Workshop

Lidar applications in forest inventory and related statistical issues

DIBAF, via San Camillo de Lellis, Viterbo, Italy

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Classification of coppice stands and high forest stands using airborne laser scanning data

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Introduction

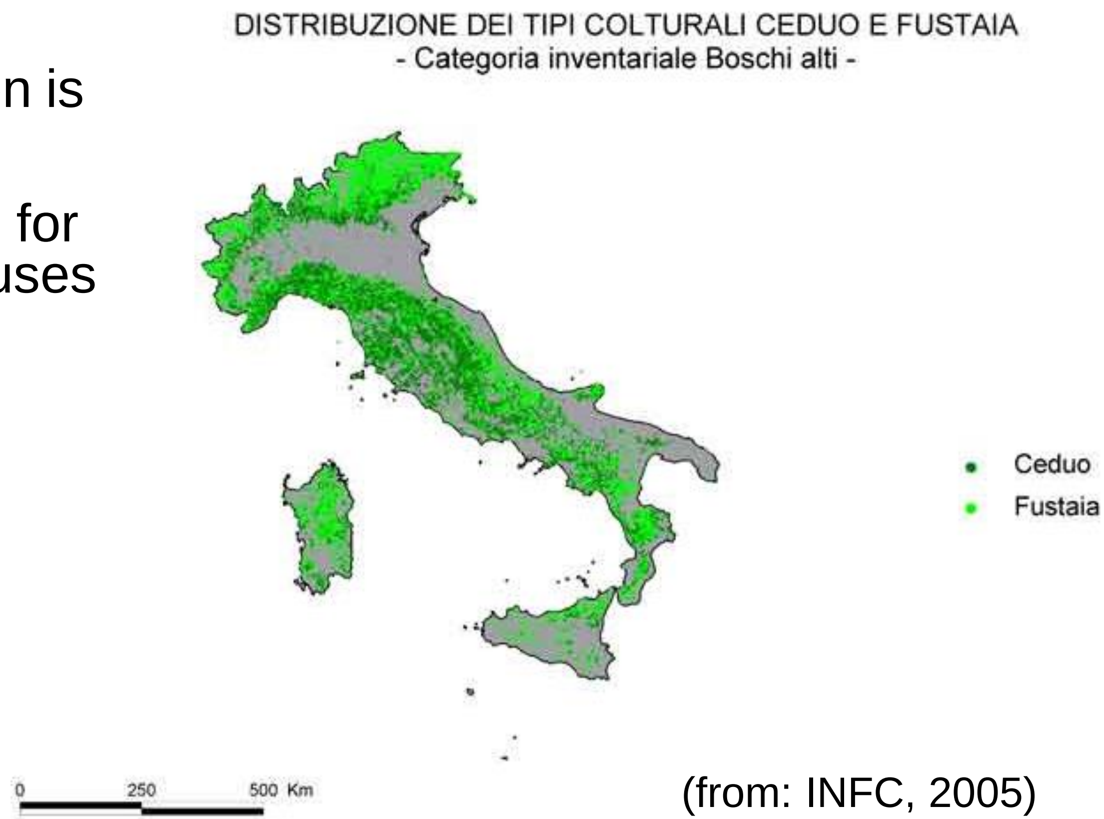
In Italy forest and other wooded lands extend over 10.5×10^6 ha

Coppices represent 41.8% of forest

High forests represent 36.1% of forest

About 60% of wood production is provided by coppice forest

The main product is fuelwood for both domestic and industrial uses

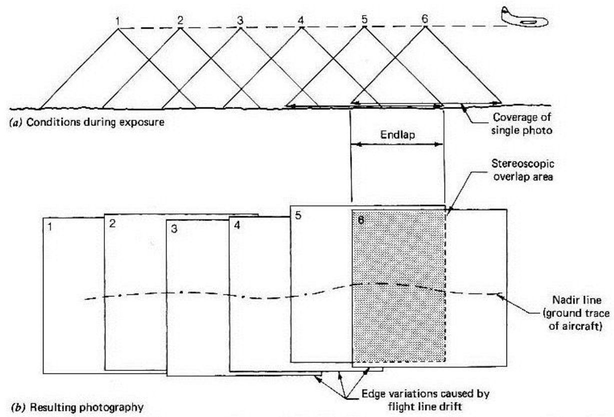


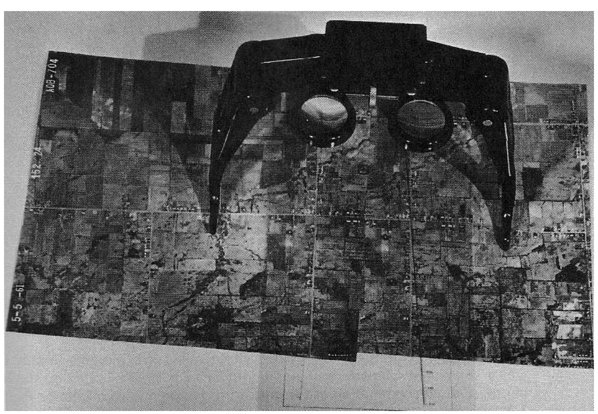
(from: INFC, 2005)

Remote sensing has been used to map coppices and high forests by polygon delineation on the basis of visual interpretation of aerial photos

Multispectral information provided by very high resolution satellite images are not efficient for automatic or semiautomatic classification of forest structure

At least to our knowledge, no studies have been devoted to map coppice stands and high forest stands using Airborne Lasere Scanning (ALS) data





ALS provides data to support forest inventory application from small scale to large scale

e.g., standing wood volume, forest biomass, forest height, forest structure, etc.

