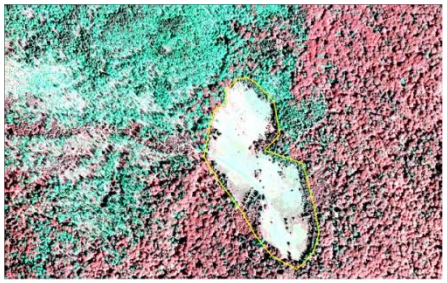
Assoc. Prof. Piotr Wezyk Ph.D. (Forestry)

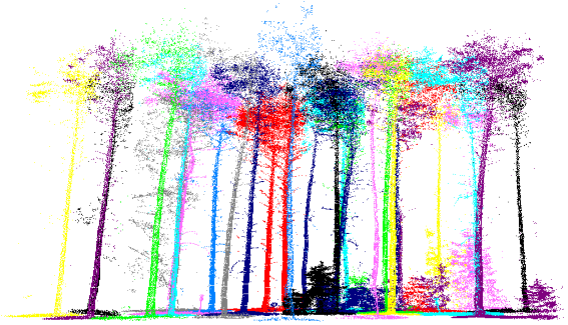
Marta Szostak Ph.D. (Geodesy and Cartography)

University of Agriculture in Krakow, Poland, Faculty of Forestry

Department of Forest Ecology, Laboratory of Geomatics










Faculty of Forestry University of Agriculture in Krakow

The Forest Faculty units - Departments

- Institute of Forest Biodiversity (Forest Botany and Nature Conservation , Zoology and Wildlife Management and Philosophy of Nature and Regional Culture ; Forest Tree Breeding)
- Forest Mensuration
- Forest Ecology (+Lab of Geomatics)
- Forest Entomology
- Forest Pathology
- Forest Soil Science
- Forest Engineering
- Forest Work Mechanisation
- Forest Protection and Forest Climatology
- Forest Silviculture
- Forest Management
- Wood Utilization

Academic staff:

Faculty employs **92 members** of academic staff including:

- 12 full professors,
- 25 persons holding D.Sc. degrees,
- 55 persons holding Ph.D.

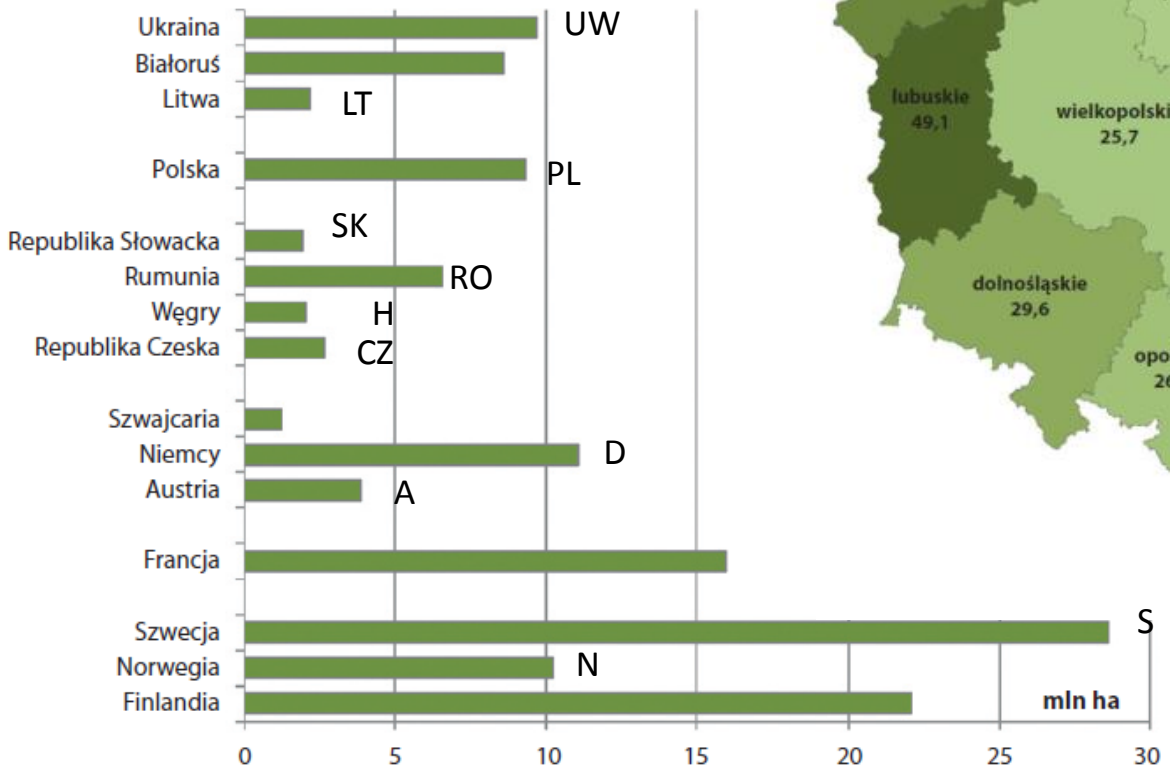
Education

The Faculty trains about **1.050 students** on both undergraduate and postgraduate programs in the field of: Forest Management and Protection of Forest Resources.

New program: Management of Environment

Forest area in Poland

Forest cover in Europe



Forest cover in Poland
9.163.800 ha

The State Forests National Forest Holding

(State Forests NFH) – the bigest owner

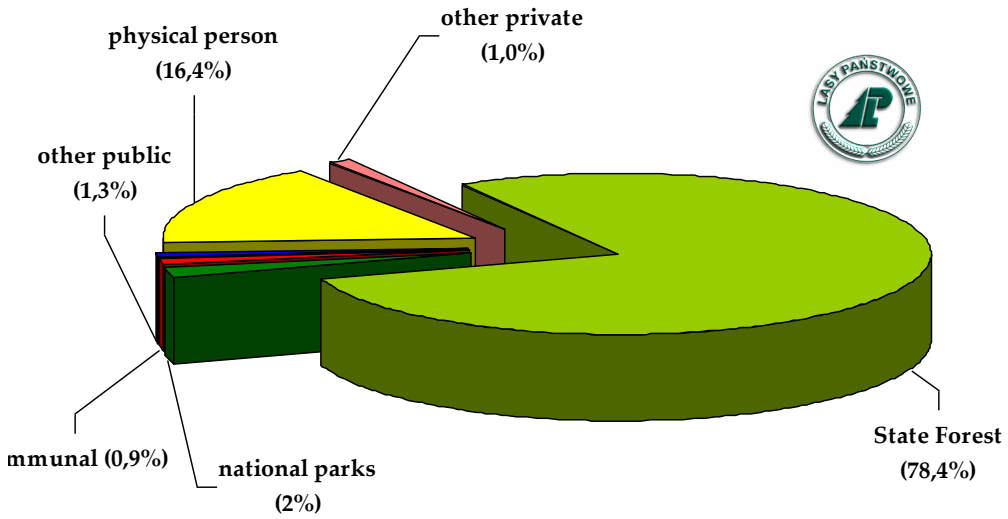
***Forest land in Poland definition according the low**: forest is a ground covered with a forest vegetation, of area above 0,1 ha; it includes forest grounds temporarily deprived of forest vegetation, and grounds related to forestry (forest roads, nurseries etc).*

Forest area in Poland: **9.163.800** ha = **29,3** % (30,3% other EU method) of the entire country (year 1945 -20.8%)

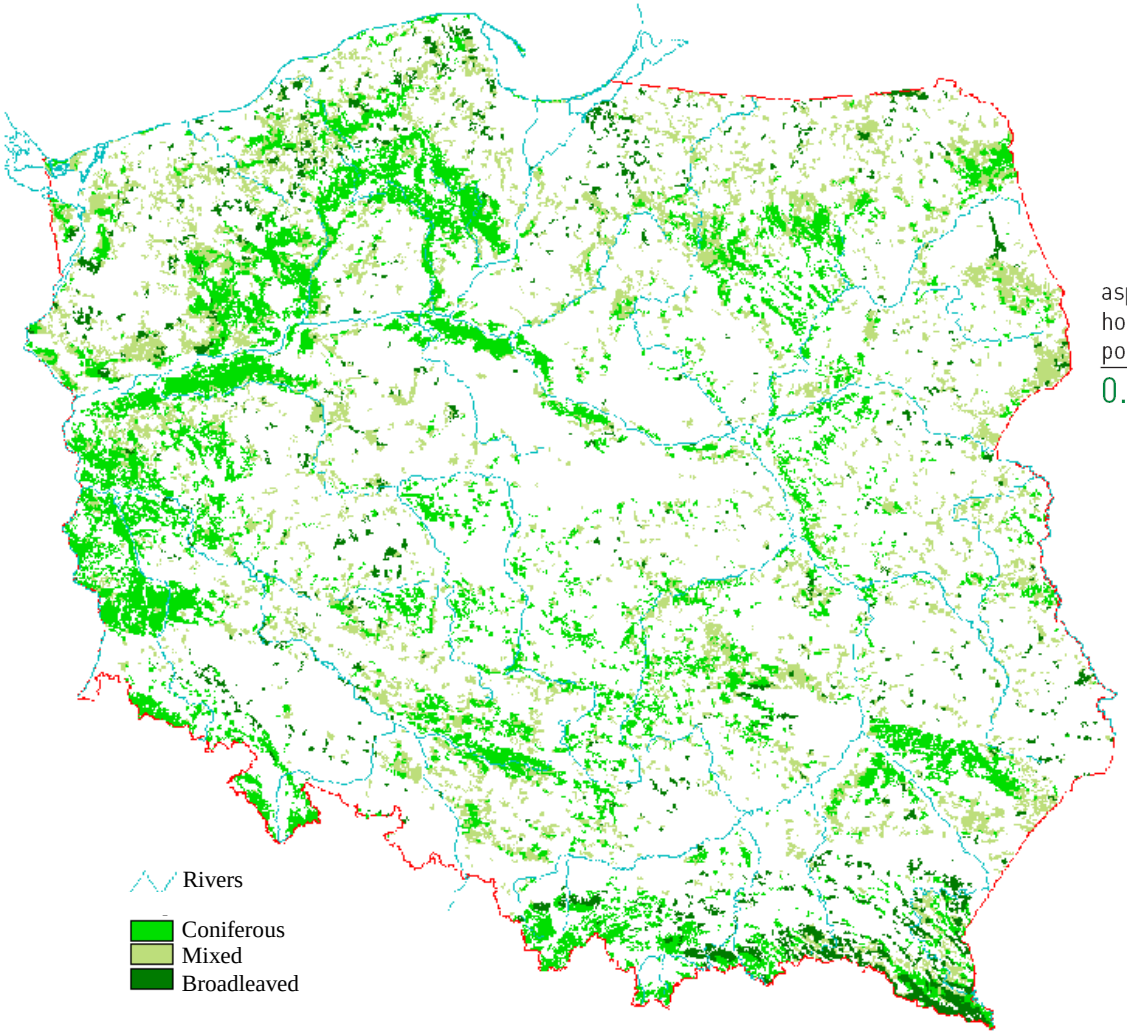
The **State Forests National Forest Holding** owned **77.3%** (**7.083.488** ha) of all Polish forests

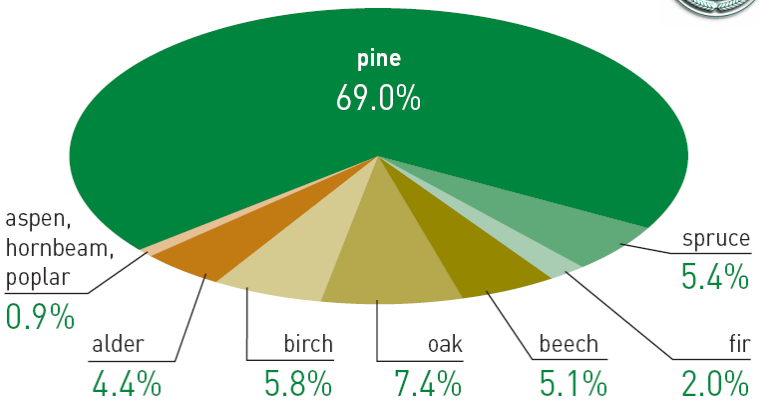
- 17 Regional Forest Directorate's,
- 428 Forest Districts (independent forest management plans)

National Plan to Augmentation of Forest Cover in Poland – increasing up to **30%** by year 2030 (0.7 mln ha) and **33%** by year 2050 (1.5 mln ha).



State Forests NFH in numbers



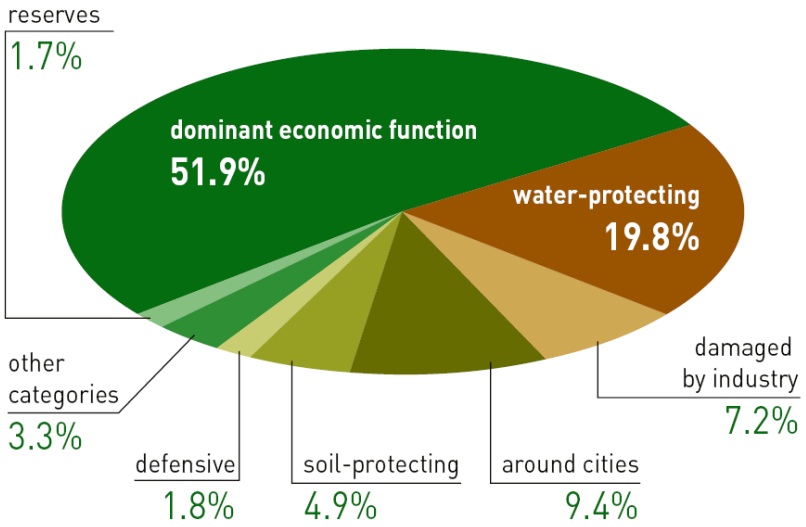


Dominant tree species in Polish State Forest

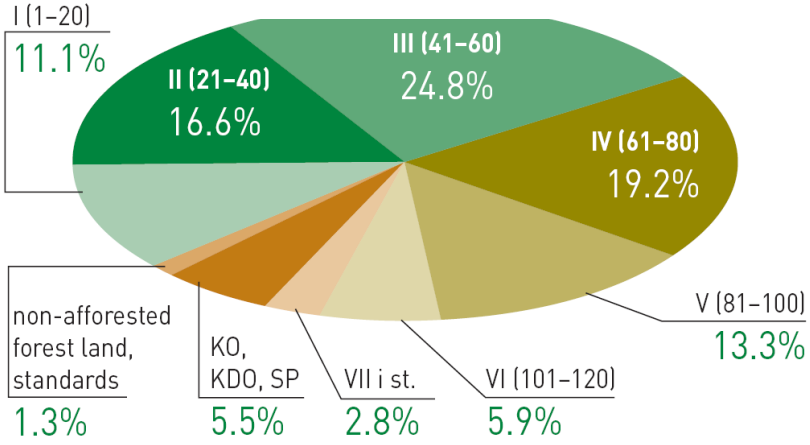
About 83% of all forest resources of Poland are potentially threatened by fire (average in EU 63%). Thus, with an area of 7.4 million ha at risk the danger is extremely high.

Source: The State Forest in Figures 2008

State Forests NFH in numbers



Share by protective forest categories within the State Forests NFH in 2007

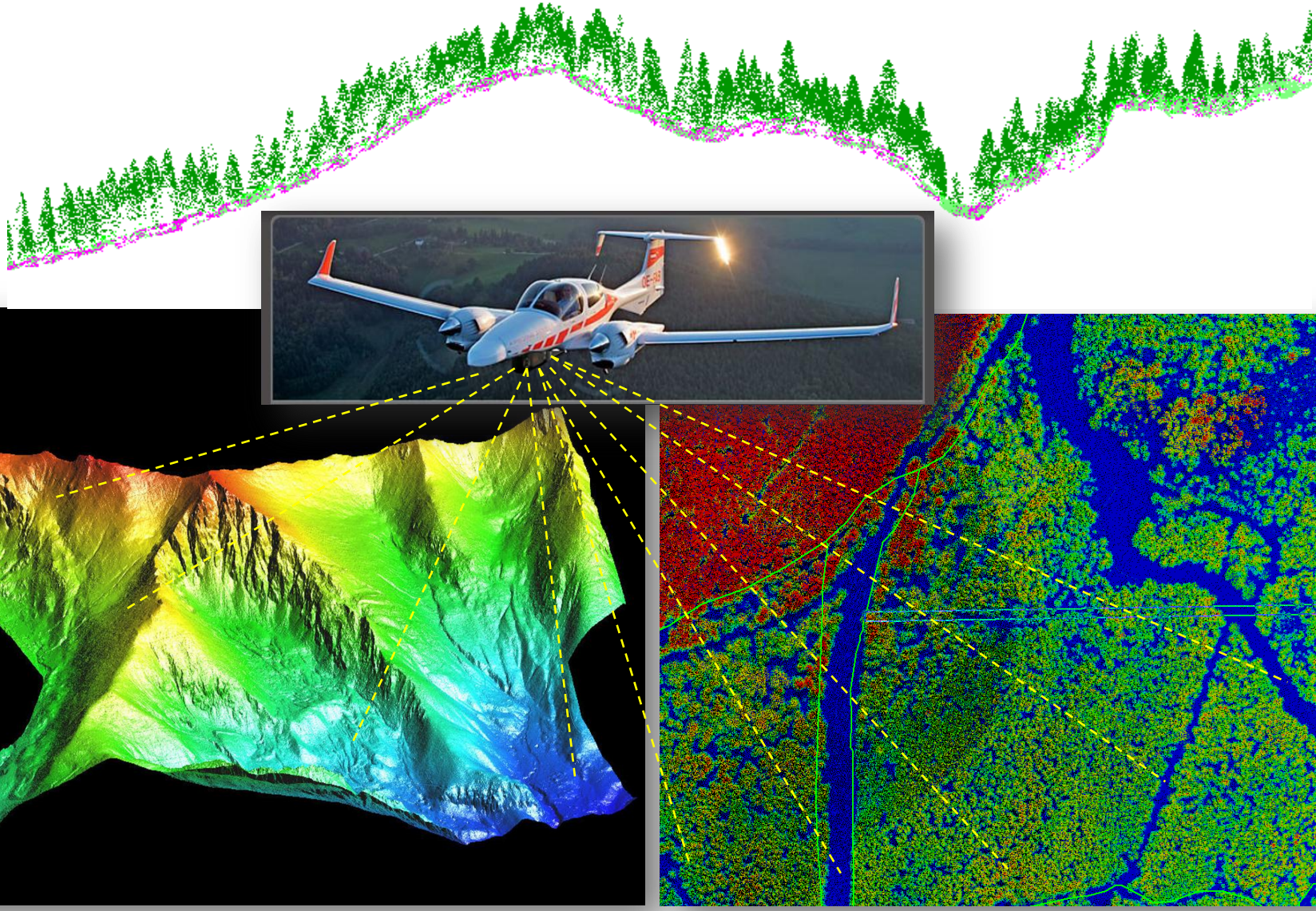


Mean age ~ 60 year's

*Poland's forests contain **736 million** tonnes of **carbon** accumulated in forest biomass of which **562 million** tonnes accumulates in the aboveground biomass, **168 million** – in the belowground biomass and **6 million** – in dead wood.*

