ETH zürich

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A p-median model to automate stand delineation

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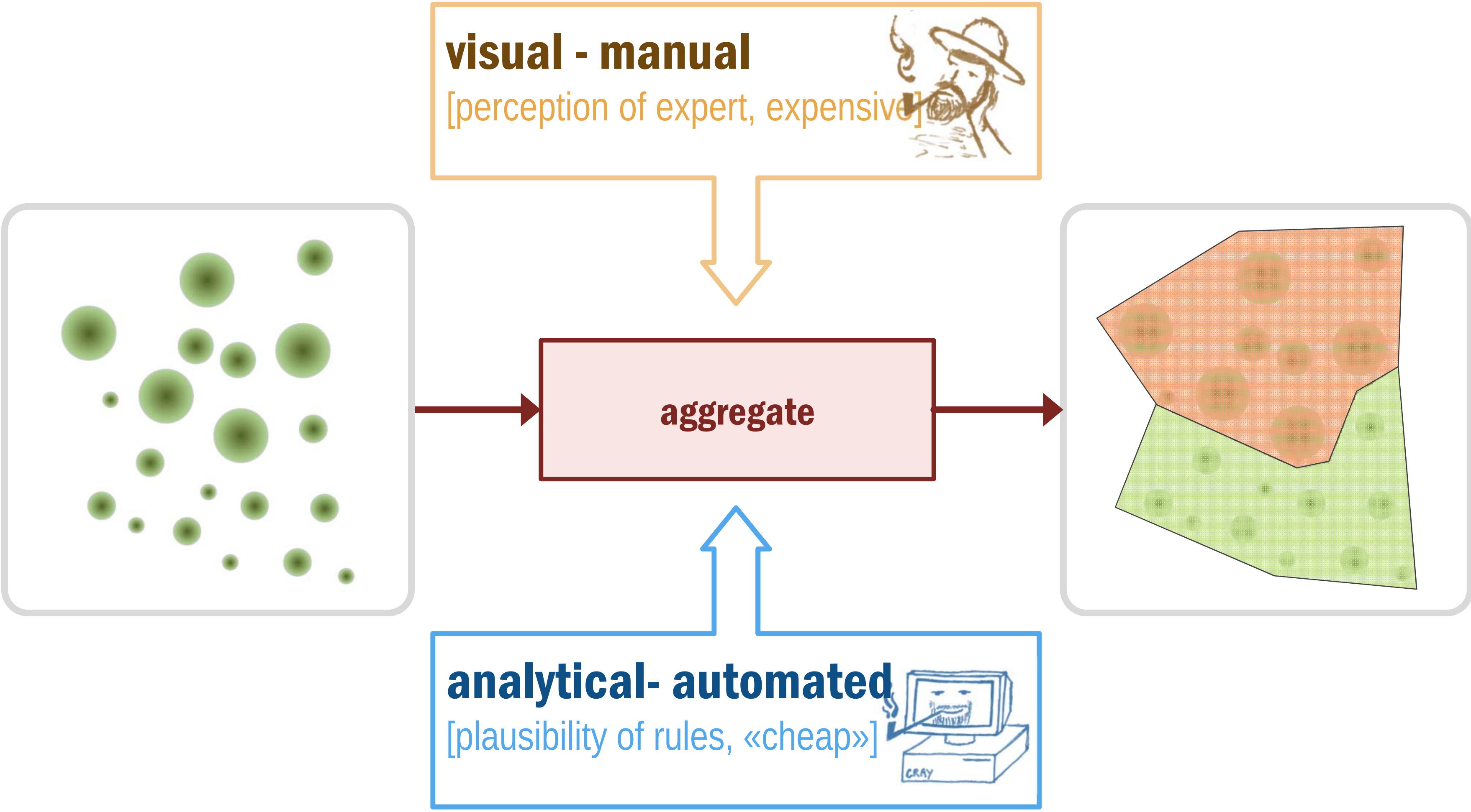
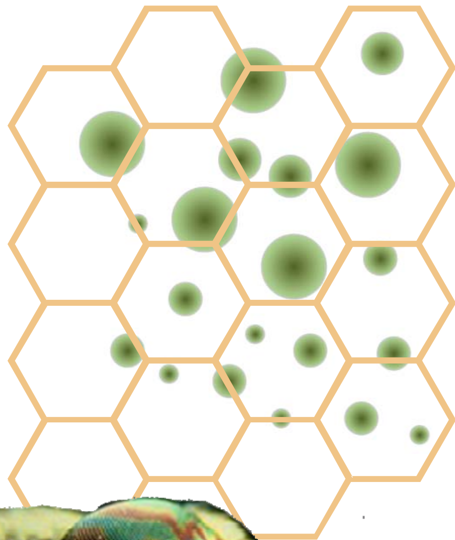
Stand delineation Problem



