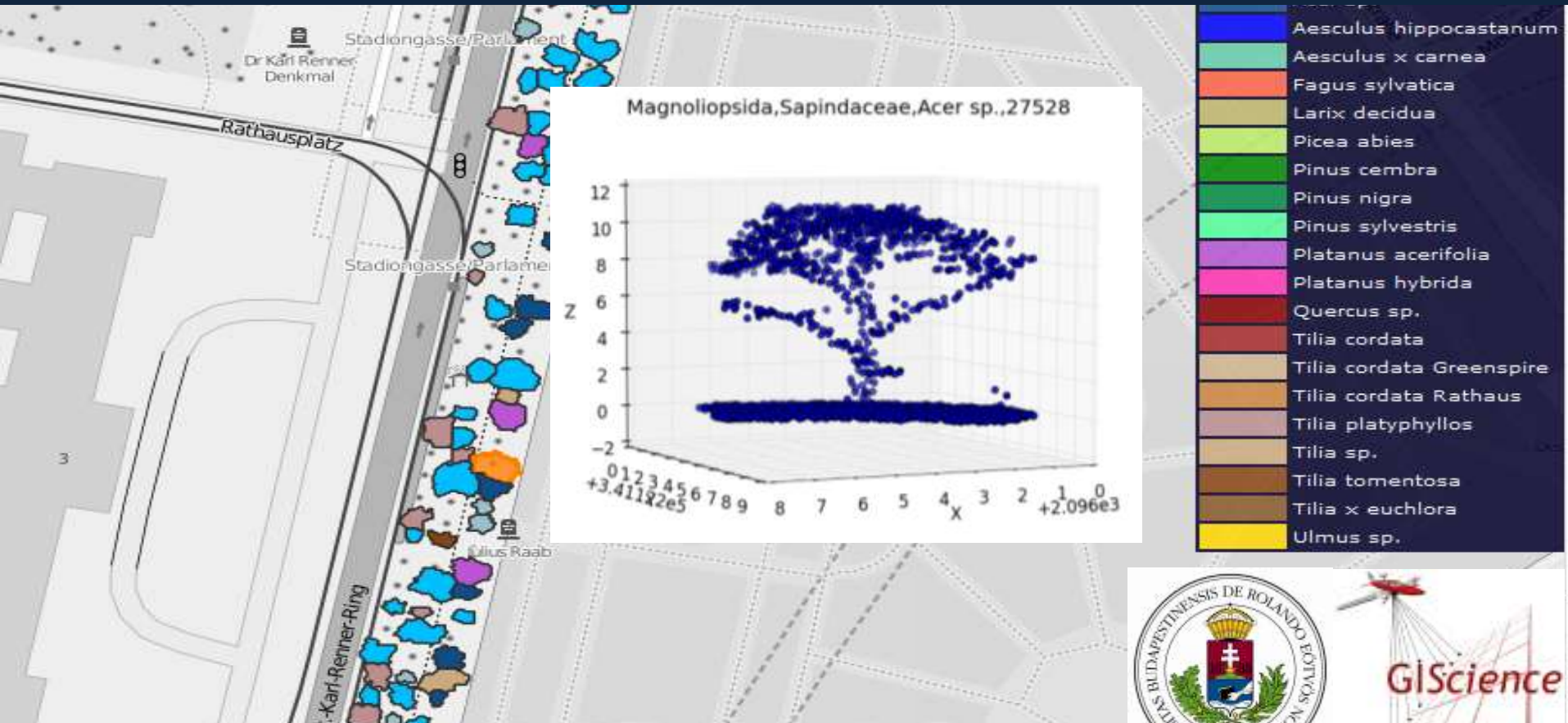# Object based tree classification in urban environment based on FWF Airborne Laser Scanning

Zsófia Koma[1], Kristina Koenig[2], Bernhard Höfle[2]
(1) Eötvös Loránd University, Department of Geophysics and Space Science
(2) Heidelberg University, Institute of Geography, GIScience Research Group, Heidelberg, Germany

- Background: **L**iDAR **V**egetation **I**nvestigation and **S**ignature **A**nalysis system project **http://lvisa.geog.uni-heidelberg.de**
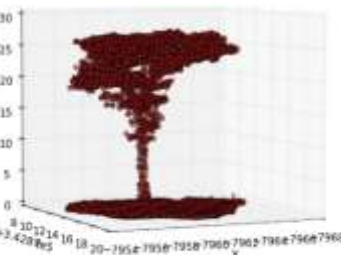
Aim: **Can be build a automatic classification system based on object based segmented trees for mapping purposes in urban environment? Analysis the limitation of geometric and radiometric features behavior in urban environment.**
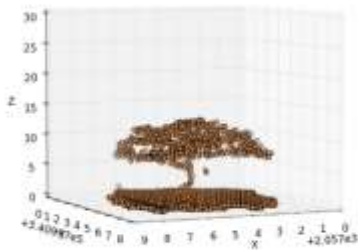
Importance of the topic:

- Automatic ways to determine taxonomy type of urban trees (where we don't have field measurements data)
- → mapping cadastre
- → more information for biologist
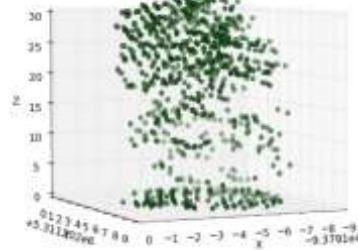- Integrate LiDAR datasets and used for vegetation analysis and accessible public
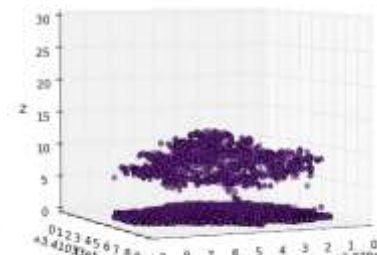

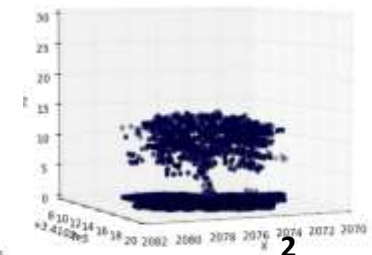Magnoliopsida,Fagaceae,Fagus sylvatica,44608 · Magnoliopsida,Malvaceae,Tilia platyphyllos,711 · Pinopsida,Pinaceae,Picea abies,75609 · Magnoliopsida,Platanaceae,Platanus acerifolia,61 · Magnoliopsida,Sapindaceae,Acer platanoides,29
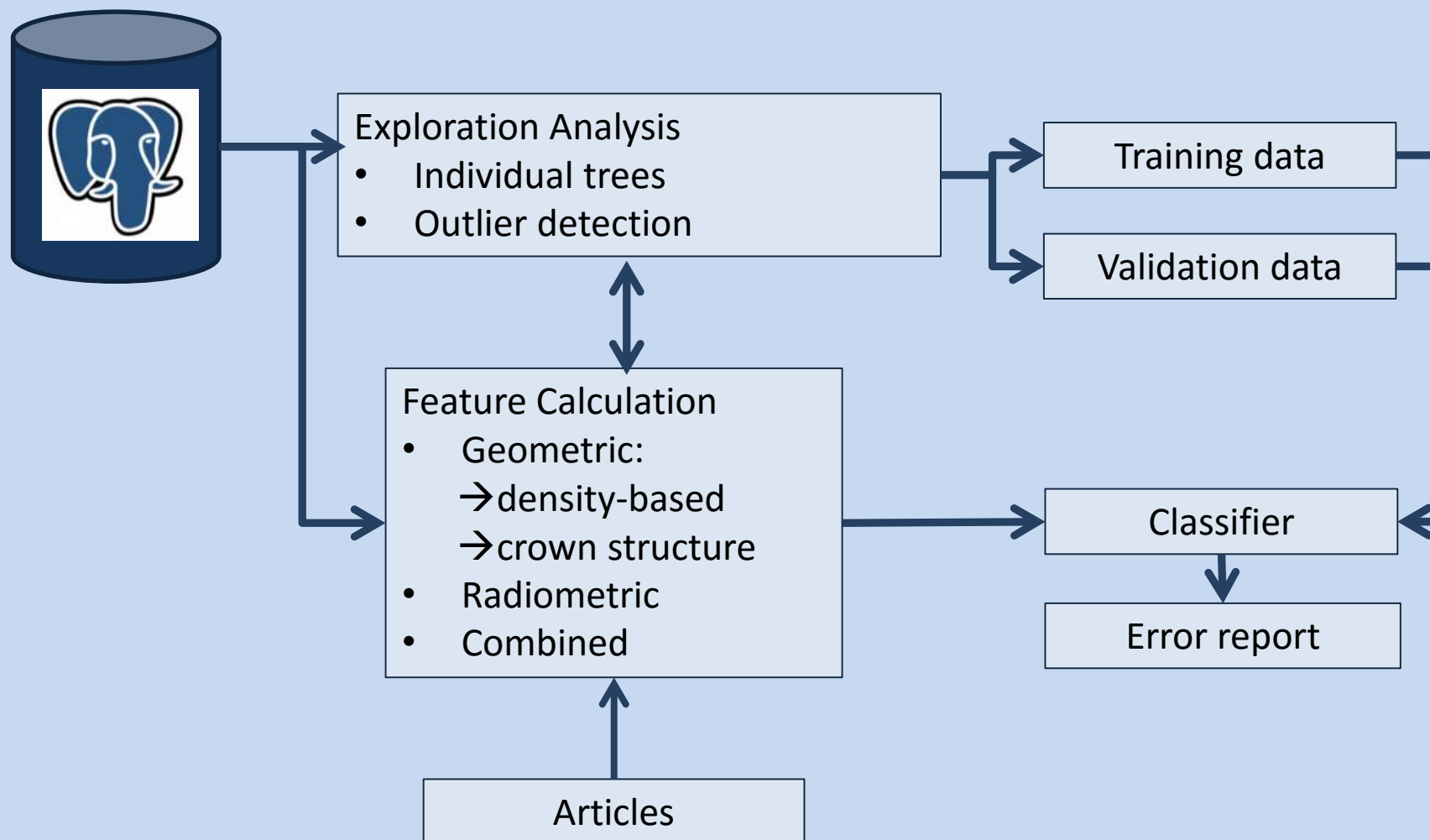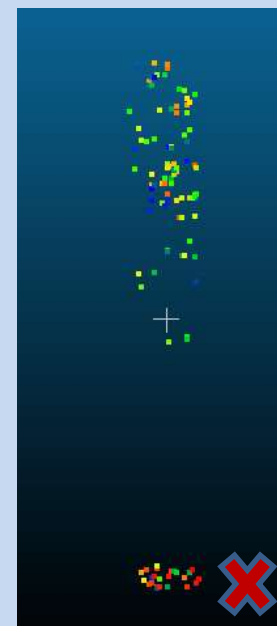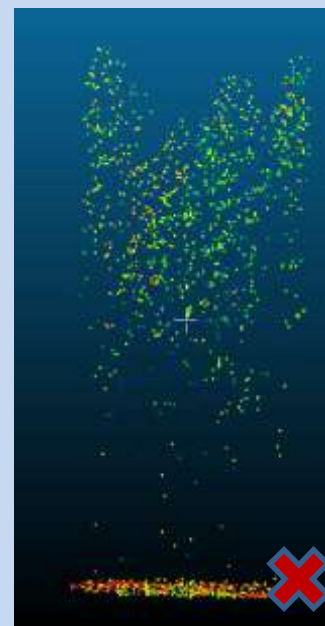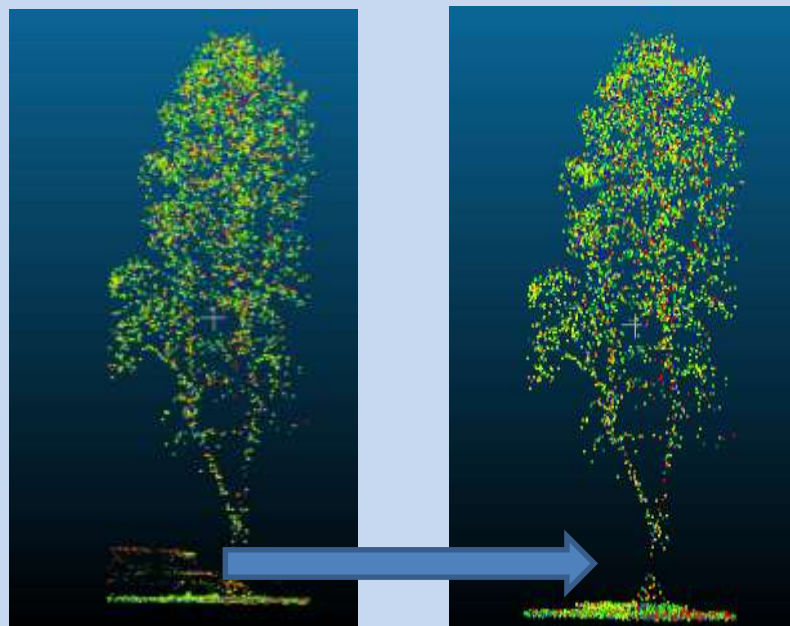
2