ALS data can be used as raw points data or raster data, depending on data availability, objectives and methods (e.g., tree-based vs area-based estimation)

When raster is used for forestry application, the Canopy Height Model (CHM) is the Lidar-derived product exploited to assess forest parameters

Objectives

ALS data has been tested to map forest structure into coppice stands and high forest stands in mixed broadleaved forests using Lidar-derived CHM

Study area

Three study areas were considered:

1) Cerbaie (Pisa) → 45 ha
2) Molise (Isernia) → 107 ha
3) Mugello (Florence) → 506 ha

Forest types:

mixed broadleaved forests dominated by Turkey oak

Forest structure:

coppice with standards

coppice with standards in conversion to high forest

high forest

Ground-truth data

In Molise and Mugello forest structure was classified in the field on the basis of a visual interpretation

In the study area “Cerbaie”, forest structure classification was derived from a forest managment plan

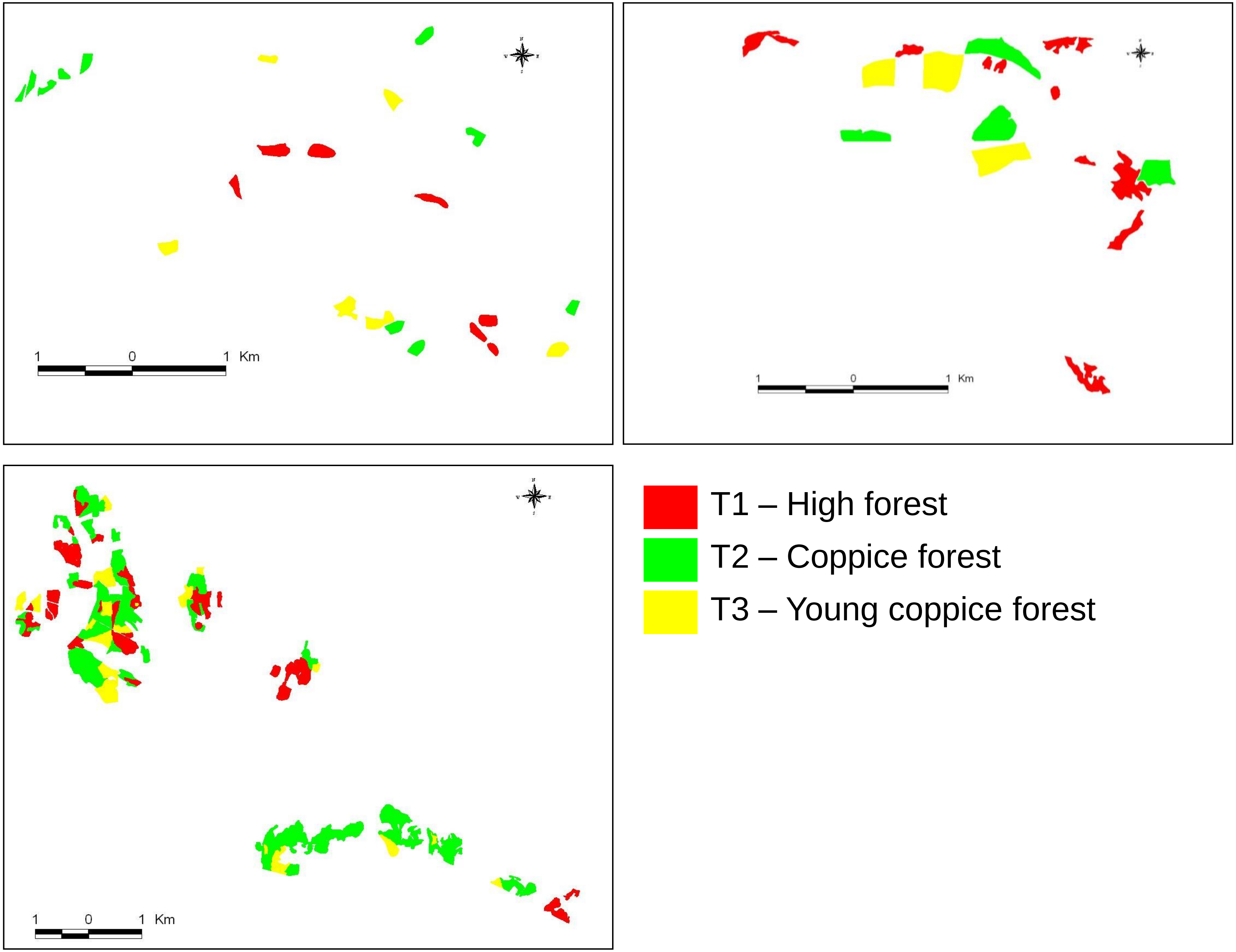
Three forest structure types were considered:

T1 – High forest (including coppice in conversion to high forest)