Source: The State Forest in Figures 2008

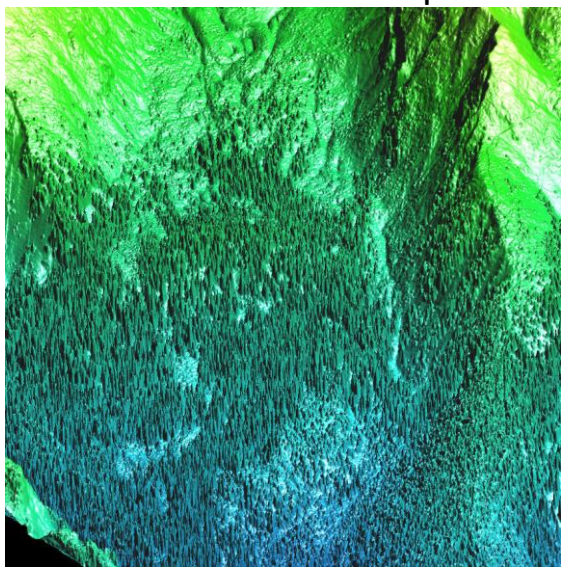
Airborne Laser Scanning (ALS)



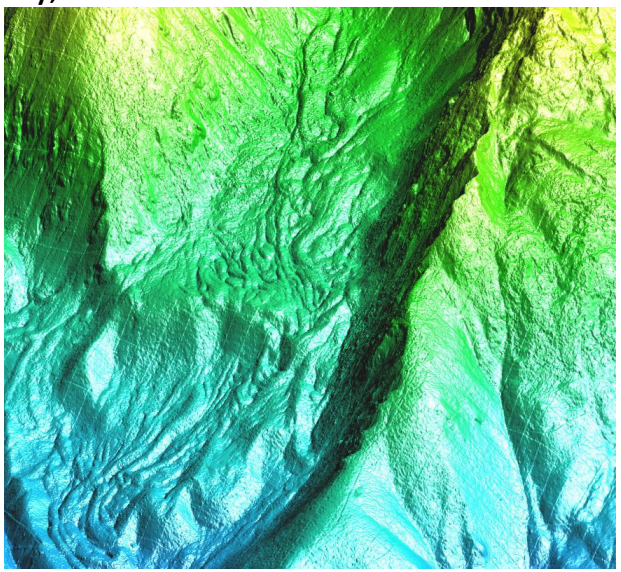
SCERIN-2 Krakow, Poland 2014

ALS - DSM/ DTM / Geomorphology

Sucha Kasprowa Valley, Polish Tatra

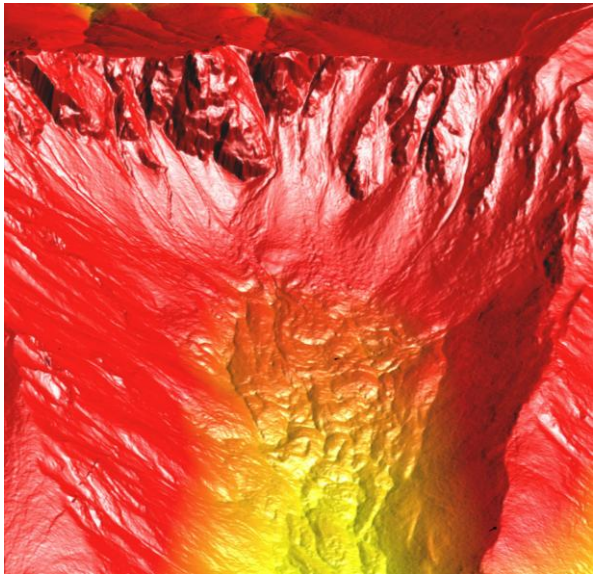


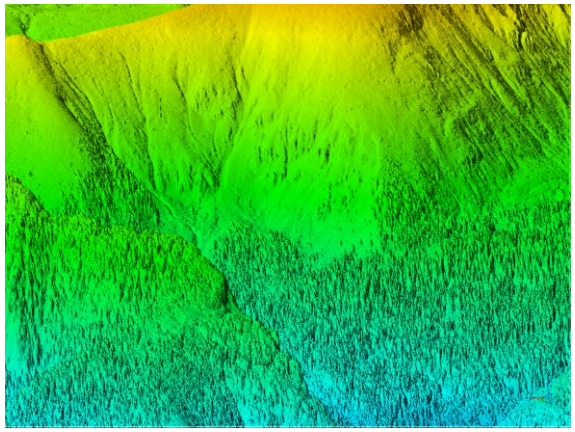
DSM; 2.5D view



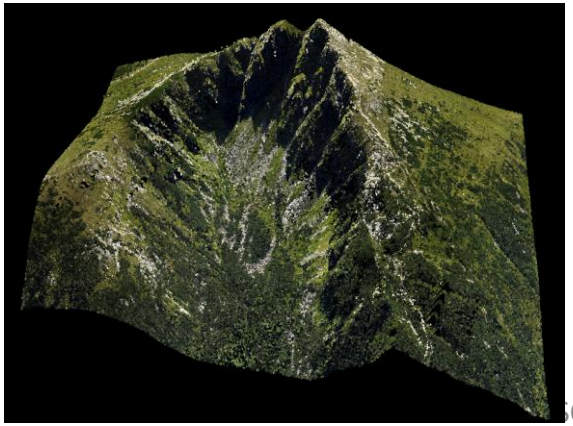
DTM; 2.5D view

Świńska Valley, Polish Tatra



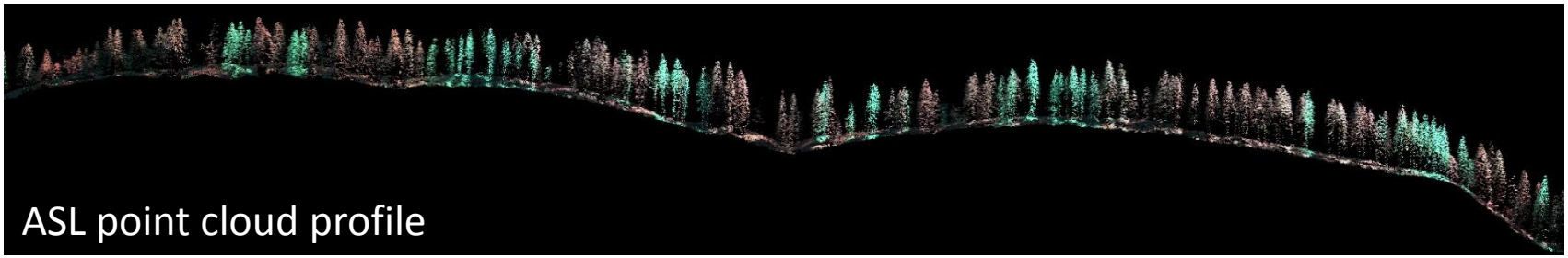


DSM; 2.5D view

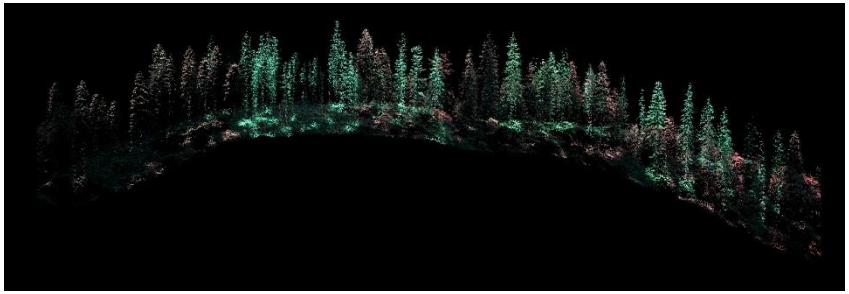


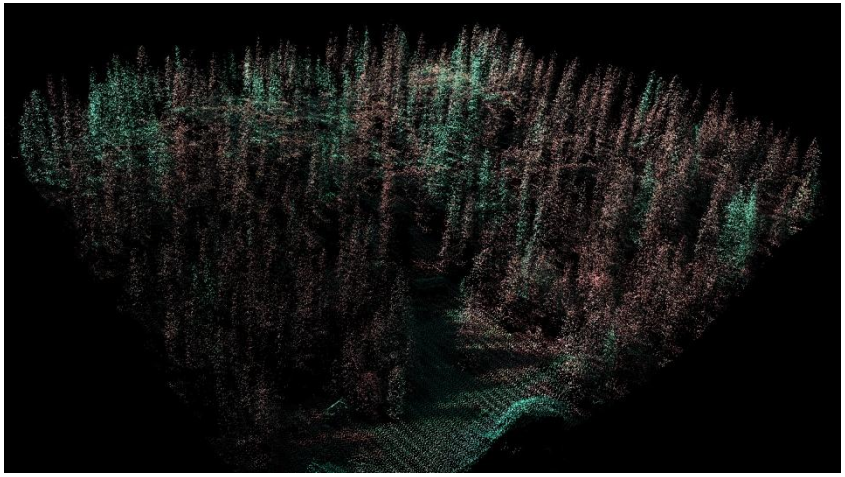
ALS – Profiles

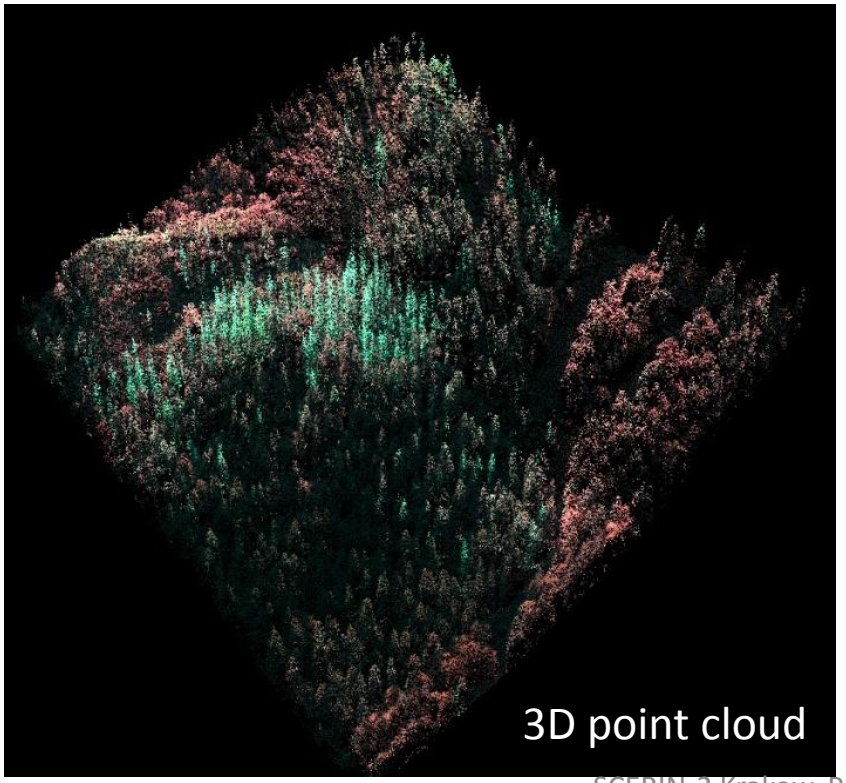
Color points RGB (Color InfaRed = CIR)



ASL point cloud profile





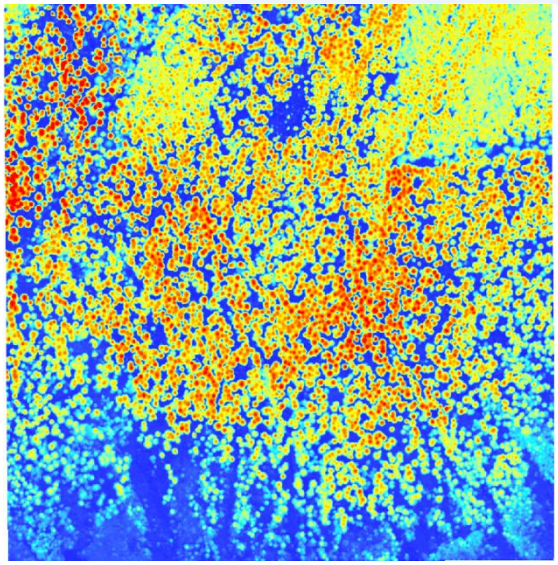


3D point cloud

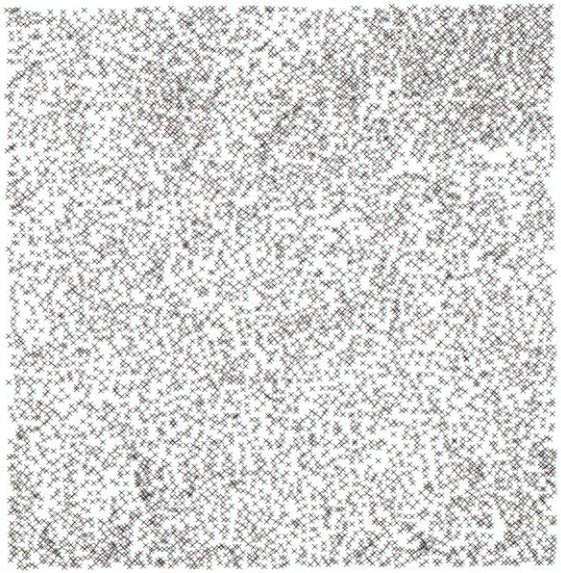
SCERIN-2 Krakow, Poland 2014

ALS - Number of trees

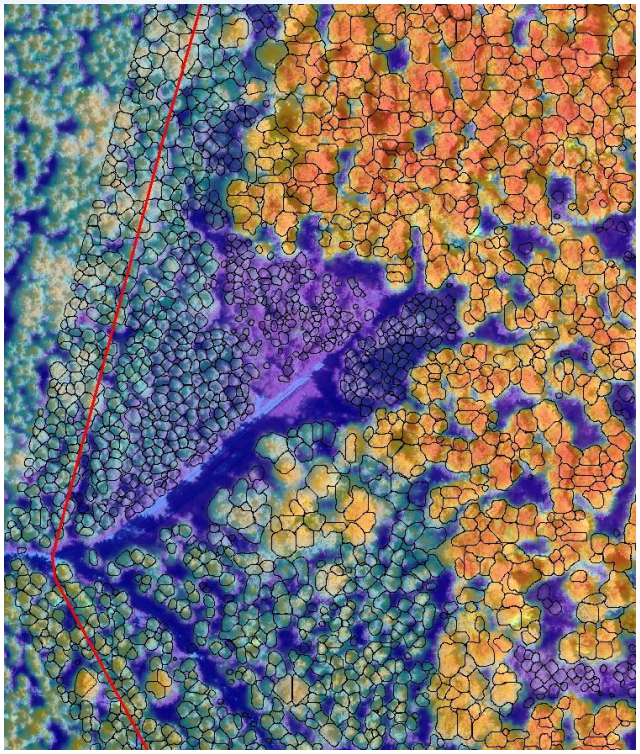
nDSM local maxima



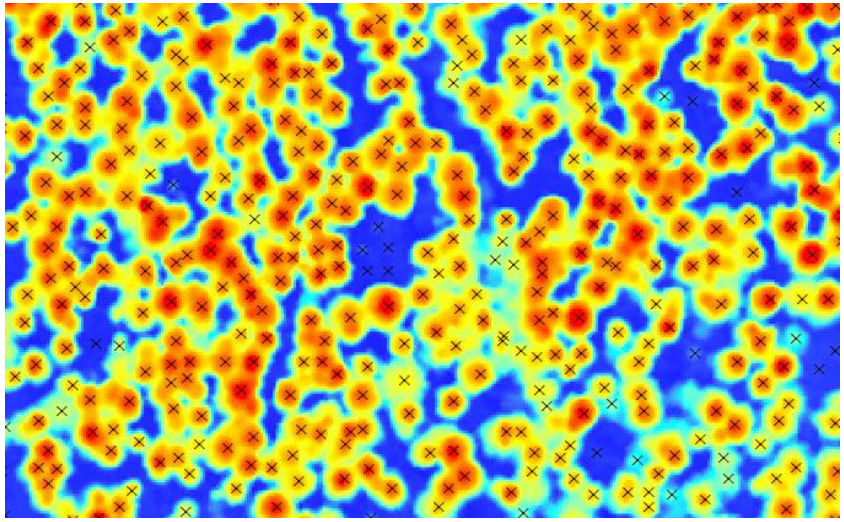
nDSM



Tree top positions



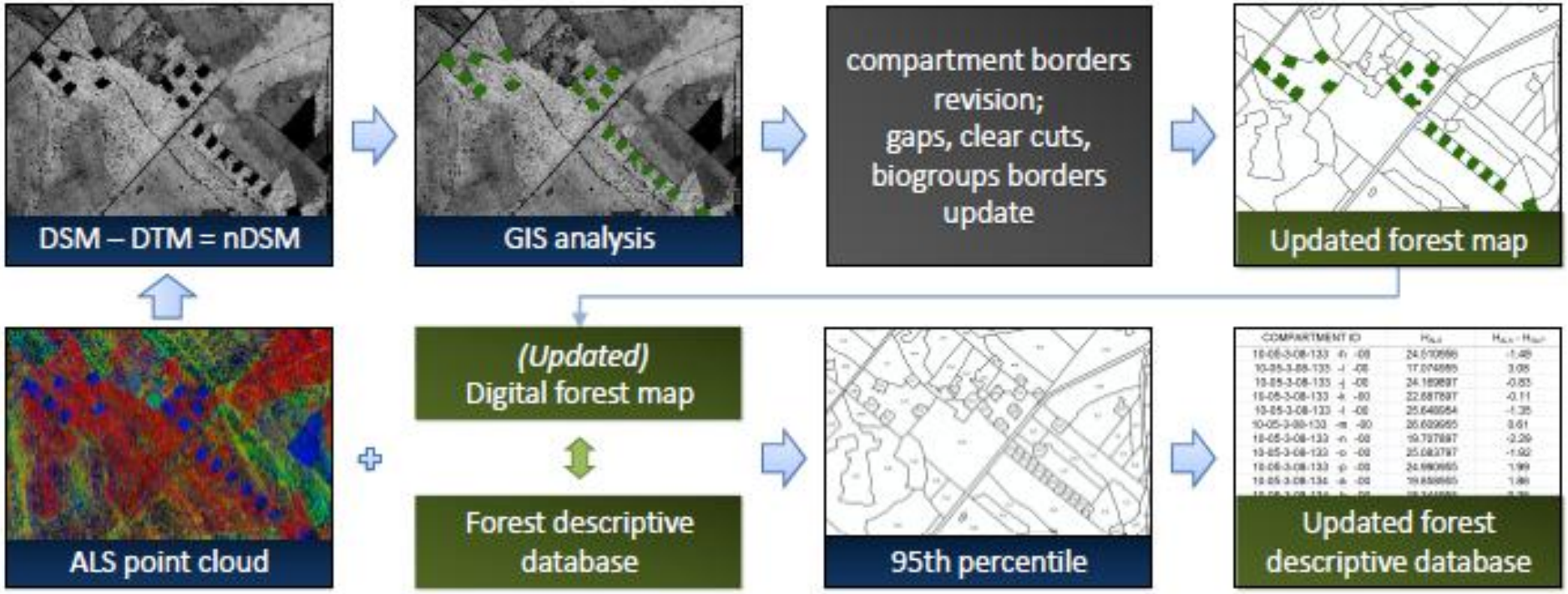
nDSM + ortho + tree crowns segmented



Number of all trees = 7003;
Trees > 25m = 2307

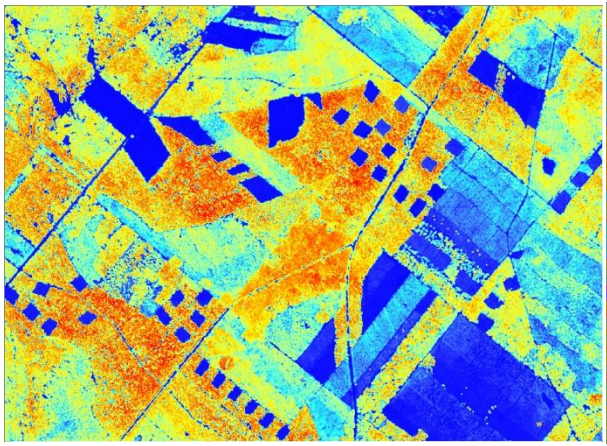
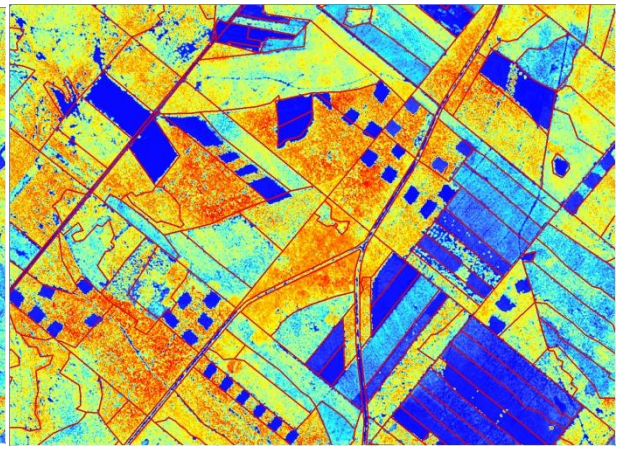
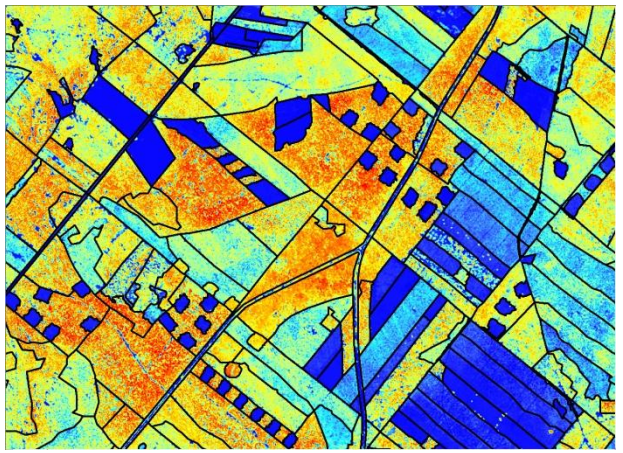
SCERIN-2 Krakow, Poland 2014

ALS – revision of digital forest map and SILP



Wężyk P., Szostak M., Tompalski P., Zajączkowski G. 2010. The role of Airborne Laser Scanning in updating and revision of GIS databases – a case study in the Polish State Forest (Chojna District). SiliviLaser 2010. 10th international conference on LiDAR applications in forest assessment and inventory. Sept. 17-19. 2010 – Freiburg, Germany. s.168 - 178.

