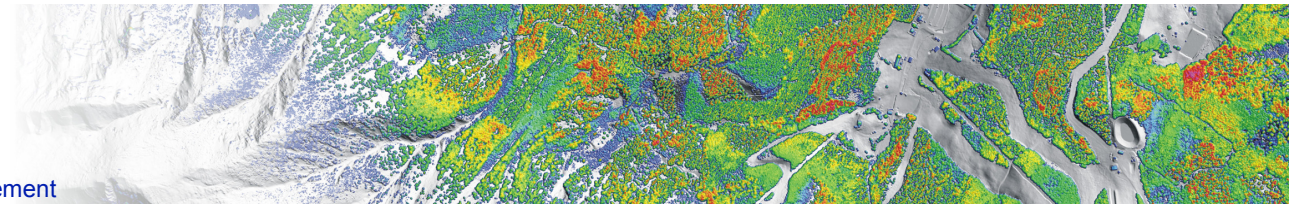


Noel Gorelick (Google) @ ForestSAT 2018:

„Hi everyone,

would you like Google to map and monitor

every tree of the world?"

answers:

…. not possible ….

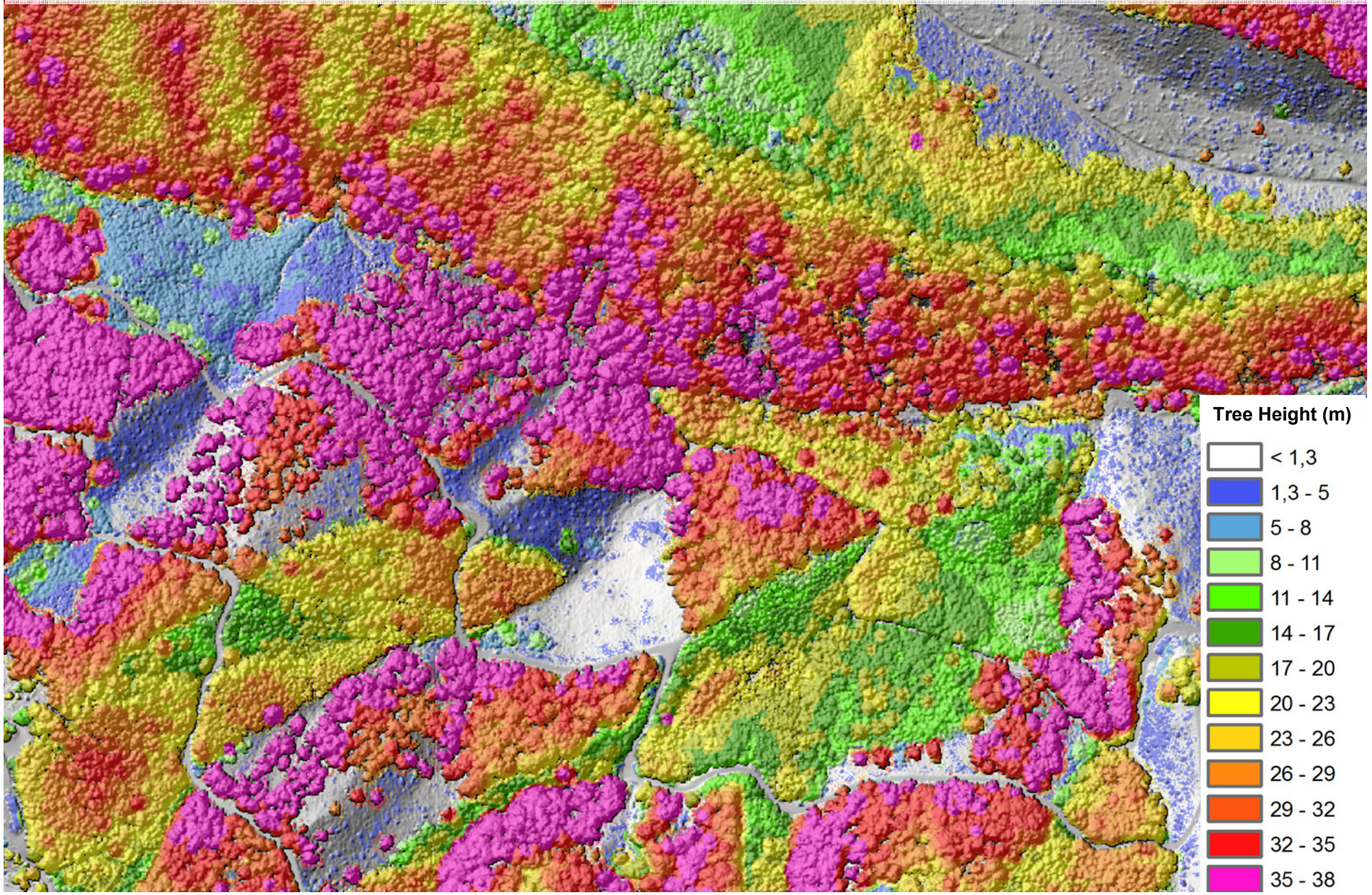
…. not necessary ….

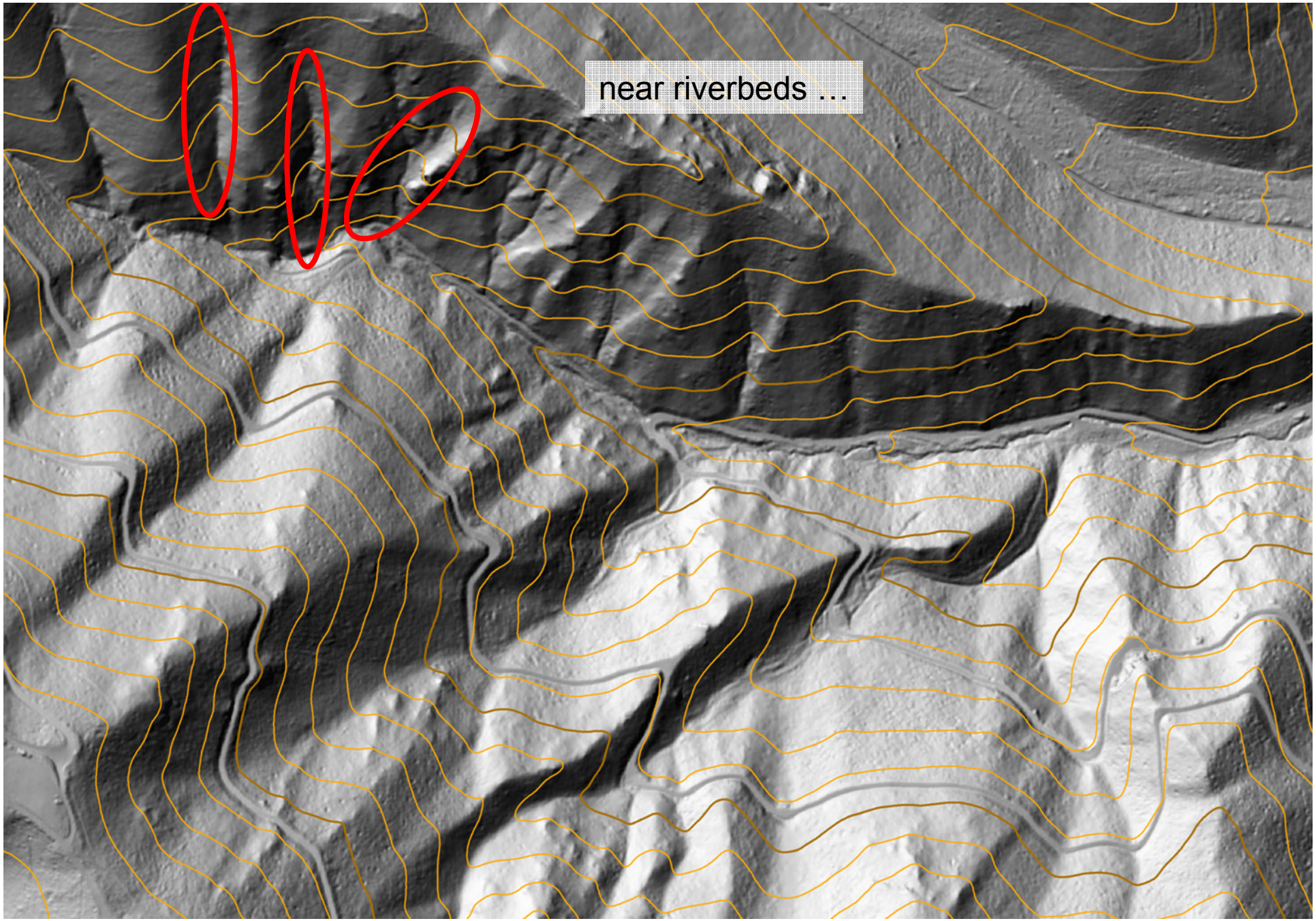
but why not let them try?

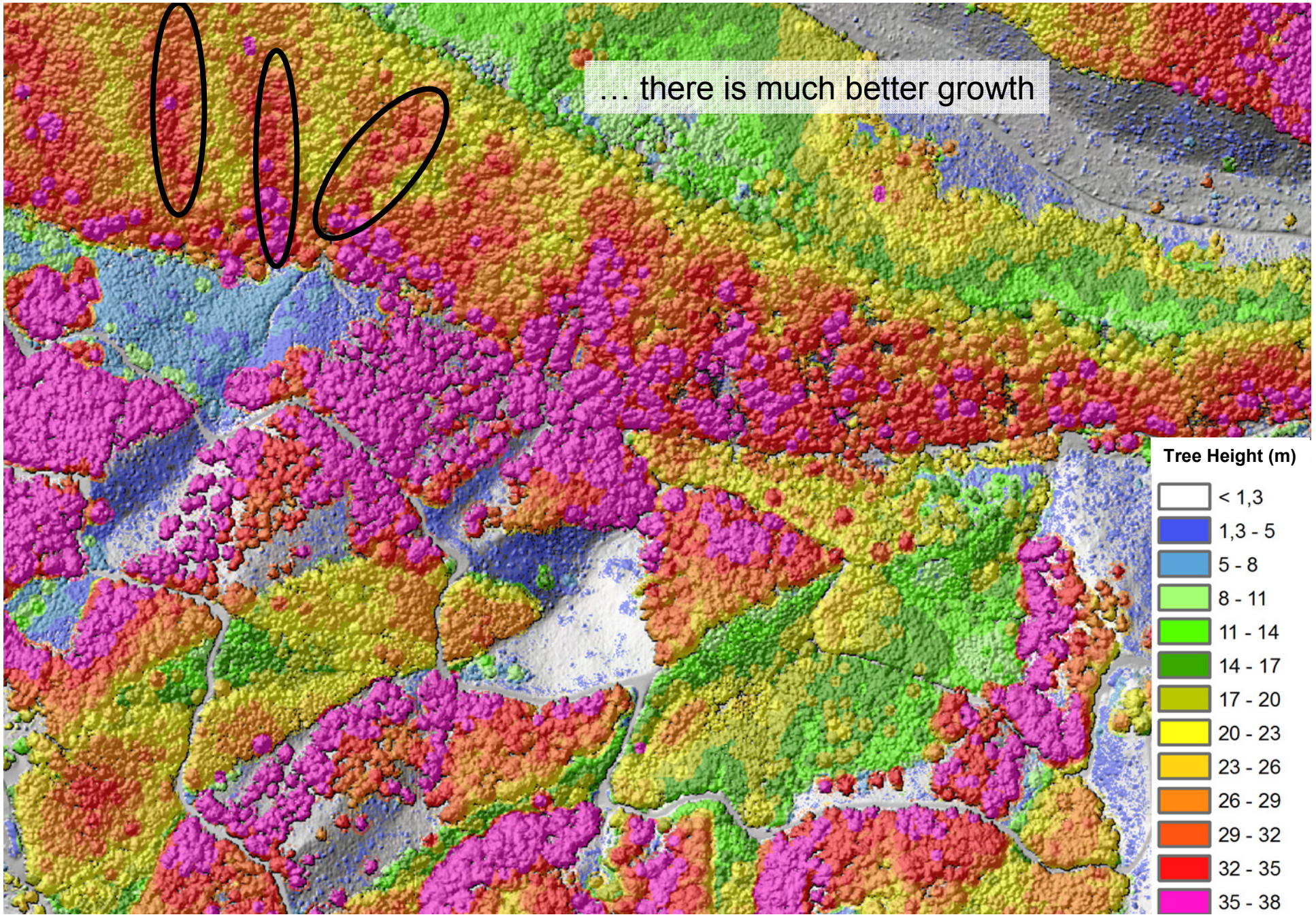
at least a **Canopy Height Model** of the planet?

… and we inventory people provide the ground truth!