T2 – Coppice

T3 – Young coppice



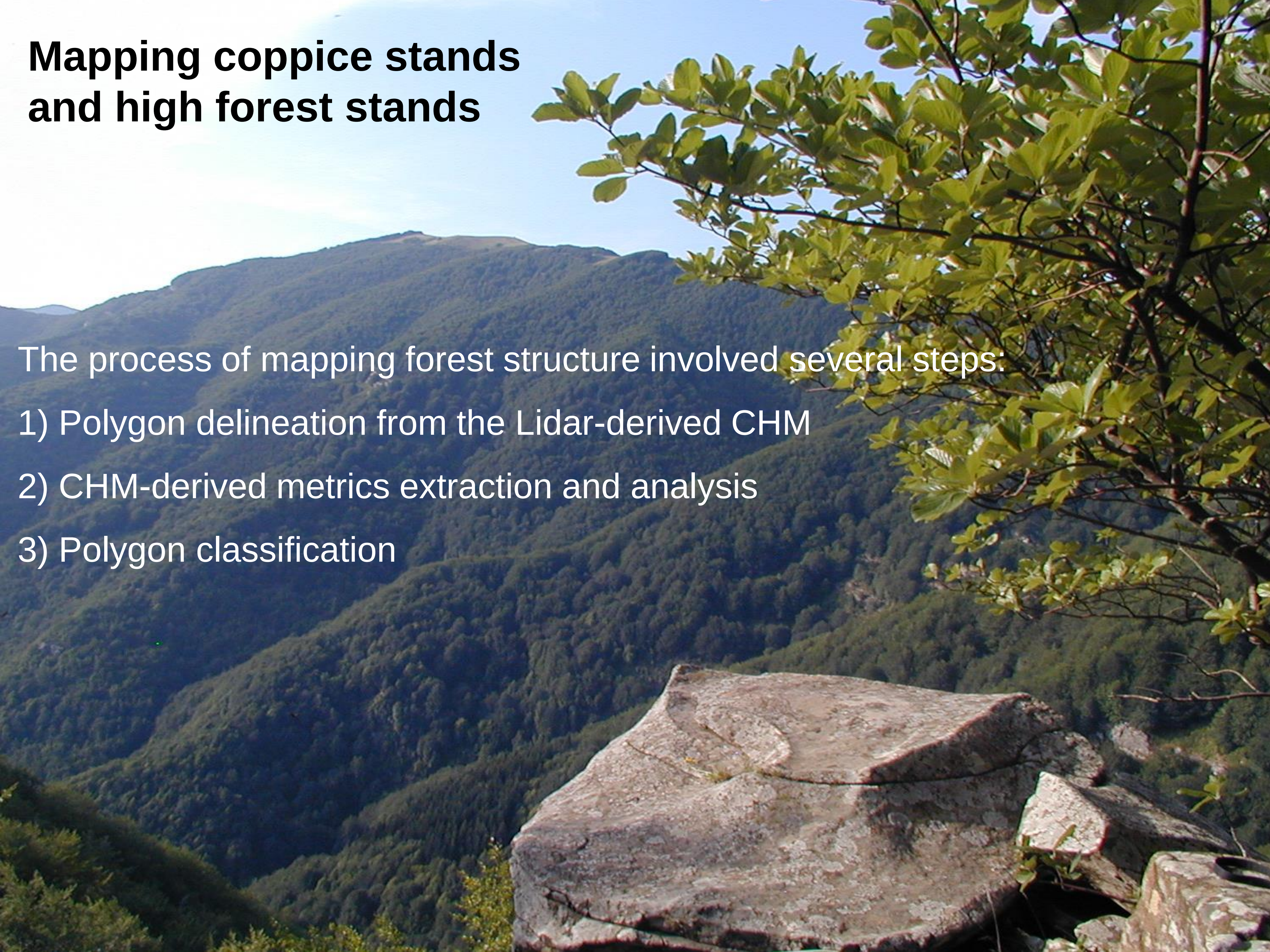

1 0 1 Km
1 0 1 Km
1 0 1 Km
T1 – High forest
T2 – Coppice forest
T3 – Young coppice forest

ALS data

Acquisition data: 2007 (Mugello), 2008 (Cerbaie), 2010 (Molise)
Sensor: Altm Gemini (Mugello and Cerbaie), Optech Pegasus (Molise)
Average point density = 1-1.6 m^2
Horizontal accuracy = 0.30-0.70 m
Vertical accuracy = 0.15-0.20 m

CHM raster (pixel size = 1 m)

Mapping coppice stands and high forest stands

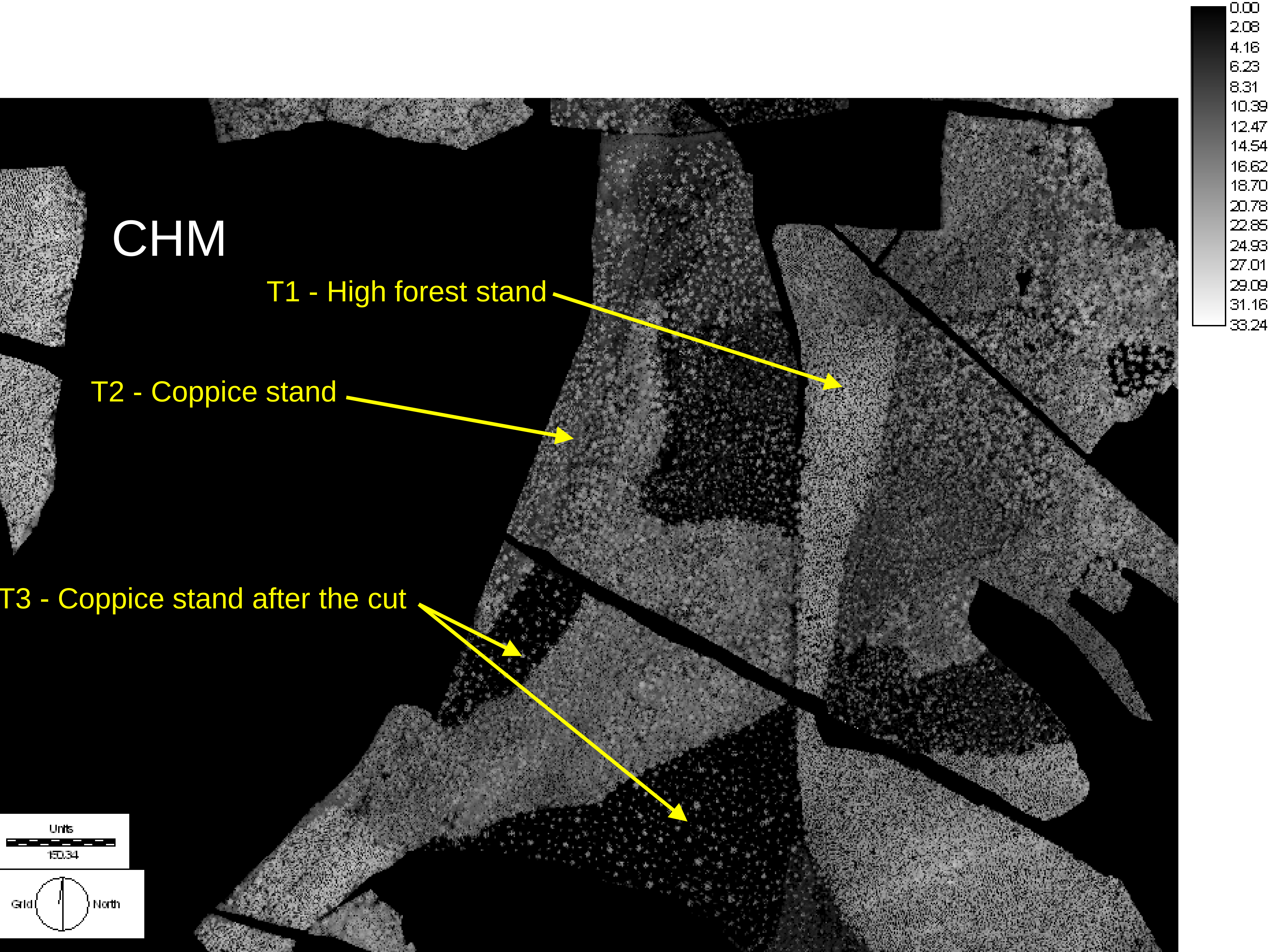


The process of mapping forest structure involved several steps:

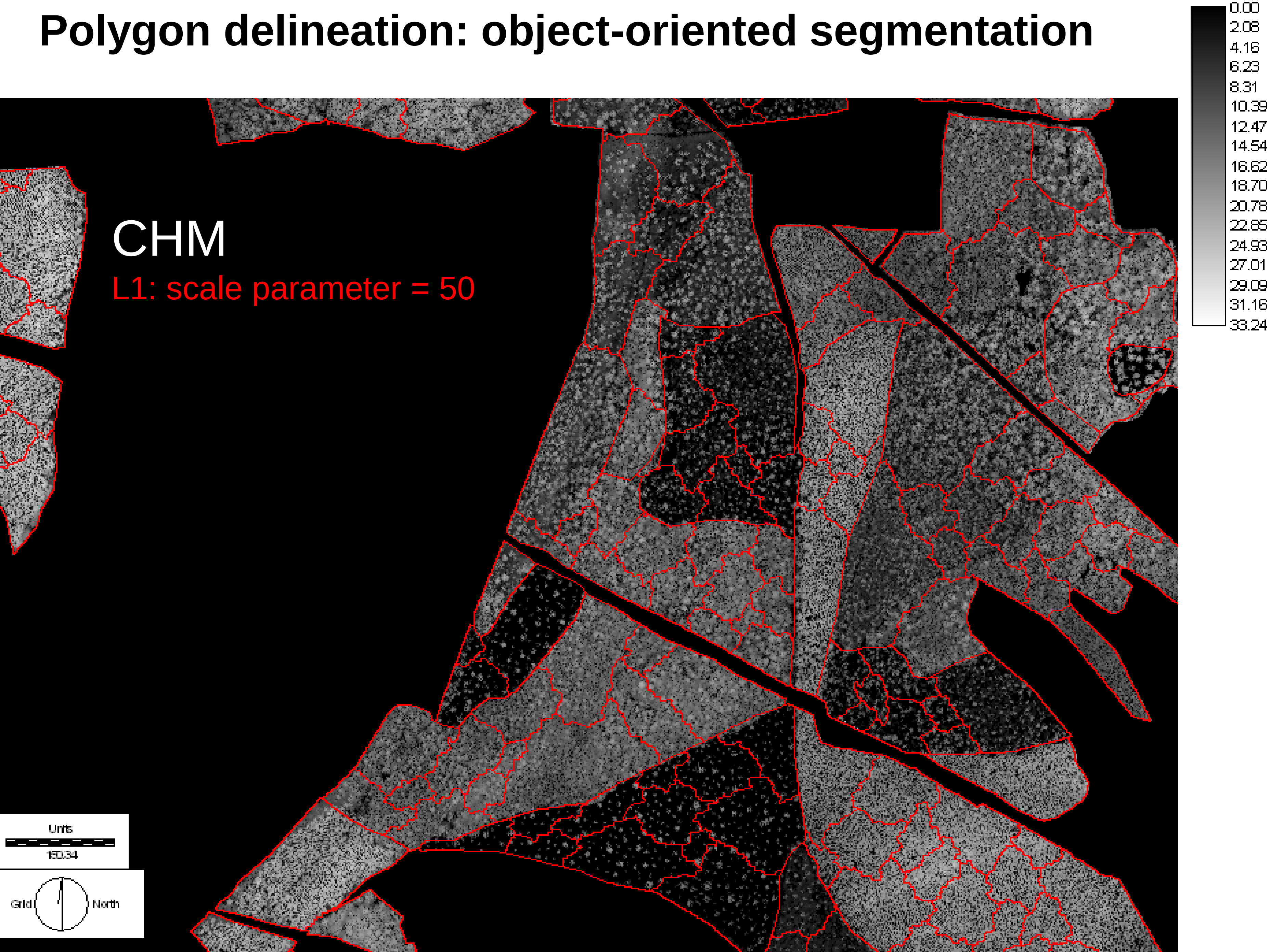
1) Polygon delineation from the Lidar-derived CHM

