LIDAR TECHNOLOGY AND APPLICATIONS IN FORESTRY

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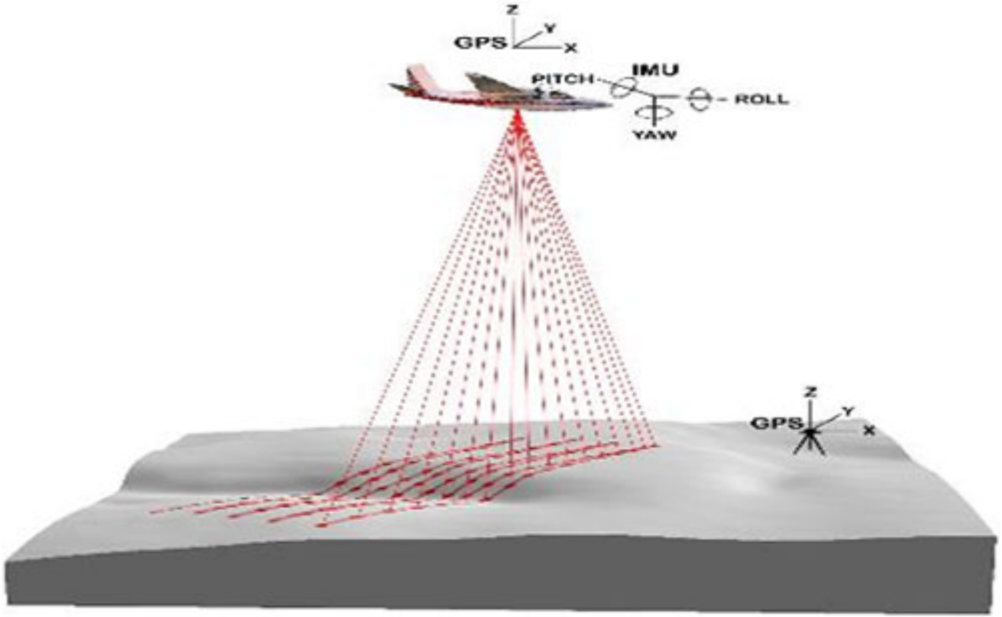
LiDAR

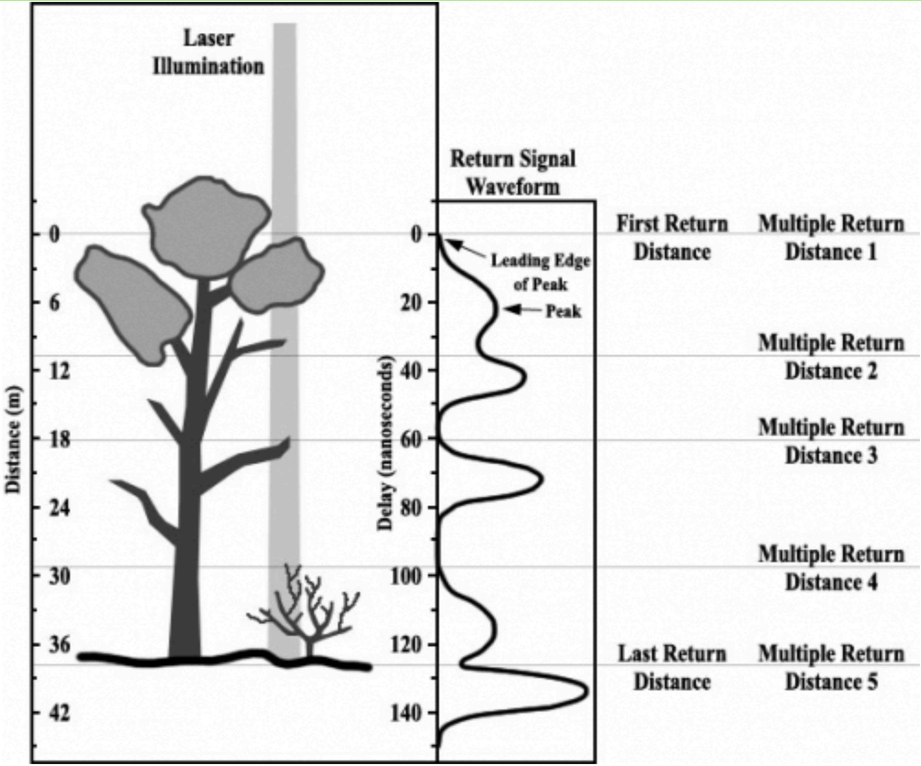
Remote sensing technique that creates 3D models from reality:

- Active sensor capable of generating up to 400.000 laser impulses per second
- At the same time, the sensor detects the reflections (returns), which bounce off the surface to the sensor
- ALS and TLS
- Based on impulse-reflection timing, GPS, and a Gyroscope, the reflecting surface is located in space (x,y,x)



