Abstract template for the conference "A century of national forest inventories – informing past, present and future decisions"

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Abstract title:		Terrestrial Laser Scanning for Assessing Ecologically Relevant Stem Structures
Take-home message:		*Dense 3D point clouds from a terrestrial laser scanner with small footprint seem to have high potential for the semi-automated identification of ecologically relevant stem structures (i.e. tree-related microhabitats), especially when applying deep learning techniques.*
Presenter name:		Nataliia Rehush
Presenter contact info:		Swiss Federal Institute for Forest, Snow and Landscape Research WSL, nataliia.rehush@wsl.ch
General topic, see website: (please double click on the check box and activate the relevant one)	☐	Improving future NFIs by learning from the past
	☐	NFIs today and in the future
	☒	Cutting edge and futuristic inventory techniques and technologies
Preferred presentation form:	☐	Oral presentation
	☒	Poster
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Terrestrial Laser Scanning for Assessing Ecologically Relevant Stem Structures

Nataliia Rehush, Meinrad Abegg, Lars T. Waser, Urs-Beat Brändli*

Introduction: Stem structures such as cavities, epiphytes and other *tree-related microhabitats* (TreMs), serve as habitats at tree level and are existential for a wide range of insect, bird and mammal species during their life cycles (Larrieu et al., 2018). TreMs are thus important indicators of forest biodiversity and have recently received more attention in forest management and monitoring. In the ongoing 5th Swiss National Forest Inventory, such stem structures are explicitly recorded during field survey (Düggeling (Ed.), in preparation). However, the assessment of TreMs by experts during field surveys is time-consuming and difficult to reproduce. Recent developments in terrestrial laser scanning (TLS) allow efficient mapping of object surfaces in dense 3D point clouds. Moreover, object recognition has been dramatically improved when applying deep learning techniques for image and point cloud processing. In this study, we evaluate the potential of close-range TLS for semi-automated identification of different tree-stem structures associated with TreMs (*bark*, *bark pockets*, *cavities*, *fungi*, *ivy* and *mosses*) using machine learning algorithms, including deep learning.

Materials and methods: A Faro Focus 3D 120S terrestrial laser scanner was used to obtain very high-resolution 3D point clouds from multiple scans of representative beech habitat trees in temperate mixed forests across Switzerland. To identify the TreMs in the point clouds, we performed point-wise sematic labeling using: 1) the Random Forest (RF) classifier, incorporating frequently used local geometric features, and 2) a deep Convolutional Neural Network (CNN) trained using rasterized multiview orthographic projections (MVOPs) of the point's local 3D neighborhood. The performance of each model was assessed using leave-one-out cross-validation.

Results: The RF trained based on local geometric features is beneficial for identifying the six groups of TreMs in dense 3D point clouds, but the CNN incorporating the rasterized MVOPs is even more suitable. Whereas the overall accuracy of the RF was 70%, that of the deep CNN was substantially higher (83%). The local geometric features are very effective in distinguishing between the structures with 2D (*bark* and *moss*) and 3D (*cavities*, *ivy* and *fungi*) properties, whereas they are less useful in distinguishing convex stem structures such as *ivy* and *fungi*, and concave structures such as *cavities*. The rasterized MVOPs are more suitable for the identification of such stem structures. The study also reveals that the identification accuracy for some types of TreMs was lower in the upper parts of the tree stems.

Conclusion: Dense 3D point clouds derived using a terrestrial laser scanner with a small footprint seem to have high potential for the semi-automated identification of ecologically relevant stem structures (i.e. TreMs). The RF trained based on the commonly used local geometric features is beneficial for identifying of TreMs, but the CNN incorporating the rasterized MVOPs is even more suitable. The study also reveals that the identification accuracy for some types of TreMs might be sensitive to their location on the tree stems.

References:

Larrieu et al., 2018, Ecol. Indic., 84, 194-207. Düggelin (*Ed.*), in preparation. Rehush et al., 2018, Remote Sens. (accepted).

Nataliia Rehush*, M. Abegg, L.T. Waser, U.-B. Brändli, Swiss Federal Institute for Forest, Snow and Landscape Research WSL, 8903 Birmensdorf, Switzerland, *nataliia.rehush@wsl.ch.