ForestMap

The next generation of forest maps - adapting a Nordic success story across the globe

ForestValue2 – Anniversary event 2024, From WoodWisdom-Net to ForestValue – 20 years of pioneering progress in European Forestry & Wood Tech, Berlin, 1-2 October, 2024

Project name: The next generation of forest maps - adapting a Nordic success story across the globe

Project acronym: ForestMap

Professor Johan Fransson, Department of Forestry and Wood Technology, Linnæus University, Sweden

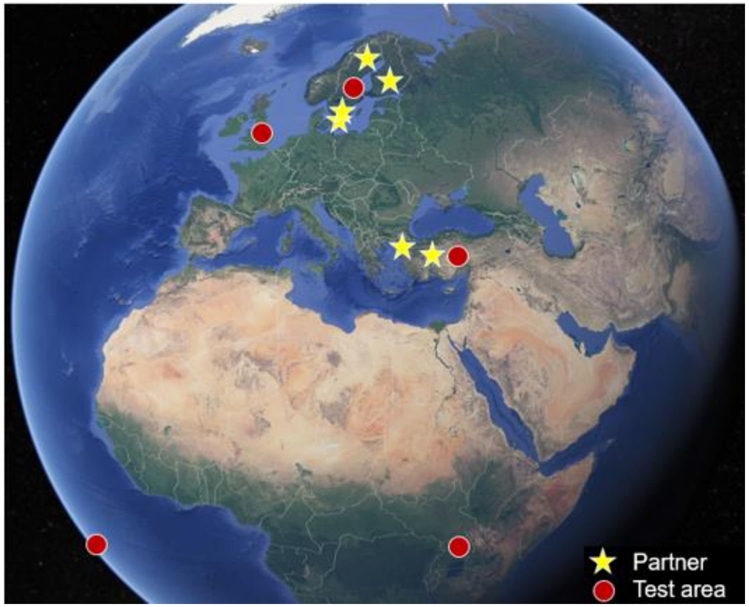
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 773324

ForestValue

Project partners

- Linnæus University, Sweden
- Swedish University of Agricultural Sciences, Sweden
- Katam Technologies AB, Sweden
- Yeditepe University, Turkey
- Istanbul Technical University, Turkey
- University of Helsinki, Finland

1 M€ for 2022-01-01 to 2024-12-31



Staff in ForestMap

Jörgen Wallerman, SLU
Researcher in Forest Remote Sensing

Mats Nilsson, SLU
Associate Professor in Forest Remote Sensing

Johan Fransson, LNU
Professor of Digitalisation in Forestry

Anton Holmström, Katam
Director of Forestry

Cem Ünsalan, Yeditepe University
Prof. Dr. in Electrical and Electronics Engineering

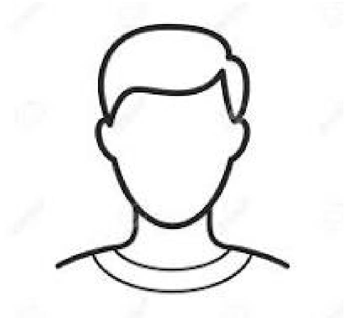
Elif Sertel, ITU
Prof. Dr. in Geomatics Engineering

Jari Salo, University of Helsinki
Professor in Marketing

Staff in ForestMap

Shafiullah Soomro, LNU
Postdoctoral Fellow in
Computer Science

Jorge Lazo, LNU
Postdoctoral Fellow in
Computer Science
(AI Sweden)



Poovaragavalu Adhiguru,
University of Helsinki,
Ph.D. student in
Economics

Ghazale Kordi,
University of Helsinki
Ph.D. student in
Economics

Dag Björnberg, LNU
Ph.D. student in
Computer Science
(Softwerk)

Esra Şengün, LNU
Ph.D. student in Forest
Remote Sensing

Samet Aksoy, ITU
Research Assistant in
Geomatics Engineering

Şule Nur Topgül, ITU
M.Sc. student in
Geomatics Engineering

Project structure

WP1 – Project management and coordination

WP2 – Field data collection and extraction of remote sensing data

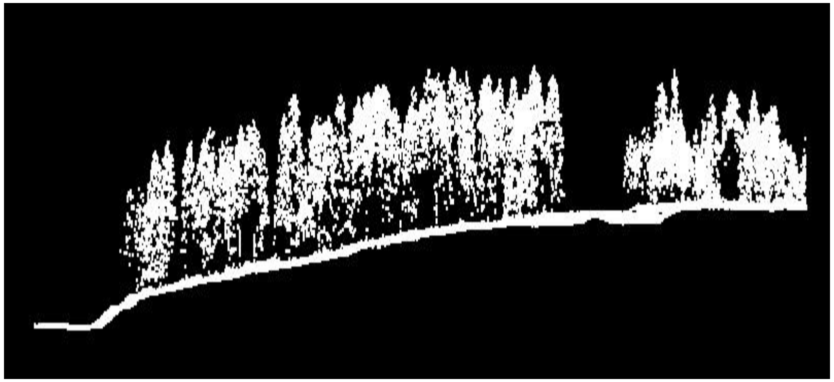
WP3 – Hierarchical decision-making system for efficient forest mapping

WP4 – Demonstration cases (Latvia in focus)