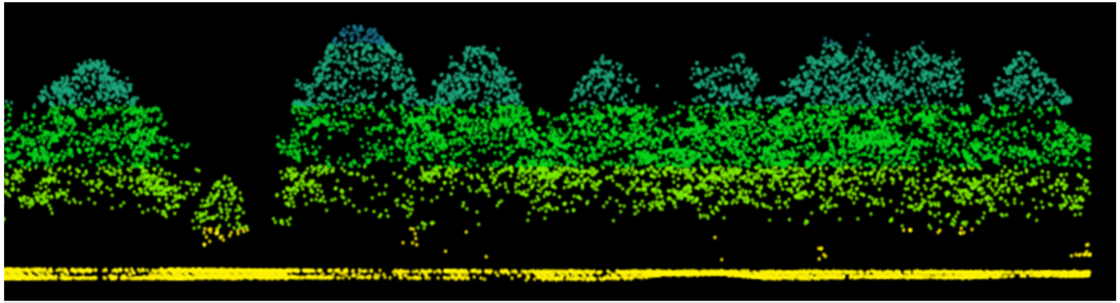
LiDAR

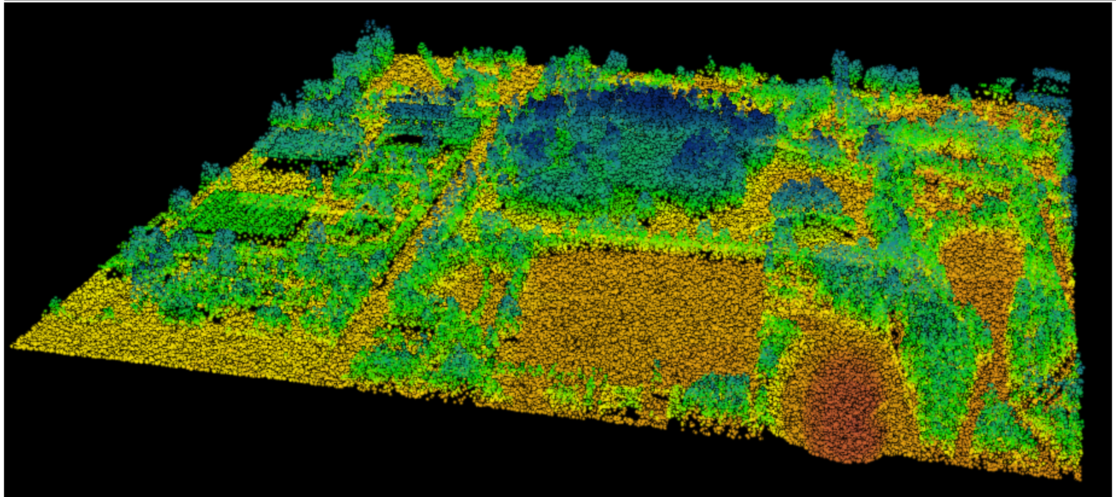
- A laser impulse becomes larger during its way to the ground, describing a cone (Footprint) (0.2-70m)
- Recent LiDAR sensors can record multiple returns for each impulse and penetrate non-uniform surfaces, such as vegetation
- Each return is discretized in a point
- The result is a highly dense point cloud



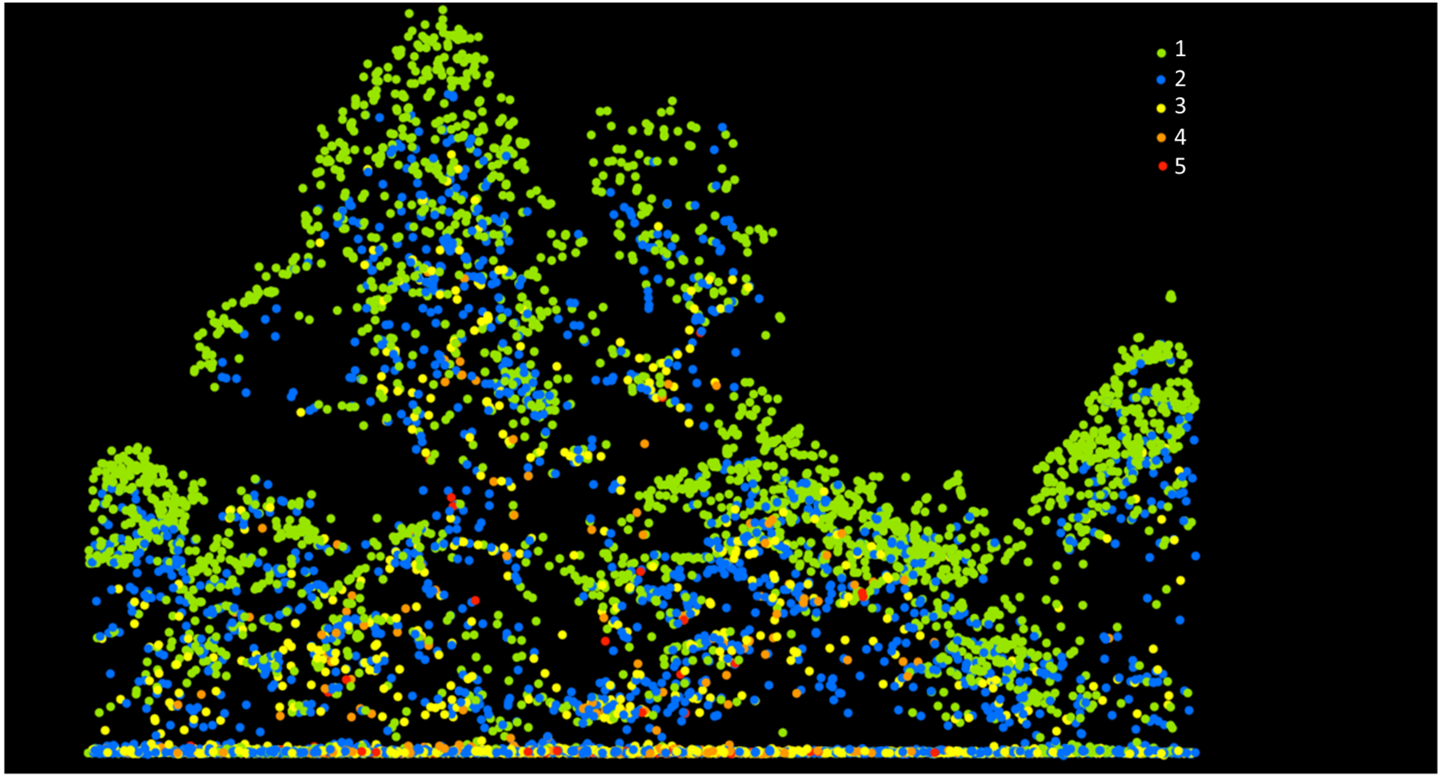
LiDAR

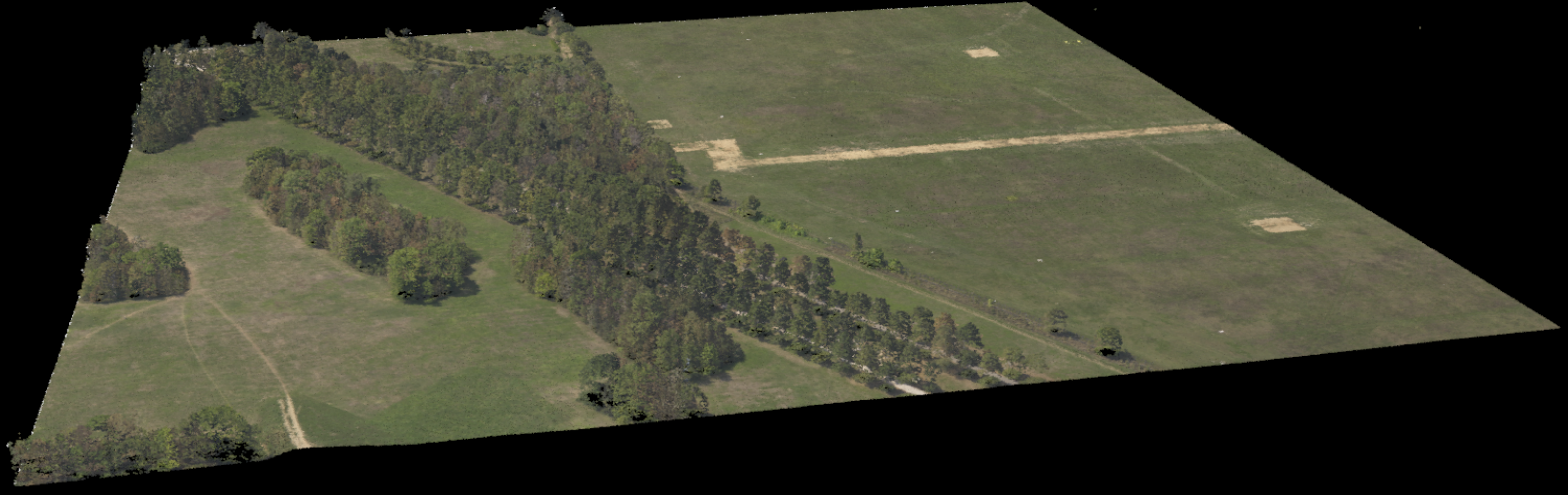
- 3D point cloud representing the portion of the earth surface scanned
- Accurate profile of forested areas
- Point density and number of returns depend on sensor frequency and flight condition
- In LAS files additional features for each point are stored (return number, classification, scan angle, RGB, etc.)



