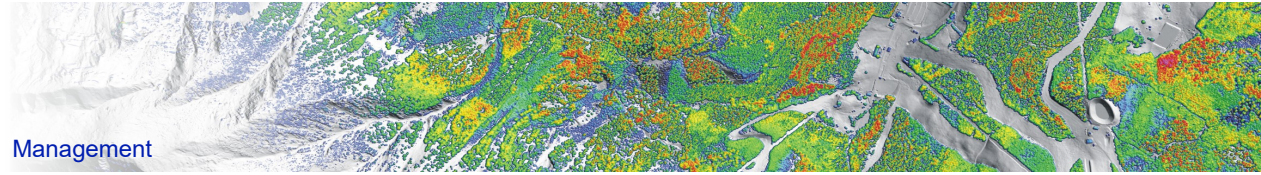




Sustainability: Monitoring Mapping Modelling Management



Deep Digital Forest

Operational Forest Inventory Workflow

ALS ► UHD-ALS ► TLS ► Mapping ► Management

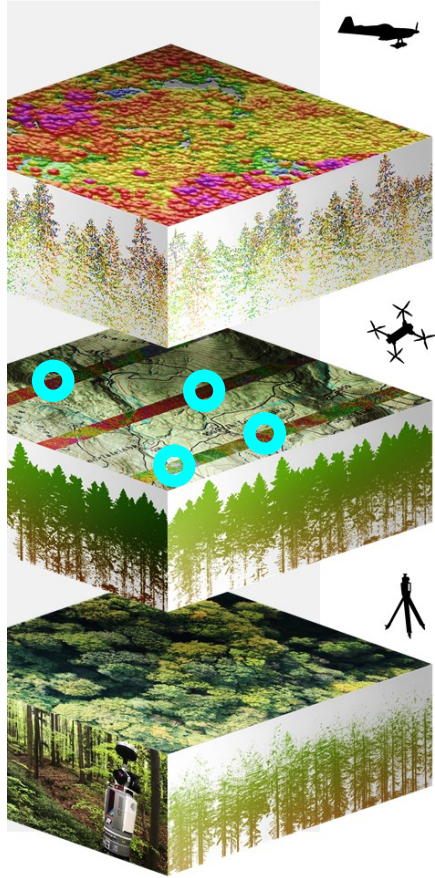
SME – Network funded by



JOANNEUM RESEARCH



SMART FOREST INVENTORY



Satellite/ Airplane

Wall-to-wall coverage by
airborne laserscanning

Light Plane/ Helicopter Drone

Low altitude mission with high
density point-clouds on stripes

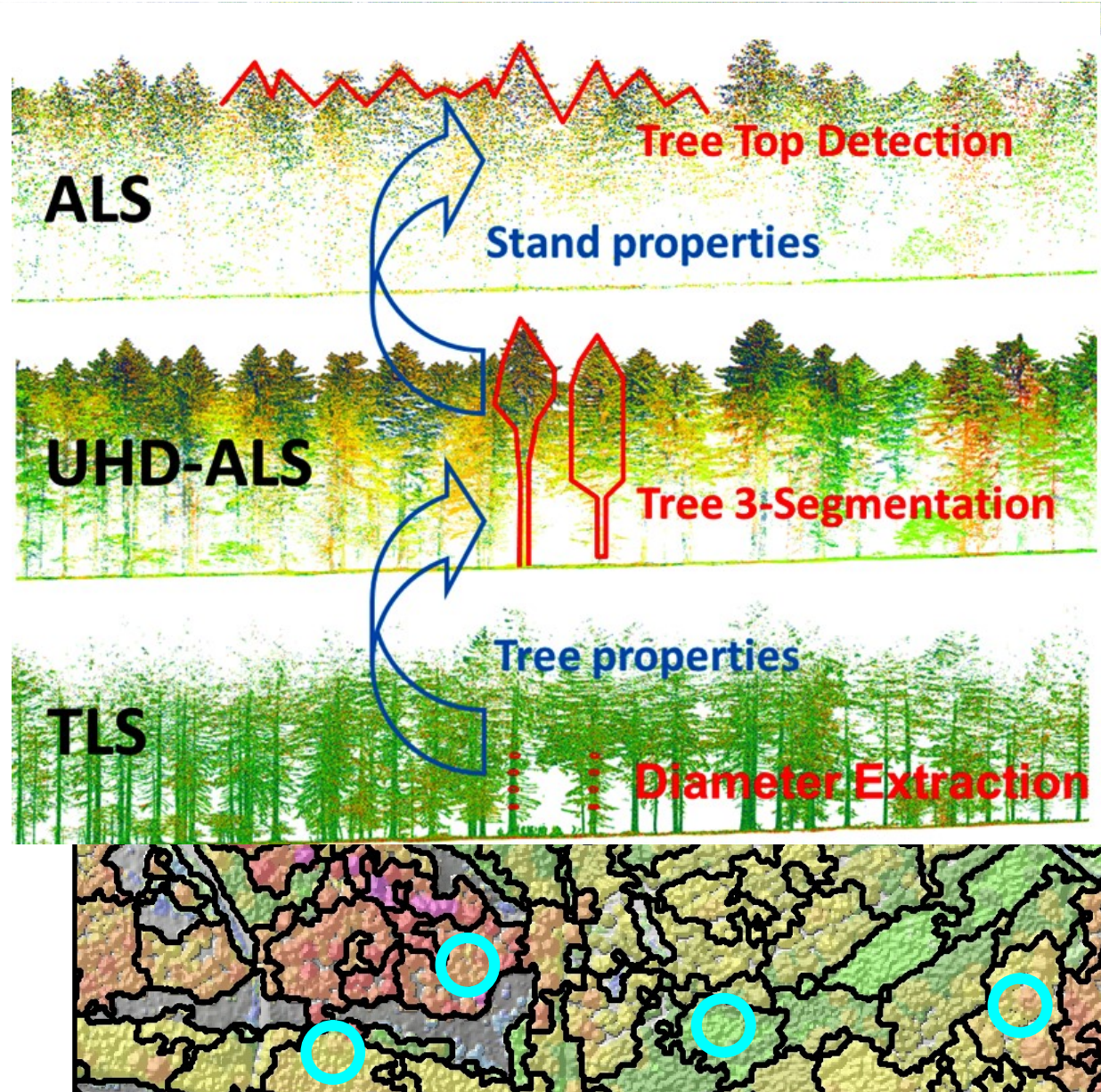
Terrestrial Laserscanning/ Fieldwork

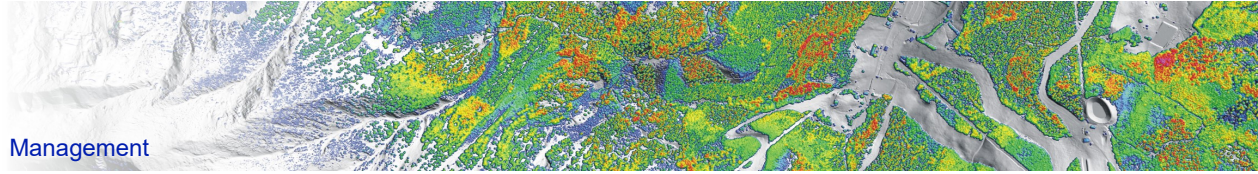
Terrestrial laserscanning on sample
plots
Conventional fieldwork



SMART FOREST TOOLS

Smart Forest Management



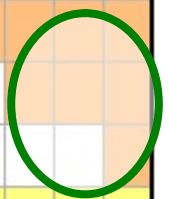


Cooperation Partners (Austria)

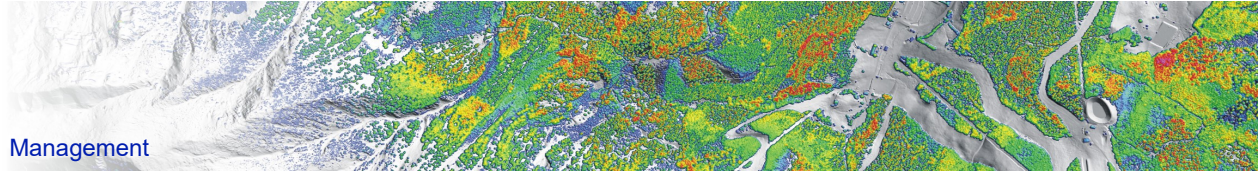
- Umweltdata Ltd. (FI, RS, mapping, FMP)
Günther Bronner, Boris Jawecki, Martin Keuschnigg
- Joanneum Research (Remote Sensing)
Mathias Schardt, Manuela Hirschmugl
- TU Vienna, department GEO (photogrammetry)
Norbert Pfeifer, Markus Hollaus, Martin Wieser
- E.C.O. (Monitoring of Biodiversity, Management of Protection areas)
Hanns Kirchmeir, Michael Jungmeier
- Aeromap (Aviation and Aerial Remote Sensing)
Roland Wack, Thomas Meißl
- Riegl Laser Measurement Systems
Horn, Lower Austria

Günther Bronner / Umweltdata records										Company					traditional					GIS, RS, GNNS					LIDAR					R&D					patent				
Year	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19		
Austrian State Forest	[Blue]																																						
Umweltdata											[Blue]																												
FMP	[Green]										[Green]																												
Forest Inventory											[Green]																												
Sustainability Monitoring											[Green]																												
GIS & Mapping											[Purple]																												
Remote Sensing											[Purple]																												
GNNS Surveying											[Purple]																												
ALS for mapping											[Orange]																												
CHM for Inventory Design											[Orange]																												
Segment based InvDes											[Orange]																												
TLS & ULS											[Orange]																												
UHD ALS stripes											[Orange]																												
VZ400i operational TLS											[Orange]																												
Silvilaser & ForestSAT											[Yellow]																												
DeepDigitalForest SME-network project											[Yellow]																												
jib-scan patent											[Pink]																												

DeepDigitalForest

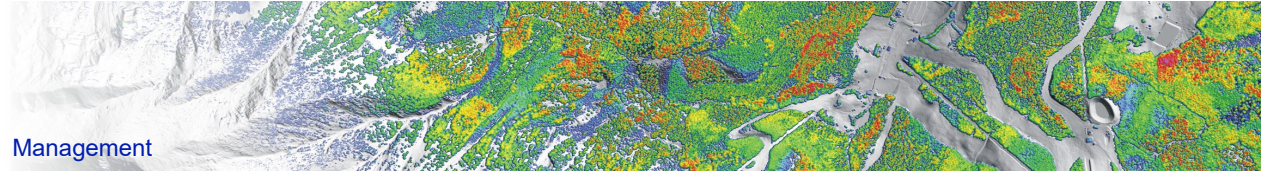


*



Digitize the Forest => Save the Planet !

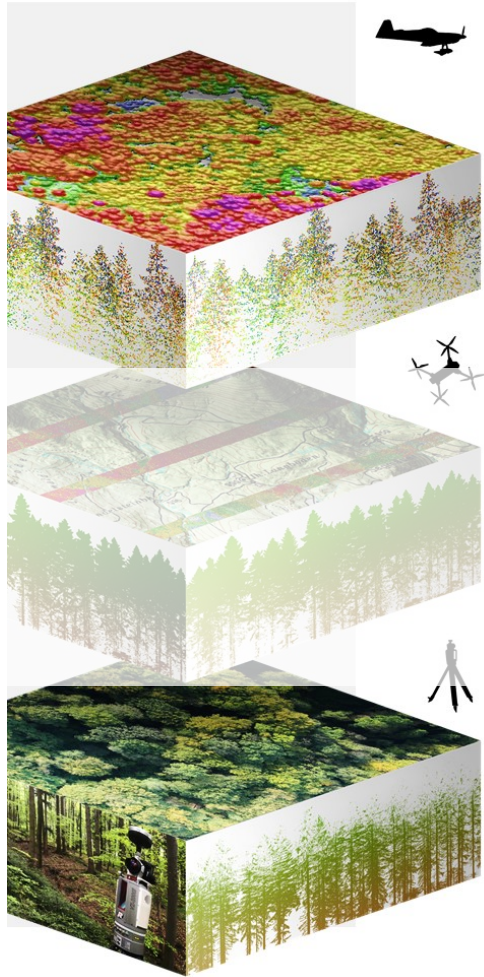
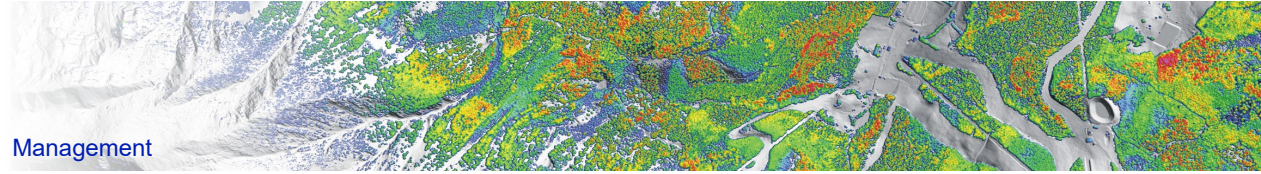
- ALS-CHMs can be a precaution against illegal logging by making the forest as transparent as possible
- TLS empowers single tree related growth modelling
- Growth modelling allows climate sensitive optimization of carbon segregation and timber value creation
- UHD-ALS can link NFI data to forest resource mapping
- Valid mapping enables good forest management



Digitize the Forest => Save the Planet !