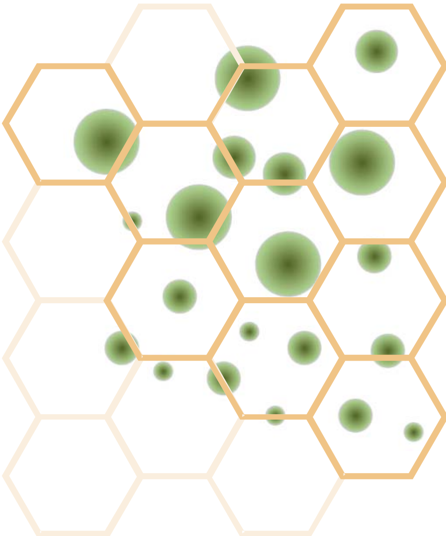
Problem representation

Hexagons...

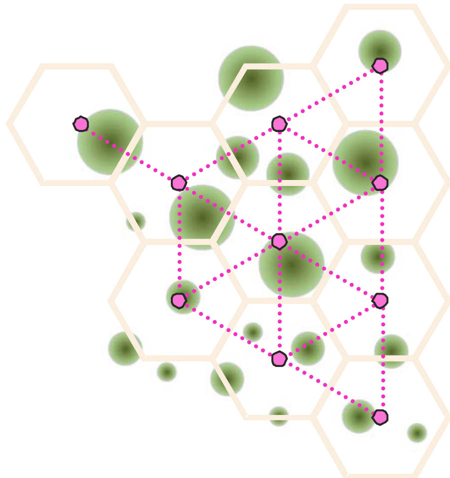
... share edges with all neighbors (compactness)



