Forestry & vegetation mapping

Forest inventory

- Accurate quantity & quality
- Timber supply forecast
- Stand delineation

Biomass estimation

- Carbon stock
- Bioenergy

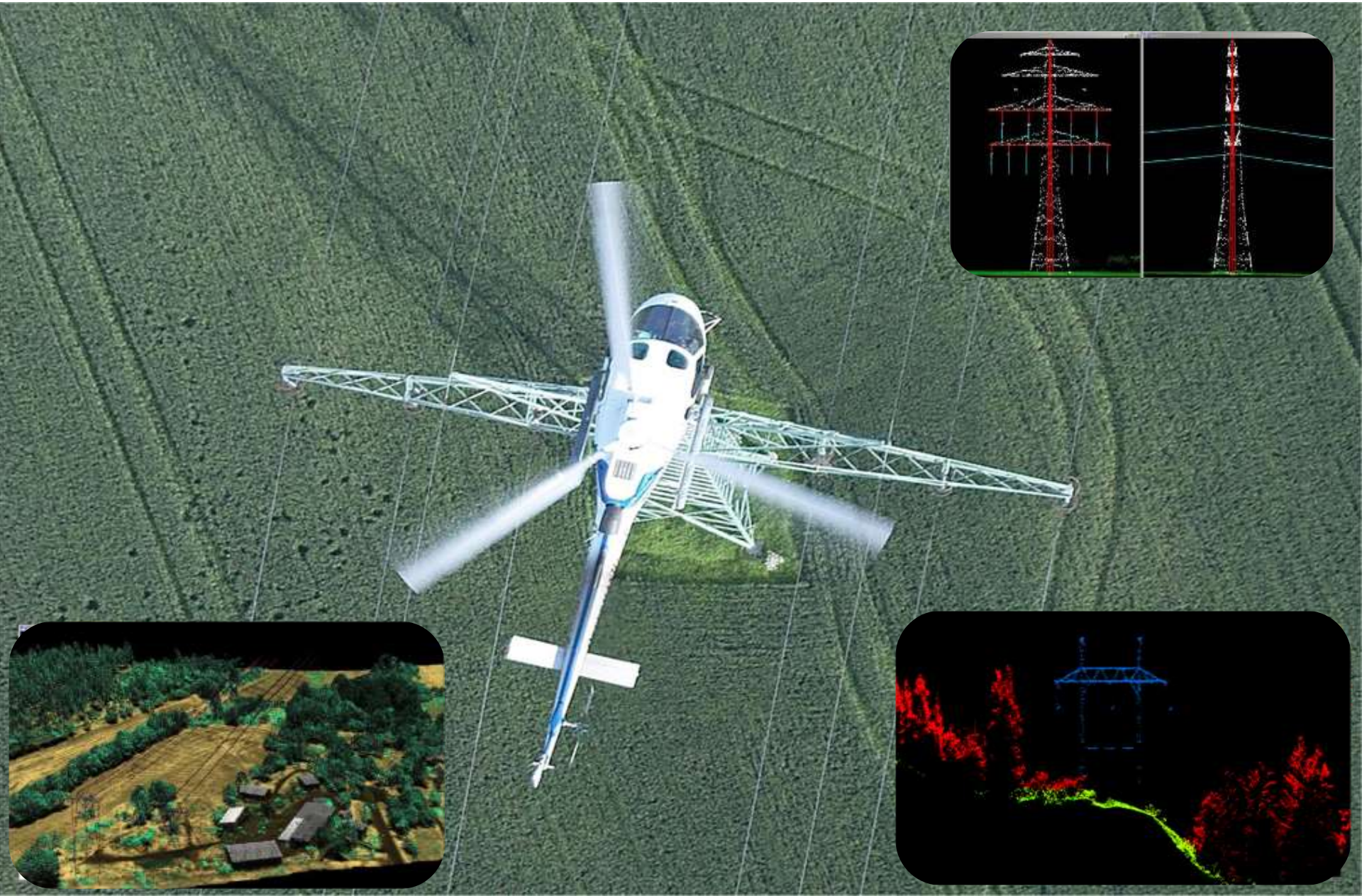
Green vegetation in urban areas

- Vegetation around power lines
- Tree objects for planning in 3D

Remote sensing – products and methods for vegetation mapping

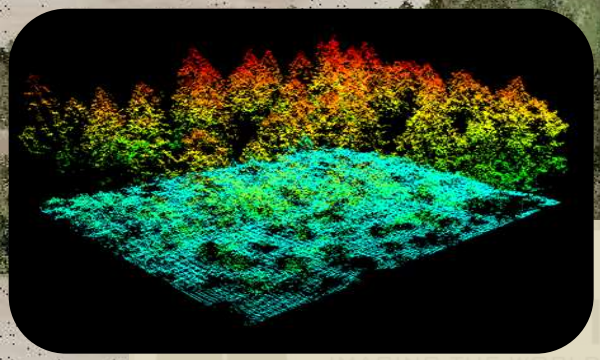
Platform	LiDAR	Image	Usage Forest Management Planning (FMP)
Rotor wing (RW)	✓	✓	1. Corridor mapping (power-lines, roads) 2. High point density LiDAR (10-100 point/m^2)
Fixed wing (FW)	✓	✓	1. Medium vast area missions (5-1000 km^2) 2. Low point density LiDAR (0,2-10 point/m^2) 3. High resolution images (0,02-0,50 m GSD)
Satellite		✓	1. Large area missions 2. Low resolution images (0,5-25 m GSD)
PAMS		✓	1. Small area missions (0,1-5 km^2) 2. High resolution images (0,02-0,1 m GSD)

Rotor wing laserscanning - Topeye



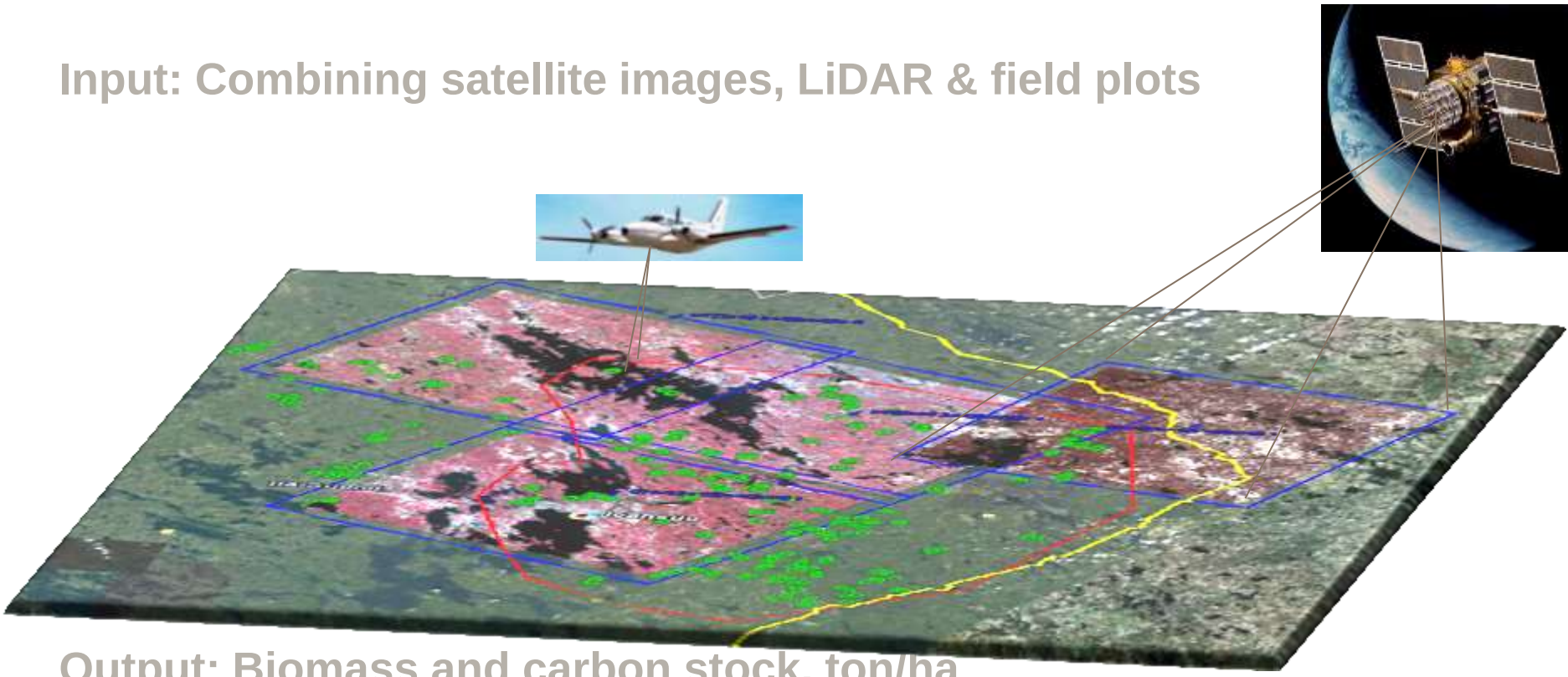
Fixed wing laserscanning

LiDAR
- 10 points/m^2
- total: 4.7 billion points
- area: 277 km^2
- average: 17 mill points/km^2