- ALS-CHMs can protect against making the forest as transparent
- TLS empowers single tree relationships
- Growth modelling allows climate change prediction of carbon segregation and storage
- UHD-ALS can link NFI to forest management
- Valid mapping enables good forest management



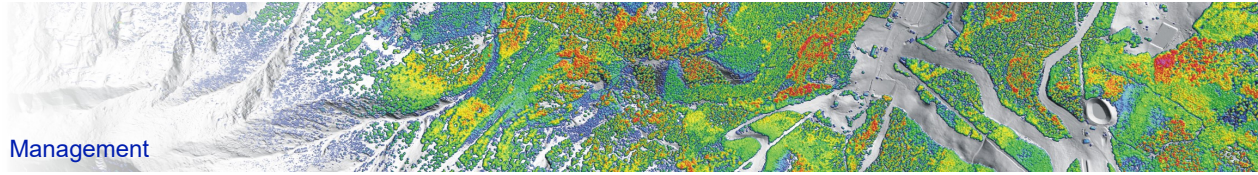


- **Phase I**
ALS wall-to-wall coverage

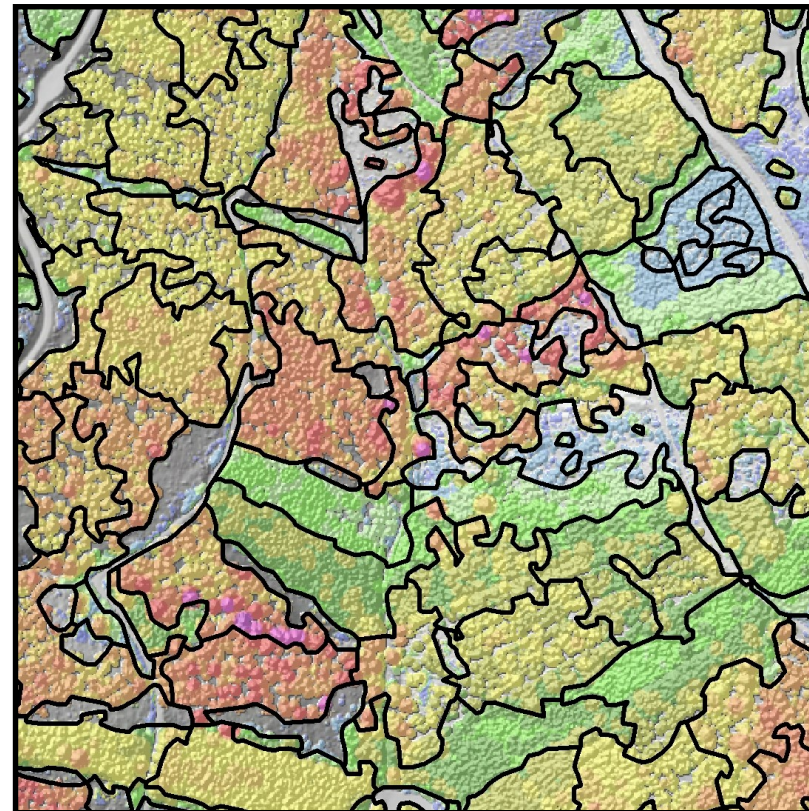
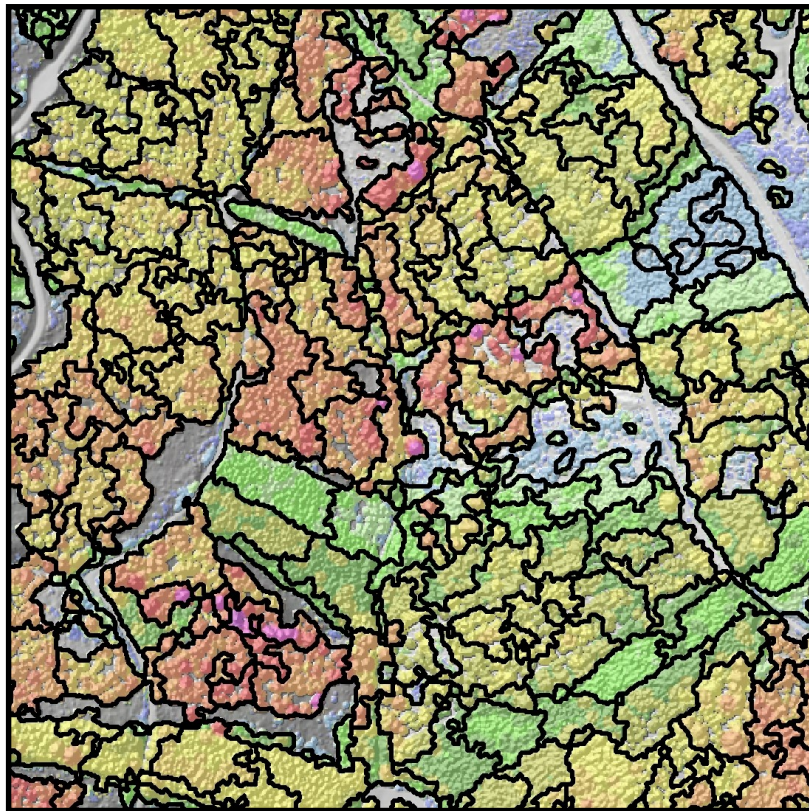
- **Phase II** **in preparation**
VHD ALS stripes in low altitude
with UAV or ultra-light plane

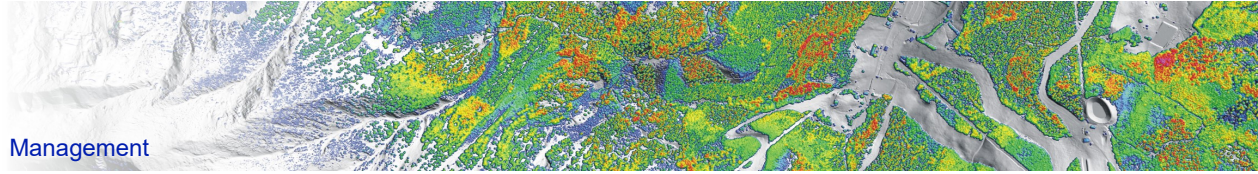
- **Phase III**
TLS and / or Fieldwork



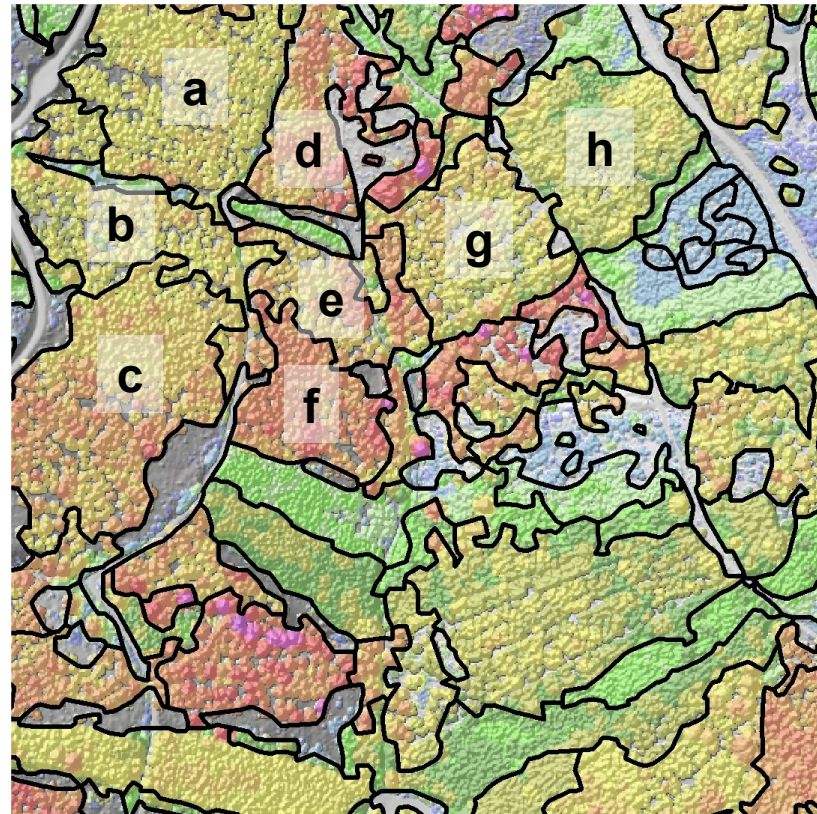
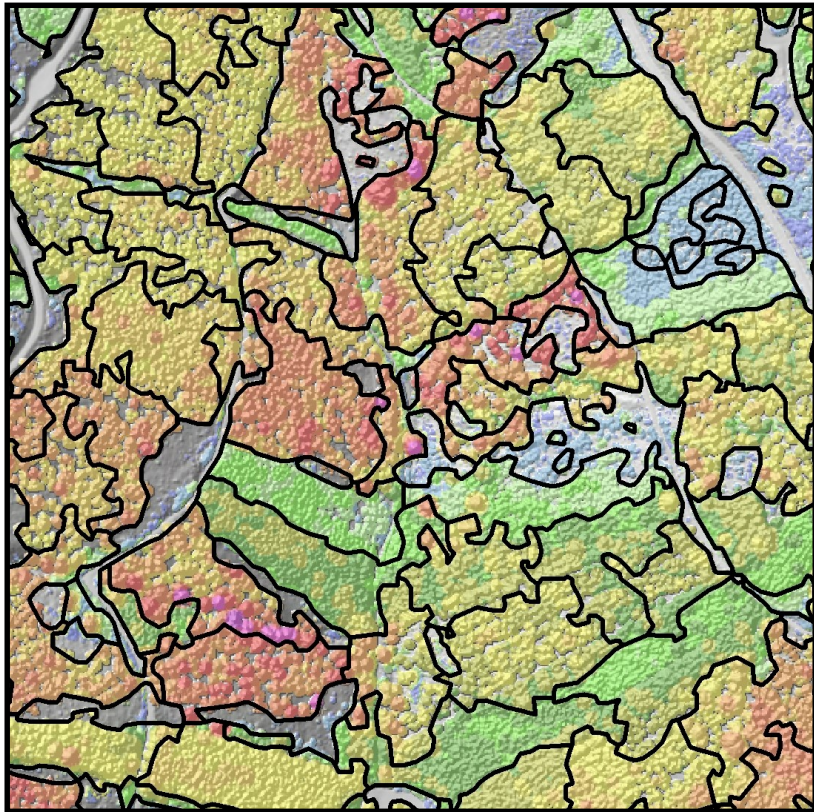


Automatic Segmentation of Canopy Height Models (i)