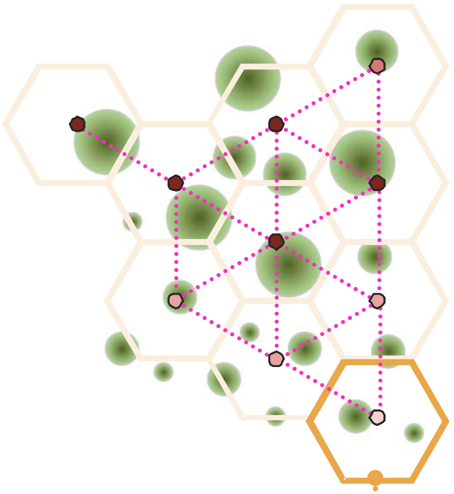
Restrict to forested area

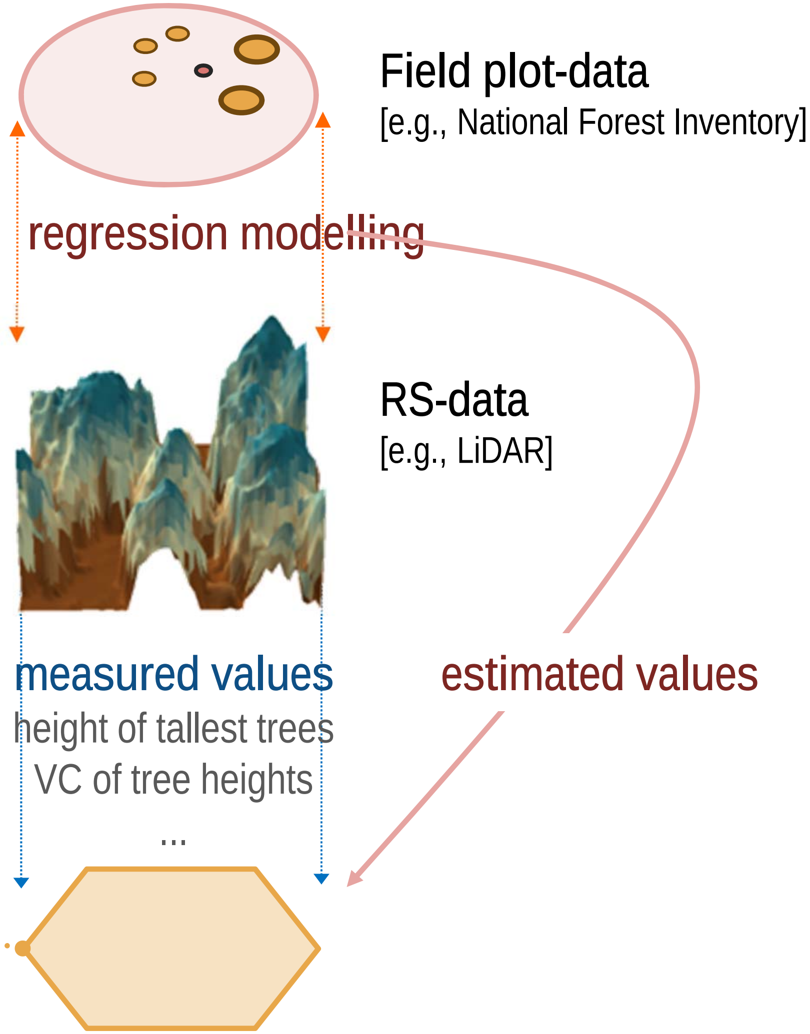


Transfer to network



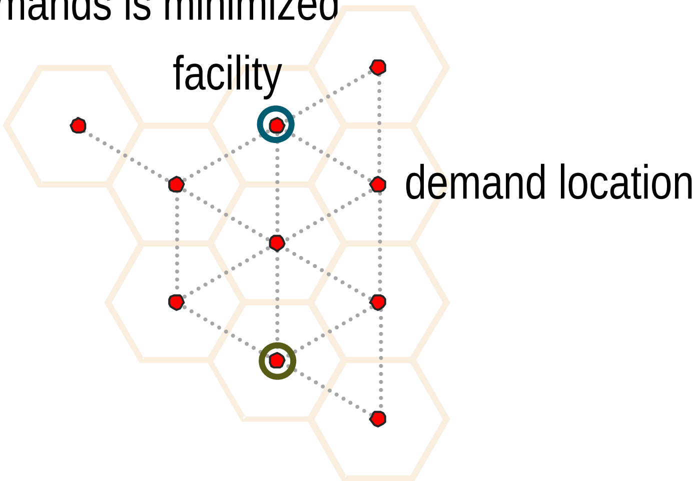
Estimation of forest parameters



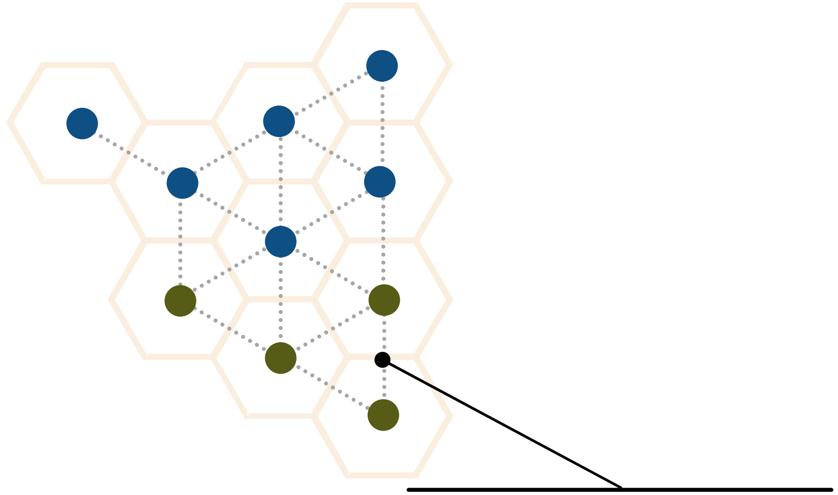


Stand delineation via p-median optimization model

Original problem
Locate p (=2) facilities on network such that total distance for supply of demands is minimized

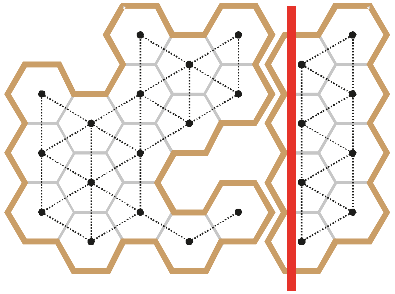


By-product
Assign closest facility to each demand location



Interface for stand delineation
demand location ↔ hexagon