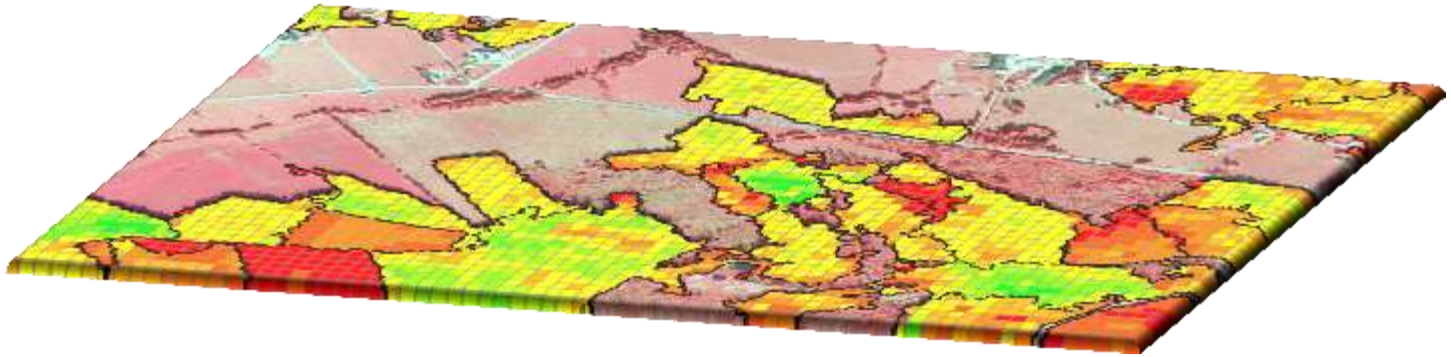


BLOM

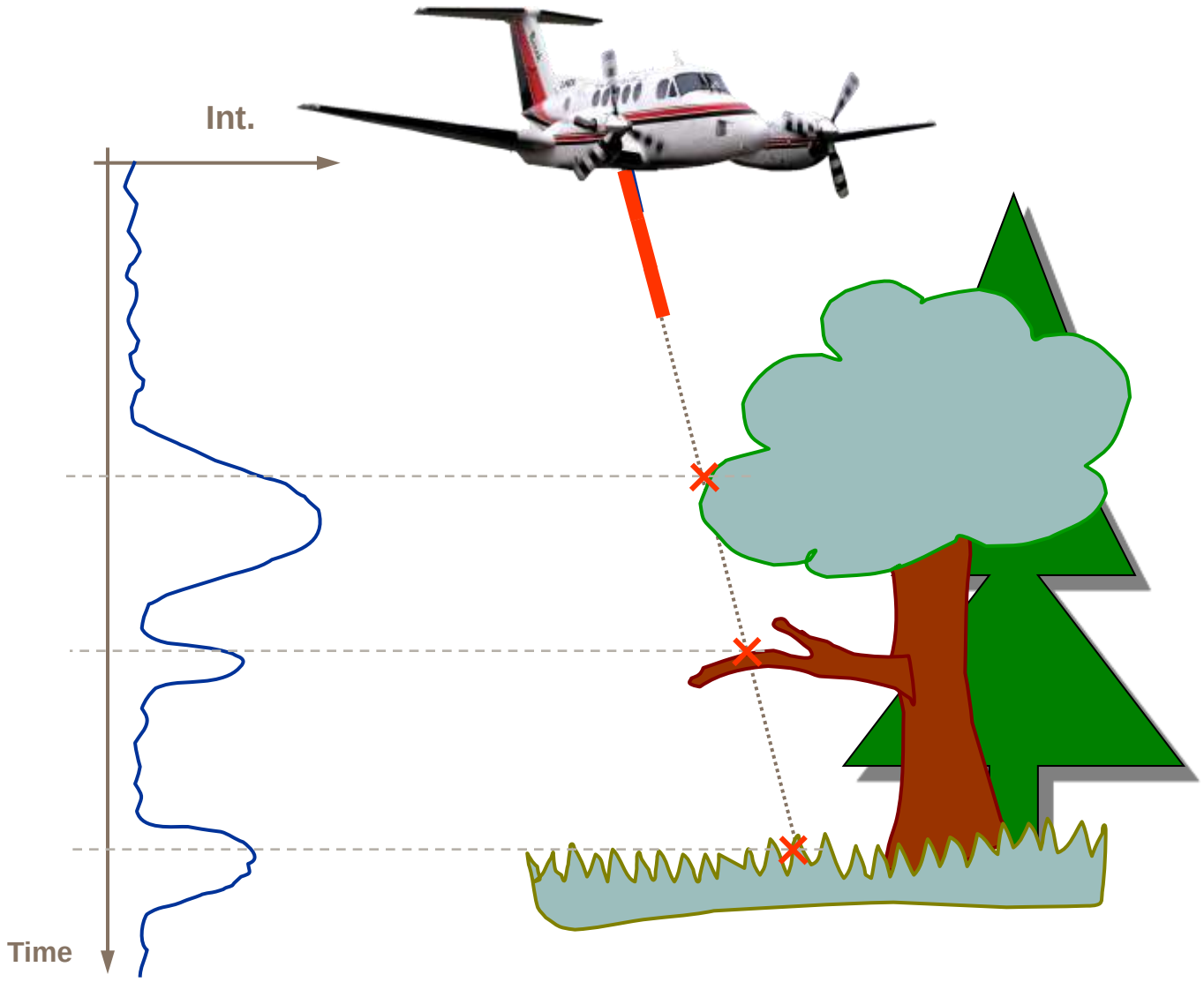
Input: Combining satellite images, LiDAR & field plots



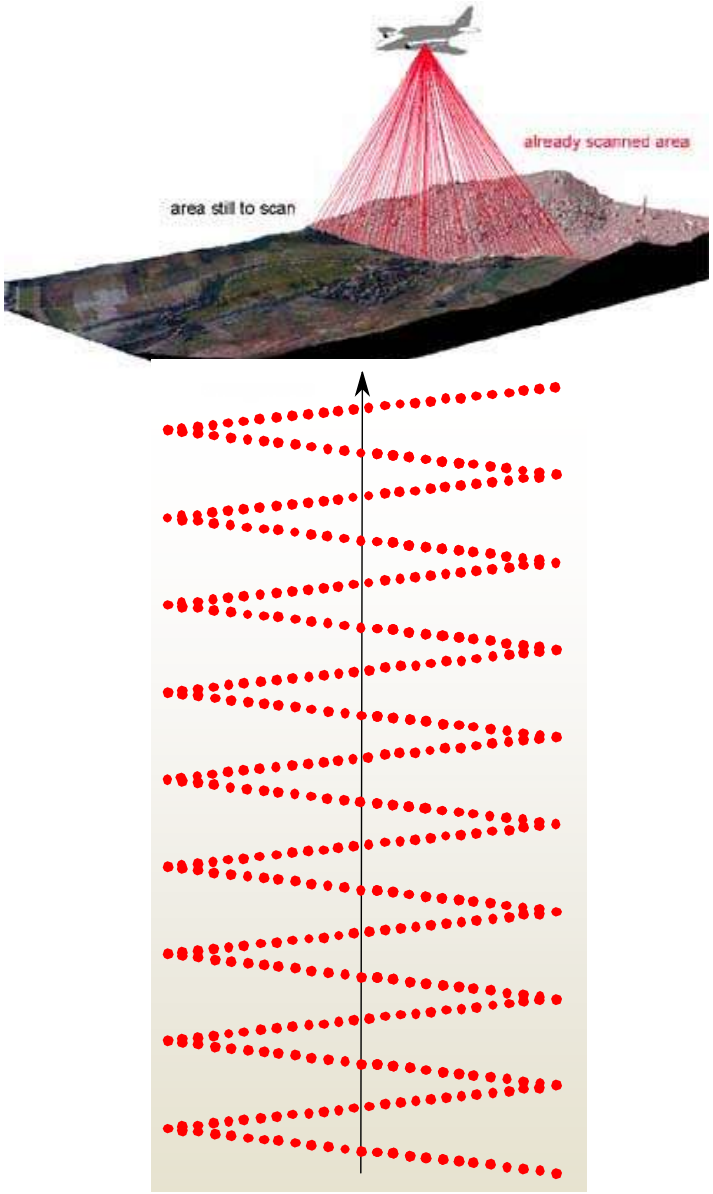
Output: Biomass and carbon stock, ton/ha

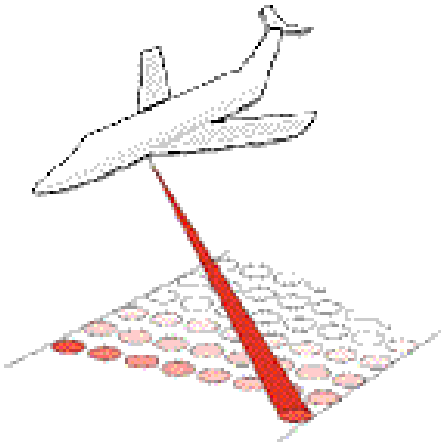


Light Detection and Ranging



LiDAR - Principle

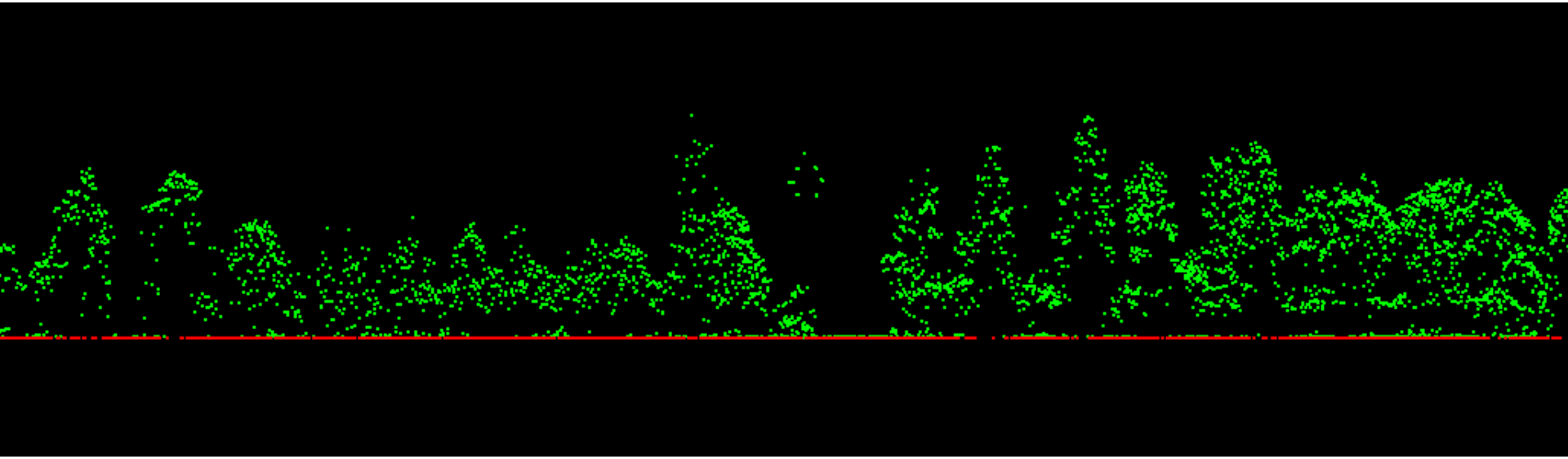


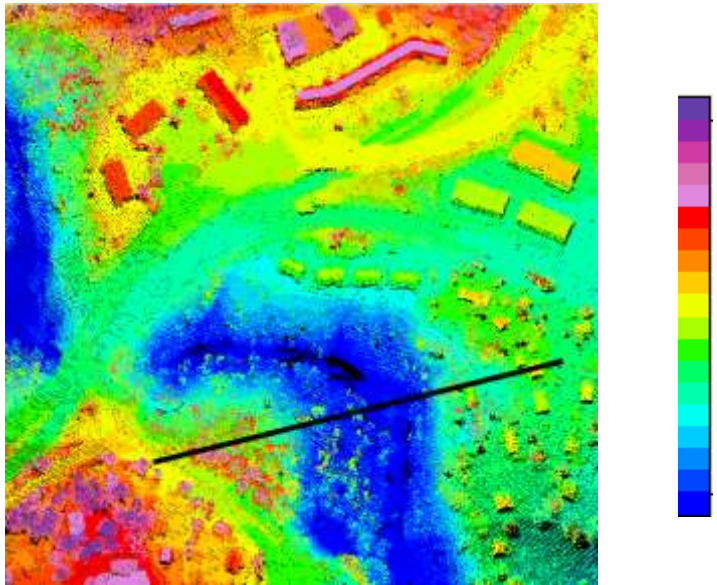


LIDAR parameters:

- First and last pulse reflection
- 50.000-200.000 pulses per sec
- 1.000-3.000 m altitude
- 20-40 cm footprint size
- 0.5-2.0 m spacing
- 500-1500 m swath

