DIGITAL INVENTORY AND DEVELOPMENT ANALYSIS FOR THE NATURAL FOREST RESERVE ROHRACH

23.02.2024

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REPETITION OF THE FOREST STRUCTURE SURVEY WITH THE LATEST LASER SCANNING TECHNOLOGIES

→ FIRST SURVEY 1995/96

- By Grabherr et al.
- Classic inventory sampling in the field

→ REPETITION 2022

- By E.C.O. and TU Wien
- Benchmarking of 3 Methods:
  1. Classic inventory sampling in the field
  2. Evaluation from terrestrial laser scanning (TLS)
  3. Evaluation from drone-based laser scanning (UAV -Unmanned Aerial Vehicle)

Source: © Altodrone

WHAT IS THE PURPOSE OF A FOREST STRUCTURE ANALYSIS?

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FORST STRUCTURE ANALYSIS

→ includes the collection of data on various aspects of the forest: (tree species, age classes, tree heights, diameter at breast height…)

BENEFITS OF FOREST STRUCTURE ANALYSIS:

1. Sustainable Forestry:
   - Informed management for long-term forest health.
   - Responsible planning of timber harvesting.
2. Biodiversity:
   - Assess and promote biodiversity in the forest.
   - Diverse structure provides habitats for various species.
3. Climate Change:
   - Monitor forest changes in response to altered climatic conditions.

IMPORTANCE OF ESTIMATING FOREST BIOMASS

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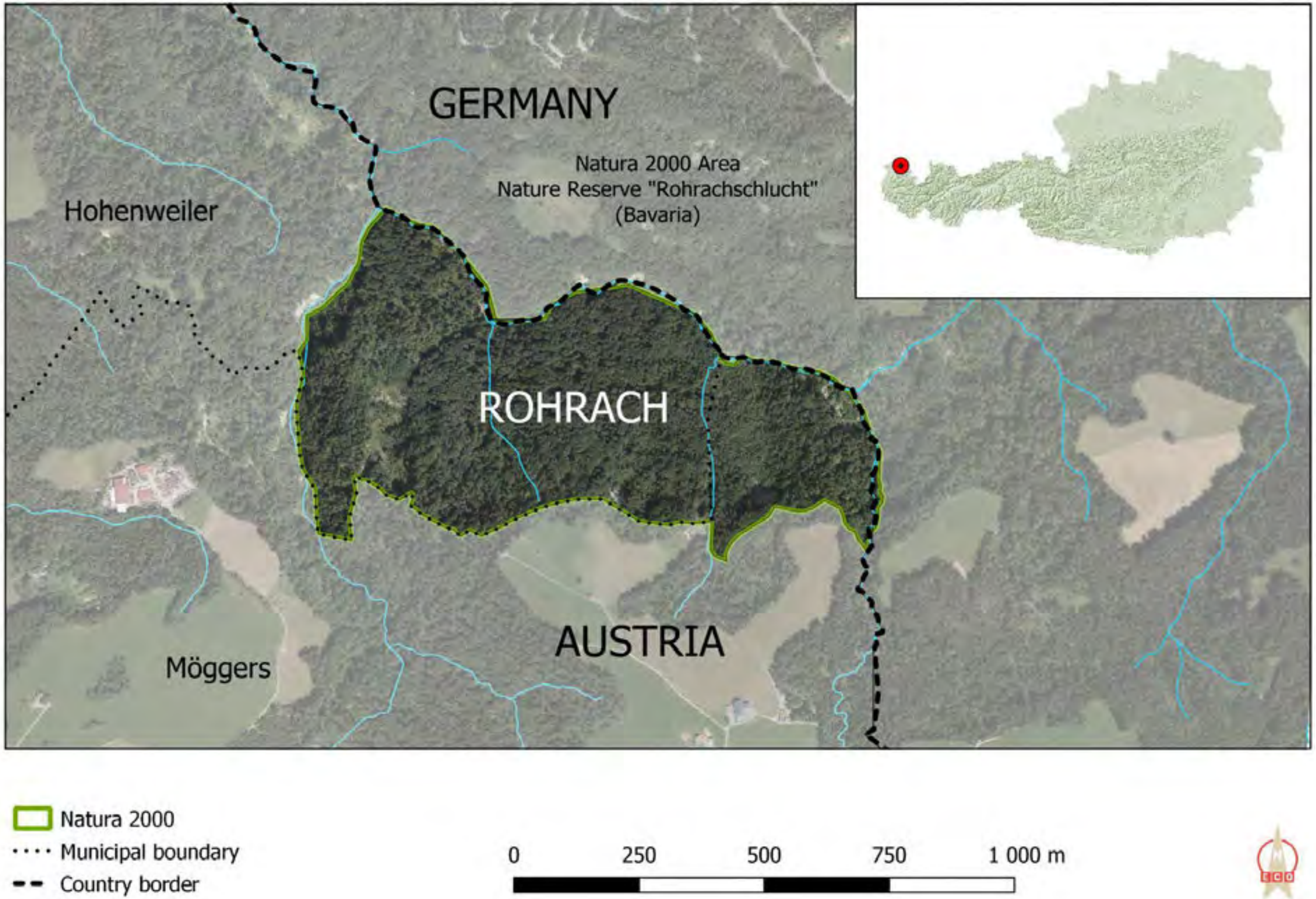
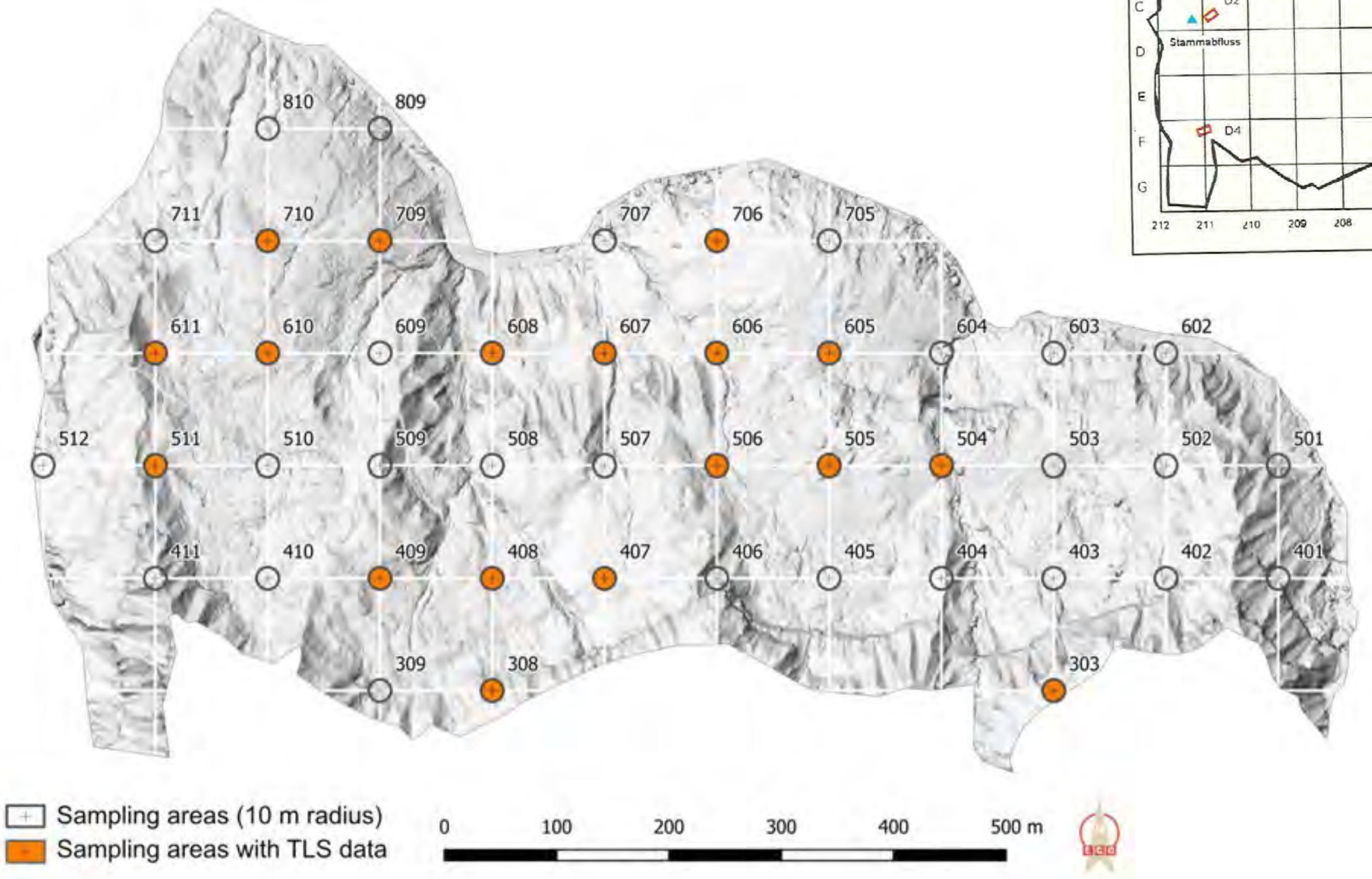
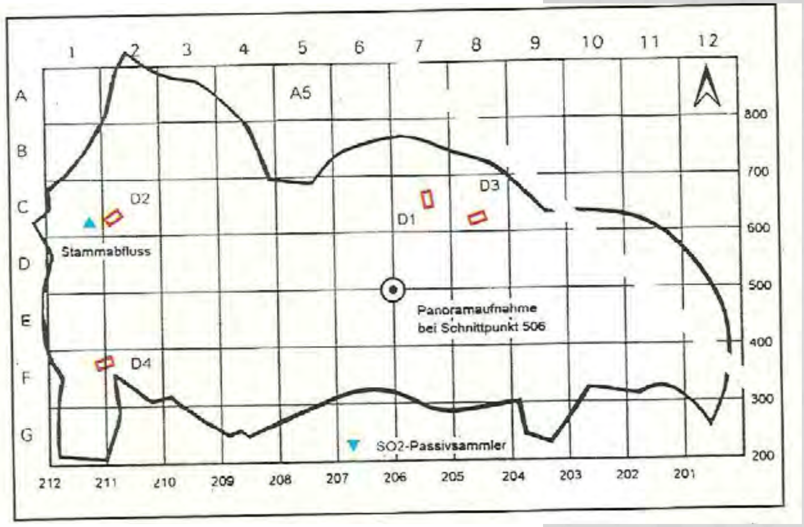
1. Climate Change / Carbon Cycle:
   - Forest biomass is a significant carbon source and sink.
2. Wood Utilization:
   - Essential for sustainable use of wood resources.
   - Informs wood harvesting decisions to preserve long-term forest health.
3. Ecosystem Services:
   - Biomass linked to various ecosystem services.
   - Includes habitat provision, water balance regulation, and soil health support.