2) CHM-derived metrics extraction and analysis

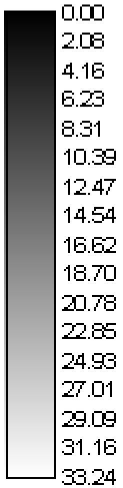
3) Polygon classification

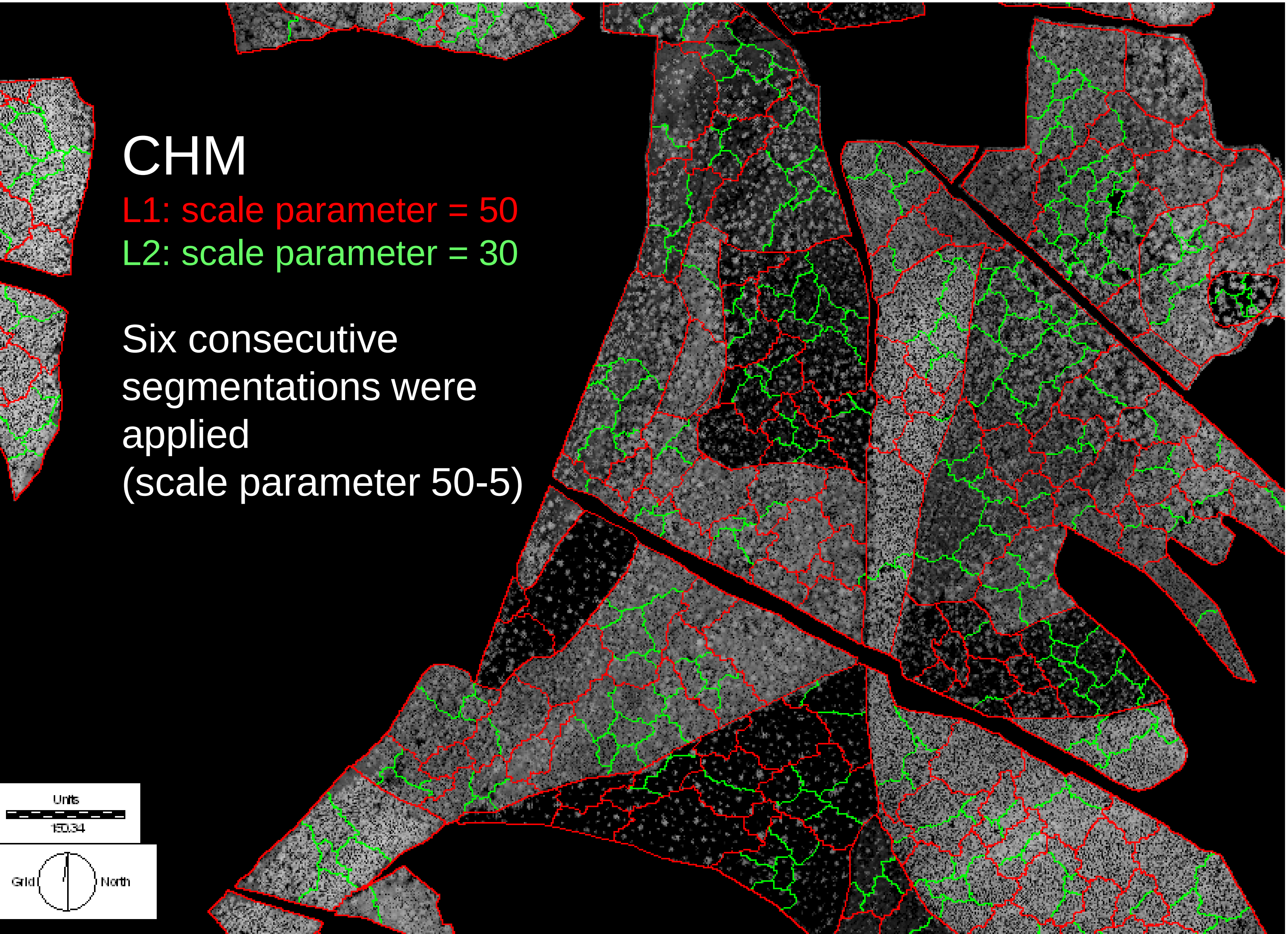

CHM
T1 - High forest stand
T2 - Coppice stand
T3 - Coppice stand after the cut
0.00
2.08
4.16
6.23
8.31
10.39
12.47
14.54
16.62
18.70
20.78
22.85
24.93
27.01
29.09
31.16
33.24
Units
150.34
Grid
North