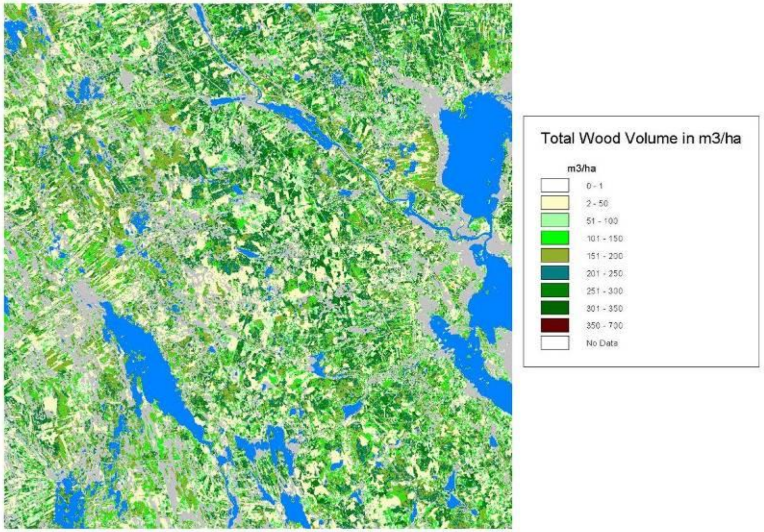
WP5 – Societal values

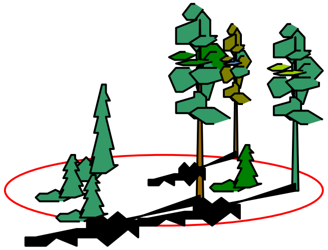
WP6 – Dissemination and communication

National forest maps – examples from Scandinavia



Remote sensing data





Field surveyed plots, training data, from the Swedish National Forest Inventory

Estimation of forest variables

Raster databases with estimated forest variables

National forest maps from satellite image data

Time-series of maps for years 2000, 2005, 2010, and 2015. Produced by combining satellite image data (Landsat, SPOT, Sentinel-2), canopy height from aerial images (year 2015), and field data from the Swedish National Forest Inventory.

Provided as open data by SLU (SLU Forest Map).

Variables

- Stem volume
- Mean tree height
- Mean diameter
- Basal area
- Above-ground biomass
- Tree species