STUDY AREA: NATURAL FOREST RESERVE ROHRACH



- 47,5 ha
- A natural forest reserve since 1992 (no forestry use)
- Beech and spruce-fir-beech forests & small-scale special forest communities





SAMPLING AREAS

- Classic inventory sampling: **44** sampling areas
- **18** TLS plots
- Drone based laserscanning over the **entire area**

CLASSIC INVENTORY SAMPLING IN THE FIELD

- → 44 test areas
- → sample size: 10 m radius
- → all trees with DBH > 10 cm
- → Data recorded:
  - Relative single tree position (angle and distance to the centre of the sample)
  - Tree species
  - Vitality (alive/dead)
  - Diameter at breast height (DBH)
  - (height was later derived from the TLS data)

VOLUME CALCULATION LIVING WOOD

CLASSIC INVENTORY SAMPLING

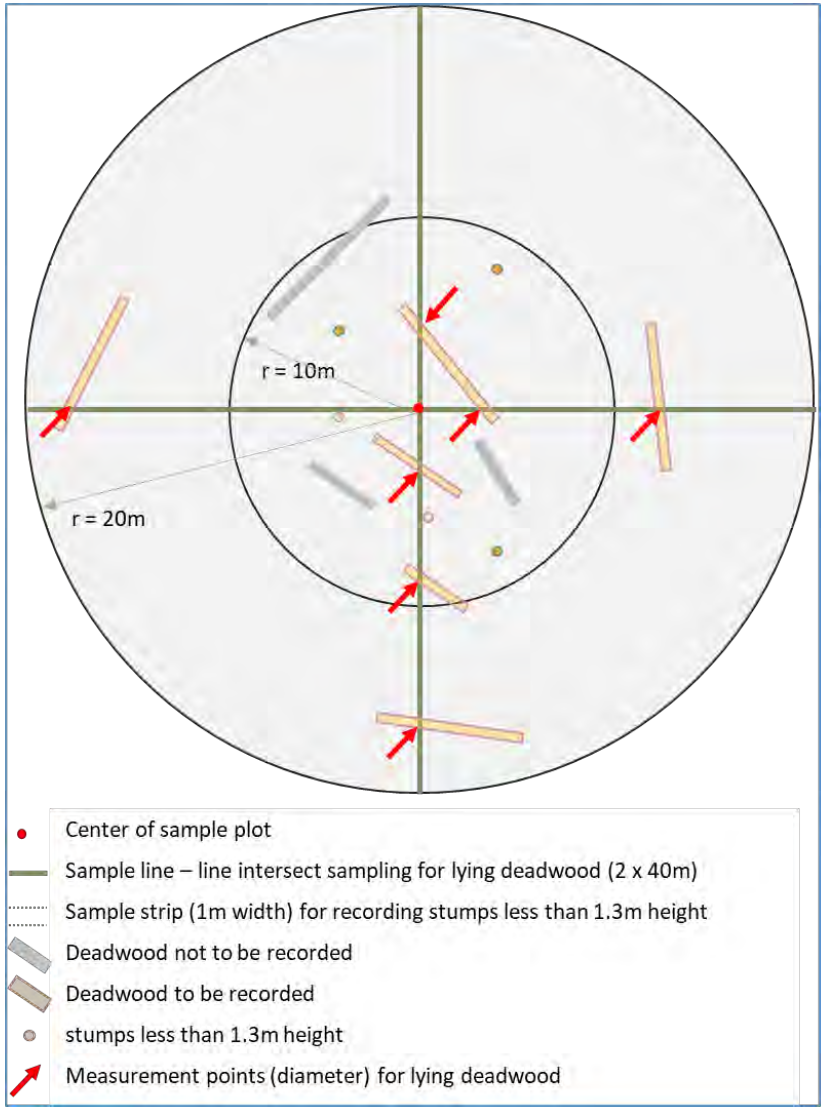
- Volume calculation of the individual trunk with Estimation formula according to DENZIN
- Subsequently, the volume could be determined using forestry form numbers (depending on tree species)
- this only evaluate the forestry-relevant trunk parts and not the total biomass of the tree.

$$Vol = \left(\frac{DBH^2}{1000}\right) + \frac{DBH^2}{1000} * (Height \ - Hnorm) * Vol\_K$$

VOLUME CALCULATION DEAD WOOD

LINE INTERSECT METHOD

Line Intersect method according to Van Wagner (1968)



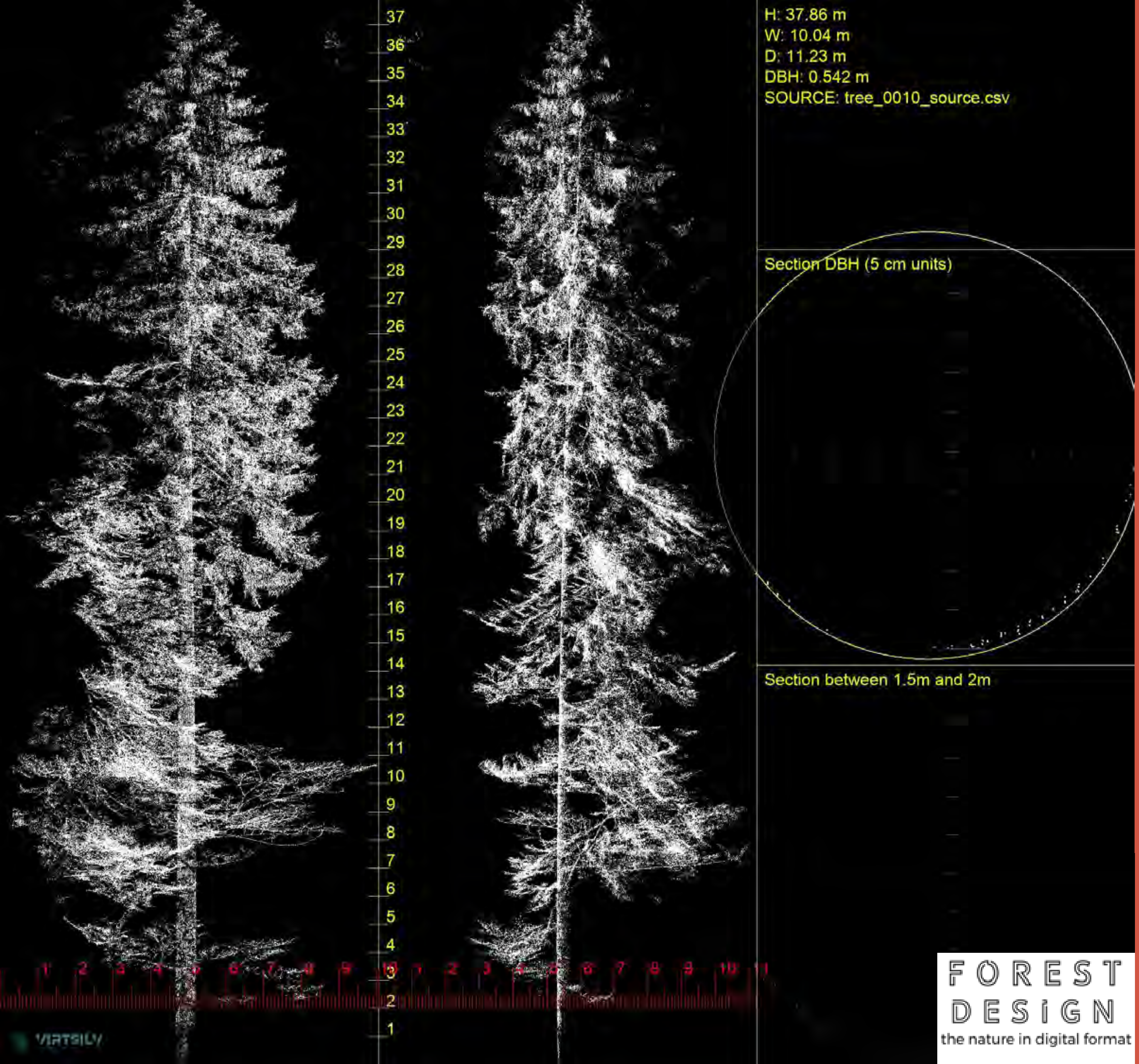
$$V_{LG} = \frac{\pi^2 \sum_{l=1}^{i} d_L^2}{8L}$$