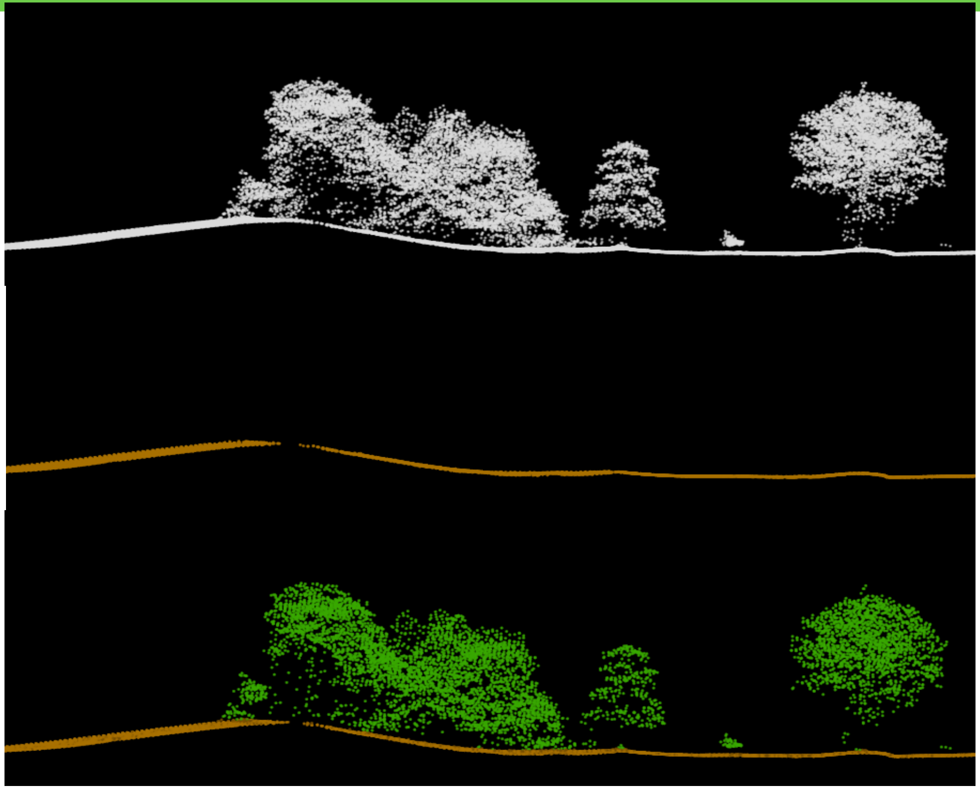


LiDAR

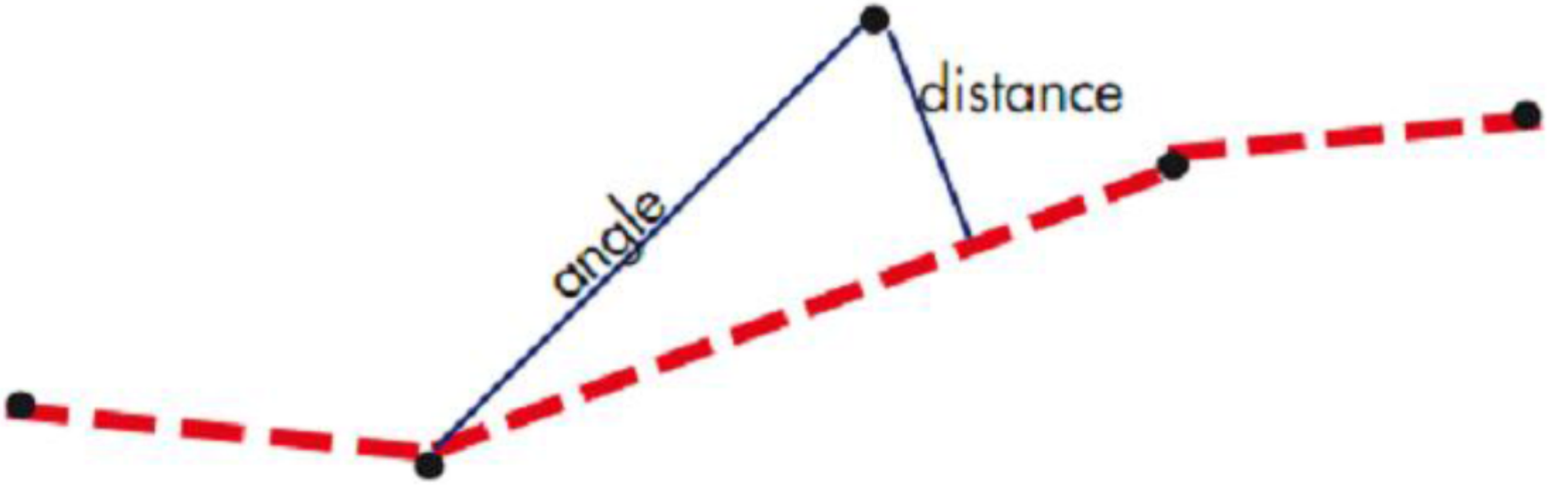




Preprocessing



Preprocessing: Ground points



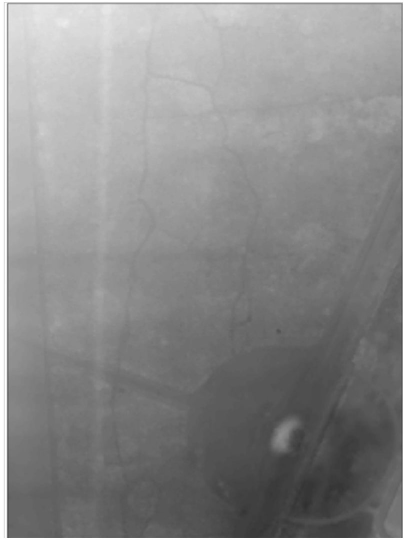
In ground point iteration user-defined parameters decide if points belongs to ground or not.

