglu et al. 2004; Ercanoglu 2005). In the last 35 years landslides in Turkey have caused hundreds of deaths (286) and affected thousands of people (13,481) (EM-DAT 2011).

On 19–21 May 1998, heavy precipitation in the western Black Sea region of Turkey caused flash floods in Bartın, Karabük, Zonguldak, Bolu, and Düzce (Gurer and Ozguler 2004). According to EM-DAT (2011), 1,240,047 people were affected by the 1998 floods in this region, which resulted in 10 deaths and caused an estimated US$1000 million in damages. Heavy precipitation also triggered landslides and caused erosion of river channels. In addition, channels were blocked due to deposition of sediment and flooding (Ercanoglu et al. 2004; Ercanoglu 2005; Duman et al. 2005; Celik et al. 2006). On 19 May 1998, one of the small-scale landslides resulted in 1 death and the destruction of 2 houses in Hanyeri village, Bartın Province. Landslides, floods, rockfall, avalanches, and snow movement affect trees in the event locality. These types of geophysical events alter tree-ring and wood anatomical properties through reduction of the assimilation area, injury, and leaning of the stem, or through exposure or tearing of the roots (Schweingruber 2007). Heavy snow movement in the winter of 1992 in the western Black Sea region caused abrupt decreases in the tree rings of Uludağ fir trees (Köse et al. 2010). Erosive processes and the (partial) denudation of roots may generate different growth reactions, both in the stem and the exposed roots (Stoffel and Bollschweiler 2008). Hitz et al. (2008) identified wood anatomical changes in roots of European ash that were influenced by the erosional process. Due to exposure, decreased fiber lumen areas and decreased to unchanged vessel lumen areas have been observed in the roots.

The aim of the present study was to investigate the changes in stem growth rates and in root wood anatomy of oriental beech trees (*Fagus orientalis* Lipsky) that were affected by the 1998 landslide in Hanyeri, Bartın.

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2. Materials and methods

The landslide area is located within the borders of Hanyeri village in Bartın Province (41°20′28.68″N, 32°19′46.68″E). The elevation is 450 m a.s.l., and the climate is humid. The slope of the landslide area is approximately 45%, and the aspect is southeast (Figure 1). The area has a mixed forest mainly composed of natural *Fagus orientalis* Lipsky and some other deciduous species such as *Quercus robur* L., *Quercus petraea* (Matt.) Liebl., *Carpinus betulus* L., *Tilia tomentosa* Moench, and *Castanea sativa* Mill.

Tree-ring analysis was performed on the stem and root woods in the area. The samples (increment cores) were taken from 3 different places in a dominant beech forest and were divided into 3 groups. The first group of trees was composed of 11 trees collected from the border of the landslide area; these are called affected trees. The mean diameter of the affected trees was 35 cm (22.6–55.4 cm). The second group was composed of 14 trees collected from an area 30–40 m from the border of the landslide area; these are called semiaffected trees. The mean diameter of semiaffected trees was 36.5 cm (29.9–43.9 cm). From a control site far from the affected area, 11 trees were sampled. The mean diameter of the control trees was 36 cm (25.0–50.5 cm). The average tree age was similar in all areas, about 95 years. The mean tree age was 96 years (72–107) among affected trees, 91 years (72–128) among semiaffected trees, and 98 years (81–118) among control trees.

Figure 1. Landslide area after 11 years and exposed beech roots at the border of landslide area.

The PAST4Lt program was used for tree-ring measurement with 0.01 precision. The ARSTAN program was used to obtain standard chronologies for each site (Cook 1985; Grissino-Mayer et al. 1996). The EVENT analysis was performed on the standard chronologies of the 3 groups. This analysis was performed for 2 different windows of years before and after the event year: ±8 years and ±11 years.

Wood anatomical analysis was performed only on the root woods from the exposed roots of the 3 affected trees from the first group of trees (affected trees) (Figure 1). We compared the wood anatomical and tree-ring width features of roots before and after the event to understand the effect of landslide on roots. Wood samples were taken using a handsaw, and they were examined in terms of structural modifications after the event year. To clarify growth rings in the preparation process, the transversal surface of root wood was cut using a microtome, and white chalk was applied to the surface. In addition, micrographs were taken using a reflected light microscope.

3. Results

According to the results of the EVENT analysis for ±8 years, growth variation in stem woods is significantly different in the affected and control trees. In control trees, growth increases after the event year (1998), and the variation after the event year is 116.22%; this value is

Table. Results of EVENT test for ±8 and ±11 years.

