Mapping old natural forest habitat using airborne laser scanning

H. O. Ørka[1], A. Sverdrup-Thygeson[1], E. Næsset[1], T. Gobakken[1]

[1] Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway
Email: {hans-ole.orka; anne.sverdrup-thygeson; erik.naesset; terje.gobakken}@nmbu.no

1. Introduction

Forest management changes structures and affects biodiversity in forest habitats. While old-growth boreal forests display high within-stand variation in age and size of trees as well as large amounts and diversity of dead wood and old trees, managed boreal forests display a more homogeneous tree composition, age structure and vertical stratification. Several species groups are negatively affected by forest management in Europe and the effect increases with intensity (Paillet et al. 2010).

In Norway, the forest harvest regime changed drastically after World War II, from selection felling to clear felling. Today only a small proportion of natural forests, here defined as forests only affected by extensive selective logging in the past, remains. It is therefore important to establish efficient methods for identifying, delineating and monitoring the remaining areas of old natural forests.

During the last two decades, methods for mapping forests with airborne laser scanning (ALS) have developed. Today, ALS is a standard tool for providing stand level forest inventories over large areas in Scandinavia and also in many other countries around the world. The high spatial detail, the potentially large area coverage and the increasing availability of such data make them an attractive source for mapping and monitoring of forest habitats. Furthermore, the height measurements by ALS provide forest structural information which has been found useful for classifying successional stages of forests (Falkowski et al. 2009). The aim of the current study was to evaluate the potential of ALS data to capture structural differences between old natural forests and old managed forests that can be used to separate these two types of old forests.

2. Materials

The study area is a 17000 ha forested area in south-eastern Norway. We combined current digital forest maps with scanned and georeferenced historical forest maps from 1954. We considered only forest stands currently categorized as old production forest, and separated these into two classes: Stands specified as old forest also in 1954, denoted “old natural forest”, and stands that were clear-cut during the 1950ies, denoted “old managed forest”. In total 667 stands were subjectively selected based on the map data.

ALS data were acquired during August and September of 2007 using a Leica ALS 50-II laser scanner. The laser scanner was mounted on a helicopter flying approximately 600 m above ground level. The scanner was operated with a pulse repetition frequency of 127.5 kHz, a scan angle of ± 36° and was flown with a side overlap of 60%, resulting in a pulse density of approximately 10 m^{-2}.

3. Methods

From the selected digitized stands, we analyzed all ALS echoes inside a circular plot of 0.2 ha in size placed in the interior of the stand. Stands that were not large enough to completely contain this circular plot were excluded from the trial. Thus, 384 plots were used in this study of which 91 were located in old natural forests.

First, we did an explorative analysis of the differences in the distributions of all laser echoes between the two classes. Second, the ability to classify the two classes was investigated. From all ALS echoes above 1.3 m, standard metrics frequently used in operational stand level forest inventories were computed (Næsset 2004). From these metrics a balanced random forest algorithm (Breiman 2001; Chen et al. 2004) was used to classify old natural forest. The random forest algorithm is a popular classification algorithm both for remote sensing data and in ecology (Cutler et al. 2007; Gislason et al. 2006). In addition, a logistic regression model representing a more standard approach was used for the separation of the two classes. For variable selection a standard stepwise technique using the Bayesian information criterion was applied for the logistic model. The classification accuracy of both classifiers was evaluated using leave-one-out cross validation.

4. Results and discussion

The main difference between the two classes is that the old natural forest has a higher density in the lower vertical layers and a lower density higher in the canopy, as can be seen from Figure 1. This indicates that the old managed forests are denser, higher and with less shrub layer vegetation. The strong signal from the lower parts in the old natural forest could also be attributed to a lower crown base height in this type of habitat.

