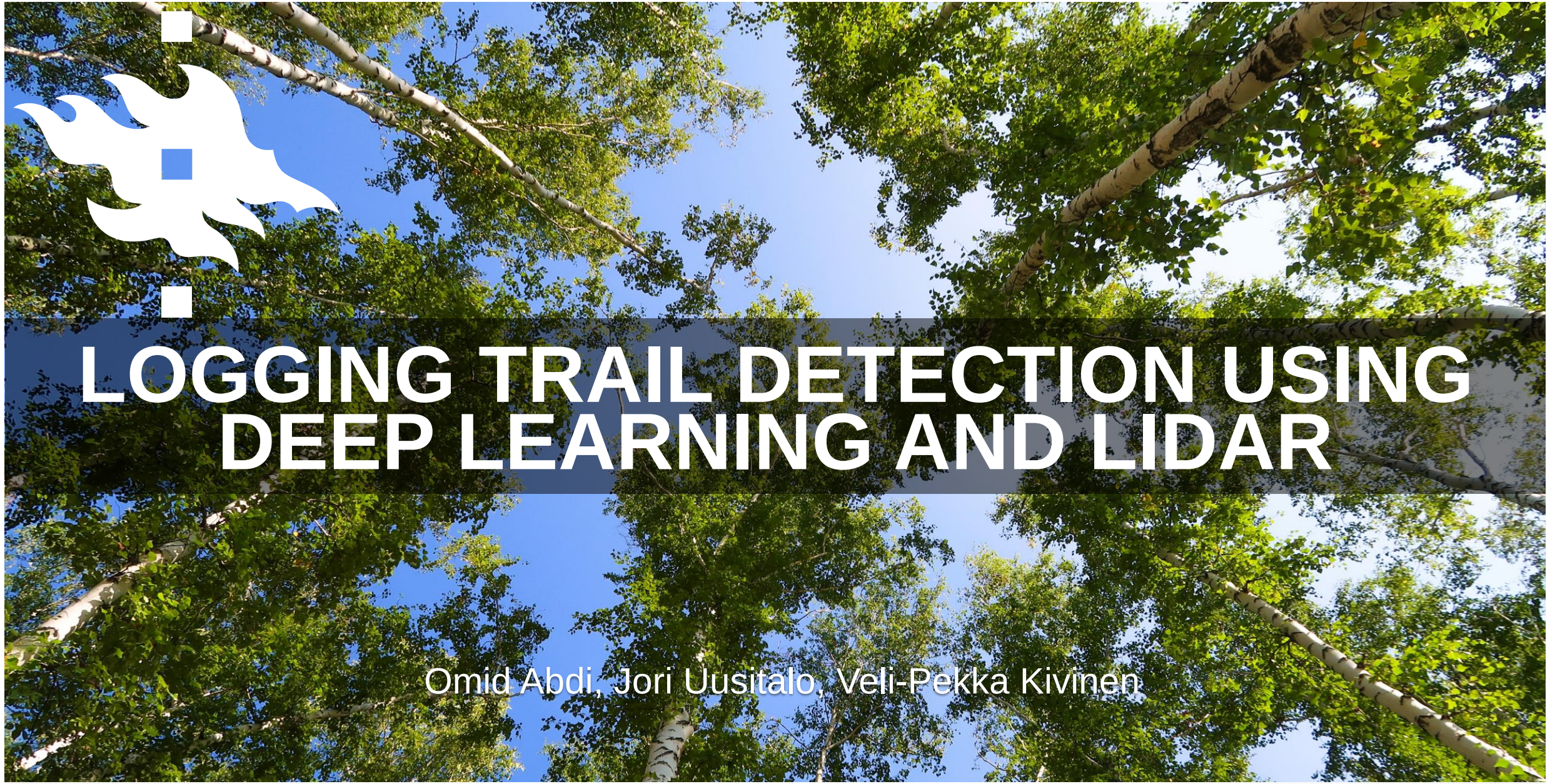


LOGGING TRAIL DETECTION USING DEEP LEARNING AND LIDAR

Omid Abdi, Jori Uusitalo, Veli-Pekka Kivinen

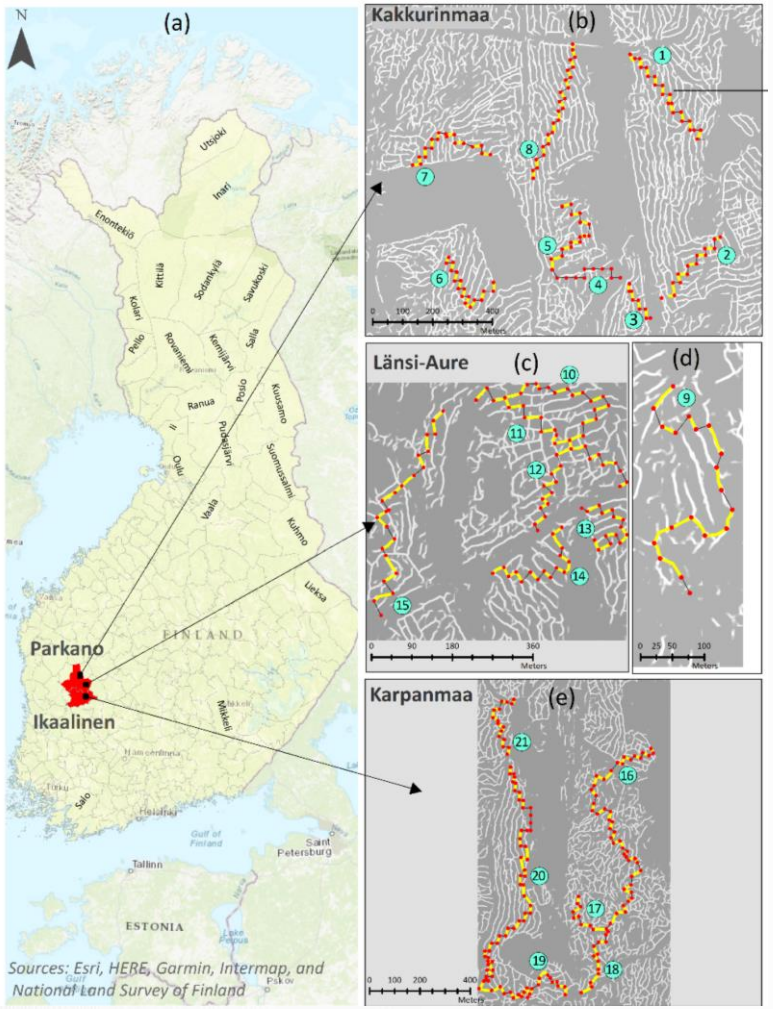
INTRODUCTION

- The importance of logging trails in forest operations for accurate navigation of vehicles
- Challenges in spotting the location of logging trails for forest owners/ drivers
- Lack of knowledge about the feasibility of LiDAR for detection logging trails

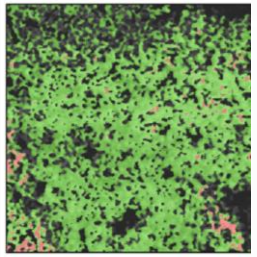
OBJECTIVES

- To develop an end-to-end deep learning-based approach that uses high-density laser scanning data to automate the detection of logging trails
- To evaluate the performance of U-Net using derivatives of laser scanning datasets (i.e., canopy height and elevation-based models) for the detection of logging trails
- To investigate the performance of the U-Net to detect logging trails in young and mature stands with different development classes

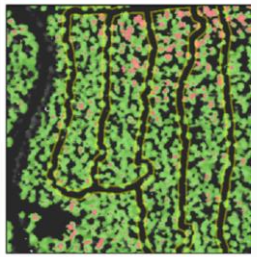
STUDY AREA



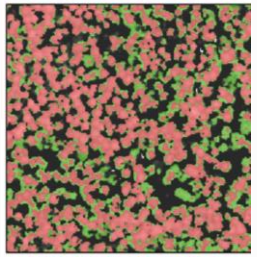
STAND CLASSES



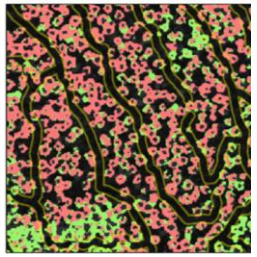
Young stands
before the first commercial thinning