		Mean growth before the event year (mm)	Mean growth after the event year (mm)	Growth variation after the event year* (%)
±8 years	Affected trees	1.259	0.876	69.59
	Semiaffected trees	1.141	1.003	87.92
	Control trees	0.964	1.120	116.22
±11 years	Affected trees	1.058	0.861	81.36
	Semiaffected trees	1.014	0.949	93.59
	Control trees	0.951	1.025	107.69

*Mean growth before the event year = 100, growth variation after the event year is equal to % of previous mean growth.

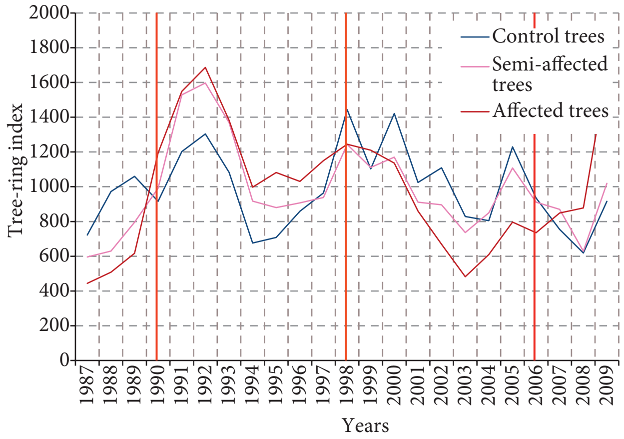

Figure 2. Graphs of the standard chronologies of the 3 groups. The graph shows ±8 years (between vertical lines) and ±11 years (entire graph) before/after the event.

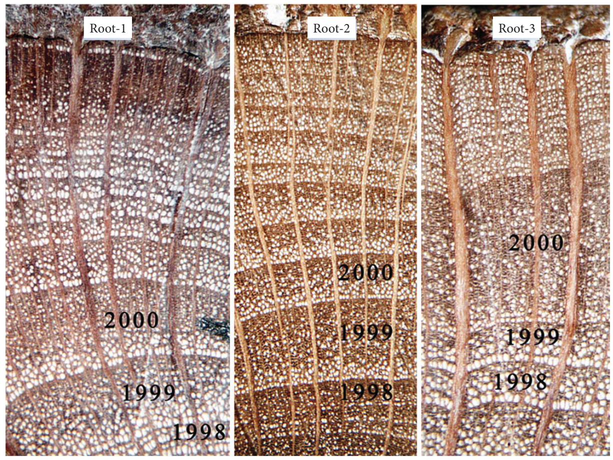

Figure 3. Exposed roots of 3 beech trees. Tree-ring widths show a clear increase 1 or 2 years after the event.

69.59% in the affected trees (Table). Figure 2 shows this difference visually. When we included ±11 years before and after the event, the results changed (Table; Figure 2). The variation decreased in the affected trees. This reveals that in stem woods the effects of soil movement started to decrease 8 years after the event.

The ring widths increased abruptly in the roots of affected trees. This is due to the formation of reaction wood (Figure 3) when tree-ring widths in stem wood decrease (Figure 2). As for the beech roots connected to the fine root system, which were exposed by the landslide, the growth rings formed in the first 2–3 years following the event are quite different than those formed before 1998 (Figure 3).

After the event year, abrupt and distinct growth increments on one side of the roots occur in 1999 or 2000, or in both years (Figure 4). In root-1 the growth rings of 1999 and 2000, in root-2 the growth ring of 1999, and in root-3 the growth ring of 2000 (Figure 4) are distinctly wider than those before 1998. In the following years, stability is reestablished and the growth rings are narrowed; however, in root-1 the growth ring of 2008 is abruptly released, and it appears darker. This 2008 finding in root-1 can be interpreted as new destabilization in the root-1 environment. In addition, earlywood vessels in growth rings formed after 1999 are distinctly narrower (about 54%) than those formed before 2000 (Figure 5) only in root-3. Another morphological alteration in exposed roots is the deviation of ray direction in root-1 and root-3 after 1999.

4. Discussion

Our results showed an abrupt change (suppression) in the tree-ring widths of affected and semiaffected trees after the event. Carrara (2007) found similar suppression in tree-

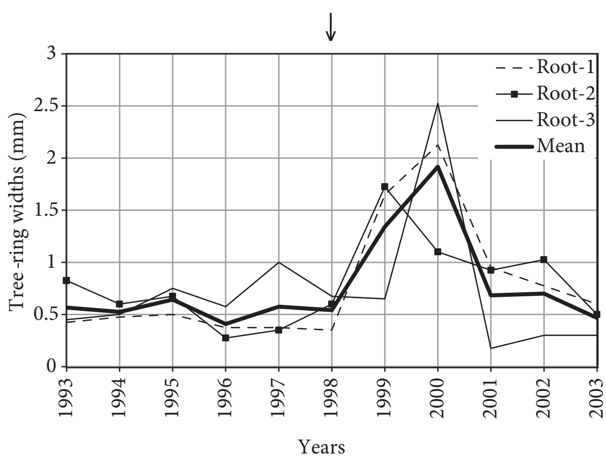

Figure 4. Growth-ring widths before/after 1998 in exposed roots (±5 years).