- Workflow
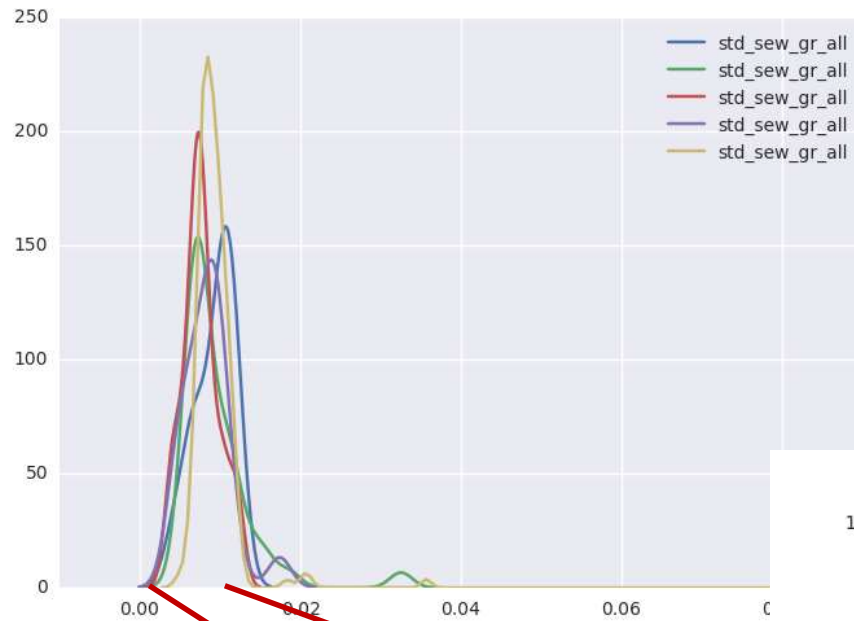
- Individual trees – segmentation reliability

Latin name	Magyar név	Without revision	Revised with trunk	Revised with gamma
Fagaceae	Bükkfaféle	75	39	12
Malvaceae	Mályvaféle	122	43	43
Pinaceae	Fenyőféle	66	31	27
Platanaceae	Platánféle	25	21	21
Sapindaceae	Szappanfaféle	497	174	174

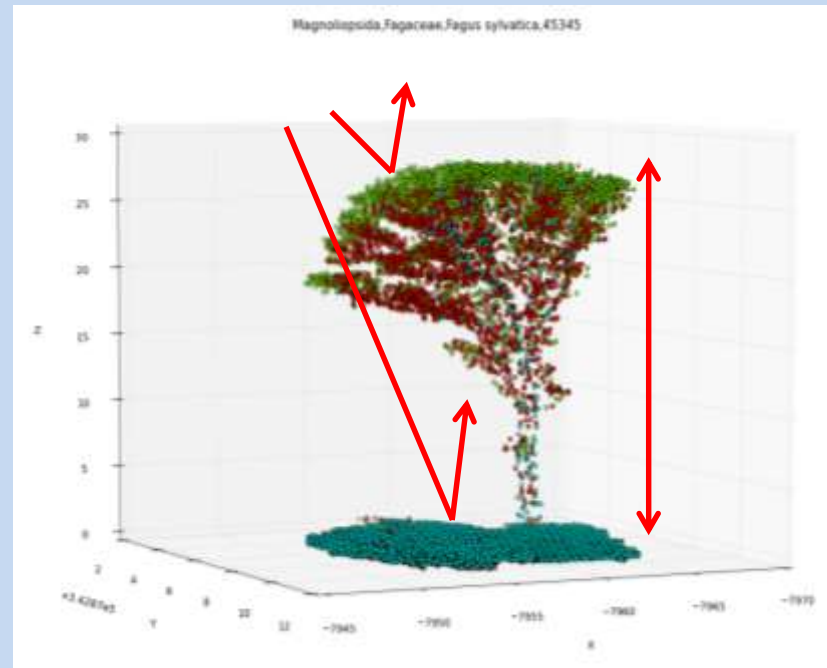- Segmentation reliability- effect of the interfering objects

With ground

Without ground
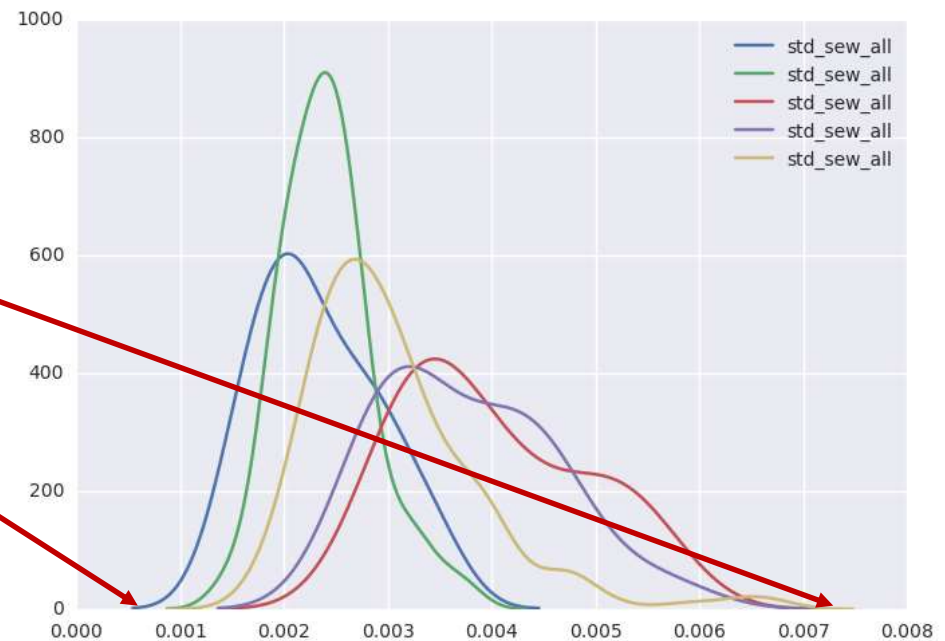
- Geometric features: density based and height statistics

First return
Second return
Third return

Pulse penetration ratio	Percentile of return density	Mean of height	Maximum of height
Ratio of first return to all return percentile	Point density above 2m or mean of height	Standard deviation of height	Percentile of height
		Range of height	Coefficient of variance of height