V_{LG} = Volume of lying deadwood

d_L = diameter in cm of the cross-sectional area of the i-th lying tree trunk l with a central diameter > 10 cm

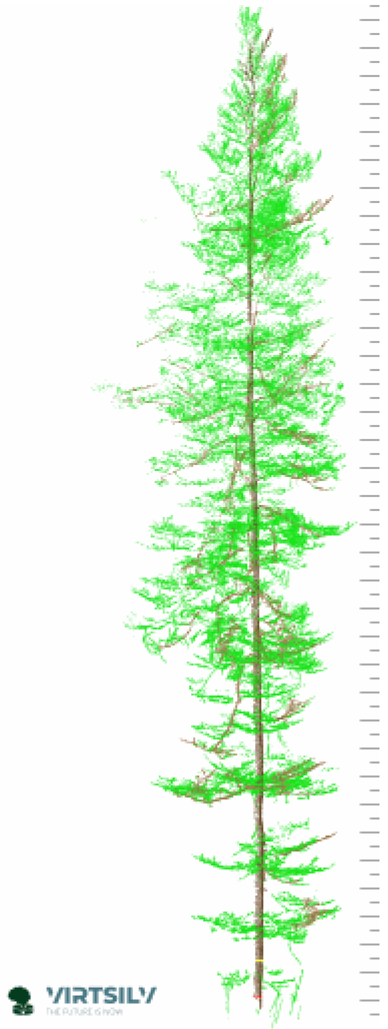
TERRESTRIAL LASER SCANNING (TLS)

- 18 plots
- Scanner:
  Riegel VZ-400i
- 10-20 scan positions
- all trees within a 30 m radius of the sampling center



TLS – HEIGHT ESTIMATION BY SC FOREST DESIGN SRL

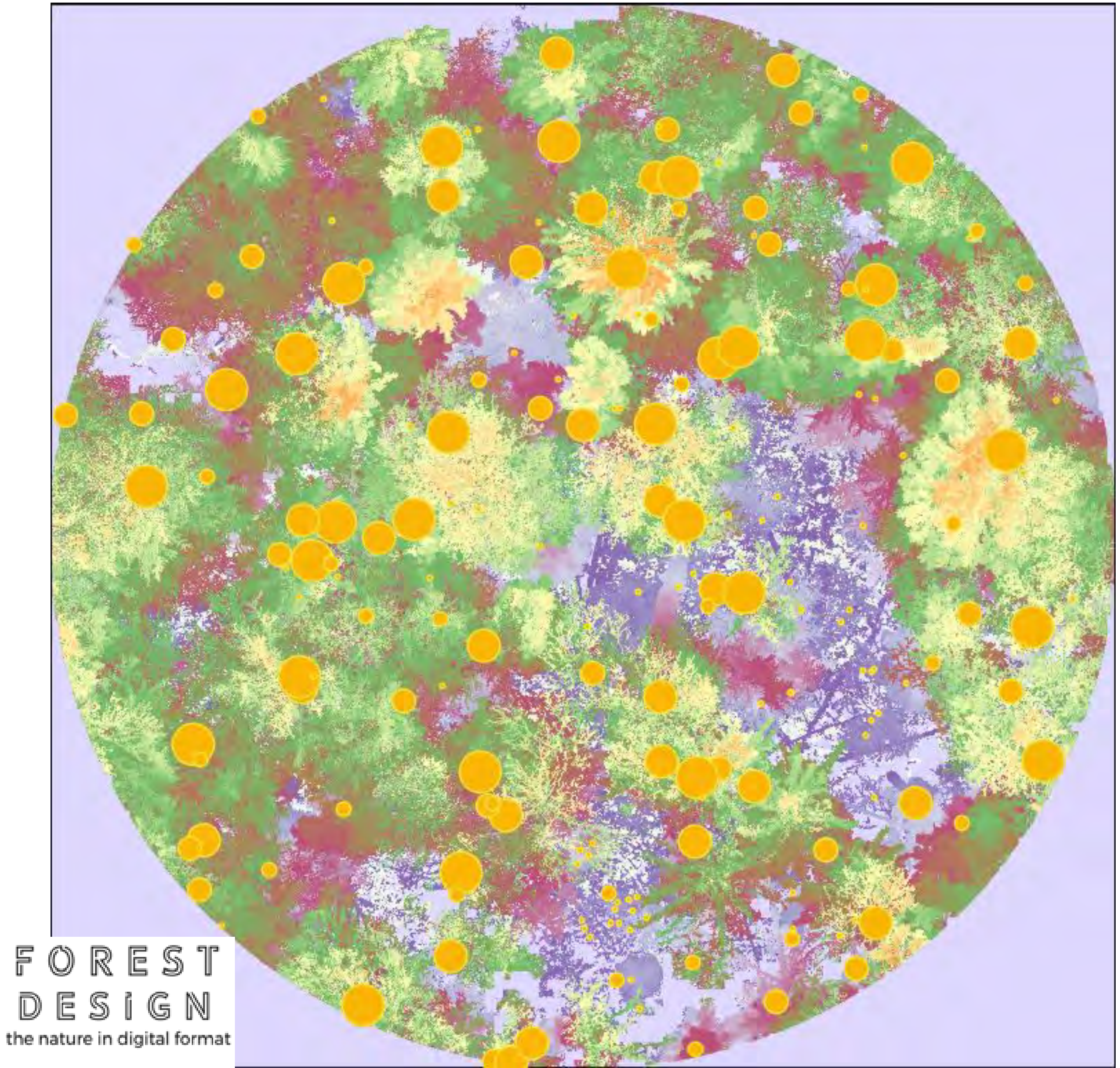
TLS – VOLUME ESTIMATION BY SC FOREST DESIGN SRL