Canopy Height Models from Aerial Laserscanning or Image Matching



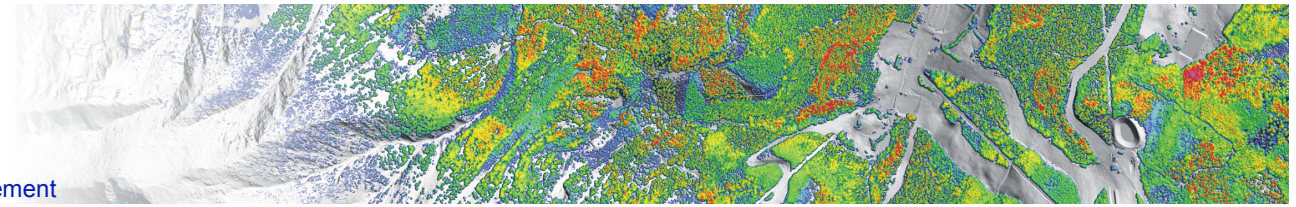

near riverbeds …


… there is much better growth
Tree Height (m)
< 1,3
1,3 - 5
5 - 8
8 - 11
11 - 14
14 - 17
17 - 20
20 - 23
23 - 26
26 - 29
29 - 32
32 - 35
35 - 38

Günther Bronner g.bronner@umweltdata.at

Professional background and experiences

- **Austrian State Forest Agency, 1983-2000**
  ForestManagementPlanning, Inventory, GIS and Remote Sensing
- **Head of Umweltdata ltd. Since 2001**
  Forest Sustainability :Monitoring :Mapping :Modeling :Management
- **>100 Forest Inventory projects, >70,000 sample plots**
- **>200 Forest Management Planning projects >1000ha**
- **Operational usage of LIDAR data since 2006**
- **Rapid forest inventories for land acquisition due diligence**
- **Monitoring of wildlife influences and damages**
- **Growth models and monitoring on plantations (Brazil)**
- **Permanent Optimization of FI and FMP based on RS**
- **Several R&D projects, Drones in Forest Inventory**
- **Silvilaser 2010, 2012, 2013, 2017; ForestSAT 2016, 2018**

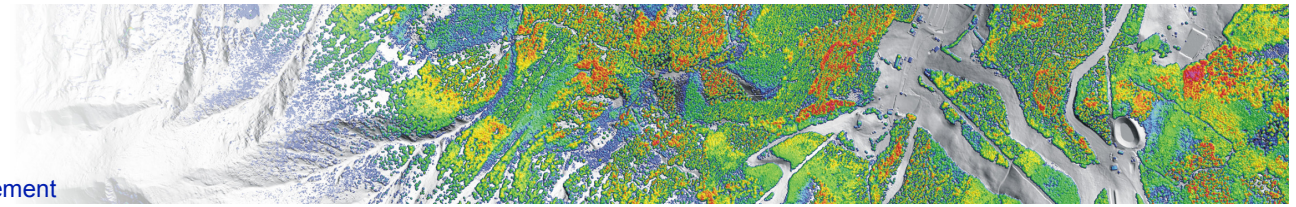


Cooperation Partners (Austria)

- Umweltdata Ltd. (FI, RS, mapping, FMP)
  Günther Bronner, Boris Jawecki, Martin Keuschnigg
- Joanneum Research (Remote Sensing)
  Mathias Schardt, Manuela Hirschmugl
- E.C.O. (Monitoring of Biodiversity, Management of Protection areas)
  Hanns Kirchmeir, Michael Jungmeier
- Aeromap (Aviation and Aerial Remote Sensing)
  Roland Wack, Thomas Meißl
- Technical University of Vienna (GEO)
  (Norbert Pfeifer, Markus Hollaus, Martin Wieser)
- Riegl Laser Measurement systems
  Aerial, Drone- and Terrestrial LIDAR
  Martin Pfennigbauer, Nikolaus Studnicka, Bernhard Groiss

umwelt data

Sustainability: Monitoring Mapping Modelling Management



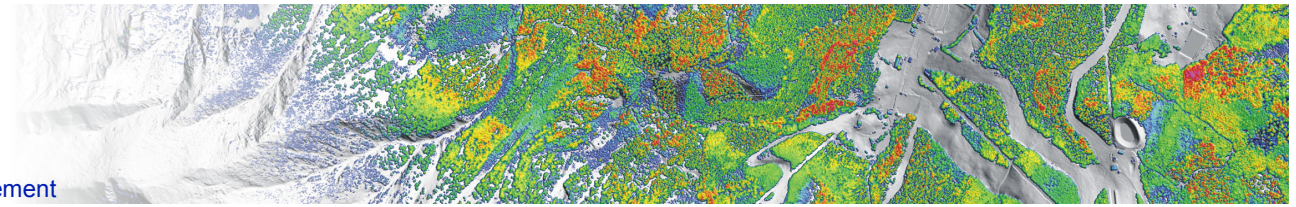
Canopy Height Models (CHM)

- Significant optimization of forest inventory cost / benefit ratio
- Streamline inventory, mapping and Forest Management Planning
- Allow quick and easy updates
- Integrate economical and ecological sustainability criteria
- Most accurate carbon mapping available

Good practise in Forest inventory can accurately describe the Problems.

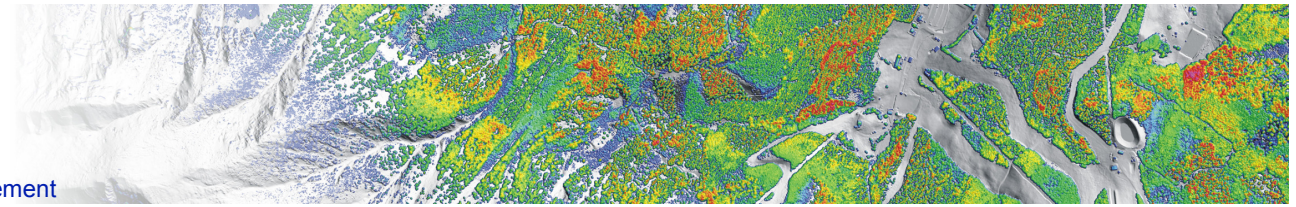
Only good practise in Forest Management can change things for the better !

Streamlining Remote Sensing, Forest Inventory, Mapping and Manangement Planning is a triple win-win-win situation.



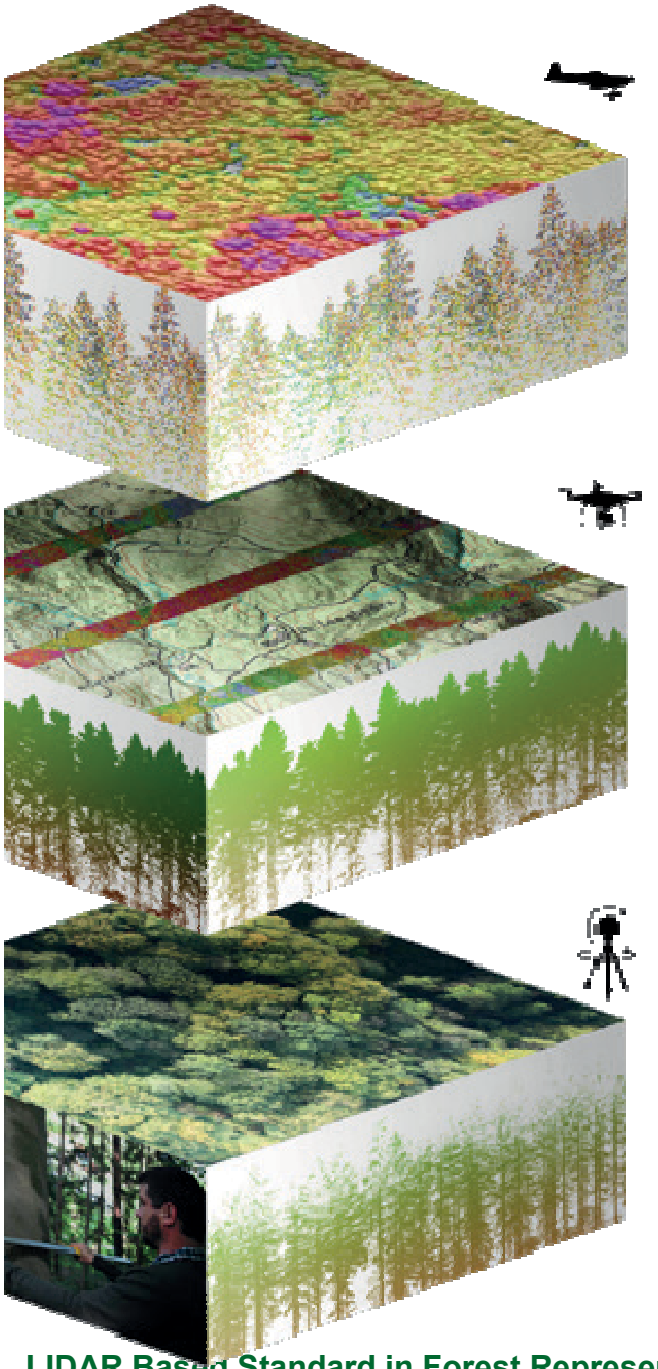
CHMs are too expensive?

- Airborne Laser Scanning (ALS) costs will further decrease (actual <50 USD / km²)
- Single Photon Scanning is emerging
- Low cost CHMs from Image Matching
- VHR space imaging capacity is increasing
  (e.g. triple stereo scenes from Planet, WV, Pleiades, …)
- Mapping by fieldwork is always ways more expensive and less accurate!

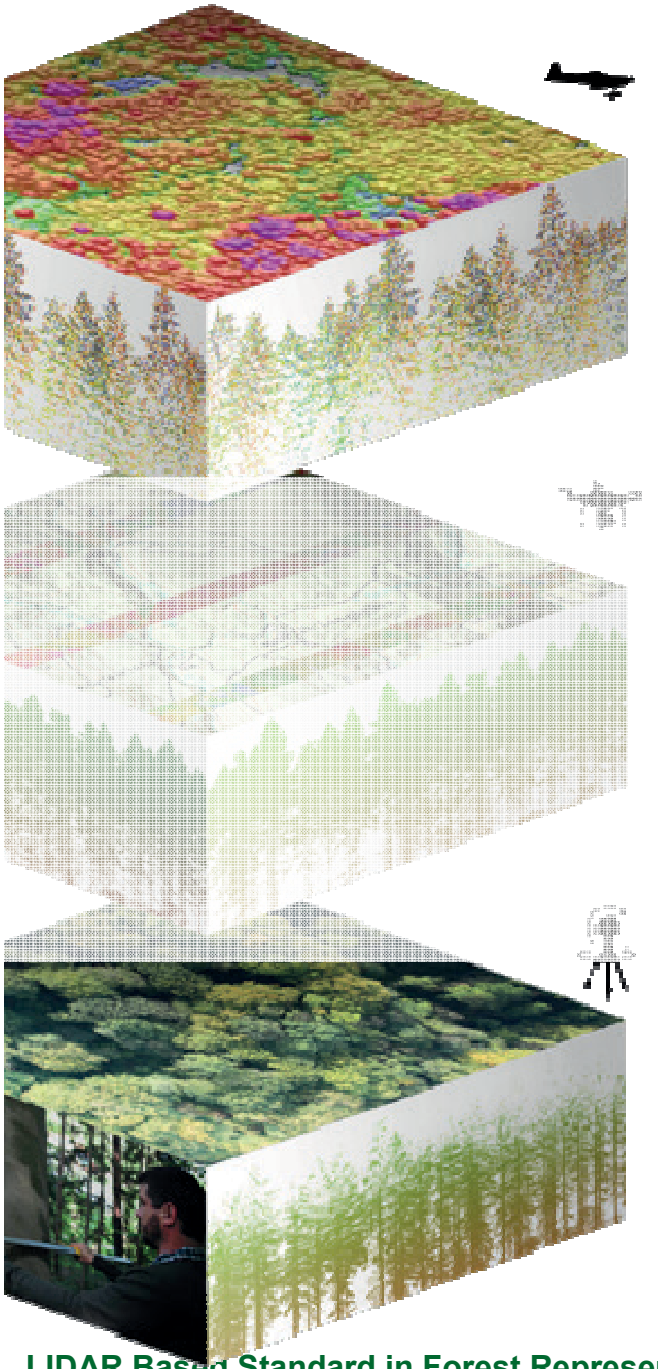


Excuses:

- … we do not dare to use new technology
  => it is state of the art, operationally tested
- … we rather want to employ local people for fieldwork => use them for management!
- … military people would not allow us to fly
  => all defence-relevant geo-data can be captured by satellite
- … we do not want to be as transparent
  => funding will make CHMs a standard



- **Phase I**
  ALS wall-to-wall coverage
- **Phase II**
  VHR ALS stripes in low altitude with ultra-light plane
- **Phase III**
  TLS and / or Fieldwork



- **Phase I**
  ALS wall-to-wall coverage
  4 – 16 Pulses / m²

- **Phase II**
  VHR ALS stripes in low altitude with ultra-light plane
  100 – 500 Pulses / m²

in preparation

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

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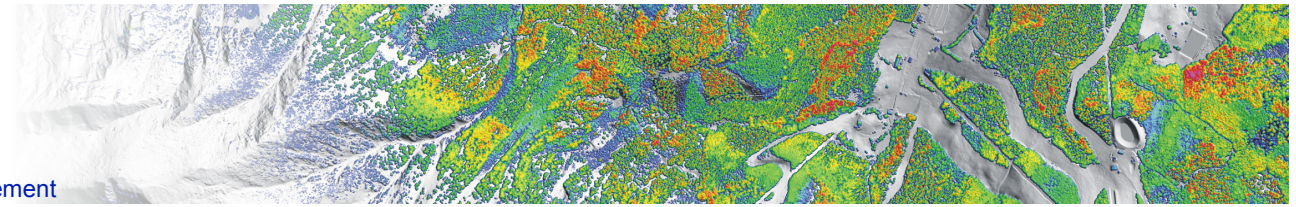
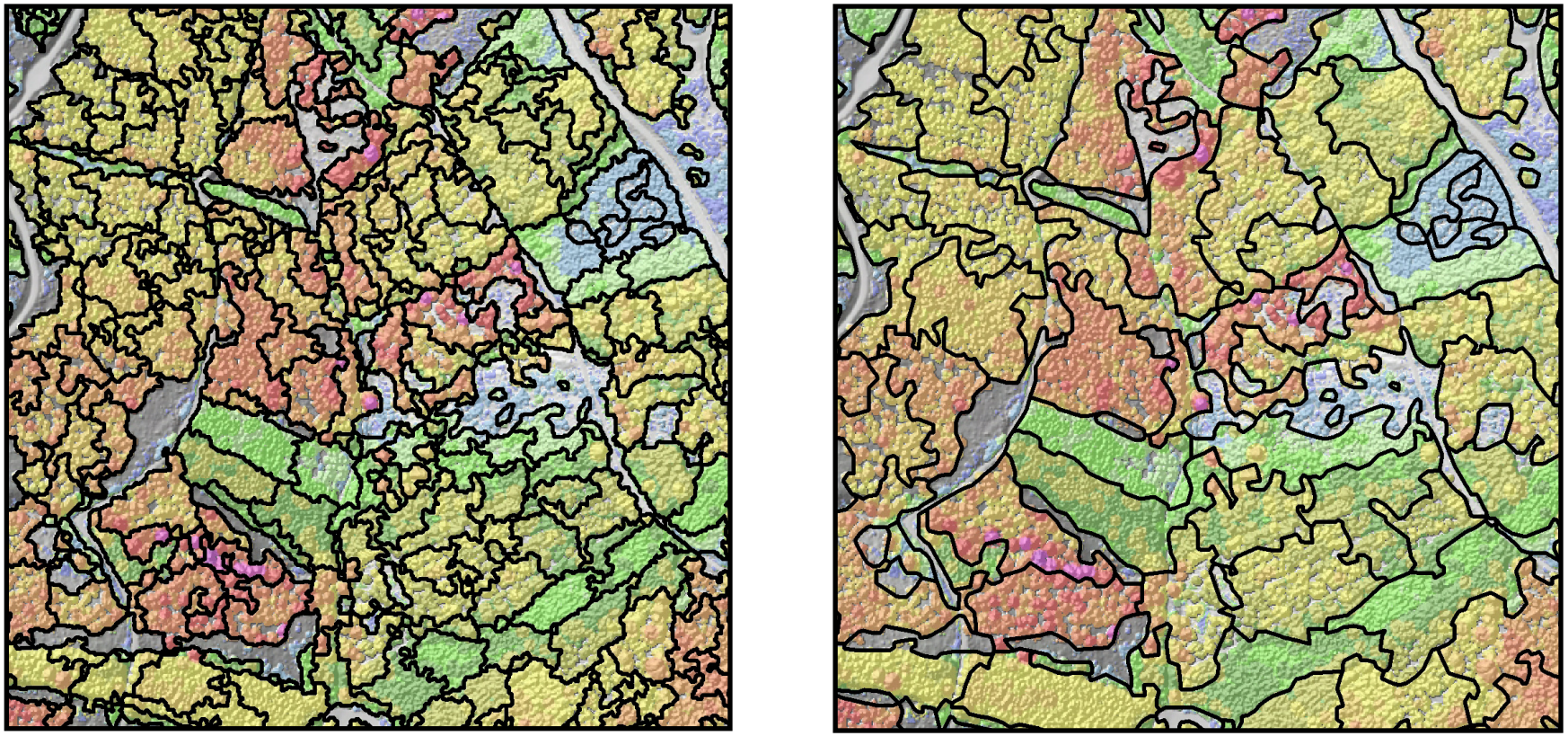
Sustainability: Monitoring Mapping Modelling Management