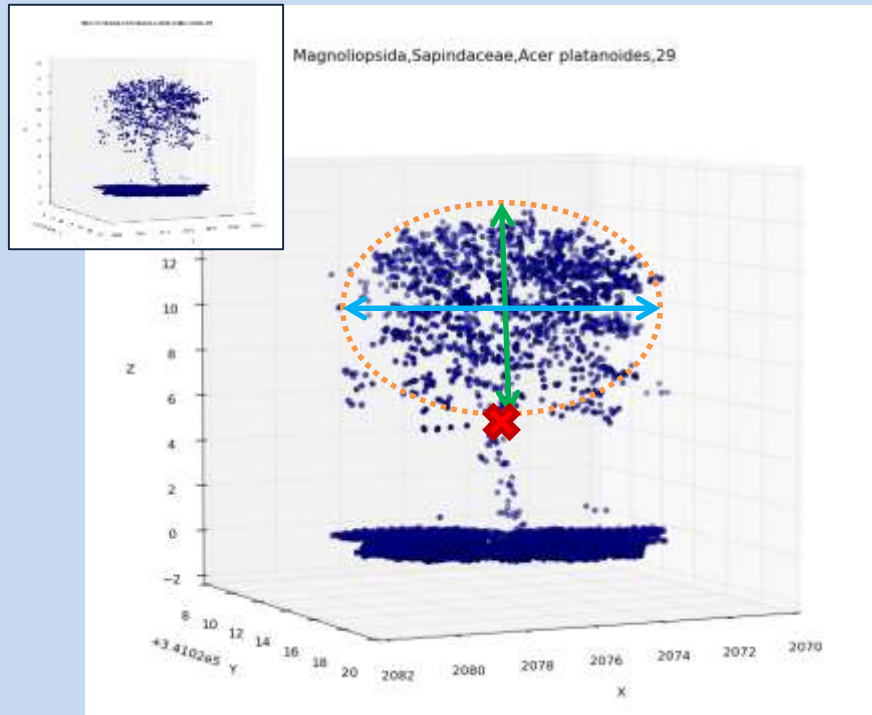| Pulse penetration ratio | Percentile of return density | Mean of height | Maximum of height |
| Ratio of first return to all return percentile | Point density above 2m or mean of height | Standard deviation of height | Percentile of height |
| | | Range of height | Coefficient of variance of height |

Boxplot grouped by family — perc_20

Boxplot grouped by family — pulse_pen_ratio

7
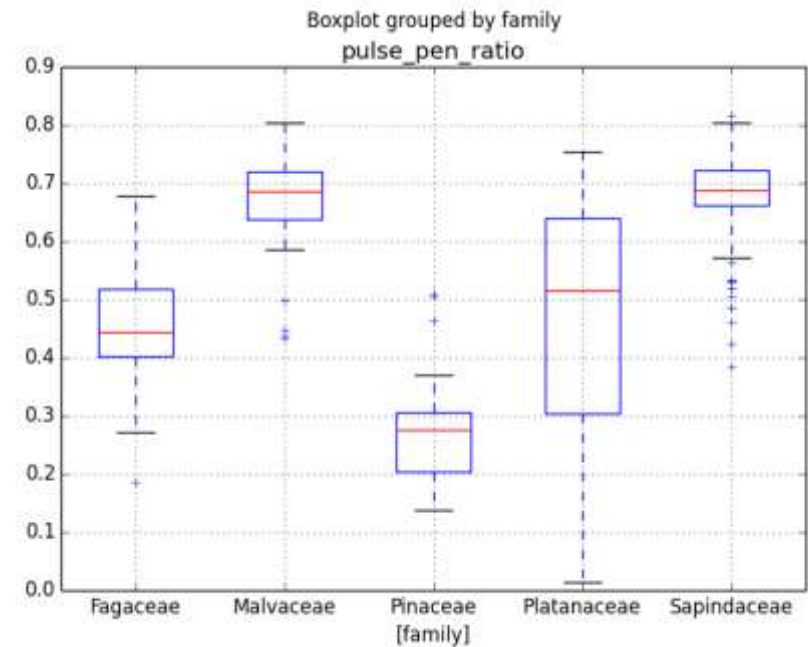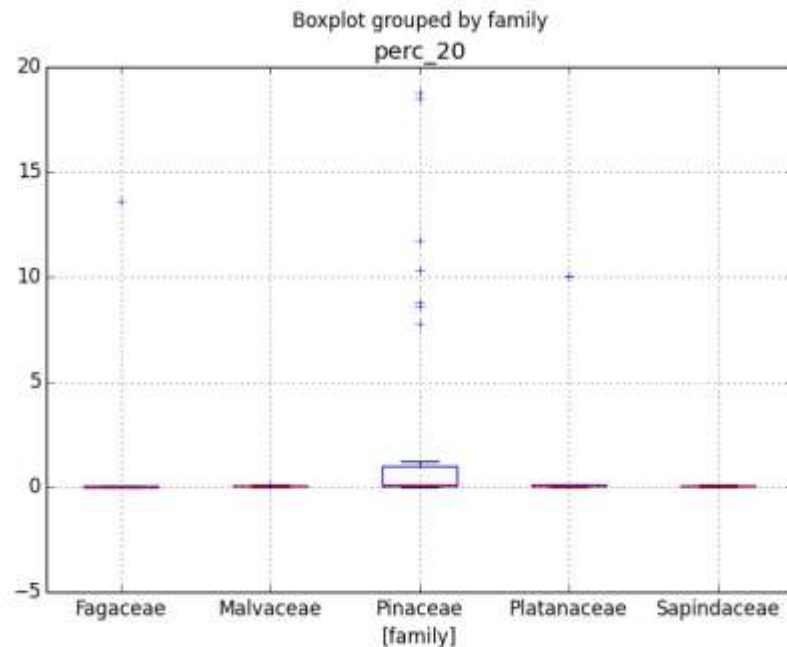
- Geometric feature: crown/tree structure based
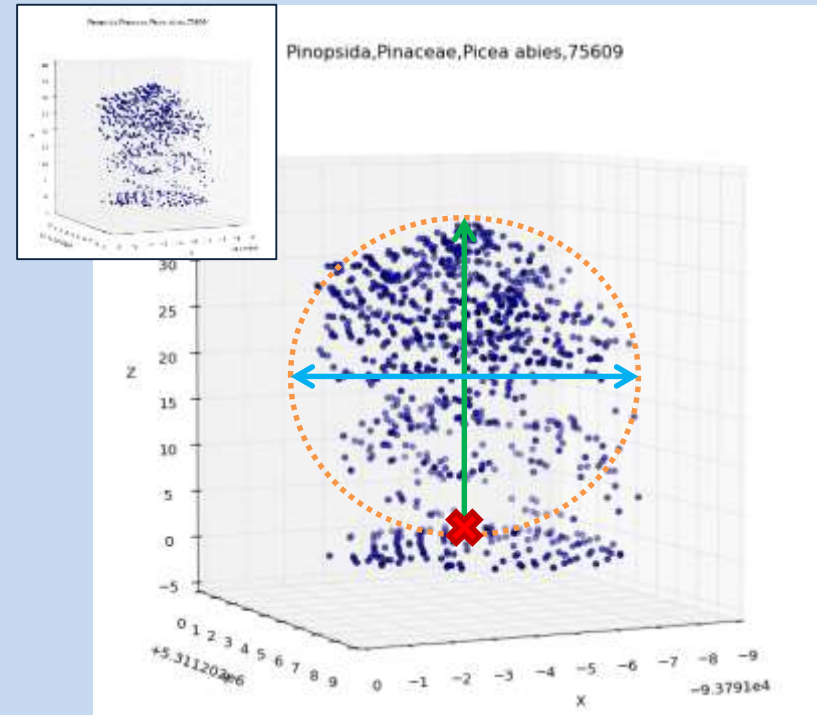
Magnoliopsida,Sapindaceae,Acer platanoides,29

Pinopsida,Pinaceae,Picea abies,75609

Crown area (2D)	Length-width ratio	Crown volume (3D) normalized by crown ratio
Canopy Base	Length-width ratio for crown depth	
Crown Depth		Crown volume (3D) normalized by tree height

- How to calculate canopy base (CB) ?

Magnoliopsida,Sapindaceae,Acer platanoides,29
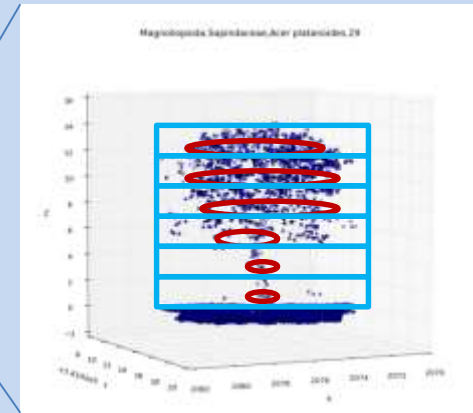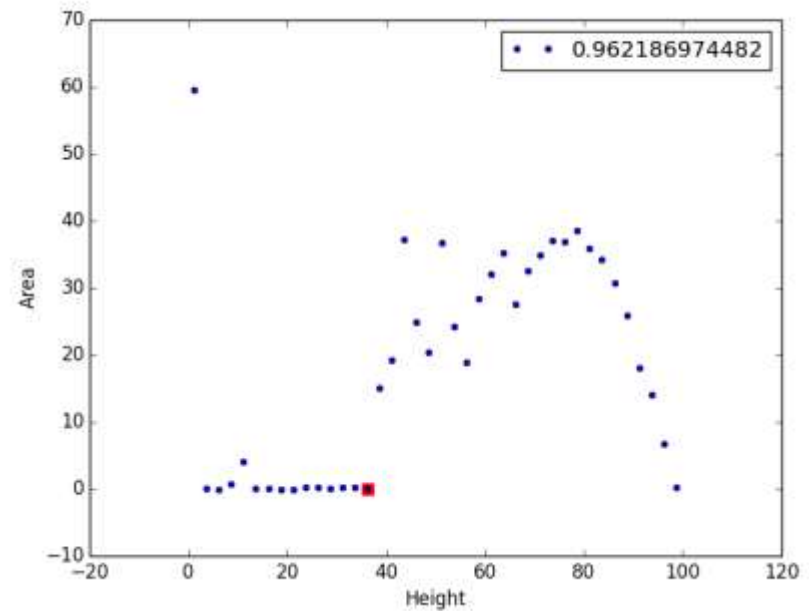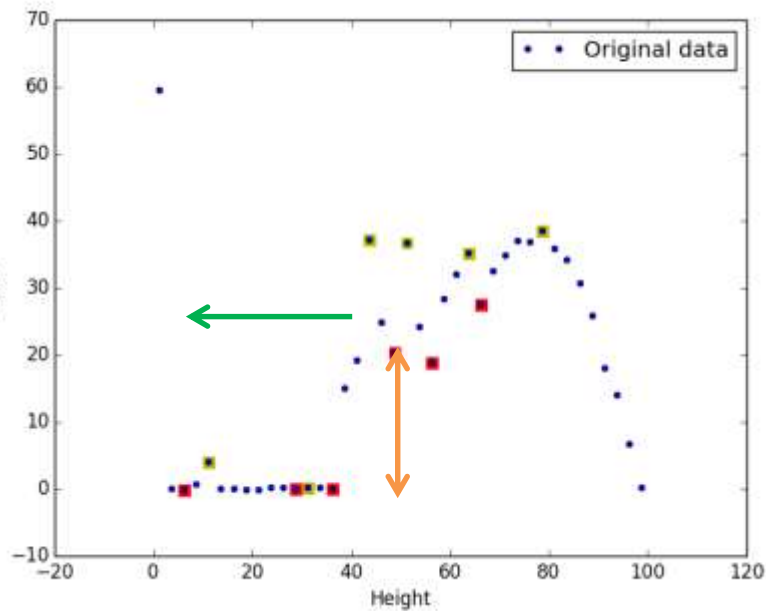
[x,y,z]
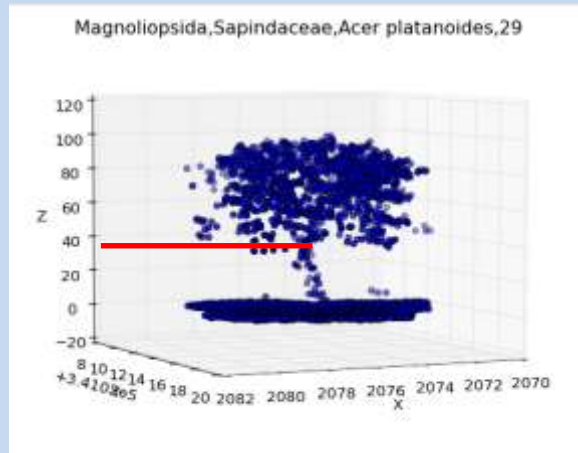
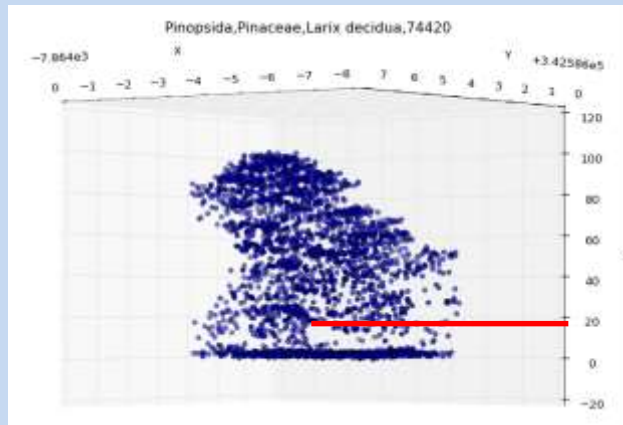Area calculation