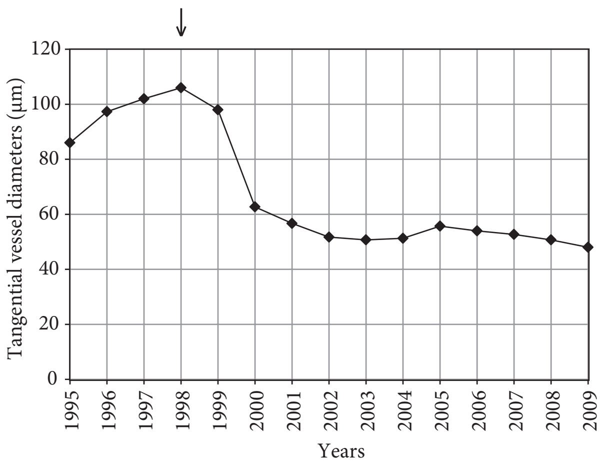

Figure 5. Changes in mean tangential diameter of vessel before/after 1998.

ring widths in *Pseudotsuga menziesii* (Mirb.) Franco trees. The most visible suppression was observed in trees from the border of the landslide area. Fantucci and Sorriso-Valvo (1999) stated that sometimes the effect of the growth decrease was so strong that the trees never recovered their regular growth. In this research, trees were able to repair the landslide effect on radial growth a few years later. Similar results in ring growth were found by Fantucci and Sorriso-Valvo (1999), Paolini et al. (2005), and Kashiwaya et al. (1987, 1989). Trees affected by landslides can show a sudden reduction in the thickness of the annual rings (suppression) due to partial damage to their crowns and root systems (Paolini et al. 2005).

We also observed root damage represented by an abrupt and distinct growth increment on one side of the roots. Schweingruber (2007) noted the following alterations in exposed roots connected with the fine root system: in conifers and deciduous woody plants, "an increased proportion of latewood, abrupt growth changes, more distinct growth-ring boundaries, thicker early- and late-wood cell walls, changed direction of growth, irregular axial orientation of fibers, phenolic deposits and injuries", and in deciduous woody plants, "smaller vessels, reduced vessel frequency, wider rays, new rays, tylosis, gumlike deposits, gum canals and tension wood". Some of these changes, namely abrupt growth change, smaller vessels, and altered direction of rays, were found in some of the examined beech roots. The abrupt growth-ring increment of 1999 or 2000 on one side of the roots may be due to cambial cell division intensity affected by the change in the mechanical load on the roots after the landslide event. Schweingruber (2007) reported that in roots showing growth on one side, the number of early- and late-wood cells depends on the cell division intensity affected by mechanical stress. In addition, deviation in ray direction seems to have resulted from the torsional movement of roots (Schweingruber 2007). Slight ray direction change was observed in 3 roots. Although there were no changes in vessel diameter in root-1 and root-2, vessel diameters in root-3 show a distinct decrease (about 54%) after 1999. Hitz et al. (2008) indicated that in exposed roots of European ash, the vessel lumen area had from a 50% size reduction to no change. Gaertner et al. (2001) stated that most anatomical alterations triggered by exposure depend on both mechanical stress on the roots and changes in temperature, decrease in the soil cover pressure, and light incidence around the roots.

The study area has a humid climate, and precipitation is about 1000 mm in the coastal part. Precipitation occurs throughout the year (Avcı 1998). Akkemik et al. (2008) stated that there is a significantly positive correlation between tree-ring growth and May–June precipitation. In addition, streamflow increases from October through April and decreases abruptly from April to September. For this reason, trees need water during May and June. There was an abrupt increase in tree-ring width in 1998 due to very high precipitation in May. However, our results showed that in damaged trees this increase is not clear, and there is no increase in the annual rings of 1998, particularly in the roots.

As a result, tree-ring widths and vessel diameters revealed significant differences after the landslide event. While tree-ring width decreases in stem wood, it increases in the roots after the event. Future studies should identify the different responses in tree rings and wood anatomy.

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