Polygon delineation: object-oriented segmentation



Polygon delineation: object-oriented segmentation

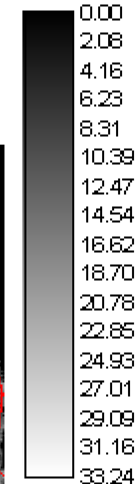


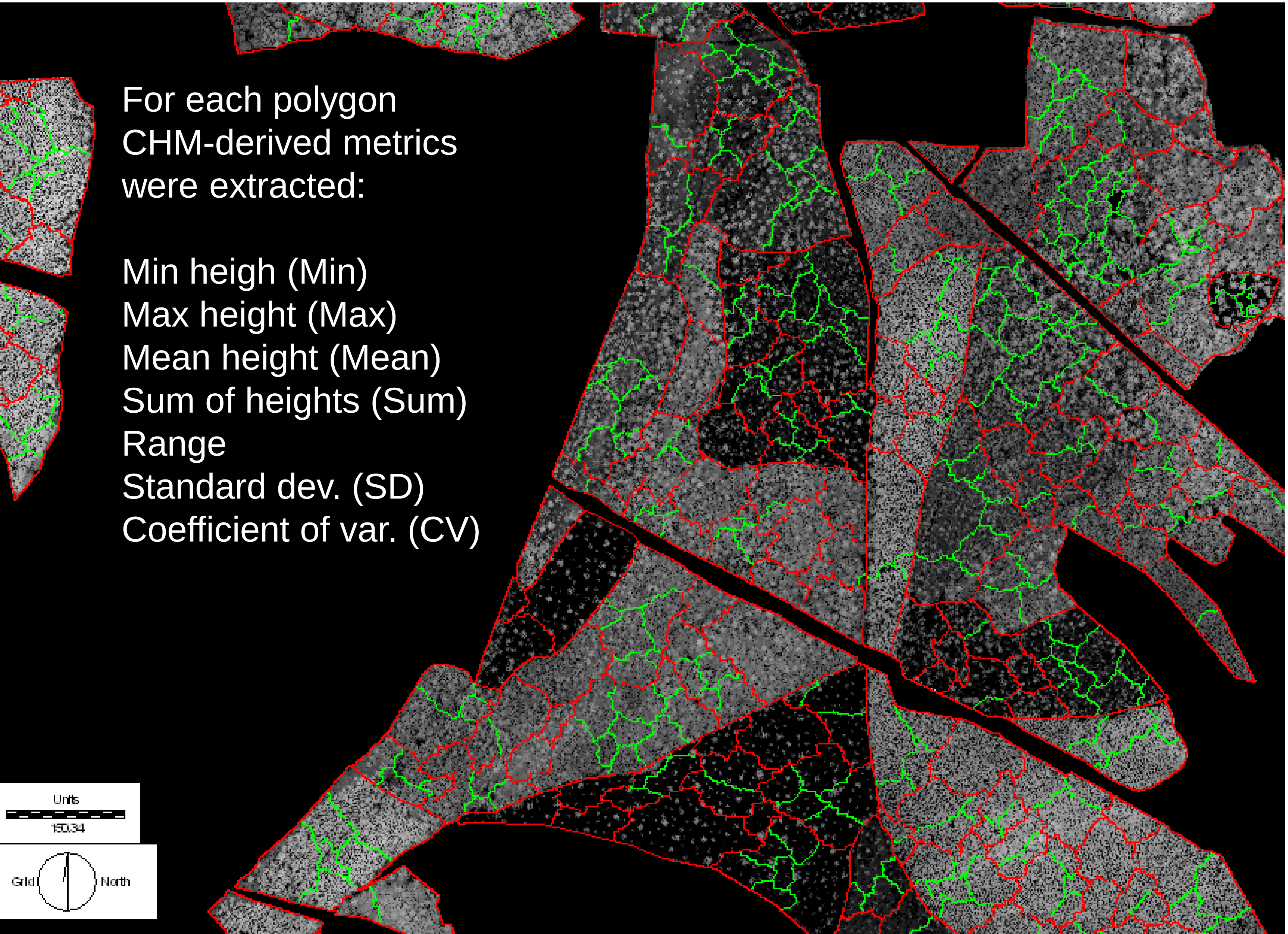


CHM-derived metrics extraction

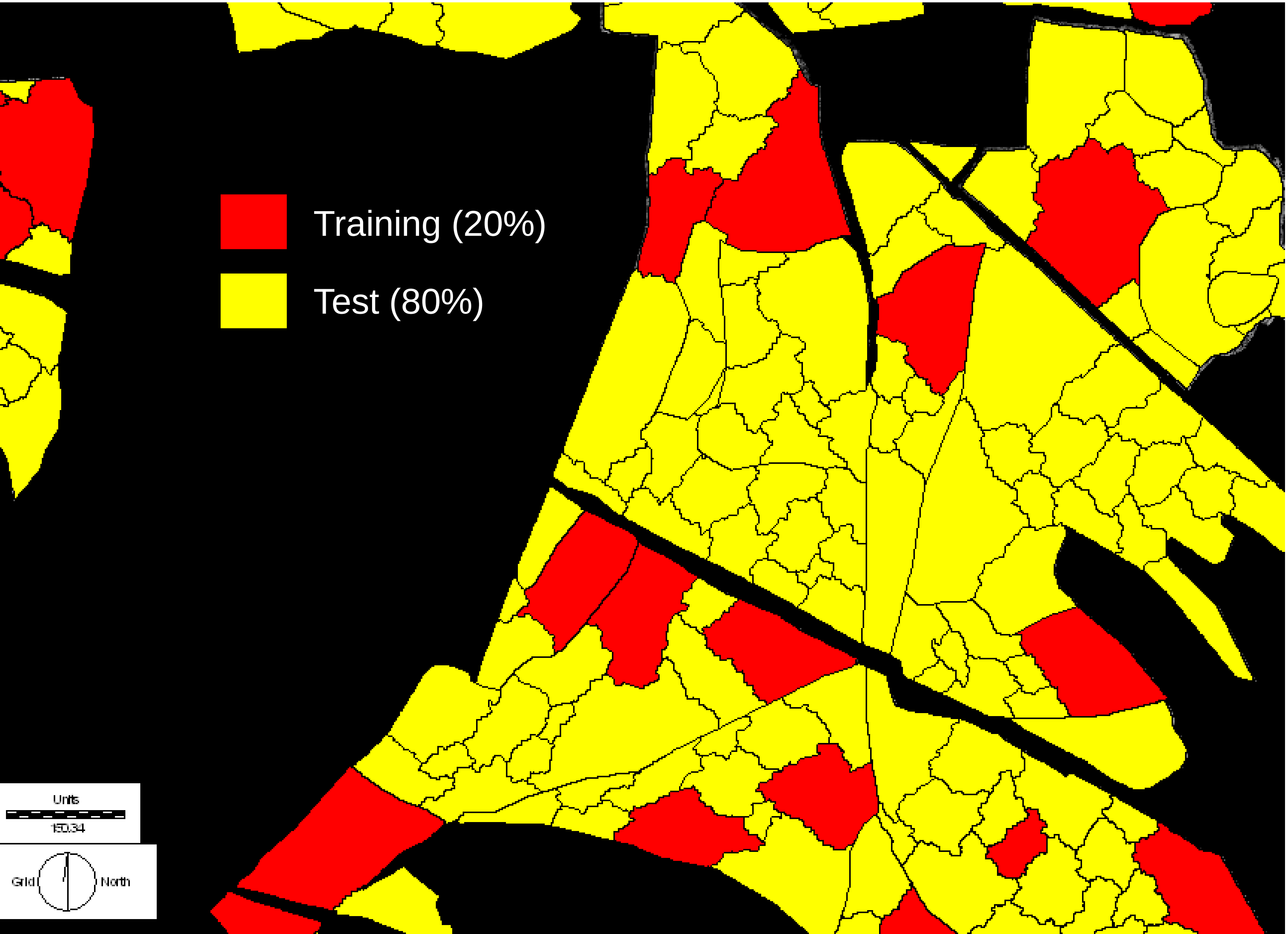
For each polygon
CHM-derived metrics
were extracted:

Min heigh (Min)
Max height (Max)
Mean height (Mean)
Sum of heights (Sum)
Range
Standard dev. (SD)
Coefficient of var. (CV)