Linear regression

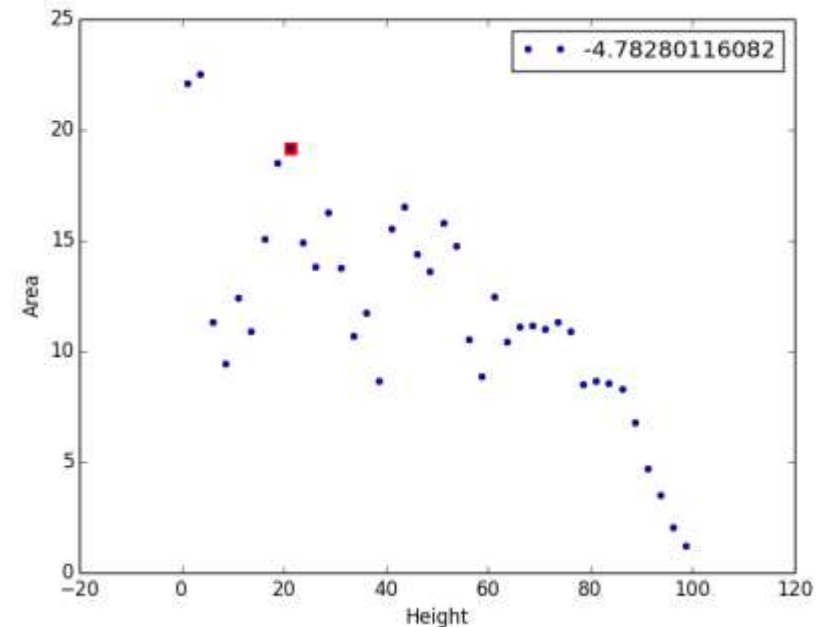$y=\textbf{m}x+b$

Area

Normalized height

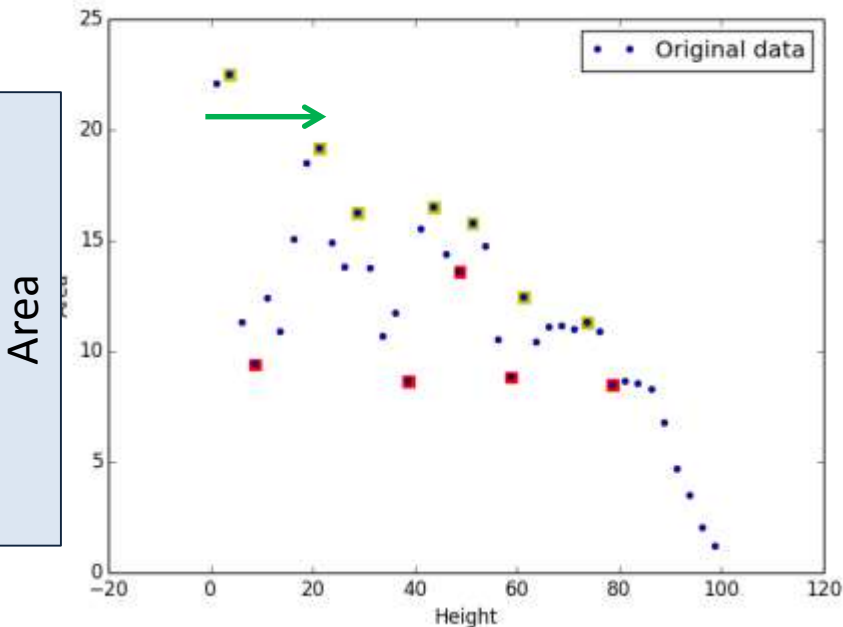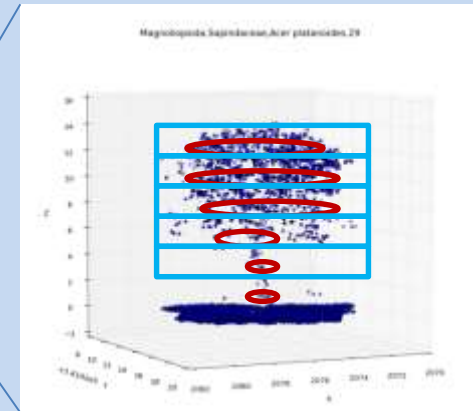- How to calculate canopy base (CB) ?
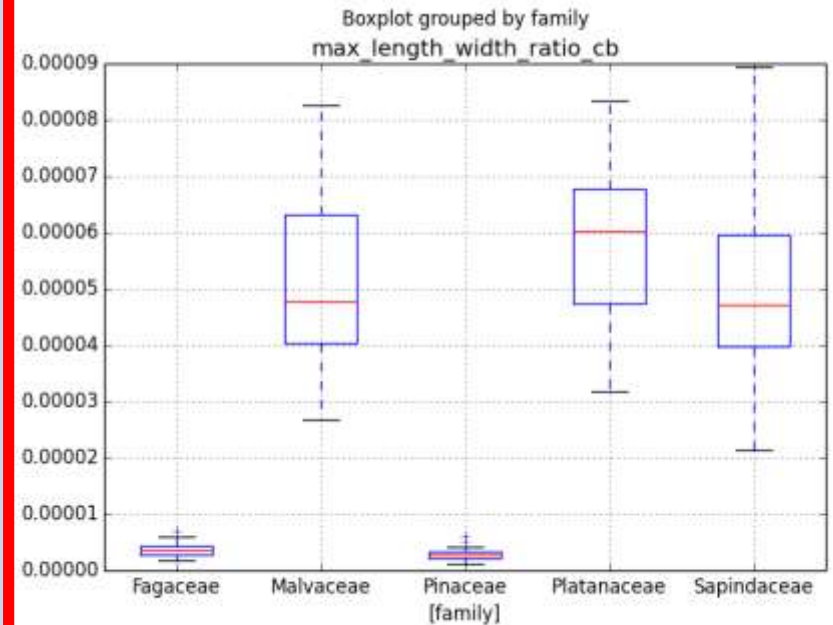

[x,y,z]