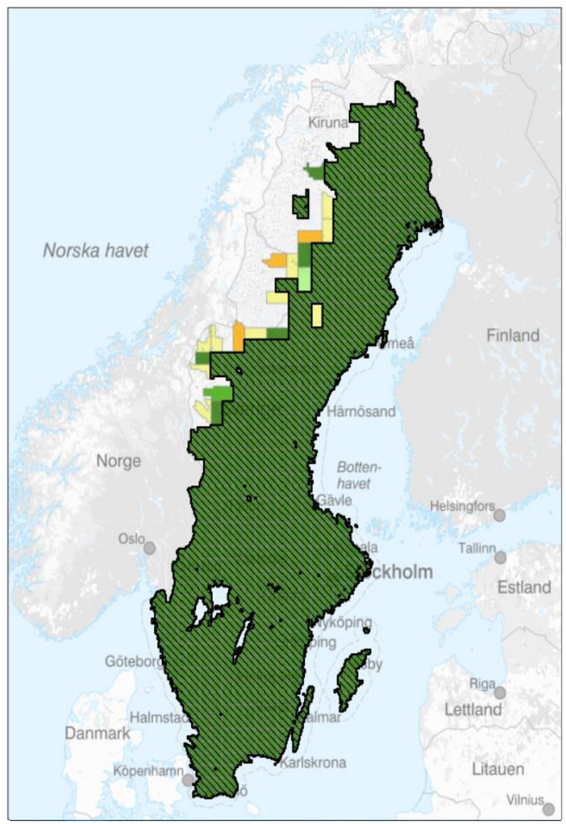
Cell size

- 25 × 25 m

National forest maps from airborne laser scanning

Version 1
2009-2016

Version 2
2024-10-01



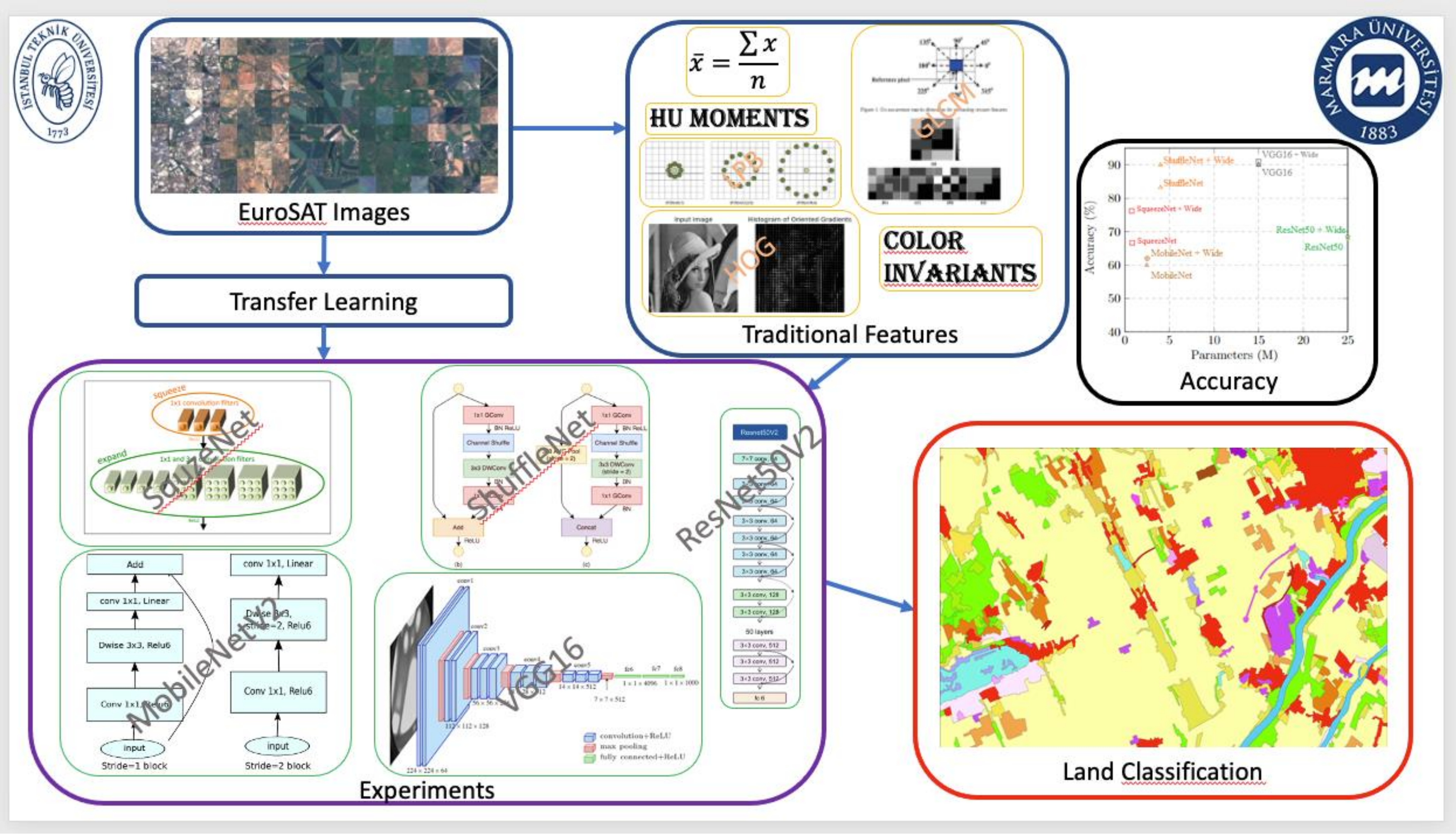
Produced by combining laser data from the Swedish National Land Survey and field data from the Swedish National Forest Inventory.

Provided as open data by the Forest Agency (Forest attribute map) (https://www.skogsstyrelsen.se/skogligagrunddata)

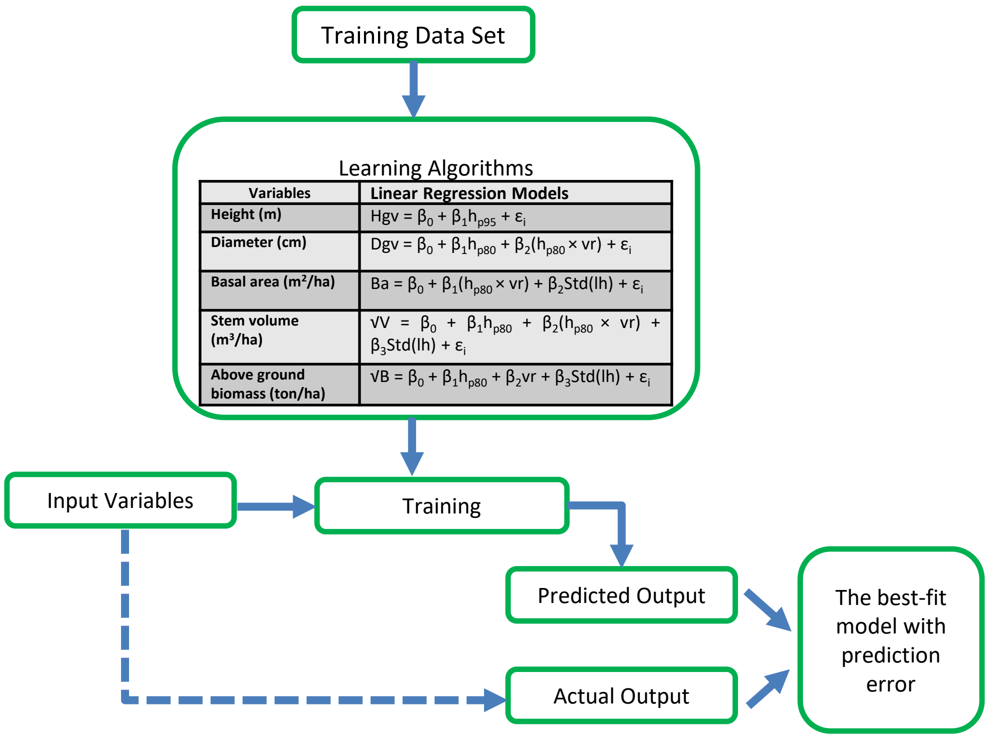
Variables
- Stem volume
- Mean tree height
- Mean diameter
- Basal area
- Above-ground biomass