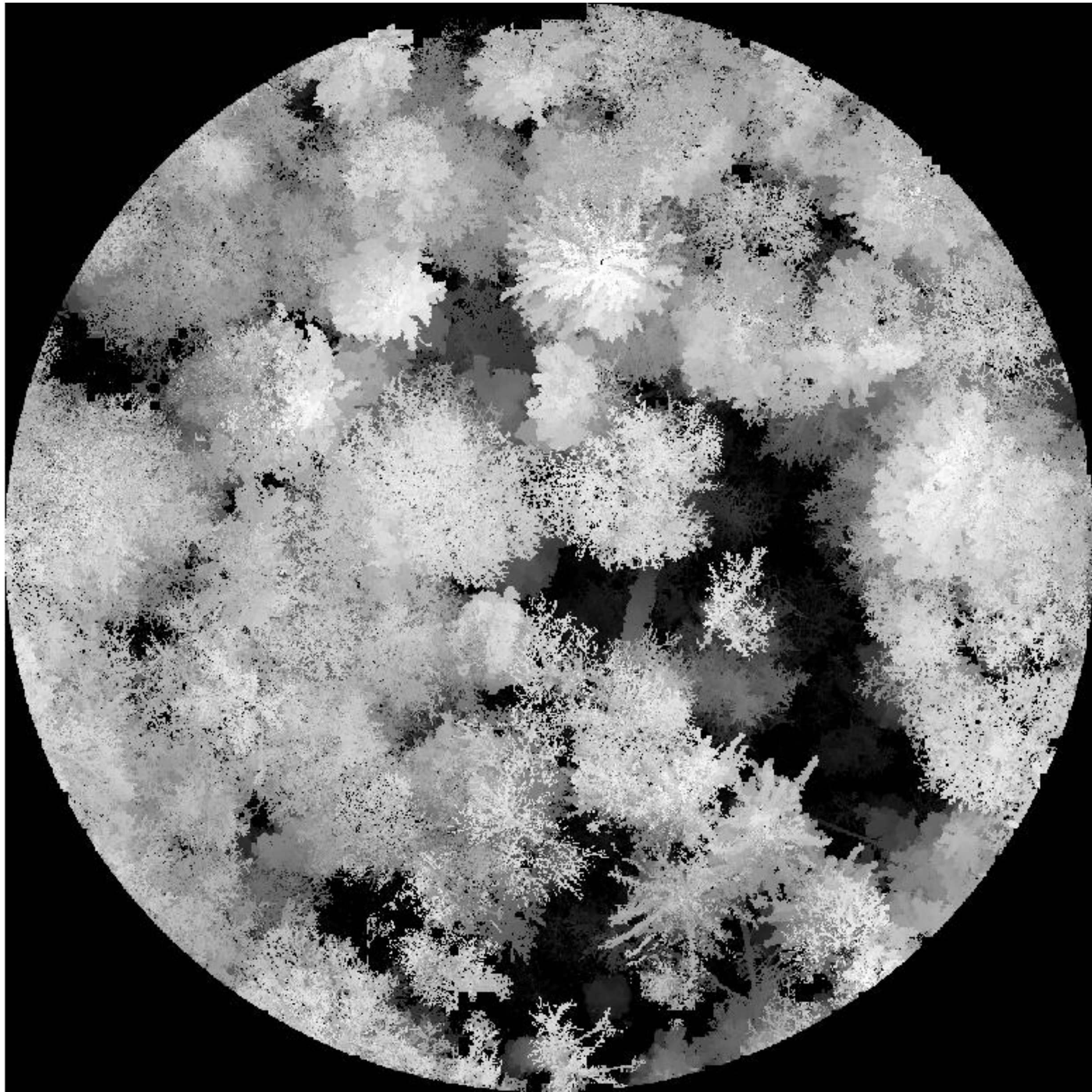


Fitting cylinders for volume calculation

FOREST DESIGN
the nature in digital format

TLS – CANOPY HEIGHT MODEL (SC FOREST DESIGN SRL)





TLS – DENS PROJECTION (SC FOREST DESIGN SRL)

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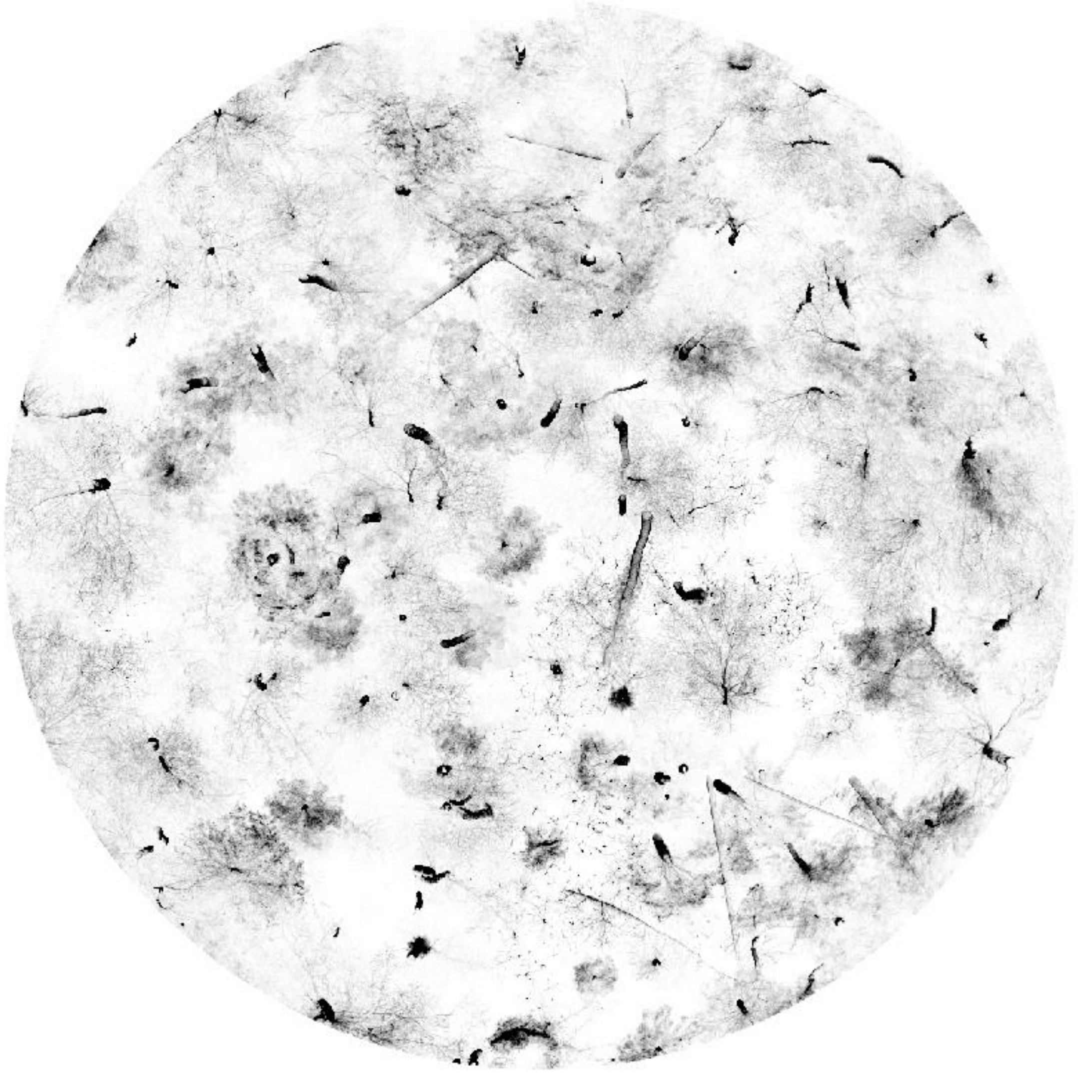
at ground level

above ground level



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Source: © Altodrone

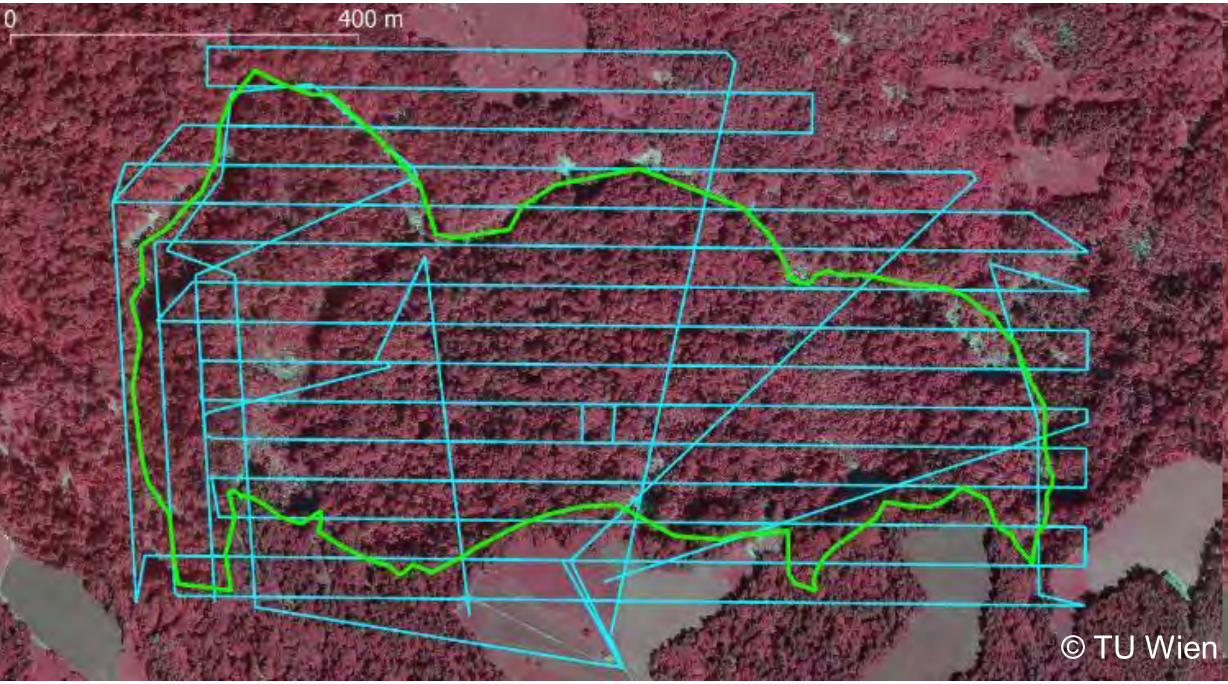
DRONE-BASED LASER SCANNING (UAV)

- Multispectral and laser scanning of the entire area
- Scanner: RIEGL VUX-120
- UAV: Multicopter Soleon LasCO 2
- IMU & GNSS: Applanix APX-20
- The aerial survey was carried out by the company alto drones