Area calculation

Linear regression

$y = -\mathbf{m}x + b$

Area
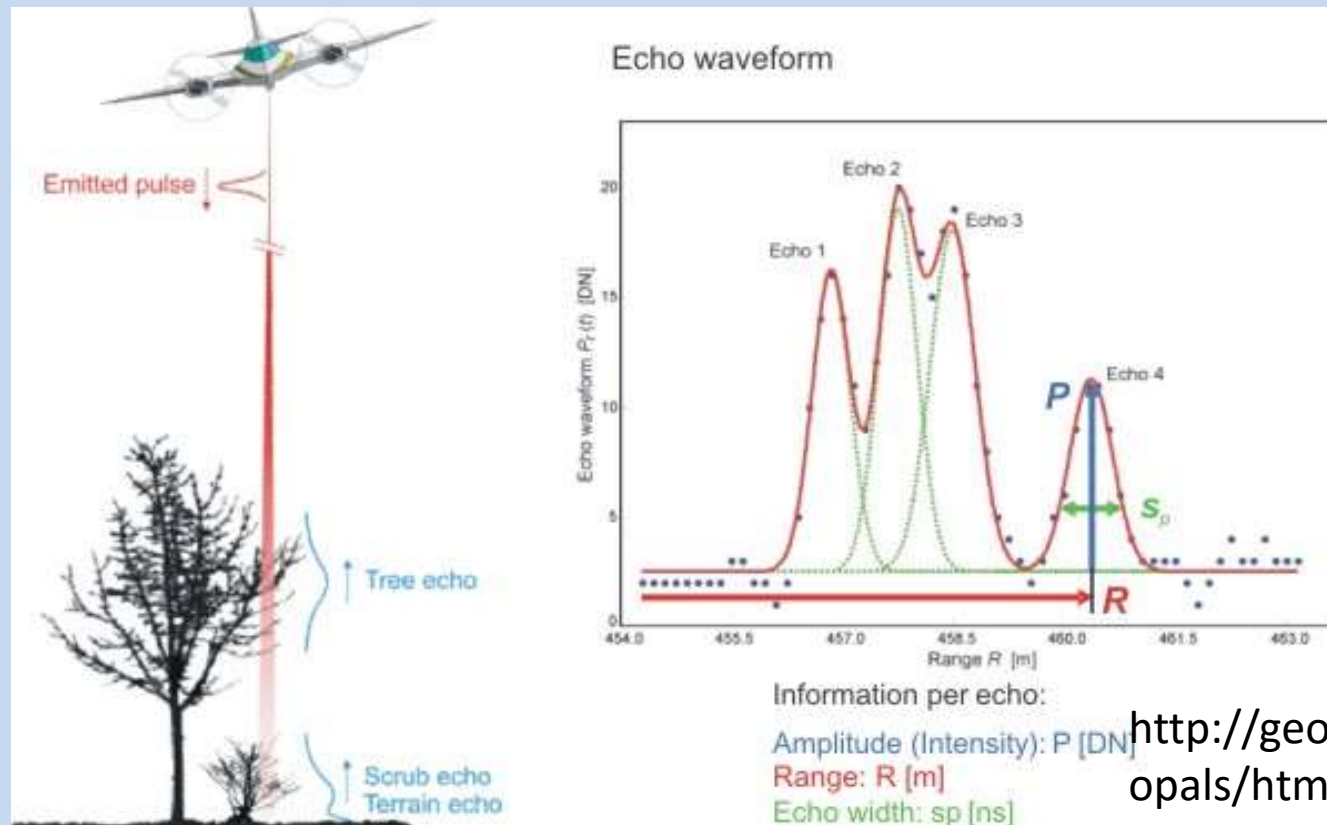
Normalized height

Crown area (2D)

Length-width ratio

Crown volume (3D) normalized by crown ratio

Canopy Base

Length-width ratio for crown depth

Crown Depth

Crown volume (3D) normalized by tree height

Boxplot grouped by family
cb_h

Boxplot grouped by family
max_length_width_ratio_cb

- Radiometric feature

Echo waveform

http://geo.tuwien.ac.at/opals/html/index.html
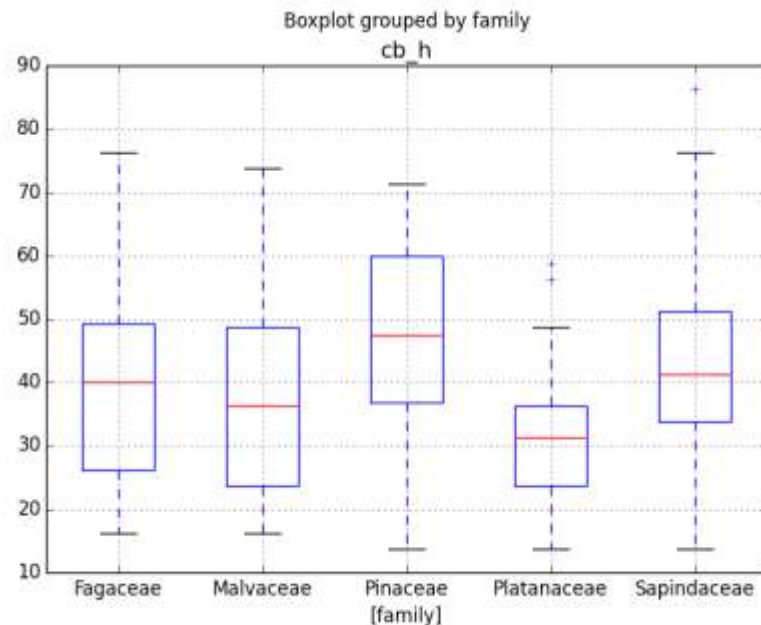
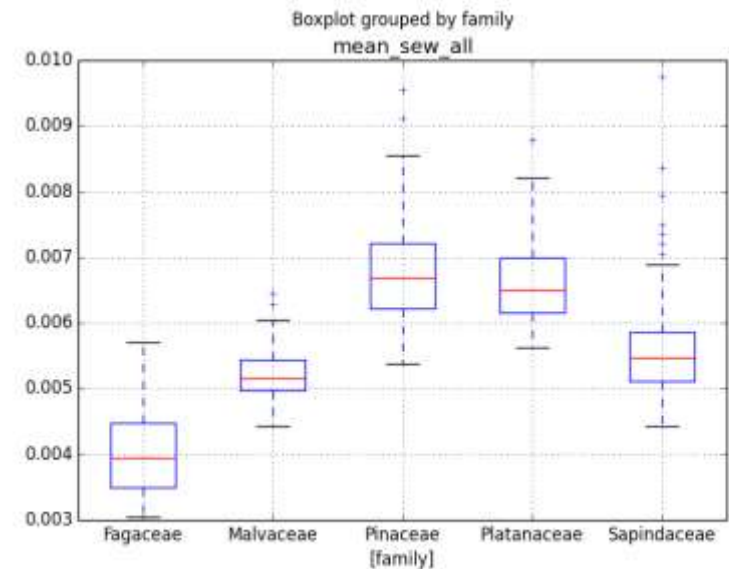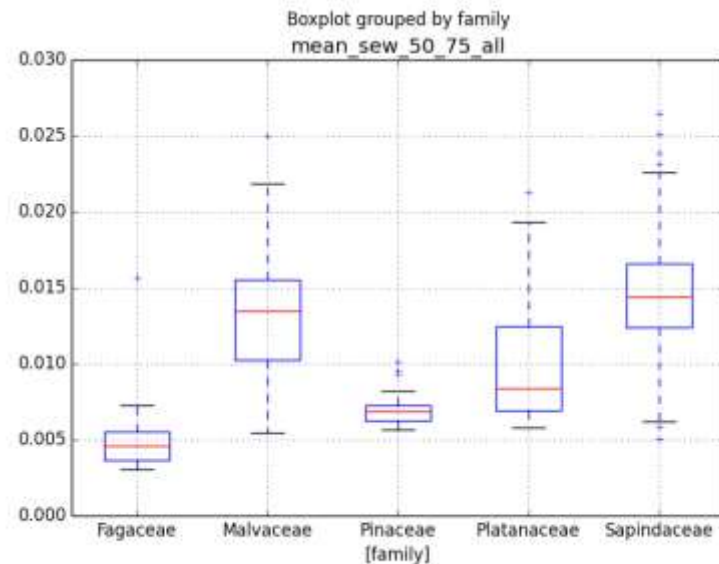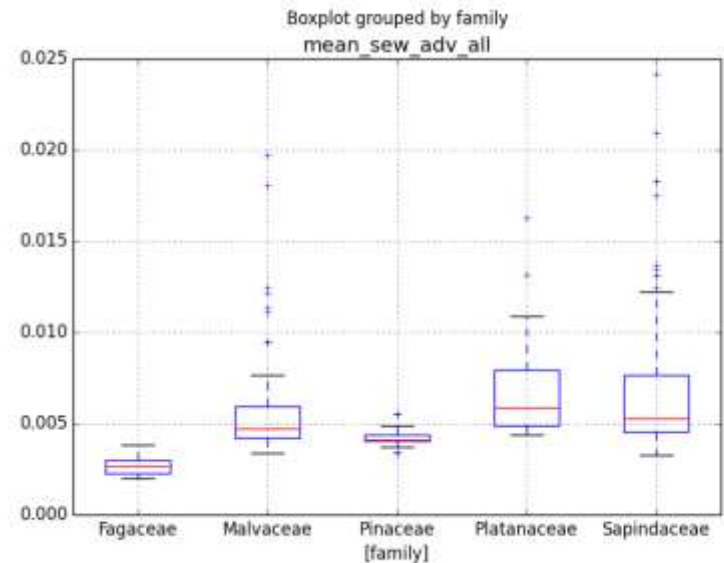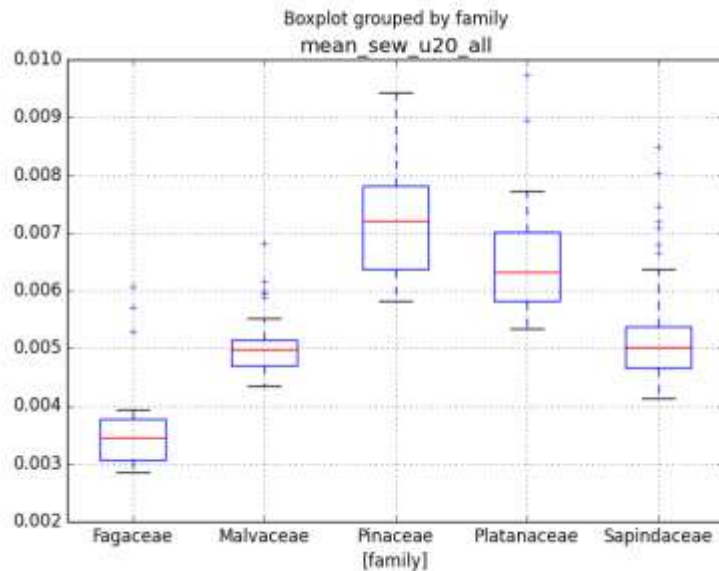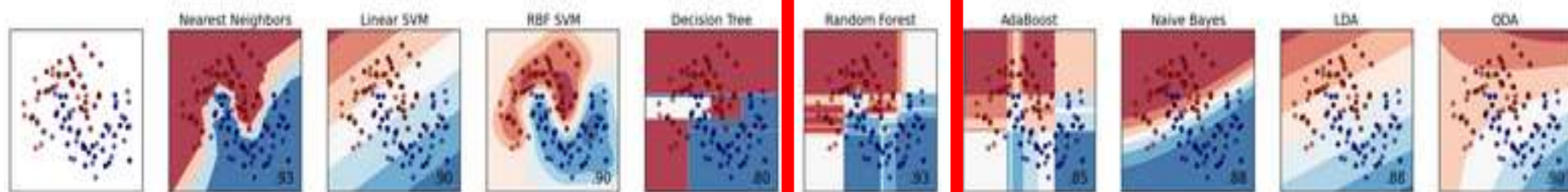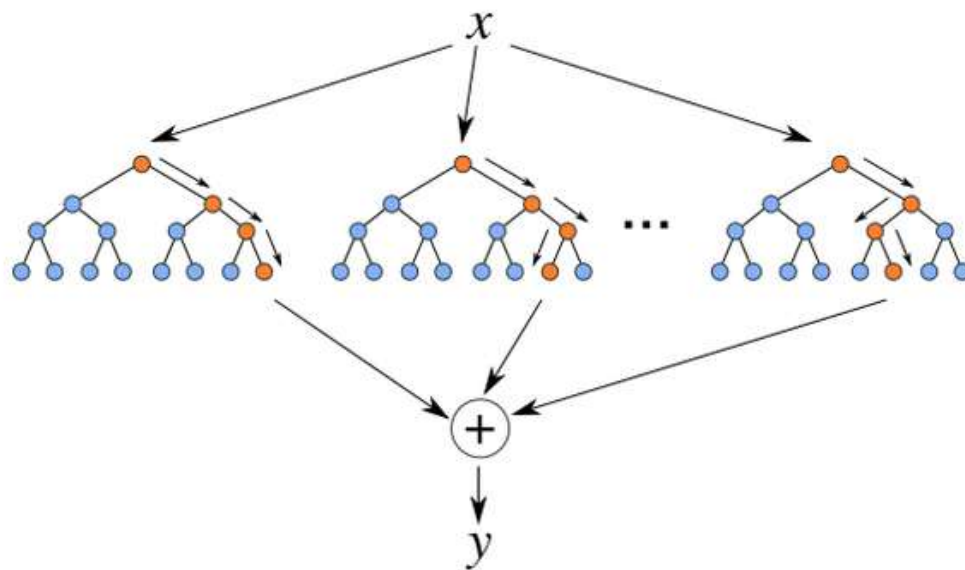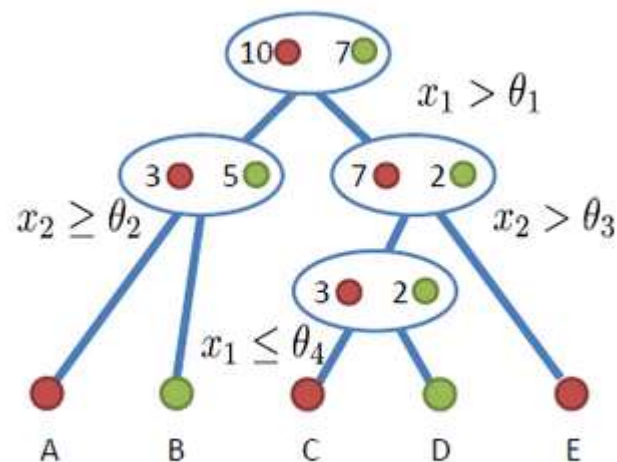| Echo width | Min, max, range, std, mean, coeffvar | Above 2m,CB |
Sigma	Min, max, range, std, mean, coeffvar	Above CB
Gamma	Min, max, range, std, mean, coeffvar	20-50,50-75 percentile
Amplitude		Upper 20th percentile

