Dendrogeomorphological observations in a landslide on Tymfristos mountain in Central Greece

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Abstract

This paper presents the effects of a landslide on vegetation located on Tymfristos mountain and more specifically in the basin of the Kati stream, Sperchios river. The landslide areas are described and related to the density and the type of vegetation. The woody vegetation developed on the gliding surface was studied using dendrogeomorphologjcal methods. In particular, the direction and tilting degree of trees as well as the deformation of trunks was compared to trees growing on a neighbouring stable surface. Subsequently, the time of mass movement reactivation was estimated using a visual growth anomaly analysis on dominant fir (*Abies borisii regis* Mattf.) individuals growing on the landslide. From the results it is suggested that the landslide negatively affected fir growth ring width increase at certain times without, however, nullifying it. Certain time periods are identified with intense past sliding phenomena due to increased rainfall that subsequently increased underground water.

Introduction

Dendrogeomorphology is a subfield of dendroecology which utilises dated tree rings to study and date geomorphic processes, e.g. landslides, mass movements and creep (Kaennel and Schweingruber, 1995). Dendrogeomorphology, first introduced by Alestalo (1971), has been used by many researchers (Braam et al., 1987; Fantucci and McCord, 1995; Fantucci and Sorriso-Valvo, 1999; Shroder, 1978) to date landslide events. The trees subjected to stress due to mass-movement, show a tilting and sometimes an S-shape of the stem as well as signs of a sudden decrease in ring growth, or changes in eccentricity (Alestalo, 1971; Fantucci and Sorriso-Valvo, 1999; Goulas, 2003; Lang et al., 1999; Schweingruber, 1996; Shroder, 1978).

Landslides' dating contributes to understanding the causes, natural or anthropogenic, that provoke them. Severe landslides are noticed in many forested mountainous areas in Greece where flysch is the geological substrate (Kotoulas, 2001). Goulas (2003), studying the biological and biotechnical properties of fir on landslides at Pertouli, a few kilometres north from the present study area, indicated that the species reaction to landslides depends on its biological properties, stand structure and the degree of perturbation imposed to the aboveground and underground tree system. The perturbation degree of each individual tree depends on its location in the area as well as on the technical characteristics of the landslide.

The objectives of the present work were to study the Tymfristos landslide using dendrogeomorphological observations and to date landslide events using dendrochronological techniques and also explore the existing knowledge on the biological and biotechnical

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behaviour of hybrid fir (*Abies borisii regis* Mattf.) on landslides.

Research area

The research area was located in the upper basin of the Kati stream, (Sperchios river), on the E-SE side of Tymfristos mountain (Figure 1). The area is known as Tymfristos landslide and is known for the problems that it causes to the construction of the Lamia-Karpenissi highway.

The area constitutes an extensive unstable-sliding zone, extending from altitudes of 1300 to 700 m. The upper part of the landslide has a width of approximately 500 m confining, on the lower side, to 100–150 m, whereas its maximum depth reaches 17.5 m below the surface (Paraschoudis, 1999). Hydrogeomorphologically, the landslide shapes a wide territorial depression, with relatively soft relief and platforms, predominated by loose materials and weathered, disturbed flysch parts. These materials are characterised by high permeability, allowing the development of underground flow, supplying the traverse streams running through the region. This landslide undergoes fractures and movement of its territorial materials, depending on the intensity of rainfall–snowfall and other factors that contribute to the erosion of the region (Paraschoudis, 1999).

Geotectonically, the study area is included in the Pindos zone, composed of sedimentary flysch formations (sandstones, siltstones), from the upper Cretaceous—Lower Tertiary era, covered at locations by recently weathered material (Quaternary). The flysch, which is also the geological substrate of the research area, is mainly composed of alternations of sandstones and silts. This formation is sensitive to weathering/erosion and it constitutes, in combination to the intense slope inclination, the rainfall–snowfall and the presence of underground flow, the most important parameter of continuous relief redevelopment, with the creation of landslide phenomena which is very intensive after repeated cycles of saturation and desiccation. The Quaternary sediments constitute mainly the weathered surface mantle and include the loose products from the weathered-eroded substrate.

The region's climate is mountainous Mediterranean with mean annual precipitation of 1400 mm. The vegetation is Oro-mediterranean and characterised by the presence of the species *Abies borisii regis* and in the lower altitudes, *Quercus frainetto* Ten.

Material and methods

In the spring and summer of 1994, the vegetation growing on the landslide was recorded and tree age was estimated both by taking core samples with a Swedish incremental borer and also cutting cross-sections. All woody vegetation higher than 4.50 m was recorded. In total, 119 trees were recorded for (i) the direction towards which the stems were tilting, (ii) the intensity of the tilting (divergence from vertical) and (iii) the amount of deformities per trunk (bending) as a consequence of inclined tree growth.

From the above trees, all fir dominant individuals without wounds and/or fungi and insects attacks were selected for core sampling. In total, 17 trees (Figure 1) growing on the landslide surface were sampled. From each tree, two core samplings at breast-height (BH) were taken, the first core on the side opposite to tilting direction and the second 180° from the first one, making a total of 34 samples. Additionally, six dominant fir individuals were selected from adjacent stand located on a stable area, showing no trace of disturbance. Two core samples were taken from these trees, as mentioned before, one from the northern direction and one from the southern, making a total of 12 samples.

All samples were subsequently treated by the standard methods used in dendrochronology, and specifically, drying and smoothing of their surfaces, cross dating using skeleton plots and ring-width measurement with a 0.01 mm accuracy (Stokes and Smiley, 1968). Tree rings were identified and measured by the Windendro software. A mean chronology was constructed for each tree from its two core samples. For the six sample trees growing outside the landslide (controls), a master chronology was constructed out of the average of the six chronologies, presenting the growth pattern of an undisturbed stand.

A principal component analysis (PCA) using the PPPHALOS software (Guiot, 1990) was applied separately on the dendochronological data from the landslide and the stable area, for the time period from 1972 to 2003, in accordance with the meteorological data. The purpose of this analysis was to compare the annual ring-width variability among trees from the landslide and the stable area, and to study the above-mentioned variability by the available precipitation data. Additionally, all samples from the landslide were analysed using visual growth analysis to identify the abrupt growth changes and specifically, reduction (suppression) of