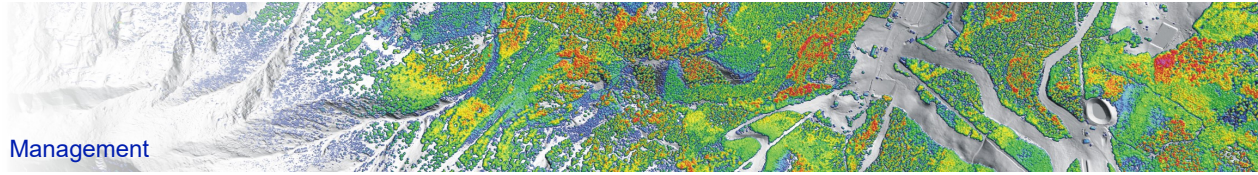




Automatic Segmentation of Canopy Height Models (ii)



step by step augmentation of forest stand polygons

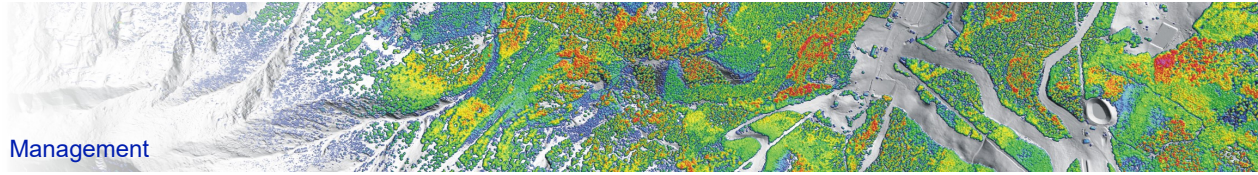


Temporary sample plots on segments

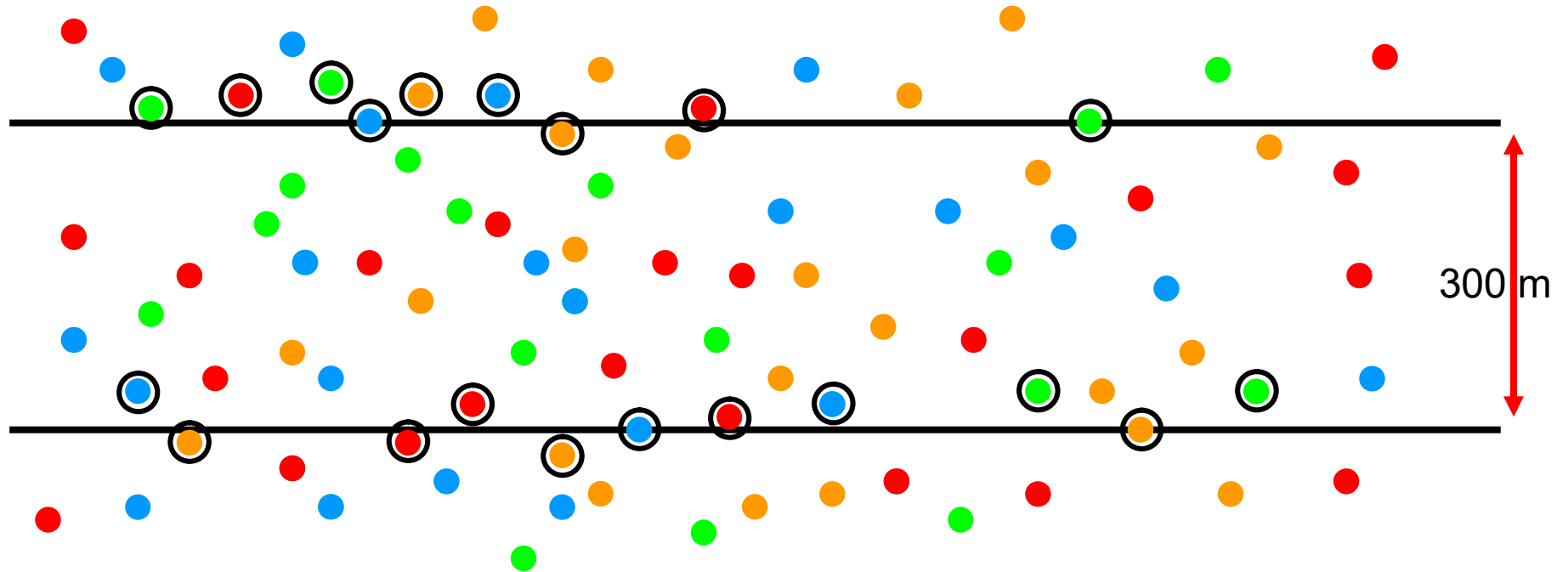
Stratification / classification strategies based on CHM segments are applied for optimization of sample plot design.

This design allows a stepwise and statistically controlled addition of sample plots to enhance accuracy.



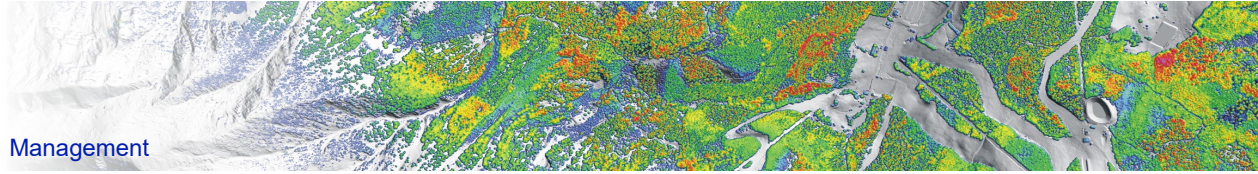


Reduction of potential sample plots by distance function ...



... grants random & ~regular distribution over whole area

    (colors indicate membership to stratum)

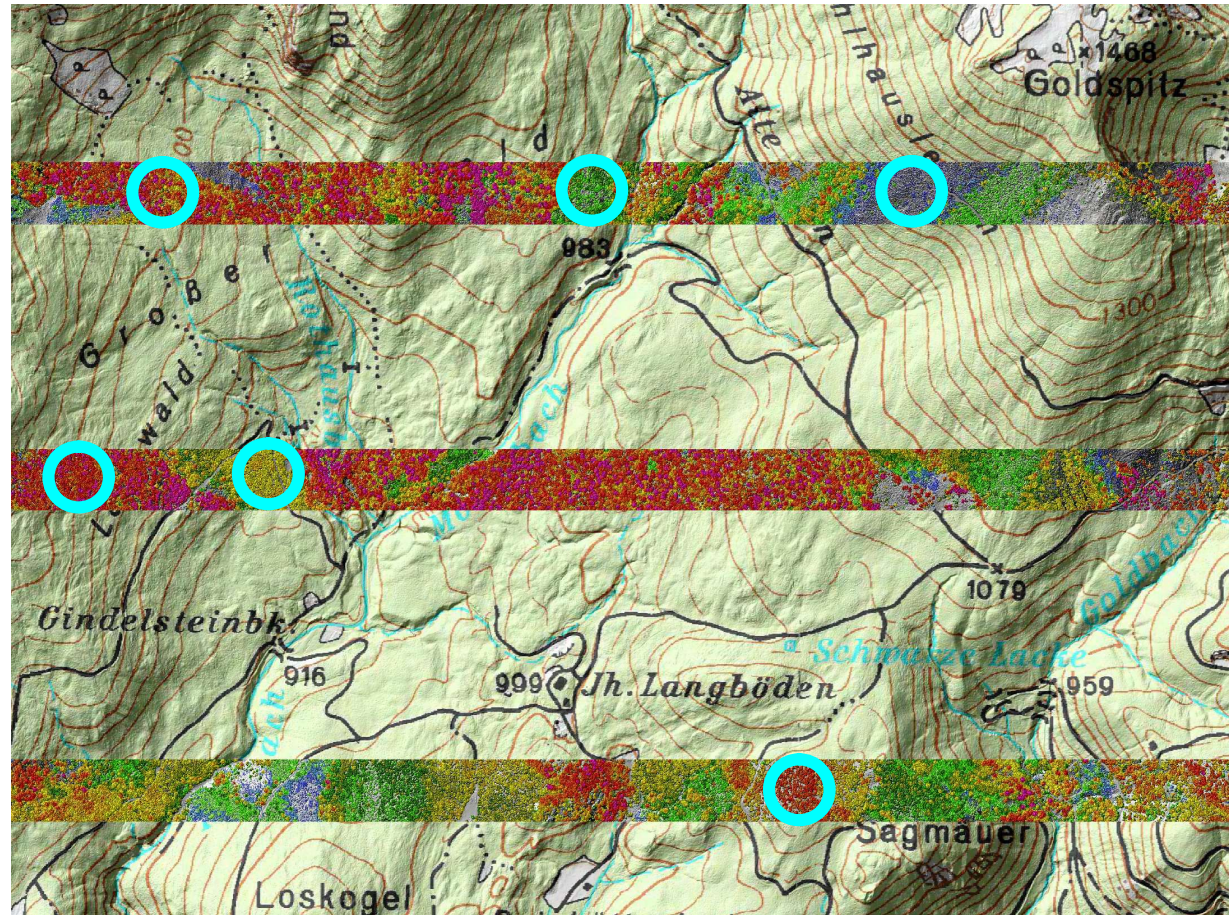


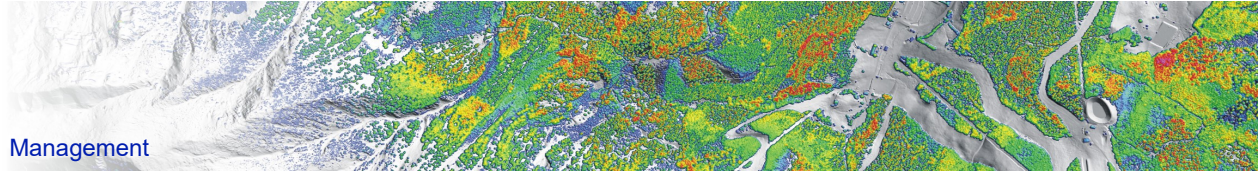
(NFI-based) 3-Phase Inventory

Stripes with very high resolution ALS data (100-1000 pulses / m²) allow single tree modelling, recognition of vertical structure, dead-wood detection and identification of natural regeneration.

NFI sample plots for TLS can be selected.

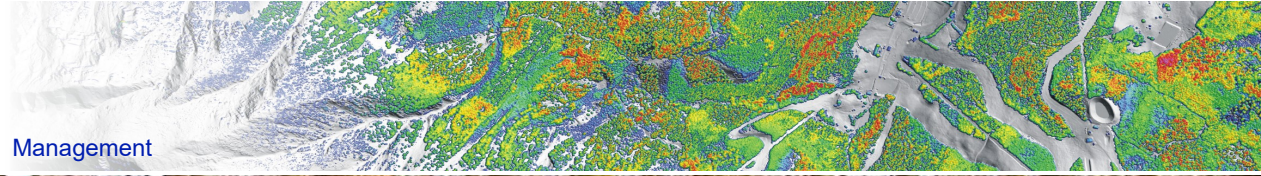
Tree by tree identification!





Traditional Fieldwork as GroundTruth

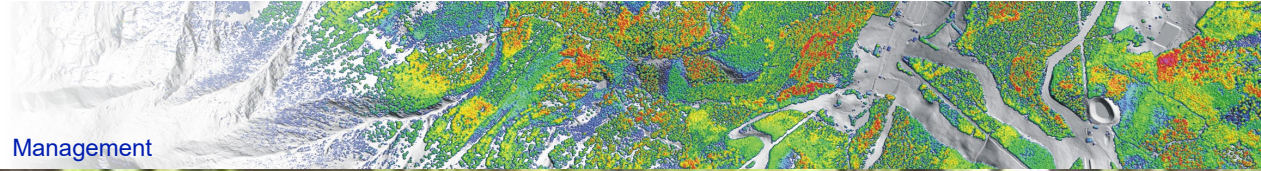
- Temporary sample plots on segments, Bitterlich K=4 including core borer extractions to measure annual increments
- GNSS accuracy 2-5m, no azimuth, distance to trees => no tree identification
- Stand-related correlation ($V_{\text{Stock}} = a \cdot V_{\text{Canopy}}^b$) ... $R^2 = 0.5$ to 0.7
Radius of LIDAR statistics on Bitterlich plot = $\text{DBH}_{\text{LOREY}} * 33.3$
- Permanent sample plots with azimuth + distance (no segments!): there is still a high effort of tree identification ALS / fieldwork
- If tree identification is successful, $R^2 = 0.65$ to 0.75