- Radiometric feature – effectivity depending on the part of the tree

Which classification method? Machine learning algorithm->Random Forest

1. only geometric features (point numbers and hieght percentiles etc.)

	Fagaceae	Malvaceae	Pinaceae	Platanaceae	Sapindaceae	User's Acc.	
Fagaceae	8	0	1	0	0	0.89	
Malvaceae	0	10	0	1	2	0.48	
Pinaceae	2	0	10	0	0	0.8	
Platanaceae	0	11	2	0	0	0	
Sapindaceae	0	5	0	0	9	0.64	
Producer's Acc.	0.8	0.38	0.77	0	0.64	Total samples	64
Cohen's Kappa	**0.46**	Overall Accuracy [%]	**0.57**	Overall Precision [%]	**0.49**	Recall [%]	**0.57**
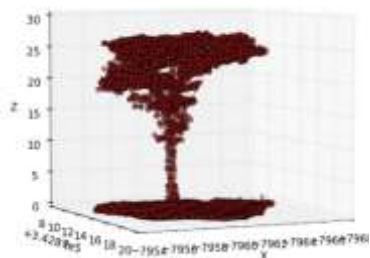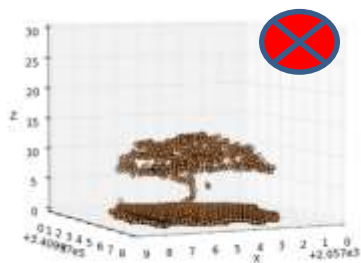
2. only crown features (canopy base, canop dith-lentgh-ratio etc.)

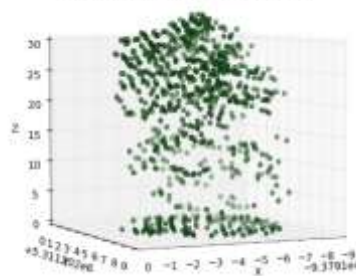|	Fagaceae	Malvaceae	Pinaceae	Platanaceae	Sapindaceae	User's Acc.	
Fagaceae	5	0	4	0	0	0.56	
Malvaceae	0	5	0	0	11	0.31	
Pinaceae	4	0	8	0	0	0.67	
Platanaceae	0	3	0	1	9	0.08	
Sapindaceae	0	3	0	0	11	0.79	
Producer's Acc.	0.56	0.45	0.67	1	0.35	Total samples	64
Cohen's Kappa	**0.33**	Overall Accuracy [%]	**0.46**	Overall Precision [%]	**0.59**	Recall [%]	**0.46**

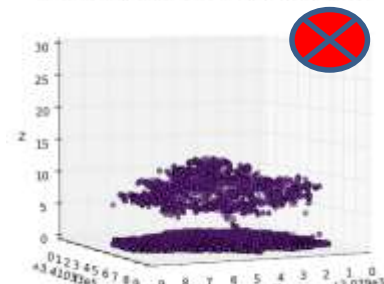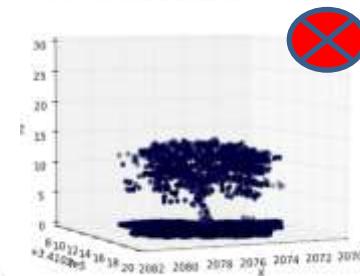Magnoliopsida,Fagaceae,Fagus sylvatica,44608 Magnoliopsida,Malvaceae,Tilia platyphyllos,711 Pinopsida,Pinaceae,Picea abies,75609 Magnoliopsida,Platanaceae,Platanus acerifolia,61 Magnoliopsida,Sapindaceae,Acer platanoides,29
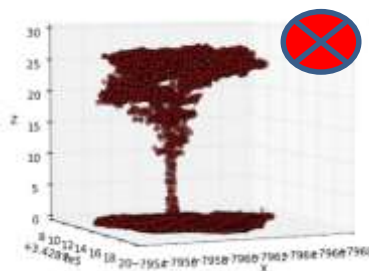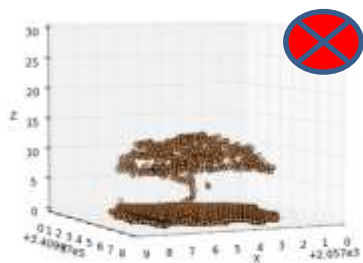
3. only radiometric features

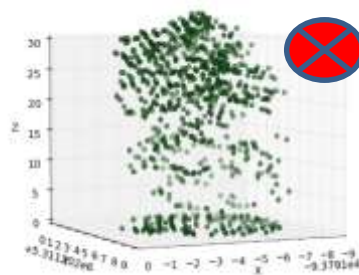|	Fagaceae	Malvaceae	Pinaceae	Platanaceae	Sapindaceae	User's Acc.	
Fagaceae	8	0	1	0	0	0.89	
Malvaceae	0	12	0	0	4	0.75	
Pinaceae	0	0	12	0	0	1.00	
Platanaceae	0	0	0	8	5	0.62	
Sapindaceae	0	3	0	1	10	0.71	
Producer's Acc.	1.00	0.80	0.92	0.89	0.53	Total samples	64
Cohen's Kappa	**0.72**	Overall Accuracy [%]	**0.78**	Overall Precision [%]	**0.80**	Recall [%]	**0.78**

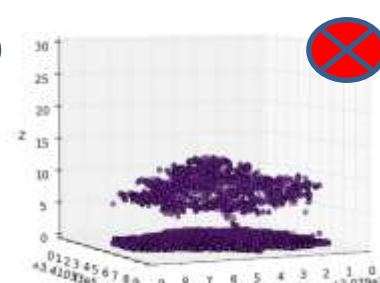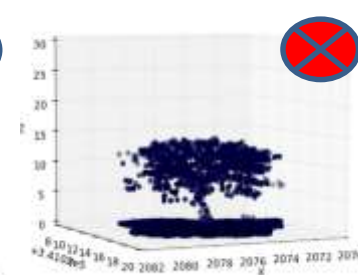Magnoliopsida,Fagaceae,Fagus sylvatica,44608   Magnoliopsida,Malvaceae,Tilia platyphllos,711   Pinopsida,Pinaceae,Picea abies,75609   Magnoliopsida,Platanaceae,Platanus acerifolia,61   Magnoliopsida,Sapindaceae,Acer platanoides,29
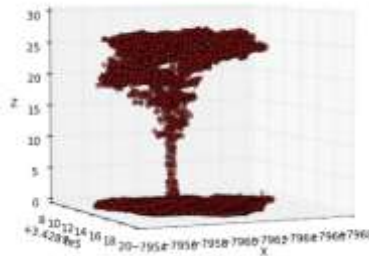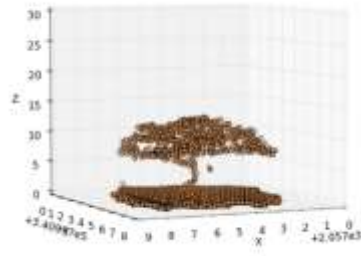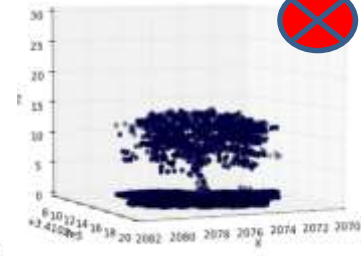
4. all three combined