Automatic Segmentation of Canopy Height Models (i)



Tree Heights: 0 | 3m | 6 | 9 | 12 | 15 | 18 | 21m | 24 | 27 | 30 | 33 | 36m

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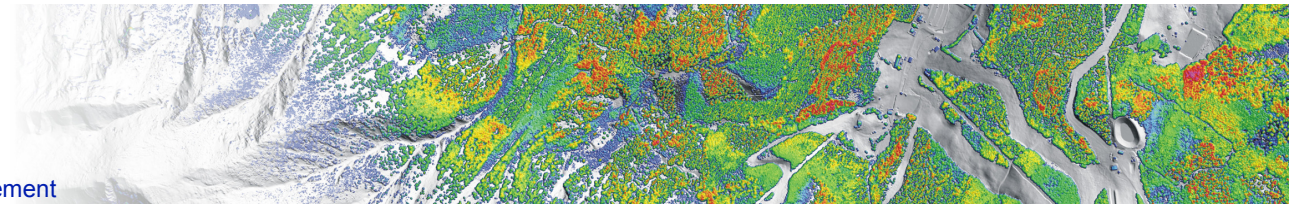
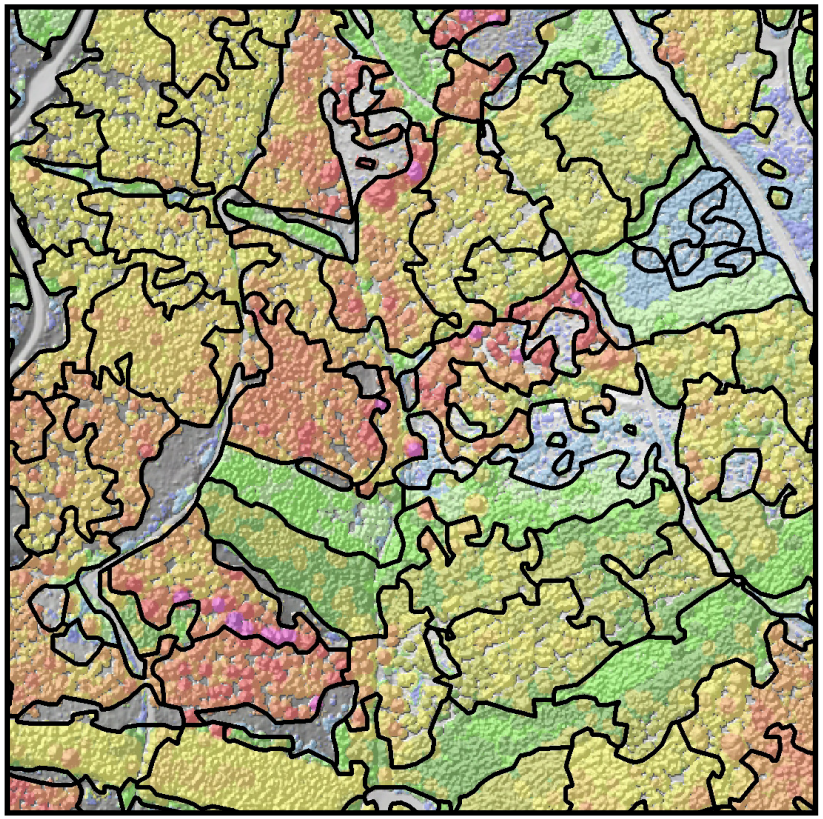
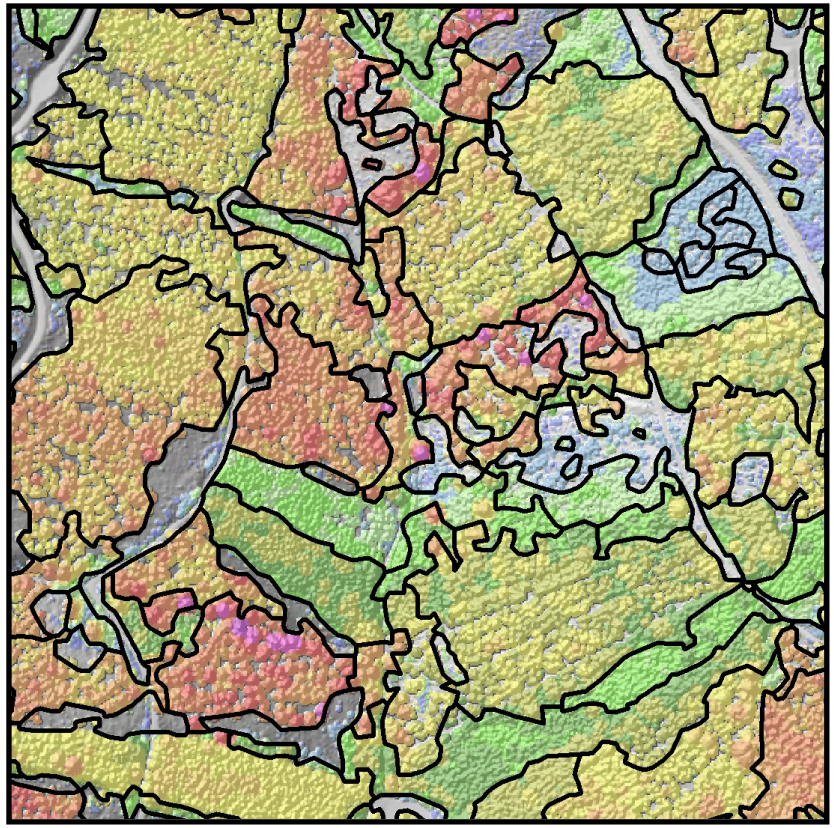
Sustainability: Monitoring Mapping Modelling Management

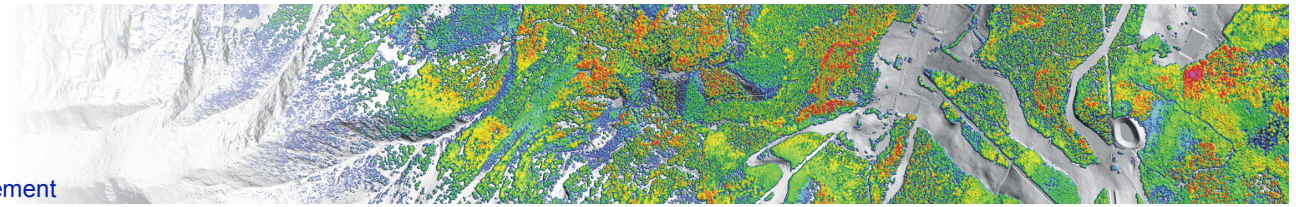


Automatic Segmentation of Canopy Height Models (ii)



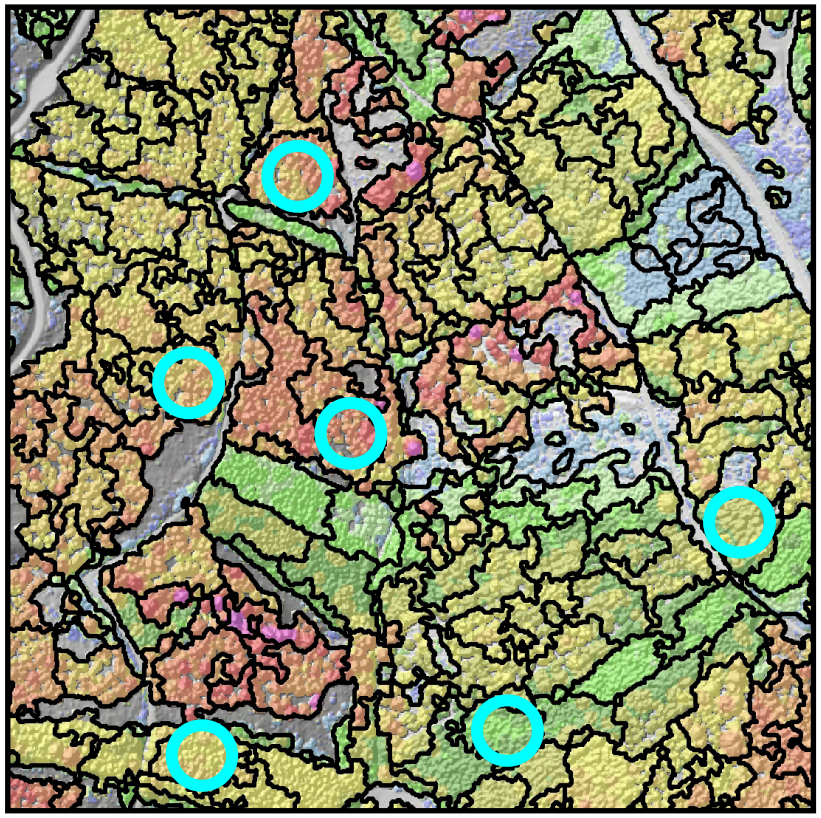


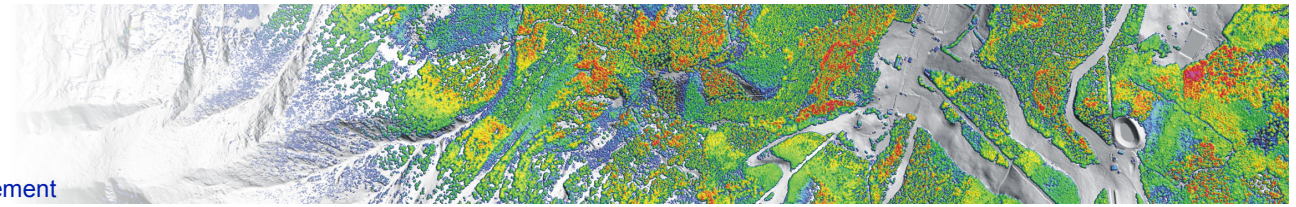
step by step augmentation of forest stand polygons



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.





CHM-based Forest Resources Mapping

- Sock volume (calibrated by sample plots)
- Tree height
- Stand density
- Trees per hectare
- Vertical structure
- Tree species from aerial or satellite images (coniferous percentage)
- Altitude, exposition, slope, topography

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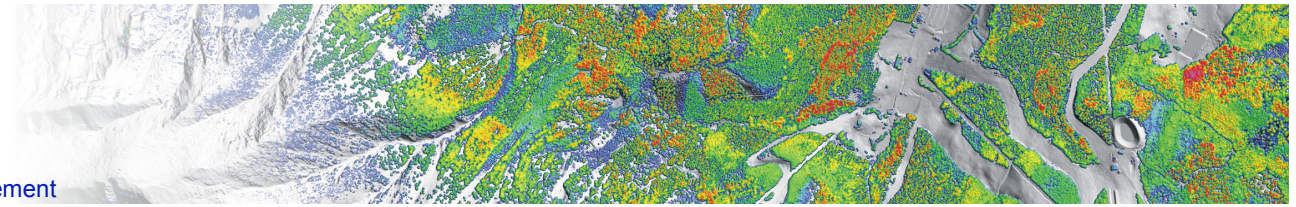
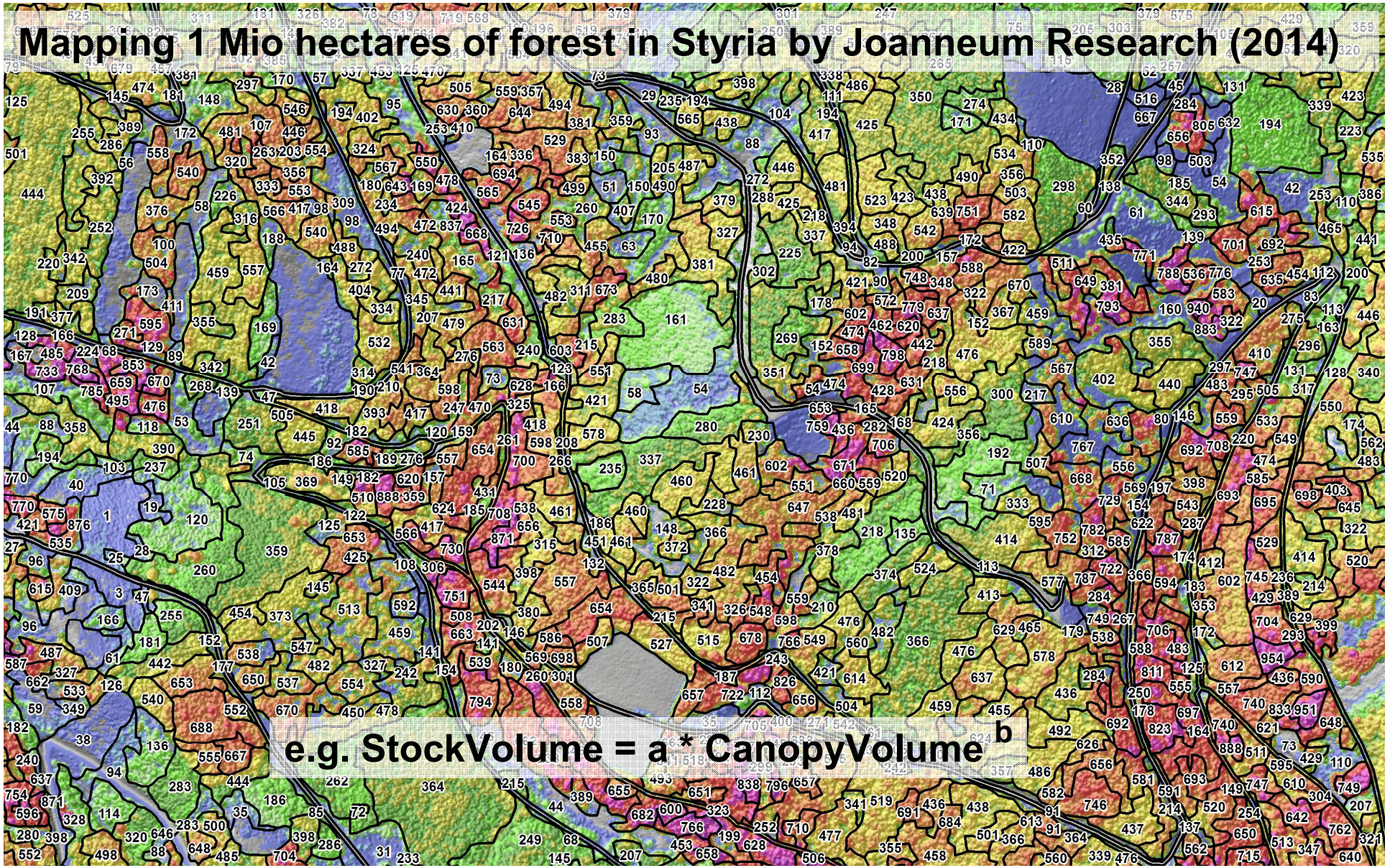
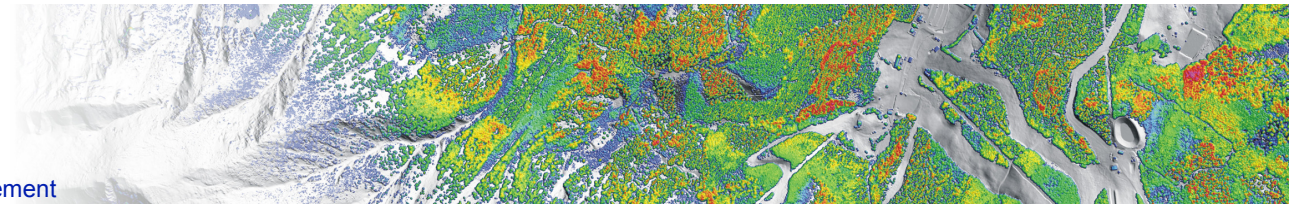
Sustainability: Monitoring Mapping Modelling Management