facility ↔ stand center
p ↔ #stands

Work flow – solve for p stands

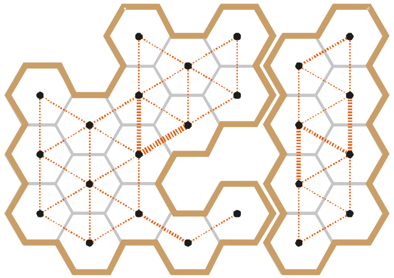


add borders

- border (e.g., road)
- compartment

«divide and conquer»

1



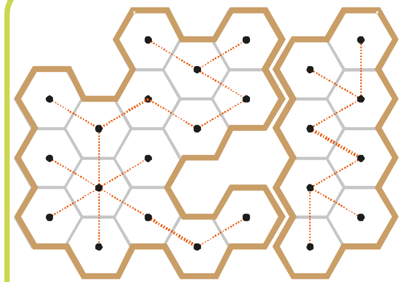
assess dissimilarity

dissimilarity degree

high

low

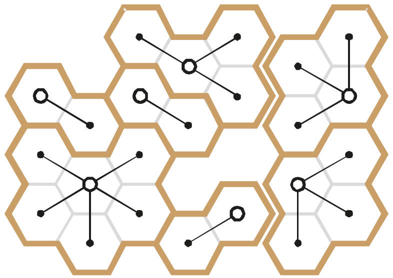
2



identify
«Minimum Spanning Tree»

[I] reduce to essential adjacency
[II] force contiguity of stands

3

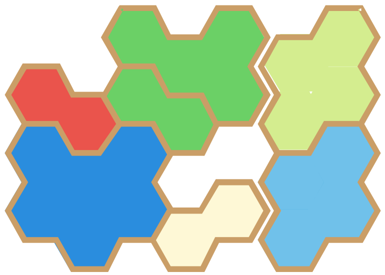


identify *p* stands

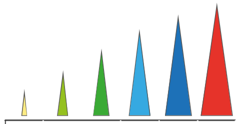
- stand center («facility»)