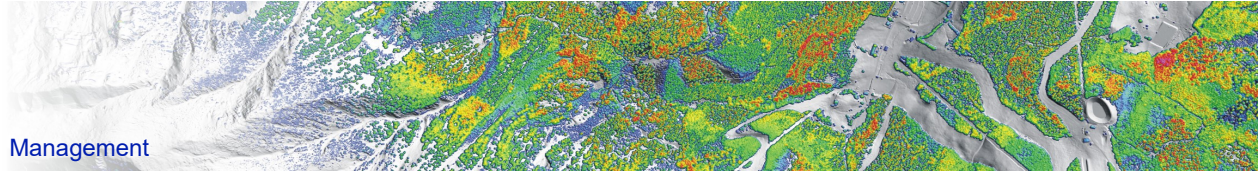
TLS for Ground Truth: 2 years ago

white spheres distributed for co-registration, 15 min / scan position



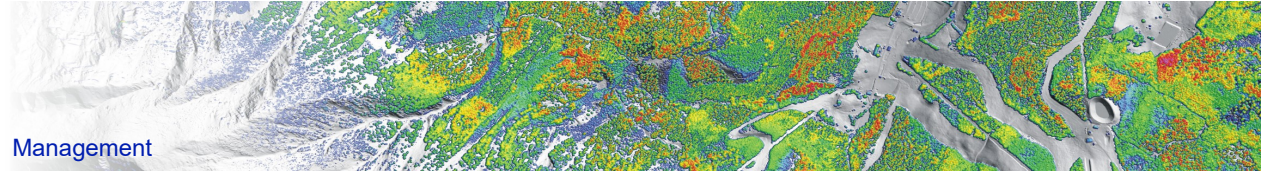


TLS actual: 10x productivity
automatic co-registration, 45 sec / scan position

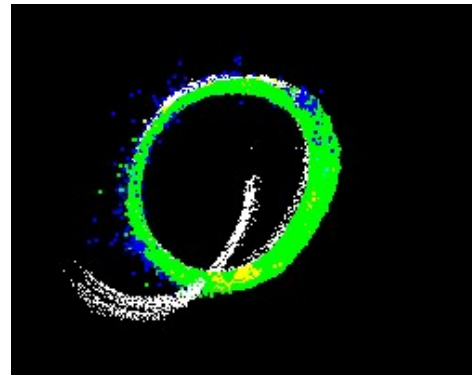
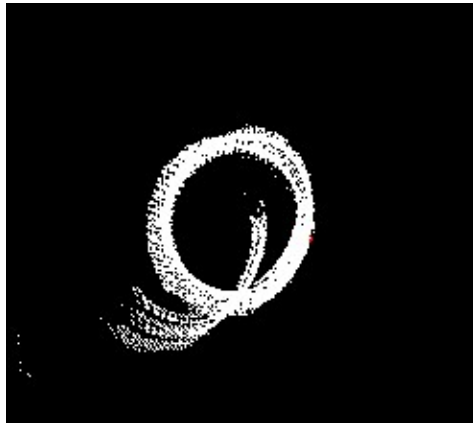


Riegl VZ400i in Operational Inventory

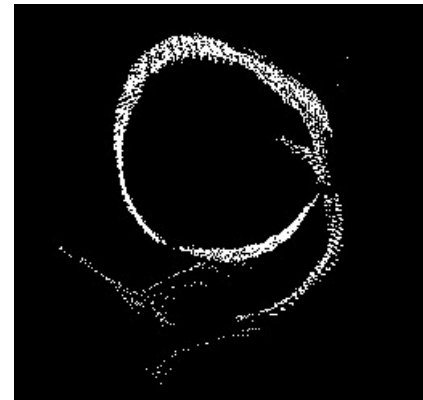
- Heavy device (>15 kg with tripod and camera)
- Limitation to 100° vertical scan angle (-40° to +60°)
- Rapid scans (30sec@50mgrad, 45sec@40mgrad)
- Accurate co-registration (realtime = battery consuming)
- TLS/ALS co-registration in development
- High sophisticated post-processing and viewing unfortunately not yet ready for batch processing
- RiPano-scenes are prefect for visual control



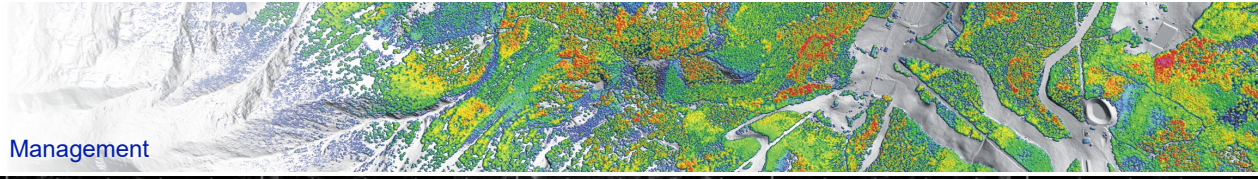
Co-Registration matters!



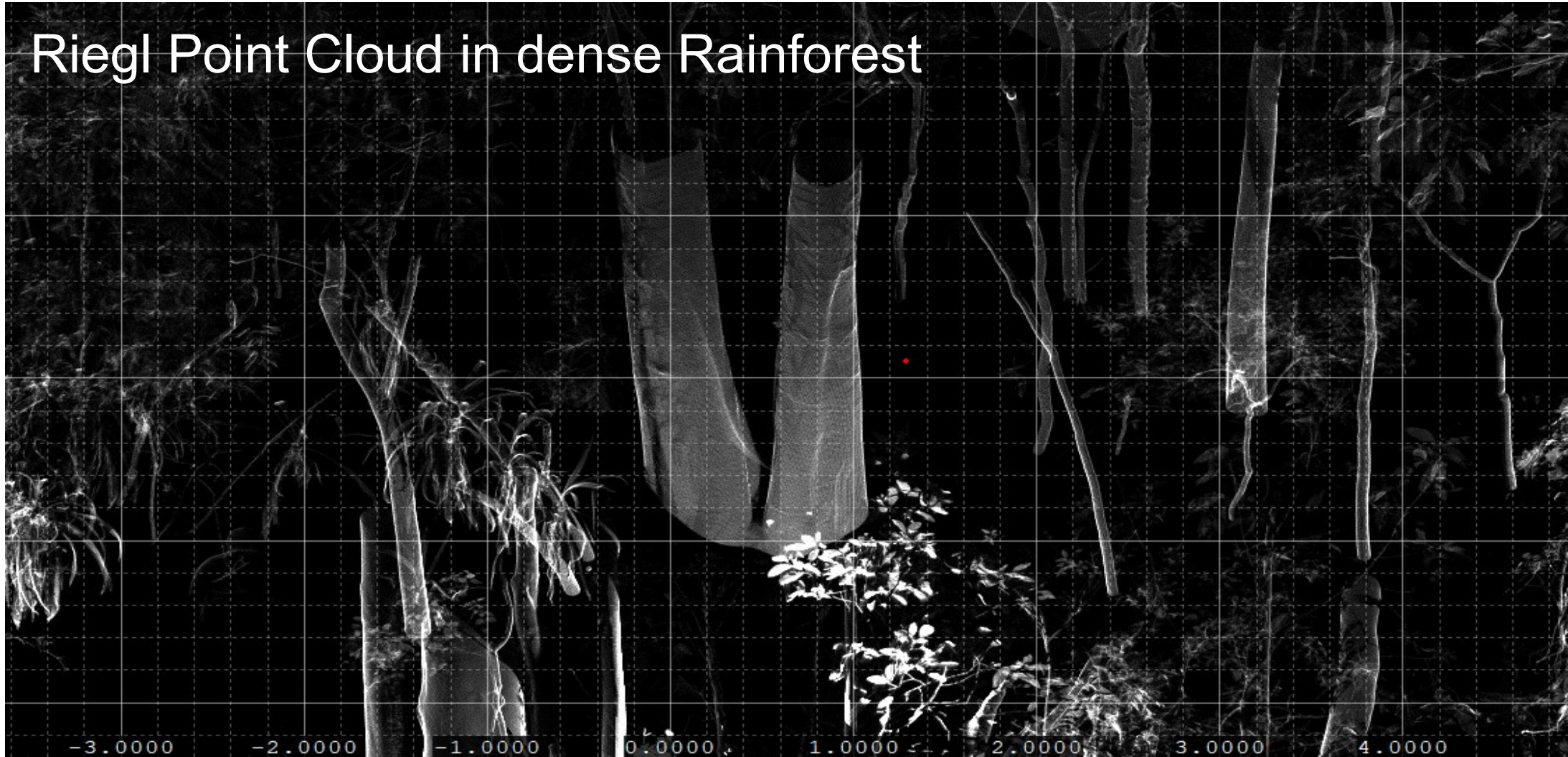
Test scans from Silvilaser 2019
Foz de Iguacu
site: “opposite of seedbank”

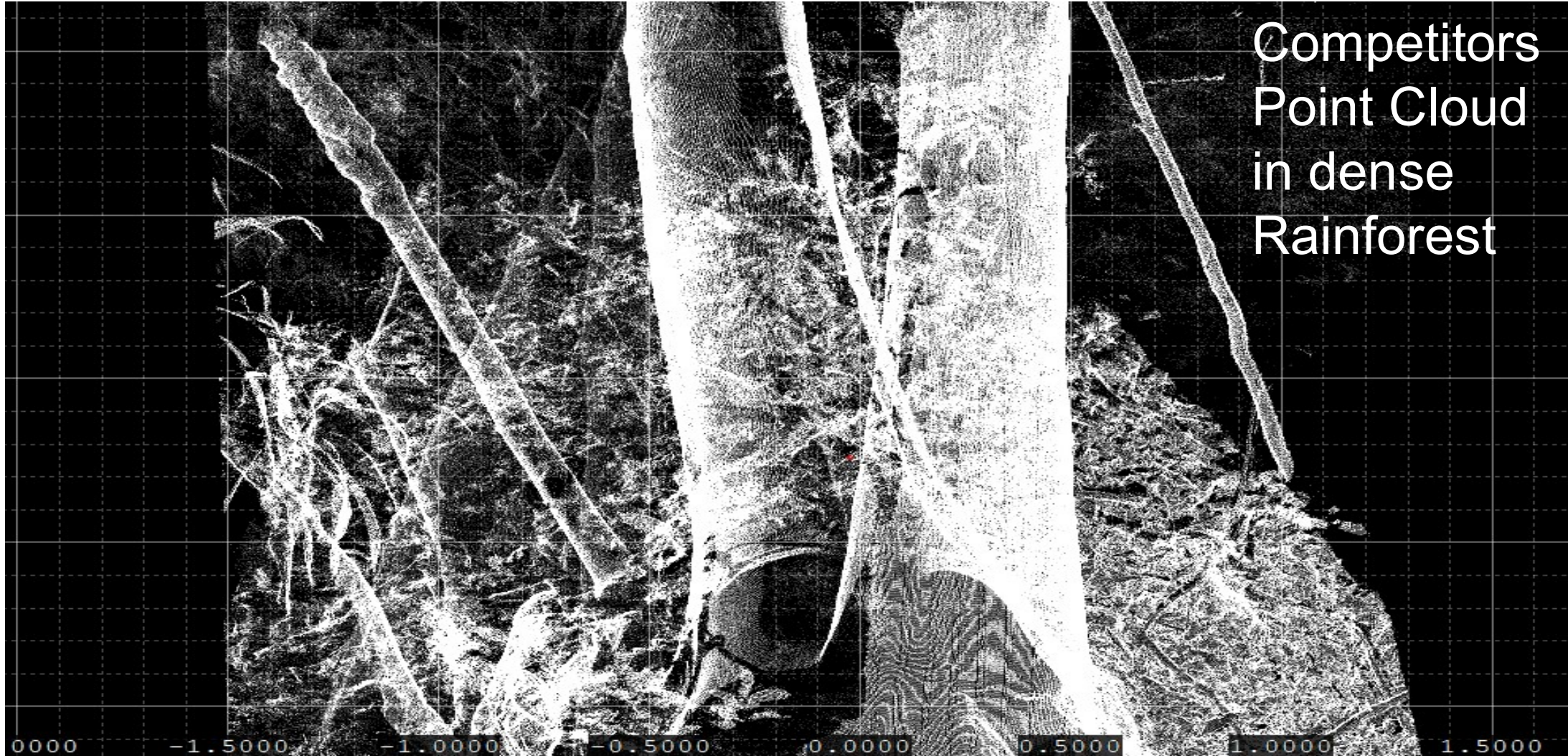
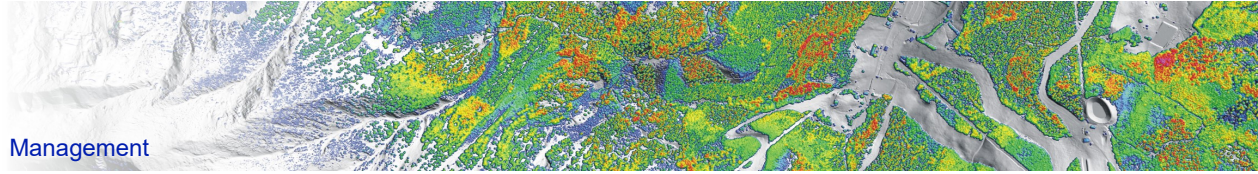


