Local variability of stand structural features in beech-dominated natural forests of Central Europe: implications for sampling

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Objectives:

The objective of this study was to identify the within-site variability of major stand structural features: i.e. density (Nl), basal area (BAl), and volume (VAl) of living trees, volume of coarse woody debris (VCWD), total volume (Vtotal) and proportion of CWD (RCWD) from total volume (RCWD) in beech-dominated natural stands of Central Europe. In addition, this within-site structural variability is tested as it is directly reflected by different simulated sampling schemes. As a result, two main questions are answered:

1. How do major stand structural characteristics vary at local scales in dependence on the size of sample plots?
2. How many and what size sample plots are needed to estimate particular stand characteristics with acceptable accuracy?

Methods:

The study makes use of stem-position datasets from three different beech-dominated natural forests in the Czech Republic – Zofin, Salajka and Zakova hora (Fig. 1). All standing and downed trees of DBH ≥ 10 cm within the core areas of the three localities have previously been mapped and the DBH recorded. The resulting stem position maps (Fig. 2) with linked databases provided detailed data about stand structure to be used in these analyses (in total about 29 000 trees on 10 ha).

The stem position maps were used for a computer-simulated placement of different sized plots using a moving window method (Zimmer, 2005; Kral et al., 2010). The focal filter scanned the input stem position map, shifting at each step by one meter and calculating the number, basal area and volume of trees inside the window. In this manner all three study sites were examined using square sample plots of the following sizes: 10x10m; 20x20m; 30x30m; 50x50m; 70x70m; 100x100m; 140x140m and 200x200m (Table 1). Reference mean values for particular characteristics and study sites were calculated from total site datasets excluding a 50m buffer around the site border.

Basic statistics (mean, standard deviation, minimum and maximum) were calculated for all sampling distributions for every plot size and each of the six major stand structural features produced by focal filtering as described above (Table 2). Variabilities of derived characteristics were compared for different plot sizes using coefficients of variation. The change in coefficients of variation with increasing plot size was evaluated by regression modeling (power functions were used; Table 3, Fig. 3).

The number of plots n needed to estimate the mean of appropriate characteristics within an error d at an error rate a was calculated by an iterative solution of (Zar, 1996):

\[ n = \frac{1}{a^2} \left( \frac{1}{1 - \alpha} \right)^2 \]

where \( n \) is the Student's t-statistic and \( \sigma \) the population variance estimate. Total sampling area (sample size) was calculated for each plot size and suggested number of plots (Table 4).

Results:

As expected, the within-site relative variability of major stand structural features decreased with increasing plot size. For particular stand features, the observed trend was expressed by significant regression models (\( y = a \cdot x^b \)) with high coefficients of determination across all study sites (Table 3, Fig. 3). According to the Chow (1960) test, the regression models appear to be specific for particular stand characteristics or pairs of related characteristics. Comparable trends in variation with increasing plot size can be observed between BAl and VAl and between VAl and RCWD, both of which can be expressed by a common regression model for the pair (Fig. 4, summarized in Table 3). The variability of VAl has a similar trend as BAl and VAl, but is generally slightly lower (Fig. 4). The variability trend of Nl, however, is different – the curve is generally more flat and relative variability is slightly higher (except for the smallest plot sizes). The deadwood variables (i.e.VCWD and RCWD) have significantly distinct variability trends, with relative variability generally almost twofold higher than that of living trees (e.g. BAl and VAl).

Using the results from Fig. 3, we can range the deadwood variables from 474 to 1049 m³/ha within one study site (Table 2). Hence, single samples of one hectare can be recommended plot numbers and sizes given here apply only to estimates of the stand structural variables studied.

Conclusions:

Observed trends in variability of estimates along increasing plot sizes appear to closely follow the power function \( y = a \cdot x^b \). It appears that plot sizes between 0.01 and 0.09ha would be the most efficient for sampling the above-mentioned variables in European beech-dominated natural forests. Considering our results (Table 4), one can conclude that a range of focal sampling sizes from 10x10m to 150x150m could be used to estimate the variability of different stand structural variables with 95% confidence for particular stand size conditions (Table 4). We emphasize that the recommended plot numbers and sizes given here apply only to estimates of the stand structural variables studied.

References:


Table 1: Specifications of the regression models (\( y = a \cdot x^b \)) of coefficients of variation [%] in relation to plot size [m²] based on data from all three study sites. The models labeled with the same letter are, according to the Chow test, better fitted by a single (common) regression model (introduced at the bottom of the table).

Table 2: Statistics for major stand structural features at Zofin; derived from sample plots of different sizes. SD: standard deviation.

Table 3: Specifications of the regression models (\( y = a \cdot x^b \)) of coefficients of variation [%] in relation to plot size [m²] based on data from all three study sites. The models labeled with the same letter are, according to the Chow test, better fitted by a single (common) regression model (introduced at the bottom of the table).

Table 4: The minimal number of plots and total sampling area required for estimations of the main stand characteristics to within 20% (\( ± 20 \% \)) of the mean with 95% confidence for particular plot sizes (m²).

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