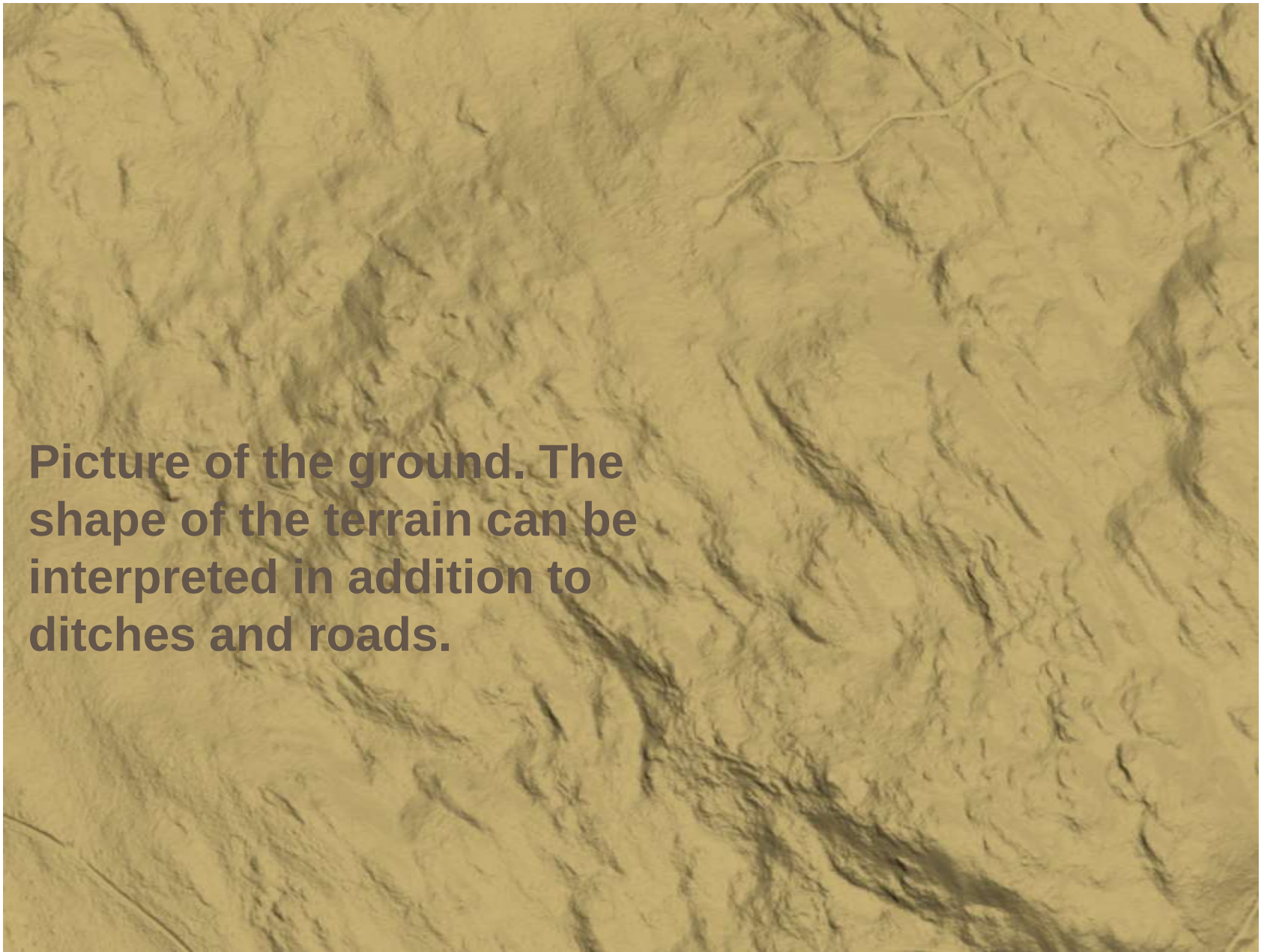
Transformation – heights



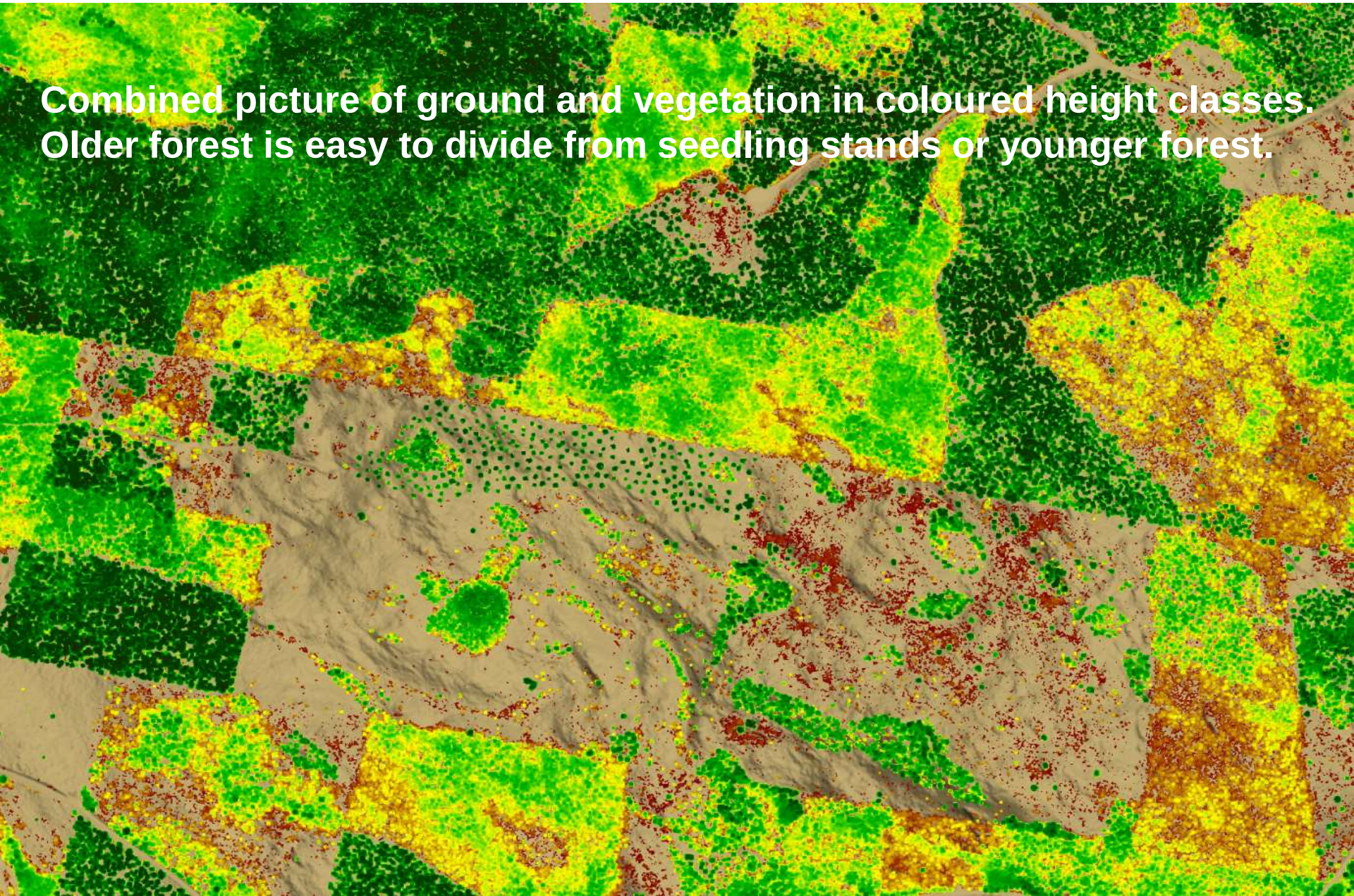


Height above ground

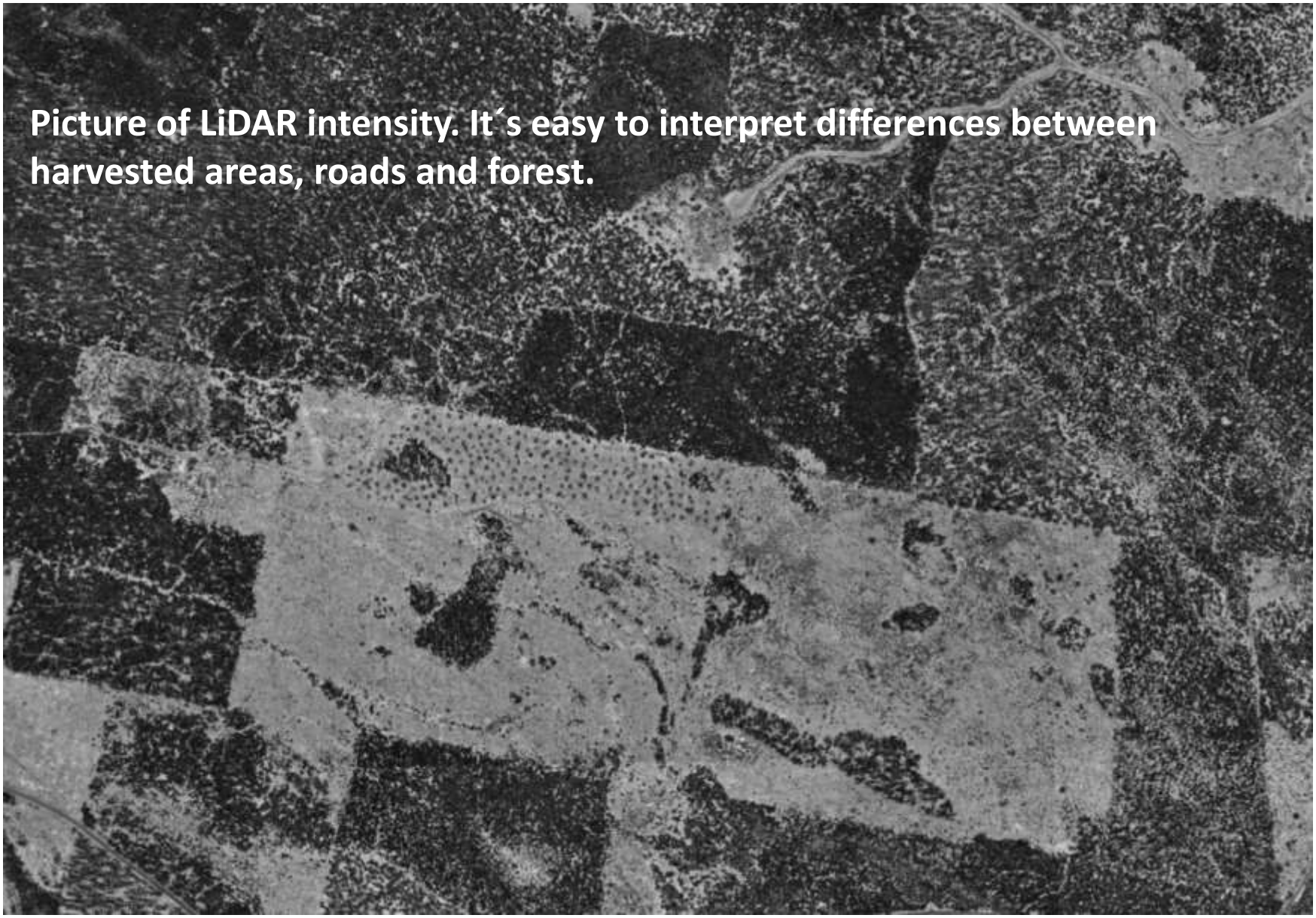
DTM - hillshade



Lidar image; DSM + LiDAR



Lidar intensity



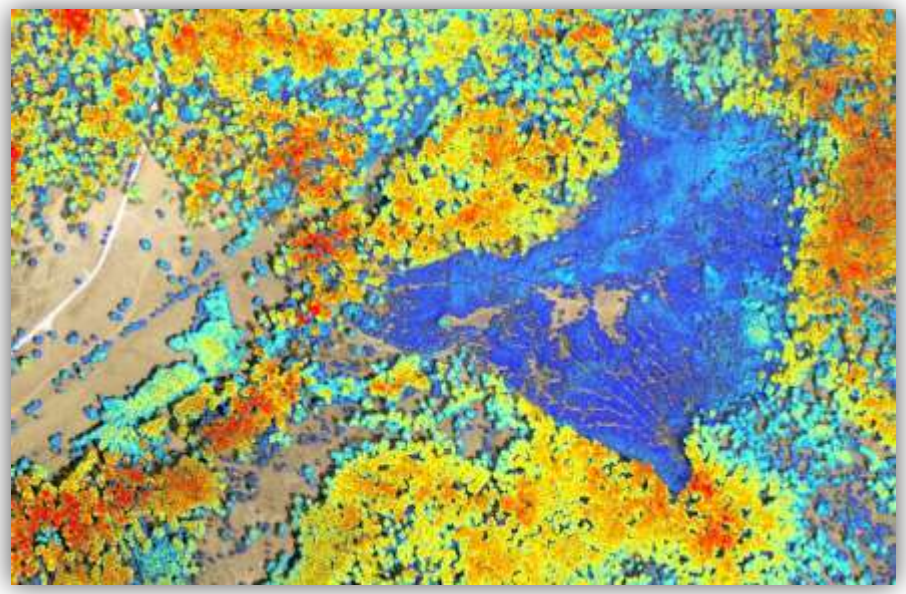
Forestry inventory

Main methods:

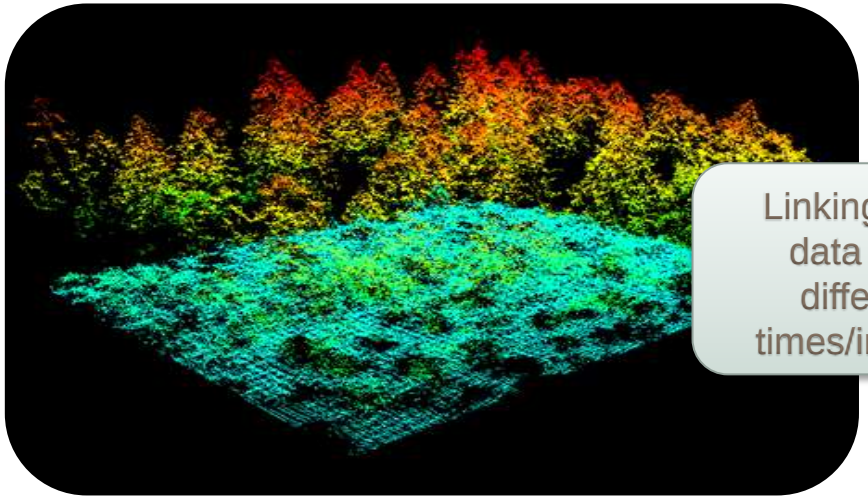
- Area based method (forest variables per area unit)
  - Point density typically 0.5 to 2.0 per m^2
- Single tree approach (variables per tree as unit)
  - Point density typically 5 to 10 per m^2
- The semi-individual tree crown approach (semi-ITC)
  - Predicting crown base heights (CBH) on the level of single crown segments
  - Point density typically 0.5 to 10 per m^2
- The k-MSN approach (variables per tree species)
  - Images needed
  - Point density typically 0,5 to 2 per m^2

Forestry – Area based methods

- Area based methods
  - kNN method
  - Regression functions
- LiDAR point density > 0.5 points / m^2
- Map with forest types (strata)
- Estimation of forest parameters
  - Mean height (m)
  - Dominant height (m)
  - Mean diameter (cm)
  - Basal area (m^2/ha)
  - Volume (m^3/ha)
  - Number of trees (N/ha)



Processing Lidar data for forestry



Airborne laser scanner data

Filtering and classification

Create DTM

Create DSM

Segmentation & classification

Variables for classification

Variables for estimation

Linking laser data from different times/individs

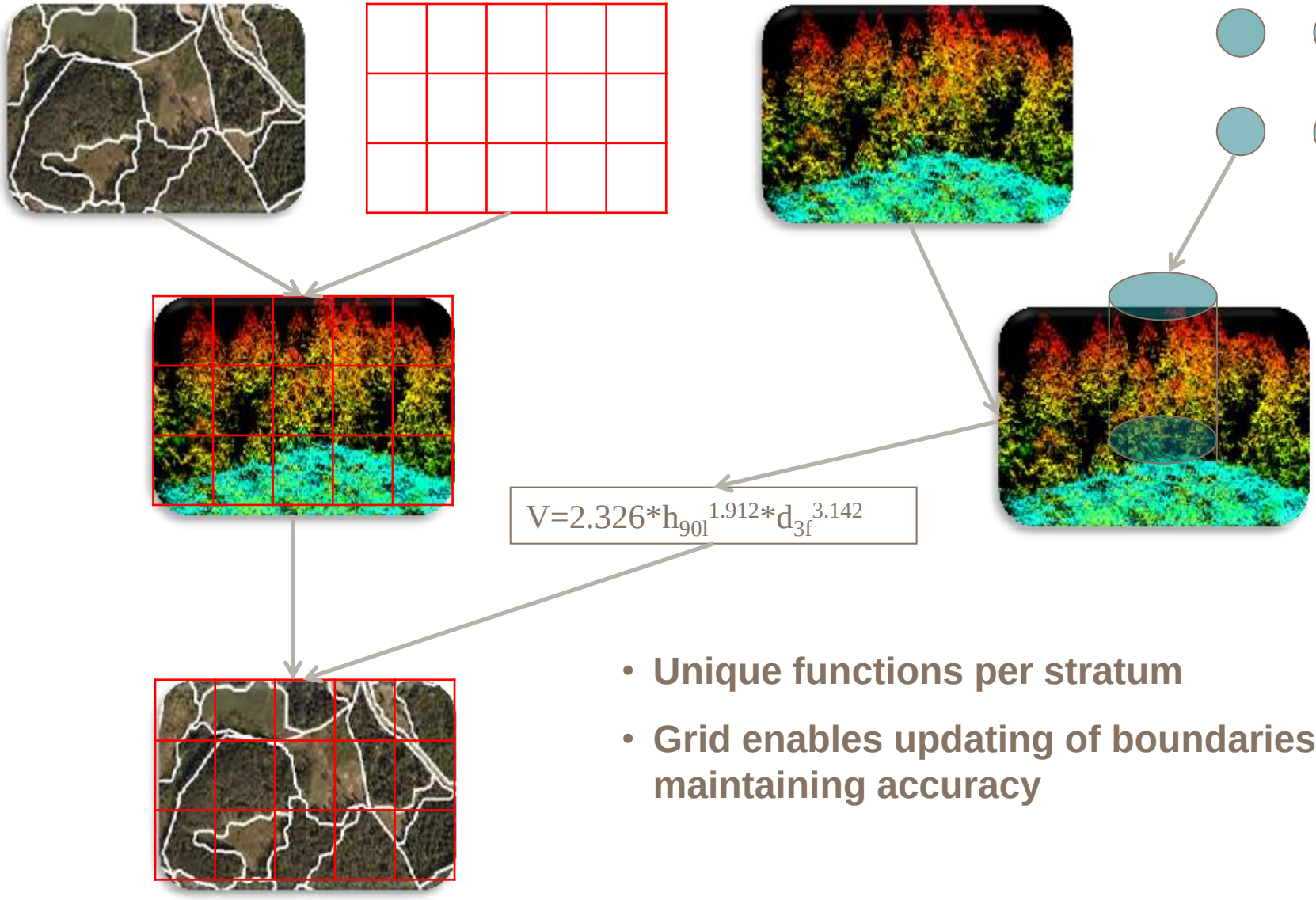
Linking field data and laser data

Sample based metod

Single tree or groups of trees variables

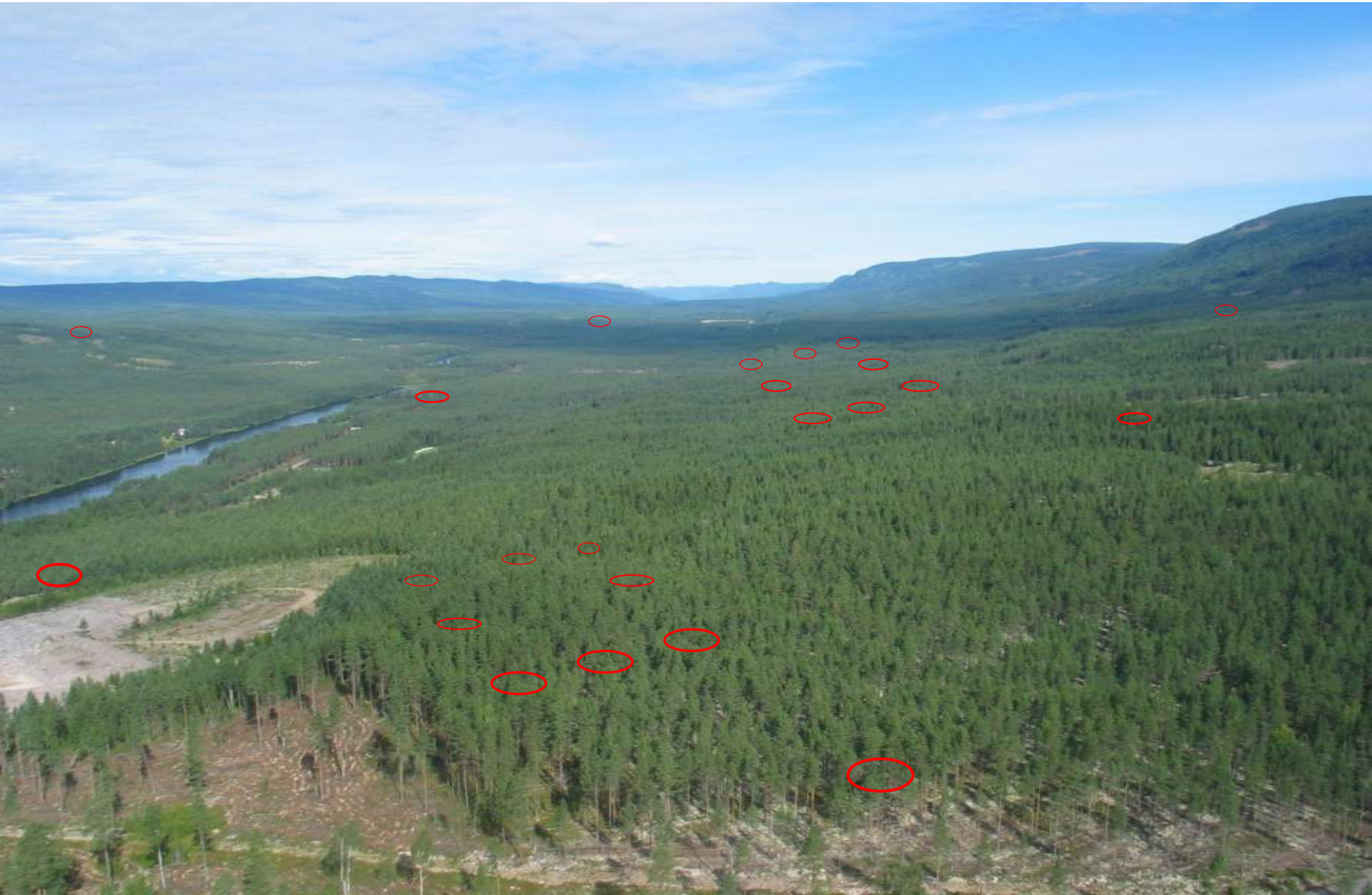
Stand attributes

Production Line - area based laser inventory



- Unique functions per stratum
- Grid enables updating of boundaries while maintaining accuracy