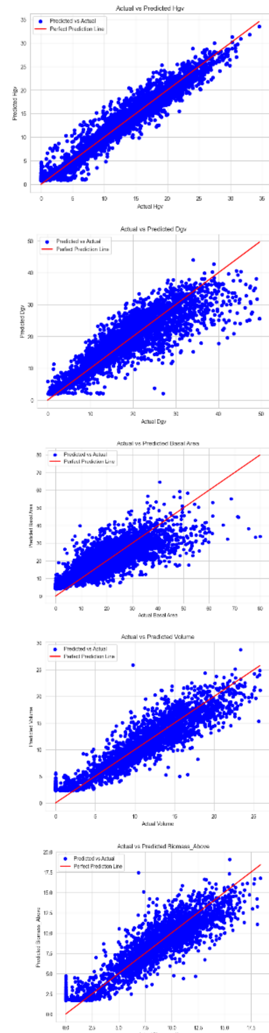
Cell size
- 10 × 10 m

AI in forest remote sensing



Linear regression using ALS data

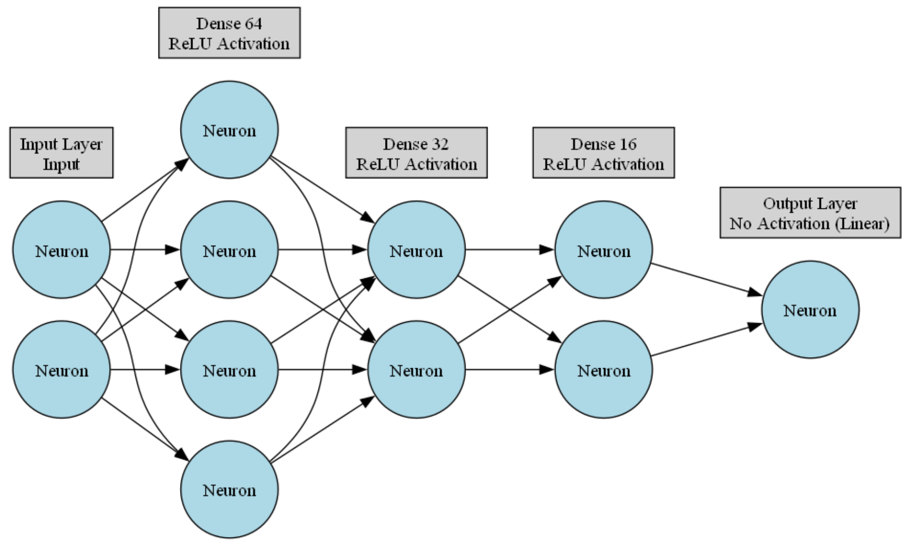




Variables	Linear regression model	
	RMSE	RMSE (%)
Mean tree height (m)	1.7	12.6
Mean tree diameter (cm)	4.5	24.1
Basal area (m^2/ha)	7.8	38.4
Stem volume (m^3/ha)	2.3	20.3
Above-ground biomass (ton/ha)	1.6	19.9

Deep Neural Network using ALS data

Training Data Set (Using Raster Metrics)



Network Architecture

Predicted variables

Mean tree height (m)

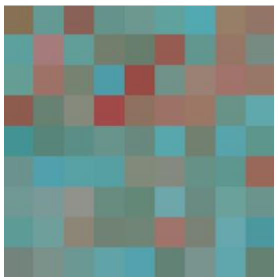
Mean tree diameter (cm)

Basal area (m^2/ha)

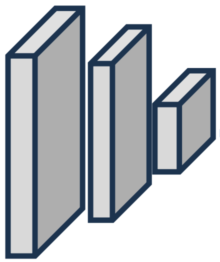
Stem volume (m^3/ha)

Above-ground biomass (ton/ha)

ResNet for transfer learning using ALS raster image data

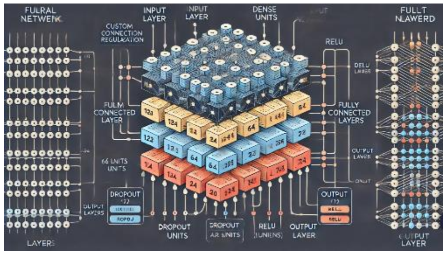


Training Data Set (using raster image data: 9 × 9 × 60)