ALS – revision of digital forest map and SILP

Difference (H_{diff}) : H ALS 95th minus H SILP (Forest descriptive database)

Tree species	H_{Diff} mean [m]		H_{Diff} modulus mean [m]		H_{Diff} area weighted mean [m]		H_{Diff} area weighted modulus mean [m]	
	Piasek	Milicz	Piasek	Milicz	Piasek	Milicz	Piasek	Milicz
All	+0.90	+2.28	2.06	3.19	+0.60	+2.38	1.52	2.70
Scots pine	+0.57	+2.21	1.76	2.83	+0.41	+2.33	1.34	2.55
Beech	+1.63	+3.61	2.51	3.93	+1.37	+2.59	2.21	2.85
Oak	+1.67	+2.28	2.89	4.96	+1.09	+2.84	2.10	3.86
Black alder	+1.00	+1.22	2.31	4.06	+1.43	+2.07	2.20	3.58

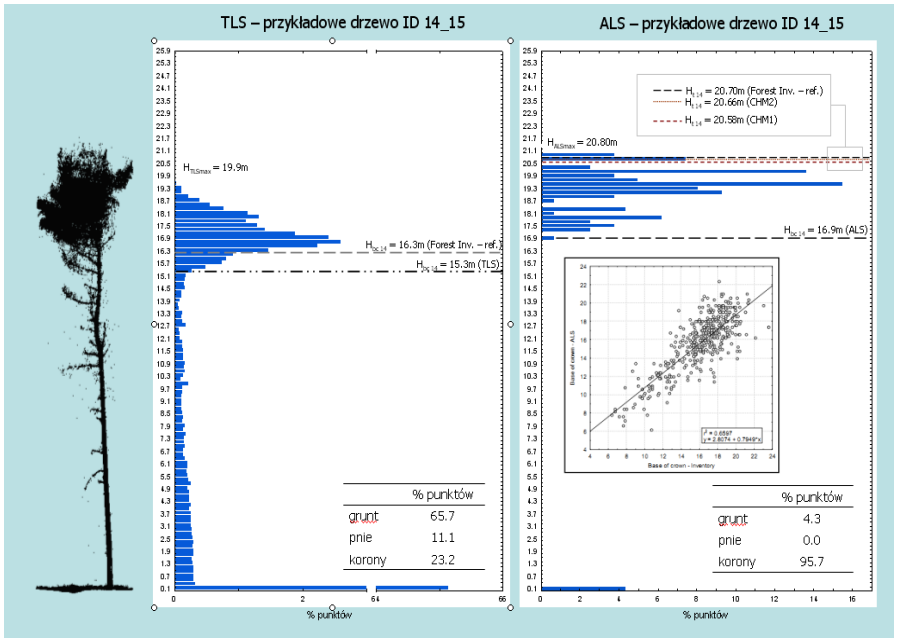
Wężyk P., Szostak M., Tompalski P. 2010. Development of automatic method for stand heigth verification on forest disctrict level using airborne laser scanning data. Annals of Geomatics. VIII;7(43), s:73-82

ALS – selected canopy layer parameters

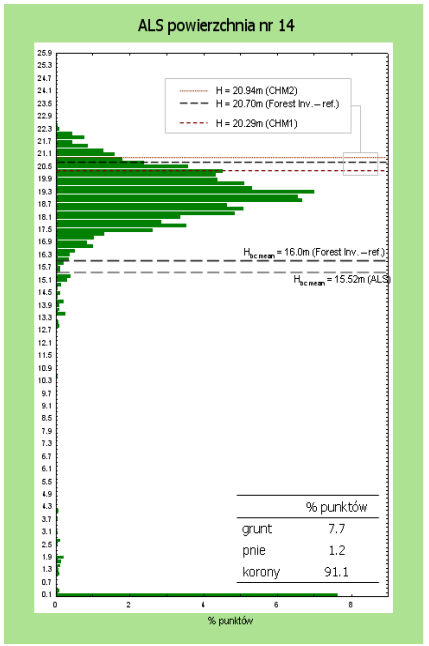
TLS method of individual trees height measurement result in underestimation up to -0.90 m in case of CHM1 surface and -0.12m for CHM2

		F. INV	SILP	TLS	CHM1	CHM2
F. INV	mean difference [m]		-1.14 (**)	-0.98 (**)	-0.90 (**)	-0.12 (n)
	R^2		0.73	0.81	0.81	0.80
	SD of difference		2.15	2.18	1.77	1.81
SILP	mean difference [m]			0.02 (n)	0.13 (n)	0.85 (*)
	R^2			0.96	0.96	0.95
	SD of difference			1.01	0.94	1.02
TLS	mean difference [m]				0.08 (n)	0.83 (**)
	R^2				0.95	0.94
	SD of difference				0.86	0.94
CHM1	mean difference [m]					0.75 (**)
	R^2					0.98
	SD of mean					0.58

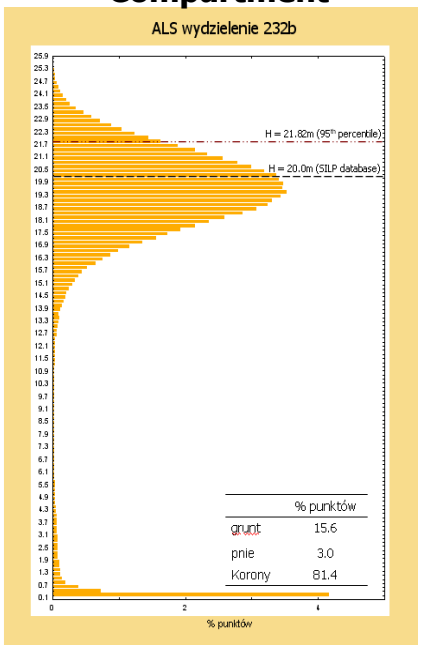
Single tree



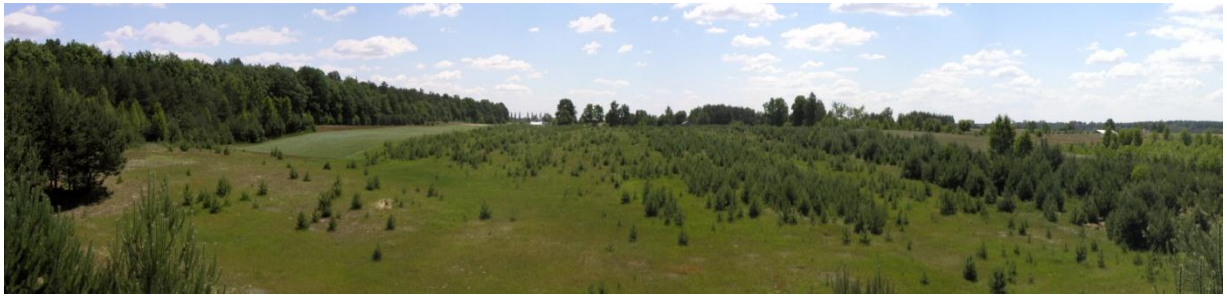
Tested area

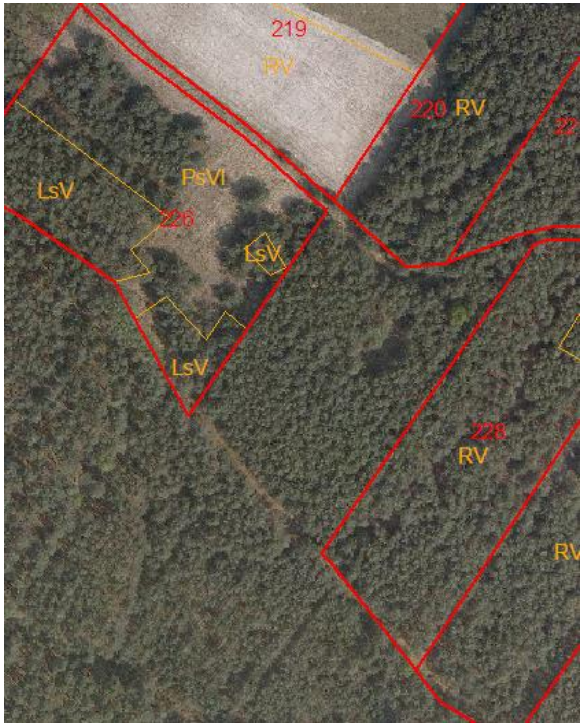


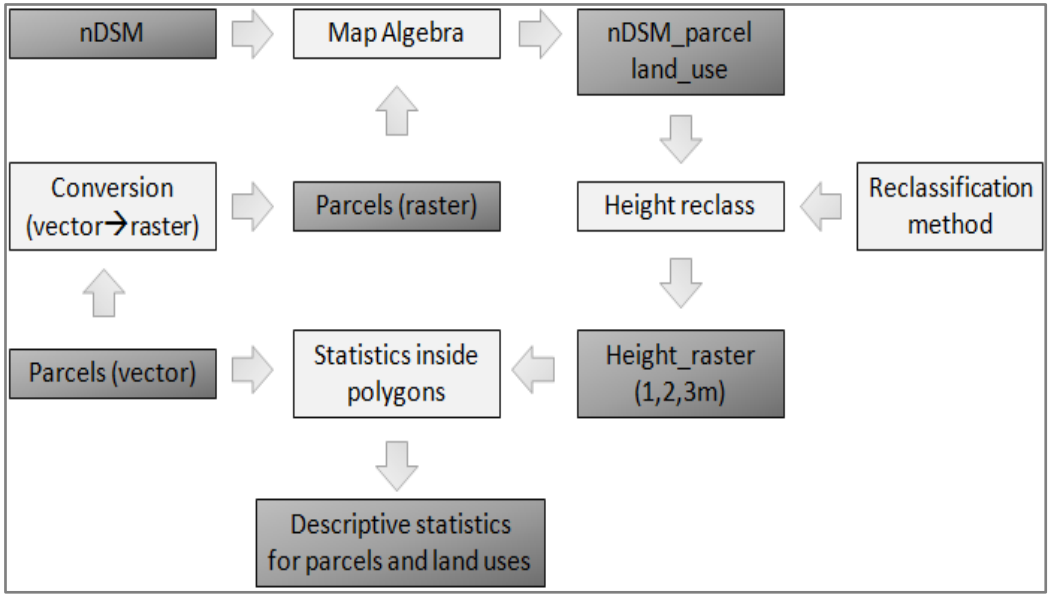
Compartment



ALS – secondary forest succession

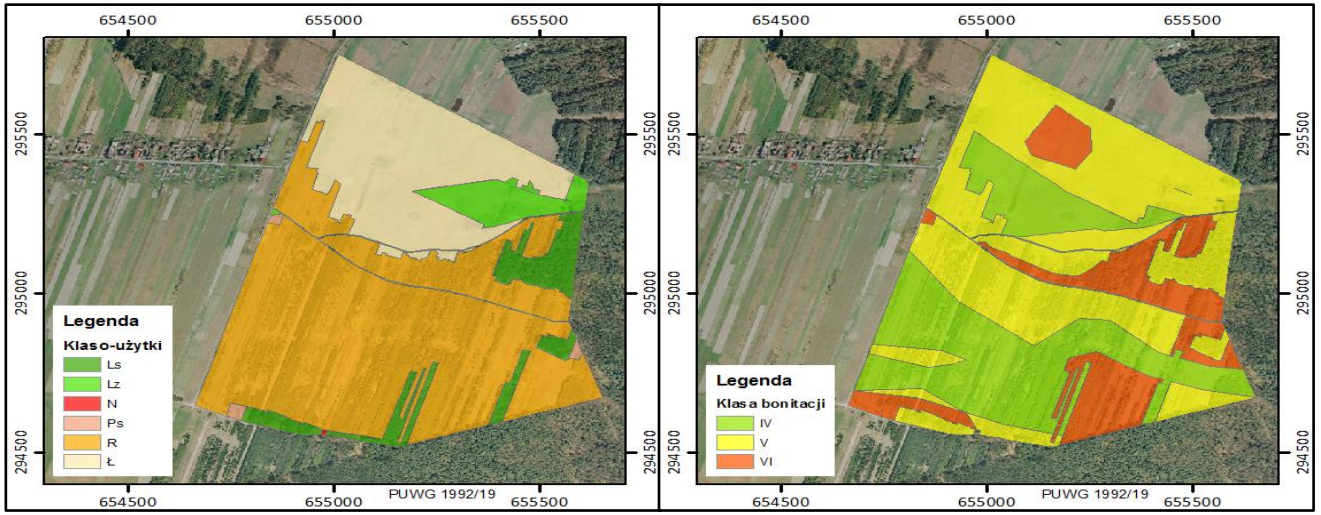


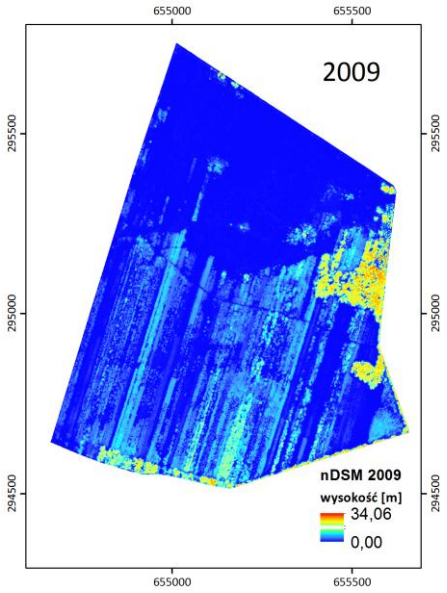




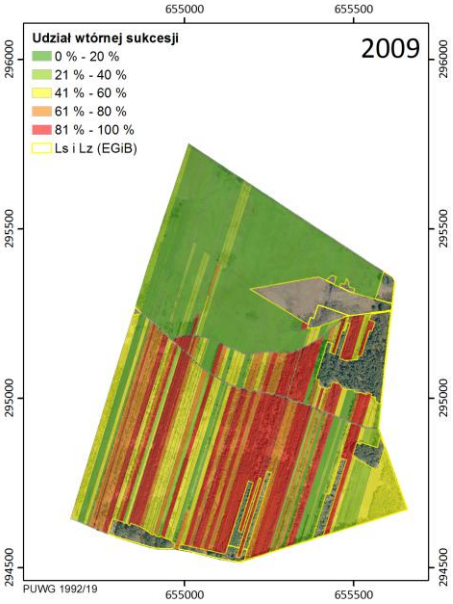
Szostak M., Wężyk P., Tompalski P. Aerial Orthophoto and Airborne Laser Scanning as Monitoring Tools for Land Cover Dynamics: A Case Study from the Milicz Forest District (Poland). Pure and Applied Geophysics, Vol. 170, No. 4