4

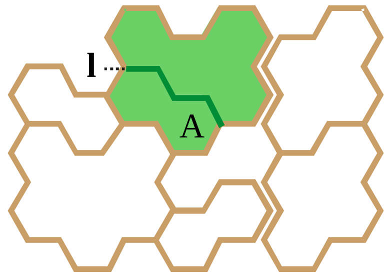
Work flow – solve for «stand size» goal



classify stands



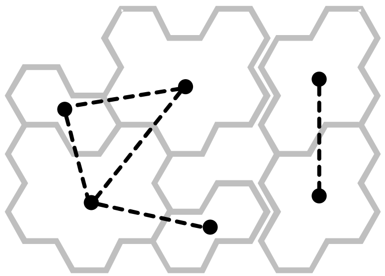
[example] ❺



aggregate identical stands

$\varrho = \frac{l^2}{A} >$ threshold ❻

identify network



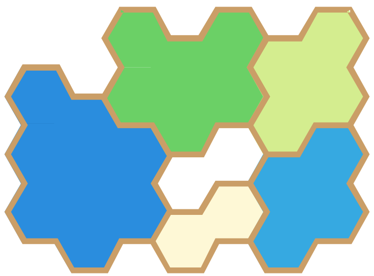
adjacency

- compactness penalty
- favor aggregation of stands which do not meet minimum stand size ❼

WHILE stand size goal is not met

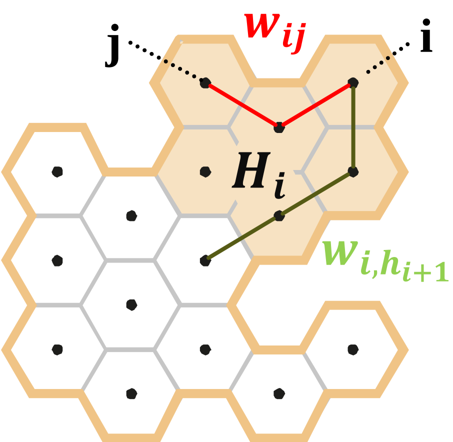
set $\boldsymbol{p} \coloneqq \lfloor \boldsymbol{\alpha} \cdot \boldsymbol{n} \rfloor;\ \ 0 < \alpha < 1$

apply ❸-❼



p-median optimization model

Variables, parameters, sets



name	type	description
x_{ij}	VAR / binary	**1**, hexagon $\mathbf{i}$ assigned to stand center $\mathbf{j}$ **0**, else
f_i	VAR / binary	**1**, hexagon $\mathbf{i}$ not assigned to stand center $\mathbf{j} \in \mathbf{H}$ **0**, else
H_i	set	set of $\mathbf{H}$ closest stand centers $\mathbf{j}$ of hexagon $\mathbf{i}$
w_{ij}	PARAM / real	shortest distance from $\mathbf{i}$ to $\mathbf{j}$, weighted by dissim
n	PARAM / integer	number of hexagons
p	PARAM / integer	number of stands

BEAMR-formulation of p-median problem [CHURCH 2008]

p-median optimization model

$$MIN \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \cdot x_{ij} + \sum_{i=1}^{n} \boldsymbol{w_{i,hi+1}} \cdot f_i$$

minimize total dissimilartity

s.t. $$\sum_{j \epsilon H_i} x_{ij} + f_i = 1 \qquad \forall\, i = 1, \ldots, n$$

assign hexagon to stand center

$$\sum_{j=1}^{n} x_{jj} = p$$

create **p** stand centers

$$x_{ij} \le x_{jj} \qquad \forall\, i = 1, \ldots, n \quad and\ j \in H_i, i \neq j$$

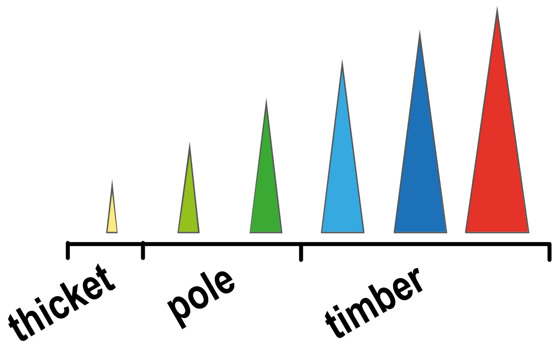
i can only be assigned to **j** when **j** is a stand center