Coloured point clouds from Rieggl,
white point clouds from competitor

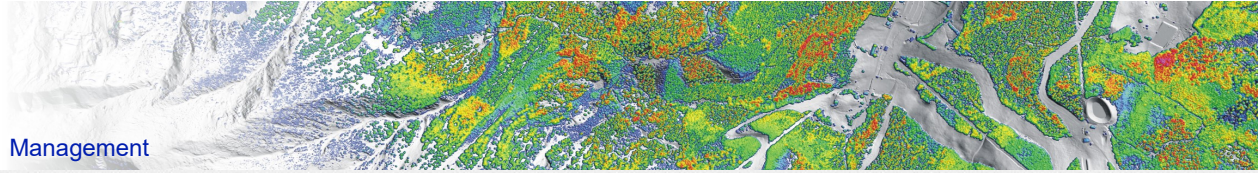


Riegl Point Cloud in dense Rainforest



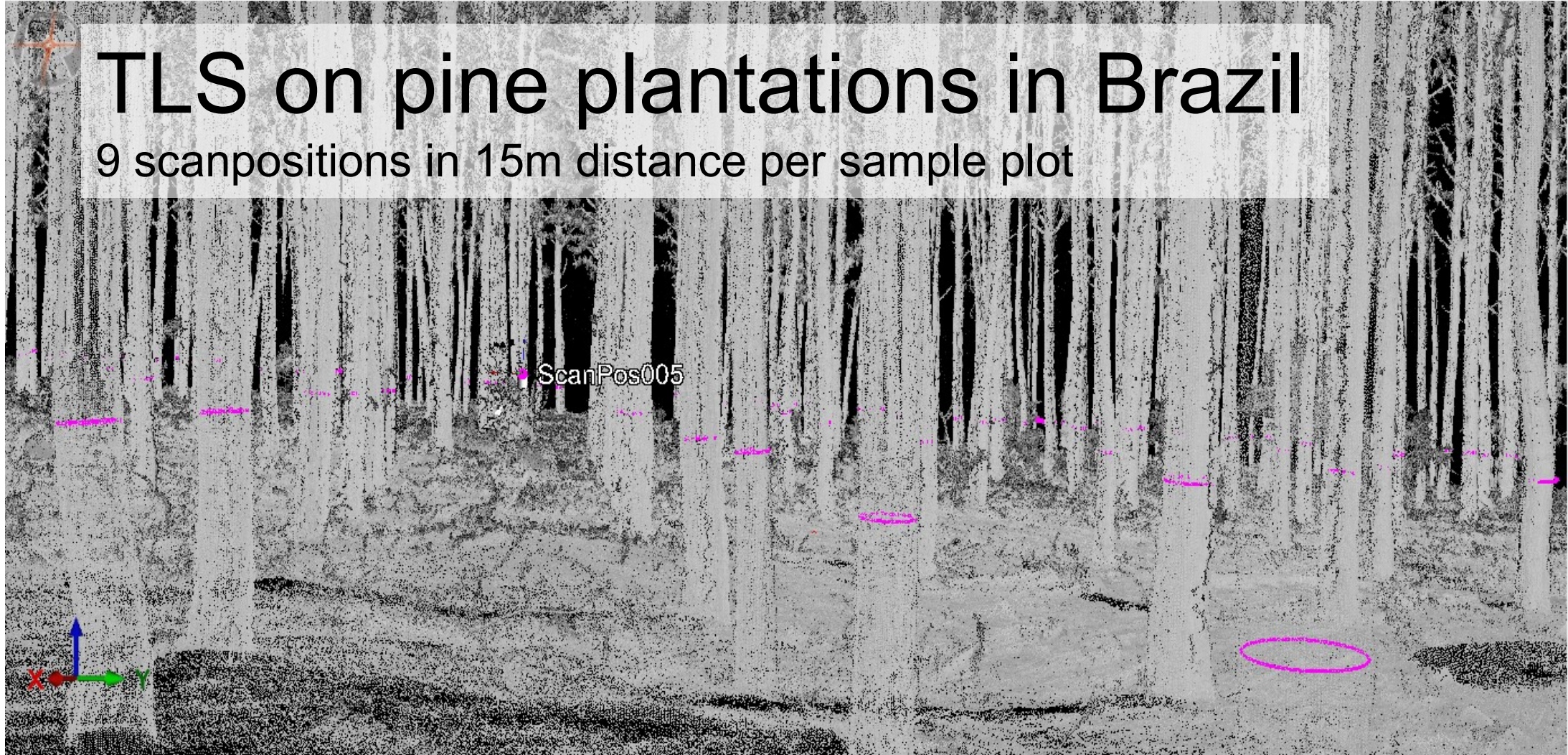


Competitors
Point Cloud
in dense
Rainforest



TLS on pine plantations in Brazil

9 scanpositions in 15m distance per sample plot





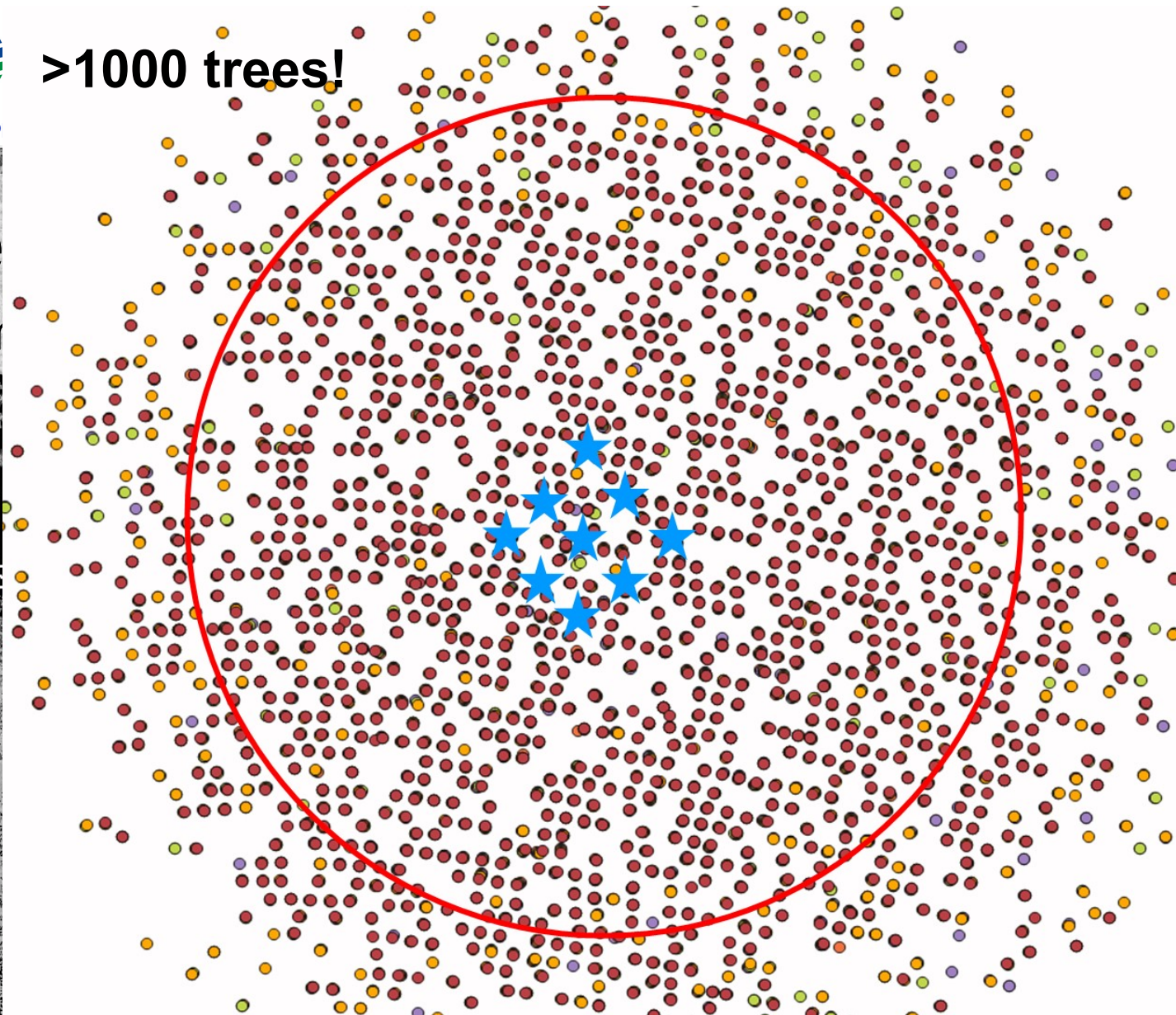
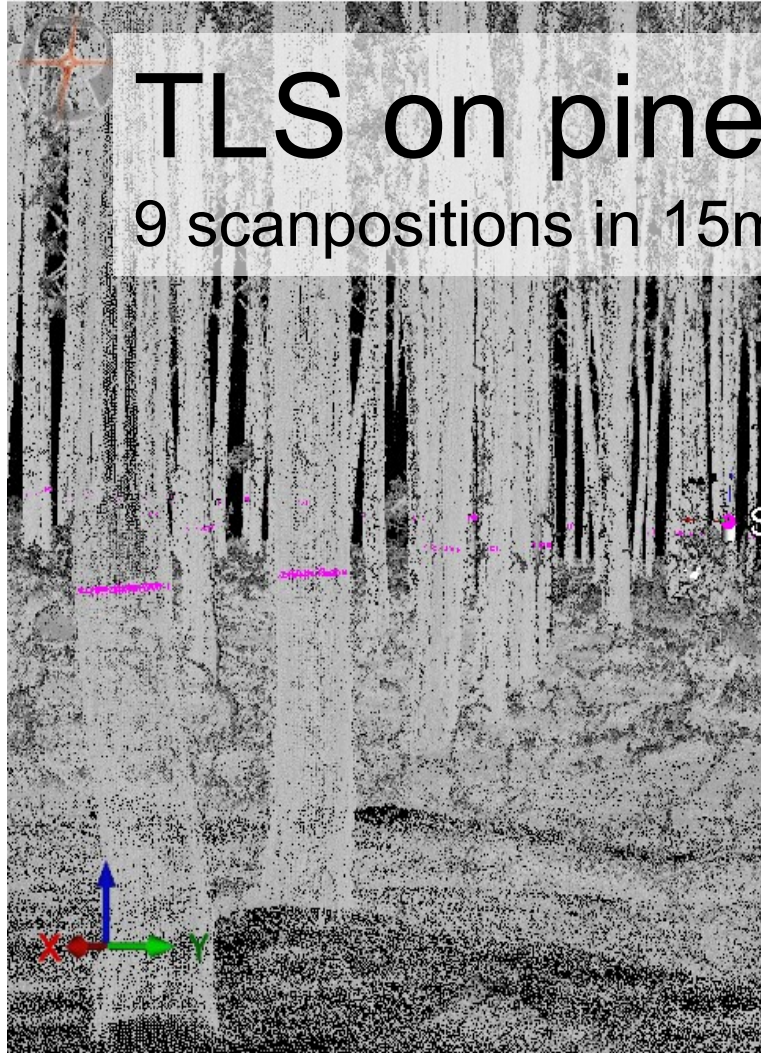
FFG
Promoting Innovation

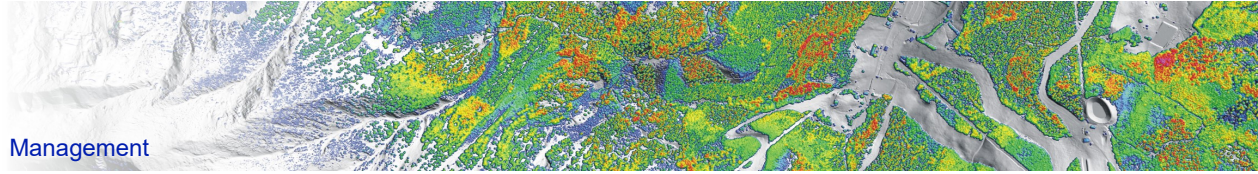
umwelt
Sustainability: Monitoring Map

>1000 trees!