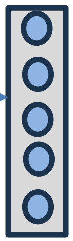


ResNet

Output Feature Map



Fine Tune using NN Custom Model



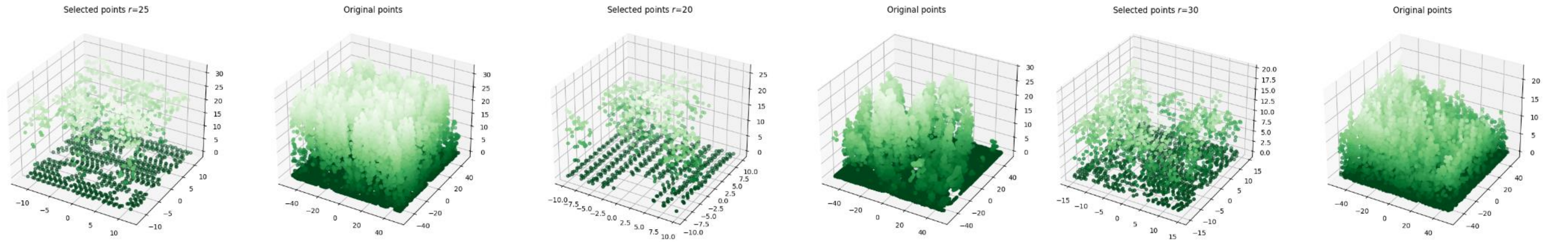
Forest Variable Predictions

Transfer Learning

Input Layer (60 Channels) Conv2D, 64 filters → ResNet Blocks ReLU Activation → Flatten Flatten → Output Features Identity (512 features) → Dense Layer 1 ReLU Activation → Dropout Dropout (0.1) → Dense Layer 2 ReLU Activation → Dropout Dropout (0.1) → Dense Layer 3 ReLU Activation → Dropout Dropout (0.1) → Output Layer Linear Activation

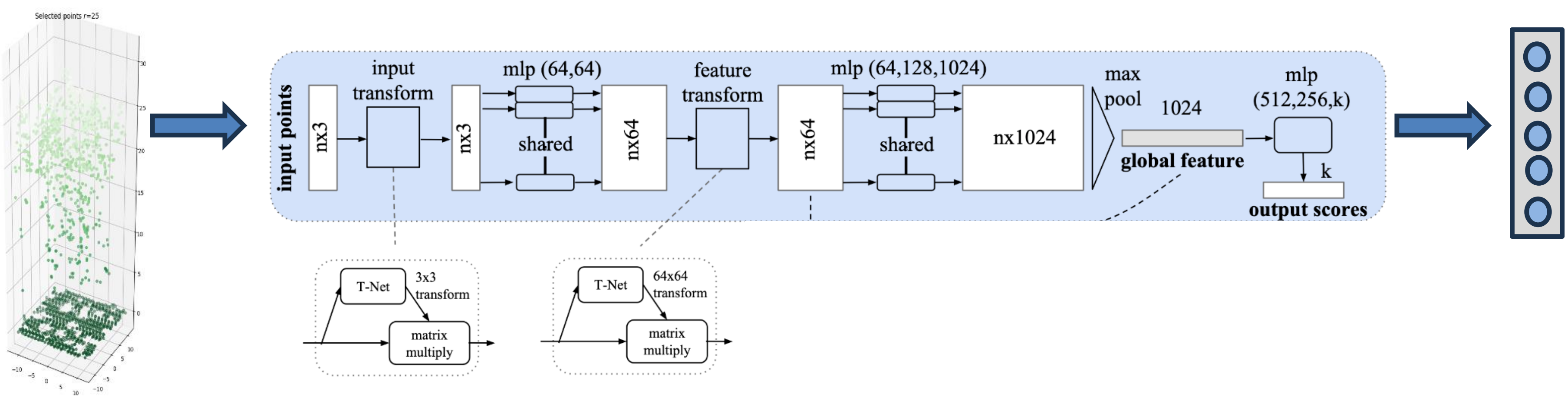
Detailed Architecture

PointNet using ALS data



Input cloud points

Forest variables



Forest biophysical parameter estimation via Machine Learning and Neural Network approaches

IGARSS
Pasadena, California 2023

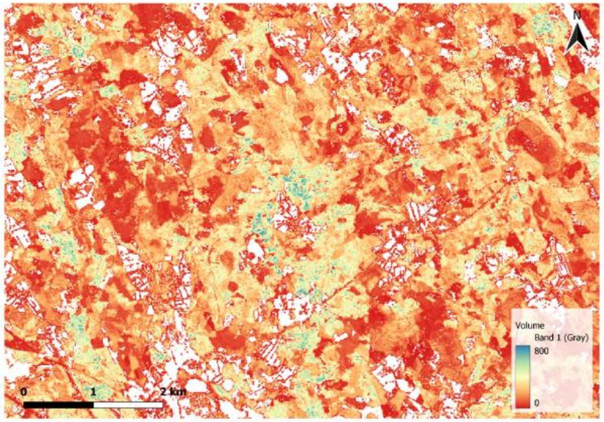
Swedish National Forest Inventory → Biophysical Parameters

Swedish National Airborne Laser Scanning → Percentiles, Point density, Standard Deviation

→ Machine Learning training & evaluation

	Neural Networks	ML - Random Forest	ML – XGBoost
Target Variable	R^2 / NRMSE	R^2 / NRMSE	R^2 / NRMSE
Hgv	0.84 / 7.3%	0.80 / 8.3%	0.82 / 7.8%
Dgv	0.66 / 4.9%	0.68 / 5.4%	0.69 / 5.2%
Basal area	0.64 / 9.1%	0.64 / 9.2%	0.68 / 8.7%
Volume	0.75 / 6.1%	0.74 / 6.1%	0.77 / 5.8%
Biomass	0.72 / 6.9%	0.71 / 7.0%	0.75 / 6.5%