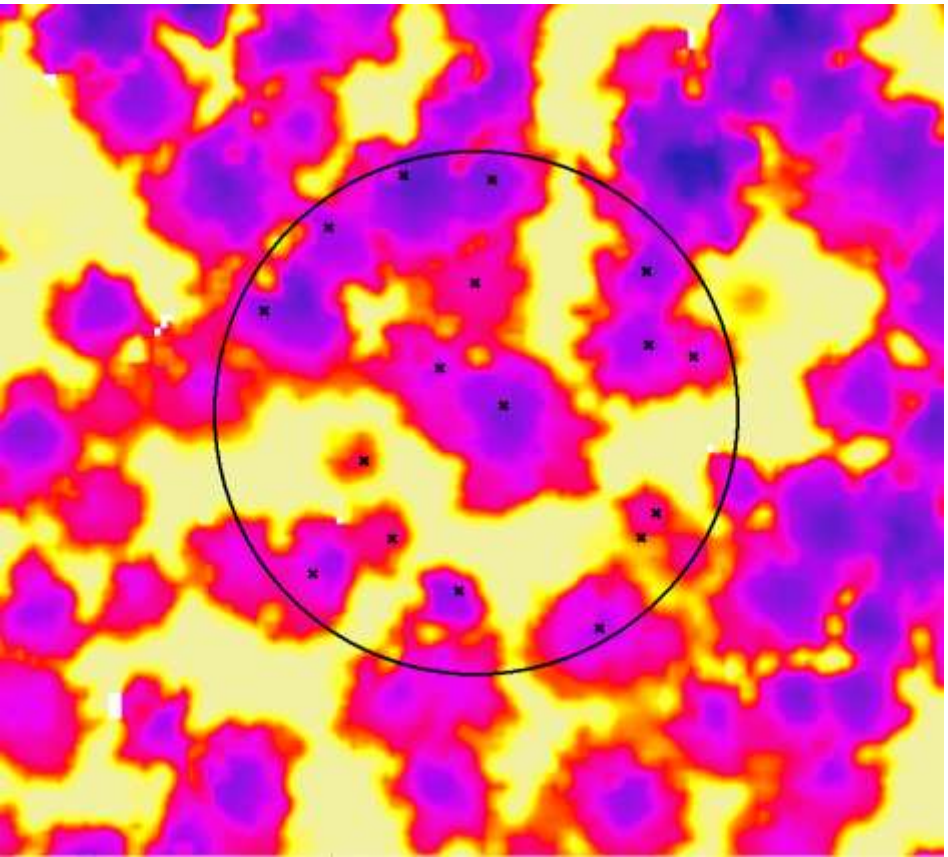
Sampling design – field plots



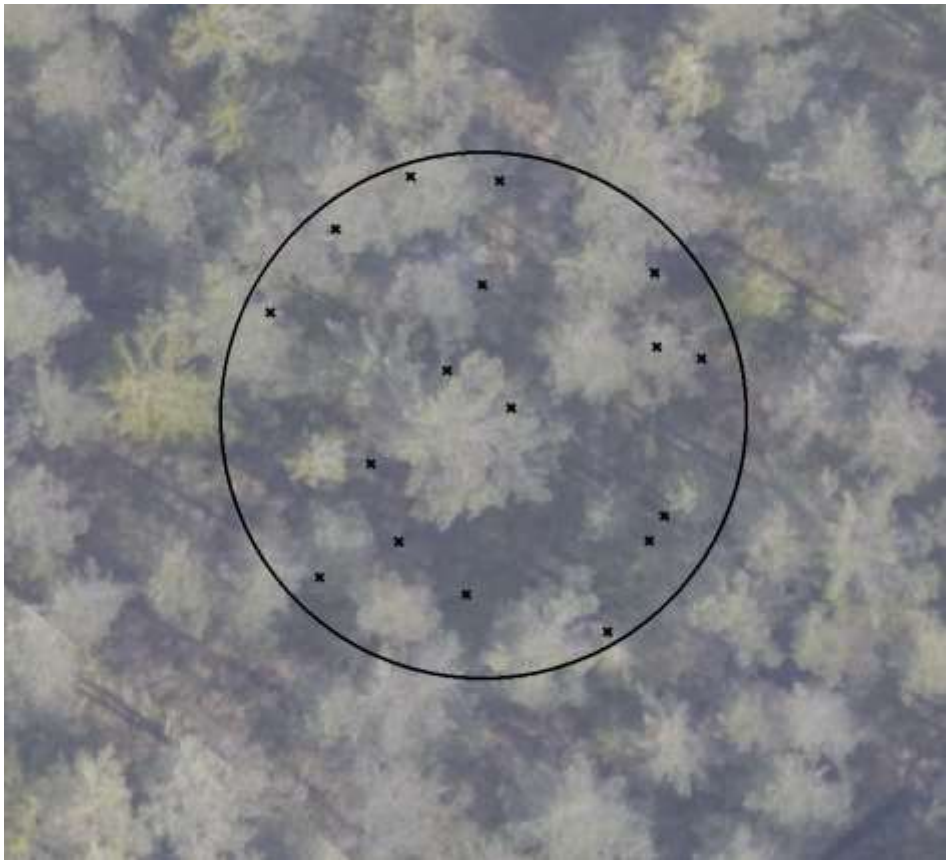
Sample plot example

- Sample plot with tree positions

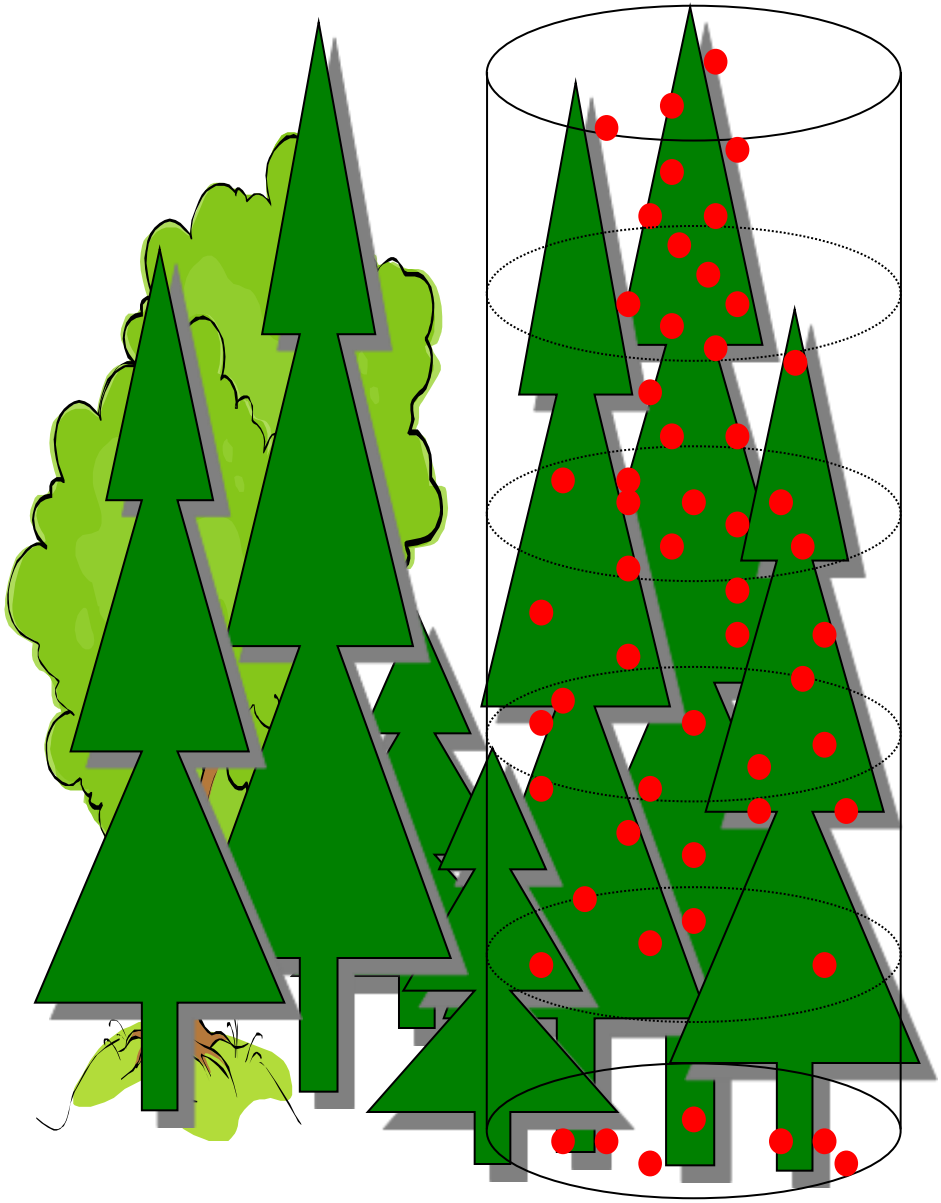
Lidar heights as background



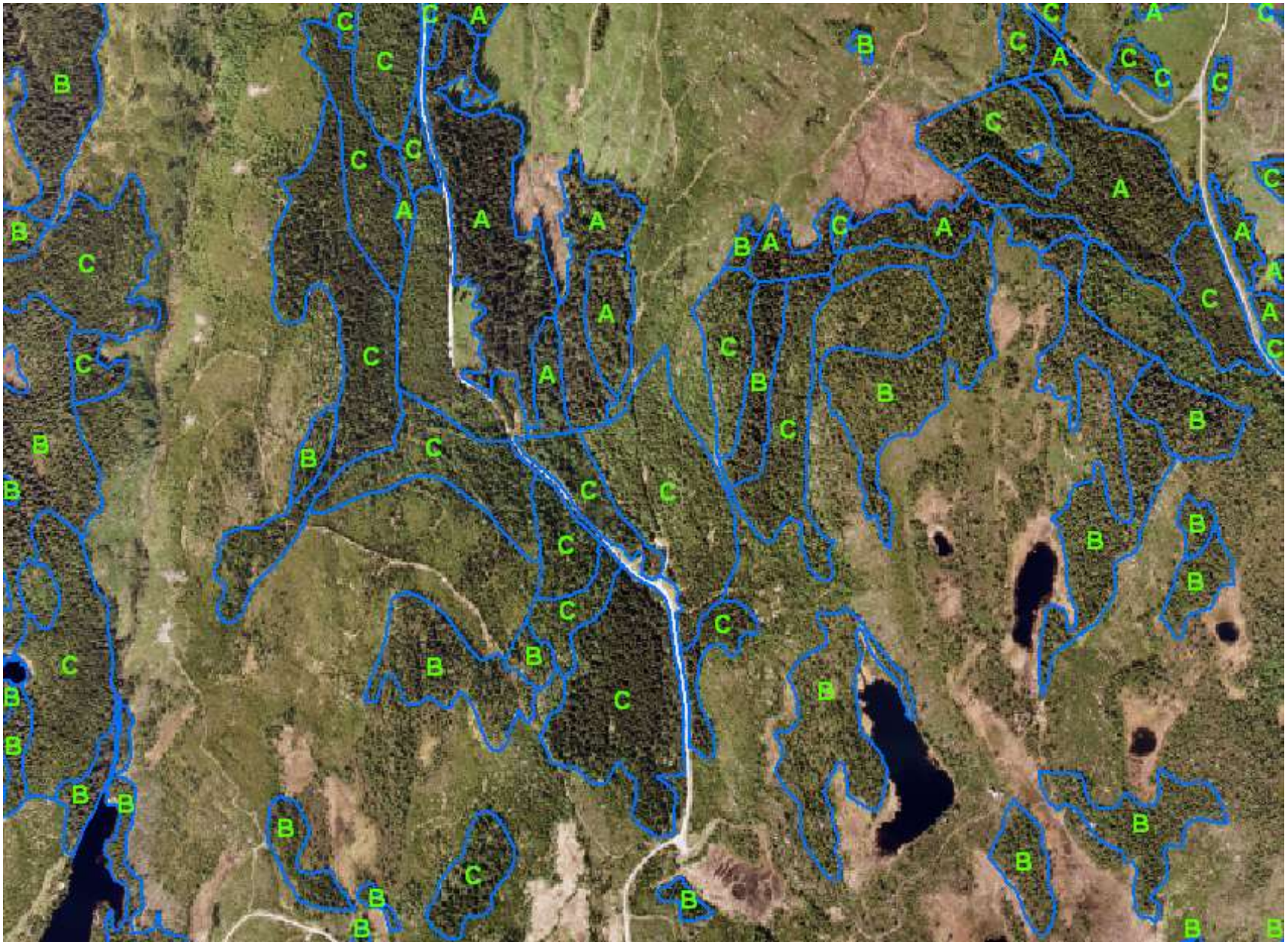