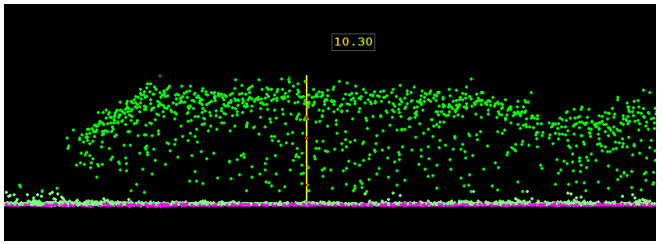
ALS – agriculture, forest succession



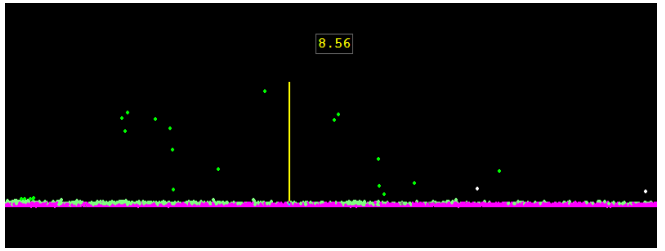


zNMPT





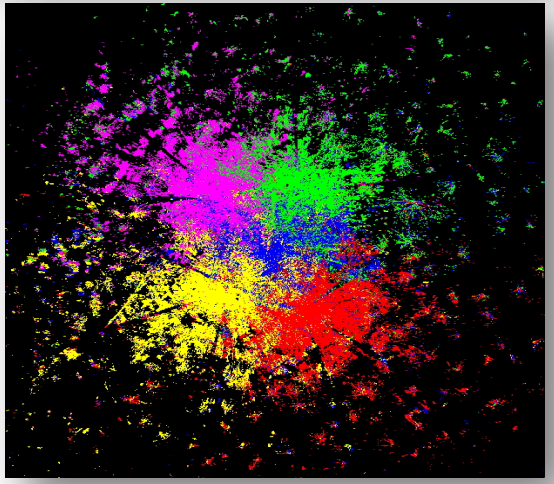
2009



2012

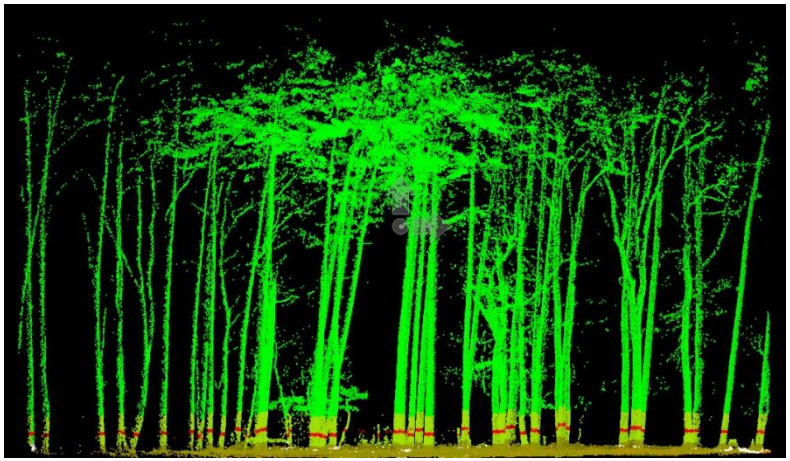
Test of ground based scanners

FARO FOCUS 3D



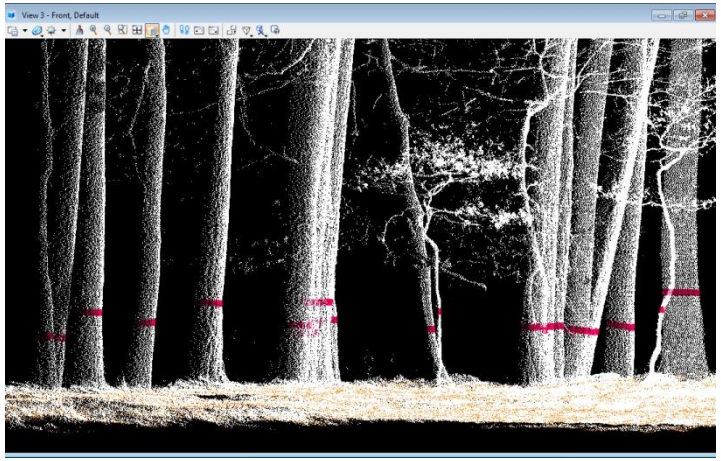
Terrestrial Laser Scanning

TLS - resolution



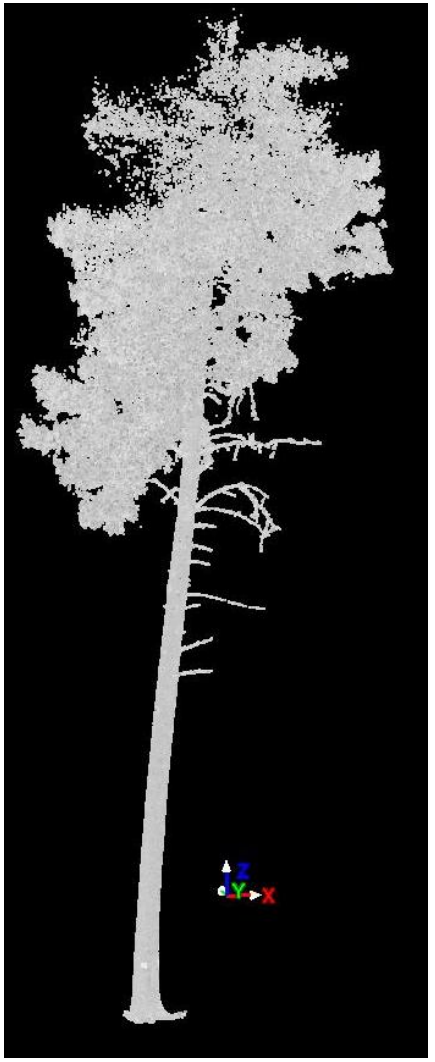
Profile trough the TLS point cloud (TerraScan; Terrasolid)

Resolution used: ¼
Time of scanning: ~7 min.
Size of file: 140 MB (*.fls)
Number of scans : 4
Software used:
FARO Scene version 4.0 for matching and export;
TerraScan (Terrasolid) for classification



Classified point cloud (red slices; BHD 1.28-1.32 cm above ground)

Colorized TLS point cloud of pine stem

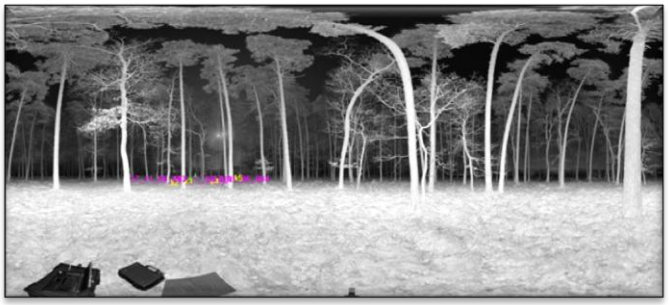


Scots pine no. 342

TLS - matching

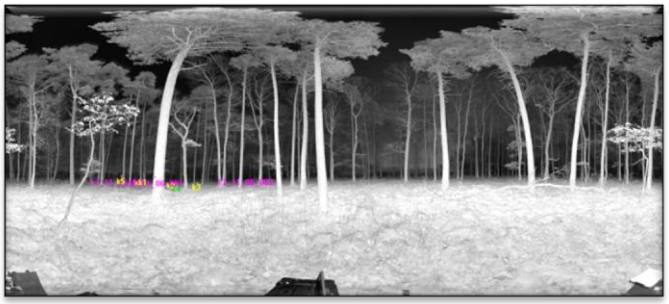
Scan S_2 (Slave)

+



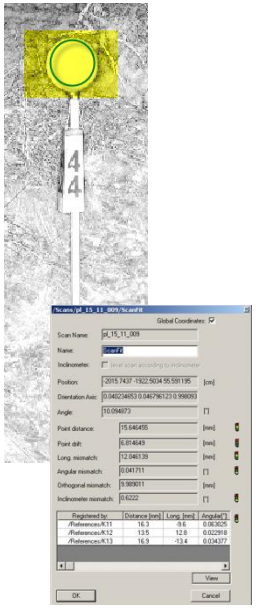
Scan S_3 (Slave)

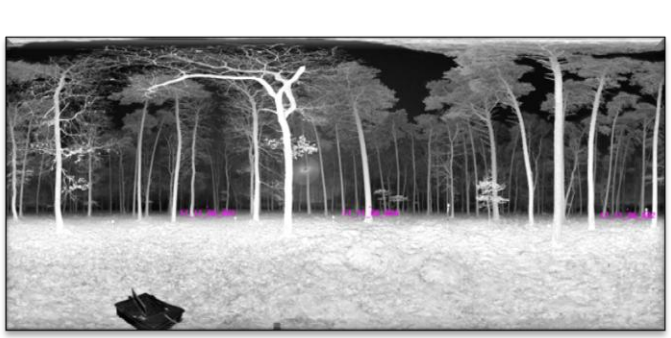
+



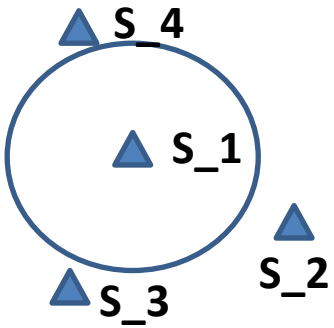
Scan S_4 (Slave)

+



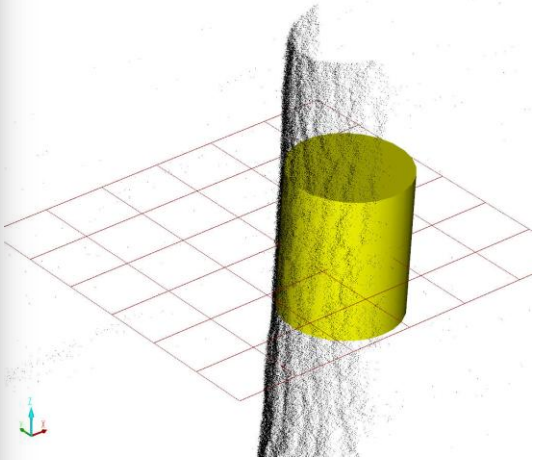


MASTER Scan S_1 (0,0,0)



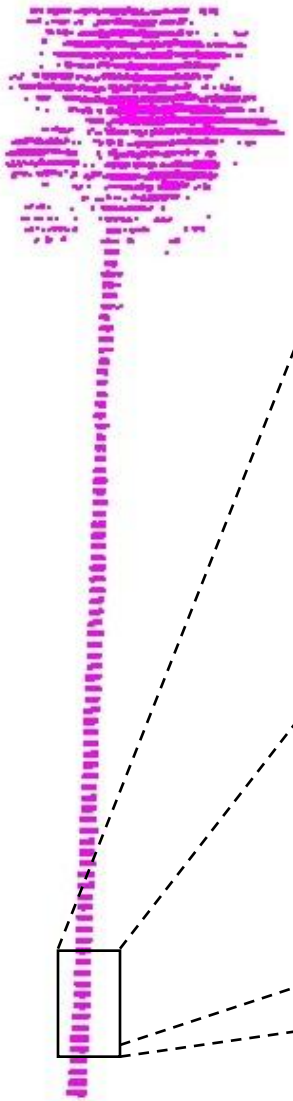
30,413,256 TLS points, class ground: 122,548

TLS versus traditional forest inventory

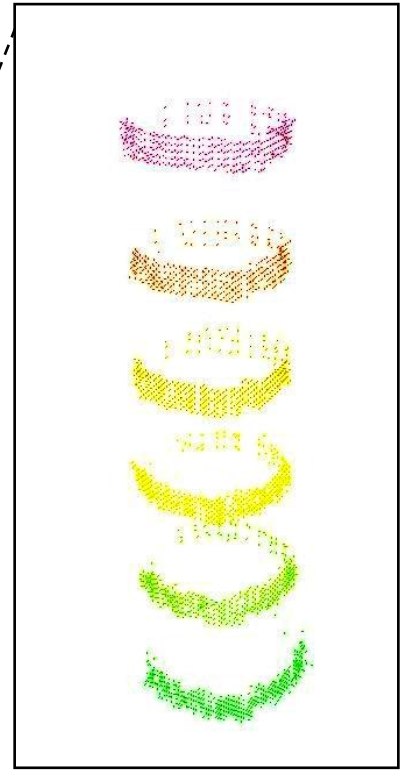


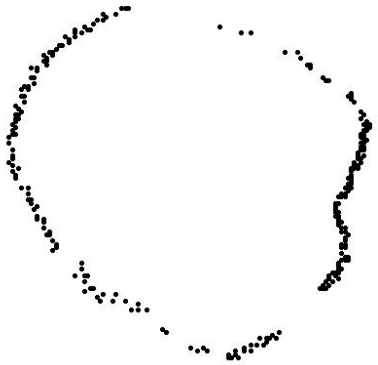
TLS „SLICE” – DBH automatically

TLS point cloud



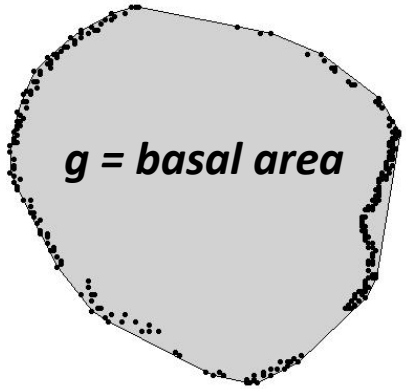
Slices each 20 cm





Single „DBH slice” (1.28m – 1.32m above ground)

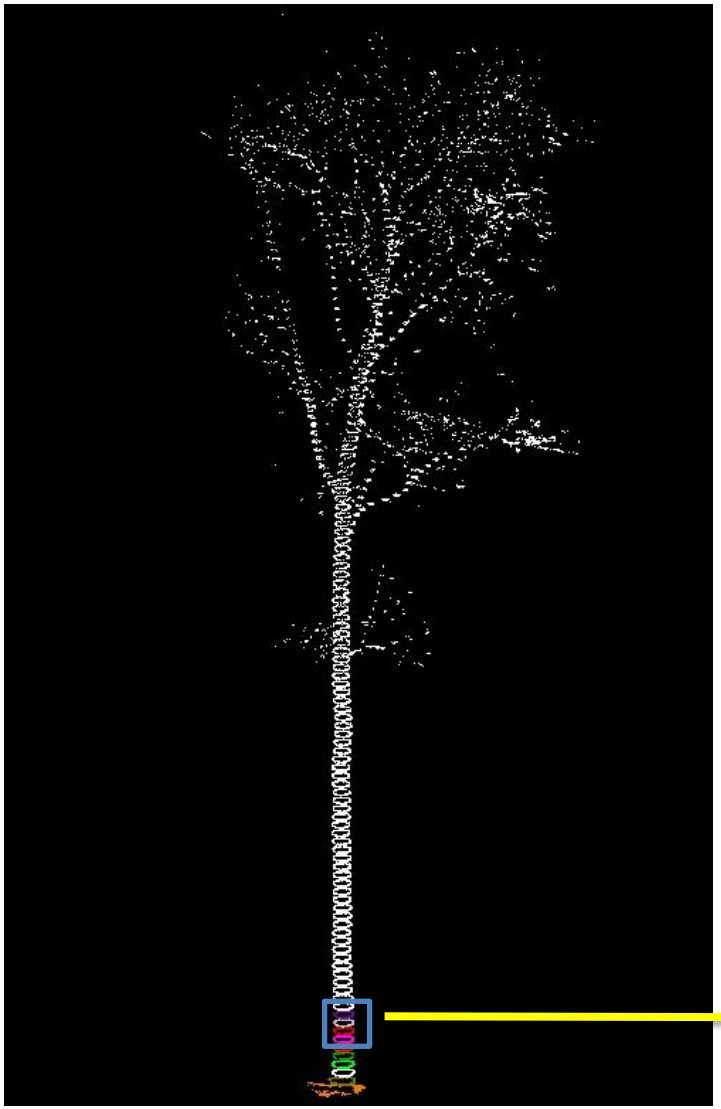
basal area (g) = convex hull

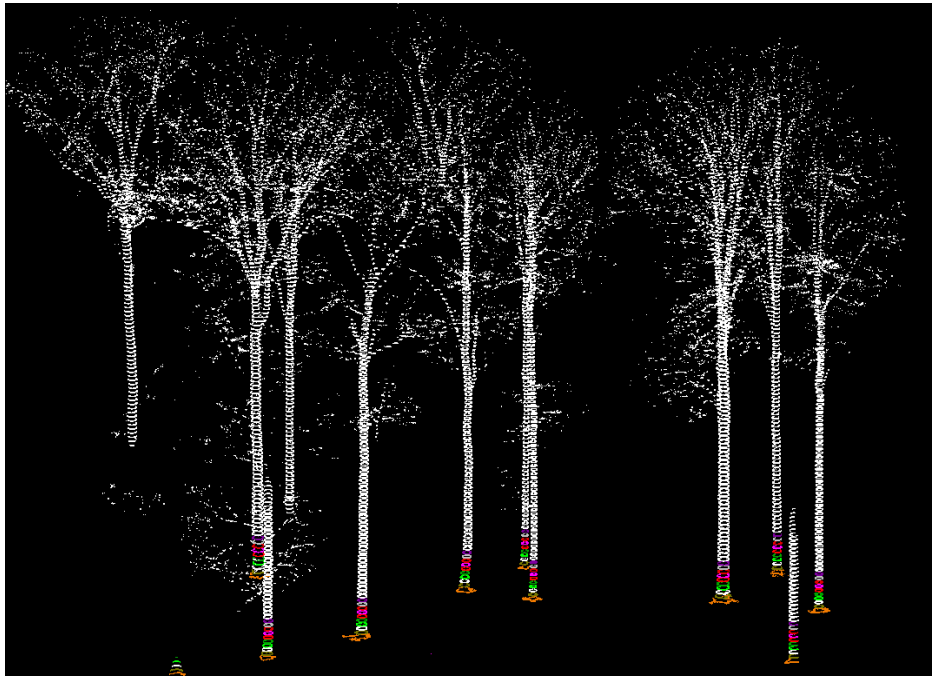


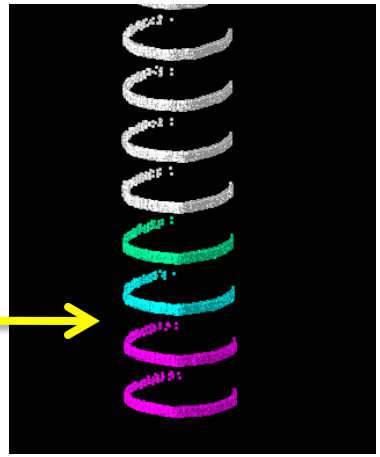
Terrasolid
Software for LiDAR Processing