Young stands
after the first commercial thinning



Mature stands
before the second commercial thinning



Mature stands
after the second/third commercial thinning

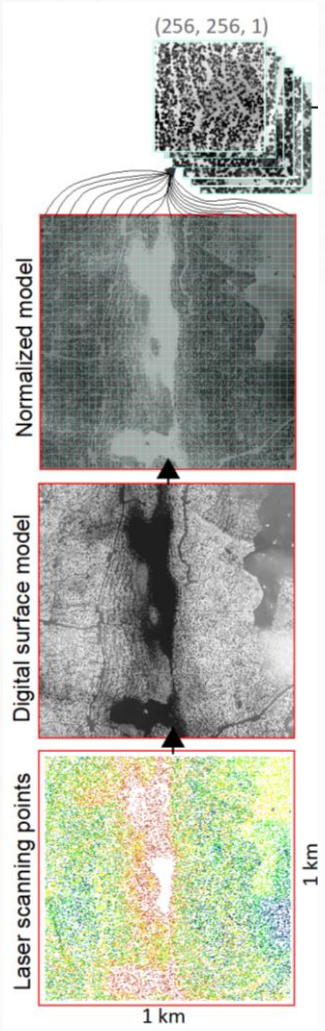
TRAINING DATASET

- Image patches

- 0-255

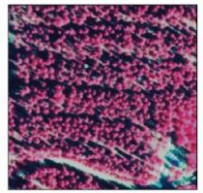
- Digital surface mode
- Digital elevation model
- Canopy height model

- 44 tiles
- Point density: 5 pts/m

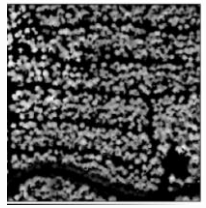


LABEL DATASET

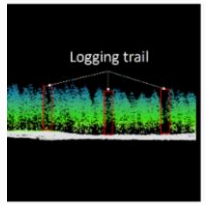
A label of logging trails



Near-infrared orthophotos



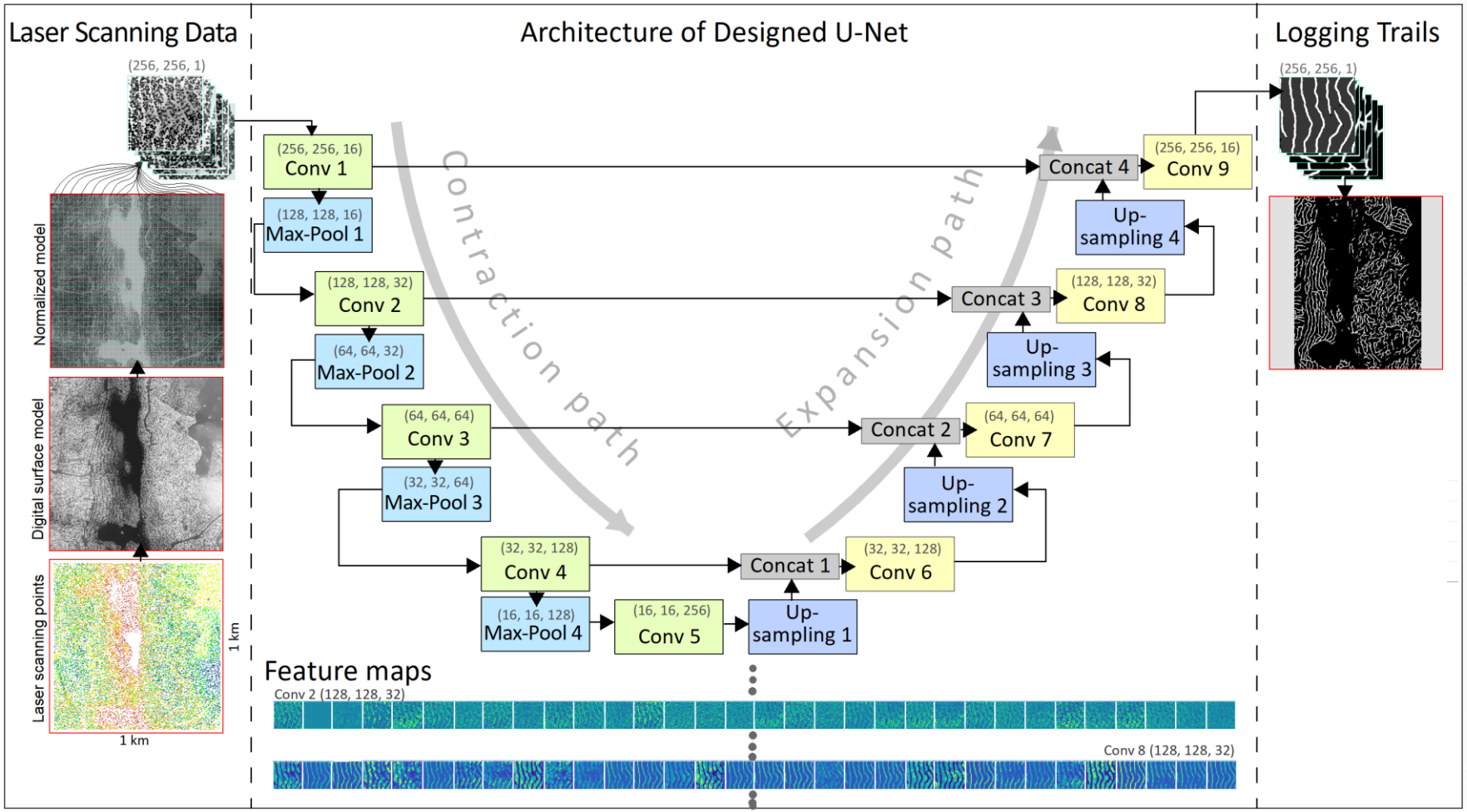
Canopy height model



Tree profiles

The ground elevation model

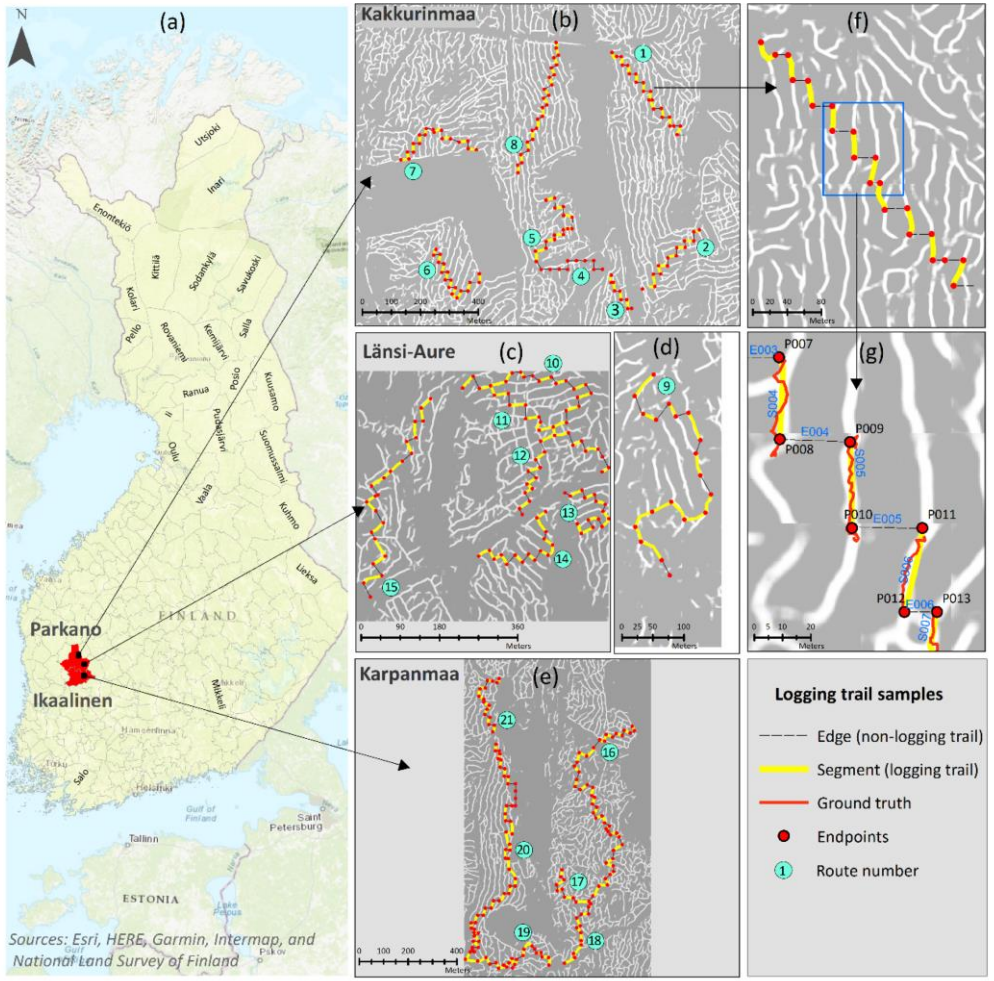
U-NET


Laser Scanning Data
Architecture of Designed U-Net
Logging Trails
(256, 256, 1)
Normalized model
Digital surface model
Laser scanning points
1 km
1 km
(256, 256, 16)
Conv 1
(128, 128, 16)
Max-Pool 1
(128, 128, 32)
Conv 2
(64, 64, 32)