Results - Test areas

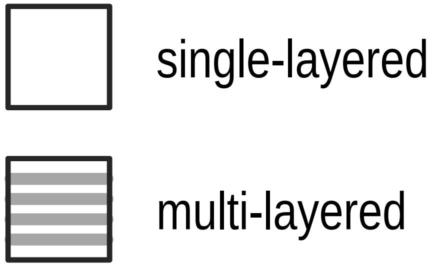
		Swiss Plateau Winterthur, 500-580 m ASL	Swiss Alps Klosters, 1500-1650 m ASL
hexagons	size [m^2]	200	300
	count [-]	776	1318
	overall area [ha]	15.52	39.54
obstacles		none	roads, waterways
forest parameters		height of dominant trees	height of dominant trees VC of tree heights
classification		stage of development	stage of development single- or multi-layered
RS-data		LiDAR (0.5x0.5m)	LiDAR (0.5x0.5m)

Classification

stage of development
[based on dominant tree height]

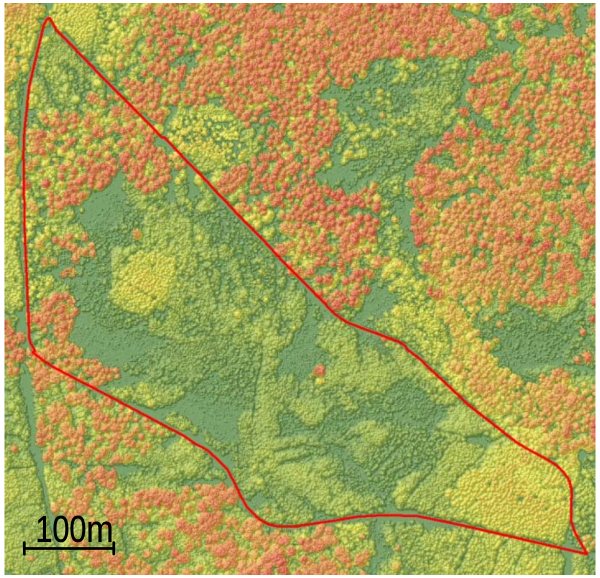


vertical structure
[based on VC of tree heights]