Automatic slice selection

Terrasolid



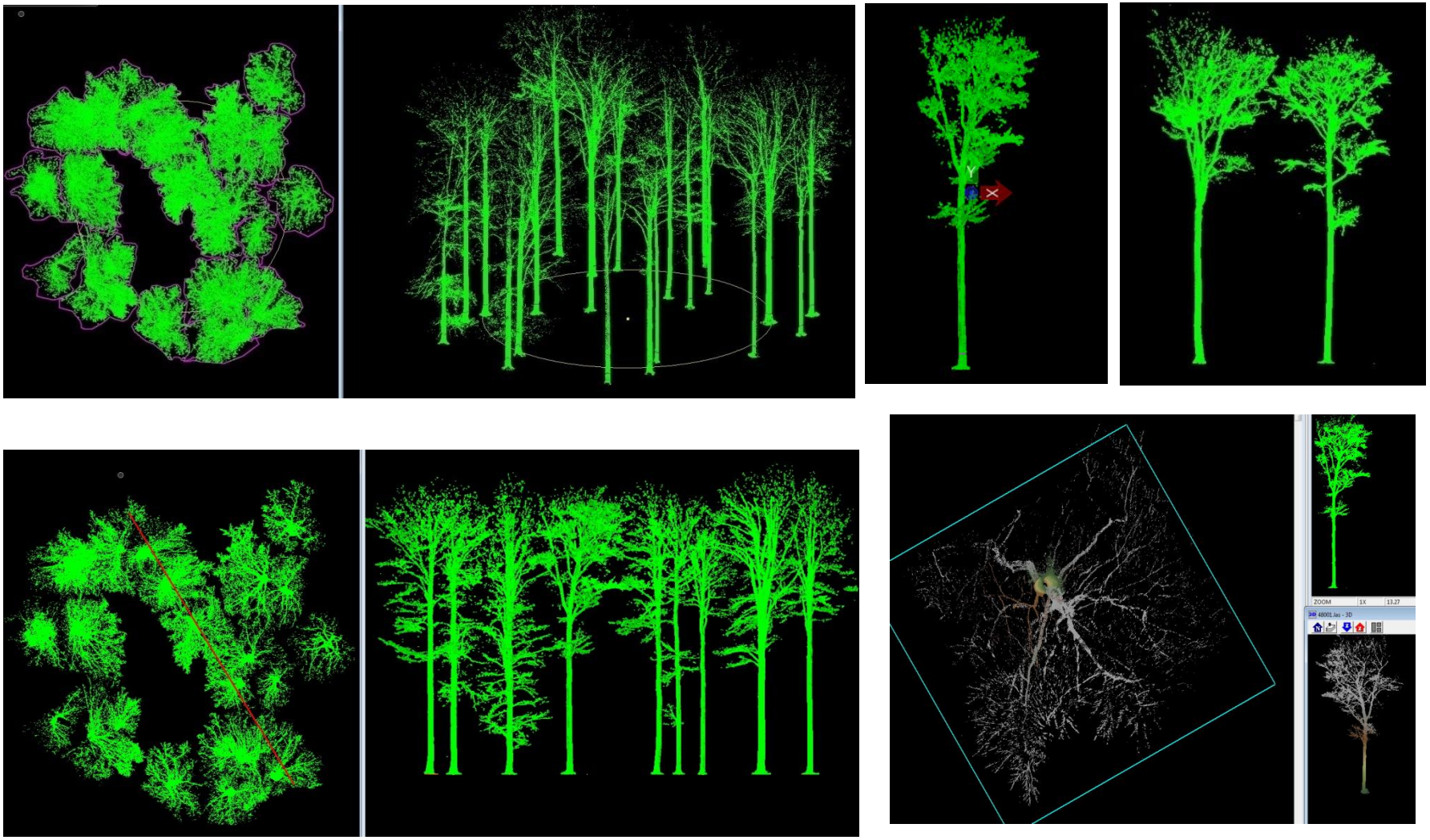




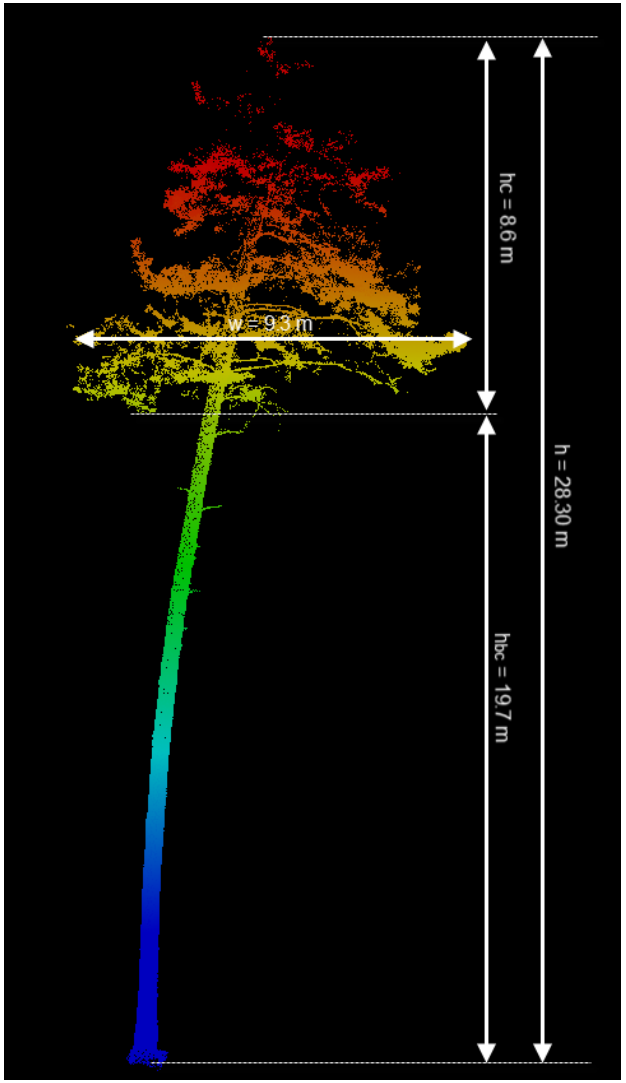
Slice 0,25m

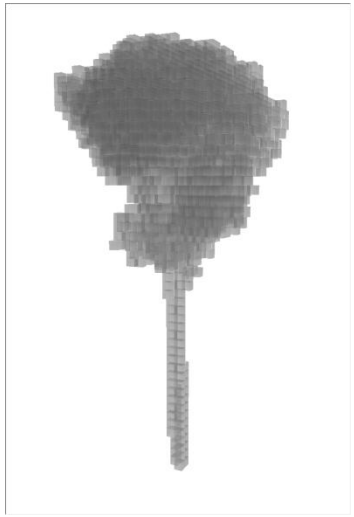
FARO FOCUS 3D – Case studies

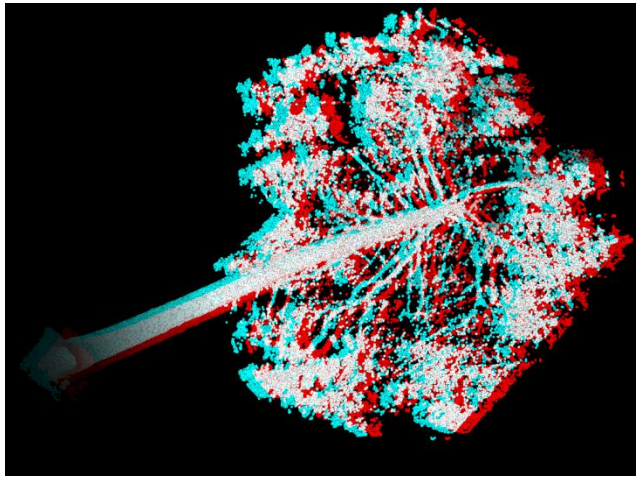
Fagus silvatica

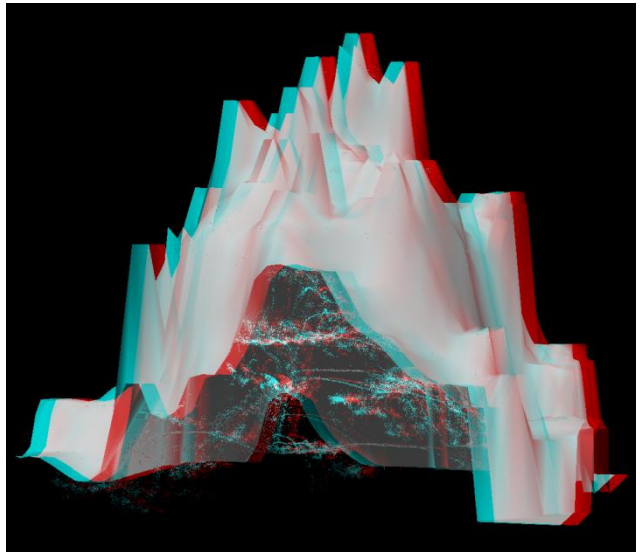


Crown Volume

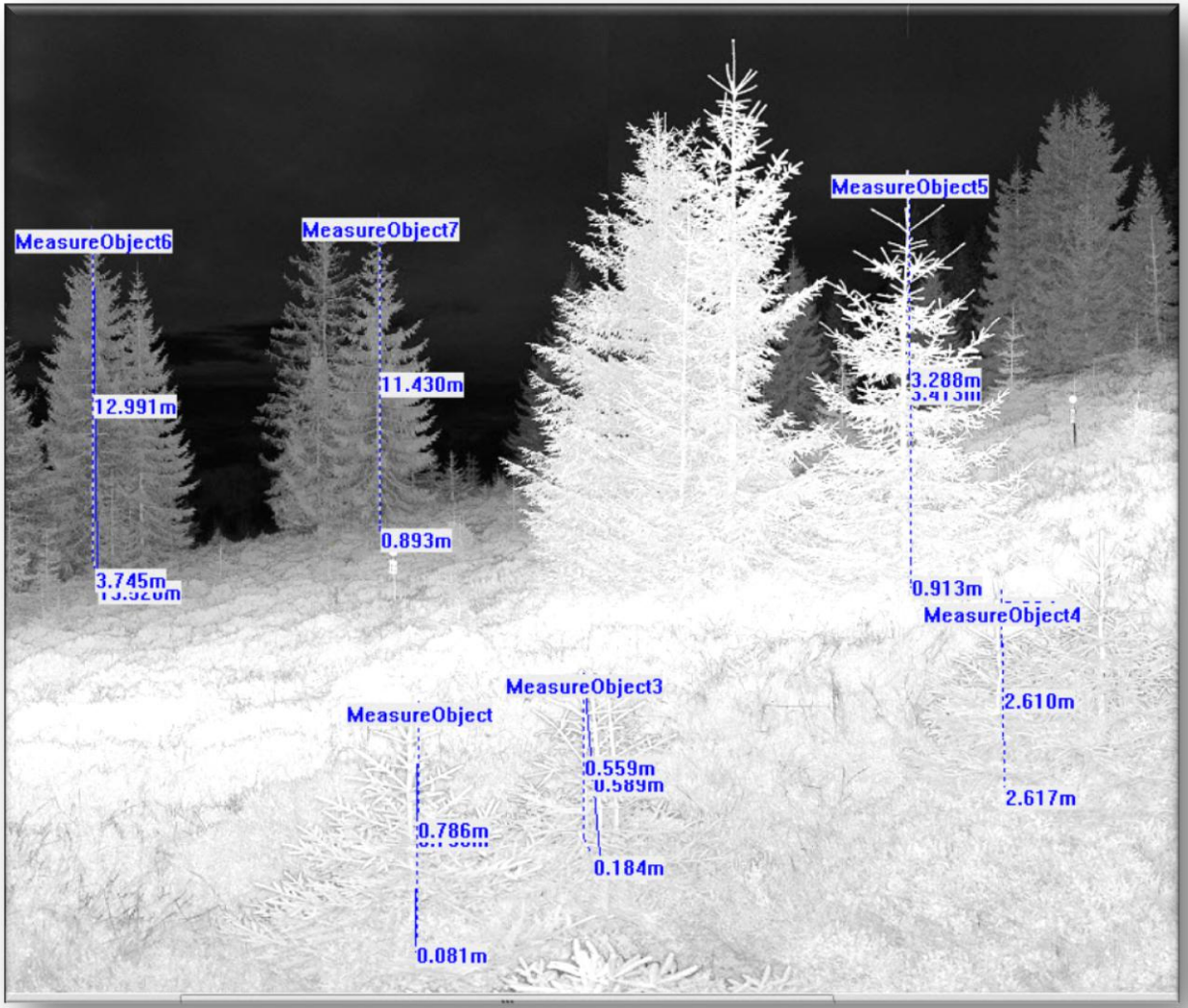








Outlook - TLS monitoring of the secondary forest succession



TLS inventory of „bark beetle nest”

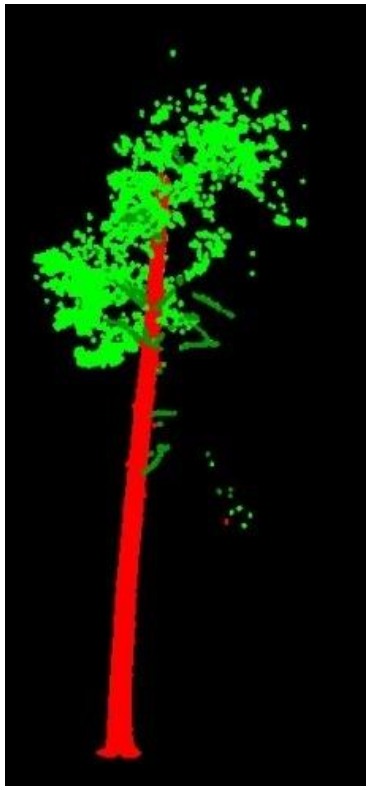
Intregration
TLS & ALS = earth & sky ?

Cesare Pavese (1908 – 1950): Italian poet, novelist, literary critic and translator.

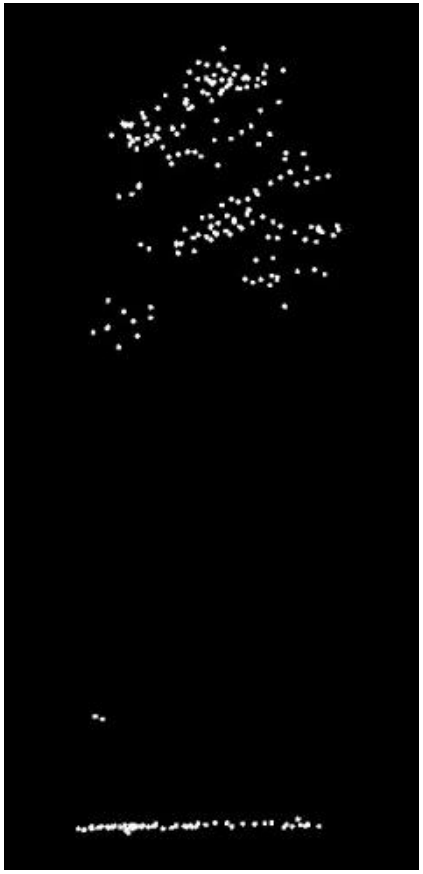
(…) the trees are a **bridge between heaven and earth** (…)

Saemtliche Gedichte 1962 Claassen Verlag

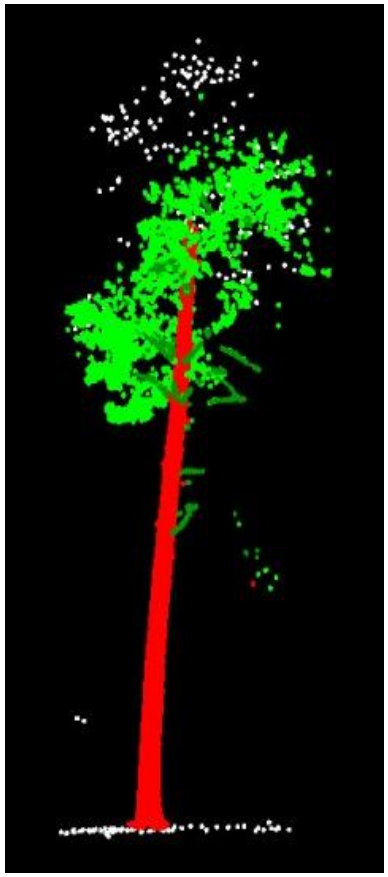
TLS & ALS Integration



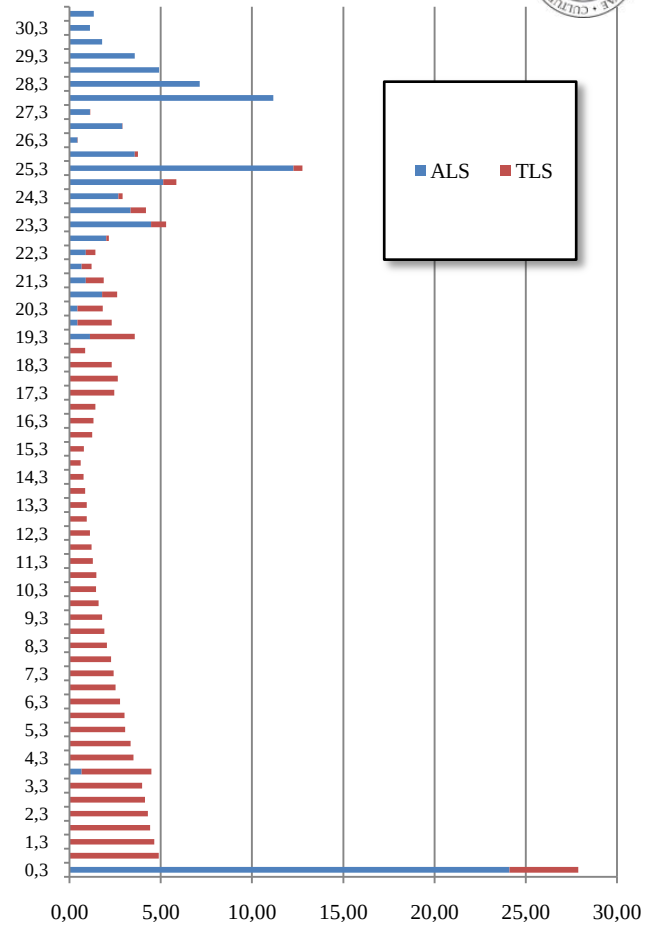
TLS - Pine



ALS - Pine



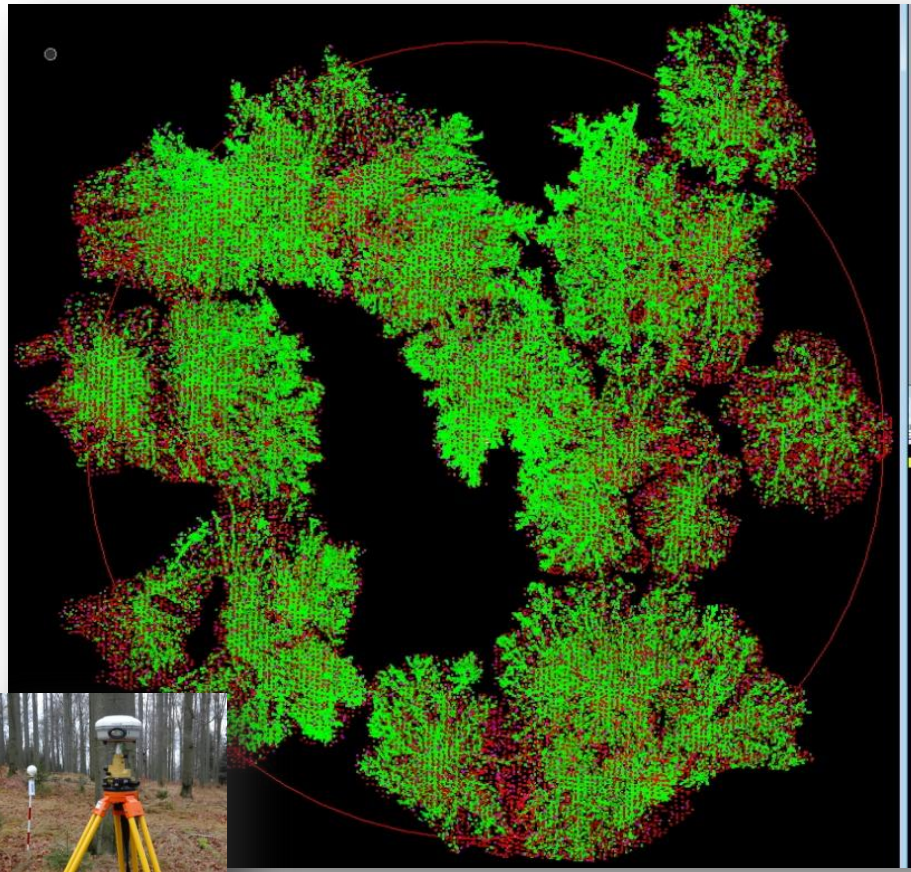
TLS&ALS - Pine

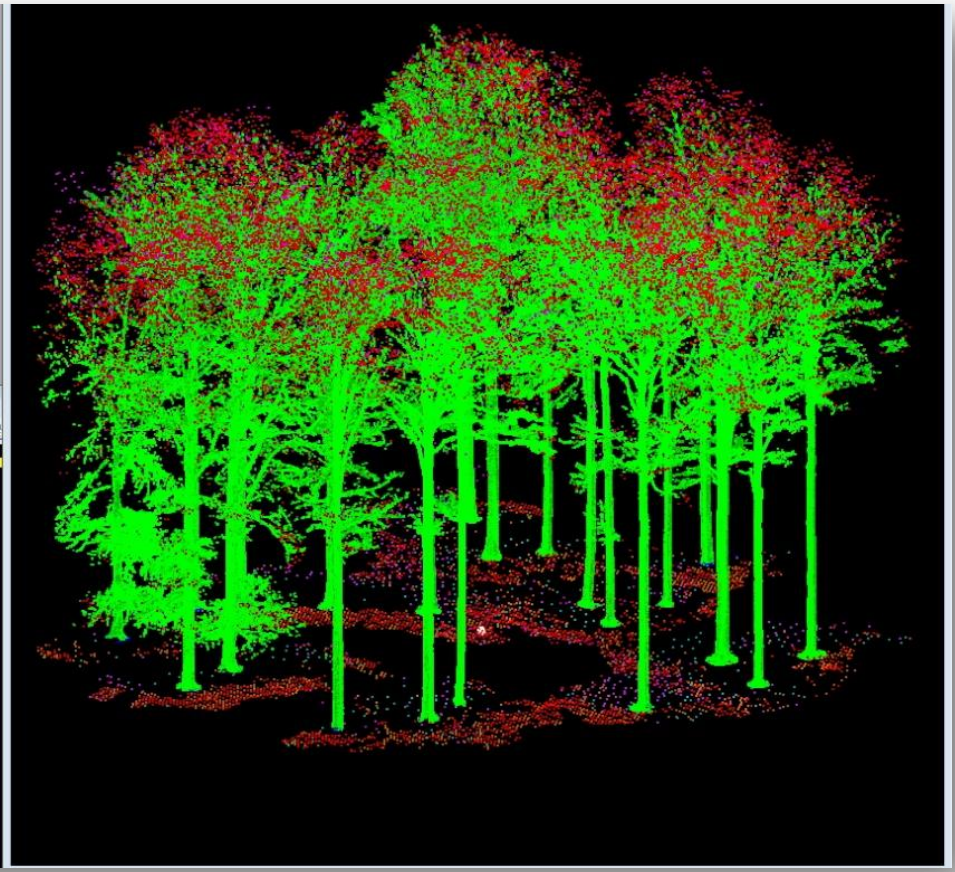


ALS & TLS are complementary source of the information !