Processing: surface models

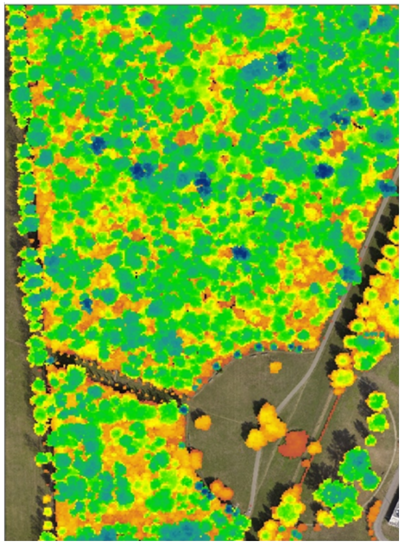
Digital models (raster) :

- *Digital Terrain Model*
- *Digital Surface Model*
- *Canopy Height Model*

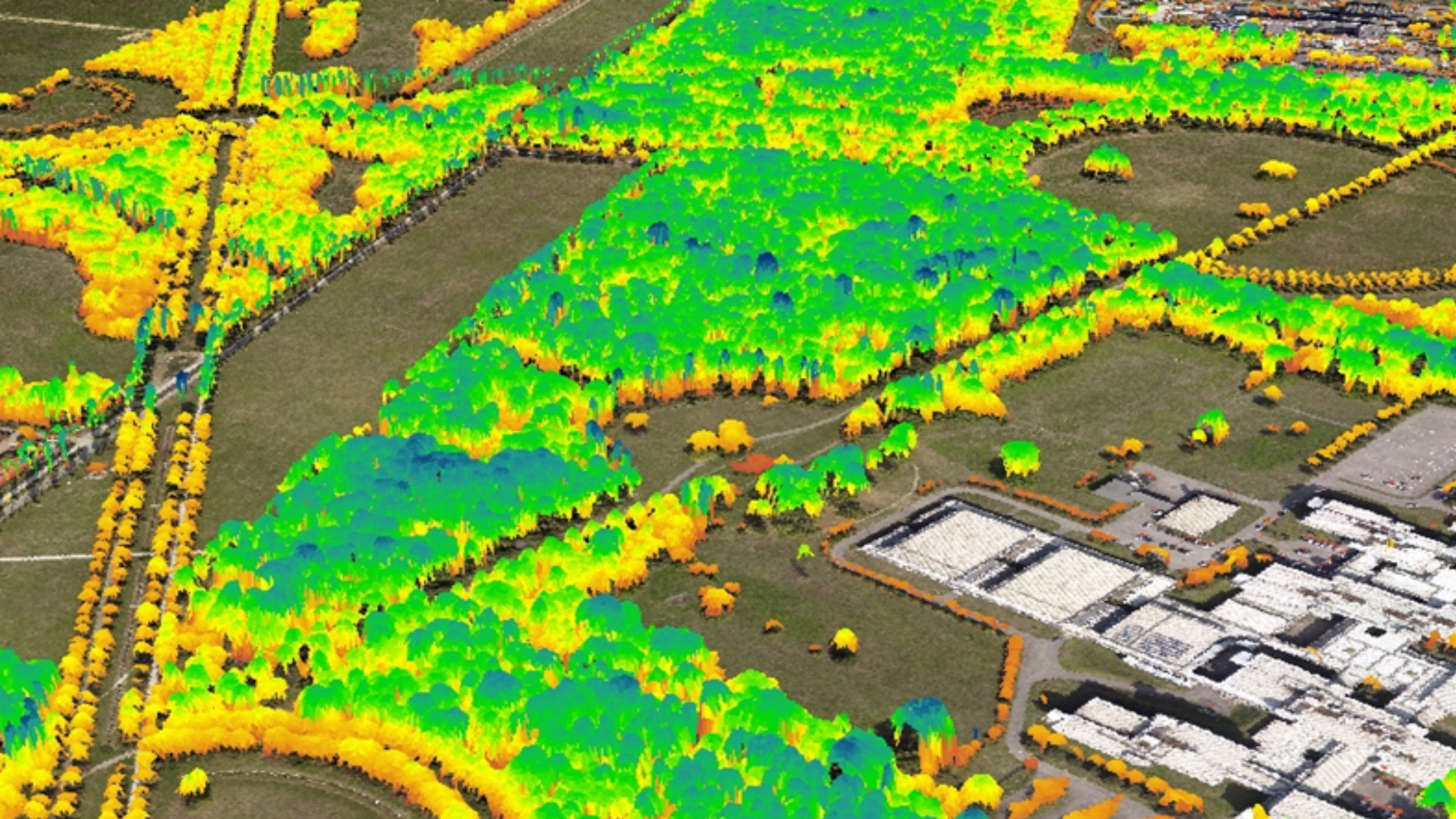
ORTHOPHOTO



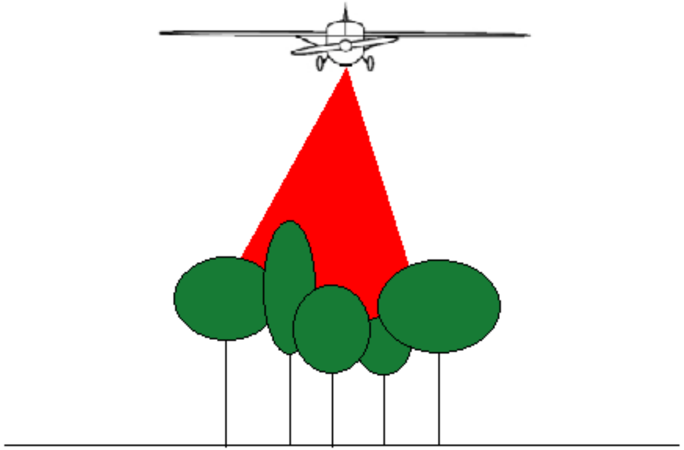
DTM



CHM



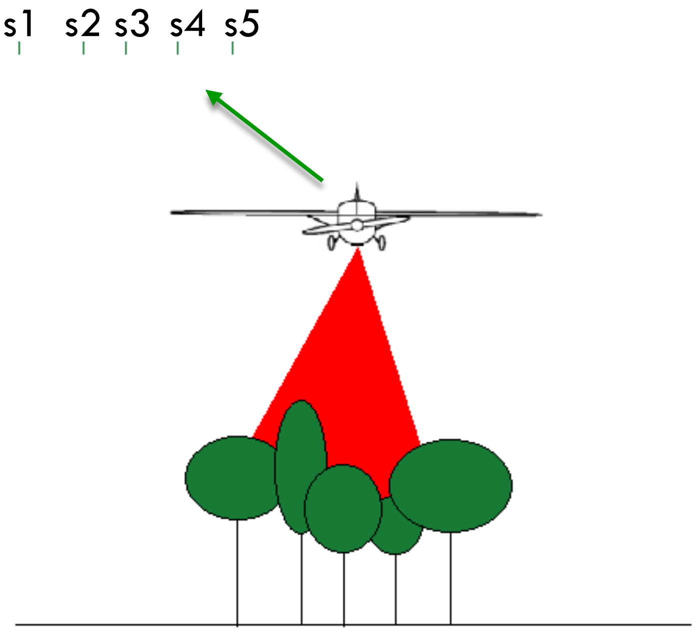
LiDAR applications in forestry