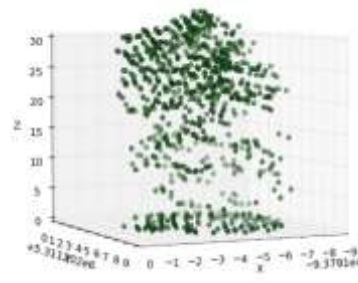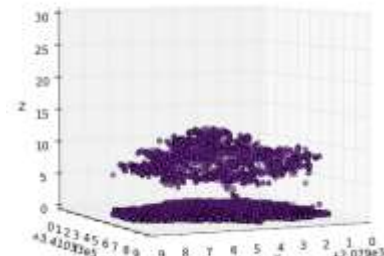|	Fagaceae	Malvaceae	Pinaceae	Platanaceae	Sapindaceae	User's Acc.	
Fagaceae	8	0	1	0	0	0.89	
Malvaceae	0	12	0	1	3	0.75	
Pinaceae	0	0	12	0	0	1	
Platanaceae	0	3	0	9	1	0.69	
Sapindaceae	0	1	0	0	13	0.93	
Producer's Acc.	1	0.75	0.92	0.9	0.76	Total samples	64
Cohen's Kappa	**0.80**	Overall Accuracy [%]	**0.84**	Overall Precision [%]	**0.85**	Recall [%]	**0.84**

Magnoliopsida,Fagaceae,Fagus sylvatica,44608

Magnoliopsida,Malvaceae,Tilia platyphyllos,711

Pinopsida,Pinaceae,Picea abies,75609
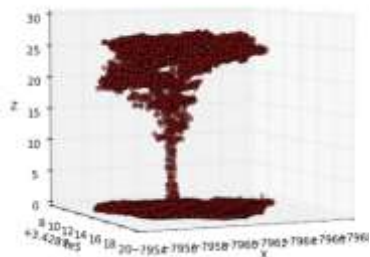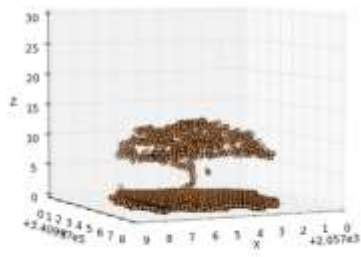
Magnoliopsida,Platanaceae,Platanus acerifolia,61

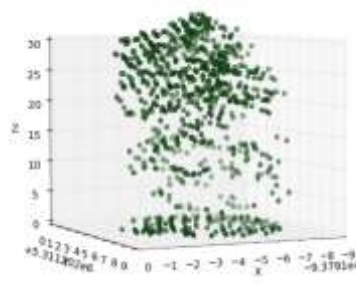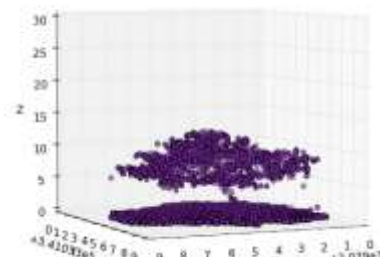Magnoliopsida,Sapindaceae,Acer platanoides,29
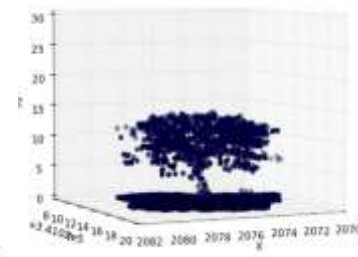
- Classification results

Classification type	Accuracy	Precision	Recall	Cohen Kappa	Features
Geometric Features RF	0.57	0.49	0.57	0.46	42
CB Geometric Features RF	0.46	0.59	0.46	0.33	6
Radiometric Features RF	0.78	0.80	0.78	0.72	100
All Features RF	0.84	0.85	0.84	0.80	148

- **The segmented tree object has the opportunity to used combined geometric and radiometric features build a automatic classification system in urban environment.**
- **In this study successfully separeted (0.84 accuracy) Fagaceae, Malvaceae, Pinaceae, Platanaceae,Sapindaceae in Vienna based on FWF laserscanning data.**

- For the automatic classification pupposes the interfering objects in each tree segment have to be removed.
- Geometric features are limited when we have families with similar structure can separeted only decidous and coniferous trees in urban environment.
- Radiometric features can be effectively use if we calculated for each specialized segment like above canopy base or upper 20th of height percentile.
- The number of samples of each family and different kind of species effect on the results.
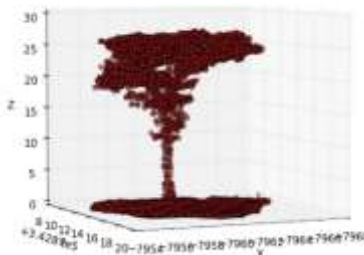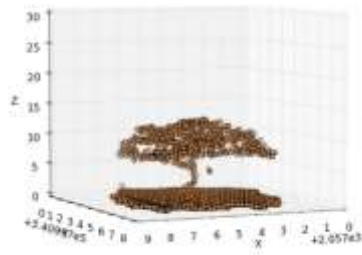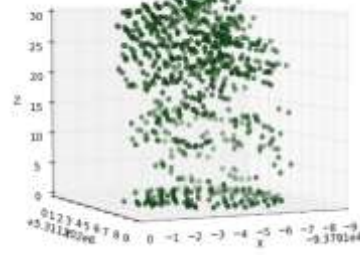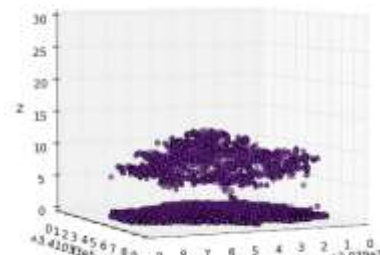
Magnoliopsida,Fagaceae,Fagus sylvatica,44608 — Magnoliopsida,Malvaceae,Tilia platyphyllos,711 — Pinopsida,Pinaceae,Picea abies,75609 — Magnoliopsida,Platanaceae,Platanus acerifolia,61 — Magnoliopsida,Sapindaceae,Acer platanoides,29
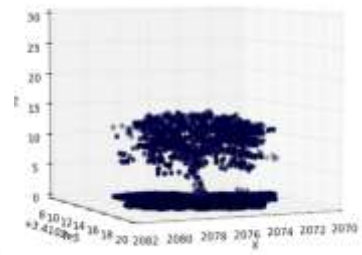
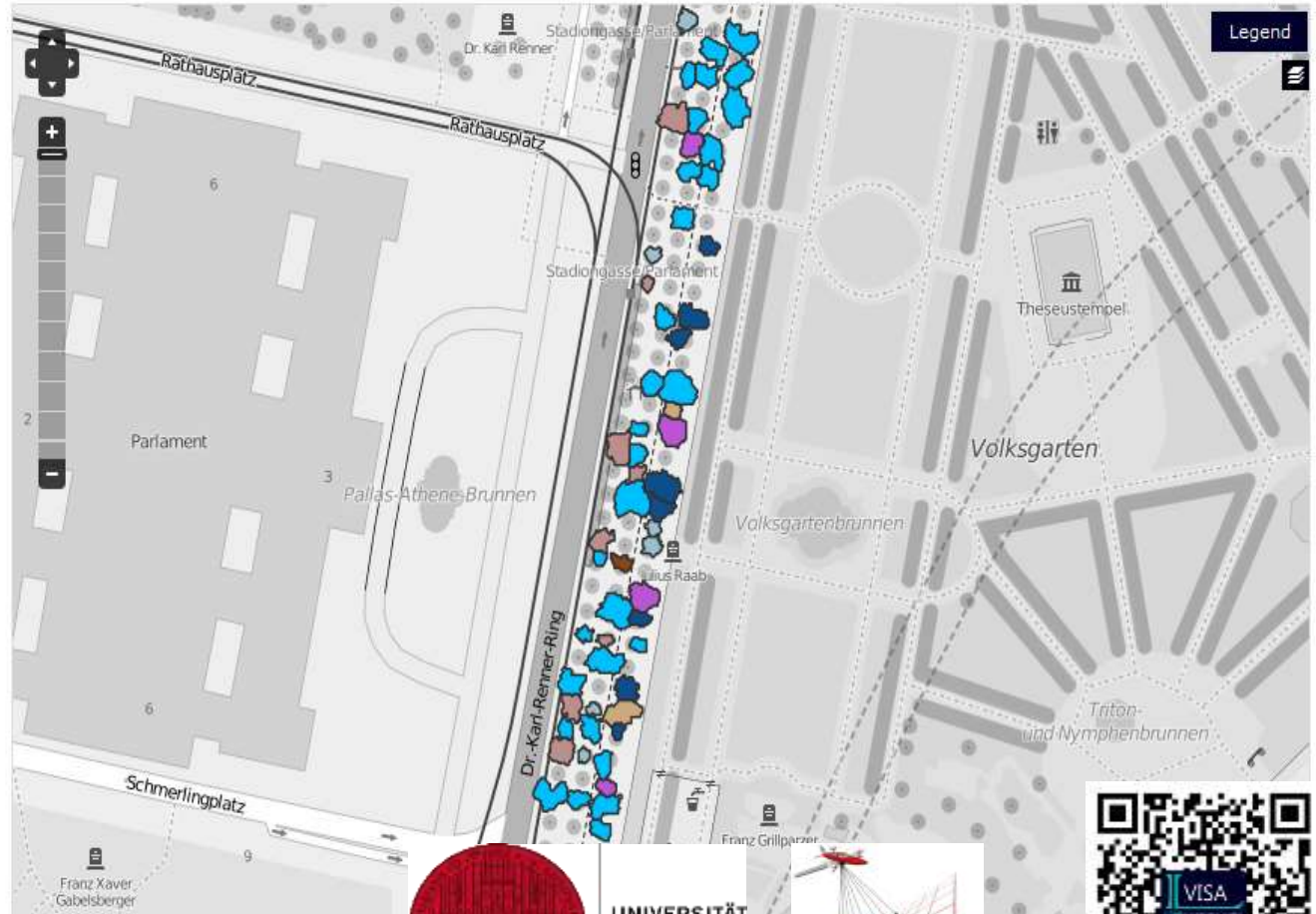# LiDAR Vegetation Investigation and Signature Analysis System (*LVISA*)

Köszönöm a figyelmet!