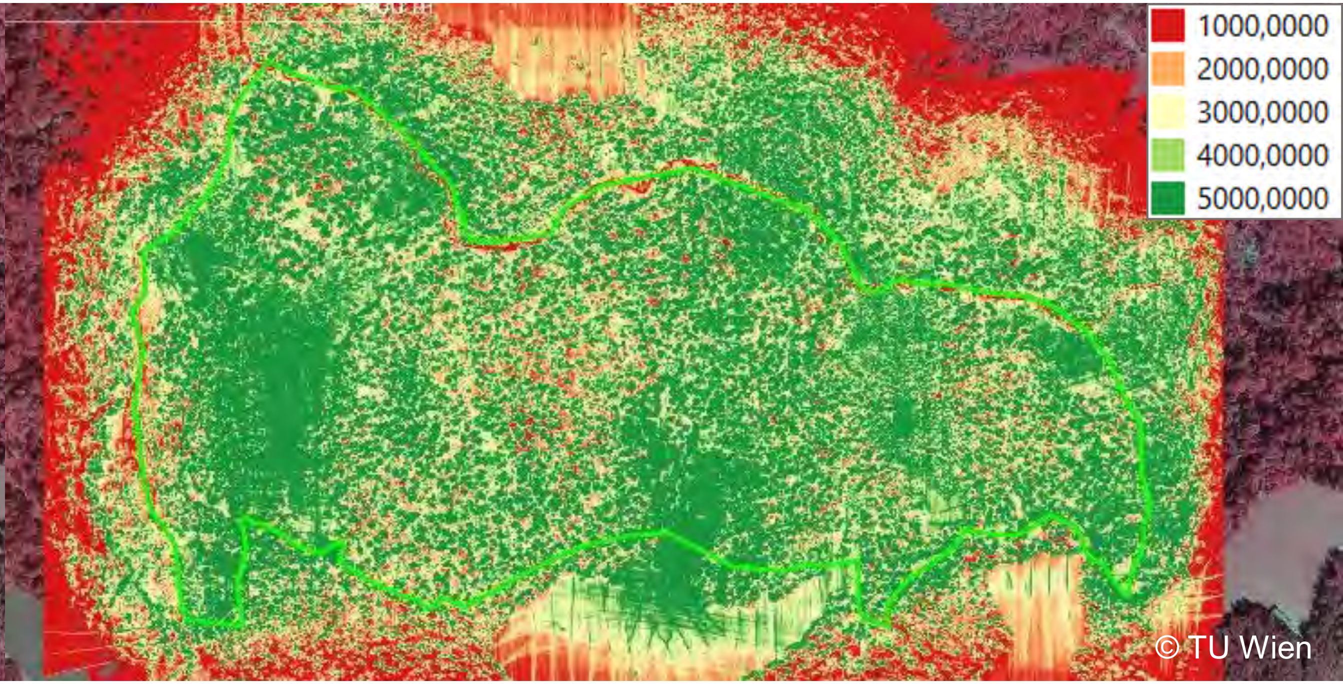
alto drones
TECHNICAL UAV SERVICES

DRONE-BASED LASER SCANNING (UAV)

FLIGHT TRAJECTORIES



POINT DENSITY



Protected area boundary (Rohrach Natural Forest Reserve)

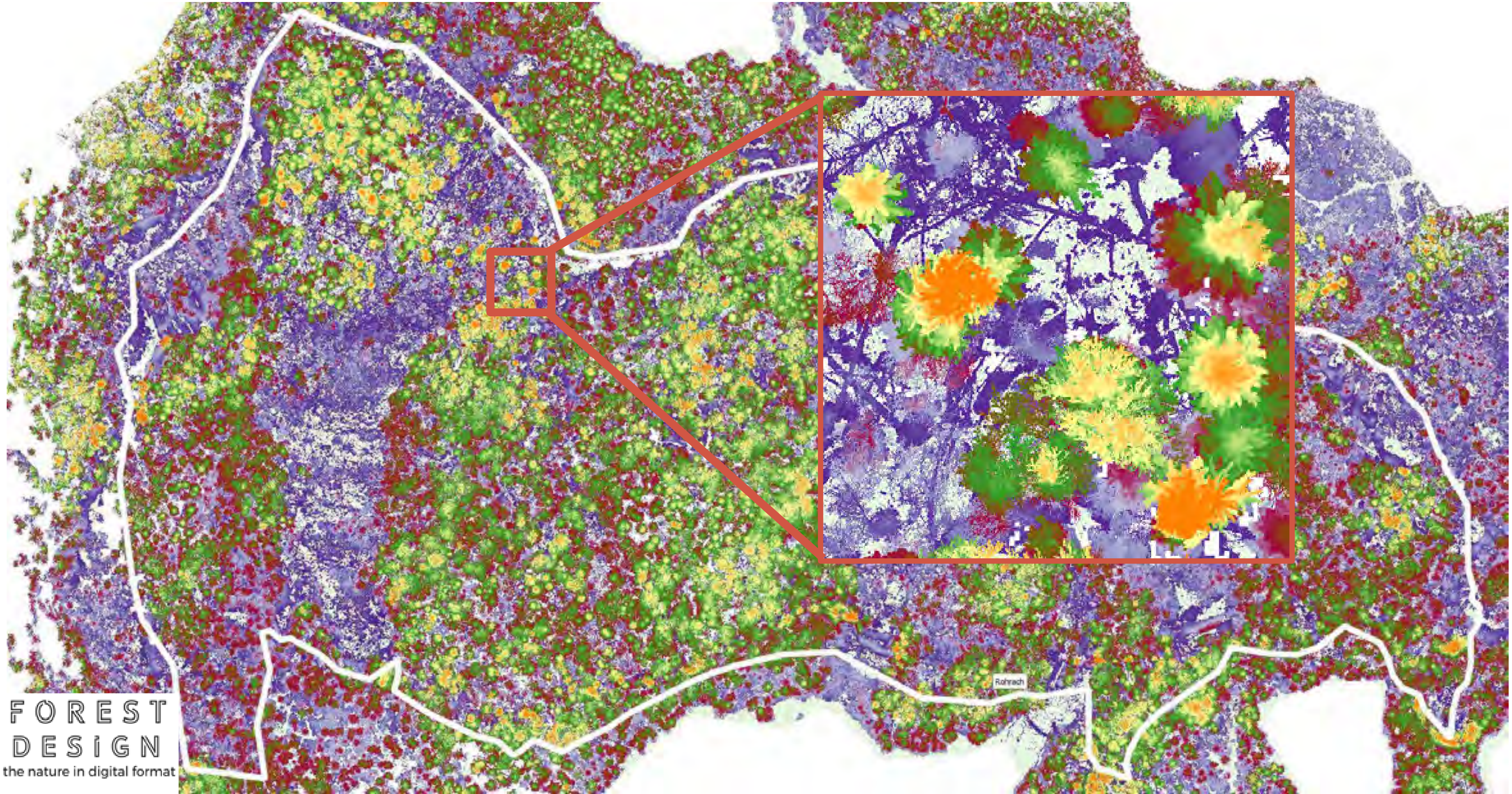
Flight trajectories

Average point density > 4.200 pts/m²

TRUE ORTHOPHOTO

5 cm pixel size

UAV – CANOPY HEIGHT MODEL (SC FOREST DESIGN SRL)