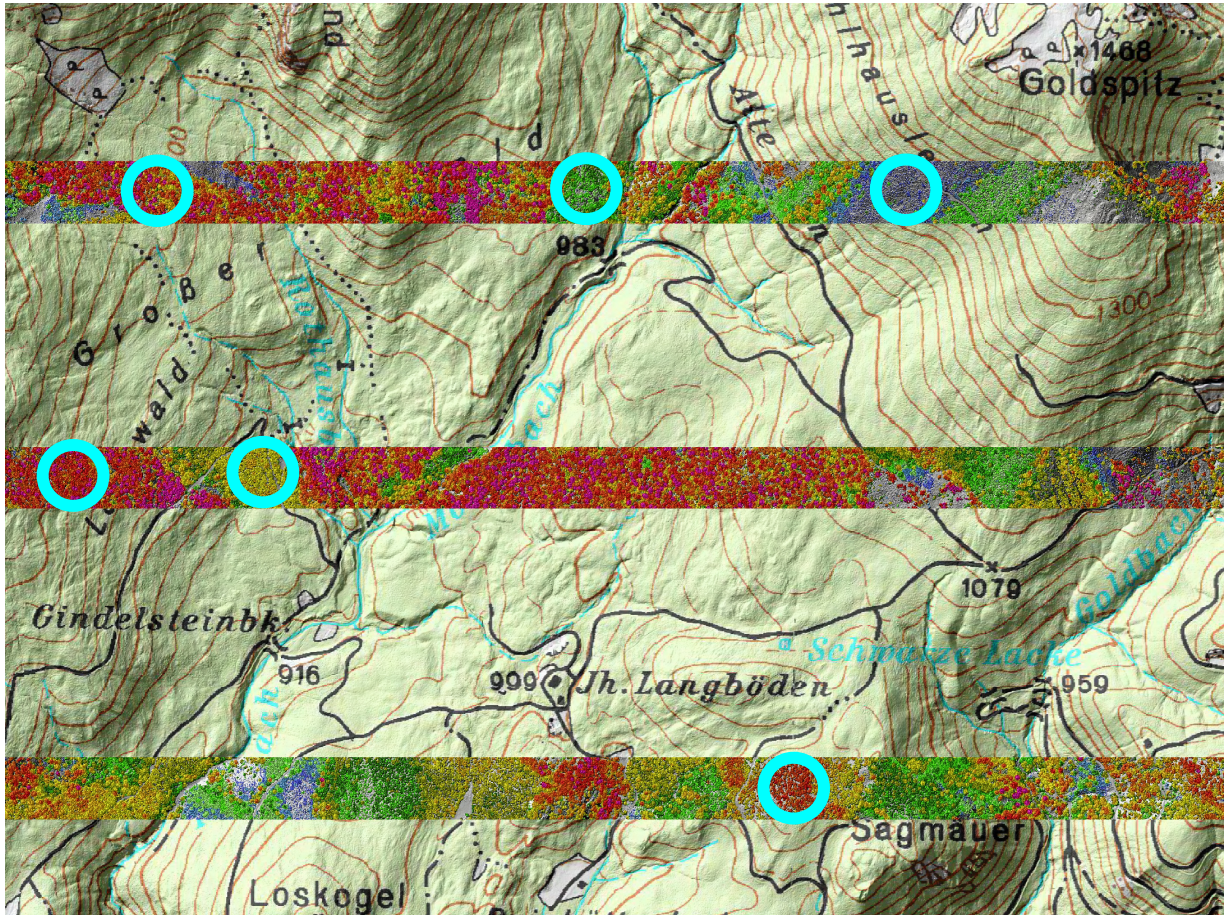
umwelt data

Sustainability: Monitoring Mapping Modelling Management



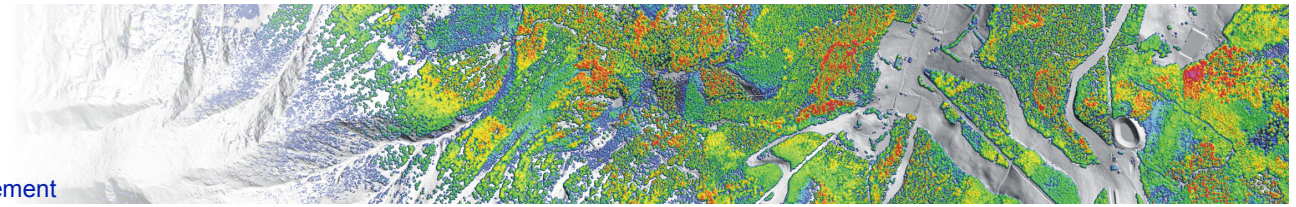
(NFI-based) 3-Phase Inventory

Stripes with very high resolution ALS data (100-500 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.

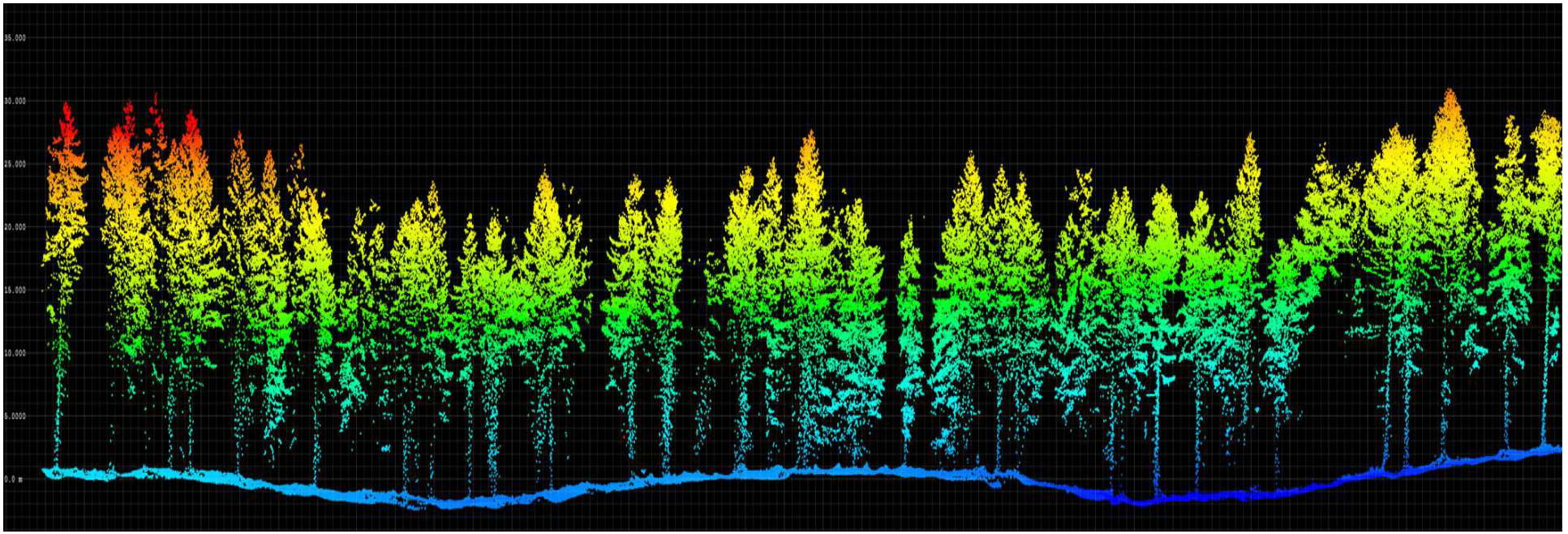


umwelt data

Sustainability: Monitoring Mapping Modelling Management



Comparison of Laserscanning Profiles



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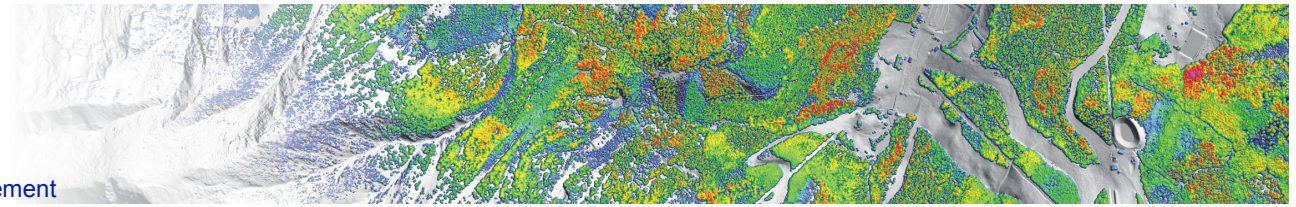
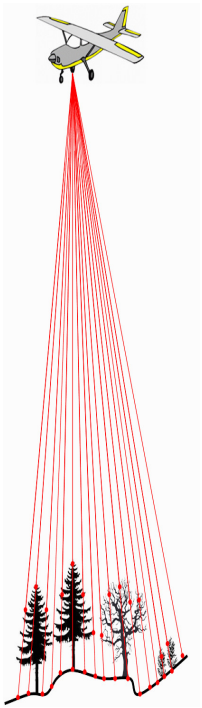
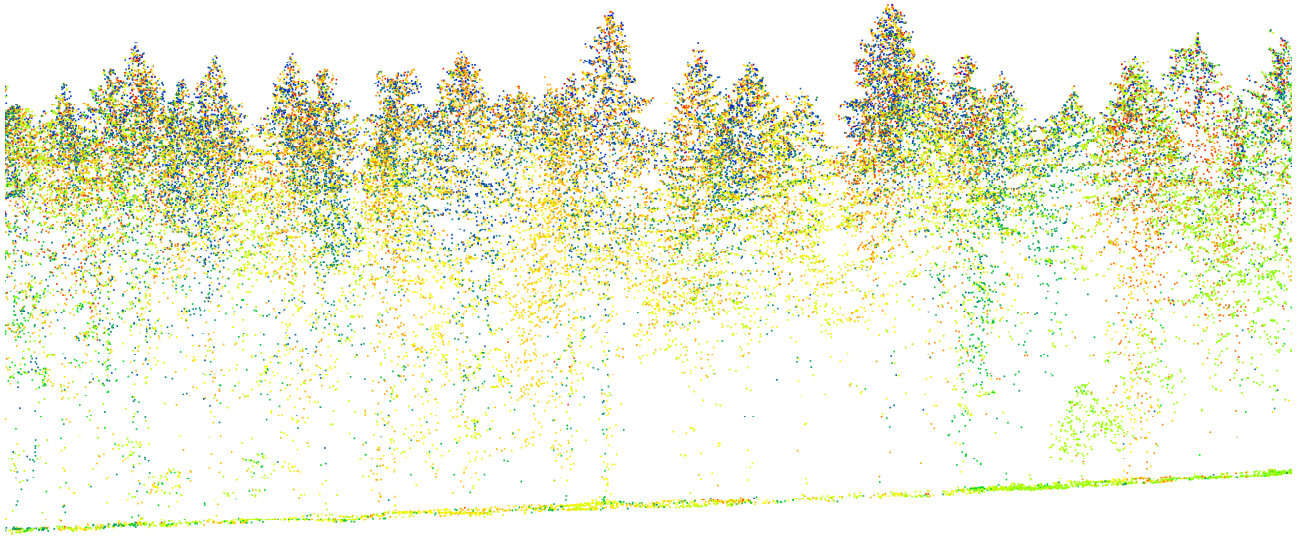
Sustainability: Monitoring Mapping Modelling Management



