Forest Ecology and Management 257 (2009) 1577–1585

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

# A giant tree stand in the West Carpathians—An exception or a relic of formerly widespread mountain European forests?

Jan Holeksa [a,*], Milan Saniga [b], Jerzy Szwagrzyk [c], Magdalena Czerniak [c], Katarzyna Staszyńska [c], Paweł Kapusta [a]

[a] W. Szafer Institute of Botany, Polish Academy of Sciences, Lubicz 46, 31-512 Kraków, Poland
[b] Department of Silviculture, Technical University of Zvolen, Masarykova 24, 960 53 Zvolen, Slovakia
[c] Department of Forest Botany and Nature Conservation, Agricultural University, 29 Listopada 46, 31-425 Kraków, Poland

ARTICLE INFO

*Article history:*
Received 18 June 2008
Received in revised form 30 December 2008
Accepted 5 January 2009

*Keywords:*
Old-growth forest
*Fagus sylvatica*
*Fraxinus excelsior*
*Acer pseudoplatanus*
Tree height
Hrončokovský grúň reserve
Western Carpathians
Slovakia

ABSTRACT

In Europe, remnants of formerly widespread natural mixed forests are rare. We analyzed an exceptionally tall tree stand with a very high wood volume in Hrončokovský grúň reserve, covering 55.2 ha in Slovenské Rudohorie Mountains in central Slovakia (48°43′N and 19°35′E) between 730 and 1050 m a.s.l. We compared our data to other natural stands to see if the growing stock and tree height were higher in Hrončokovský grúň.

Fifty-four circular plots of 0.05 ha each and spaced at 100 m × 100 m distance sampled the entire reserve. Within each plot, live and dead trees were measured. Number, basal area and volume of live trees and volume of CWD were calculated. Moreover, measurements of the tallest trees were conducted in the whole reserve area.

Total volume of live trees and CWD in the studied reserve was 1030 $m^3$ per hectare. It is the second highest value ever recorded in an area of several hectares or larger in European forests. The feature that makes the stand in Hrončokovský grúň a unique one is the height of trees. In the whole reserve, about 600 trees exceeded the height of 45 m. Individuals of three deciduous species (*Acer pseudoplatanus*, *Fraxinus excelsior*, *Ulmus glabra*) are the tallest ones found in unmanaged forests in the whole Europe. Those of *Fagus sylvatica* reached height near the maximum value ever recorded.

In Europe, stands of average total live and dead wood volume above 1000 $m^3$ $ha^{-1}$ with numerous trees above 40 m tall were probably very rare even several centuries ago, when virgin forests were widespread. Most likely, they were confined to rather small mountain areas, where rich soils supporting high stand productivity occurred along with wind-protected slopes, where natural disturbances were rare and stand turnover rate was low.



## 1. Introduction

Mountain mixed forests occurring on fertile soils used to be common in Europe several centuries ago, but their area has markedly decreased due to transformation to agricultural lands or forest plantations. Only small areas have survived as remnant patches in less accessible Carpathian and Balkan mountain ranges. They are mainly situated in Slovakia, Romania, Ukraine, Bosnia and Herzegovina, Croatia, Slovenia and Albania with small areas in Poland, Czech Republic and Austria (Korpeľ, 1995; Borlea, 1998; Hartman, 1998; Matić, 1998; Pintarić, 1998). Because of scarcity, these small remnants of natural forests are unlikely to provide a full picture of the forests that once may have covered vast areas in Europe.

In the research conducted in European old-growth forests attention has been focused on growing stock, basal area and diameter of large trees. These stand features are of particular interest, because they form a basis for economic use of forest stands. Size of boles, both living and dead, has also been identified as very important for preservation of biodiversity (e.g. Peterken, 1996; Arseneau et al., 1997; Nilsson et al., 2001; Heilmann-Clausen and Christensen, 2004). At the same time, tree height has attracted relatively less attention as its measurement is much more difficult, and because European tree species are not very tall compared with trees from other continents. Tree height was commonly measured for the estimation of growing stock, but the number of trees sampled for height was much smaller than for diameter. Moreover, very small area of old-growth forests in conditions favourable for tree growth makes the chance for finding individuals reaching maximum possible sizes very low.

* Corresponding author.
*E-mail address:* j.holeksa@botany.pl (J. Holeksa).

0378-1127/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2009.01.008

Apart from very small areas of natural forests that are far from being representative for particular forest types, the methodological approach to stand measurements probably have not provided representative data even for these small remnants of Central European forest. Subjective selection of few small sized (up to 1 ha) research plots was predominant method of choosing the studied patches (Mayer et al., 1972; Korpel', 1995; Jaworski et al., 1994, 2001a, 2001b, 2002, 2004; Jaworski and Paluch, 2001; Jaworski and Podlaski, 2007; Giurgiu et al., 2001). Only in few instances areas larger then several hectares have been sampled (Dziewolski, 1991; Jaworski et al., 1994; Korpel', 1995; Tabaku, 1999; Boncina, 2000; Commarmot et al., 2005; Vrška et al., 2002). We suggest that stand areas with higher volume may have been preferentially sampled, possibly biasing the values reported in publications.

The aim of our work was to provide more detailed information on the stand structure and tree size distribution in Hrončokovský grúň reserve. The mixed mountain forest in the Hrončokovský grúň reserve has been well known because of its very high growing stock reported for the first time by Korpel' (1982). As many as seven tree species occur in this forest, which is unusual in mountain and in lowland Central European forests, and some of these species are represented by individuals that reach maximum or near maximum heights recorded in the whole of Europe.