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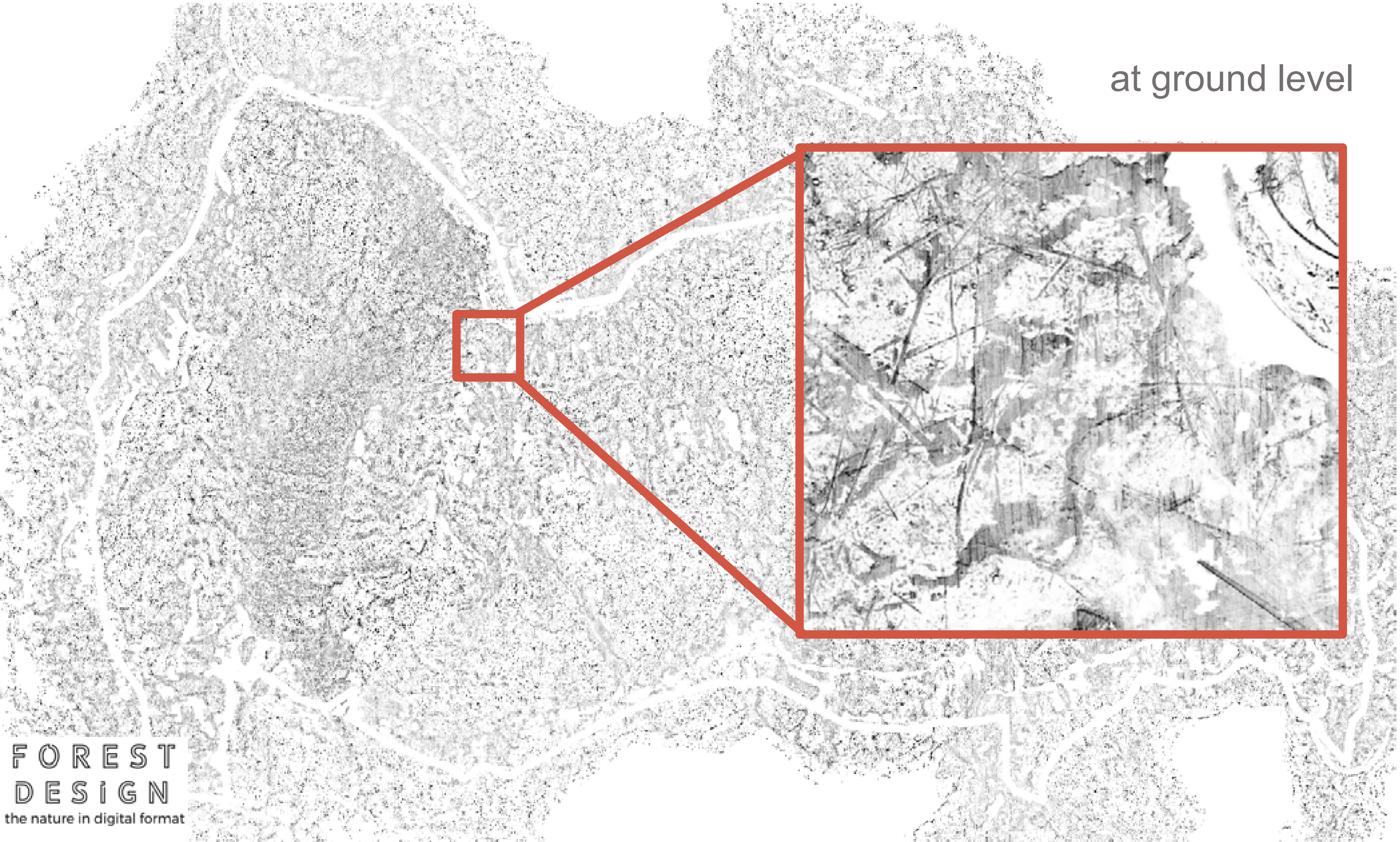
UAV – DENS PROJECTION (SC FOREST DESIGN SRL)



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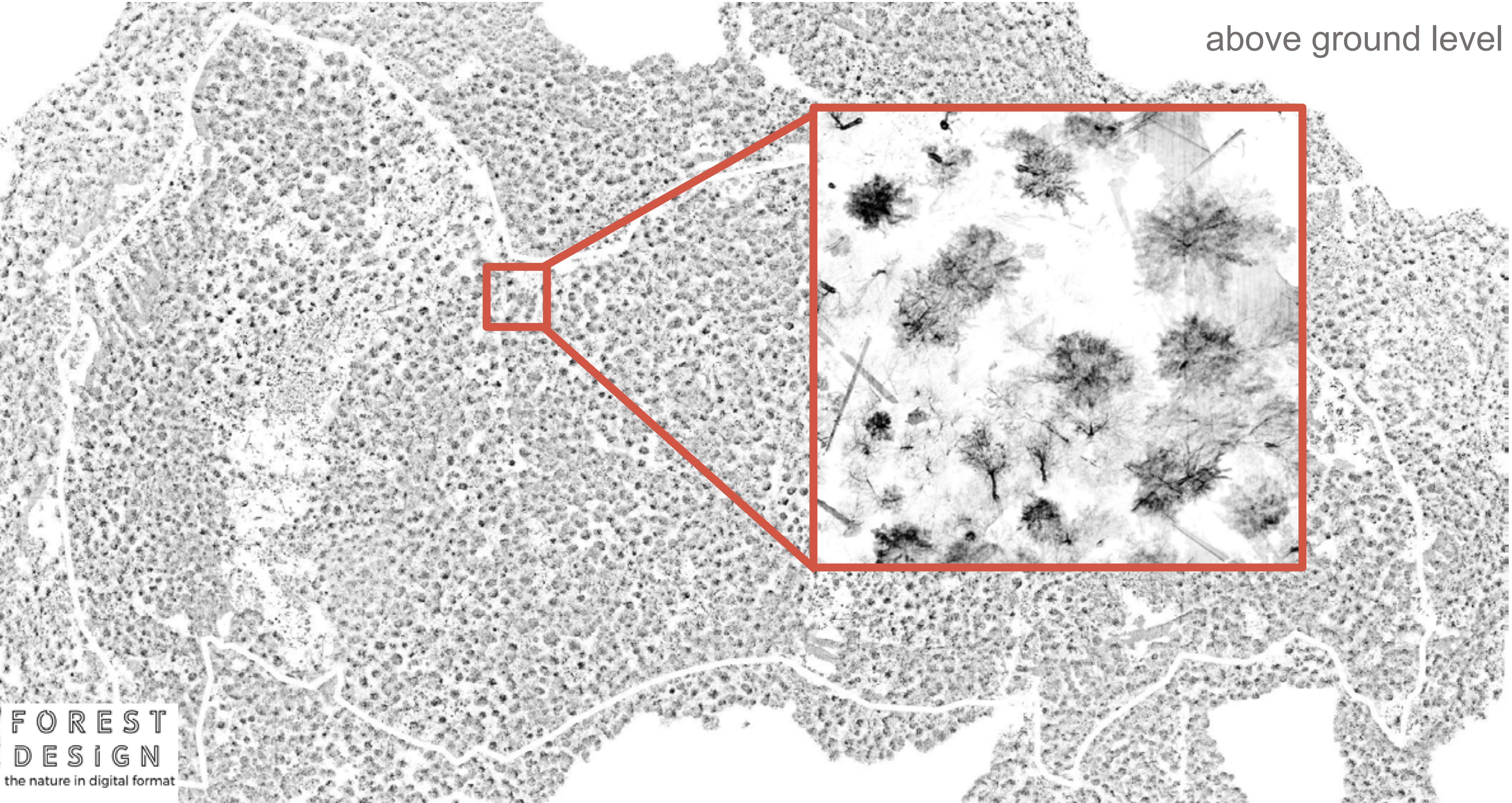
UAV – DENS PROJECTION (SC FOREST DESIGN SRL)

E.C.O.