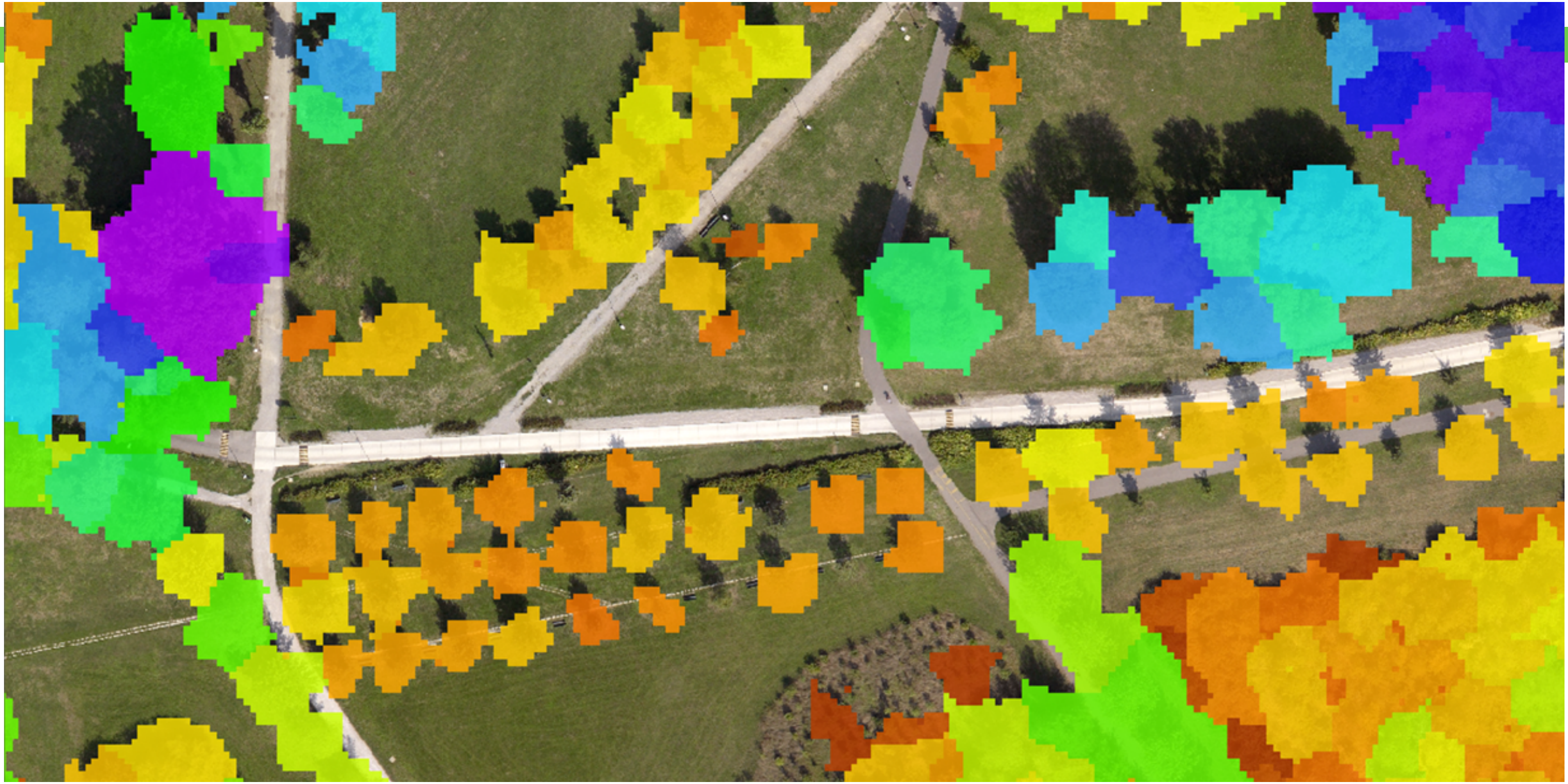
LiDAR applications in forestry

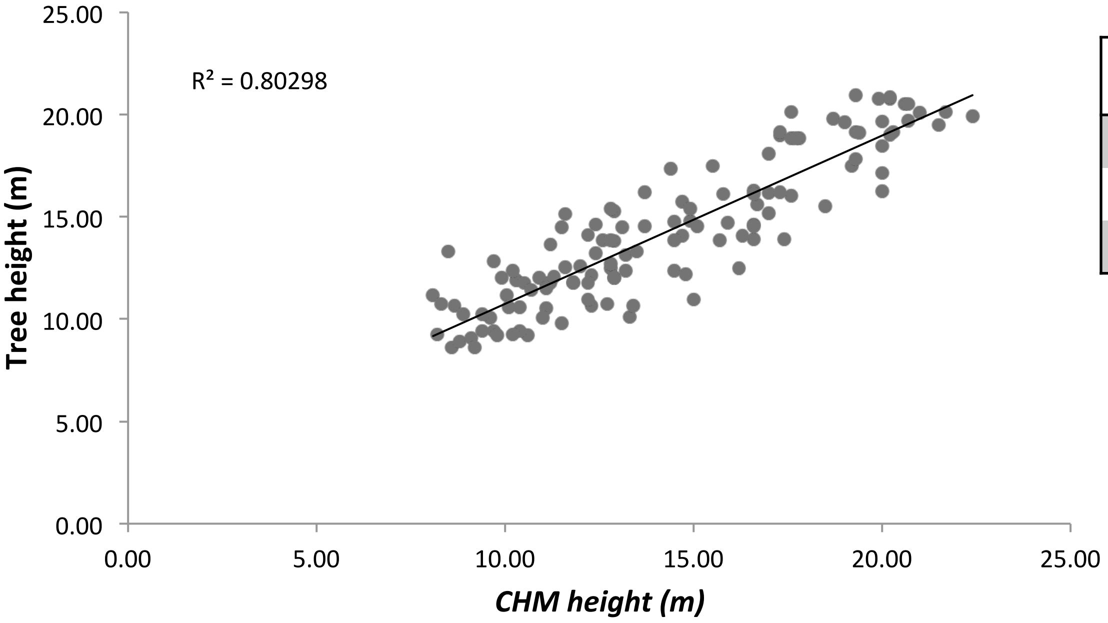
Single tree approach

- Tree segmentation
- Tree species detection
- Individual tree biophysical characteristics (DBH, H, Crown diameter)
- …



LiDAR applications in forestry





	Mean	Max	Min	σ
H Field	14.28	22.40	8.09	3.78
H CHM	14.26	20.96	8.59	3.47
Delta	0.02	1.44	-0.50	0.31