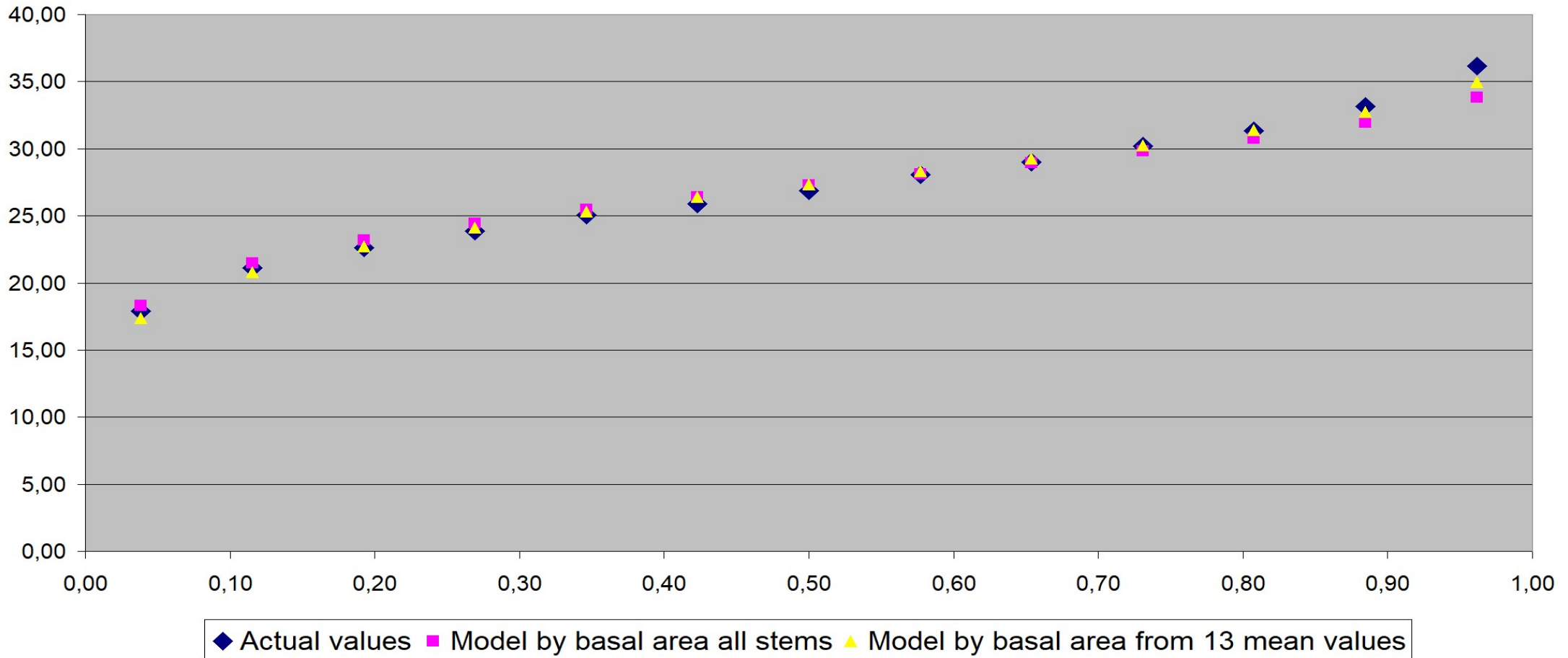
TLS on pine

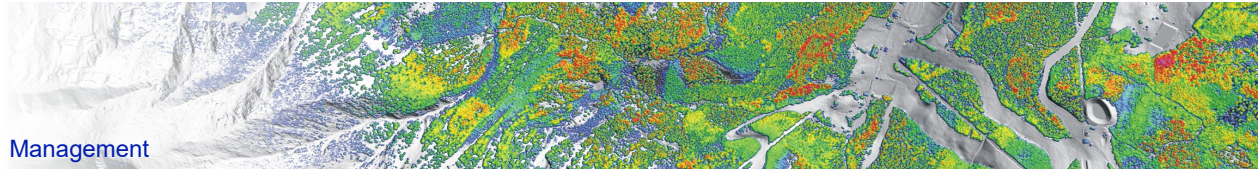
9 scanpositions in 15m



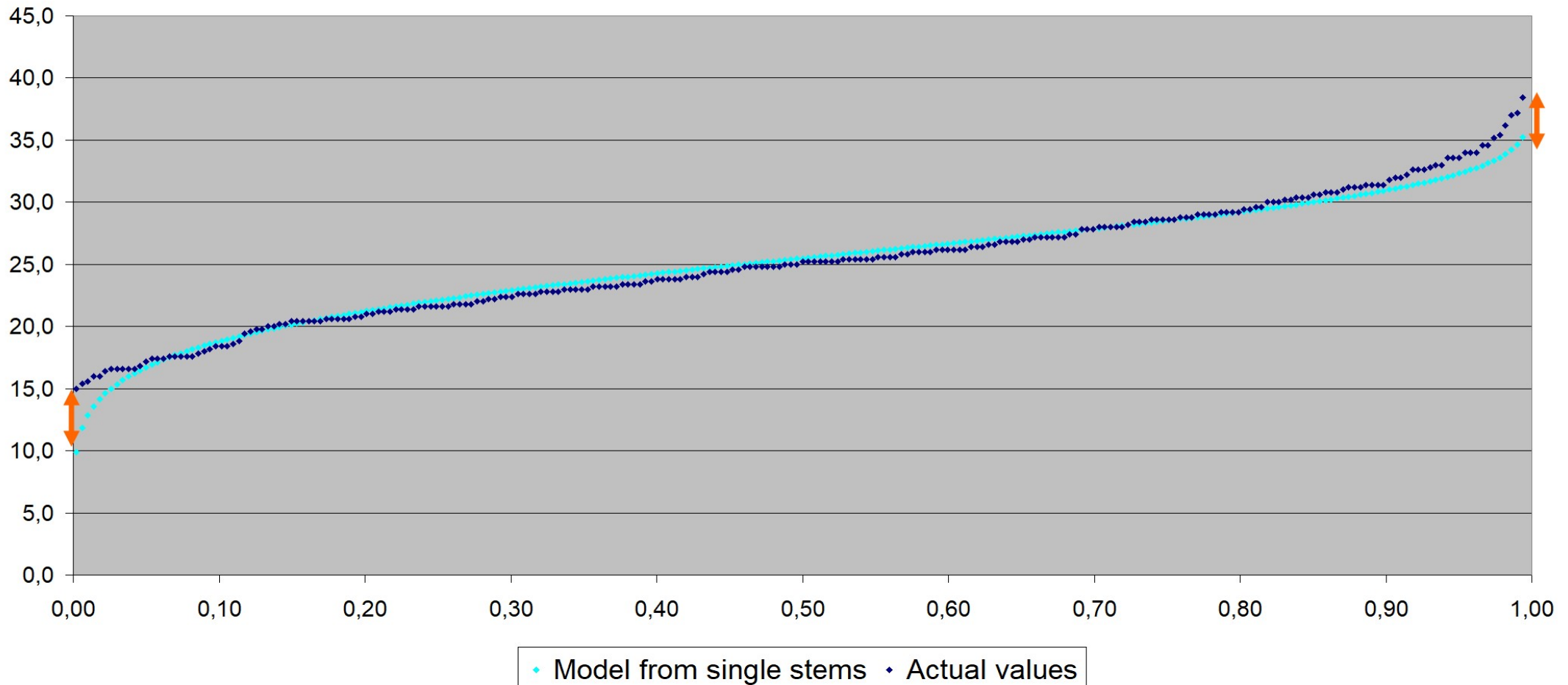


Weibull-distribution of DBH through basal area

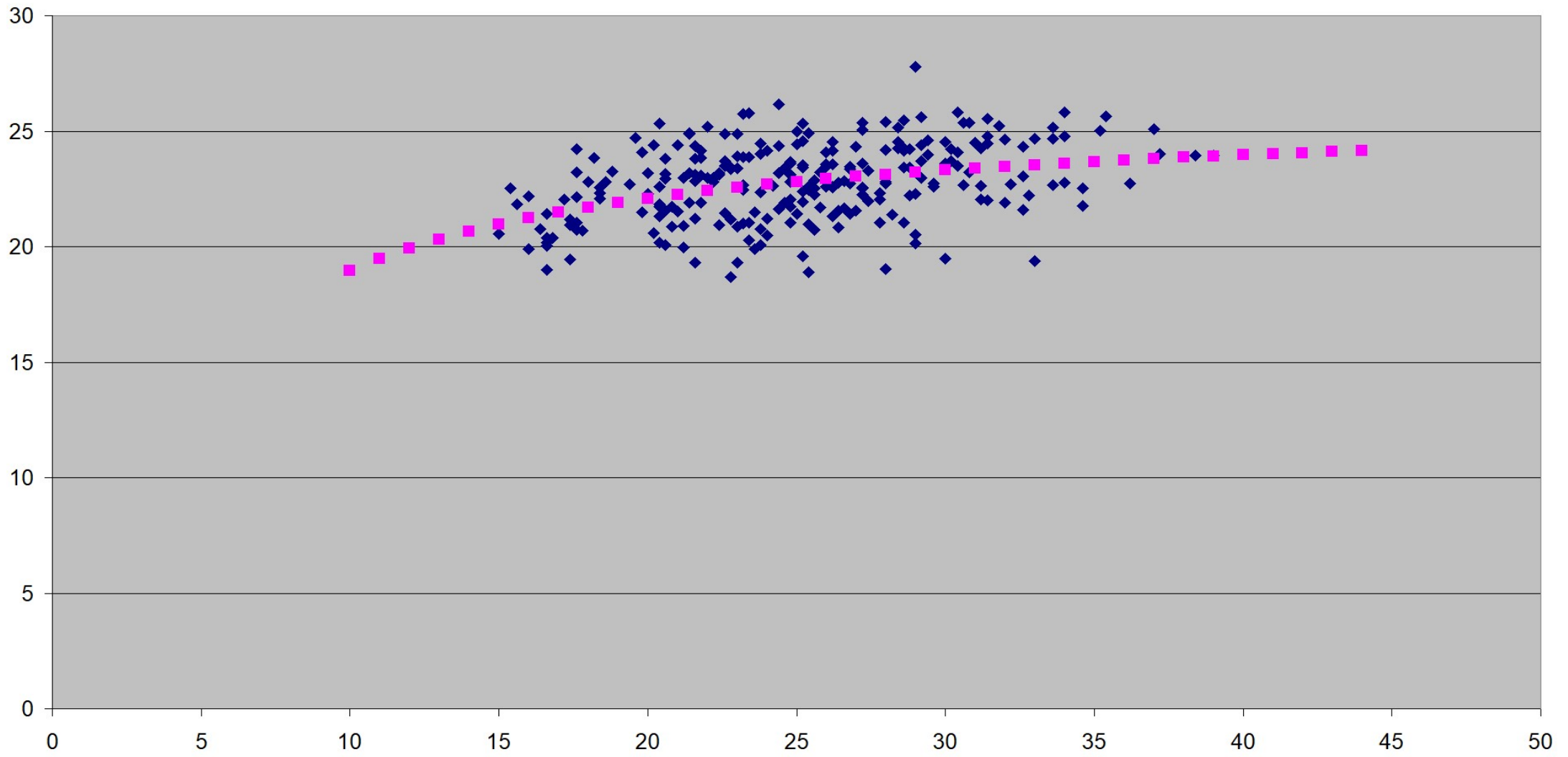




Weibull-distribution of DBH through single stems



Peterson DBH - height function



RiPano Image



Gasthaus Rieger



Point Cloud true colour



Gasthaus Rieger



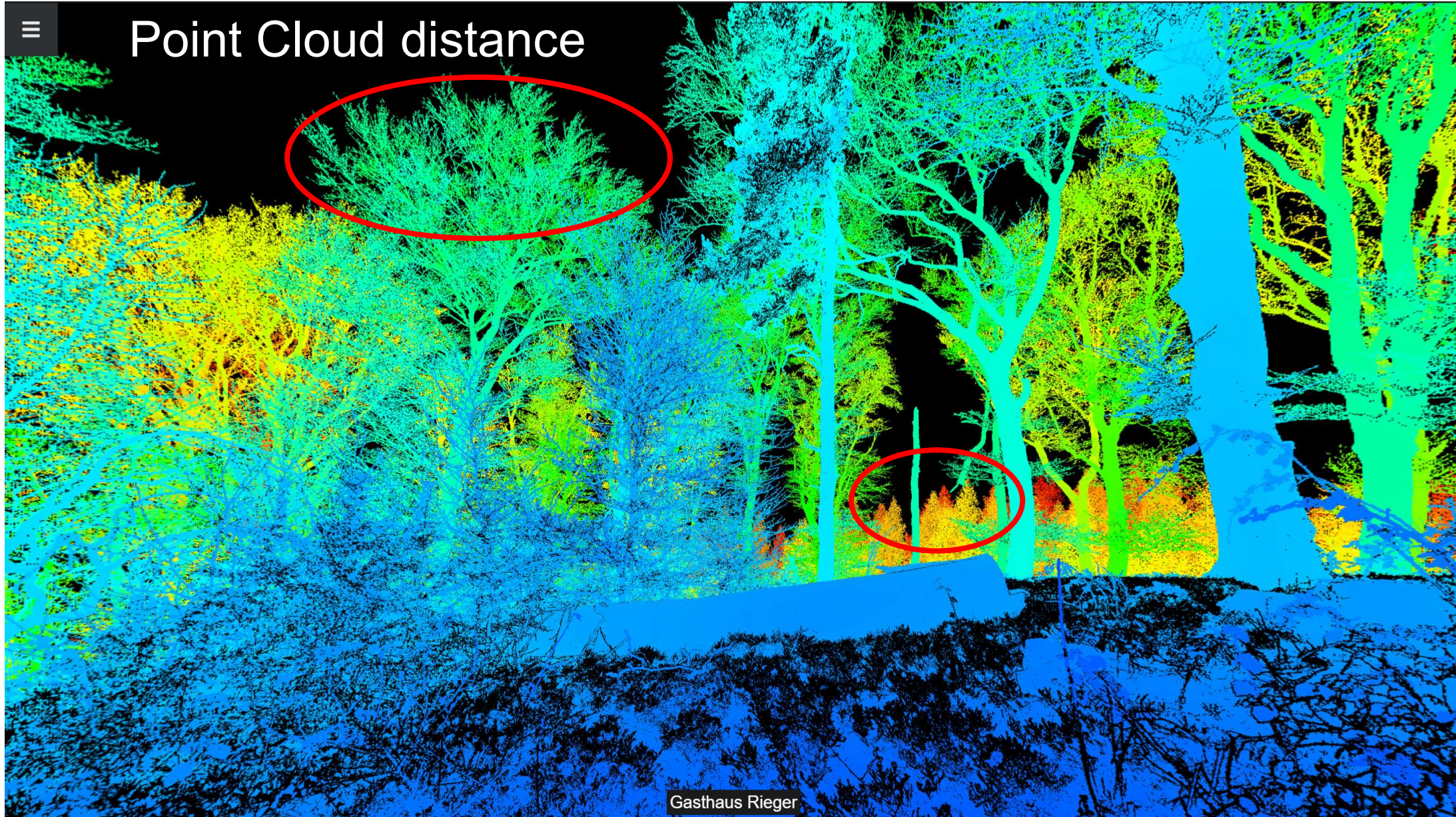
Point Cloud reflectance



Gasthaus Rieger



Point Cloud distance

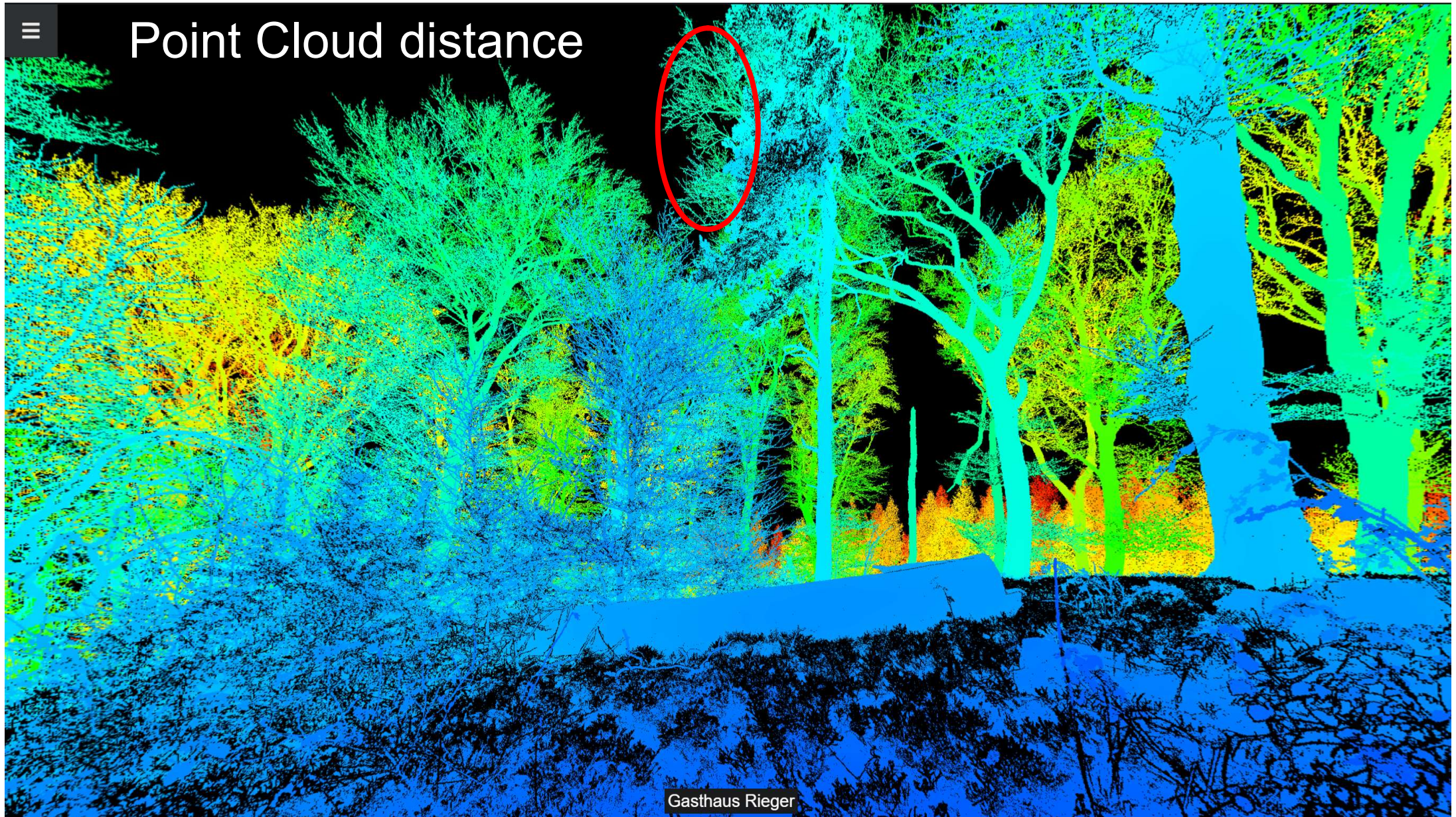


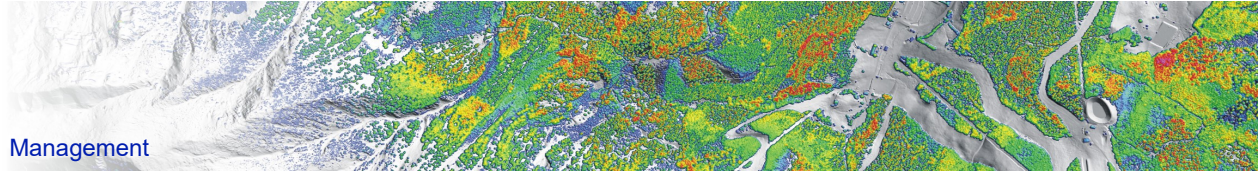


Gasthaus Rieger



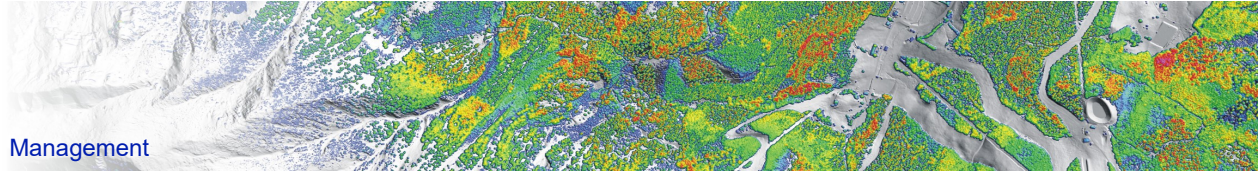
Point Cloud distance





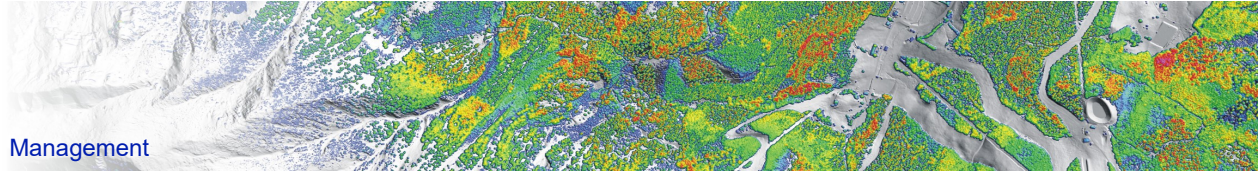
VZ400i Configuration Recommendations