Orthophoto as background



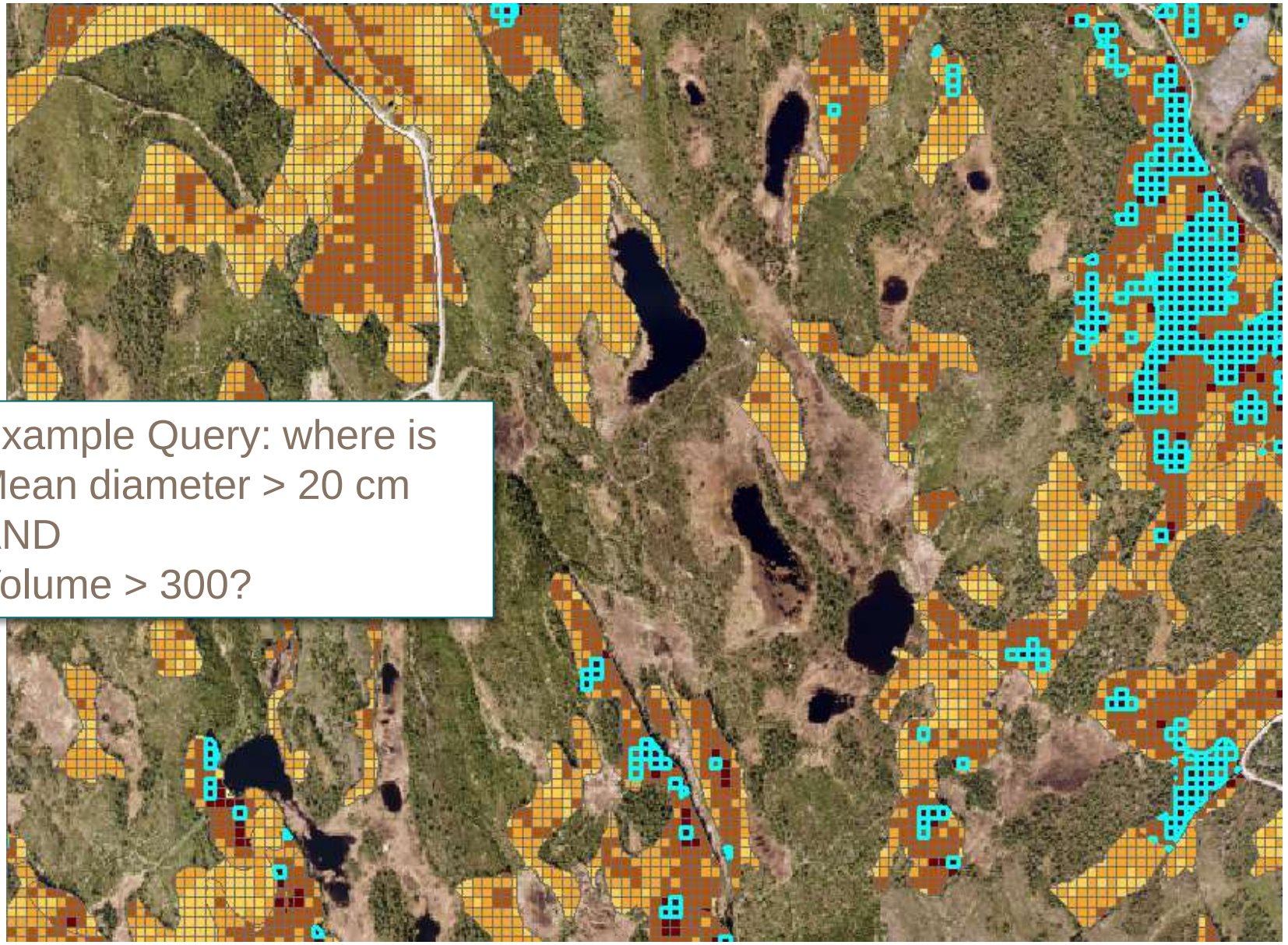
Height and density – sample plots



Forest Map

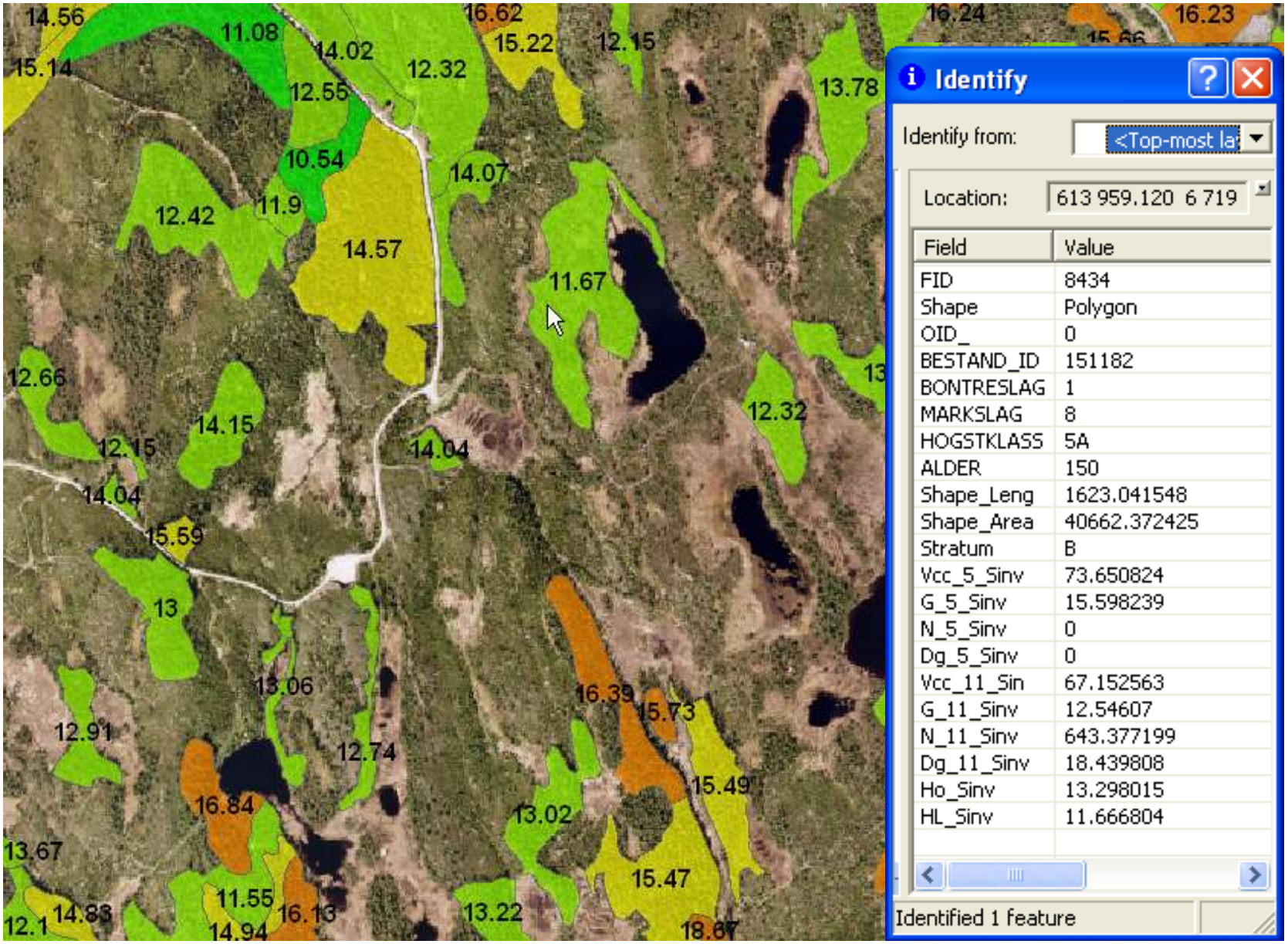


Results per grid cell - query



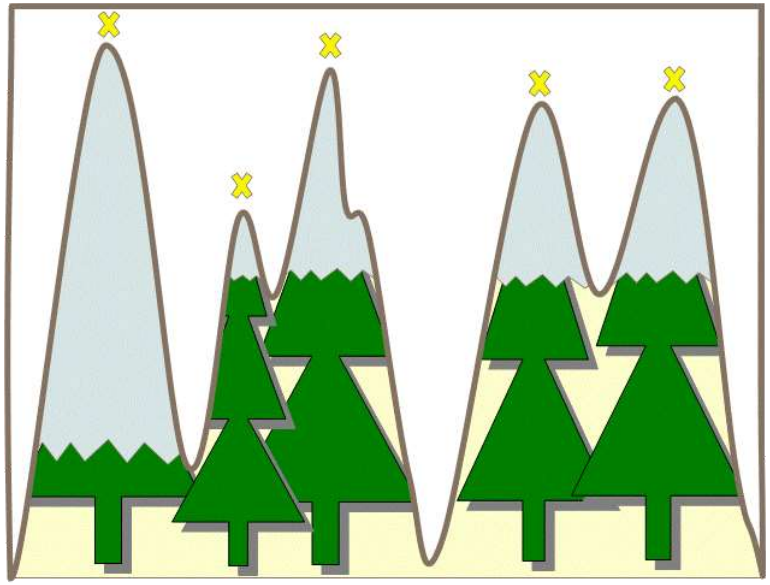
Example Query: where is
Mean diameter > 20 cm
AND
Volume > 300?

