Using airborne small-footprint laser scanner to assess the quantity of seedlings in an uneven-aged spruce forest

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Introduction
The number of seedlings in uneven-aged forest types is influenced by several factors that are correlated to stand structure. Small footprint airborne laser scanning has shown to produce good data for reproducing forest structures. Even though there are several factors that influence establishment and growth that are not, or only partly, affected by the stand structure, it is likely that there exist some relationship between the laser-depicted canopy and the variation in young growth. We believe that utilization of laser data describing canopy structure to detect young growth could be a valuable contribution for improving existing recruitment models or constructing new ones based solely on laser variables.

The objective of the present study was to analyze the relationship between measures of forest structure as derived from airborne laser scanner data and variation in the quantity of young trees in the height range of 0.1 to 3 m in a size-diverse spruce-dominated forest. The focus was on exploration and identification of laser-derived variables that have a potential for development of future prediction models that might be used in operational forest management.

Field inventory
The data were collected on 18 clusters of circular field plots (r=8.46). From the centre of each cluster, one plot was located 12 meters from this centre in each cardinal direction (total of 72 plots). The position of each cluster centre was determined by differential GPS+GLONASS measurements. Each plot was split into four by two perpendicular lines through the plot centre in a north/south and east/west direction. In each of these resulting 6.25 m² quadrants, the number of seedlings between 0.1 and 3 m were recorded. A regeneration success rate (RSR) was computed from these records by first counting seedlings in each quadrant (n). However, we stopped counting if the number reached a limit considered sufficient on an area of 6.25 m² (nsuf). This limit was set to three seedlings. Then we summed η for the four quadrants and RSR was computed as this sum relative to the number of seedlings considered sufficient for the entire plot (4nsuf).

Data analysis
Because the data originate from clustered plots, there exists spatial dependency between plots within clusters. Thus, data analysis was carried out by estimating random coefficient models. Each variable extracted from the laser data were regressed against RSR. Subsequently, each of the models was ranked by their Akaike information criterion (AIC) (Akaike, 1974) score. Then, each laser variable was attributed to groups of first- or last return; height- and density metrics. Each variable category was attributed to groups of first- or last return, and the maximum canopy height into four uniform fractions. Cumulative canopy densities, henceforth called density variables, were then computed as the proportions of first and last pulse laser hits between the lower limit of each fraction and maximum laser height to total number of pulses. Moreover, maximum and mean height variables, standard deviations and coefficients of variation were derived. Further details are provided by Næsset (2004).

Results and conclusion
Establishment (RSR) was found to be best explained by density metrics and last return data. While the first return data describes the surface of the canopy, the last returns penetrate deeper into the canopy and thus account for more vertical canopy variation. Last return data are therefore better accounting for light conditions on the ground. This may also be the reason why density metrics are better than height metrics. Since they are greatly affected by the density and structure of the canopy, they also account for light conditions on the ground better than the height variables.

Our study was a screening which aimed at identifying laser variables that might explain regeneration success. A full correlation between laser data variables derived from the canopy and regeneration will never be found, as factors not affected by canopy structure also strongly influence regeneration success. However, the study has shown that already existing data derived from laser scanning, for instance during a regular forest inventory, may give us surplus information on regeneration. Our data show that there is a relationship between canopy structure and seedling number, possibly strong enough for prediction of regeneration success in future prediction models.

References: