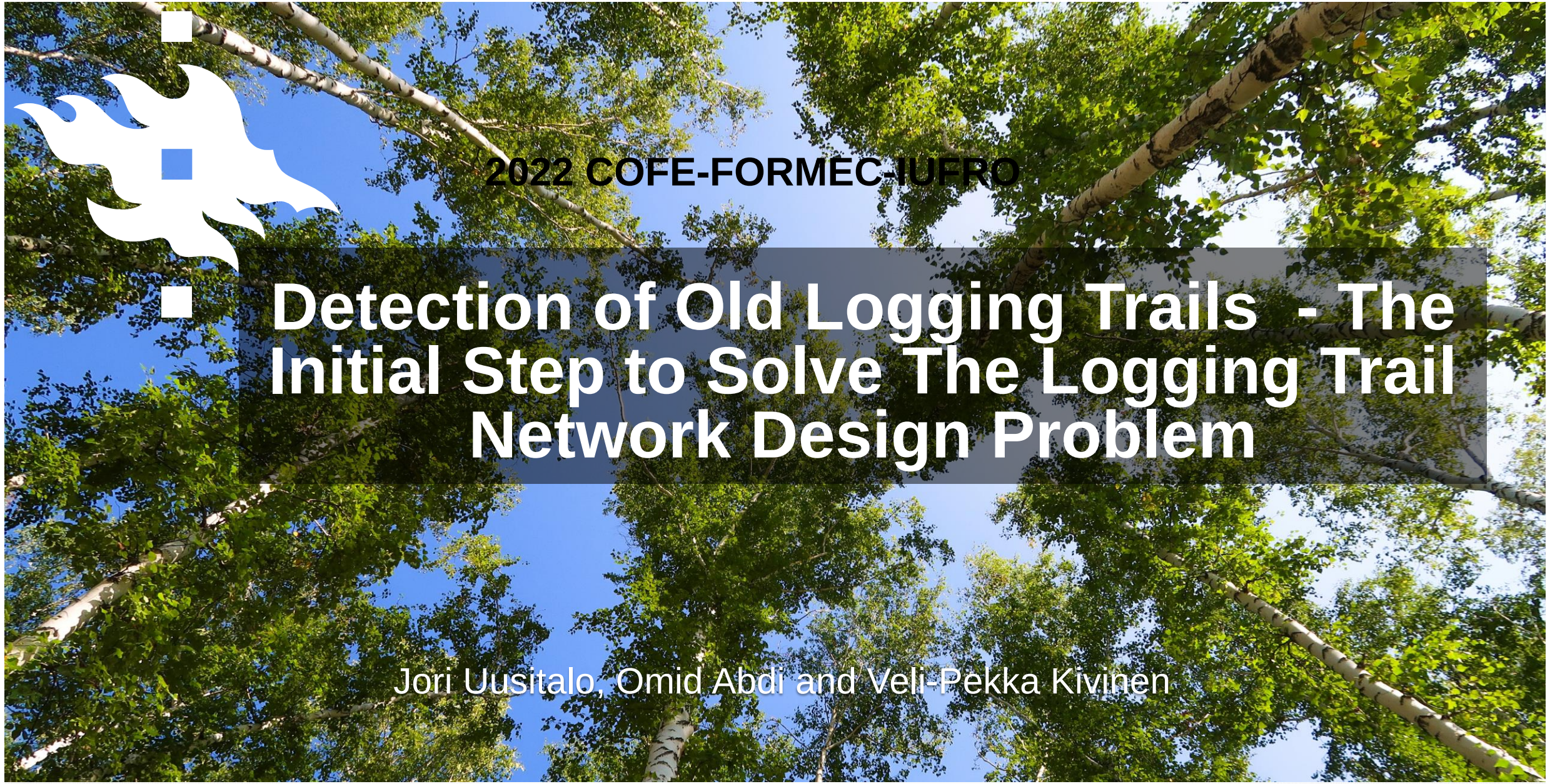


2022 COFE-FORMEC-IUFRO

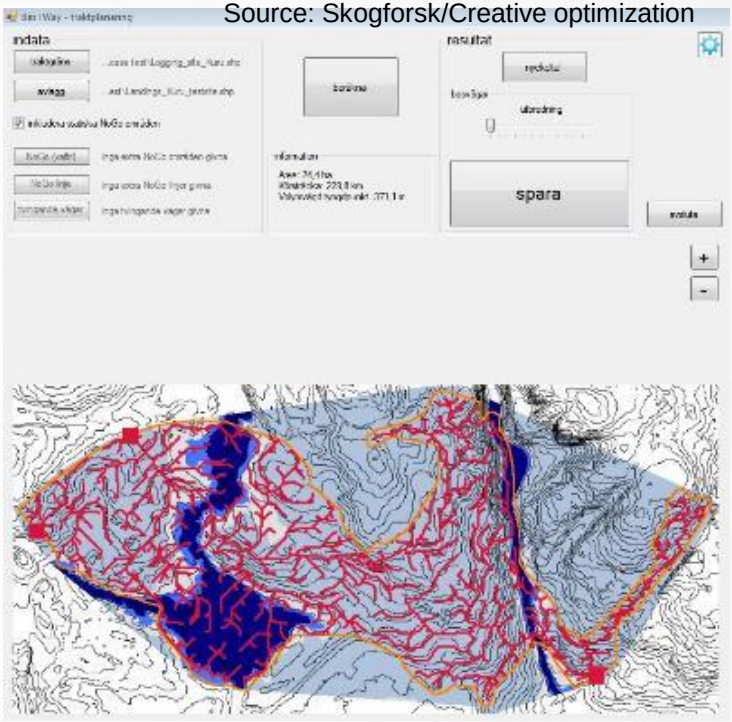
Detection of Old Logging Trails - The Initial Step to Solve The Logging Trail Network Design Problem

Jori Uusitalo, Omid Abdi and Veli-Pekka Kivinen

LOGGING TRAIL NETWORK PLANNING

- The first attempts to optimize placement of logging trails or routing of vehicle traffic has not been largely adopted by practitioners
  - Too scarce data on environment
  - Neglecting the operator affect (habits to create the network)
- It is expected that much better solutions will appear in the future

Source: Skogforsk/Creative optimization

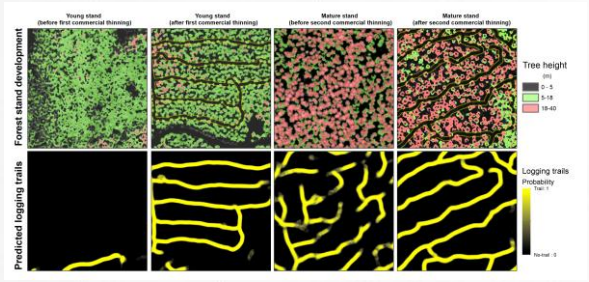


ISource: CGI/Metsäteho

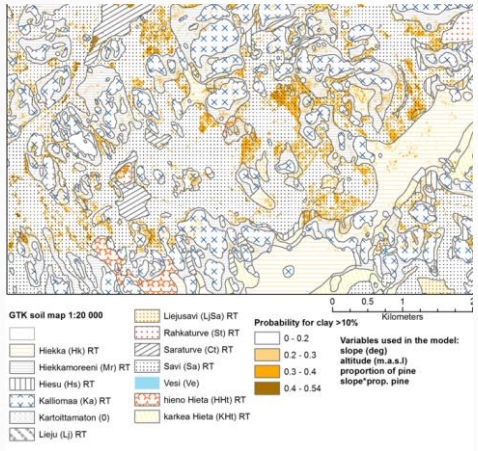
“OLD” LOGGING TRAILS

- One important starting point of the optimal logging trail network also includes assessment/understanding the history of the forest
- The forest may comprise old logging trail network that is more or less visible when cruising the forest prior to forest

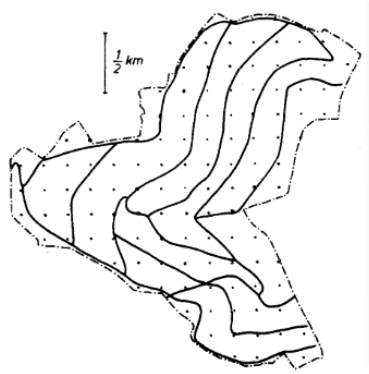
OPTIMAL LOGGING TRAIL NETWORK



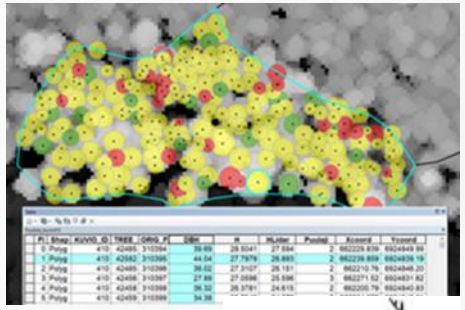
Detection of old trails



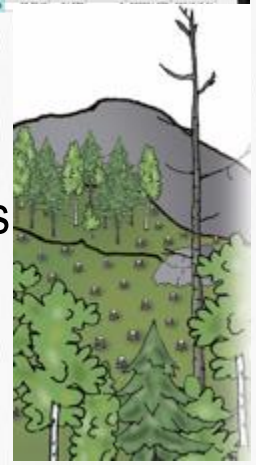
Intelligent detection of soil properties



Efficiency of the network



Tree maps

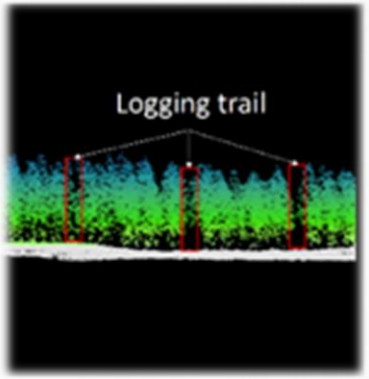


Biodiversity hot spots

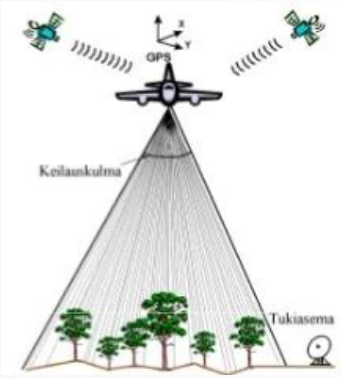
Optimal logging trail network

OBJECTIVES

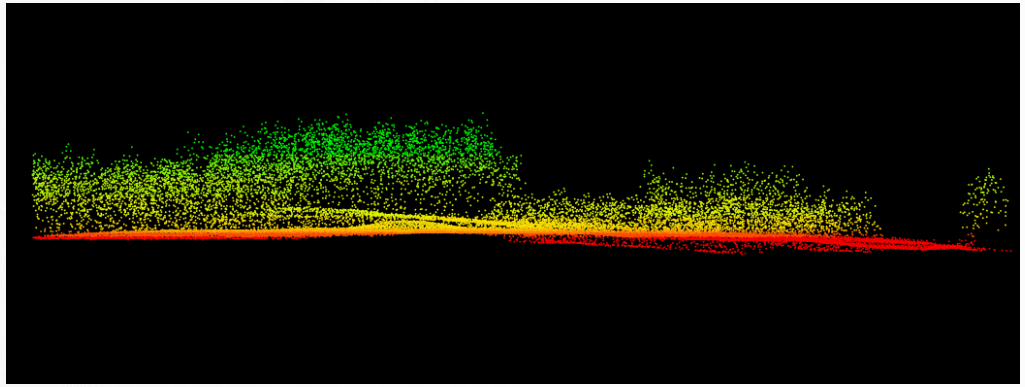
- To develop a deep learning-based approach that uses high-density laser scanning data to automate the detection of logging trails
- To investigate the performance of the U-Net to detect logging trails in young and mature stands with different development classes



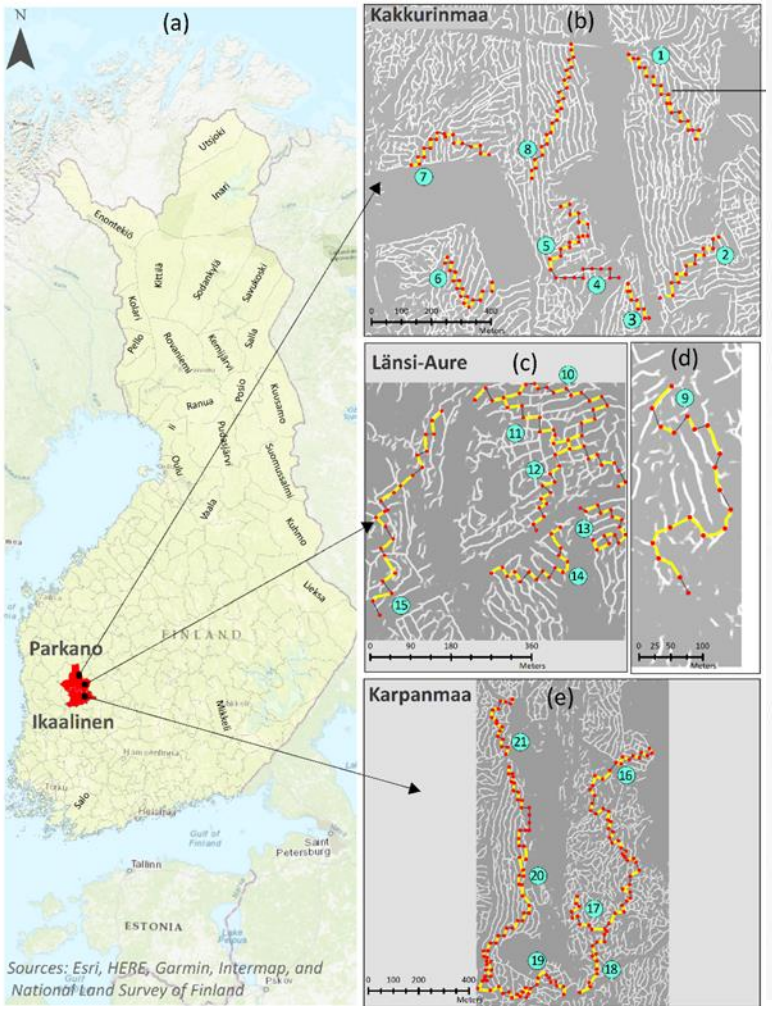
STUDY AREA



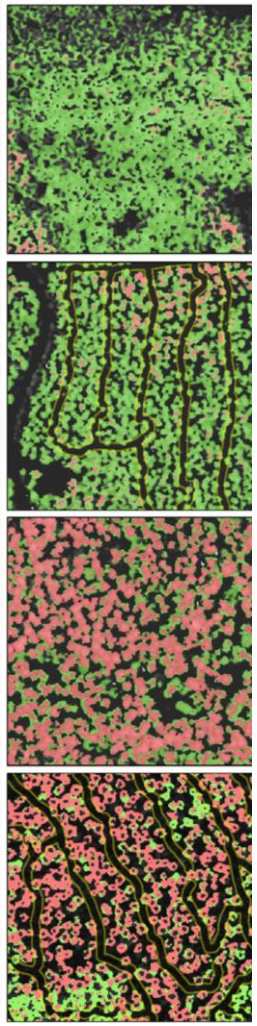
HD ALS data available (5 hits/m2)



Three forest areas in the municipalities of Ikaalinen and Parkano in southern Finland



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

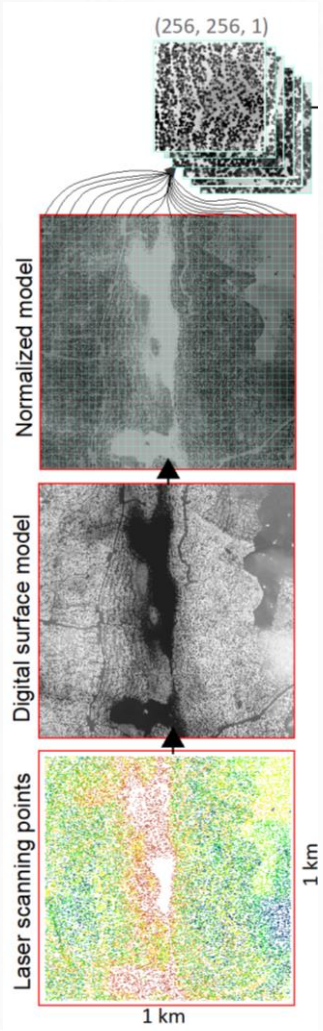
TRAINING DATASET

- Image patches

- 0-255

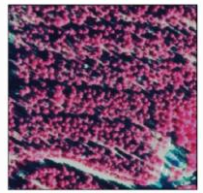
- Digital surface mode
- Digital elevation model
- Canopy height model

- 44 tiles
- Point density: 5 pts/m

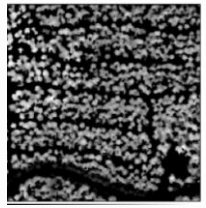


LABEL DATASET

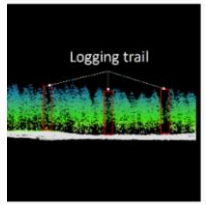
A label of logging trails



Near-infrared orthophotos



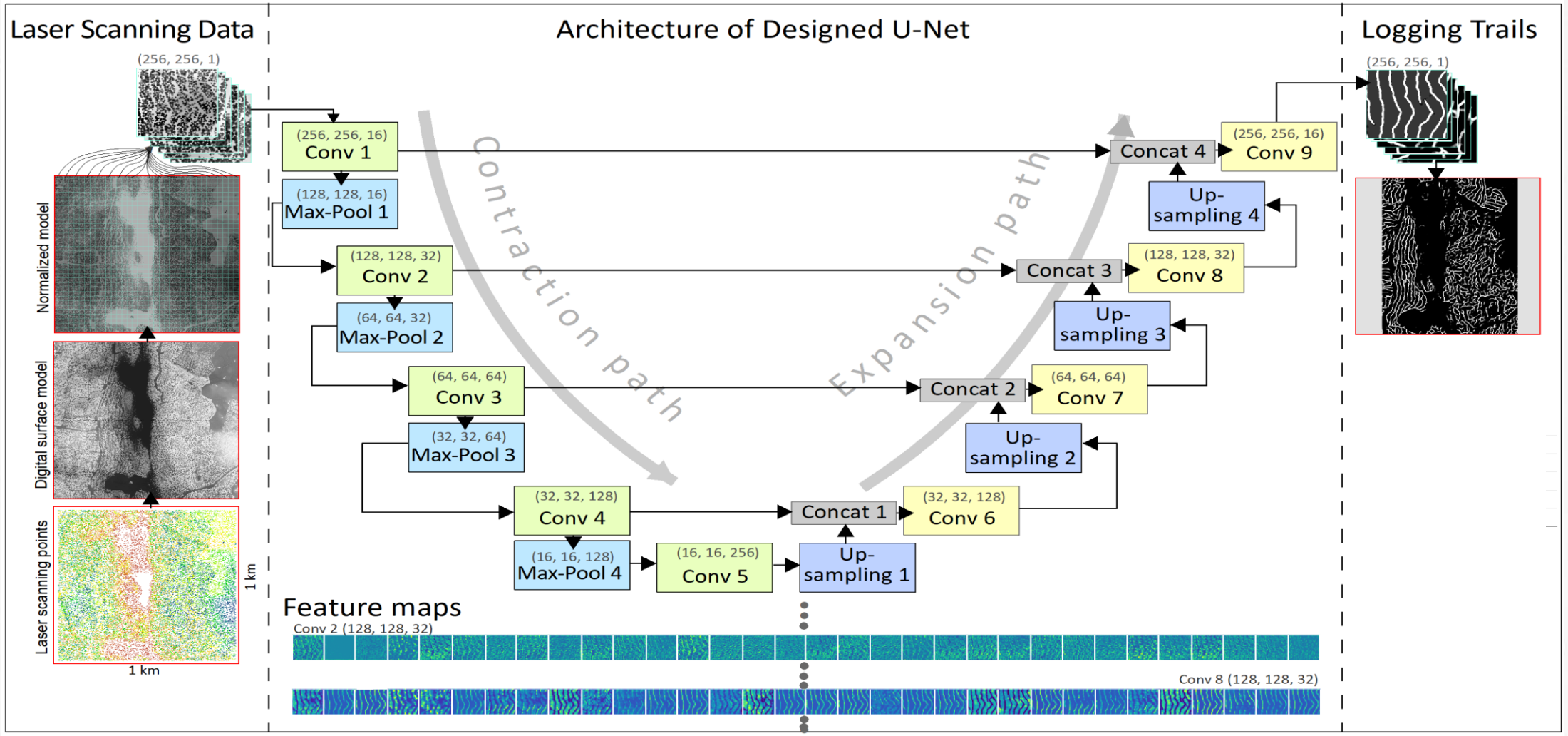
Canopy height model



Tree profiles

The ground elevation model

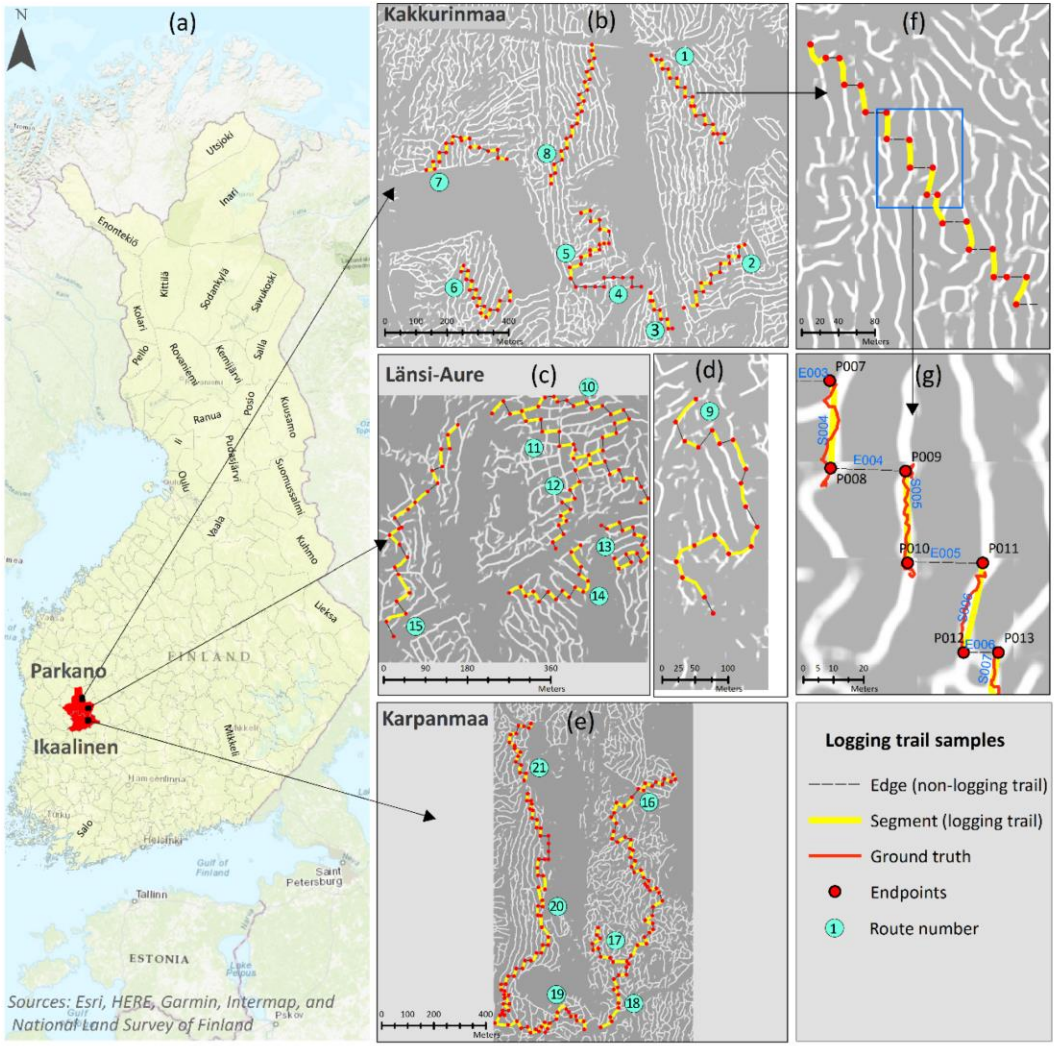
U-NET


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

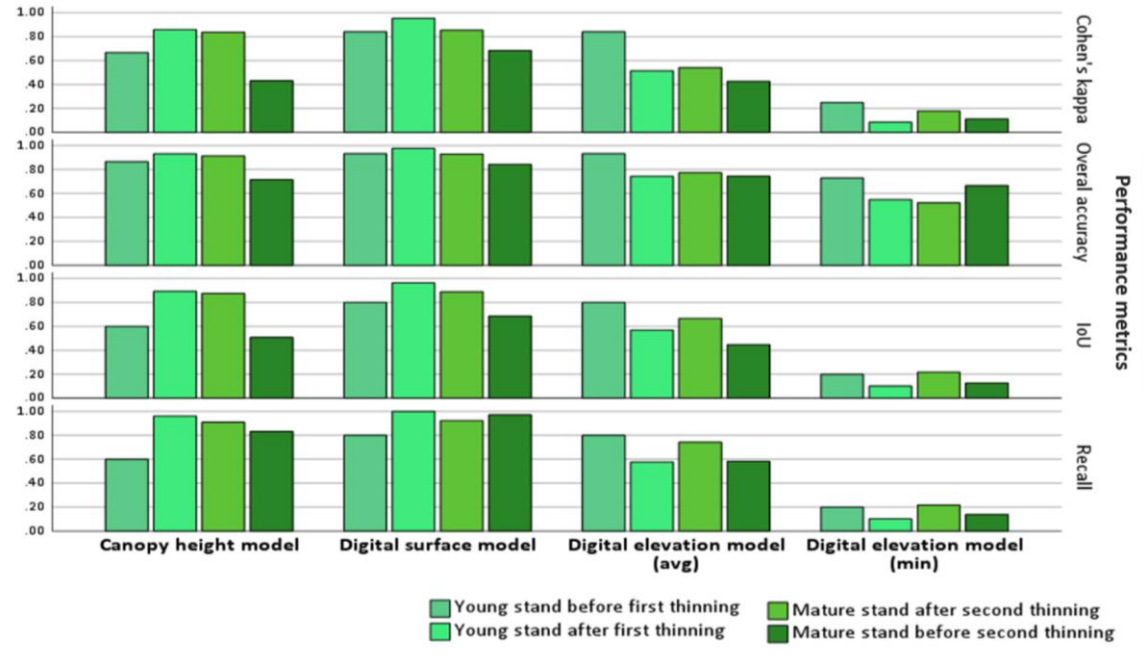
- Three forest areas
- 21 routes
- Endpoints, trail segments (~30 m), and edges
- 390 samples

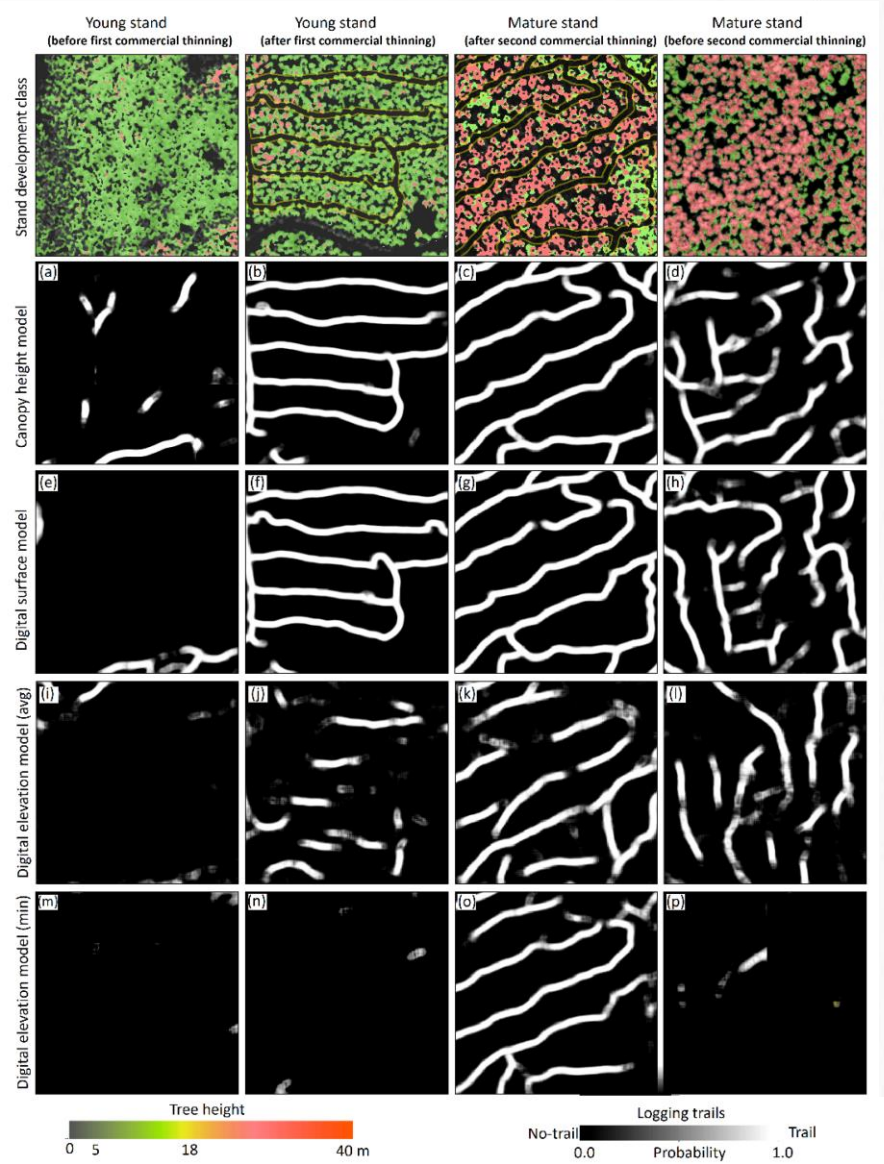


Accuracy Metrics

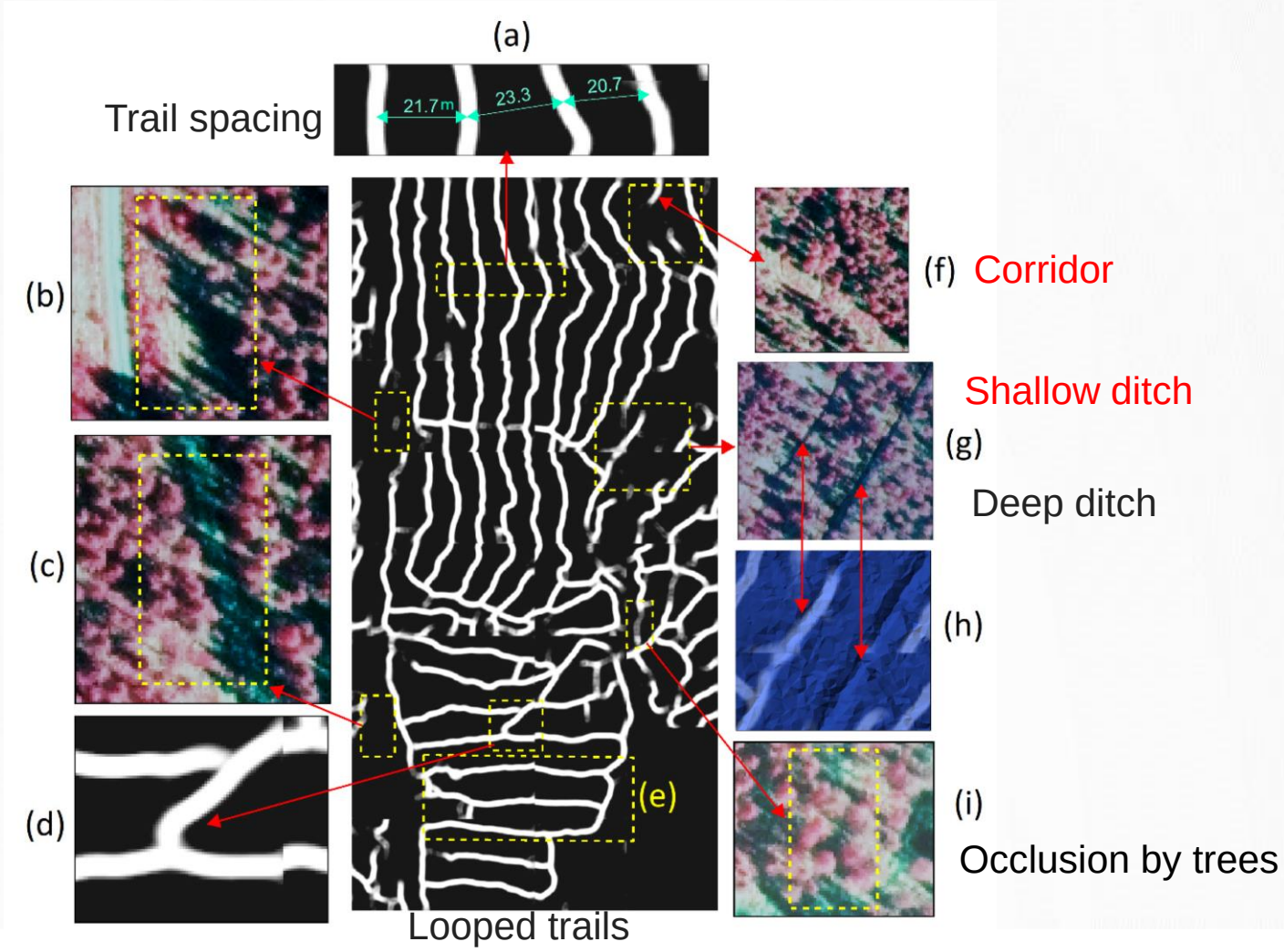
- Cohen's kappa
- Overall accuracy
- Intersection over union (IoU)
- recall

PERFORMANCE OF TRAINED U-NET



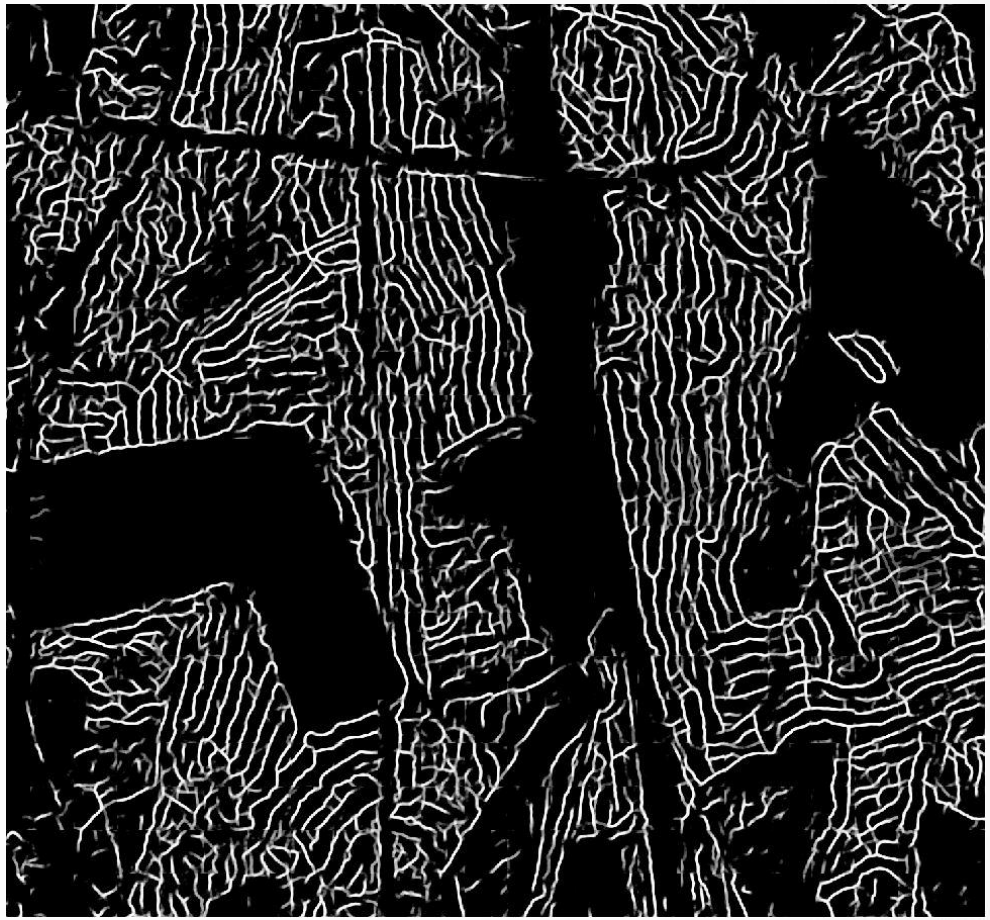


U-NET AND THE CHARACTERISTICS OF LOGGING TRAILS



SUMMARY/CONCLUSIONS

- The trained U-Net using DSM was able to distinguish logging trails from the background with a high probability and very high performance
- The developed model can be used easily by the end-users, without heavy pre-processing of the laser scanning data
- Large tests with forest practitioners (harvester operators) will be carried out in the coming winter



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