Point Cloud from Aerial Laserscanning



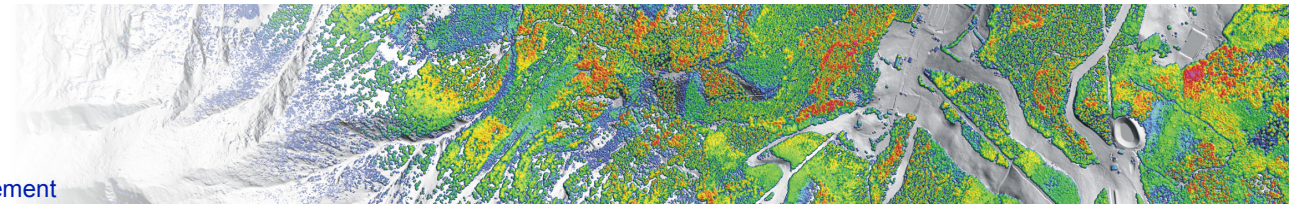


- wall-to-wall coverage
- 2 – 16 pulses per m²

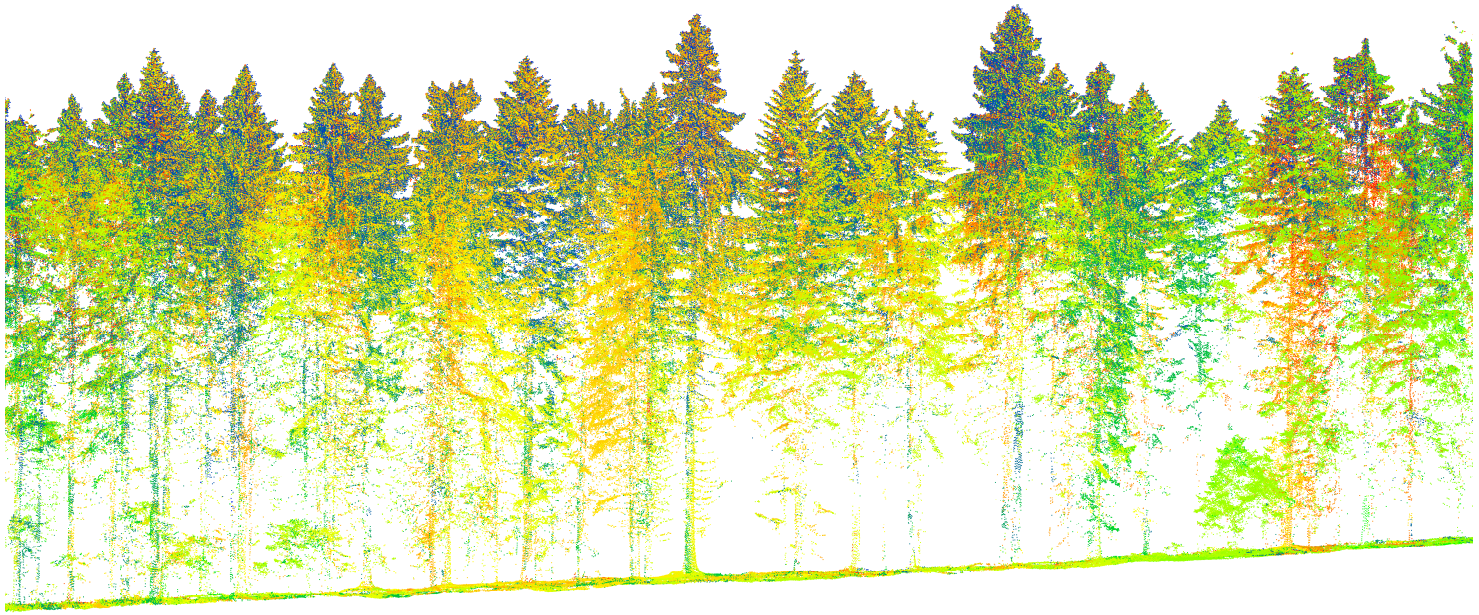
→ **Tree Top Recognition**

umwelt data

Sustainability: Monitoring Mapping Modelling Management



Point Cloud from Very High Resolution Aerial Laserscanning



- Stripes with airplane or drones ~150m above ground
- Point Clouds with 100 – 500 points per m²

→ **Single Tree Segmentation**

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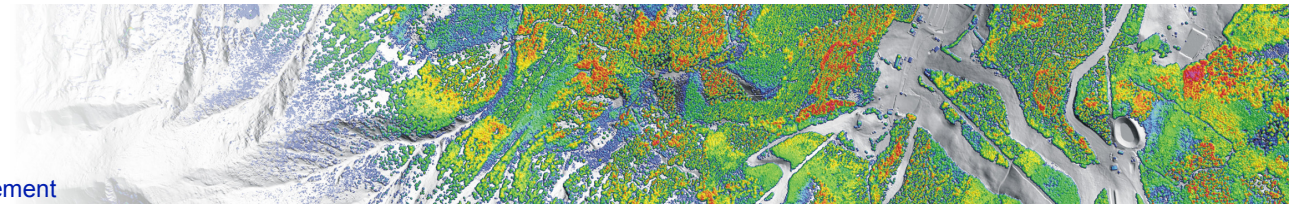
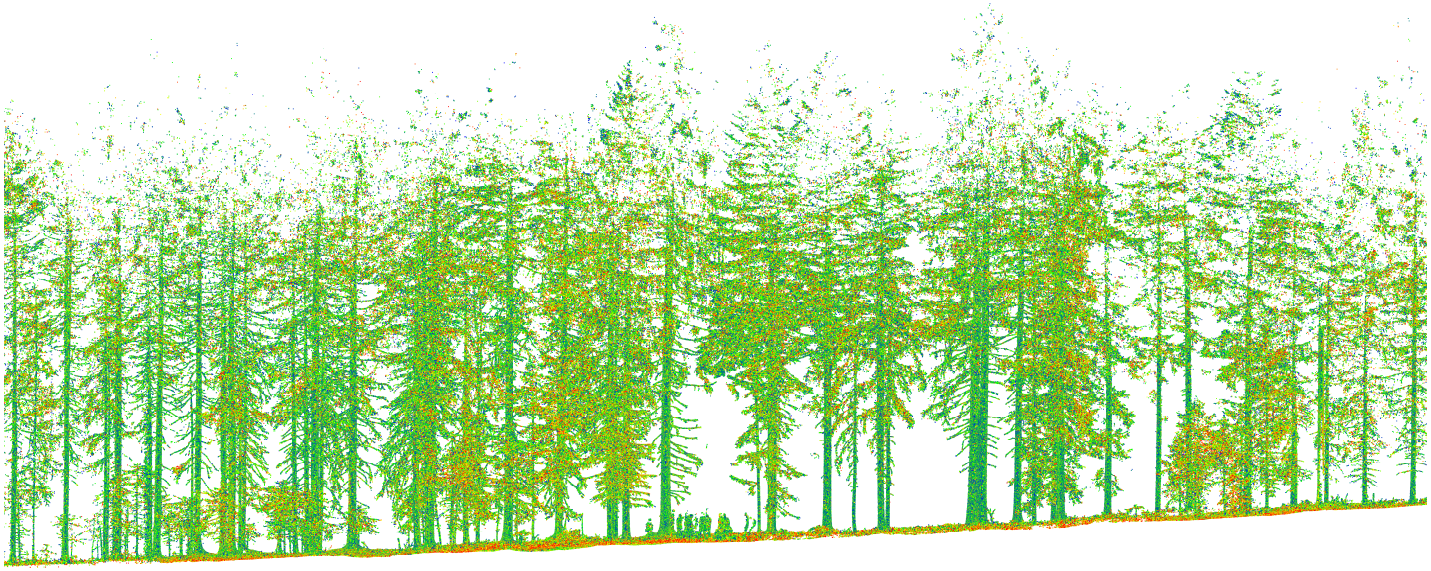
Sustainability: Monitoring Mapping Modelling Management

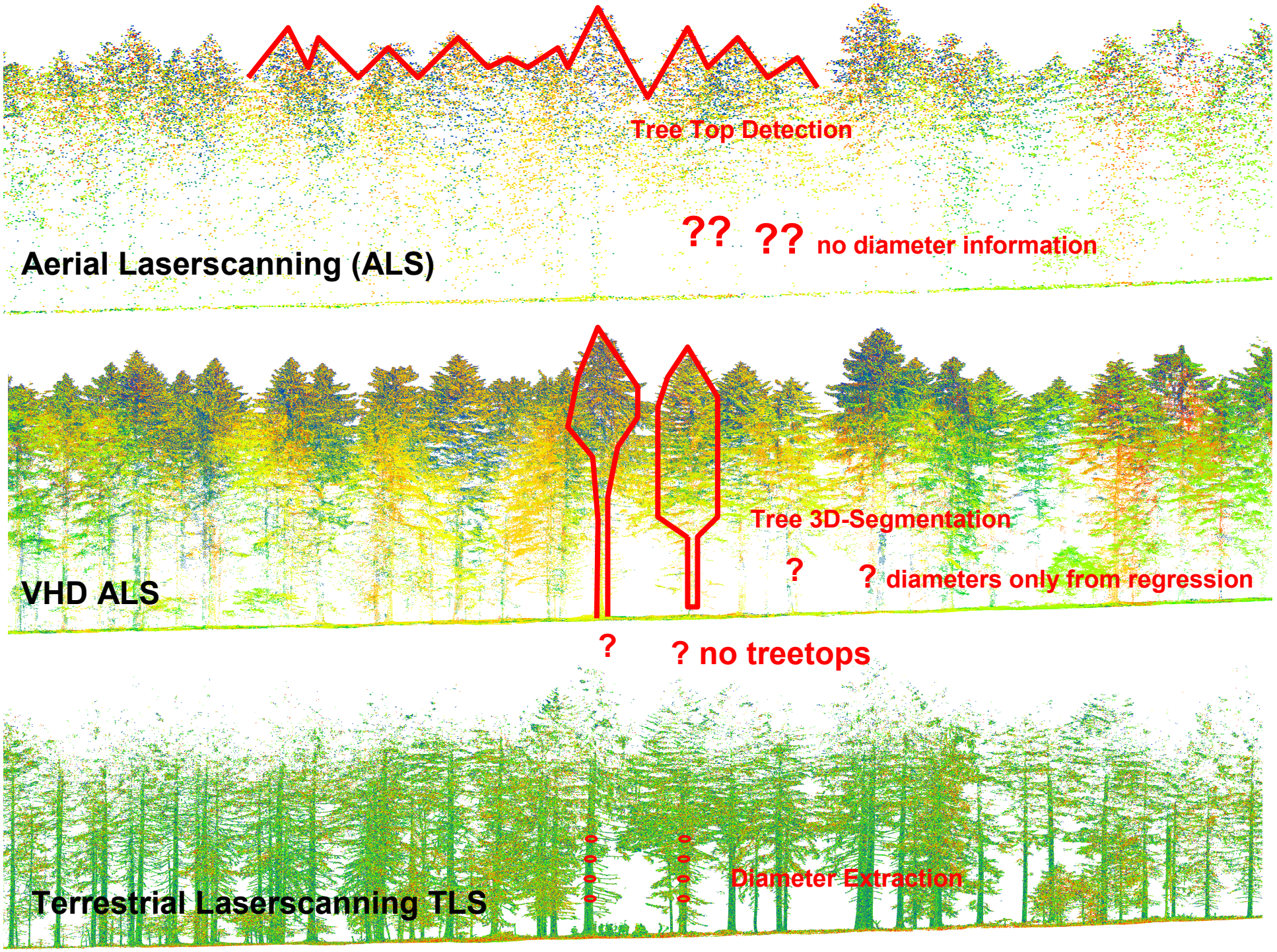


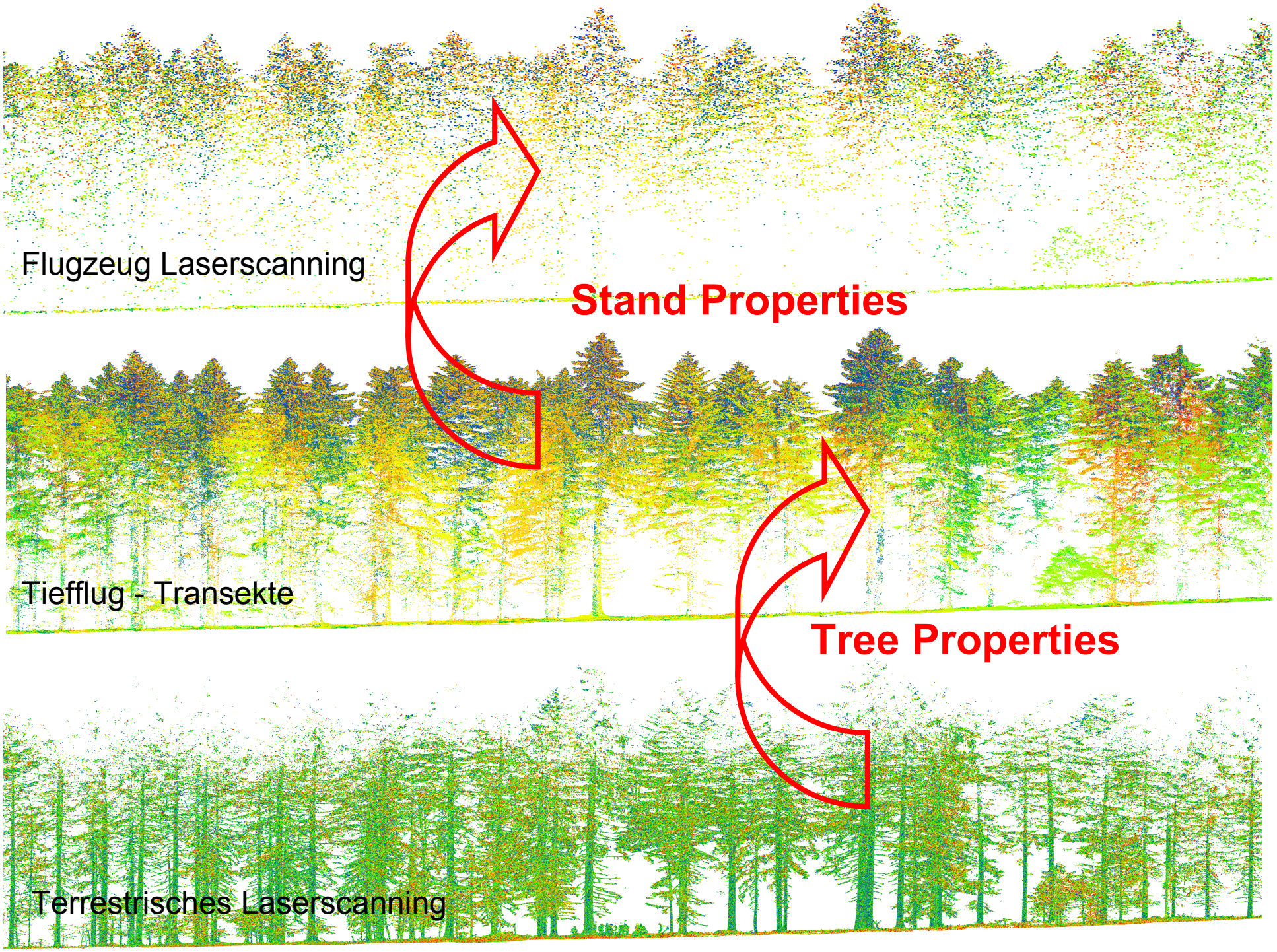
Point Clouds from Terrestrial Laserscanning (TLS)



- Only few points in tree tops, (enough to get tree tops)
- Point clouds with 10 Mio to 500 Mio echos per sample plot

→ **DBH and stem curve extraction**


Tree Top Detection
?? ?? no diameter information
Aerial Laserscanning (ALS)
Tree 3D-Segmentation
? ? diameters only from regression
VHD ALS
? ? no treetops
Diameter Extraction
Terrestrial Laserscanning TLS


Flugzeug Laserscanning
Stand Properties
Tiefflug - Transekte
Tree Properties
Terrestrisches Laserscanning