Tree Species

Larix decidua
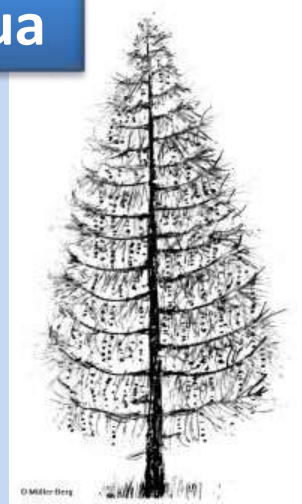
Abies alba
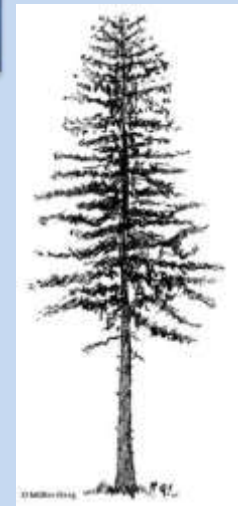
Acer platanoides

Fagus sylvatica

(a) Multi-echo based ER

(b) Geometry-based slope-adaptive ER

temp. booths   cars on street

(c) Effect of temporary objects on geometry-based ER

- ● t1 - time 1
- ○ t2 - time 2

[1]
$ER_{t1} = 100\%$
$ER_{t2} = 100\%$
$ER_{t1,2} = \underline{60\%}$

[2]
$ER_{t1} = 100\%$
$ER_{t2} = 100\%$
$ER_{t1,2} = 100\%$
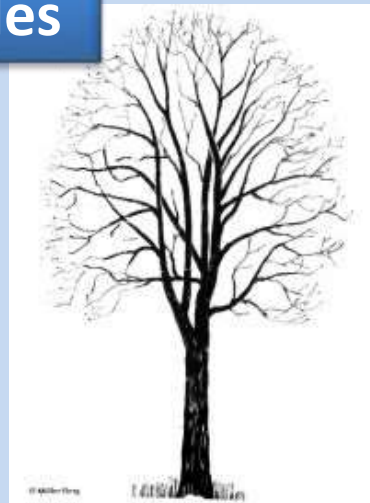
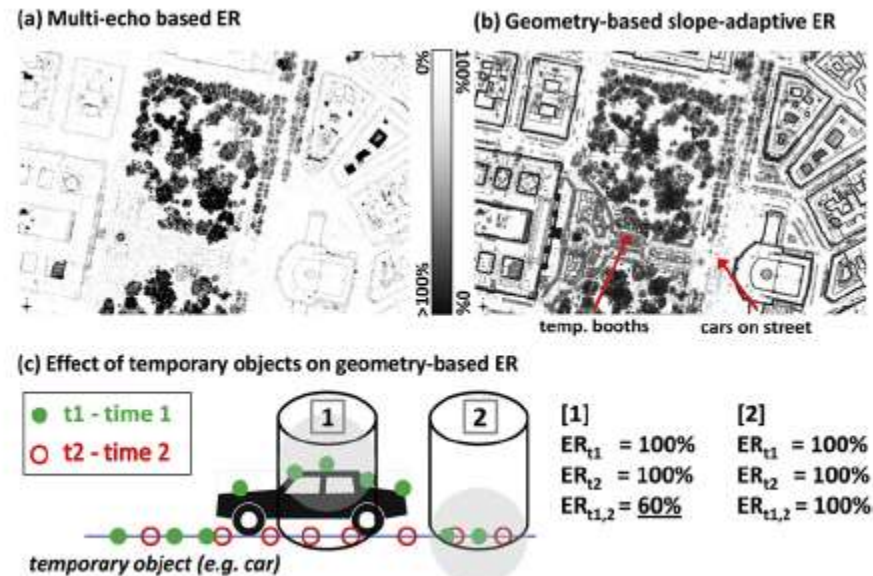temporary object (e.g. car)

Fig. 3. (a) Multi-echo based echo ratio (ER_{ME}), (b) geometry-based echo ratio (ER_{geom}) (Höfle et al., 2009b). Temporary objects can clearly be identified in ER_{geom}. (c) Temporary objects not present in all scans cause a decrease in the values of ER_{geom}.

(a) Normalized DSM [m]
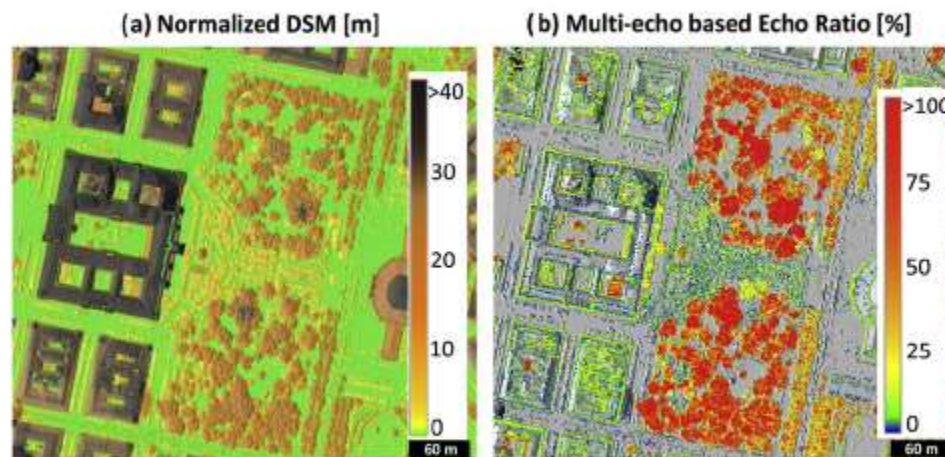
(b) Multi-echo based Echo Ratio [%]

Fig. 4. Input layers for segmentation of convex regions in the (a) nDSM having (b) high penetrability of parts of the laser beam through small gaps parameterized by ER_{ME}.

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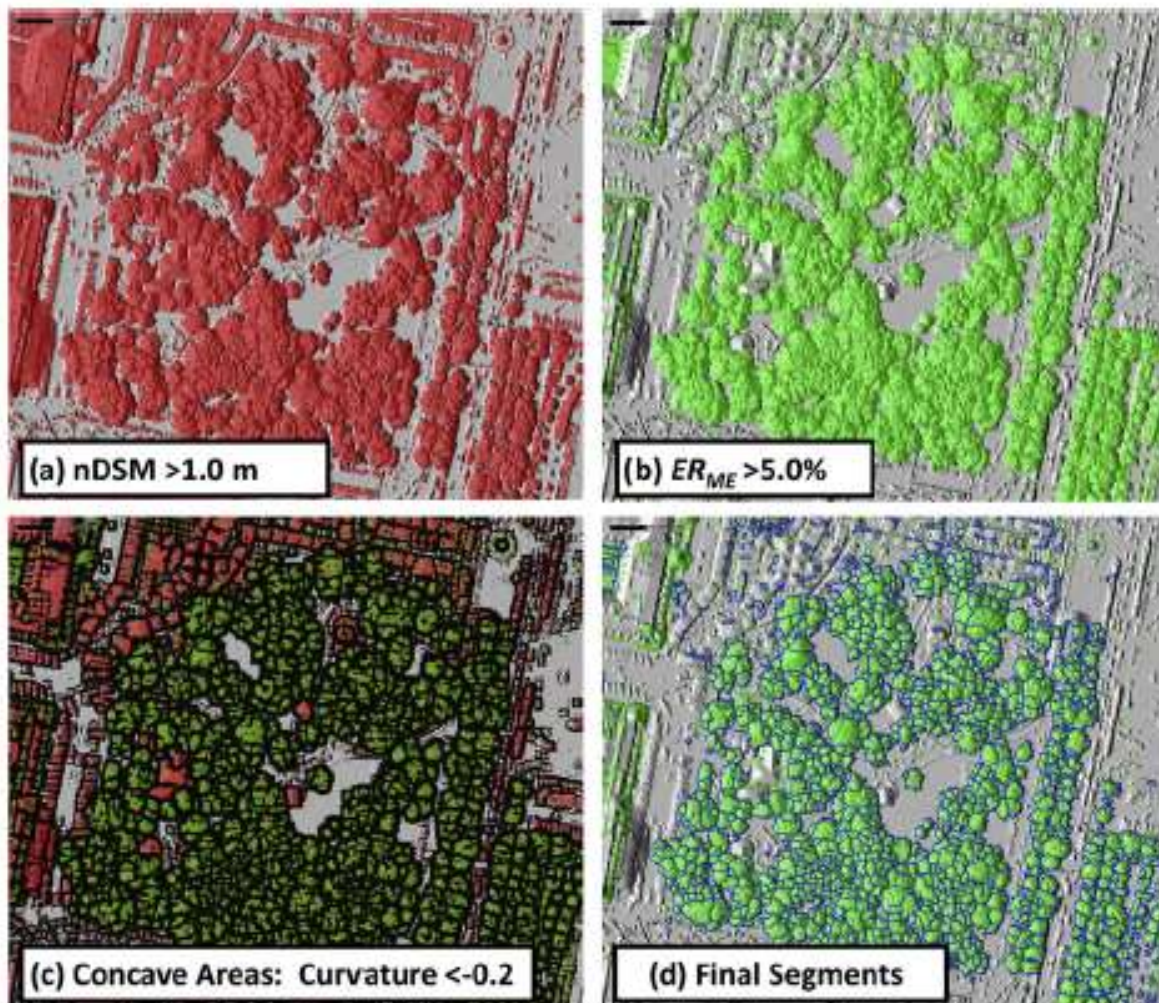Fig. 5. Input layers for segmentation of convex regions in the nDSM having high multi-echo based echo ratio (ER_{ME}).