above ground level



FOREST DESIGN
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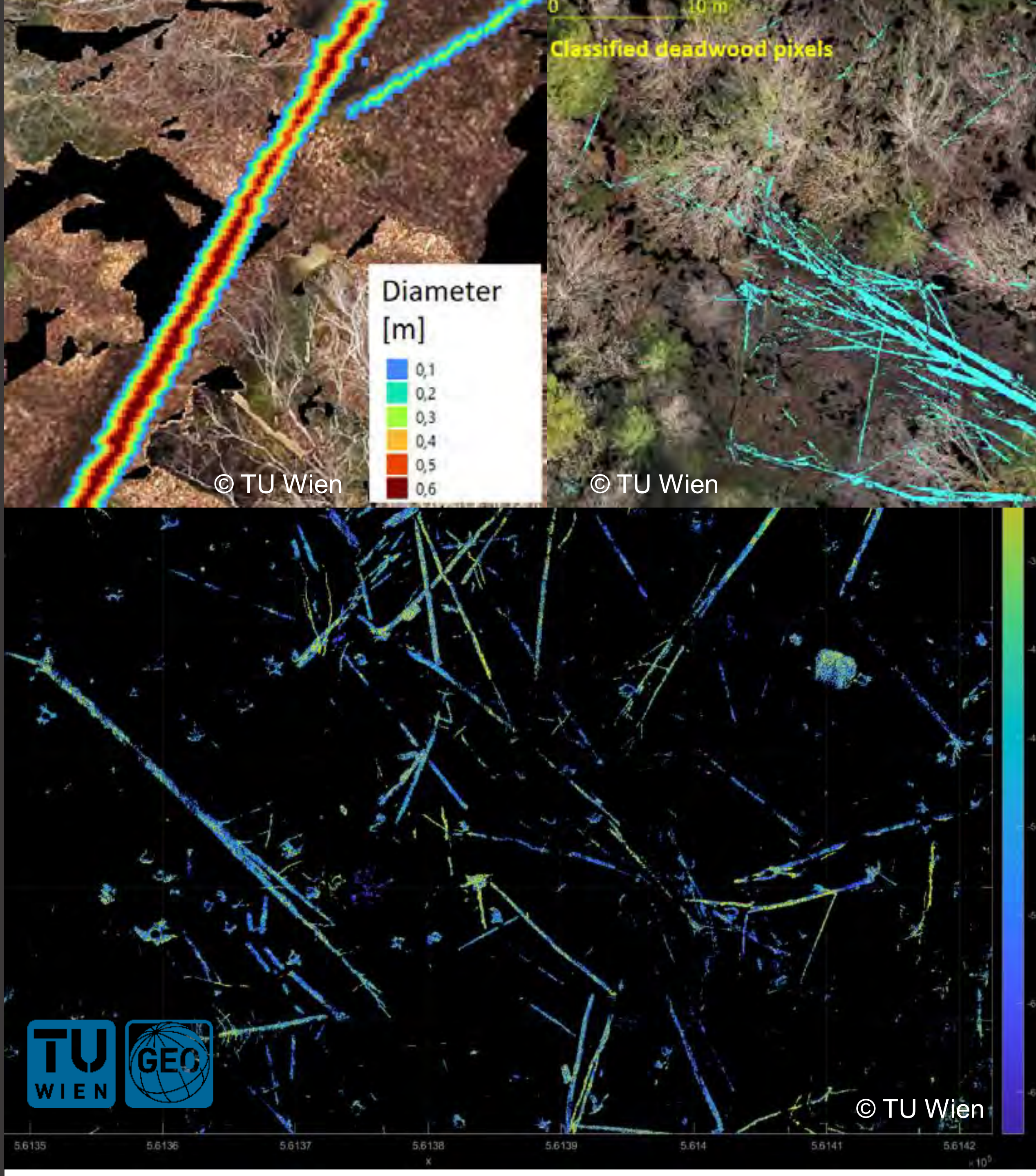
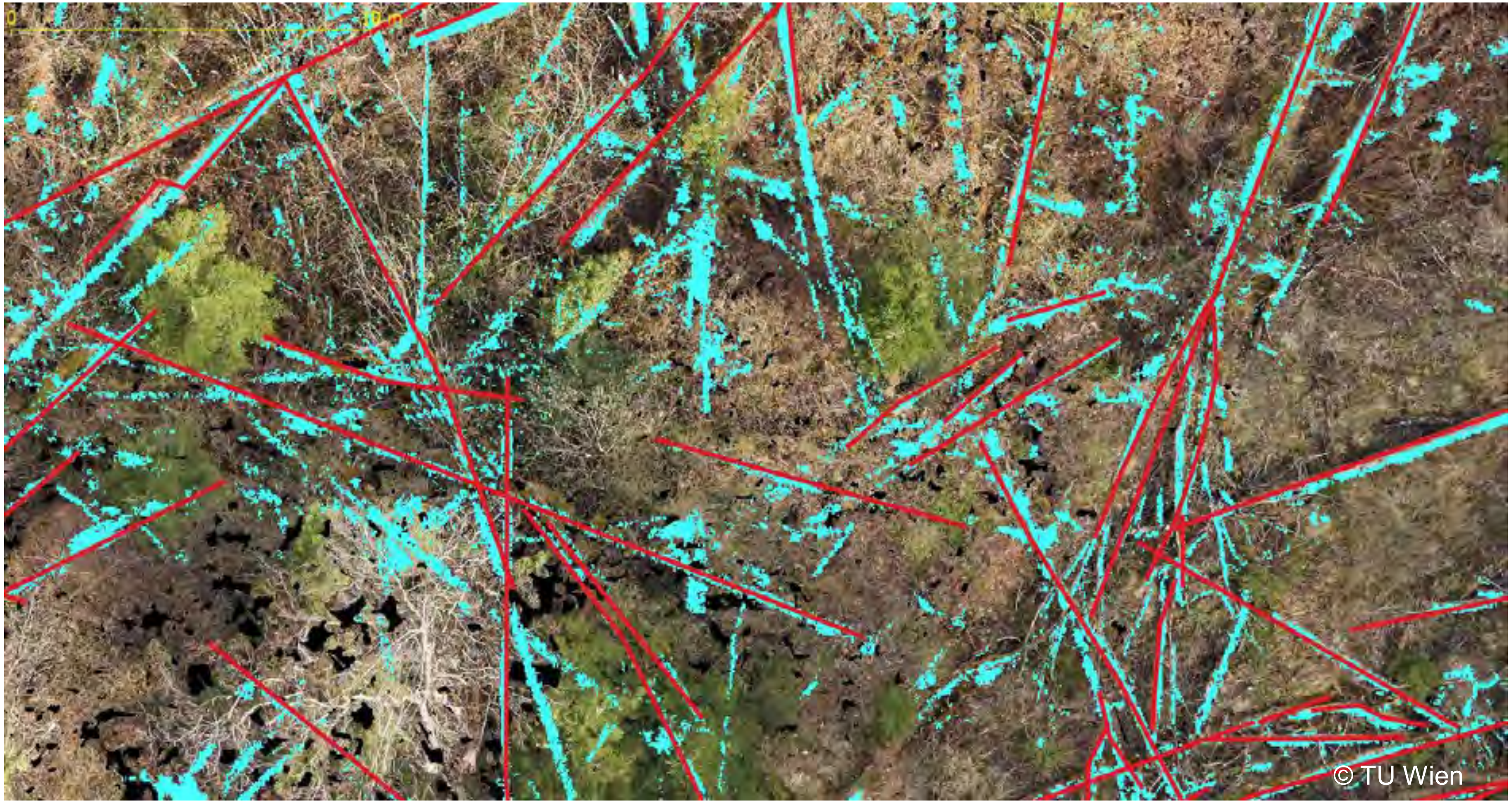
UAV – LYING DEADWOOD

- knowledge-based decision tree to detect the lying deadwood based on the normalized 3D points
- geometric and radiometric properties of the laser points were taken into account
- Horizontal deadwood was only considered up to 5 m above the ground.
- After the detection of lying deadwood, its volume was estimated using a voxel-based approach.
- 5x5x5 cm³ voxels
- limitations in the area of superimposed trunks or in the area of missing laser points (e.g. due to shading)
- only horizontal distances are considered with this approach, which leads to an underestimation of the lying deadwood mass in steep terrain



UAV – LYING DEADWOOD

MANUAL DIGITIZATION VS CLASSIFICATION



MANUEL

AUTOMATIC

CALCULATION OF CARBON STORAGE

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- Stock volumes
  - Cubic meter
- Extension to whole tree
  - Cubic meter
- Dry weight
  - tons of biomass
- Carbon content
  - tons of carbon

Treespecies	mean density stem t/m^3
Spruce	0.43
Larch	0.55
Fir	0.41
Pine	0.49
Beech	0.68
Oak	0.65
Hornbeam	0.79
Esh	0.65
Mapel	0.59
Elm	0.64
Sweet chestnut	0.59
Robinia	0.74
Sorbus	0.64
Prunus	0.64
Birch	0.61
Alder	0.51
Lime	0.49
Poplar	0.43
Willow	0.33

Source: Weiss, P., Schieler, K., Schadauer, K., Radunsky, K., Englisch, M., 2000. Die Kohlenstoffbilanz des österreichischen Waldes und Betrachtungen zum Kyoto Protokoll.

CALCULATION OF CARBON STORAGE

Carbon storage in wood biomass

- Stock volume timber

- Dry mass

- Brunches

- Dry mass

- Roots

- Dry mass

- Needle/Leaf

- Dry mass

Results of standing stock volume

- Between the classic inventory sampling method and the TLS method only **24 m³/ha** difference (697 m³/ha vs. 673 m³/ha)
- If all 44 forest inventory points are included, the total stock is slightly lower: **549.27 m³/ha**
- TLS samples were collected on the fully stocked areas and not on the landslides with the pioneer forests.
- TU Vienna - UAV volume: **547.42 m³/ha**
- This value corresponds very well with the value determined from the 44 manually recorded sampling points (549.27 m³/ha)

PLOT-Nr.	m³/ha Classic inventory sampling (10 m radius)	m³/ha TLS (10 m radius)	m³/ha TLS (20 m radius)
303	416	476	590
308	1321	1149	759
407	826	795	791
408	124	150	491
409	464	416	656
504	687	669	748
505	1066	845	740
506	731	893	588
511	790	289	351
605	715	1060	816
606	357	651	728
607	668	676	845
608	824	758	753
610	119	194	172
611	635	844	665
706	1612	1462	874
709	786	745	543
710	397	43	755
Average Volume/ha	697	673	659

RESULTS LYING DEADWOOD

AVERAGE LYING DEADWOOD (m³/ha)		
Field survey (Line Intersect Methode)	UAV in relation to total area of the Rohrach natural forest reserve(47,5 ha)	UAV related to the 10m radius plots
99,6	55,9	45,8

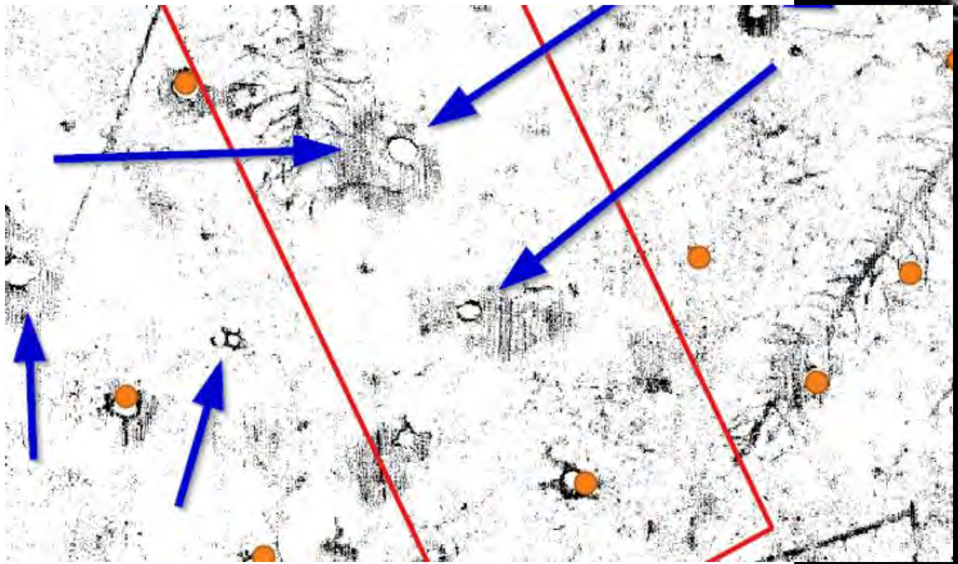
- Although artifacts such as the outlines of stones and terrain lines were also classified as deadwood in the automated **UAV evaluation**, the average value of the lying deadwood obtained is **almost half** the value calculated by the Line Intersect method.