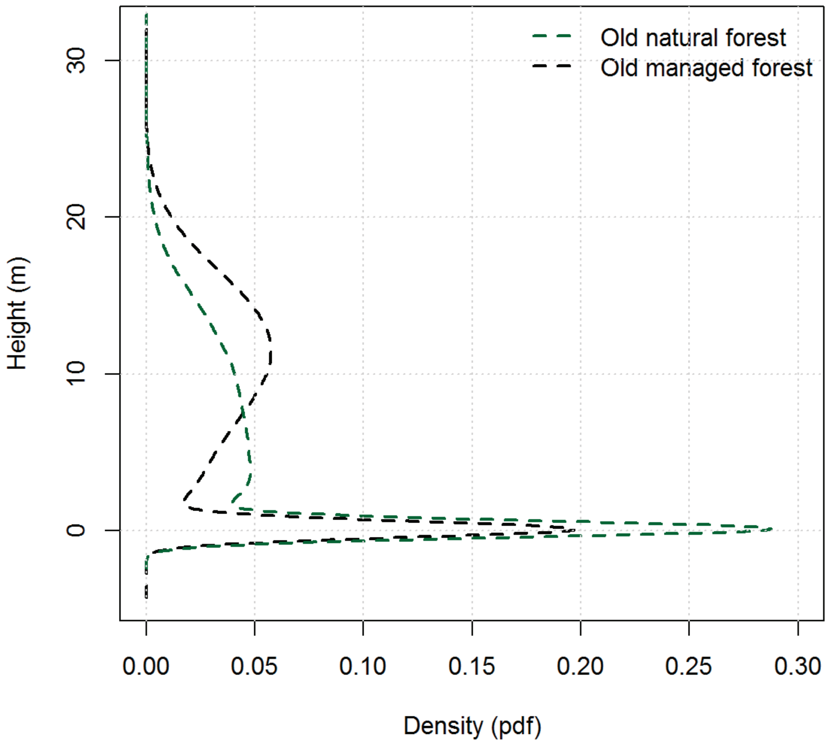

Figure 1: Estimated probability density function of laser echo height for old natural forest and old managed forest for all 384 plots.

The accuracy obtained by the two classifiers appears in Table 1 and Table 2. The overall accuracy was 86-88%, which must be considered as high. The class accuracies were lower for old natural forest than for old managed forest in both cases. The reason why the false positives are higher and the false negatives lower when using random forest were mainly due to the use of a correction for the unbalance in number of observations in the classes in the random forest classification, but not in the logistic classification.

Table 1. Error matrix of the random forest classification of old natural forest and old managed forest.

Classification	Old managed forest	Old natural forest	Sum	User's accuracy
Old managed forest	255	19	270	94.4
Old natural forest	38	76	114	66.7
Sum	293	91	384	
Produser's accuracy	87.0	83.5		
Overall accuracy				86.2
Cohen's kappa				0.65

Table 2. Error matrix of the logistic regression classification of old natural forest and old managed forest.

Classification	Old managed forest	Old natural forest	Sum	User’s accuracy
Old managed forest	274	26	300	91.3
Old natural forest	19	65	77.4	77.4
Sum	293	91	384	
Produser’s accuracy	93.5	71.4		
Overall accuracy				88.3
Cohen’s kappa				0.67

In this study only one size of the observation units was used (0.2 ha). When dealing with classification of forests based on structure, the spatial scale will influence the results and additional scales should be analysed. Also, quantifying spatial heterogeneity horizontally might provide additional and relevant information complementing the information from the vertical stratification. This could improve the classification. Furthermore, for large-scale mapping and monitoring of old natural forest habitat it is important to develop methods to capture reference data also in areas where historical stand records are missing.

References

Breiman L, 2001, Random forests. *Machine Learning,* 45(1):5-32.

Chen C, Liaw A, & Breiman L, 2004, Using random forest to learn imbalanced data. In, *Tech. Rep* (pp. 1-12): Dept. Statistics, Univ. California Berkeley.

Cutler DR, Edwards TC, Beard KH, Cutler A, Hess KT., Gibson J, & Lawler JJ, 2007, Random forests for classification in ecology. *Ecology,* 88(11):2783-2792.

Falkowski MJ, Evans JS, Martinuzzi S, Gessler PE, & Hudak AT, 2009, Characterizing forest succession with lidar data: An evaluation for the Inland Northwest, USA. *Remote Sensing of Environment,* 113(5):946-956.

Gislason PO, Benediktsson JA, & Sveinsson JR, 2006, Random Forests for land cover classification. *Pattern Recognition Letters,* 27(4):294-300.

Næsset E, 2004, Practical large-scale forest stand inventory using a small-footprint airborne scanning laser. *Scandinavian Journal of Forest Research,* 19(2):164-179.

Paillet Y, Berges L, Hjalten J, Odor P, Avon C, Bernhardt-Romermann M, Bijlsma RJ, De Bruyn L, Fuhr M, Grandin U, Kanka R, Lundin L, Luque S, Magura T, Matesanz S, Meszaros I, Sebastia MT, Schmidt W, Standovar T, Tothmeresz B, Uotila A, Valladares F, Vellak K, Virtanen R, 2010, Biodiversity Differences between Managed and Unmanaged Forests: Meta-Analysis of Species Richness in Europe. *Conservation Biology* 24(1): 101-112.