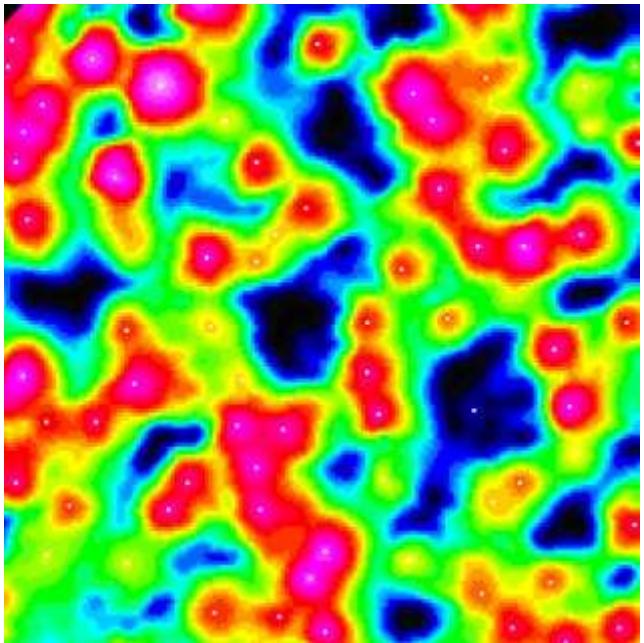
Result per forest compartment



Forestry – Single tree methods

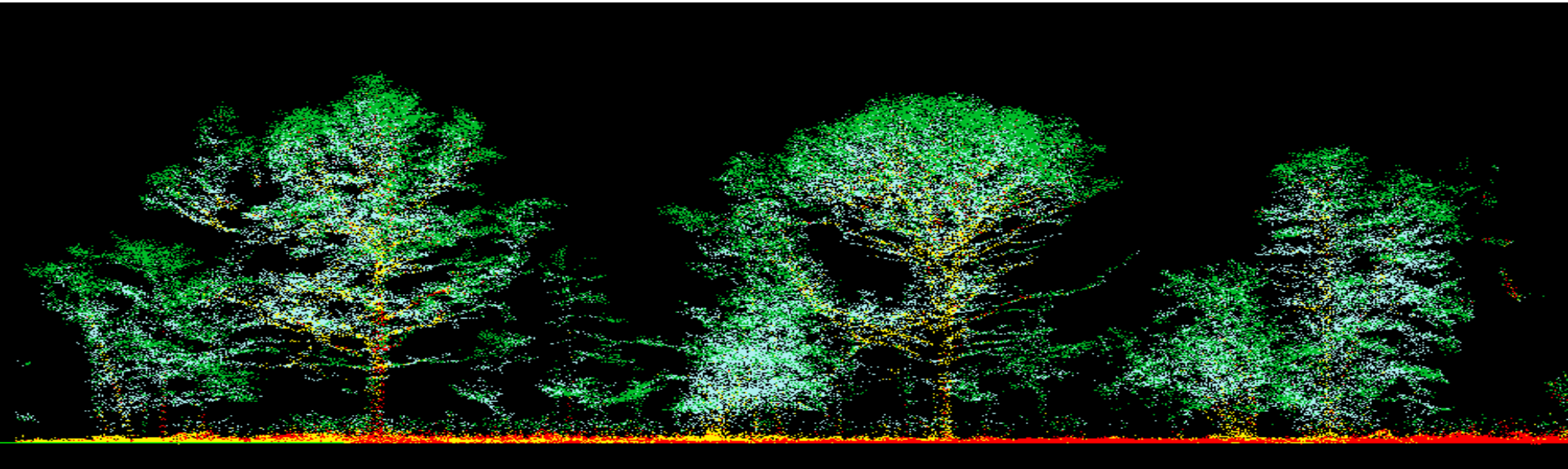
- Main input
  - Digital Surface model (LiDAR raster)
  - Aerial images
- Inverse watershed for tree segmentation
- Establishment of a relationship between
  - LiDAR height and tree height measured in the field
  - Tree height and tree diameter
- Classification tree species from aerial images
  - Images with orientation parameters
  - Re-projection of the LiDAR tree crown on the image
  - Extraction of spectral values
  - Classification
- Volume calculation (height, diameter, tree species)





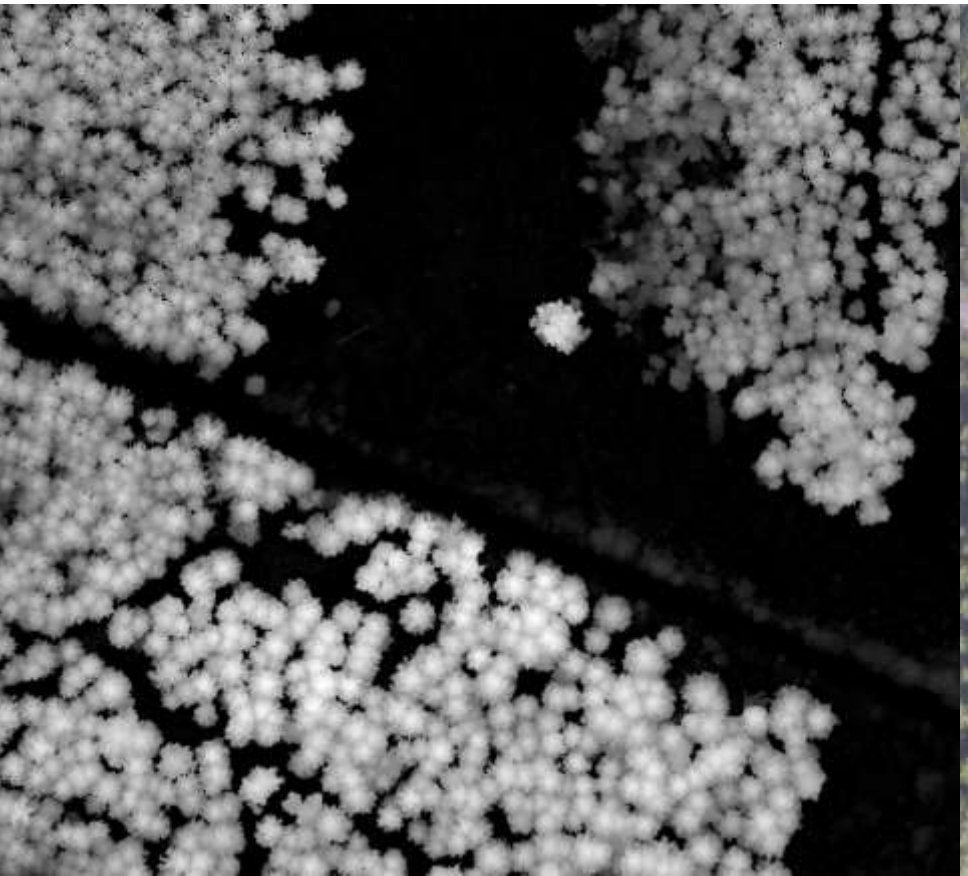
Processing

- LiDAR point cloud
- Transformation to relative heights
- Rasterization: nDSM (normalized Digital Surface model)
- Single tree delineation / height extraction
- Comparison with field data
- Tree height evaluation
- Height / diameter relationship
- Tree species classification
- Diameter calculation for all trees
- Volume calculation for all trees

