Estimation of nature conservation value using airborne laser scanning data by deadwood recognition

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1. Introduction

Planning of forest management operations in boreal forests requires assessment of the biodiversity potential of the forest stands to determine if they can be harvested or should be set aside due to high conservation values, and to identify patches with high conservation values for retention of biodiversity. The latter includes the preservation of deadwood and trees with high conservation values, often of uncommon species (Gustafsson et al. 2020). There is currently no way to acquire this information automatically and objectively for large areas.

Information relevant for habitat studies that can be derived from airborne laser scanning (ALS) data includes canopy openness and foliage height diversity as well as the height and species of individual trees (Müller and Vierling 2014). Dense ALS data have the potential to provide information about structures in the forest relevant for biodiversity such as standing and downed deadwood and trees with high conservation values (i.e., biodiversity indicators). The full 3D representation of the forest from laser scanning data provides insights into ecologically relevant features of the forest (Onojeghuo and Onojeghuo 2017).

The amount of deadwood is important for the maintenance of biodiversity since hundreds of Fennoscandian forest-dwelling species depend on deadwood (ArtDatabanken 2020). Deadwood has been the focus of many studies of retention forestry (Gustafsson et al. 2020). Downed deadwood has been detected from ALS data with 3D reconstruction methods (Lindberg et al. 2013; Mücke et al. 2013) as well as with statistical methods based on the canopy structure (Tanhuanpaa et al. 2015).

This study presents a new method to detect downed deadwood from dense ALS data. The results from the method are compared with biodiversity indicators that have been assessed in the field. The method for detecting dead wood is planned to be a part of a processing chain to estimate the amount of structures relevant for biodiversity that can be used for creating maps of biodiversity indicators for laser-scanned forest stands to determine if a forest stand should be harvested or set aside for conservation and to guide retention in the forest stand in connection to forest management operations.

2. Data and Methods

2.1 Data

The study area Siljansfors is located in mid-Sweden (Lat. 60.9° N, Long. 14.3° E). Most of the area is covered with managed hemi-boreal forest. The most common tree species are Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), and birch (*Betula spp.*).

During the summer of 2019, a field inventory was done to assess the forest biodiversity potential in 19 forest stands in the study area. The inventory was done in 1 ha field plots according to the methodology developed by Skogsbiologerna AB (Drakenberg and Lindhe 2001). The assessment is based on a field form with eighty questions in different categories: site, dynamics, habitats, trees, structure and deadwood. The scores from the questions are then combined into site score and stand score, and the total biodiversity potential score is calculated as the sum of them for each field plot.

ALS data were collected on June 28, 2019, with a Riegl VQ 1560i-DW (Riegl, 2020) scanner at 800 m above the ground. The scanner records two channels (CH): CH1 with 532 nm (Green) and CH2 with 1064 nm (near infrared (NIR)). The average density of first returns was 26.5 m^{-2}.

2.2 Methods

Downed deadwood trunks were detected using a template matching algorithm. The steps were as follows.

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Step 1. Rasterization. Point clouds were sliced into [0.2, 0.5], [0.4 – 0.7], [0.6 – 0.9] and [0.2 – 1.0] m height intervals, and rasterized with 0.25 m resolution.

Step 2. Creation of templates. Linear filters with 0.25 m resolution were designed with 6 m length and 0.25 m or 0.50 m width. The filters have 0 – π horizontal angle with 0.01 π intervals (Denoted as directions of templates, examples in Figure 1).

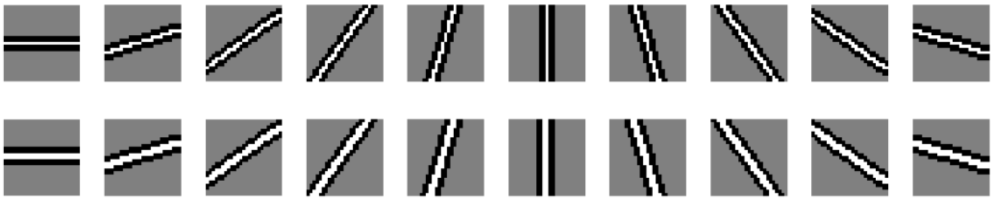
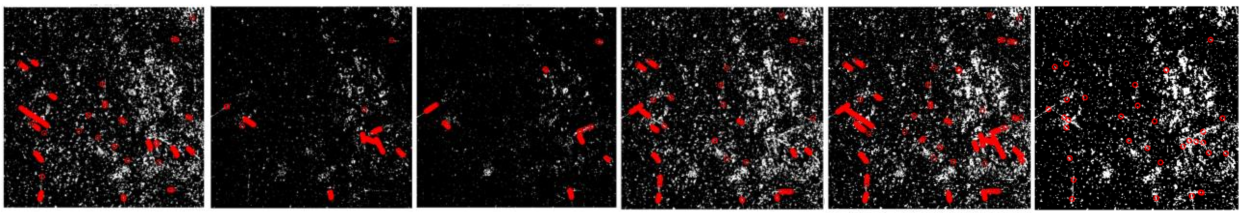


Figure 1. Examples of the linear filters (templates). The templates have 0.25 m width (first line) and 0.50 m width (second line). The pixel values are 1, -1, and 0 for the white, black, and grey pixels.