- Nikon Camera with fixed focal length 14mm
- New battery pack with 3 separate lithium batteries
- Auto-registration off (battery consuming)
- 40 mgrad under good conditions, 10-15m move
- 50 mgrad with dense understory, 5-10m move
- 20% image overlap = 5 images / 360°
storage of high image quality becomes bottleneck



Feature Extraction (Opals TU-Vienna)

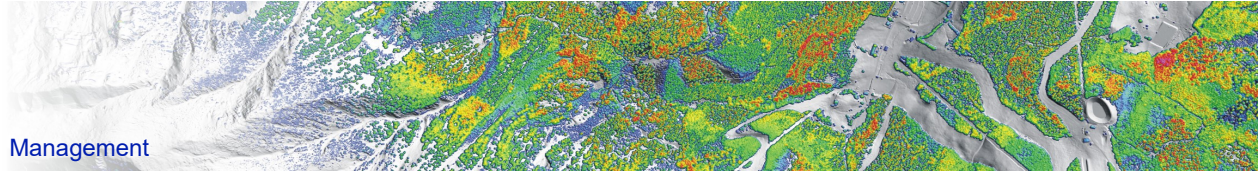
- Enabled for batch processing (!!!)
- Cylinder-fitting vs. Cone-fitting (both options avail.)
(e.g. comparison of 120-140 / 110-150 / 100-160 cm for DBH,
Cone-fitting 150-250 cm if DBH is hidden in dense understory)
- Tree segments scalable in any regard
- Number of used hits and residues for quality control
- Batch aborts, undetected trees, artefacts, no height