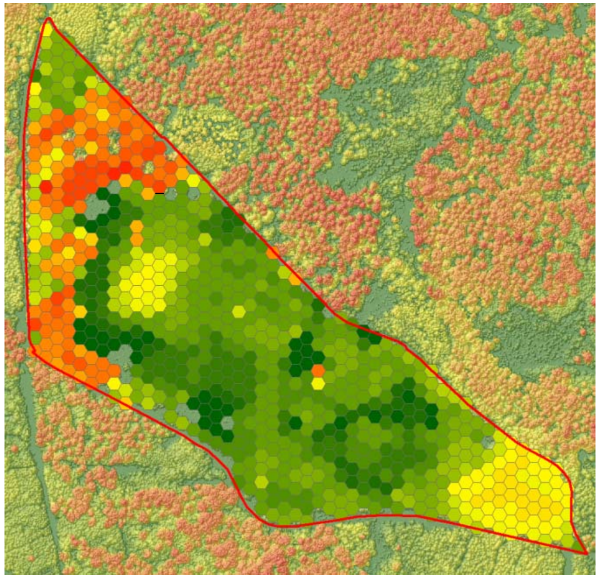


Results - SWISS PLATEAU

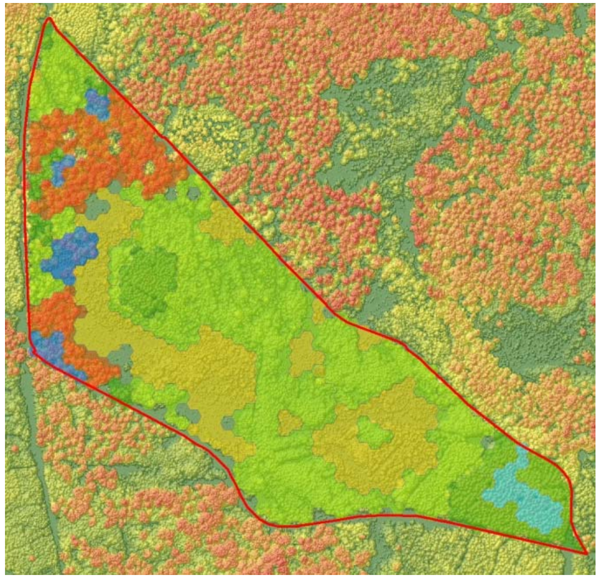
Canopy Height Model



Hexagon dataset
[dominant tree height]