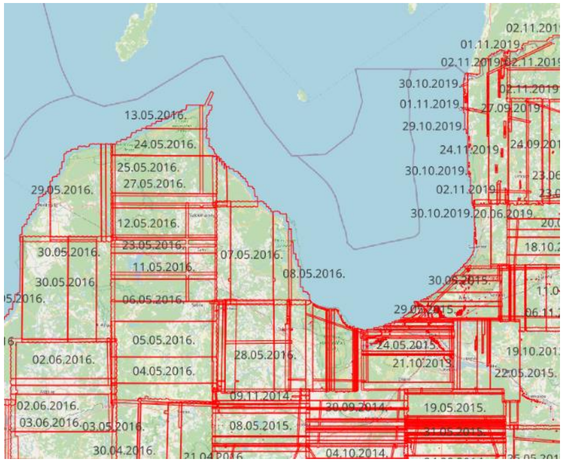
Quantitative Comparison of ML Models

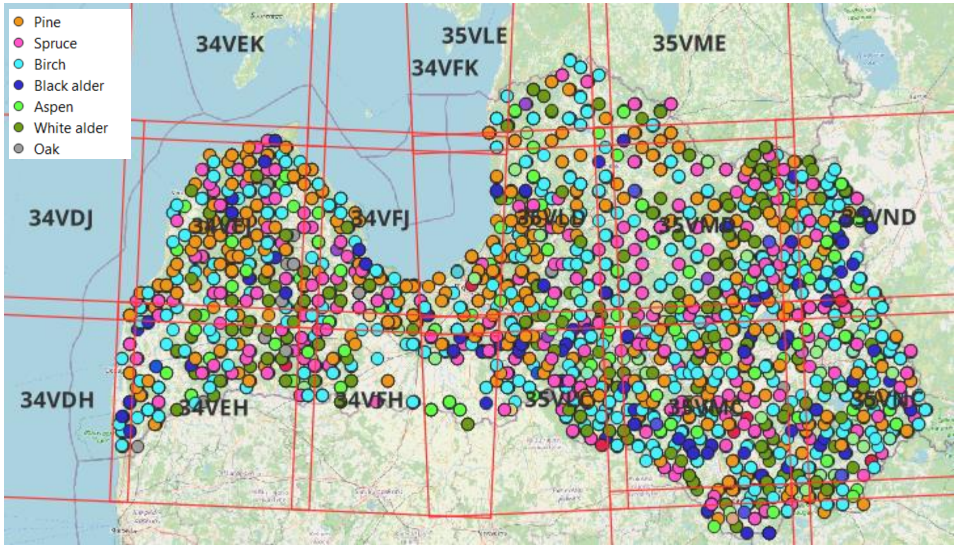


Biophysical Parameters Maps Generation

National forest inventory data from Latvia

- Transfer of the project’s algorithms to the territory of Latvia using sample plot data from another country.
- Data preparation.
  - Compare NFI to LiDAR scanning (open data in Latvia):
    - sample plot coordinates vs LiDAR metadata,
    - selecting data of scanning and plot measurement data within ± 1 year,
    - ~ 3500 sample plots with trees for classification,
    - forest and trees on agriculture lands.
- Latvia NFI based growth algorithms will be used to equalize LiDAR and NFI measurement in time.

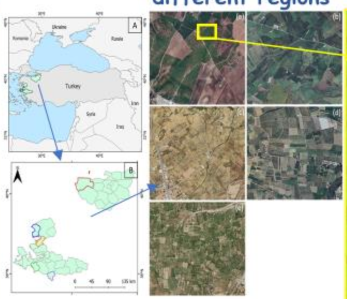




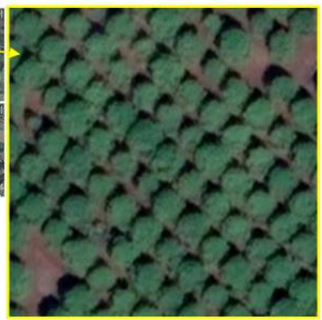
A benchmark dataset for very high-resolution tree detection in deep learning applications: VHRTrees

1

Study Area: Five different regions

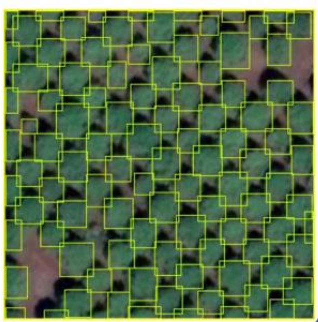


Sample image patch



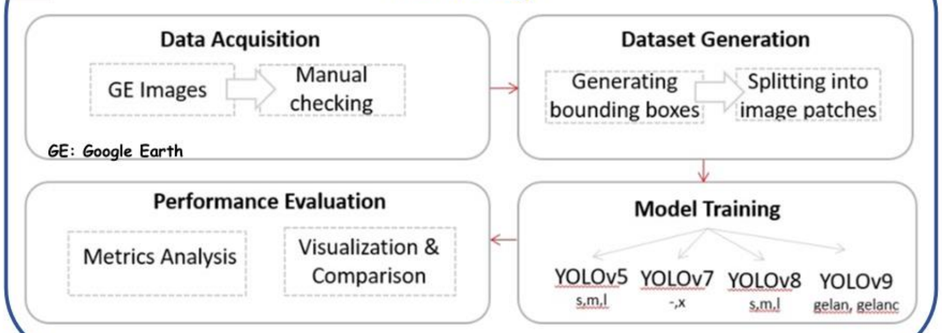
Region	Patch	Sample
Karacabey		4,191
Dikili		11,767
Aliağa		6,008
Seferihisar		1,385
Selçuk		2,615
Dataset		
Train	1,023	
Valid	226	
Test	222	
Total	1,471	25,966