Step 3. Template matching. The rasters of the sliced point clouds were convoluted using the templates. After the convolution, all the pixels with values larger than *Th* were marked as potential positions (denoted as *Set A*) of the deadwood, and the directions of the templates were recorded for the next step (*Set A* {(x, y, α)}, where x and y were the relative coordination and α was the direction of the templates which resulted in a convoluted pixel value larger than *Th*). Th was set to 0.4 times the length × width (24 × 1 or 2 pixel) of the templates.

Step 4. Determination of the deadwood positions. After Step 3, *Set A* included the positions from the downed deadwood (denoted as *Set A1*), and other linear objects on the ground such as bushes (*Set A2*). We observed that *Set A1* usually contained positions with the same x and y and similar α, while *Set A2* usually contained isolated positions. We set a standard to separate *Set A2* from *Set A1*, e.g. the isolated positions within 1 m radius circular range with α differences no larger than 0.02 π. Then we merged elements in *Set A1* which belong to the same deadwood trunk. We used the Mean Shift Clustering algorithm on *Set A1*, which clustered the elements with similar x, y, and α. The average x, y of each cluster were determined as the positions of the deadwood.



(a) (b) (c) (d) (e) (f)

Figure 2. Process of detecting downed dead wood. (a - d) Detection from rasters of [0.2, 0.5], [0.4 – 0.7], [0.6 – 0.9] and [0.2 – 1.0] height intervals. (e) The potential positions from all rasters (*Set A*). (f) Final positions of the dead wood.

3. Results and discussions

Among the 19 plots, 228 deadwood trunks were recorded from the field measurement, with 219 trunks detected by the algorithm. The detection yielded 1.55 RMSE (12.9%) on estimating the number of deadwood trunks, with underestimation for the plots with large numbers of deadwood trunks (Figure (a)).

The number of deadwood trunks was used to classify plots with high and low conservation values. Based on the field observation, a threshold of 8 trunks was used for the classification, e.g. plots with ≥ 8 deadwood trunks were classified as high conservation value plots (CV ≥ 15), and plots with < 8 deadwood trunks were classified as low conservation value plots (CV < 15). Based on the criteria, six out of 19 plots in the study area have high conservation value. By using the detected number of deadwood trunks from laser data, seven plots were classified as high conservation value. The overall classification accuracy was 0.89 (Table 1), and the Kappa coefficient was 0.78.

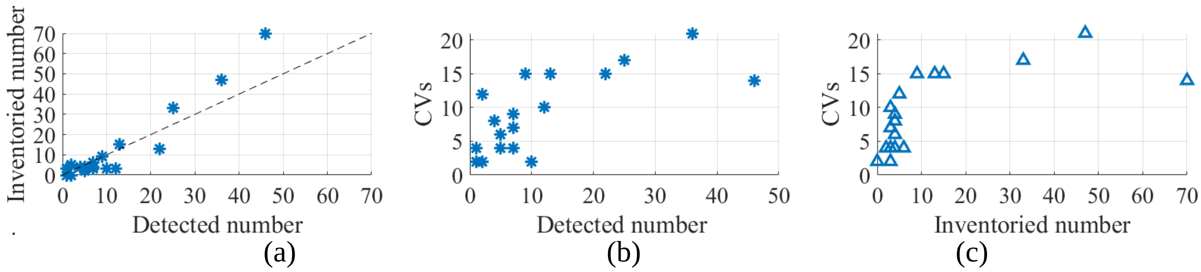


Figure 3. (a) Inventoried and detected number of deadwood trunks. (b) Detected number of deadwood trunks from each plot and the CVs. (c) Inventoried number of deadwood trunks from each plot and the CVs

Table 1. The classification accuracy of estimation of the conservation values.

		Actual class			User's accuracy
		Low CV (<15)	High CV (≥15)	Total	
Predicted class	Low CV (<15)	11	0	11	1.00
	High CV (≥15)	2	6	8	0.75
	Total	13	6	Overall accuracy	
Producer's accuracy		0.85	1.00	0.89	

4. Conclusions

This study used a template matching method to detect downed dead wood from ALS data. It obtained a 1.55 RMSE (12.9%) on estimating the number of deadwood trunks for each plot. The results illustrated the potential of ALS data for deadwood recognition. The number of deadwood trunks was used as a feature to classify forest stands with high and low conservation values, with 0.94 overall classification accuracy and 0.88 kappa coefficient. We conclude that the amount of deadwood is a crucial indicator of habitat quality in boreal forests, and ALS data is an efficient tool to estimate the conservation value. The proposed method could be used to map the forest conservation value in large areas in the future.

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