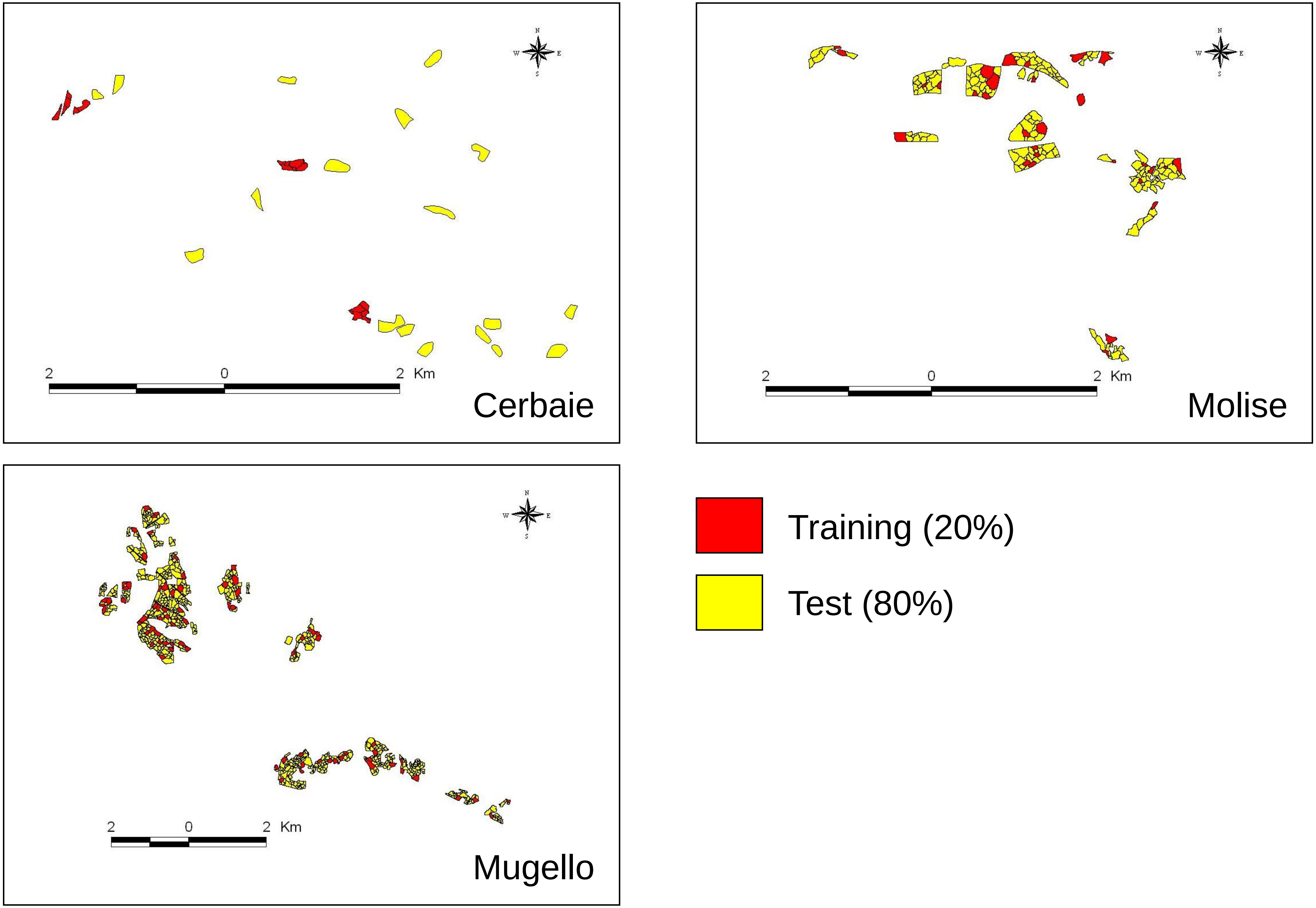




Training sites and test sites



Training sites and test sites



Analysis

For each level of segmentation, the Kruskal-Wallis test and the Median test were used to test whether CHM-derived metrics extracted on training sites varied significantly among forest structure types (T1, T2, T3)

The Mann-Whitney method was used for pairwise comparisons

These results were useful for determining which metric provided better separability of structure types and the influence of the scale parameter used for polygon delineation

Polygon classification

The best CHM-derived metrics were selected

A supervised approach was used for polygon classification (Maximum Likelihood classification)

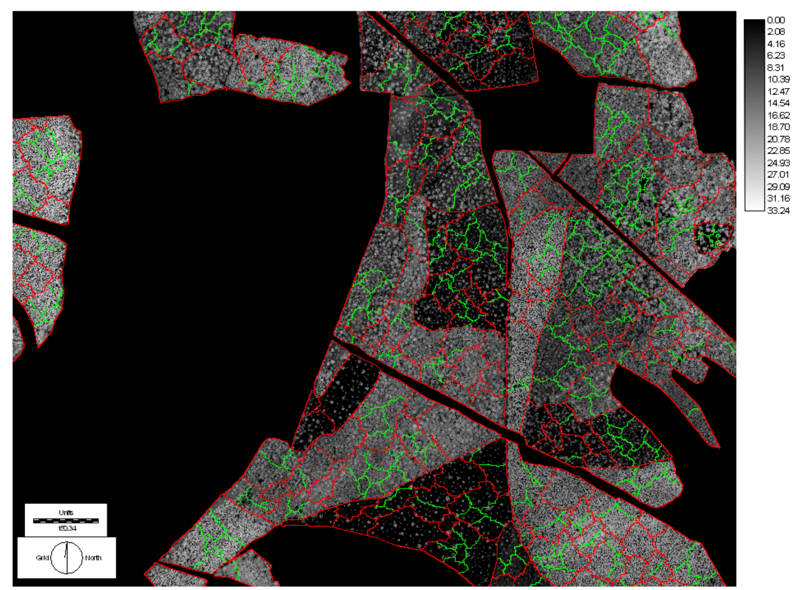
Test sites were used for assessing the classification accuracy:
overall accuracy (OA), producer's accuracy (PA), user's accuracy (UA), kappa index of agreement (KIA)