Automatic annotated Roboflow



2

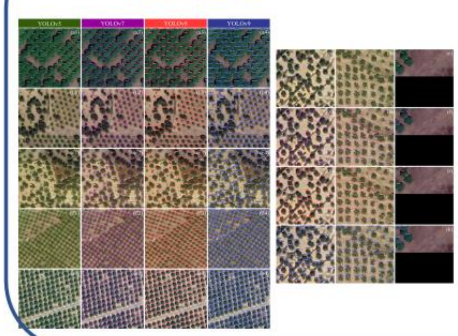
Methodology



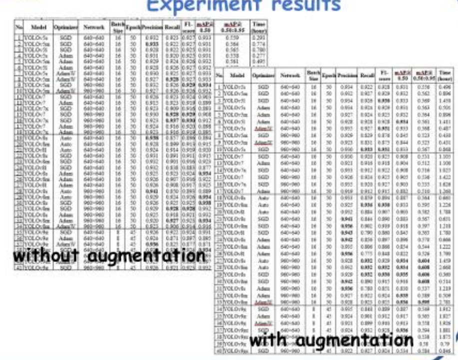
3

Results

Visual results



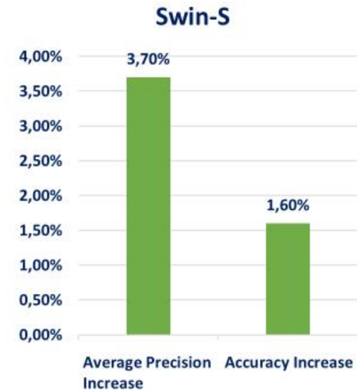
Experiment results

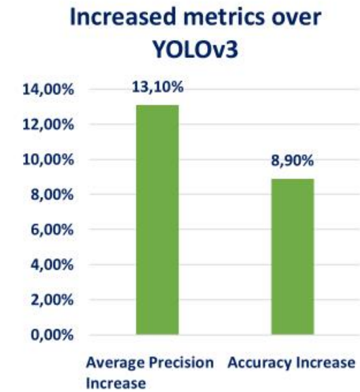


A Swin Transformer, YOLO, and Weighted Boxes Fusion-Based approach for tree detection in satellite images

This paper won the Young Researchers Award at SIU 2024

This article proposes combining Swin transformers and YOLO models with weighted boxes fusion to enhance detection accuracy. Swin transformers offer broad variation detection, while YOLO provides sharp, precise results. Together, the method improves tree detection accuracy by 3.7% over Swin transformers and 13.1% over YOLO.





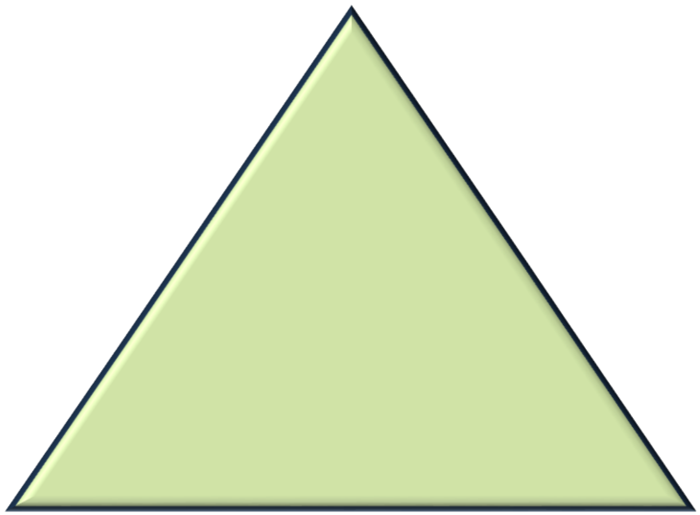
Project impacts and potential for industrial implementation / societal contextualization

- **Forest Management and Monitoring**: The predictive models developed can enhance forest management practices by providing accurate forecasts of forest variables, and other ecological variables. This offers significant value for the forestry industry, especially in sustainable resource management and optimization of timber production.
- **Environmental Conservation**: These predictive tools can be vital for environmental conservation efforts, aiding in tracking deforestation, reforestation, and biodiversity changes. This can be particularly beneficial for governmental agencies and NGOs focused on environmental protection.
- **New Paths for Research**: The integration of multiple data sources and machine learning models (Neural Networks and CNNs) opens new avenues for further research in ecological modeling, particularly in improving the precision of forest variable predictions.