Max-Pool 2
(64, 64, 64)
Conv 3
(32, 32, 64)
Max-Pool 3
(32, 32, 128)
Conv 4
(16, 16, 128)
Max-Pool 4
(16, 16, 256)
Conv 5
Up-sampling 1
Concat 1
(32, 32, 128)
Conv 6
Up-sampling 2
Concat 2
(64, 64, 64)
Conv 7
Up-sampling 3
Concat 3
(128, 128, 32)
Conv 8
Up-sampling 4
Concat 4
(256, 256, 16)
Conv 9
Contraction path
Expansion path
Feature maps
Conv 2 (128, 128, 32)
Conv 8 (128, 128, 32)

ACCURACY ASSESSMENT OF U-NET

Collecting Testing Data

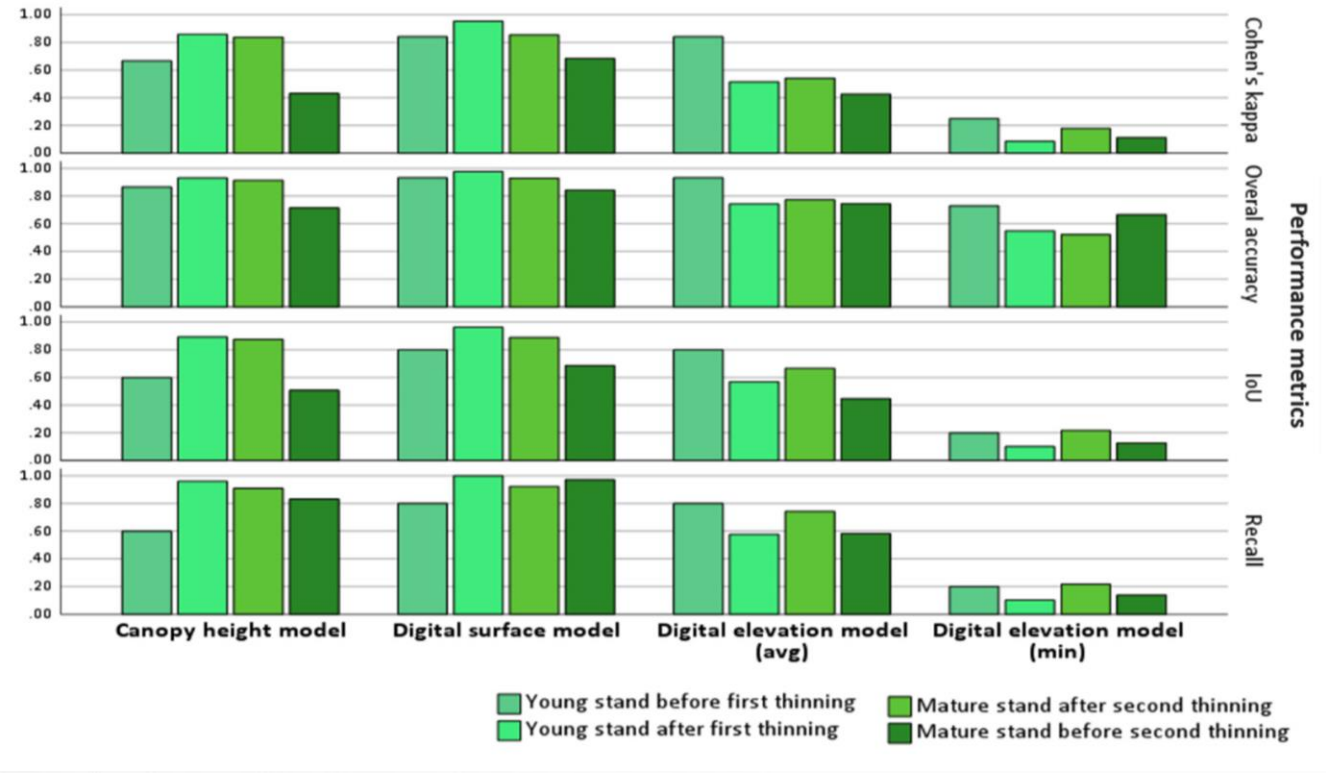
- Three forest areas
- 21 routes
- Endpoints, trail segments (~30 m), and edges
- 390 samples