Multi-plot-size approach in TLS inventory

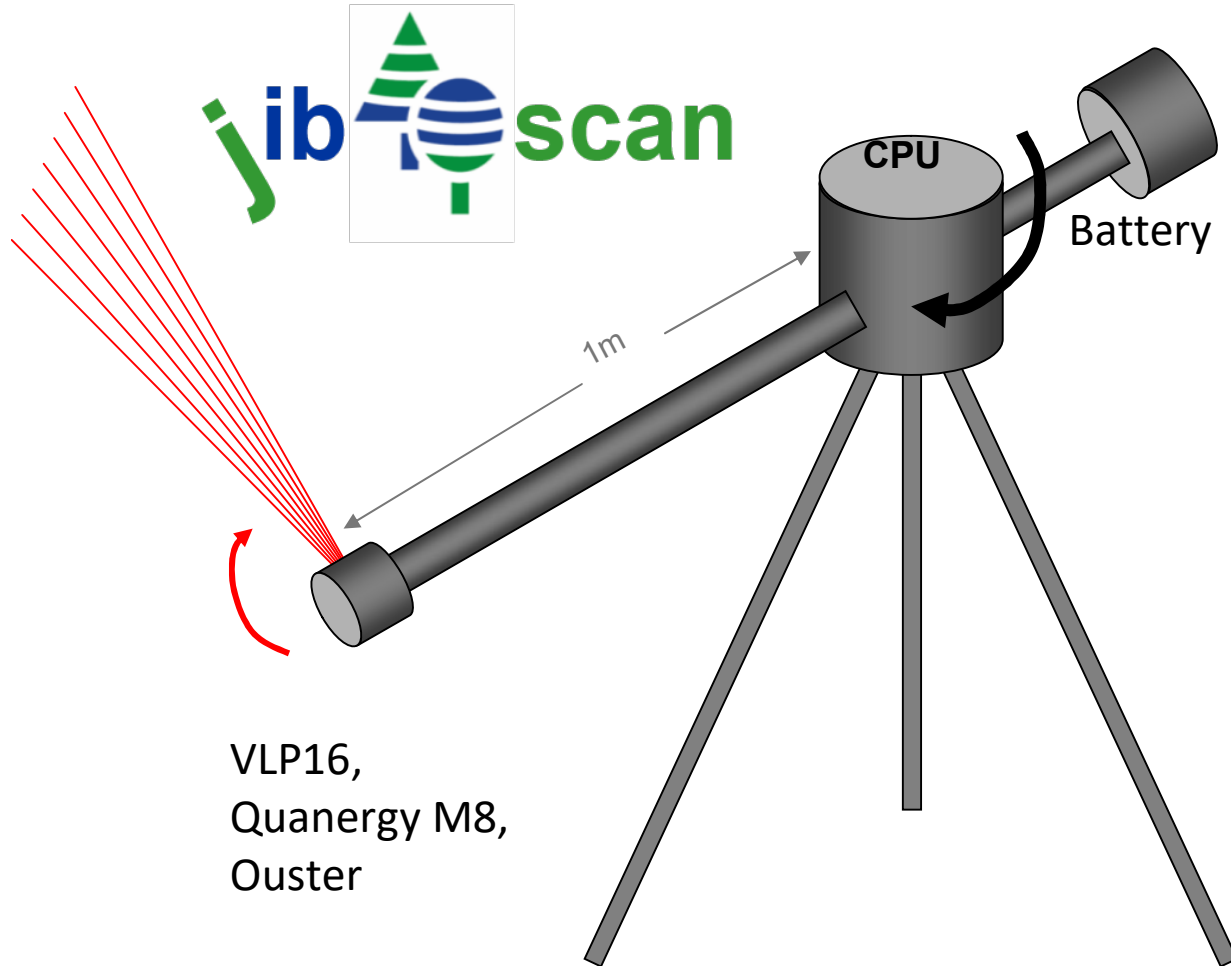
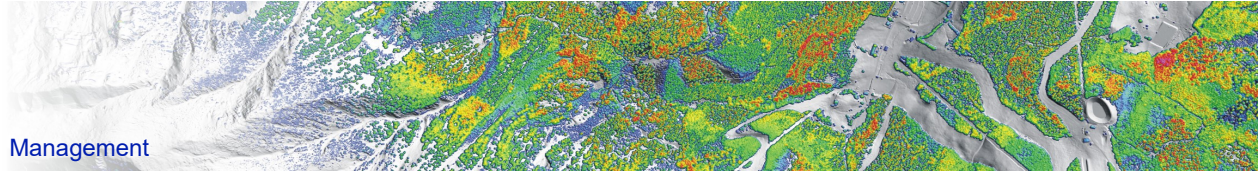
- Tree + taper recognition Bitterlich $K=1$ or $R=30m$
- Tree quality + competition + growth $K=2$ or $R=20m$
- Natural regeneration + deadwood $R=10m$
- Manual calibration measurements $N=4$ or $K=6$

Proposal of trees / features to be measured should come from the scanning software in real-time



TLS & Occlusion ...

- Scan performance allow multiple scan positions.
5 pos. with high resolution vs. 10 pos with high resol.
=> less occlusion, better co-registration, eq. points
- UHD-ALS would possibly allow single pos. TLS scans complementing missing trees+allometry from ALS
- **Jib-scan** could be a solution (prototype still under construction)

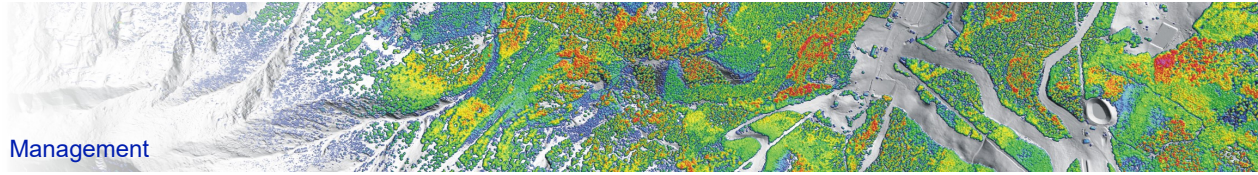


How to avoid occlusion in single station TLS measurements

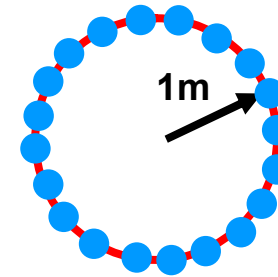
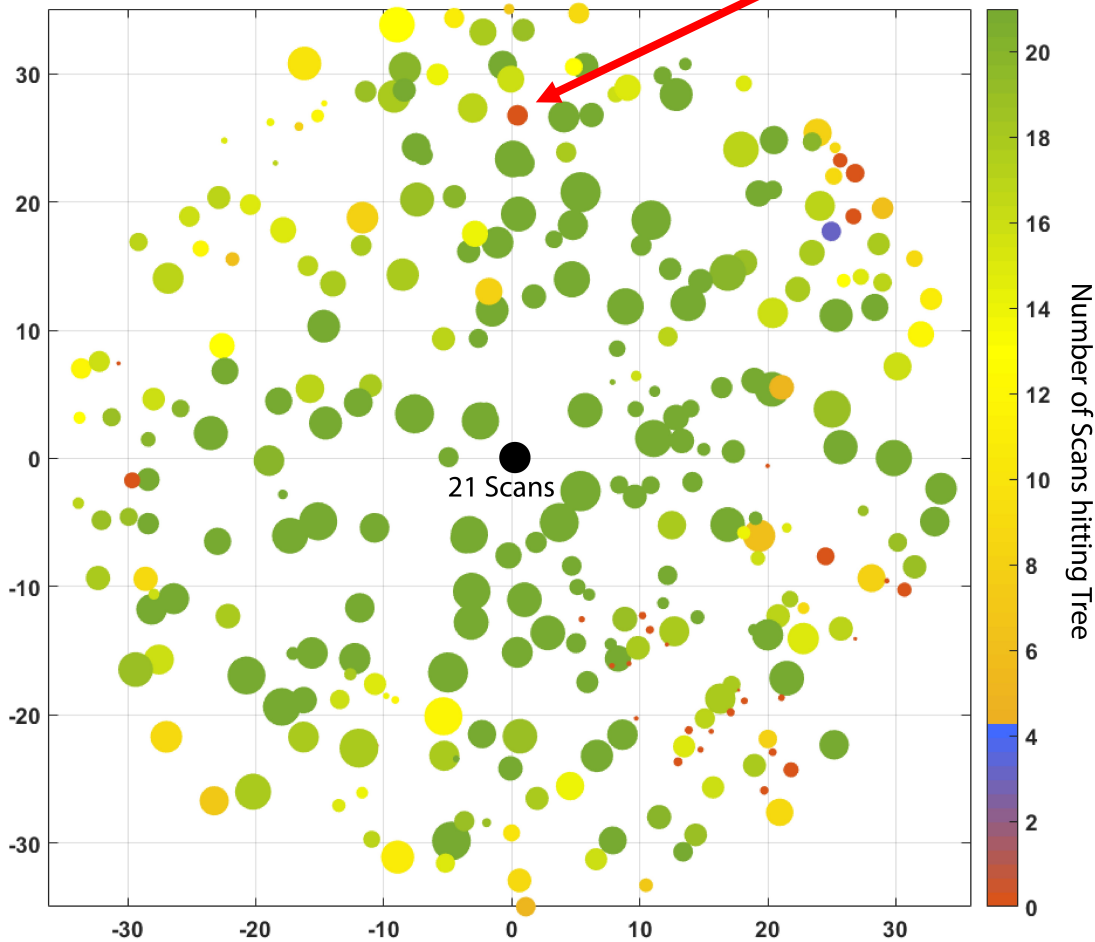
Günther Bronner
Umweltdata AUSTRIA

Martin Wieser

g.bronner@umweltdata.at
wieser_martin@gmx.at

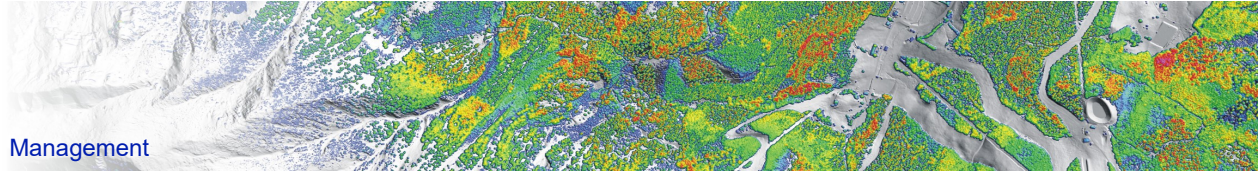


DBH=13cm, d= 27m



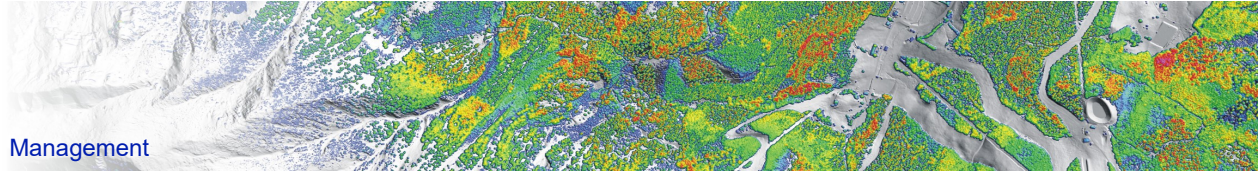
Jib-scan simulation
from 21 scan positions
on a circle with $r=1m$

Red trees are not
detected, green trees
are visible from all
positions.



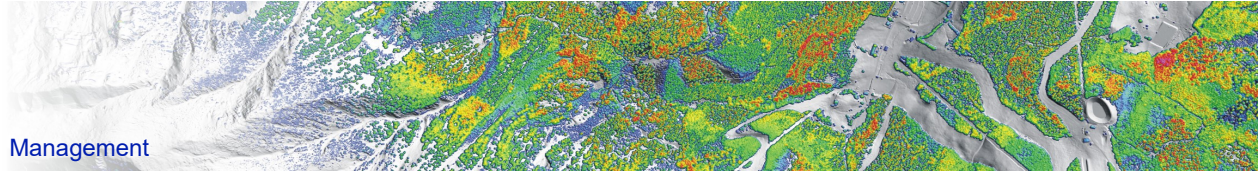
Wish-list to Research & Development I

- Lightweight scanning devices
- Real-time TLS / ALS co-registration
- Nr. of scan-position as attribute in the point-cloud
- Batch-enabled point cloud processing
- Robust feature extraction (hit-rate >98%)
- Robustness against wind (combine image + pointcloud?)



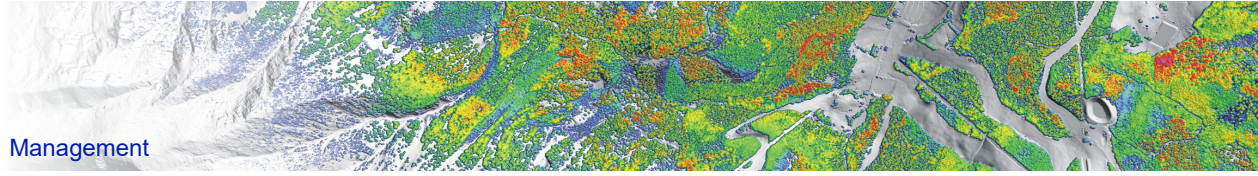
Wish-list to Research & Development II

- Robust (branch-avoiding) taper extraction
- Compact standard for tree representation beyond QMS including timber value relevant criteria and growth prognosis suitable for single tree based management applications
- Augmented Reality to support the inventory process
- Small image capturing drone passing autonomously through the canopy, collecting images (and GNSS position) from above and return thus combining bird-eyes and ants view ...



What we will investigate in DeepDigitalForest

- Workflows for TLS-based inventories
- Workflows for 3-phase-inventories including UHD-ALS-stripes
- Key figures from ALS and UHD-ALS for vertical structure and heterogeneity on stand level
- Feature extraction from UHS-ALS-data
- Enhancement of SmartForestTools functionality



What we can offer to the community

- Point clouds + features + ground truth from TLS
 - Point clouds from ALS + UHD-ALS
 - TLS services with Riegl VZ400i
 - Cooperation in research projects covering mainly the application side
- Any growth modelling projects are highly welcome!



g.bronner@umweltdata.at
Thank you for your attention!