- Two possible explanations:
  1. A prerequisite for the Line Intersect method is that the deadwood logs are randomly distributed and not arranged in a pattern on the sample area. It is possible that **there is no random distribution** in the Rohrach natural forest reserve,
  2. It is possible that the **UAV evaluation** could not detect some tree trunks under the canopy and therefore **underestimates the lying deadwood**.

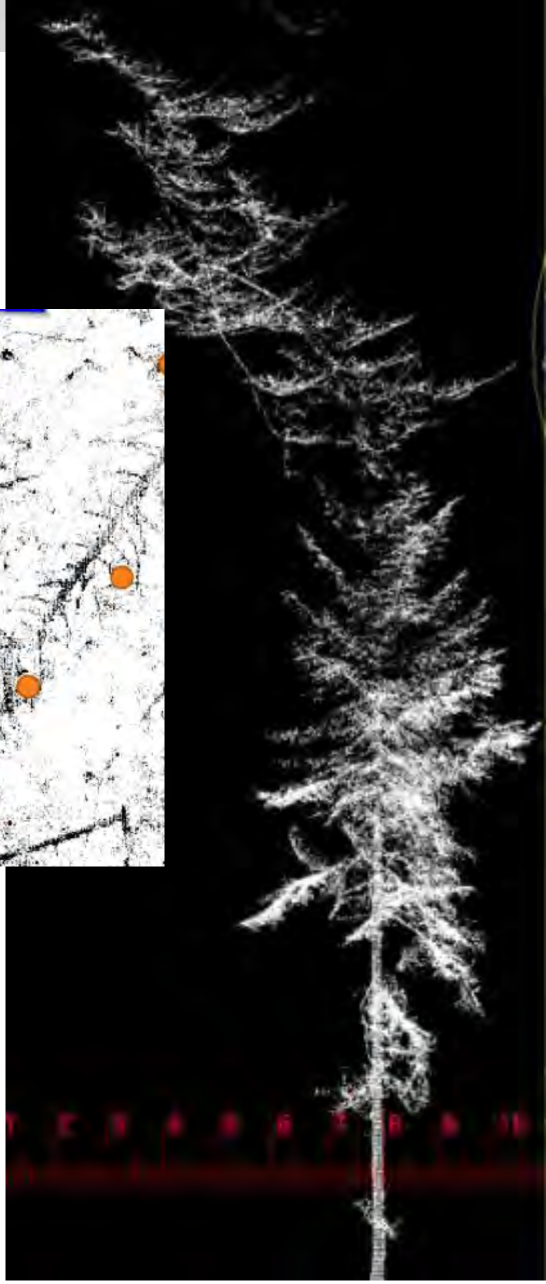
CONCLUSION/NEXT STEPS

- The evaluation of the UAV data resulted in approximately half the amount of deadwood.
- Further research into whether the UAV data overestimates the volume or the Line Intersect method is not applicable to the area
- Still a lot of cumulative uncertainties in the laserscan data elevation
- But the laserscan elevation is more accurate than the conventional sampling inventory (exact 3D point cloud of the tree for the volume calculation)

missing trees

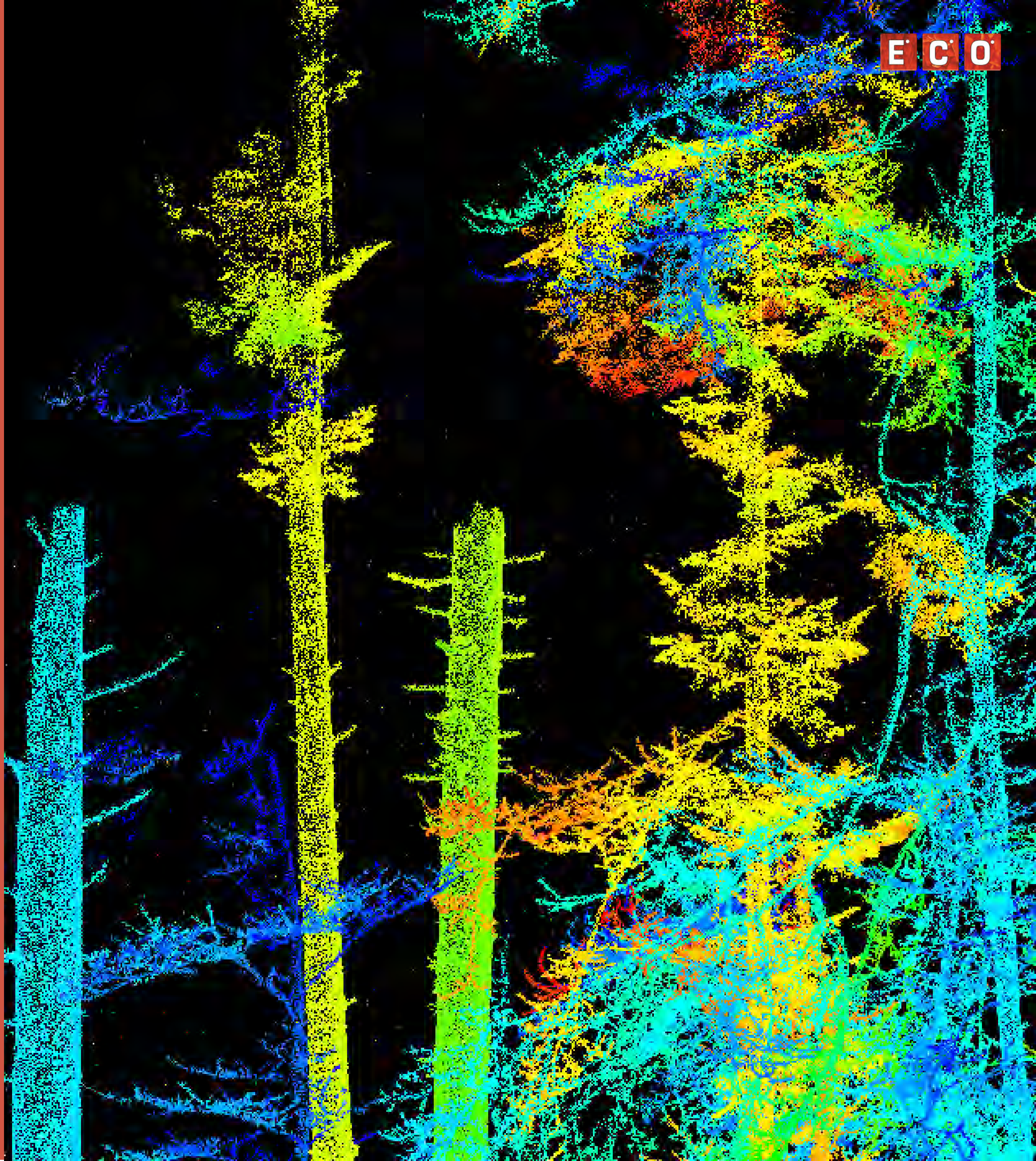


two trees recognized as one



WHY LASER SCANNING TECHNOLOGIES?

- **High Precision and Accuracy** because of 3D Data leading to more accurate biomass estimation
- **Efficient Data Collection**:
  covers large areas quickly → cost-effective
- **Non-Destructive and Non-Intrusive:** allowing remote data collection without the need for physical contact with the forest.
- **Suitability for Challenging Terrain:**
  (such as steep slopes or areas with difficult accessibility)
- **Monitoring option**: allowing a temporal analysis of biomass changes (and Carbon) over time
- **Effective forest resource management and planning**:
  It aids in decision-making processes related to sustainable forestry, carbon sequestration, and biodiversity conservation



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THANK YOU FOR YOUR ATTENTION

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