The value of scientific cooperation

- Linnaeus University
- Swedish University of Agricultural Sciences

Forest Science



Societal values

- University of Helsinki

Start-up tech company

- Katam Technologies

Computer Science

- Yeditepe University
- Istanbul Technical University
- Linnaeus University

Publications

- Fransson, J.E.S., Björnberg, D., Holmström, A., Lazo, J.F., Löwe, W., Nilsson, M., Salo, J., Santoro, M., Sertel, E., Soomro, S., Wallerman, J., Ünsalan, C., and Zariņš, J., 2024. Applying machine learning for forest attribute mapping in Latvia – Sharing insights from the Swedish approach. In Proceedings of IGARSS 2024, Acting for Sustainability and Resilience, Athens, Greece, 7-12 July, 2024, pp. 5320-5323. https://doi.org/10.1109/IGARSS53475.2024.10641620
- Fransson, J.E.S., Soomro, S., Holmström, A., Nilsson, M., Salo, J., Santoro, M., Sertel, E., Wallerman, J., Ünsalan, C., and Zariņš, J., 2024. ForestMap: The next generation of forest maps - adapting a Nordic success story across the globe. In Proceedings of EGU General Assembly 2024, Vienna, Austria, 14-19 April, 2024, p. 22372.
- Soomro, S., Niaz, A., Wallerman, J., Löwe, W., and Fransson, J.E.S., 2024. Advancing forest attribute prediction using machine learning techniques. In Proceedings of the SRS Conference 2024, Linnaeus University, Växjö, Sweden, 20-21 March, 2024, poster.
- Soomro, S., Wallerman, J., Löwe, W., and Fransson, J.E.S., 2024. Prediction of forest attributes using machine learning and neural network innovations. In Proceedings of the 2nd Young Researchers Conference in Green and Blue Sustainable Development 2024, Linnaeus University, Kalmar, Sweden, 14-15 March, 2024.
- Fransson, J.E.S., Sertel, E., Ünsalan, C., Salo, J., Holmström, A., Wallerman, J., and Nilsson, M. 2023. ForestMap: Mapping forest attributes across the globe - first case study. In Proceedings of IGARSS 2023, Pasadena, California, USA, 16-21 July, 2023, pp. 3395-3397. https://doi.org/10.1109/IGARSS52108.2023.10283354

Publications

- Aksoy, M.Ç., Sirmacek, B., and Ünsalan, C., 2023. Land classification in satellite images by injecting traditional features to CNN models. Remote Sensing Letters 14, 157–167. https://doi.org/10.1080/2150704X.2023.2167057
- Aksoy, S., Hasan Al Shwayyat, S.Z., Nur Topgül, Ş., Sertel, E., Ünsalan, C., Salo, J., Holmström, A., Wallerman, J., Nilsson, M., and Fransson, J.E.S., 2023. Forest Biophysical Parameter Estimation via Machine Learning and Neural Network Approaches, in: IGARSS 2023 - 2023 IEEE International Geoscience and Remote Sensing Symposium. Presented at the IGARSS 2023 - 2023 IEEE International Geoscience and Remote Sensing Symposium, IEEE, Pasadena, CA, USA, pp. 2661–2664. https://doi.org/10.1109/IGARSS52108.2023.10282899
- Durgut, O. and Ünsalan, C., 2024. A Swin Transformer, YOLO, and Weighted Boxes Fusion-Based Approach for Tree Detection in Satellite Images, in: 2024 32nd Signal Processing and Communications Applications Conference (SIU). Presented at the 2024 32nd Signal Processing and Communications Applications Conference (SIU), IEEE, Mersin, Turkiye, pp. 1–4. https://doi.org/10.1109/SIU61531.2024.10601134
- Nur Topgül, Ş., Sertel, E., Aksoy, S., Ünsalan, C., Fransson, J.E.S. (under review). A Benchmark Very High-Resolution Tree Detection Dataset for Deep Learning Applications: VHRTrees. Frontiers in Forests and Global Change, section Planted Forests.

Publications

- Kordi, G. and Salo, J., 2024. Optimizing Forest Mapping Technologies for Sustainable B2B Resource Management Strategies. Proceedings of the Nordic Academy of Management, 13-14 August, 2024, Iceland.
- Adhiguru, P. and Salo, J., 2023. Learnings from the forest mapping research: Can we roadmap a futuristic forest industry? 16th Annual Euromed Academy of Business (EMAB) Conference, Business Transformation in Uncertain Global Environments, Vilnus, Lithuania, 27-29 September, 2023.
- Kordi, G. and Salo, J., 2023. Systematic Literature Review of Forest Mapping Technologies: Trends and Future Directions. 16th Annual Euromed Academy of Business (EMAB) Conference, Business Transformation in Uncertain Global Environments, Vilnus, Lithuania, 27-29 September, 2023.
- Salo, J., 2022. Forest maps as business services. In Proceedings of the 6th Academy of Business and Emerging Markets (ABEM 2022) Conference, Collaboration and Cooperation to Create Efficient Economies, Santo Domingo, Dominican Republic, 9-11 August, 2022, p. 6.
- Fransson, J.E.S., 2022. ForestMap – The next generation of forest maps – adapting a Nordic success story across the globe. ForestValue Joint Call 2021: Project Introductions, ForestValue, Newsletter #10, December 2022.

Acknowledgements

Project ForestMap is supported under the umbrella of ERA-NET Cofund ForestValue by Swedish Governmental Agency for Innovation Systems, Swedish Energy Agency, The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Academy of Finland, and The Scientific and Technological Research Council of Turkey. ForestValue has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 773324.

Thank you!

Professor Johan Fransson
Linnæeus University, Sweden
johan.fransson@lnu.se
www.lnu.se

ForestValue

Website: https://forestvalue.org/
Twitter: https://twitter.com/ForestValue2017
LinkedIn: https://www.linkedin.com/groups/12110816/