Results

Scale-dependent | Non scale-dependent

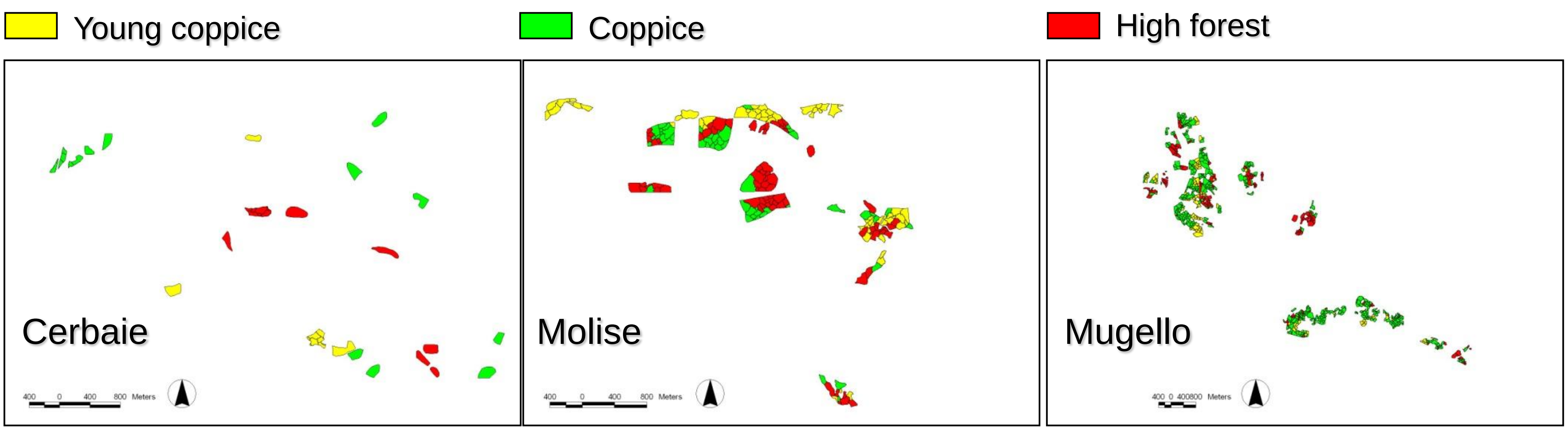
Level of segmentation (Scale parameter)	CHM-derived metric	Mean value of the CHM-derived metric extracted on training site			Kruskal-Wallis test (sig.)	Median test (sig.)	Mann-Whitney test
		T1 – High for.	T2 - Coppice	T3 – Young coppice			
L1 (50)	Min	0,0	0,0	0,0	-	-	-
	Max	26,5	20,5	13,0	0,000	0,001	T1≠T2≠T3
	Sum	91123	27661	9490	0,009	0,002	T1=T2=T3
	Mean	18,9	6,4	2,2	0,000	0,001	T1≠T2≠T3
	Range	26,5	20,5	13,0	0,000	0,001	T1≠T2≠T3
	SD	4,3	4,3	3,1	0,002	0,002	T1=T2≠T3
	CV	0,2	0,7	1,4	0,000	0,000	T1≠T2≠T3
L2 (30)	Min	0,4	0,0	0,0	0,157	0.151	T1=T2=T3
	Max	26,8	20,1	12,9	0,000	0,000	T1≠T2≠T3
	Sum	63786	13831	3615	0,000	0,000	T1≠T2≠T3
	Mean	19,5	7,0	2,3	0,000	0,000	T1≠T2≠T3
	Range	26,3	20,1	12,9	0,000	0,000	T1≠T2≠T3
	SD	4,3	4,2	3,1	0,000	0,000	T1=T2≠T3
	CV	0,2	0,7	1,5	0,000	0,000	T1≠T2≠T3
L3 (20)	Min	1,7	0,5	0,0	0,000	0,000	T1≠T2=T3
	Max	23,5	16,7	10,4	0,000	0,000	T1≠T2≠T3
	Sum	17238	4610	1808	0,000	0,000	T1≠T2≠T3
	Mean	17,5	7,1	2,0	0,000	0,000	T1≠T2≠T3
	Range	21,9	16,3	10,4	0,000	0,000	T1≠T2≠T3
	SD	3,6	3,5	2,6	0,000	0.001	T1=T2≠T3
	CV	0,2	0,7	1,6	0,000	0,000	T1≠T2≠T3
L4 (15)	Min	3,7	0,8	0,0	0,000	0,000	T1≠T2≠T3
	Max	24,0	15,4	9,9	0,000	0,000	T1≠T2≠T3
	Sum	8737	2170	949	0,000	0,000	T1≠T2≠T3
	Mean	18,4	7,2	2,2	0,000	0,000	T1≠T2≠T3
	Range	20,2	14,5	9,9	0,000	0,000	T1≠T2≠T3
	SD	3,4	3,3	2,5	0,000	0,000	T1=T2≠T3
	CV	0,2	0,7	1,6	0,000	0,000	T1≠T2≠T3
L5 (10)	Min	6,8	1,6	0,1	0,000	0,000	T1≠T2≠T3
	Max	23,3	13,4	9,0	0,000	0,000	T1≠T2≠T3
	Sum	3774	942	358	0,000	0,000	T1≠T2≠T3
	Mean	18,3	7,3	2,6	0,000	0,000	T1≠T2≠T3
	Range	16,5	11,8	8,9	0,000	0,000	T1≠T2≠T3
	SD	3,2	2,8	2,4	0,000	0,029	T1≠T2≠T3
	CV	0,2	0,6	1,6	0,000	0,000	T1≠T2≠T3
L6 (5)	Min	12,1	2,9	0,6	0,000	0,000	T1≠T2≠T3
	Max	21,9	10,7	6,2	0,000	0,000	T1≠T2≠T3
	Sum	828	282	86	0,000	0,000	T1≠T2≠T3
	Mean	18,4	7,0	2,8	0,000	0,000	T1≠T2≠T3
	Range	9,8	7,8	5,6	0,000	0,000	T1≠T2≠T3
	SD	2,4	2,0	1,6	0,000	0,000	T1≠T2≠T3
	CV	0,2	0,5	1,1	0,000	0,000	T1≠T2≠T3

Study area	**CHM-derived metrics selected on the basis of the satistical analysis**	**CHM-derived metrics selected for polygon classification**
Cerbaie	Max, mean, range, CV	Mean, CV
Molise	Mean, CV	Mean, CV
Mugello	Sum, mean, SD, CV	Mean, CV



Study area	Area (ha)	CHM-derived metric	OA (%)		KIA	
			3 classes	2 classes	3 classes	2 classes
Cerbaie	45	Mean, CV	86	100	0.79	1.00
Molise	107	Mean, CV	93	95	0.89	0.89
Mugello	506	Mean, CV	86	91	0.75	0.76

Study area	T1: high forest		T2: coppice		T3: young coppice	
	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)
Cerbaie	100	100	71	100	100	58
Molise	86	99	94	83	100	96
Mugello	88	77	85	91	87	81



Conclusions

- ALS data were useful for forest structure classification
- The best metrics were mean height and CV
- These two metrics were not influenced by scale parameter used for polygon delineation
- It is worth noting that information extracted from a raster CHM were sufficient to discriminate forest structure into coppice stands and high forest stands
- Similar results were obtained by Lefsky et al. (2005) and Pascual et al. (2008) for forest structure classification in coniferous forests
- Further investigations are necessary to test this method on different forest types and to compare the performances of raw point data vs raster CHM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Thanks for your attention
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