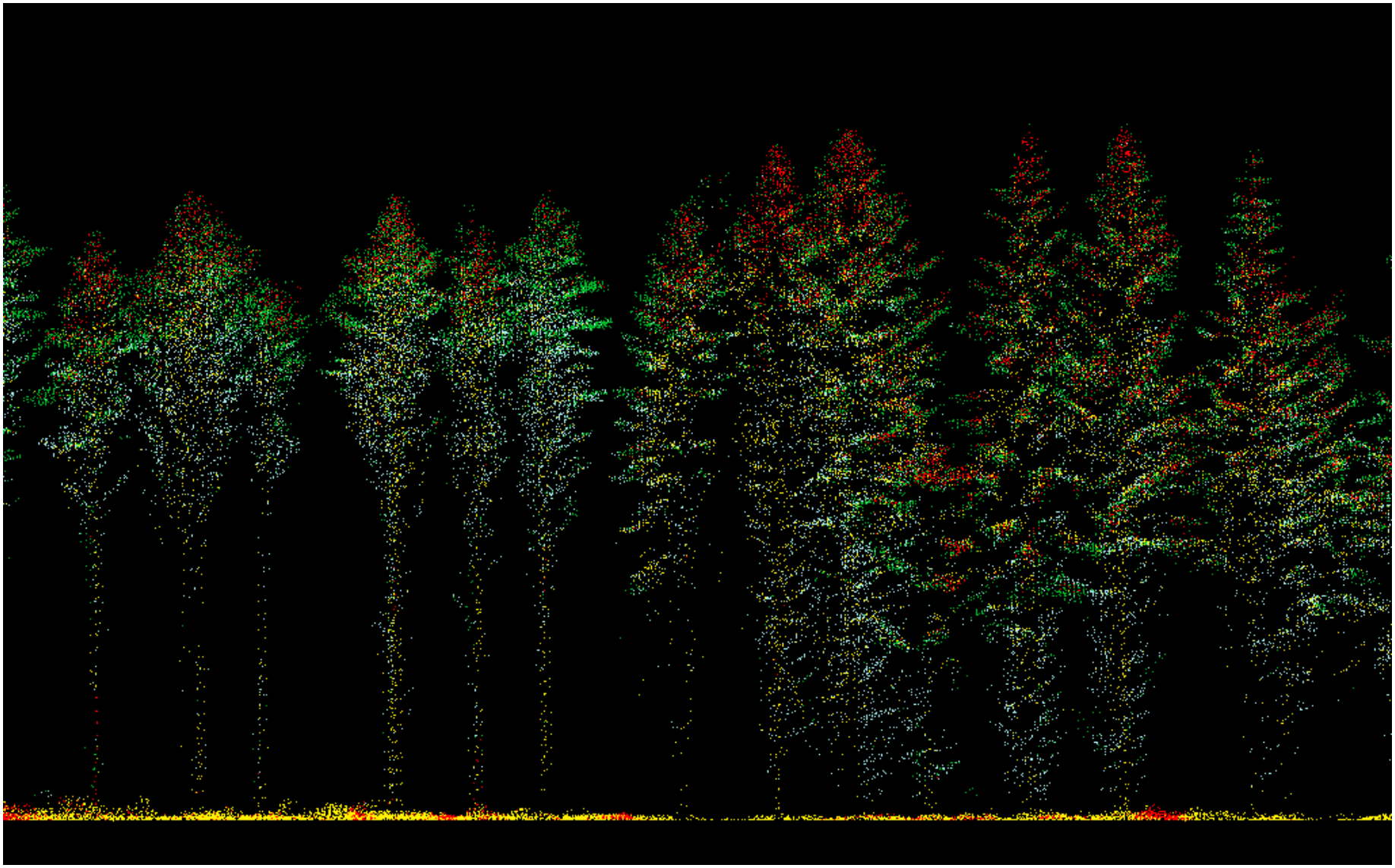


Rasterization: nDSM

- nDSM
- Black: 0 meter above ground
- White: 25 meter above ground



Example – RW scanning

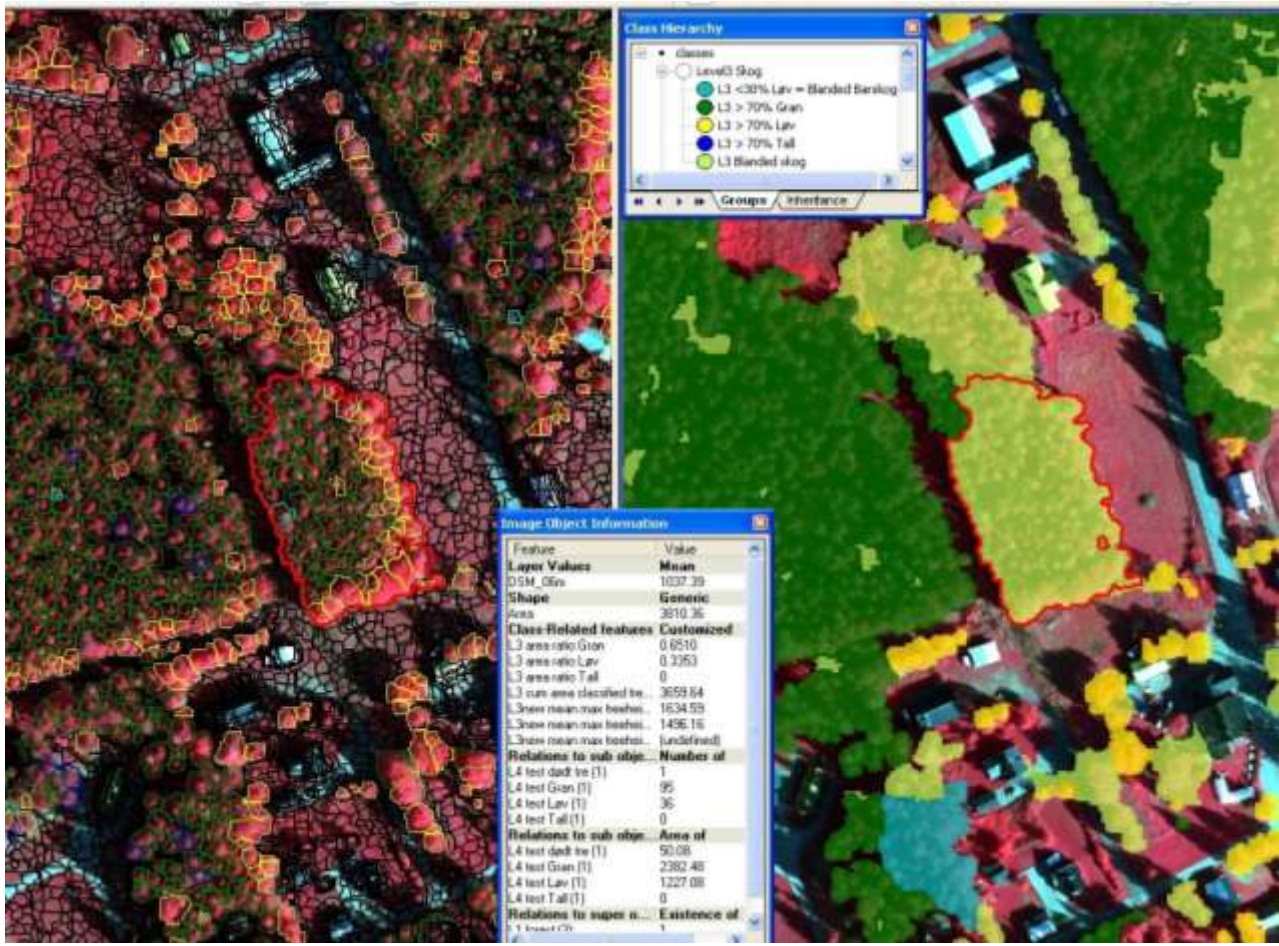


Accuracy (RMSE) on stand level

Stand variables	Traditional	LIDAR		
	Photo-interpretation	Area based method	K-MSN approach	Single Tree method
Mean height, H_L	15-25 %	5-10 %	5-10 %	5-10 %
Dominant height, H_{100}	15-25 %	5-10 %	5-10 %	5-10 %
Basal area, G	20-30 %	10-15%	10-15%	5-15%
Mean diameter, D_g	25-35 %	10-15%	10-15%	10-15%
Diameter distribution on tree species level	Not possible	Not possible	15-30%	10-20%
Tree species distribution	20-30%	20-30%	10-20%	5-20%
Volume, V/ha	15-30 %	5-15%	5-15%	5-15%
No of trees, N/ha	20-30%	10-15%	5-20%	5-20%

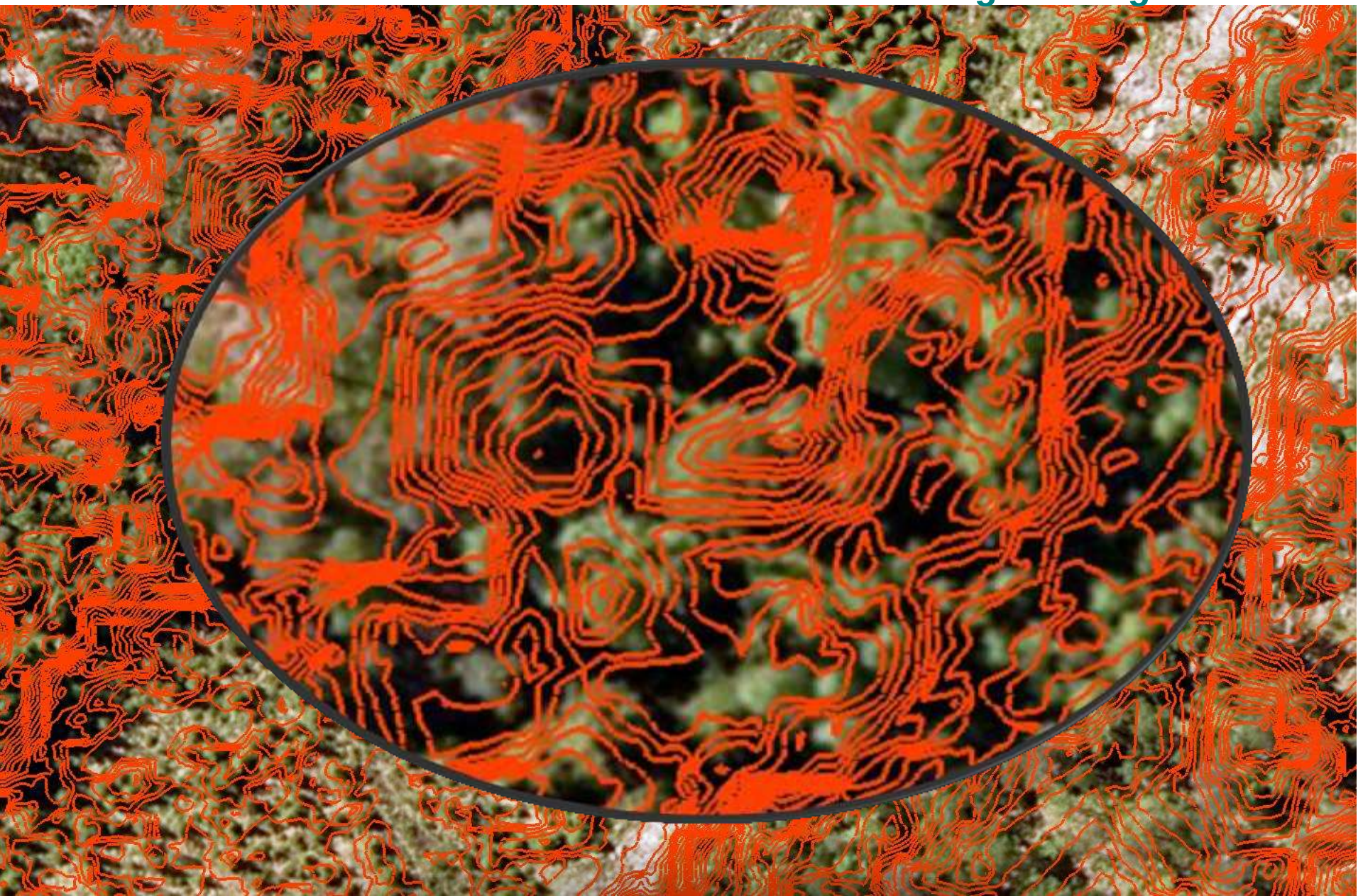
Stand delineation & tree species classification including dead trees

- Stand delineation based on several criteria
  - Region growing algorithm
  - Merging neighbouring objects that are alike, with regard to:
    - Tree height
    - “forest structure”
    - Tree species
  - Additional criteria:
    - Shape of the stand
    - Max area
    - Min area
    - …



BLOM

Single pixel correlation:
- height crown model (DCM)
based on digital images



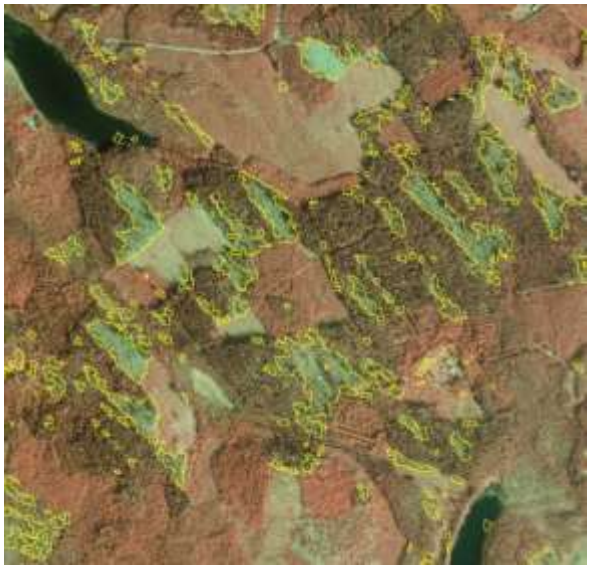
BLOM

“Storm” product based on aerial photo

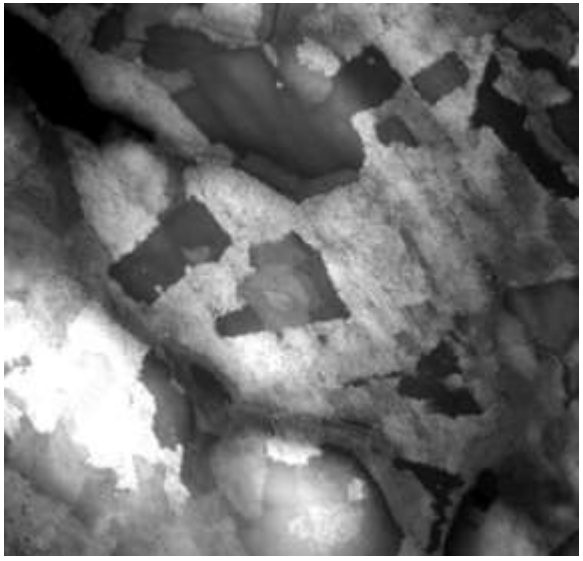
→ Single pixel correlation

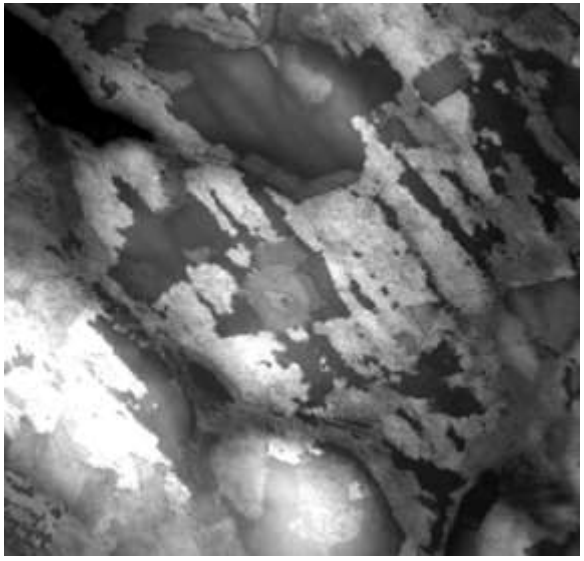
2008

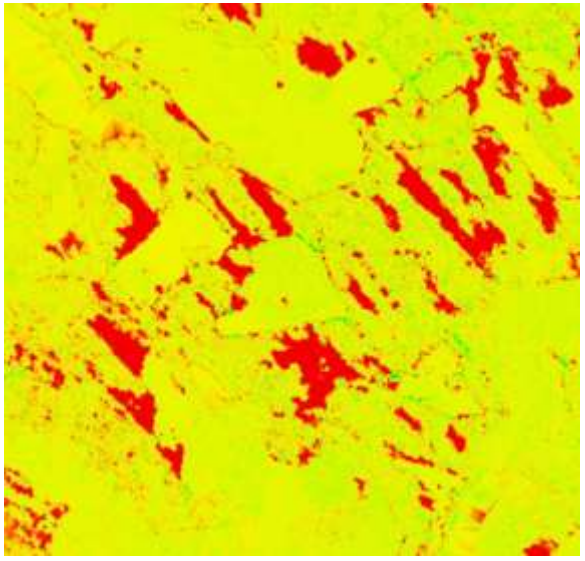
2010



Analysis of differences







Summary: Products, variables and methods

Product	LiDAR*			Aerial image**			Satellite image***		
	Low	Med	High	Low	Med	High	Low	Med	High
Digital surface model (DSM)	x								
Digital crown model (DCM)	x								
Forest variables (see list)	x				x				
Single tree estimation		x			x				
Dead wood & trees					x				x
Understory layer			x			x			
Tree species					x				x
Habitat analyses		x			x				
Carbon counting	x							x	
Biomass estimation	x			x				x	

The marker (x) indicate lowest level of resolution for each product or variable

* LIDAR resolution (point per m^2): Low; 0,2-2, Medium; 2-10, High; >10
** Aerial image (GSD): Low; > 0,4 m, Medium; 0,1-0,4 m, High; 0,02-0,1 m
*** Satellite image (GSD): Low; > 20 m, Medium; 5-20 m, High; 0,5-5 m

References

- Norway
- Sweden
- Denmark
- Finland
- UK
- Portugal
- Spain
- Poland
- Canada
- Uruguay
- Tanzania