LiDAR applications in forestry

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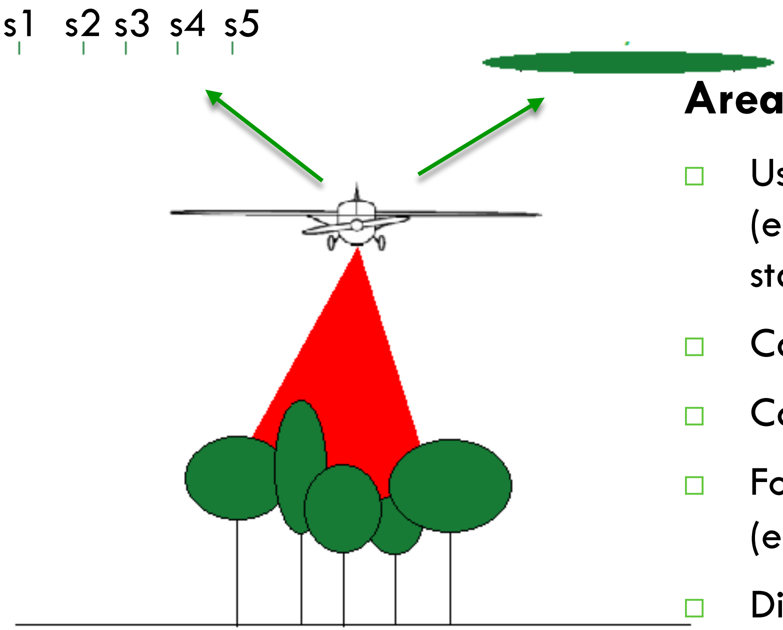


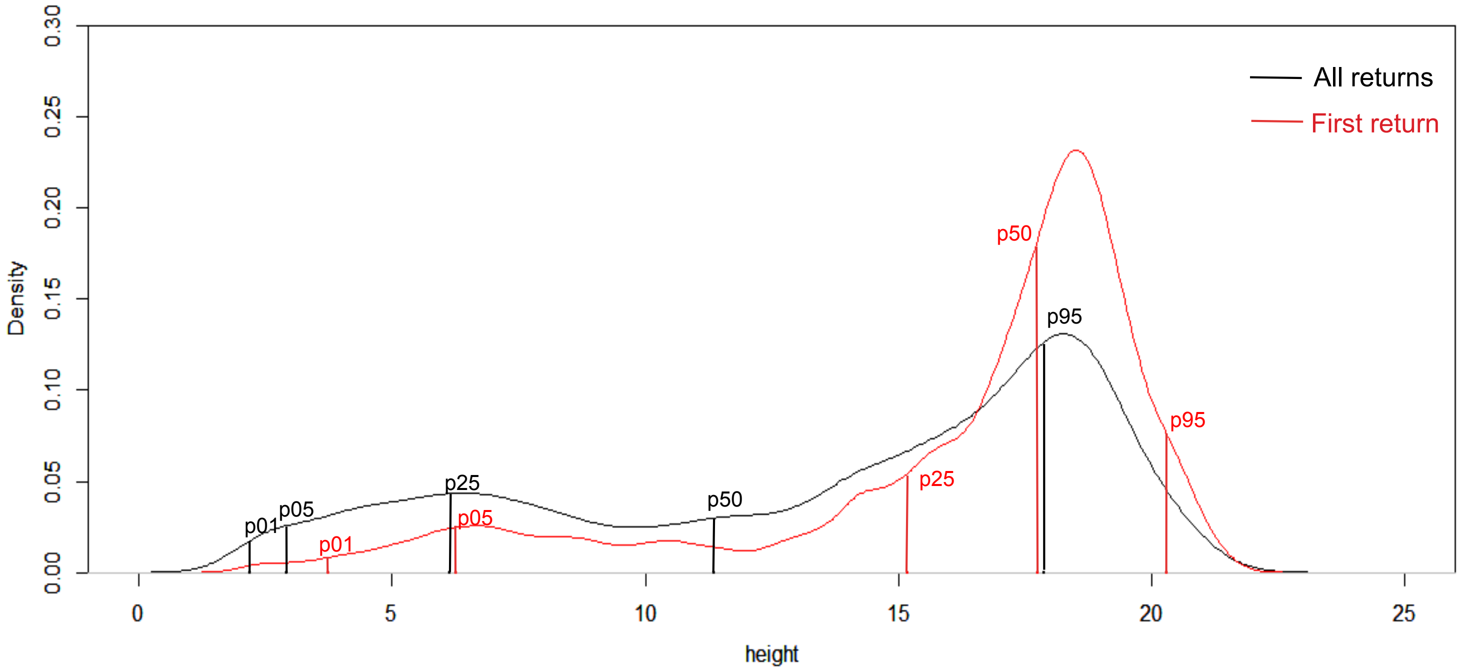
Area-based approach

- Use of **LiDAR-derived metrics** (e.g. percentiles, descriptive statistics, indices, etc.)
- Canopy cover
- Calculation of biomass/ha
- Forest stand level classifications (e.g. sp. composition, density)
- Diversity indices detection
- …

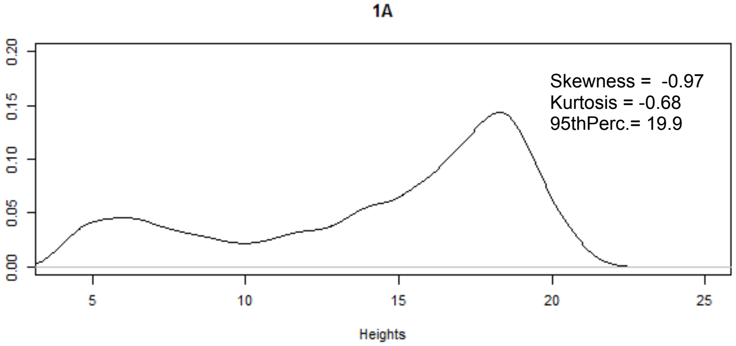
LiDAR metrics

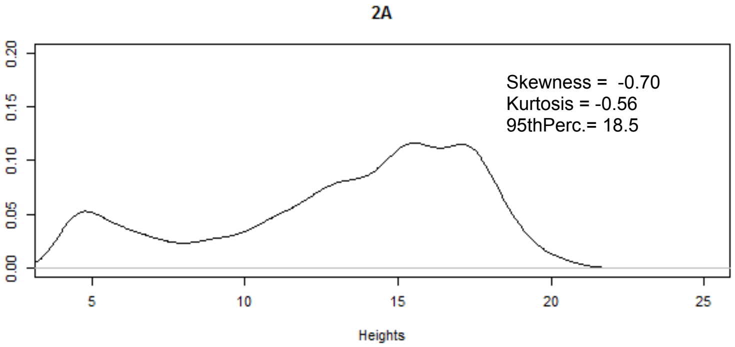
Examples of LiDAR-derived metrics (descriptive statistics)	
95th percentile height of first returns (m)	Similar to maximum height but less sensitive to anomalously high points.
Skewness of all returns	A measure for the degree of symmetry in the Point-cloud density distribution.
Kurtosis of all returns	A measure for the degree of peakedness/flatness in the Point-cloud density distribution.