FARO FOCUS 3D – Case studies

Integration ALS & TLS



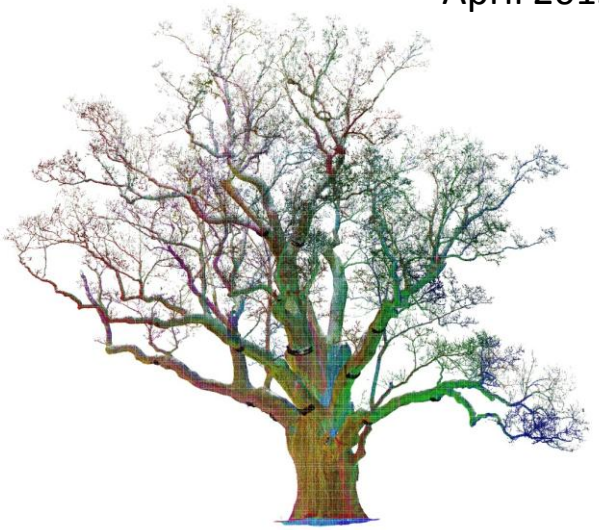


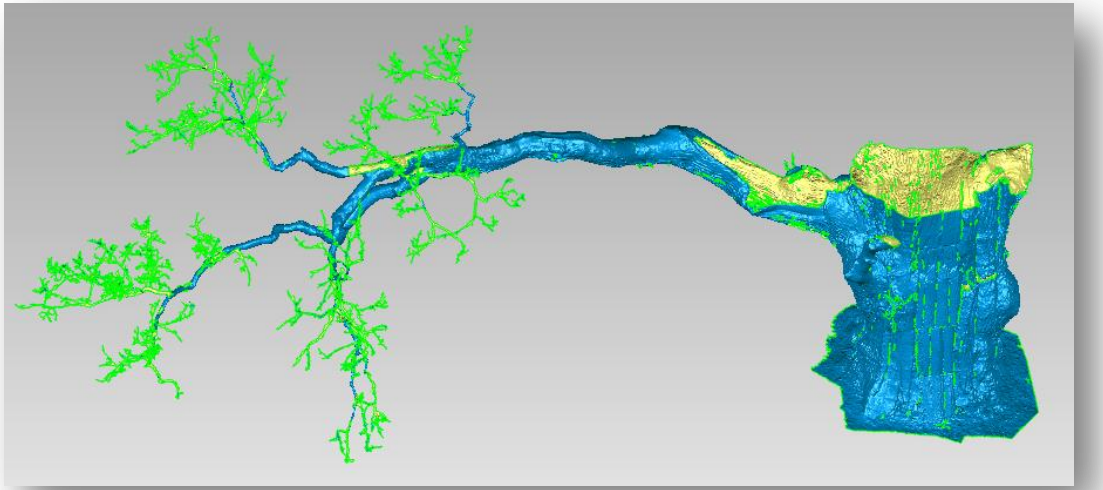
Monitoring of protected trees

Oak „Bartek” 3D

April 2013

July 2013

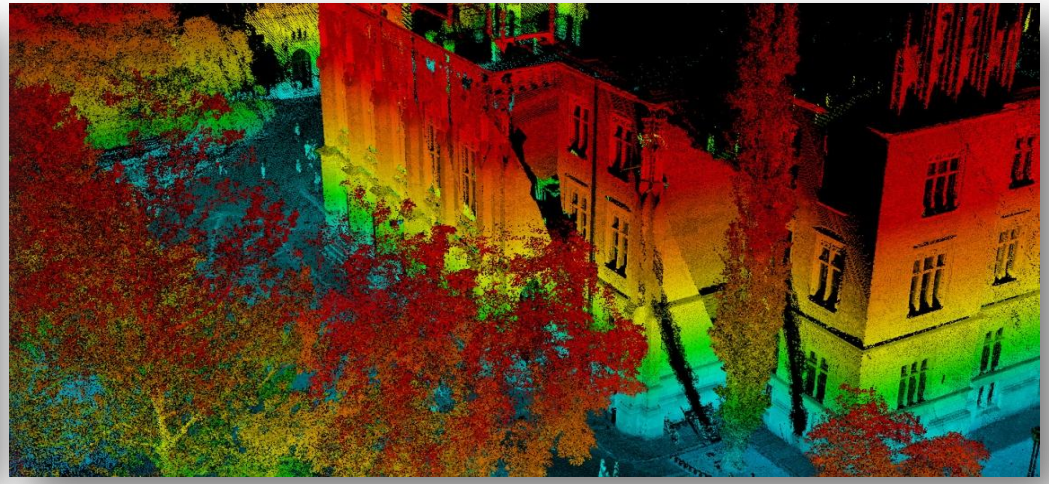


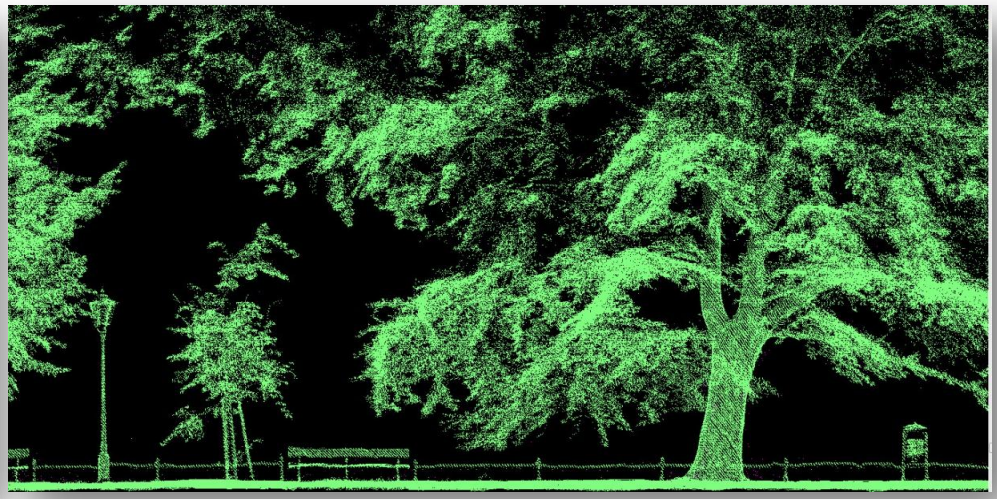


LiDAR / MLS

Kraków, Old Town

RIEGL
LASER MEASUREMENT SYSTEMS





The LULC changes in Gorce National Park (South Poland) using GEOBIA approach of CIR aerial orthophotos and nDSM from stereomatching

Piotr Wężyk[1], **Paweł Hawryło** [1], **Bartłomiej Janus** [1], **Markus Weidenbach** [2]

[1] ***Laboratory of Geomatics, Department of Forest Ecology, Faculty of Forestry, Agricultural University of Krakow,*** *http://geo.ur.krakow.pl*
Address: Al. 29 Listopada 46, 31-425 Krakow, Poland
[2]***landConsult,*** *Buehl, Germany*

Introduction (1)

Forest cover changes in the mountain environment

Deforestations:

Factors:

- **abiotic:**
  wind, drought, water, snow, low and higher temperature, fire, landslides, avalanches;
- **biotic**: insects, fungi; animals
- **anthropogenic**: clear cutings, fire, grazing of animals, infrastructure, shepherding, air

Afforestations:

Type:

- natural forest regeneration;
- secondary forest succession on abandoned agriculture land;
- silviculture treatments;
- agro-forestry;
- bio-energy plantations;

Introduction (2)

Forest change

Deforestation

Ski slopes on Jaworzyna Krynicka (RGB 2009)

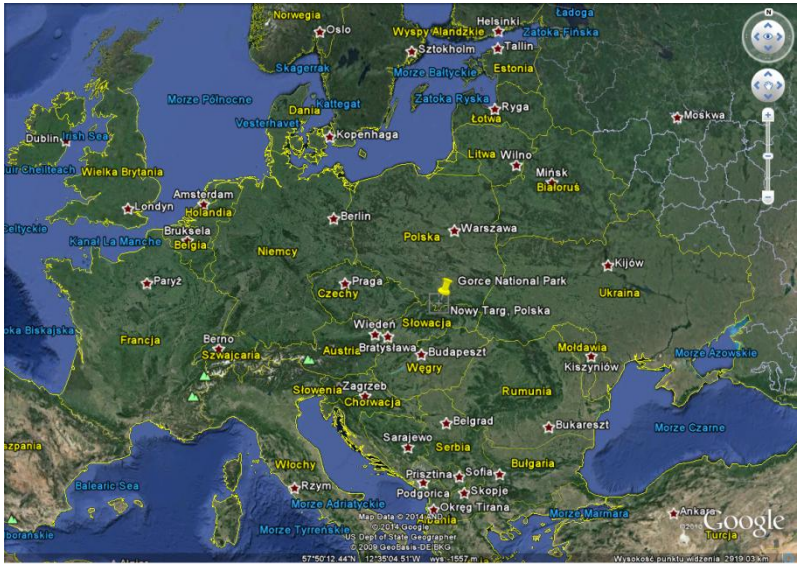
Afforestation

Secondary forest succession (CIR 1997)

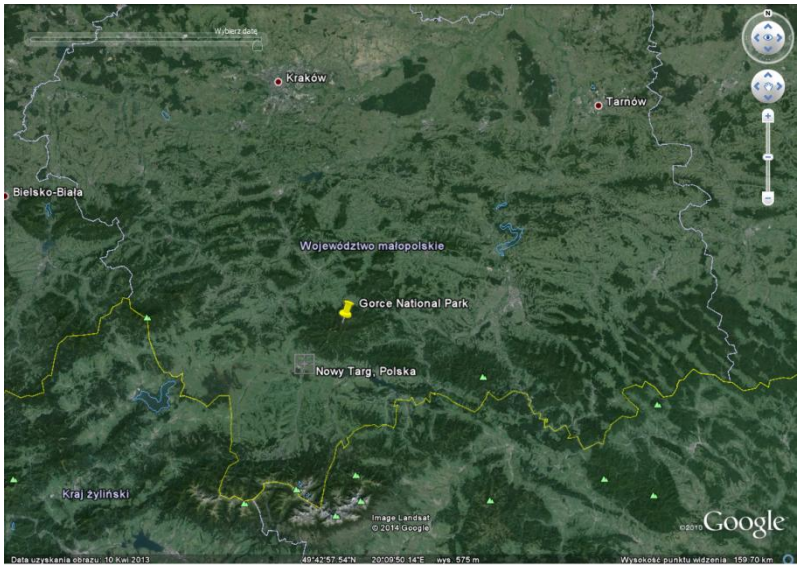
Introduction (3)

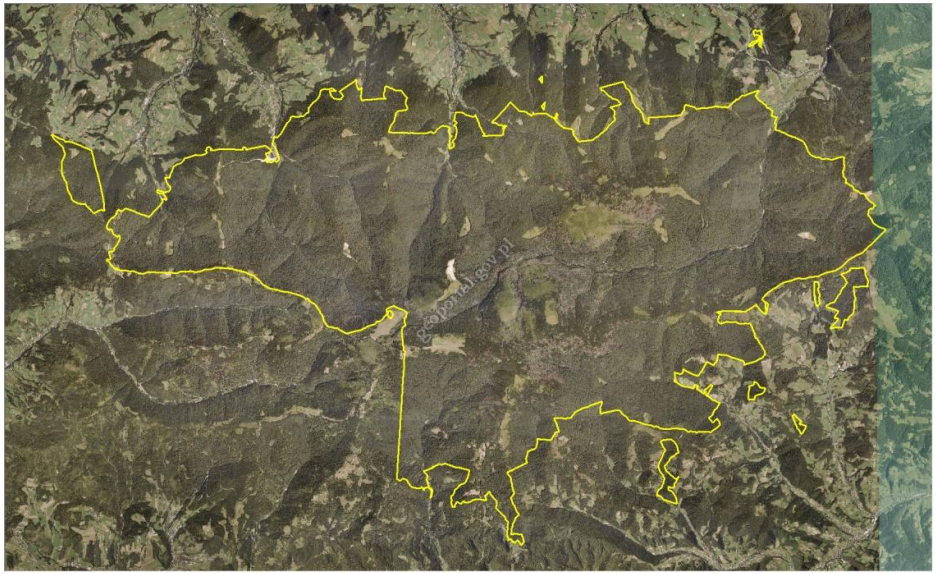
Windthrow

Study area (1)
Gorce National Park

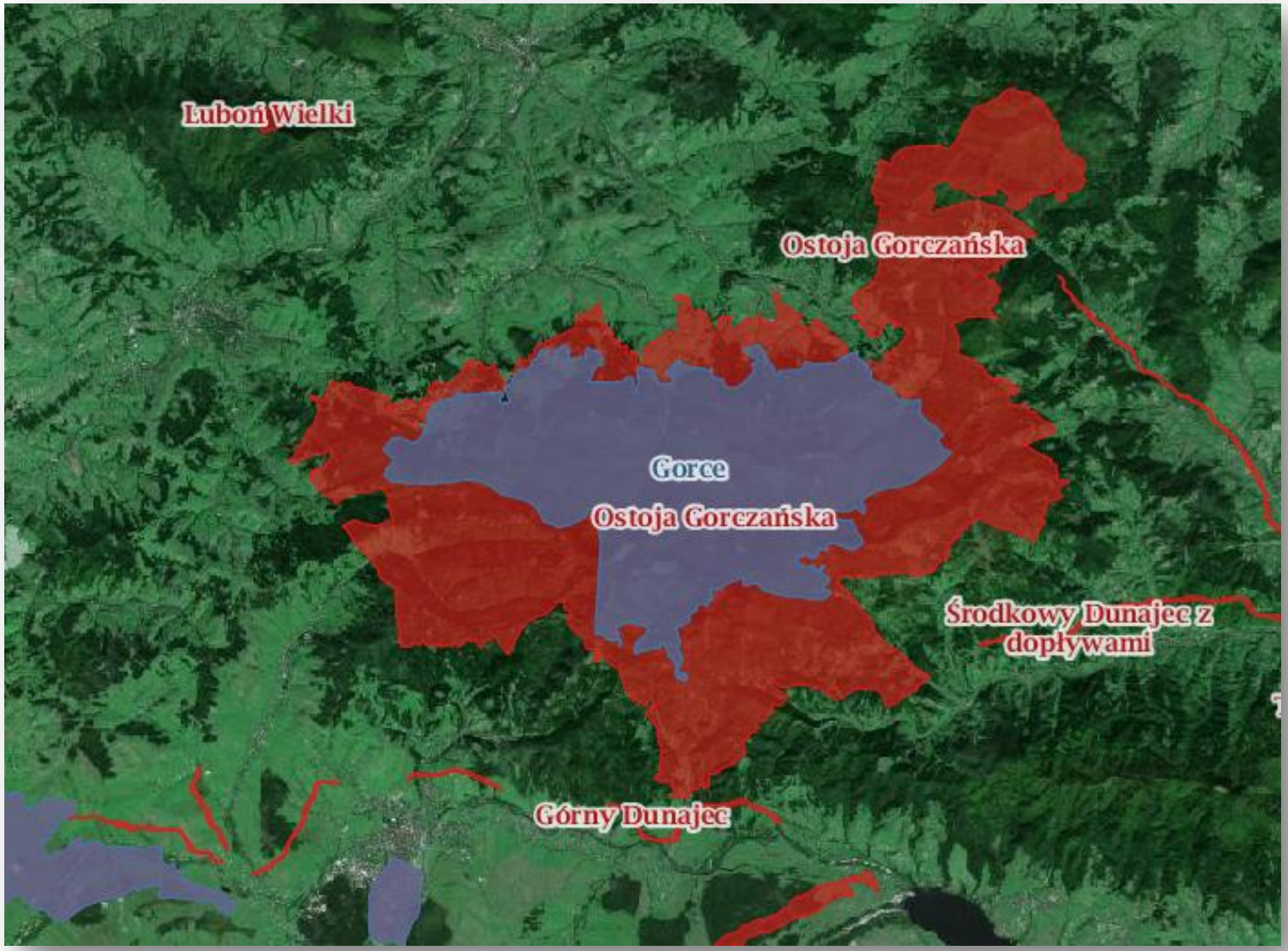


Gorce National Park – was established in 1981 and cover ~**7.030 ha** of natural Carpathian forests. Tree species compossition (2012): 60% *Dentario glanulose Fagetum; 15% Abieti-Piceetum (montanum)* and 25% *Plagiothecio-Piceetum (>1150m a.s.l.).* In 1981, the 95% of Gorce PN area was covered by forest. Today 51% area of GNP is under strict protection. Highest peak of Gorce is Turbacz (1.314,7 m a.s.l.) .