In our work we attempted to compare our data from Hrončokovský grúň reserve with other natural stands in European mountains to see, if the analyzed stand is really unique in terms of growing stock and tree height. We also discuss, what makes tree stand in Hrončokovský grúň so tall: Is it a result of site factors, or is it just an example of well-preserved low-elevation mountain forests, once widespread in the Carpathians?

## 2. Methods

### 2.1. Study area

The Hrončokovský grúň reserve is situated in central Slovakia, in Slovenské Rudohorie Mountains (48°43′N and 19°35′E). It was established in 1964 and it belongs to the Pol'ana Biosphere reserve. The whole forest reserve has never been managed for timber and it has been strictly protected, i.e. without any direct human influence and wood extraction, for the last 44 years. There is a buffer zone around the reserve that reduces disturbances caused by human activity. In the 1972, the stand growing stock in this reserve ranged from 829 to 1102 $m^3$ $ha^{-1}$ (average 999 $m^3$ $ha^{-1}$) in four plots (Korpel', 1989). These values were larger by 110–480 $m^3$ per 1 ha than that in eight other well-protected Carpathian beech, fir–beech and fir–spruce–beech forests measured in 1970s (Korpel', 1982, 1987). As in other reserves, in Hrončokovský grúň data was collected in plots of 0.5 ha, which were located to represent developmental phases of tree stand—growing up, optimum and destruction (Korpel', 1982).

The reserve is situated on gentle east facing slope between 730 and 1050 m a.s.l. and covers an area of 55.2 ha. The dominant soils are andosolic cambisols that developed from pyroclastic andesite with less solid tufs and tufaceous rocks. The annual mean temperature ranges from 4.5 to 5.5 °C, the annual precipitation is about 1000 mm, and the snow cover lasts for approximately 120 days (Hancinsky, 1972).

According to Slovak zonation of vegetation the reserve belongs to the fir–beech (fifth) zone and the spruce–beech–fir (sixth) zone. Four forest types were distinguished: *Fageto–Abietum*, *Abieto–Fagetum*, *Fageto–Aceretum* and *Fraxineto–Aceretum* (Korpel', 1989).

### 2.2. Field studies

In 2004 and 2005, we established a set of 54 regularly distributed circular sample plots with a radius of 12.6 m and an area of 0.05 ha each. The plots were spaced at 100 m × 100 m distance and sampled the entire Hrončokovský grúň reserve. Location of each plot in the field was determined using a GPS receiver. The plots were located between 805 and 1010 m a.s.l.

Within each plot, we measured all living trees and snags with dbh >7 cm, and stumps taller than 0.5 m. For each living tree, we measured dbh to the nearest cm and height with the accuracy of 0.5 m (Haglöf Vertex III Ultrasonic Hypsometer). For standing dead trees (snags), only dbh was measured.

Usually, in studies on CWD all downed wood pieces that are present within sampled plots are measured. We chose another method. For downed logs, we measured pieces with butt end and/or stumps situated within the circular plot boundaries and exceeding a diameter of 7 cm. We omitted all the pieces with butt end and/or stumps outside plots (Fig. 1). In this way we measured only these logs that originated in sample plots and we were able to measure the whole wood volume (living, standing dead and downed) originated in individual plots. The rationale for our method is as follow: assuming that $N$ logs of the volume $V$ are deposited on the forest floor in the whole forest of $A$ hectares, we can calculate that on the average $N/(A/a)$ logs with their total volume $V/(A/a)$ came from a sample plot of $a$ hectares. It does not mean that for an individual plot the volume of logs situated in this plot and the volume of logs originated in it are equal, but it means that the averages for many small plots do not differ between methods and both methods are equally good to estimate deadwood characteristics. However, in our approach less downed wood pieces are to be measured and the method is less time consuming.

Apart from the measurements of dimensions of trees in small circular plots a complete inventory of tallest trees was conducted in the whole reserve area. Ten tallest individuals of *Acer pseudoplatanus*, *Fagus sylvatica*, *Fraxinus excelsior* and *Picea abies*, eight tallest trees of *Abies alba* and one *Ulmus glabra* were measured including their height, dbh, crown length and crown width in four cardinal directions.

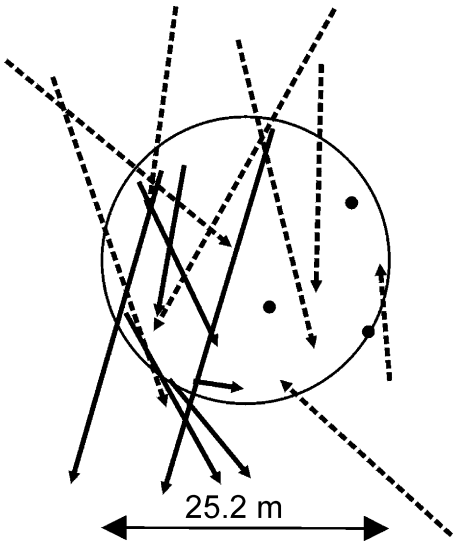


**Fig. 1.** Selection example of measured CWD pieces in a circular plot of 0.05 ha: all snags (black dots) were measured, each log marked with black line was measured as a whole and all logs marked with dashed lines were omitted.