Stands

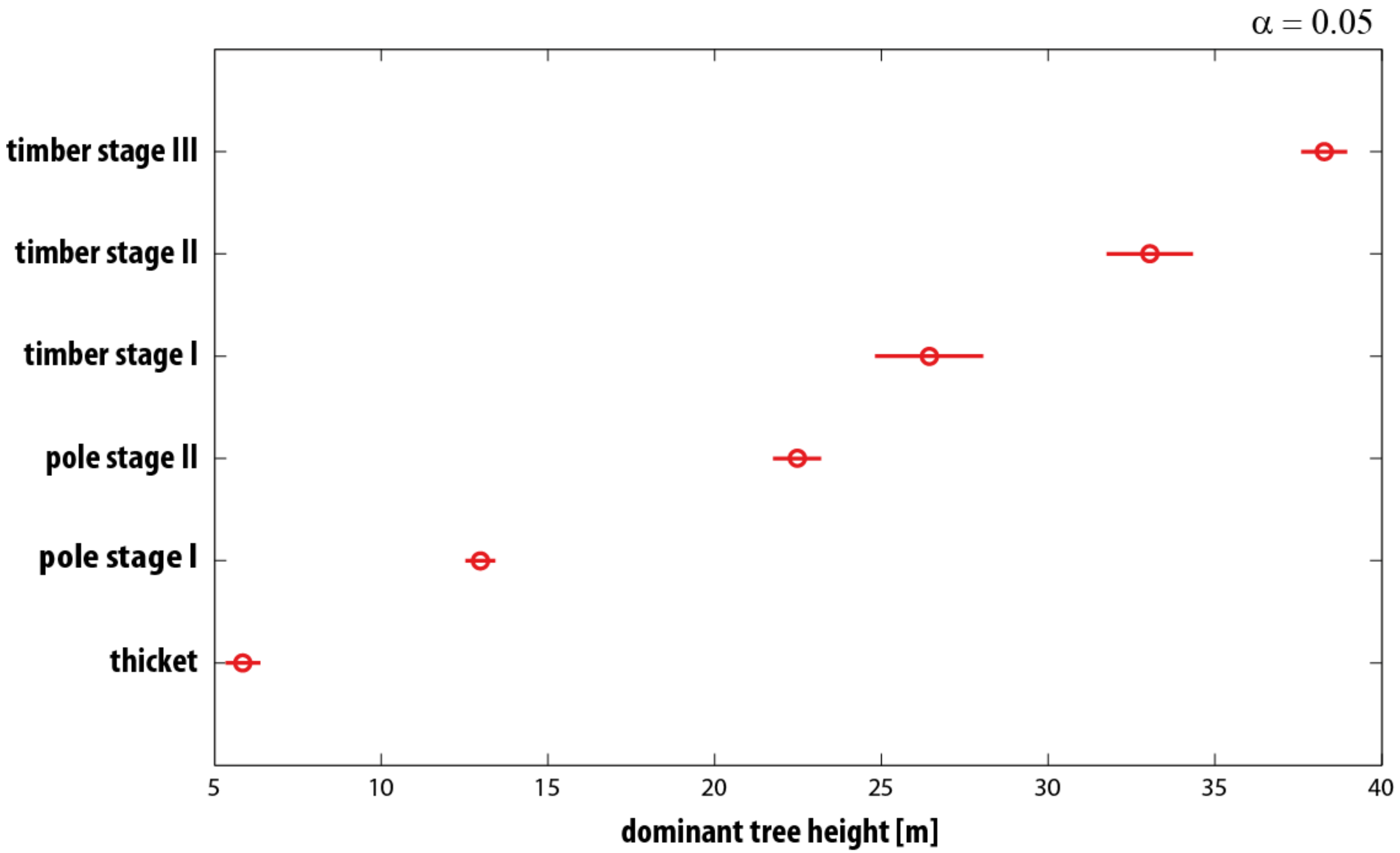


1.5 min

0.5 min

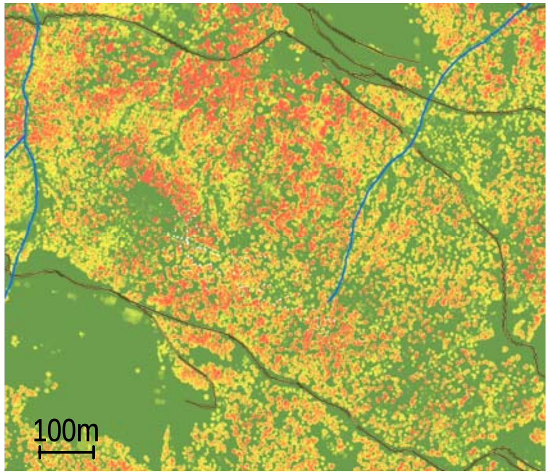
Source: Geodaten © GIS-ZH

Classification quality [Tukey's Test]

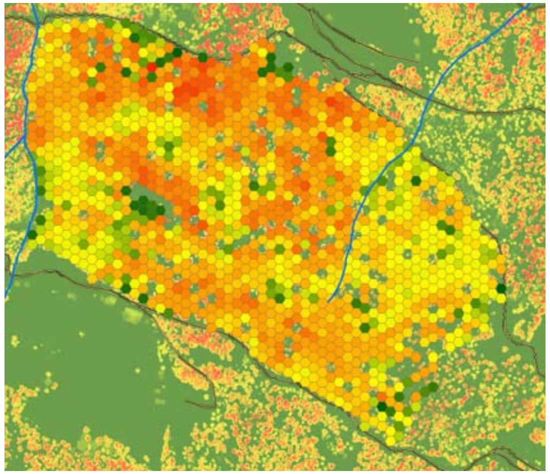


Results - SWISS ALPS

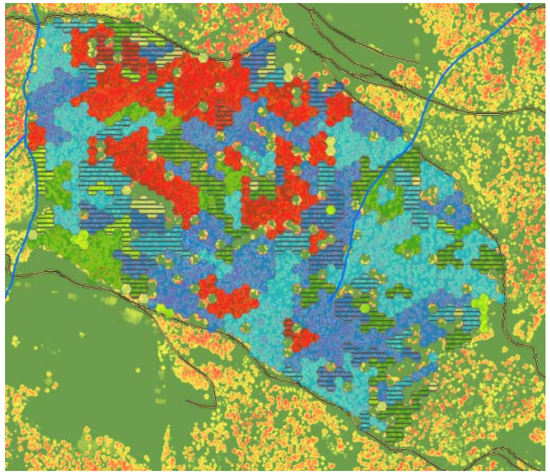
Canopy Height Model



Hexagon dataset
[dominant tree height]



Stands



1.5 min

1.0 min

Source: Municipalities Klosters/Davos; Agency for Forest and Natural Hazards, Canton of Grisons; Remote Sensing Laboratori

Discussion and Outlook

ILP-approach for automated stand delineation

- produces contiguous stands that meet minimum size requirement
- quality assessement of stand map
- fast computation
- adaptable to local requirements
- interface to forest inventory

Outlook

- add tree species information to stand delineation
- generalize forest parameter values in hexagons prior to optimization