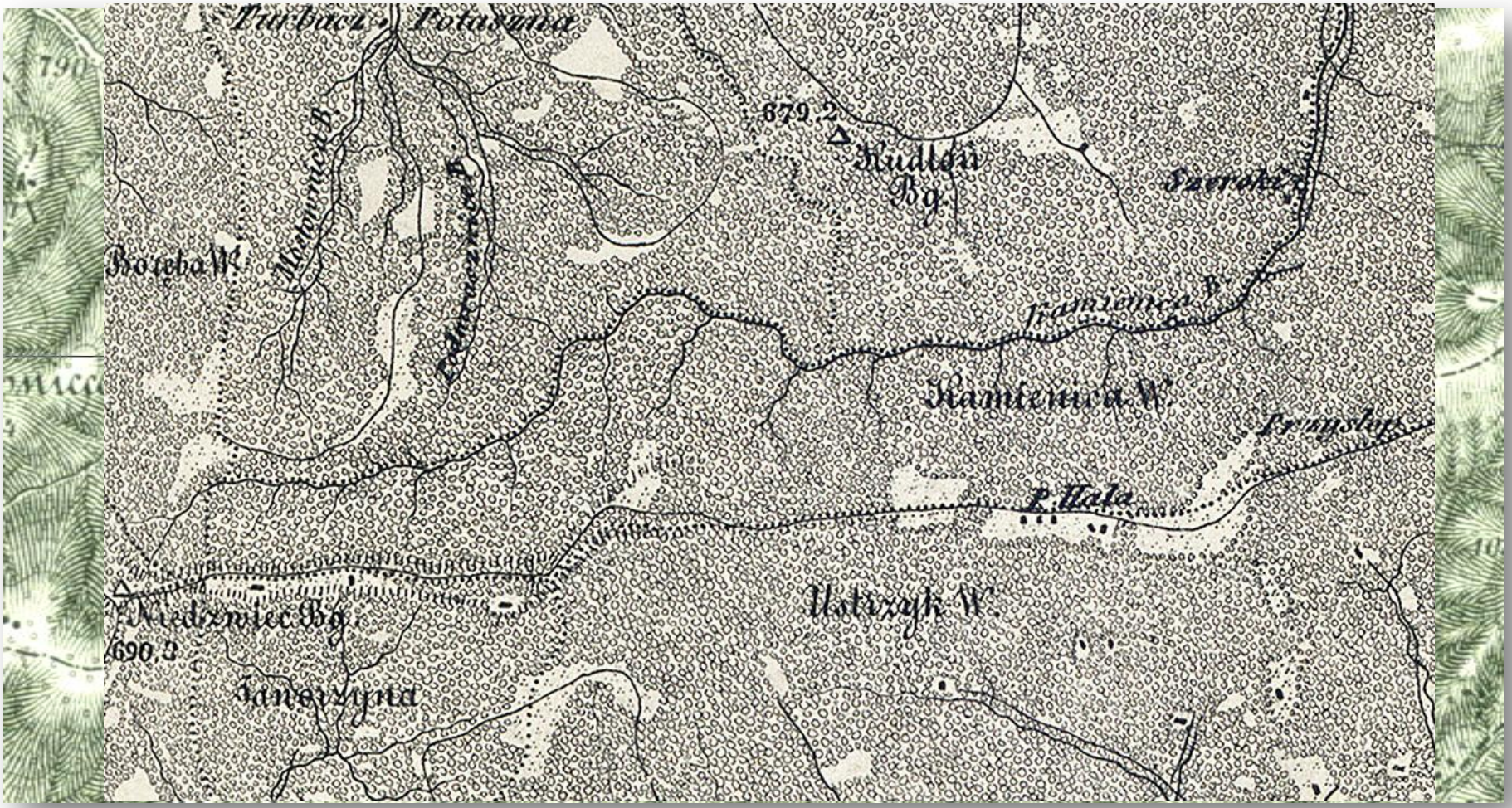
Study area (2)
Natura 2000 Sites



PLH 120018 – Ostoja Gorczańska (SCI – Habitat Directive Sites)

PLB 120001 - Gorce (SPA – Bird Directive Sites)

Archival topographic maps of Gorce



Spezialkarte der österreichisch-ungarischen Monarchie 1:75 000. 7 XXII (4164). 1912

Historical landscapes transformations in Gorce

Stawieniec meadow – year 1938

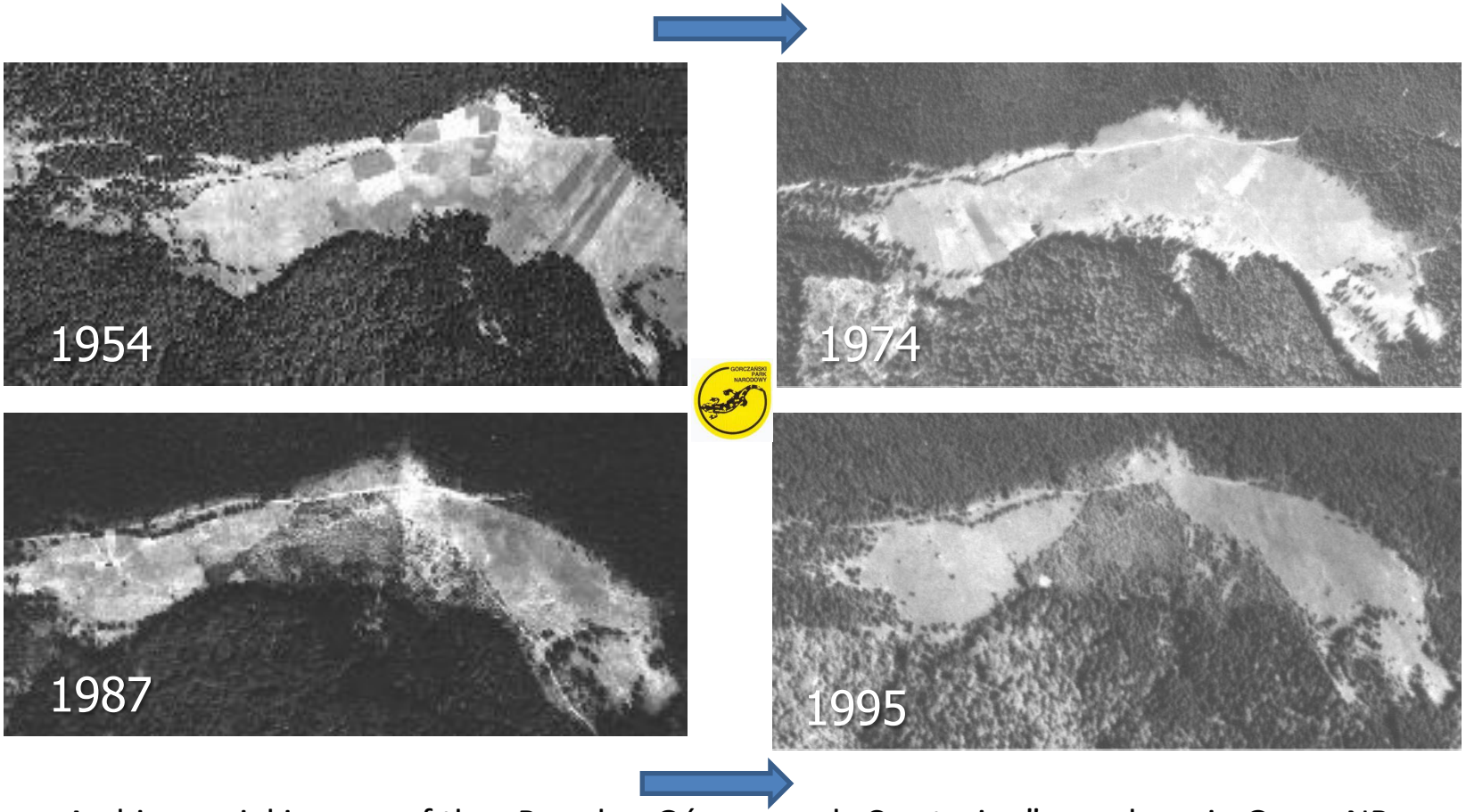
Stawieniec meadow in 2011 – M. Mucha (Photo)

http://www.gorczanskipark.pl

1932, WIG

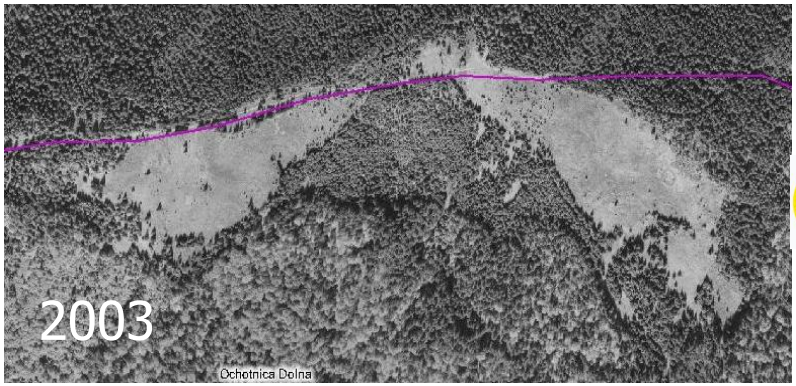
Archive aerial photographs as input data

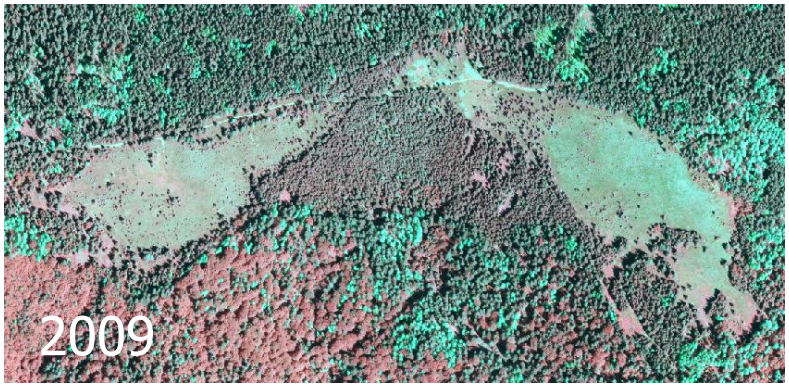
In the Polish archives of aerial photographs (civil and military), the different materials from years: 1946-2012 like: analogue black and white (B&W), color (RGB) and Color InfraRed (CIR) and digital imagery (4 bands) as well, can be found.

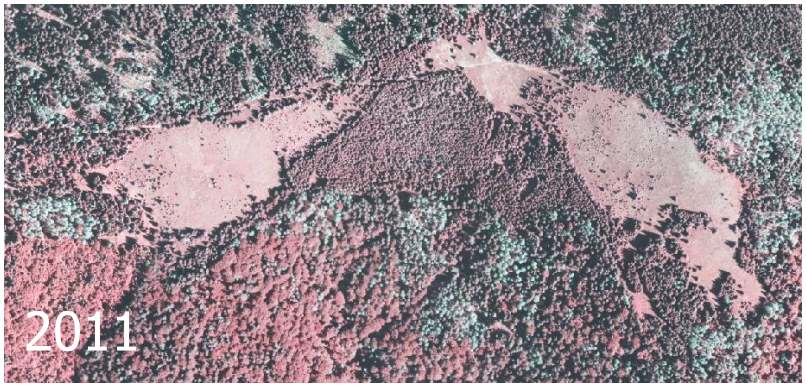


Archive aerial images of the „Przysłop Górny „ and „Czertezina” meadows in Gorce NP.

Archive aerial photographs as input data



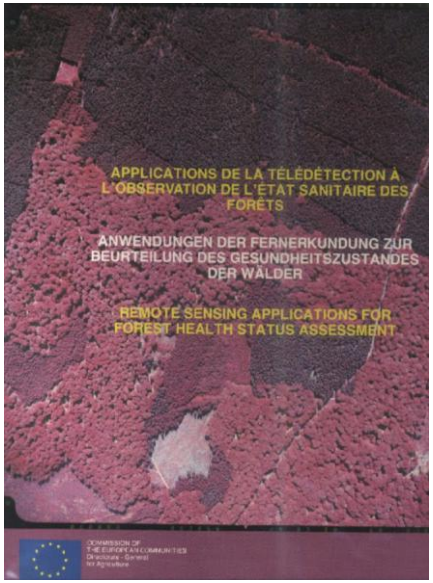




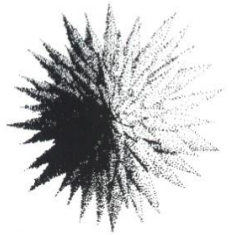
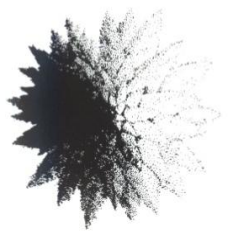
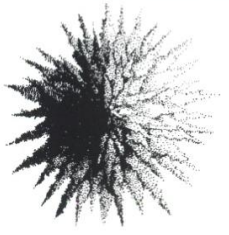
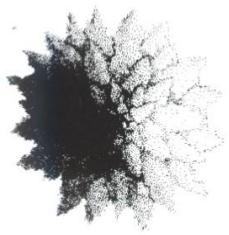
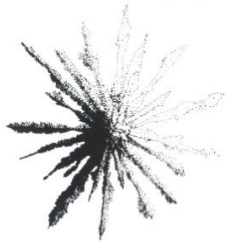
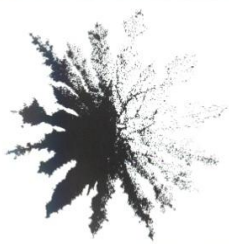
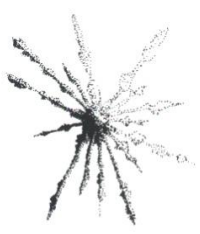
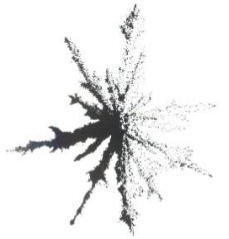
Photointerpretation key

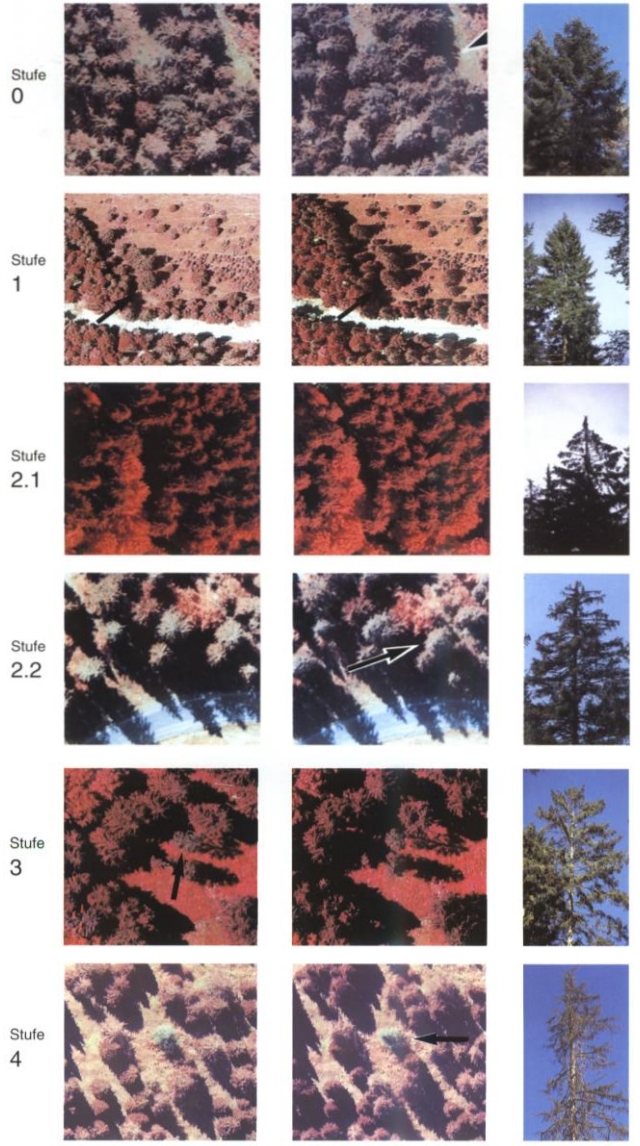
CIR aerial photos

The traditional mapping of forest health condition and type of vegetation based on the **photointerpretation key** of CIR aerial photos. This is a very subjective and time consuming method.

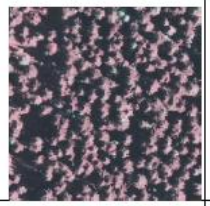
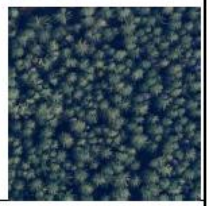
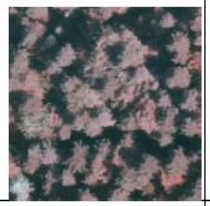
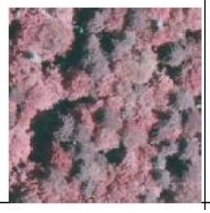


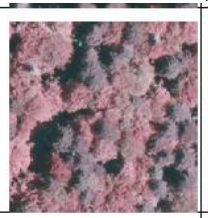
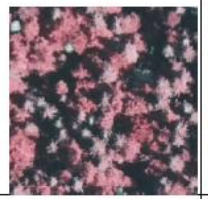
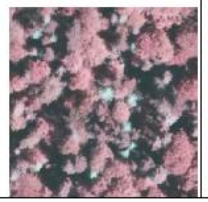
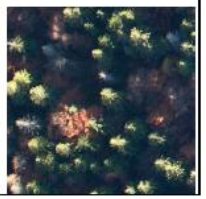
EU guidelines'

Stufe	Kammfichte	Bürstenfichte
0		
1		
2		
3		



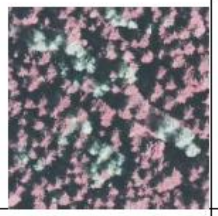
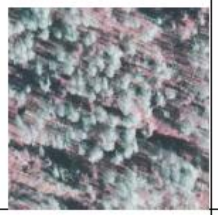
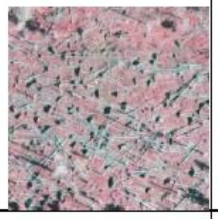
Photointerpretation key GPN (1)

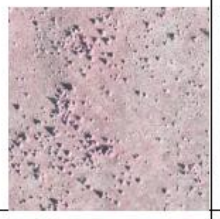
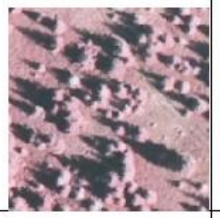
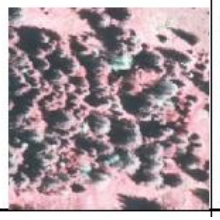
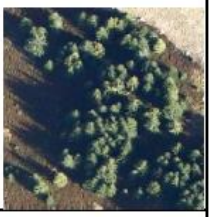
Nazwa	Kod	Fragment ortofotomapy CIR	Fragment zdjęcia RGB z motolotni
buczyna	bk100		
świerczyna	sw100		
jedlina	jd100		
drzewostan bukowo-jodłowy	d_bk_jd		

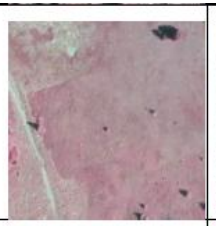
Nazwa	Kod	Fragment ortofotomapy CIR	Fragment zdjęcia RGB z motolotni
drzewostan bukowo-jodłowy	d_bk_jd		
drzewostan bukowo-świerkowy	d_bk_sw		
drzewostan mieszany	d_miesz		
drzewostan mieszany z pojedynczymi martwymi świerkami	d_miesz_poj_sw		

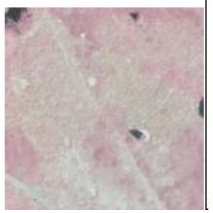
Mapa pokrycia i użytkowania terenu fragmentu Doliny Kamienicy, Pasma Kudłonia i Jaworzyny Kamienickiej w Gorczańskim Parku Narodowym wykonana w oparciu o interpretację ortofotomap lotniczych z roku 2011 – Miłosz Mucha. *Bachleler thesis. dr inż. Piotr Wężyk. 2012 Laboratorium Geomatyki UR*

Photointerpretation key GPN (2)

Nazwa	Kod	Fragment ortofotomapy CIR	Fragment zdjęcia RGB z motolotni
gniazda kornikowe	gniazda		
drzewostany martwe stojące	d_martwe_stoj		
drzewostany martwe leżące	d_martwe_lez		