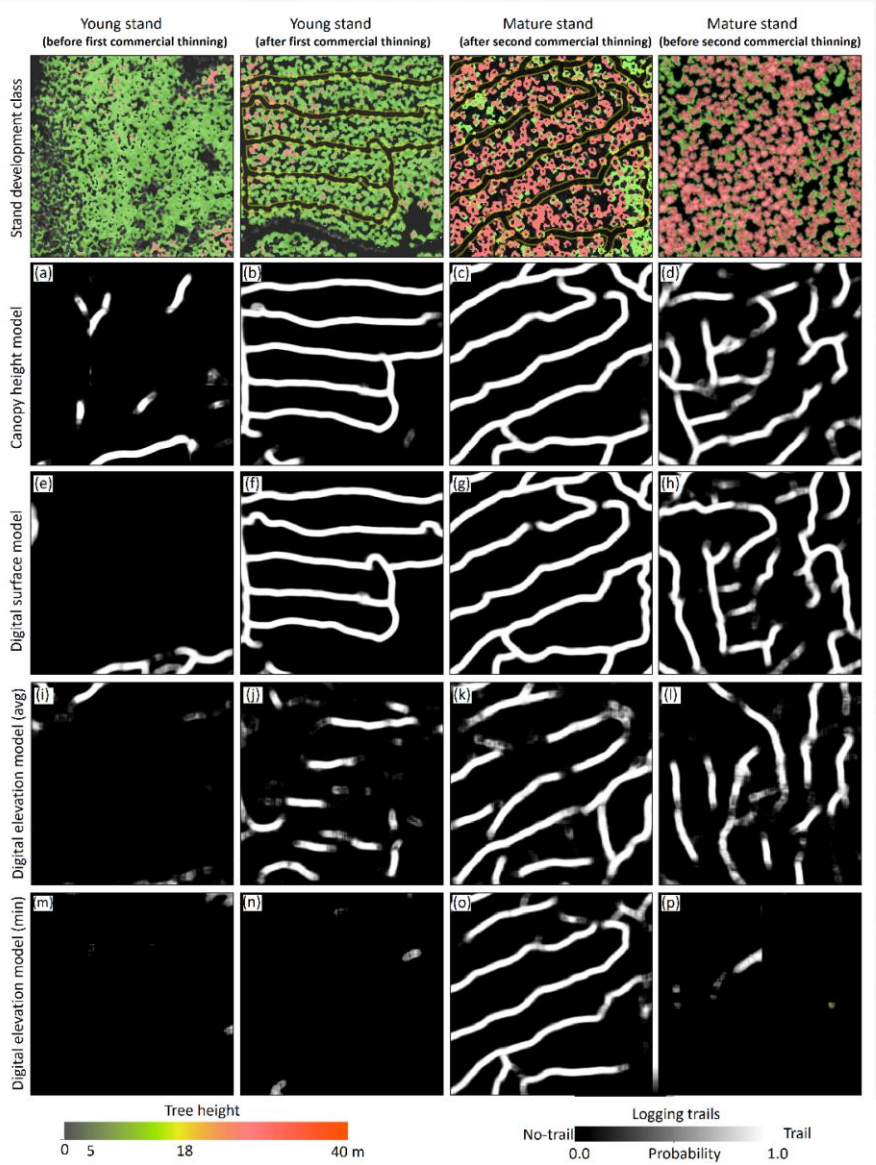


Accuracy Metrics

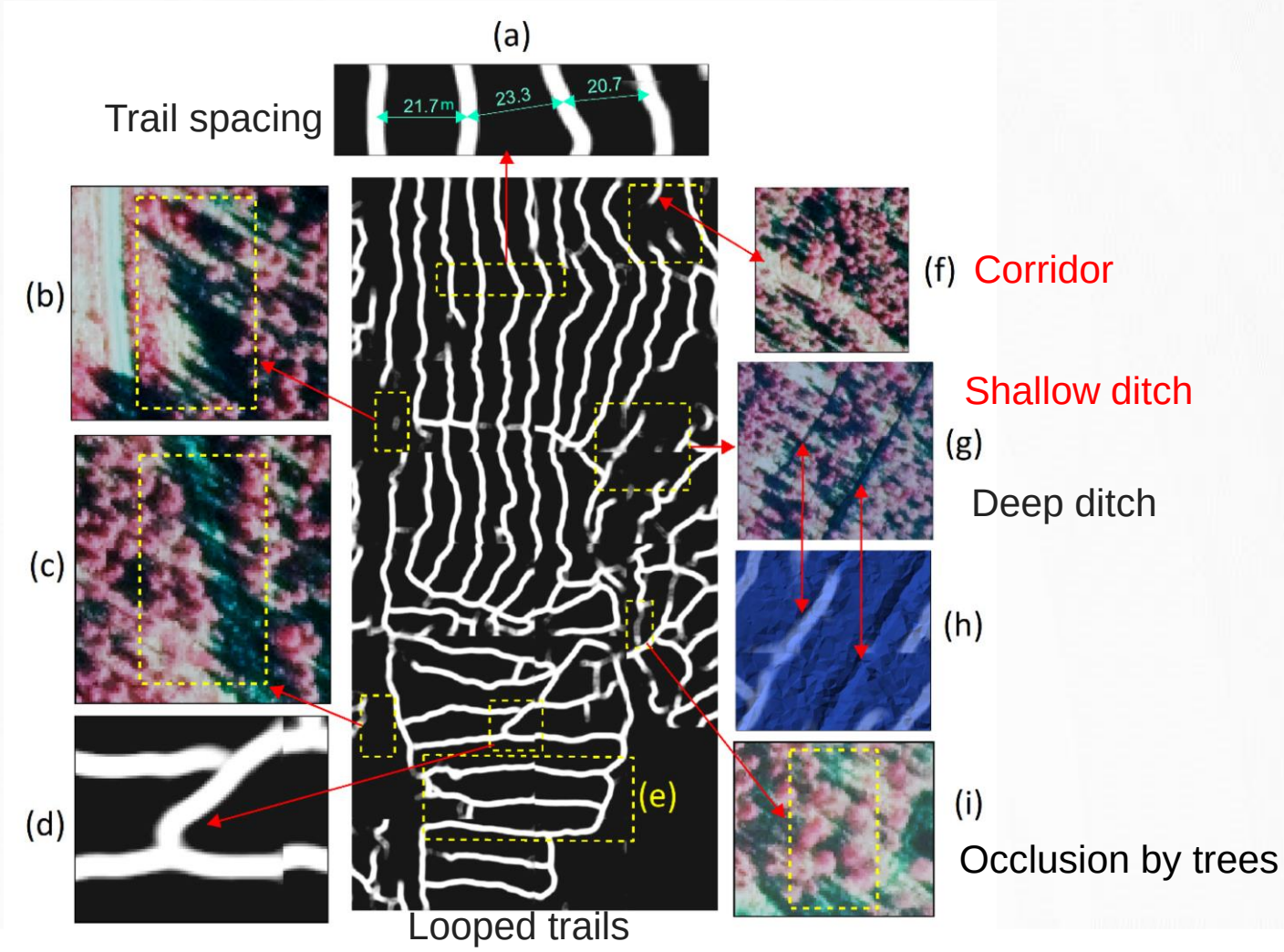
- Cohen's kappa
- Overall accuracy
- Intersection over union (IoU)
- recall

PERFORMANCE OF TRAINED U-NET





U-NET AND THE CHARACTERISTICS OF LOGGING TRAILS



SUMMARY

- The trained U-Net using DSM was able to distinguish logging trails from the background with a high probability and very high performance (young and mature stands that had undergone commercial thinning)
- The developed model can be used easily by the end-users, without heavy pre-processing of the laser scanning data or heavy post-processing of the outputs
- The model needs to be improved for the very old stands that have not received second commercial thinning for a long time
- Creating a large labeled dataset from logging trials is required (e.g., collected data by harvesters during thinning operations) to train the deep-learning based algorithms

Abdi, O.; Uusitalo, J.; Kivinen, V.-P. Logging Trail Segmentation via a Novel U-Net Convolutional Neural Network and High-Density Laser Scanning Data. *Remote Sens.* **2022**, *14*, 349. https://doi.org/10.3390/rs14020349