LiDAR metrics

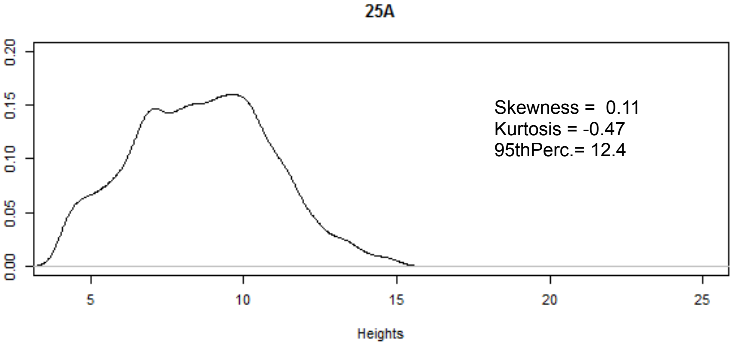


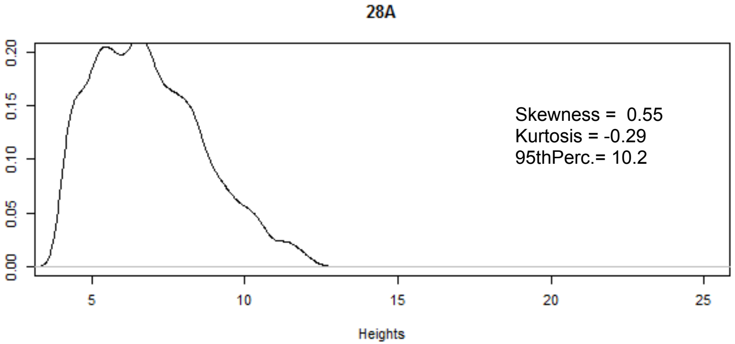
“Mature” stands → negatively skewed





“Young” stands → positively skewed





LiDAR metrics

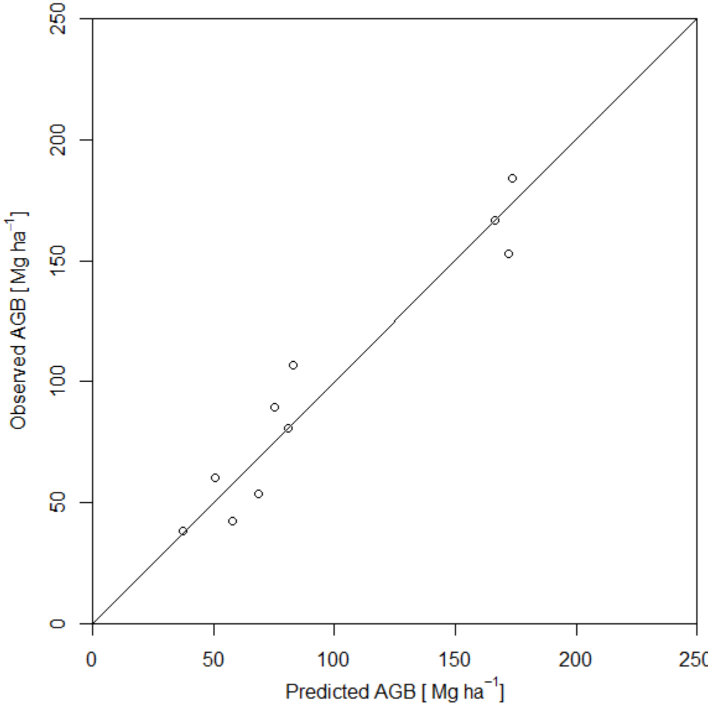
Examples LiDAR-derived metrics (indices)	
Canopy density index	The canopy density is computed as the number of all points above the cover cutoff divided by the number of all returns.
Canopy cover index	The number of first returns above the cover cutoff divided by the number of all first returns.
Vegetation permeability	Proportion of first returns for which there is a second (either vegetation or ground) return; higher proportion of these dual returns indicates more light energy penetrating the canopy.