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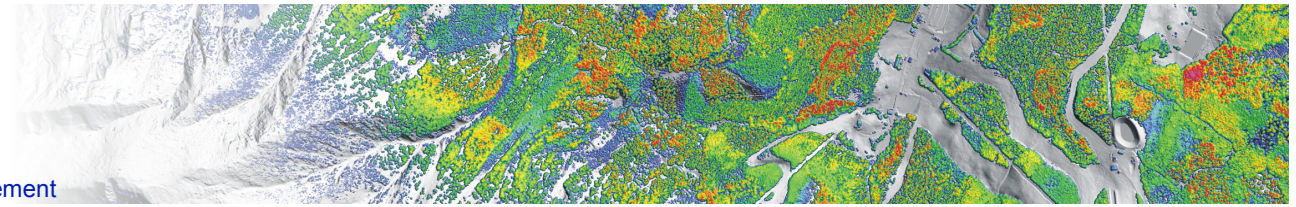
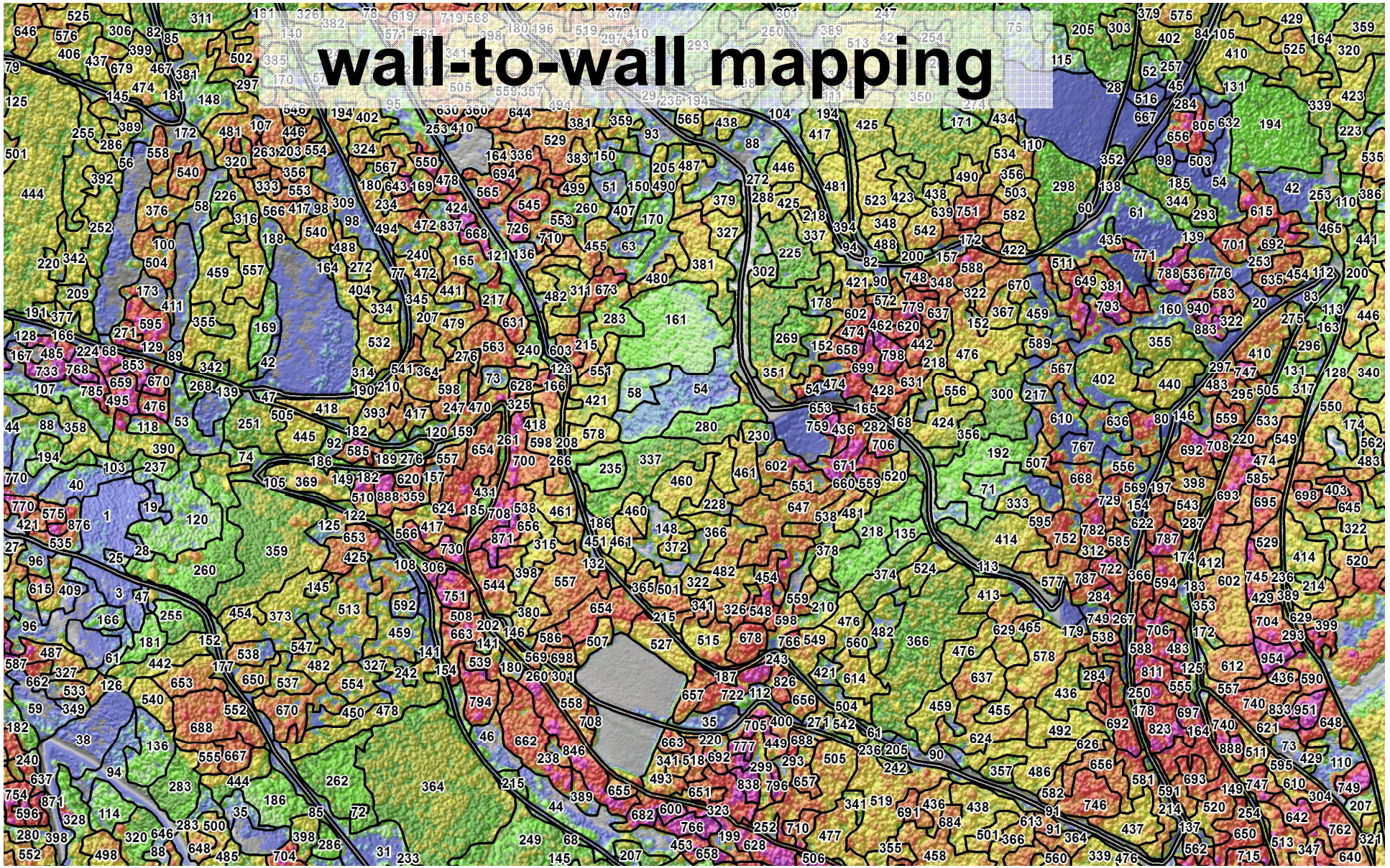
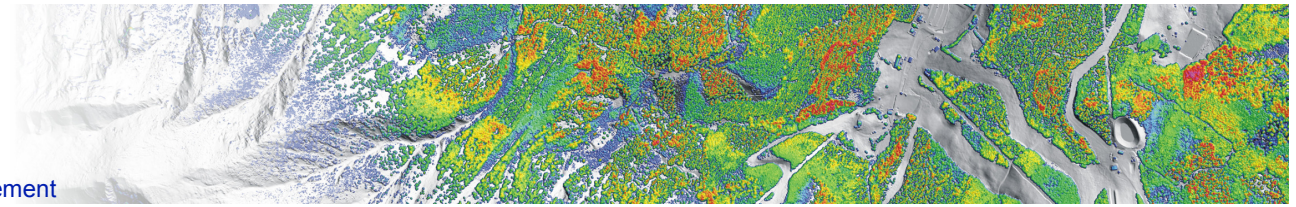
Sustainability: Monitoring Mapping Modelling Management





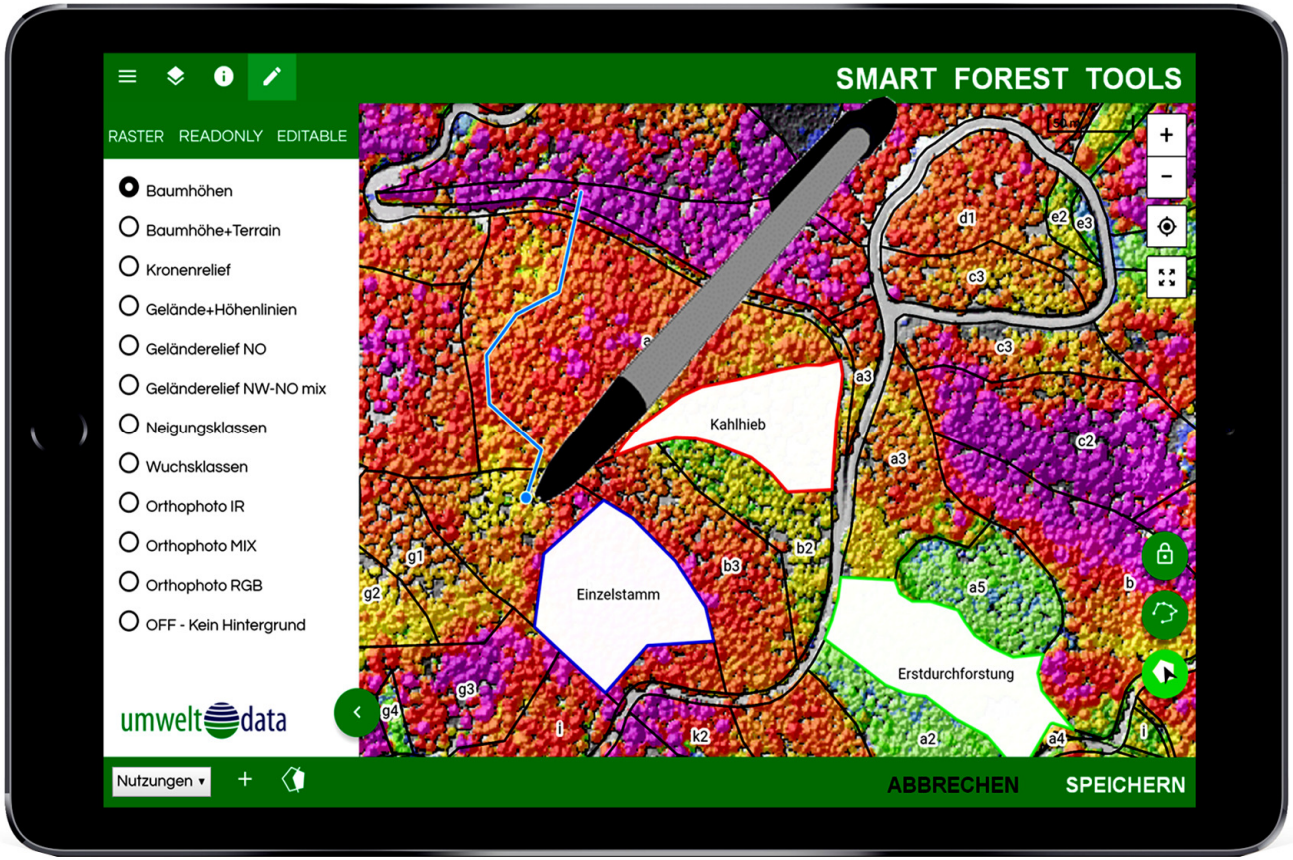
umwelt data

Sustainability: Monitoring Mapping Modelling Management



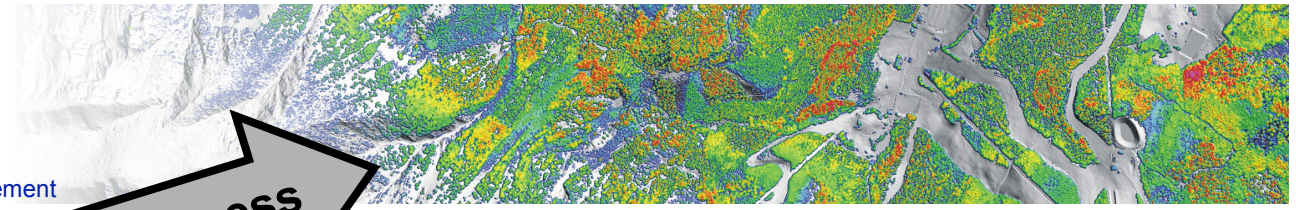
Smart Forest Tools, our shortcut to Forest Management Planning

- user-friendly
- flexible
- responsive
- off-line enabled
- single trees enabled
- multi-user