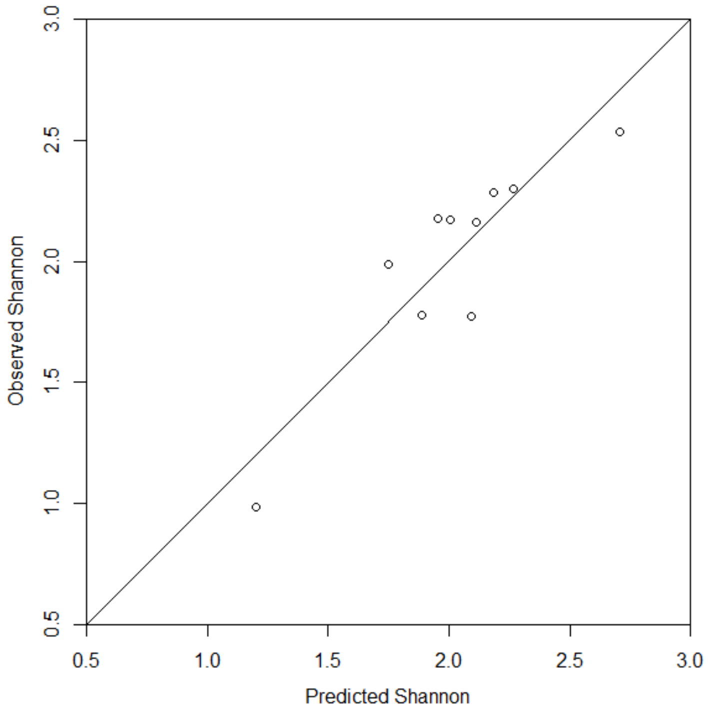
MODELS: BIOPHISICAL PARAMETERS

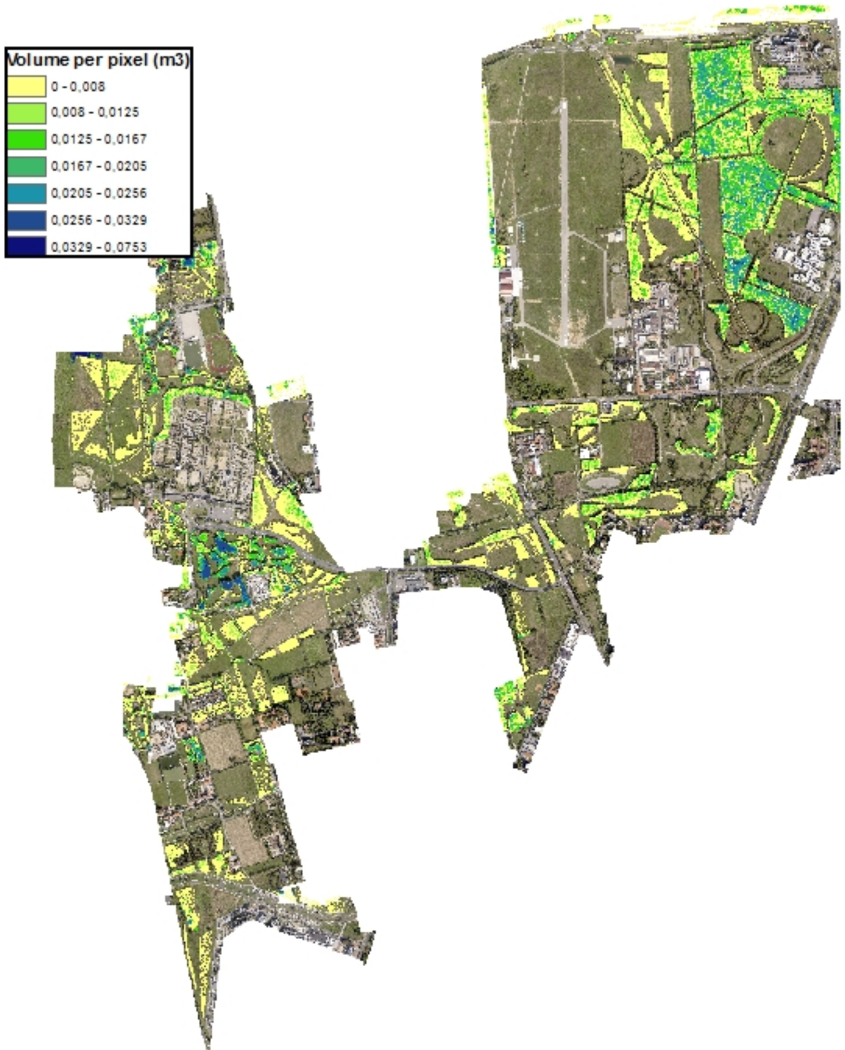
Models ($p<0.005$)	β_0	β_1	β_2	β_3
$ln(AGB) = \beta_0+\beta_1 ln(p95\_all)+\beta_2 ln(p01\_first)+\beta_3 ln(p25\_first)$	6.3746	1.4907	-0.7169	0.7969
$Shannon = \beta_0+\beta_1 ln(kurtosis\_first)+\beta_2 ln(p01\_first)+\beta_3 ln(p25\_first)$	0.85199	0.44057	0.50977	-0.17491

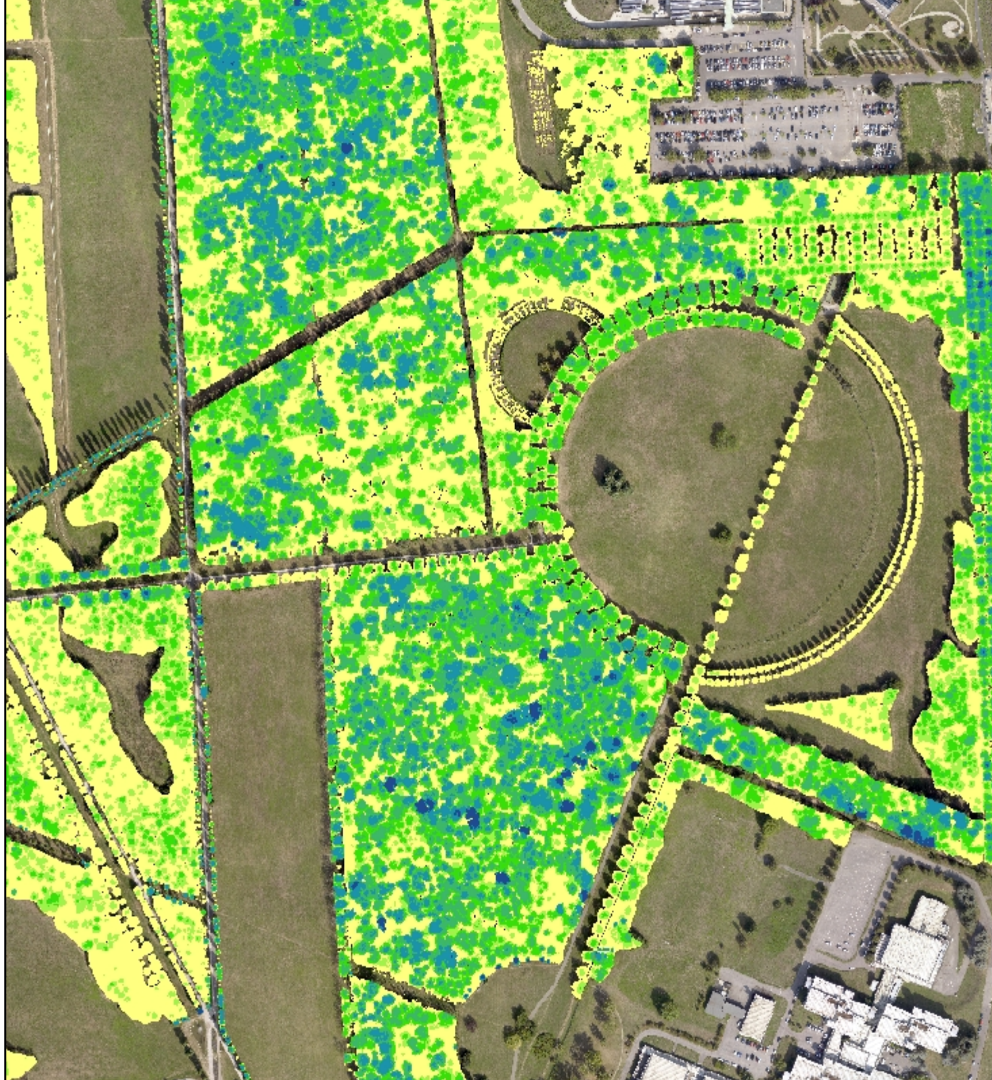
Models ($p<0.005$)	*RMSE*	*RMSEcv*	*normRMSE*	*normRMSEcv*	*adj*R^2
AGB	13.5 [Mg h^{-1}]	26.6 [Mg h-1]	0.0925	0.183	0.84
Shannon Index	0.18	0.39	0.12	0.25	0.7

MODEL ACCURACY






Volume per pixel (m3)
0 - 0,008
0,008 - 0,0125
0,0125 - 0,0167
0,0167 - 0,0205
0,0205 - 0,0256
0,0256 - 0,0329
0,0329 - 0,0753



LiDAR: summary

Advantages

- High accuracy in estimation of biophysical parameters correlated with structural characteristics of forest stand
- Less expensive compared to field surveys (only limited field surveys are needed)
- Great potential in combination with other type of data (e.g. Multi- or Hyperspectral data)

Limitations

- Low accuracy in estimating understory vegetation's biophysical characteristics
- Limited by $< 50\%$ veg. cover
- Very low biochemical information about the scanned surface (as opposed to optical passive sensors)

MICHIGAN STATE UNIVERSITY

This presentation was made available through collaborations in the Landscape Ecology and Ecosystem Science Lab (LEES) at Michigan State University with University of Bari, Italy.

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http://lees.geo.msu.edu/