umwelt data

Sustainability: Monitoring Mapping Modelling Management



Browser-access

Postgres Database

Synchronization

Web Feature Service T

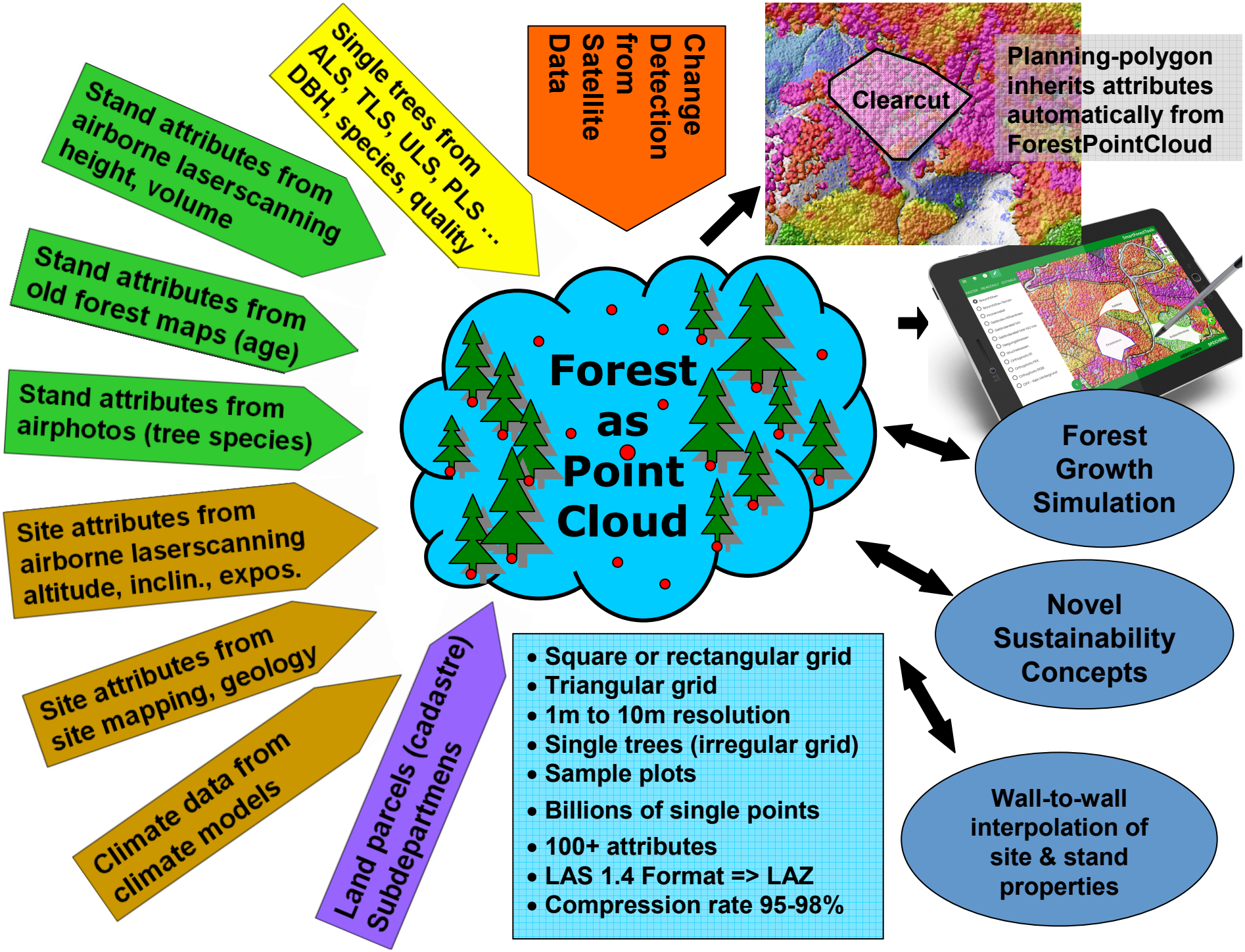
Import Export

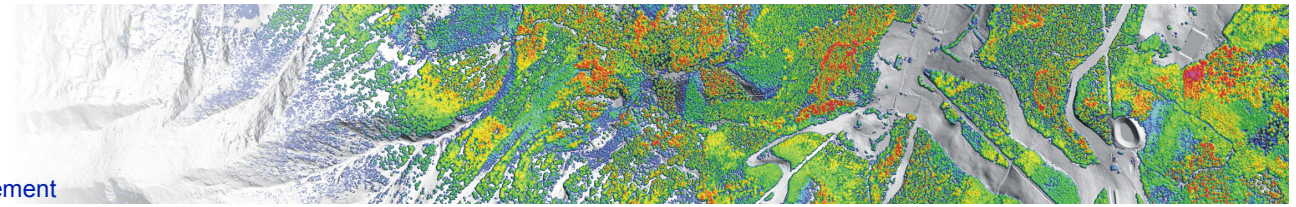
ODBC access

Quantum GIS
Arc GIS
Dektop GIS

Shape-files
GPX-files
Tables

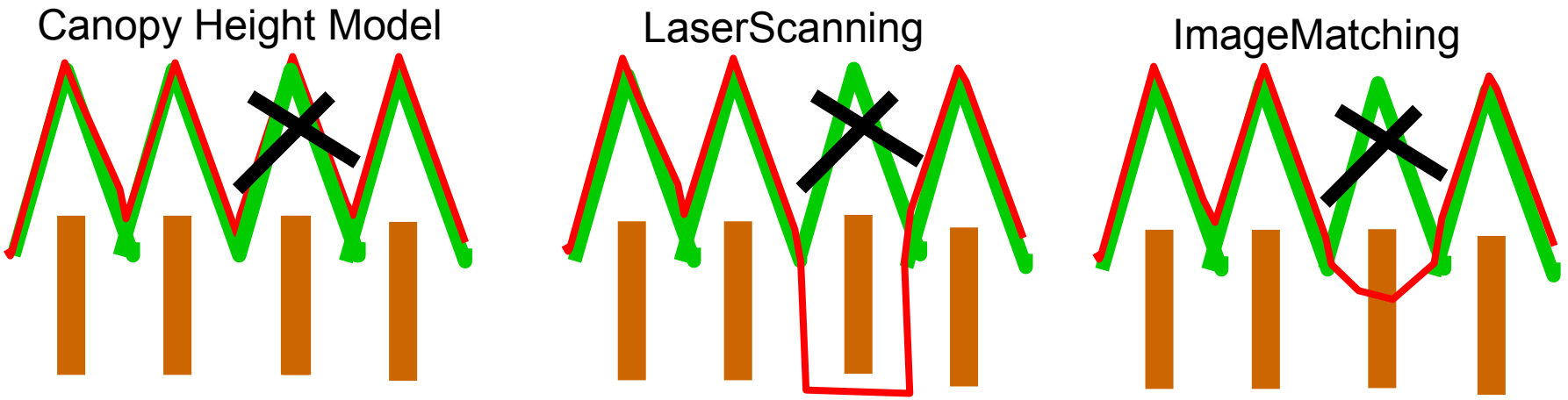
Reports
Excel-Tables

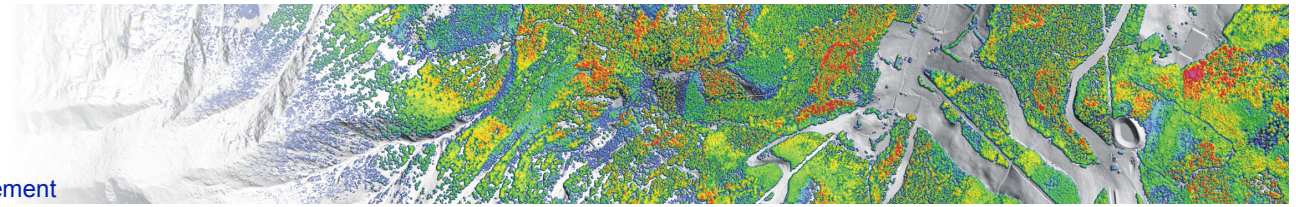

Single trees from ALS, TLS, ULS, PLS ... DBH, species, quality
Change Detection from Satellite Data
Clearcut
Planning-polygon inherits attributes automatically from ForestPointCloud
Stand attributes from airborne laserscanning height, volume
Stand attributes from old forest maps (age)
Stand attributes from airphotos (tree species)
Forest as Point Cloud
Forest Growth Simulation
Site attributes from airborne laserscanning altitude, inclin., expos.
Site attributes from site mapping, geology
Climate data from climate models
Land parcels (cadastre) Subdepartmens
Novel Sustainability Concepts
• Square or rectangular grid
• Triangular grid
• 1m to 10m resolution
• Single trees (irregular grid)
• Sample plots
• Billions of single points
• 100+ attributes
• LAS 1.4 Format => LAZ
• Compression rate 95-98%
Wall-to-wall interpolation of site & stand properties



Update Strategies and Monitoring

- Clear cut detection by Sentinel 2 scenes
- CHMs from Image Matching (aerial)
  single tree harvest detection
- CHMs from Image Matching (satellite)
  tree group and big tree harvest detection

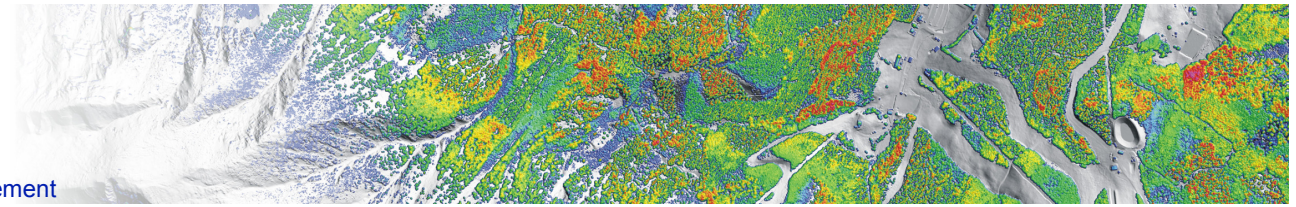




Smart Forest Inventory Costs

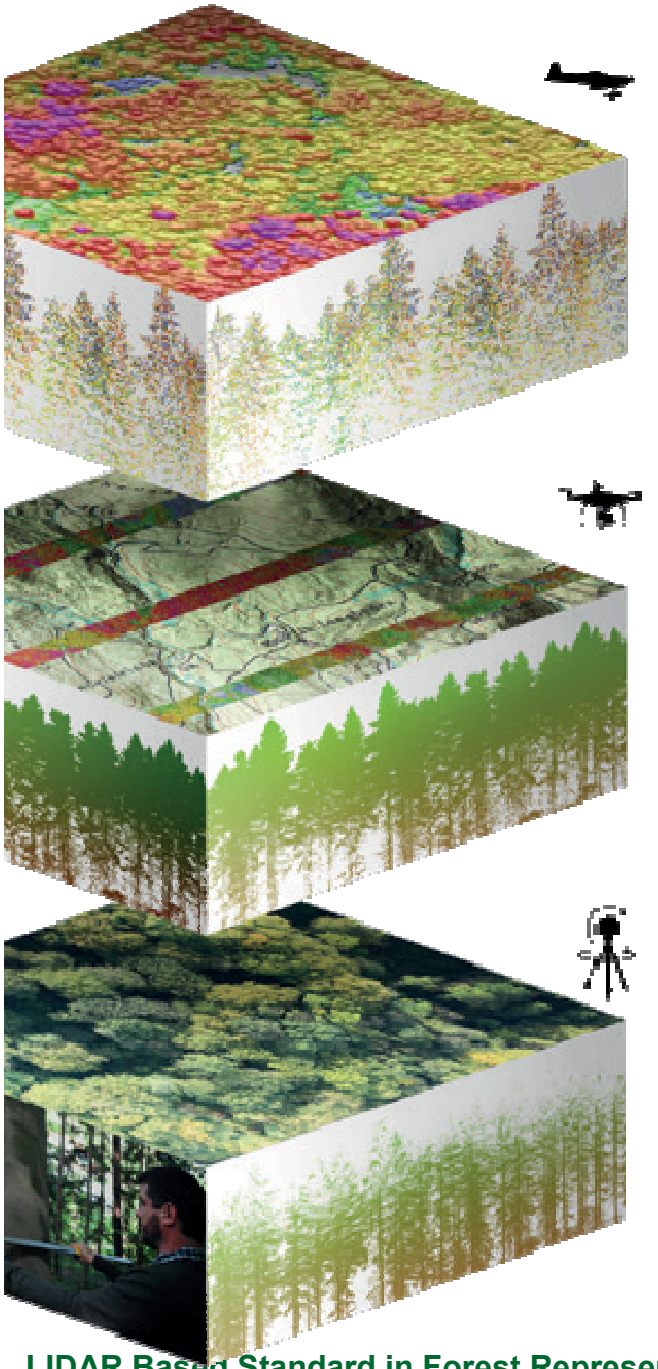
Areas > 100,000 hectares, operational, non-NFI

- Aerial Campaign (ALS, ortho-images): ~ 2 $/ha
- Data Processing, segmentation etc.: ~ 1 $/ha
- Inventory Fieldwork: 1 - 2 $/ha
- FMP Fieldwork: 1 – 2 $/ha
- Final Mapping, GIS and Reporting: ~ 1 $/ha
- Total Costs: 6 – 8 $/ha



Added Value

- Maximum Transparency in Forest Resources
- Accurate carbon mapping
- Shortcut to Forest Management Planning
- Integration of Nature Protection, Carbon and Biodiversity Issues (ready for FSC-Certification)
- Forest Sustainability Assessment and Monitoring by Evaluation of Spatial Harvesting Patterns
- Interfaces to Forest Growth Simulation
- Cost-efficient Data Update Strategies

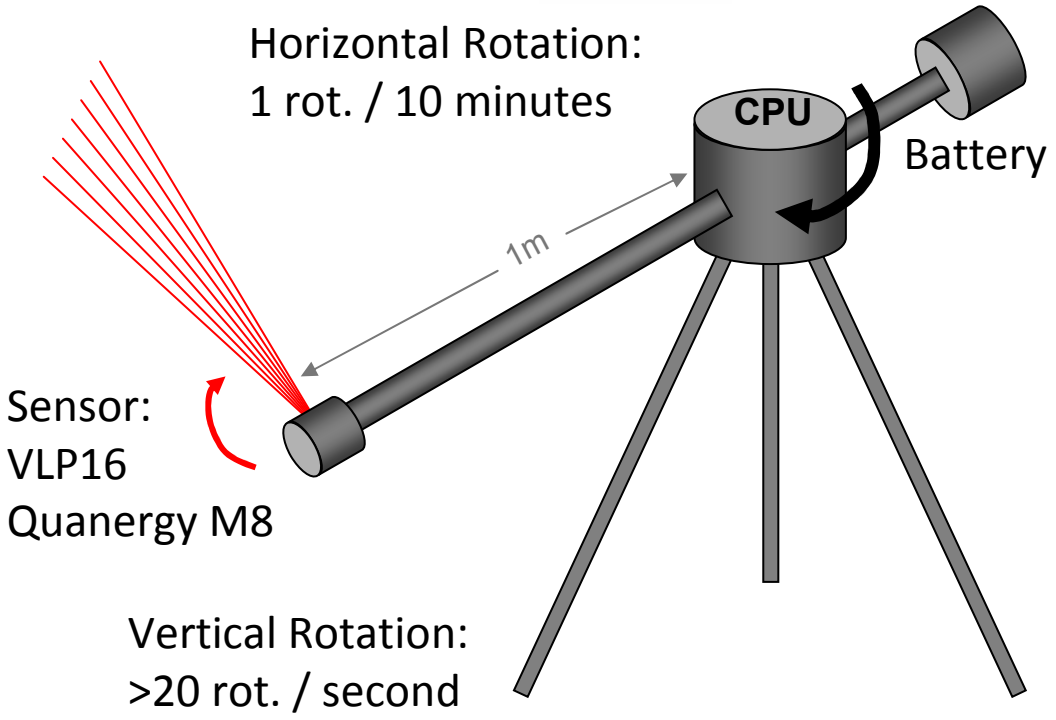


- **Phase I**
  ALS wall-to-wall coverage
- **Phase II**
  VHR ALS stripes in low altitude with ultra-light plane
- **Phase III**
  TLS and / or Fieldwork

Phase III the future of fieldwork:

jib scan

- from **single position**
- within **30m radius**
- **90% reduction of occlusion**
  from 20% to <2% in stands
  with basal area 50m²/ha
- with **Bitterlich angle count**
  basal area factor 1
  <1% trees are not detected
  (basal area 45m²/ha)
- from central perspective, **diameter extraction** will change from cylinder fitting to edge detection, which is more robust with low-cost scanners



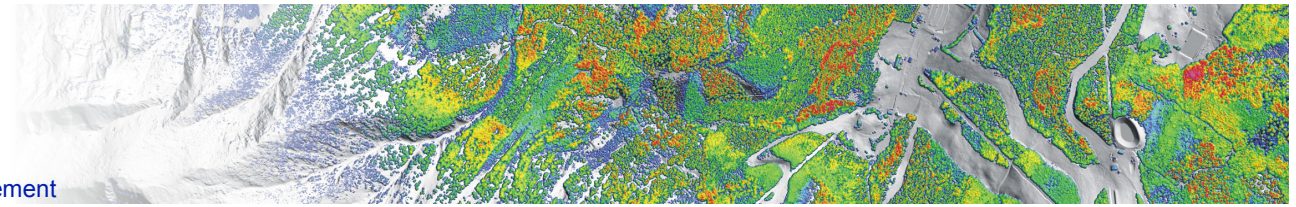
advanced forest scanning

one position - zero occlusion

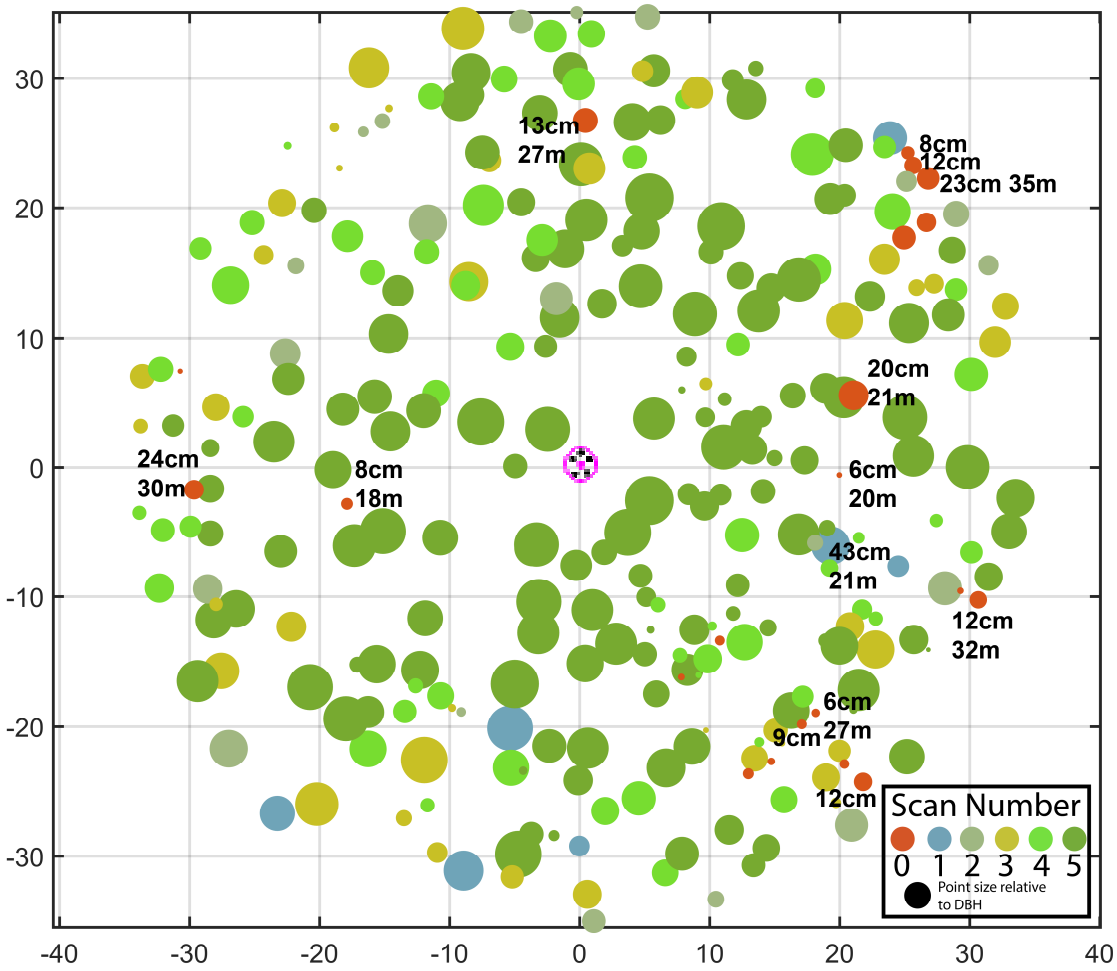
jib-scan detects 99.5% of basal area!

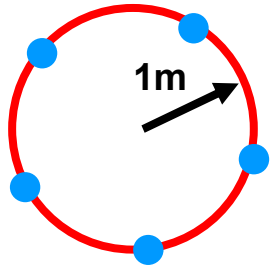
umwelt data

Sustainability: Monitoring Mapping Modelling Management



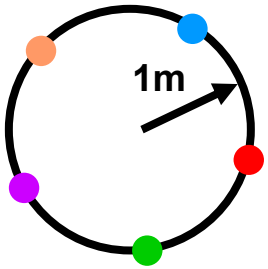
jib-scan-simulation i)

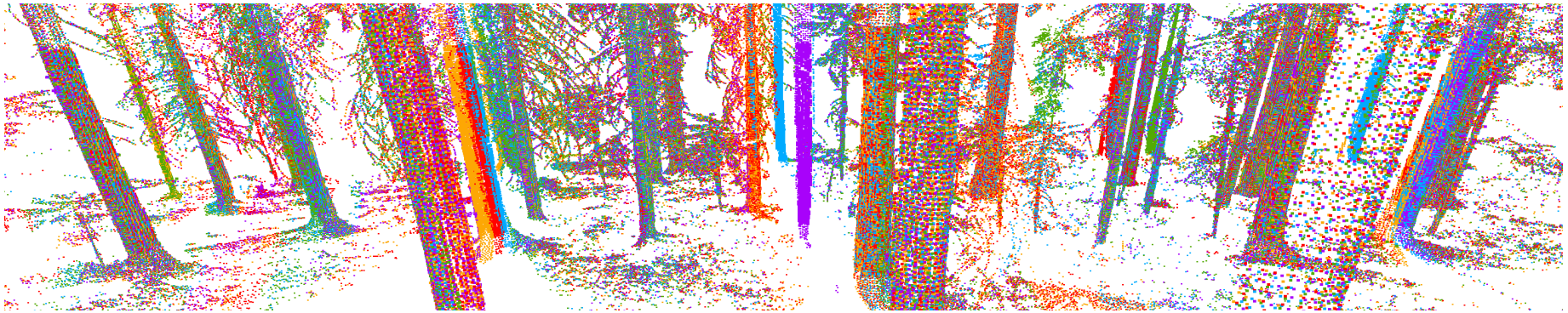


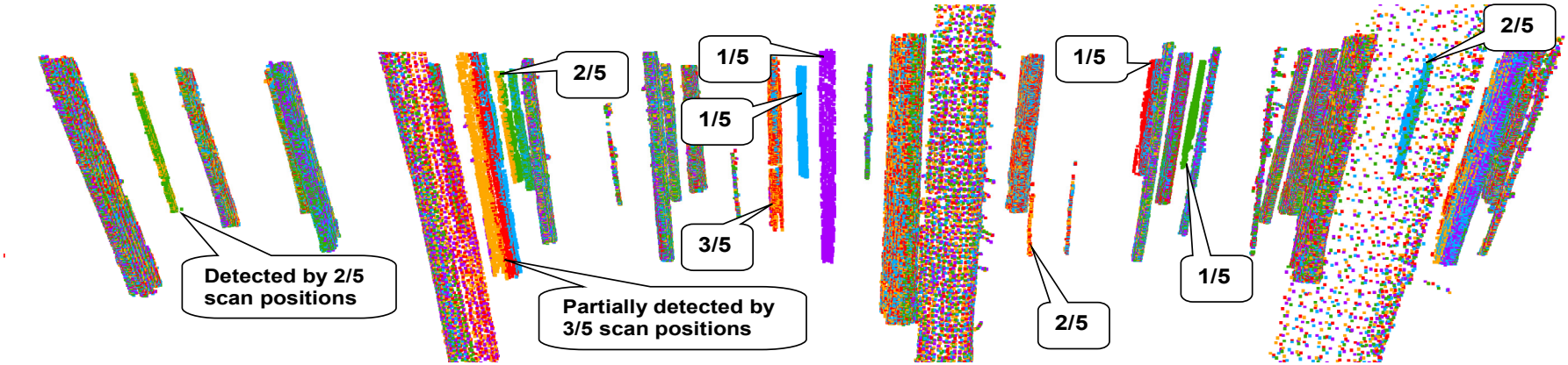


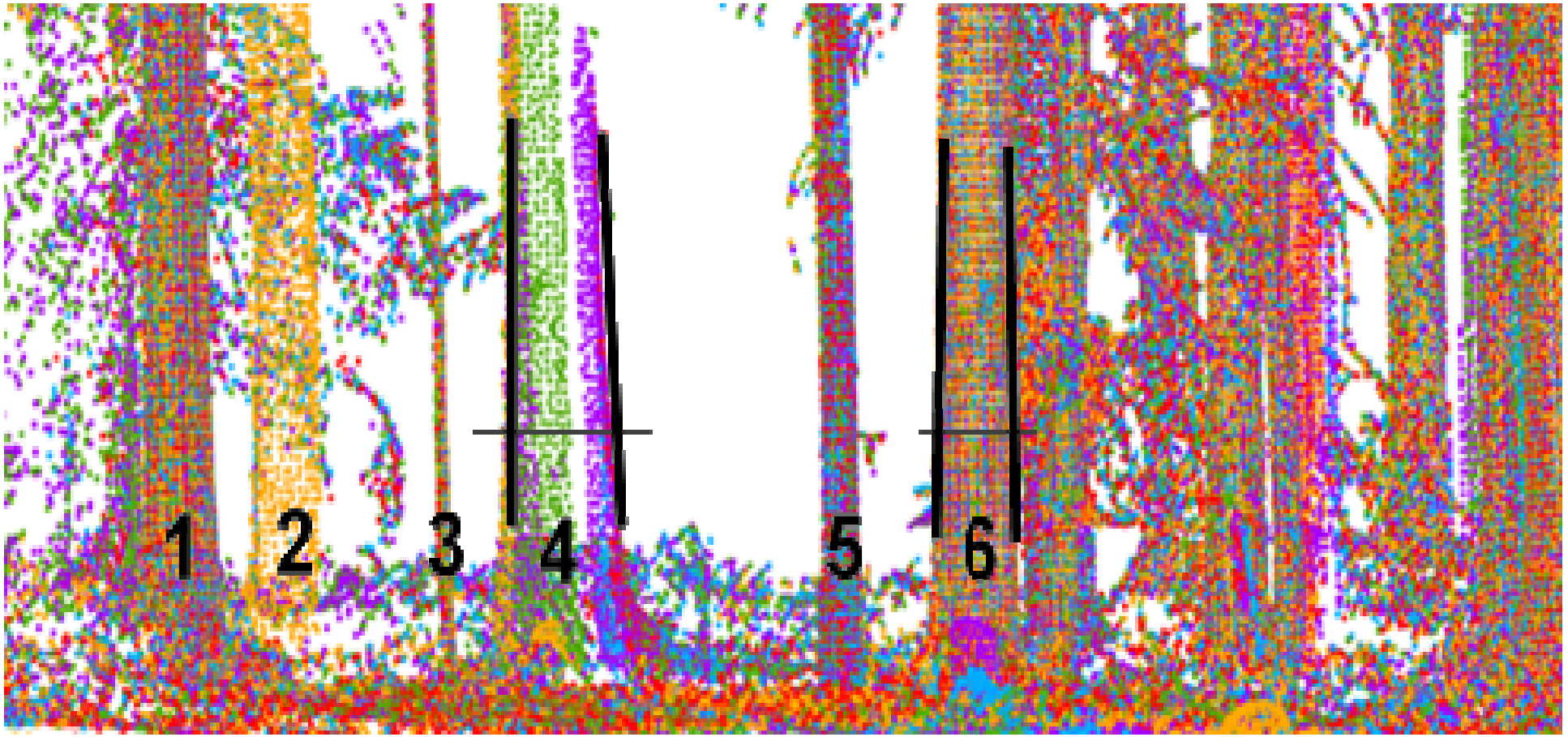
- from **single position**
- within **35m radius**
- **only few hidden trees**
- with **Bitterlich angle count**
  basal area **factor K = 1**
  none of the hidden trees
  would be counted
- with K = 1 there are more
  than 50 trees counted
  in total

jib-scan-simulation ii)

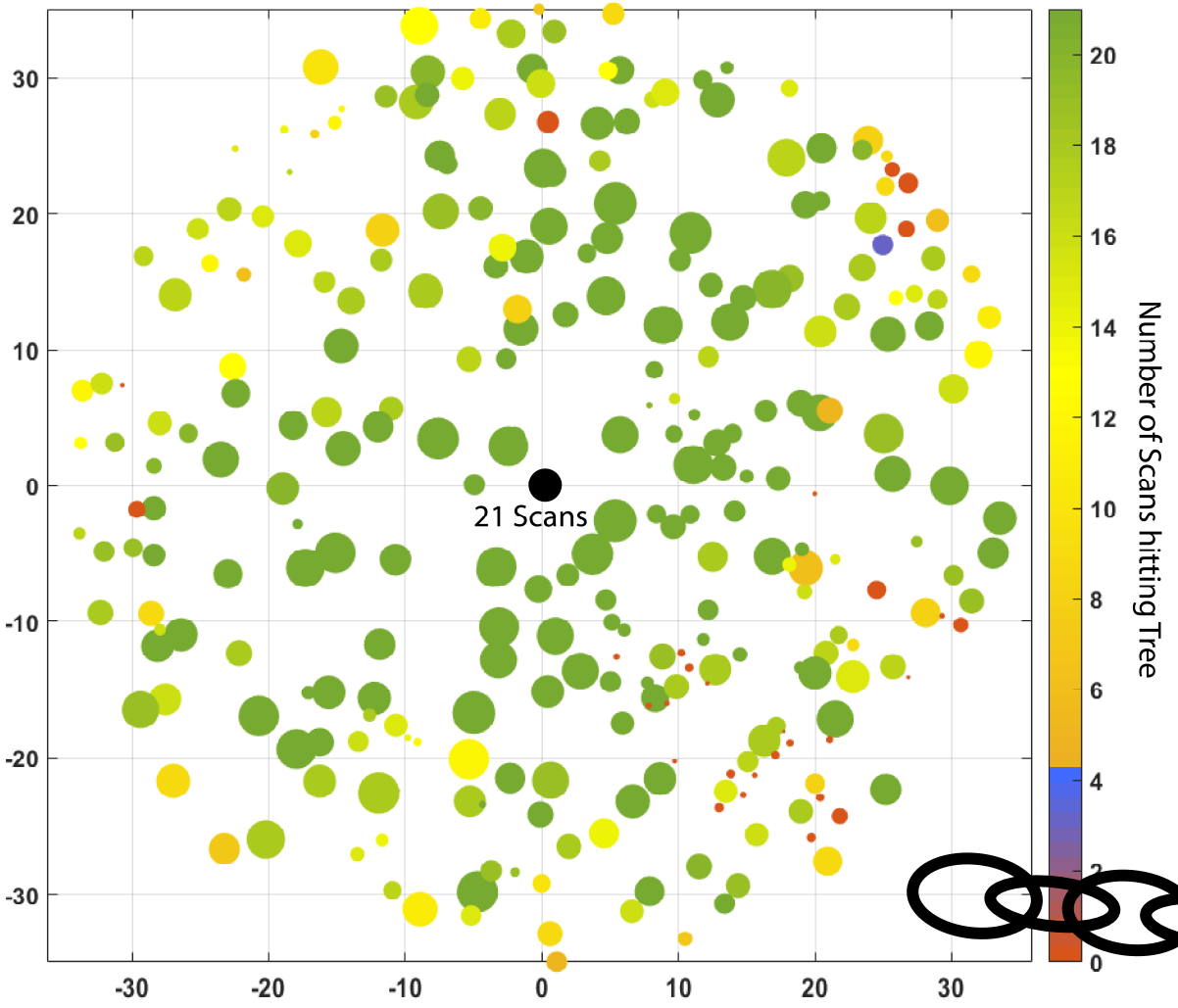






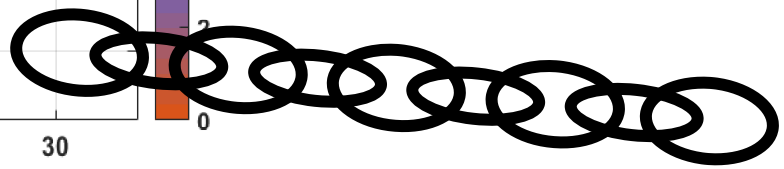


Diameter extraction and the derivation of taper functions by edge detection is more stable than diameter extraction from cylinder-fitting or cone-fitting. It is less sensible regarding noise from i) sensor, ii) bark, iii) small branches, iv) point cloud fusion. Using a permanent sample plot design with marked sample plot center points, the increments can be derived from identical geometric setup of measurement time series. TLS cost benefit ratio can be significantly enhanced.



One single scan delivers
- 50-200 trees
- with accurate position
- DBH, height
- taper function
- QSM+biomass
- tree species from QSM
- dead wood
- regeneration
- micro+meso relief

can be correlated to ALS, GEDI, satellite images



Could such certified snapshots serve as a global standard for REDD+ issues?
- no more NFI compatibility discussion
- can be reprocessed with new methods in the future for monitoring purposes

could be easily certified by block-chain tokens or watermarks.