Nazwa	Kod	Fragment ortofotomapy CIR	Fragment zdjęcia RGB z motolotni
sukcesja wtórna stadium inicjalne	sukcesja_inic		
sukcesja wtórna stadium zaawansowane	sukcesja_zaaw		
sukcesja wtórna zwarte kępy drzew	sukcesja_kepy		

borówczyska	borowka		
obszary koszarowania na polanie	ob_koszarowania		

polana wykaszana	pol_wyk		
polana niewykaszana	pol_nwyk		

Forest mapping

Photogrametry 3D vs. 2D

CIR aerial photos – 3D photointerpretation

- archival analogue films (Kodak Aerochrome 2443),
- digital cameras: 4 bands: R, G, B, NIR; high overlap
- 3D photogrammetry work-out of stereograms;
- very accurate mapping (no shifting);

External Orientation

→

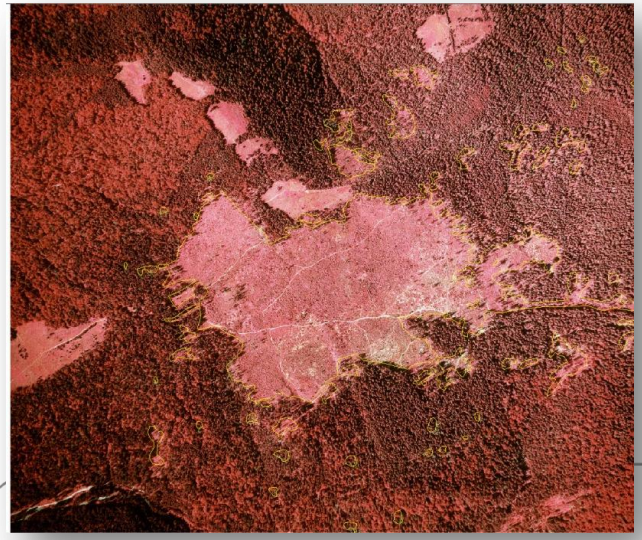
DTM

CIR aerial 2D orthophotomaps:

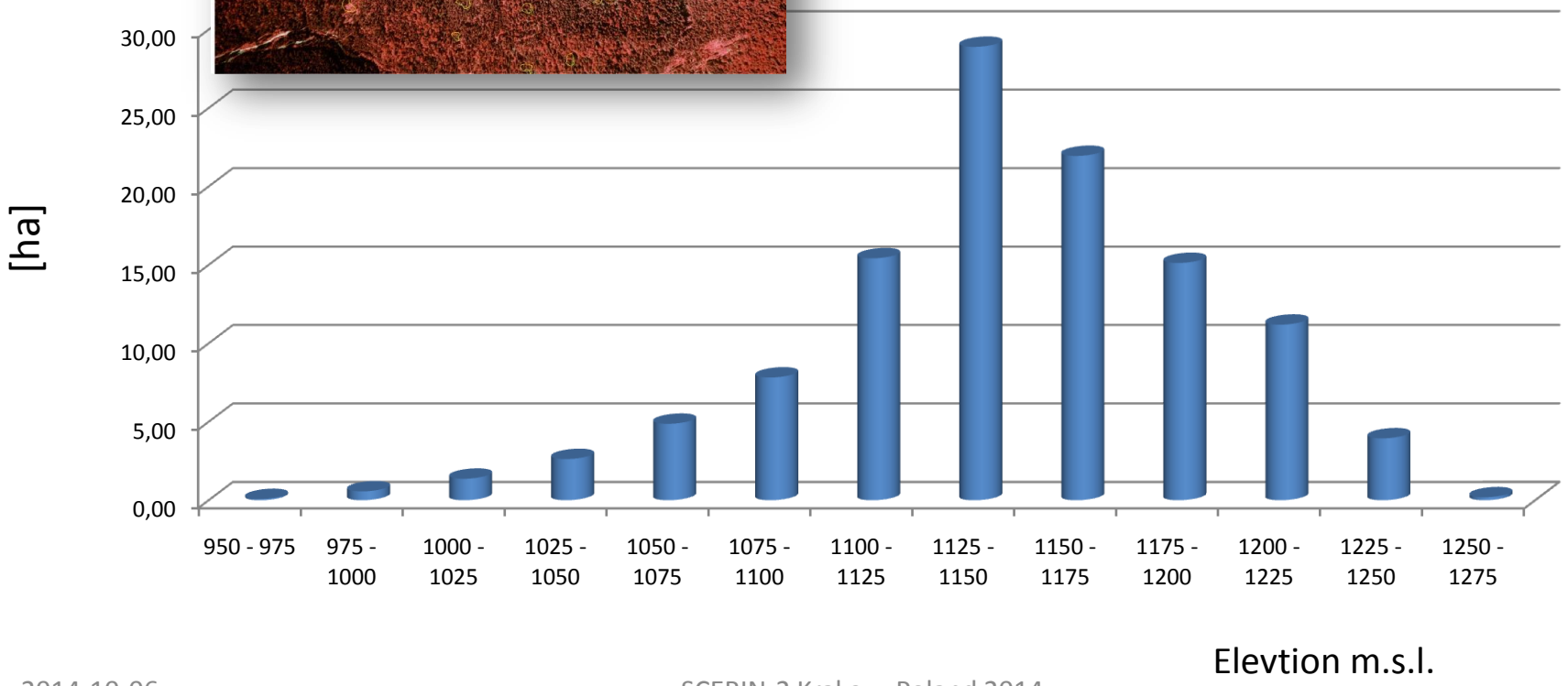
- only 2D interpretation;
- effect of central projection;
- geometry problem of tall objects (which are shifted)

Material and Methods

Photogrametry 3D (VSD-AGH) CIR 1997



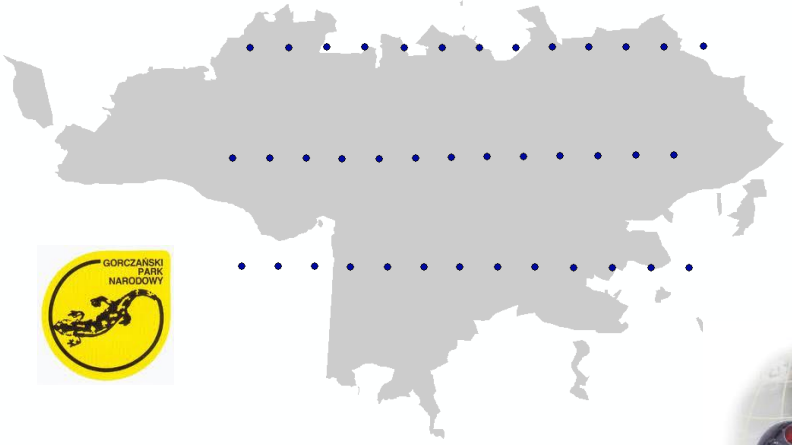
In Aug. 1997 the analogue CIR Kodak Aerochrome 2443 aerial photos was taken. Later the steropairs were elaborated in 3-D mode using VSD-AGH Soft Copy Station.
3D mapping of dead Norway spruce stands was performed - **~114 ha of dead wood and gaps**.

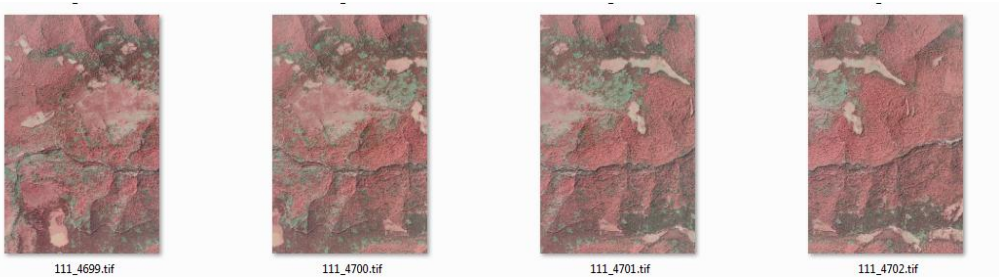


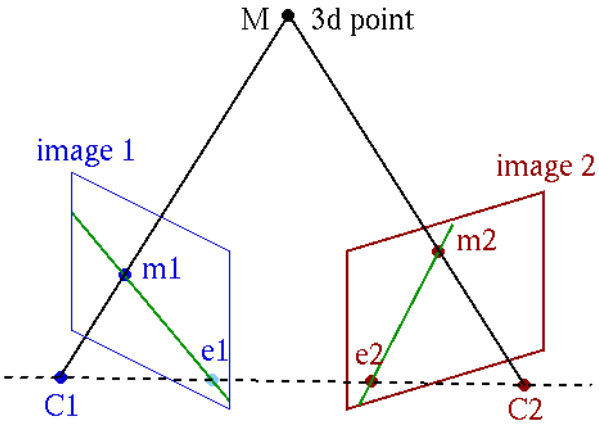
Material and Methods

Stereomatching approach – SGM (Aug. 2009)

main point's of CIR single digital aerial photos (R, G, B, NIR) from Aug. 2009;
8 bit ; GSD 0.17 m, UltraCam Xp, VEXCEL



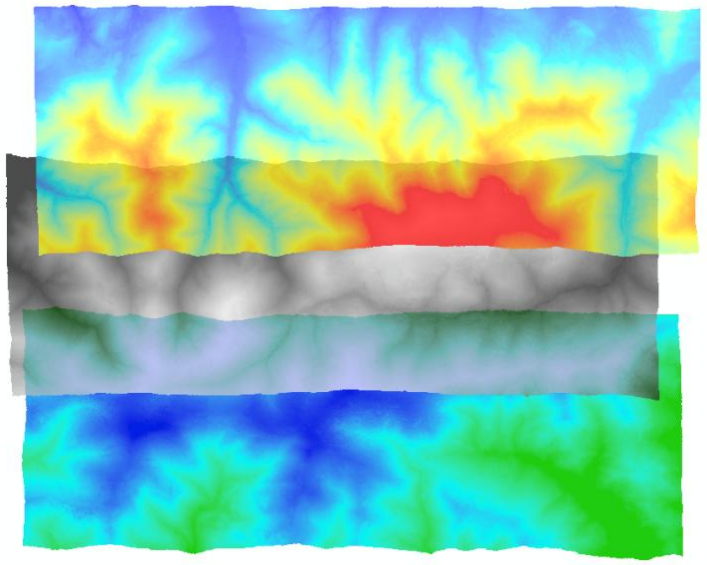




Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track	67.860mm	11310pixel
	cross track	103.860mm	17310pixel
Image Extent		(-33.91, -51.95)mm	(33.91, 51.95)mm
Pixel Size		6.000µm*6.000µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.120 mm	± 0.002mm
	Y_ppa	0.180 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

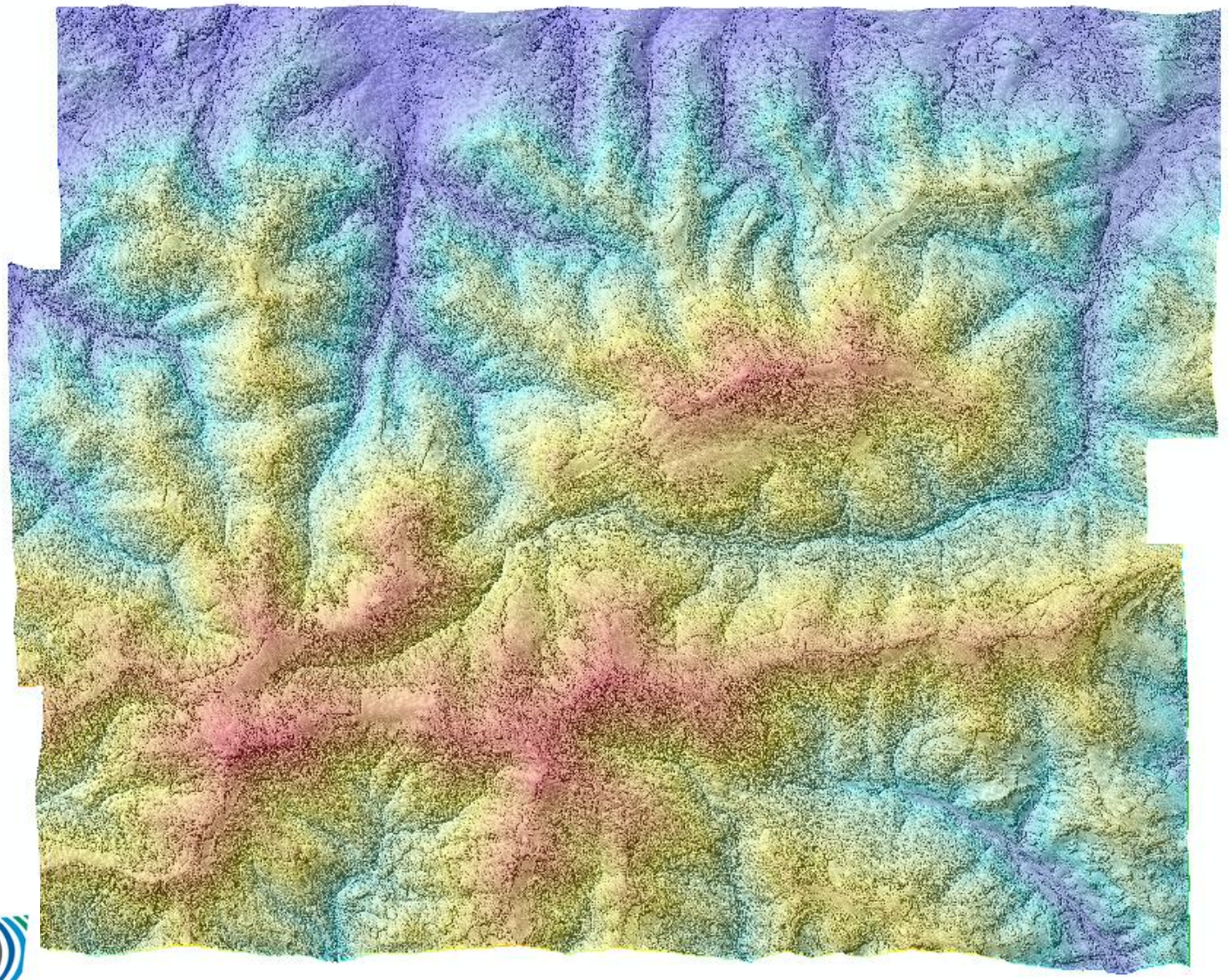


generation map of disparity
using Semi-Global Matching

Stereomatching - DSM mosaick

Material and methods

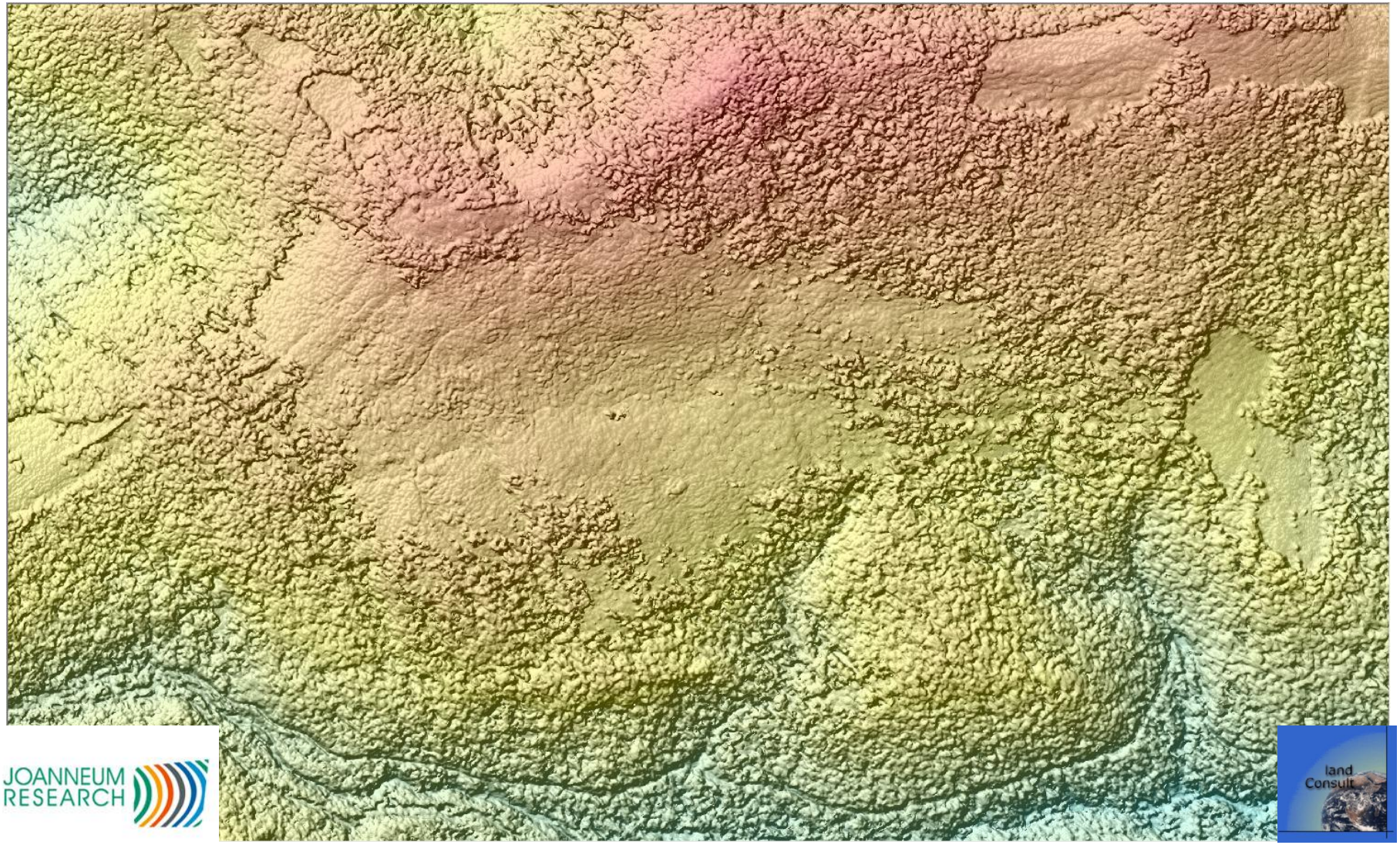
Stereomatching approach – SGM



DSM stereomatching – mosaic for GPN study area (ArcGIS Esri)

Material and methods

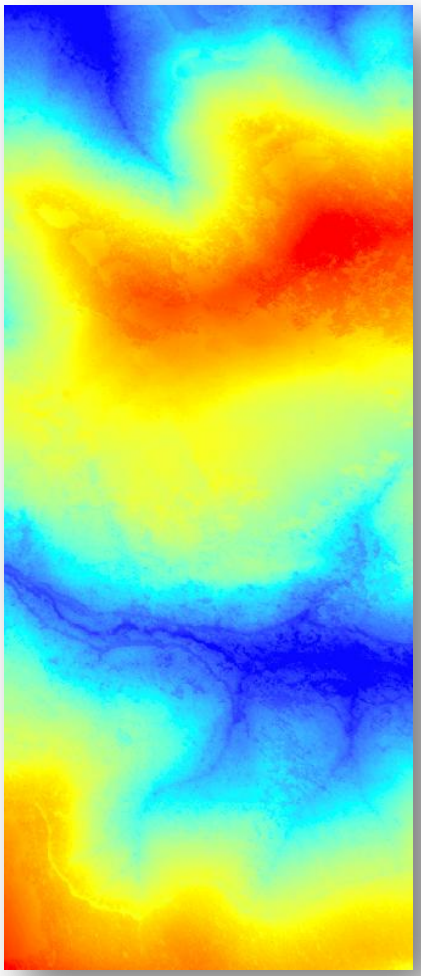
Stereomatching approach – SGM



DSM steromatching (Semi Global Matching - RSG – Kudlon (GPN)

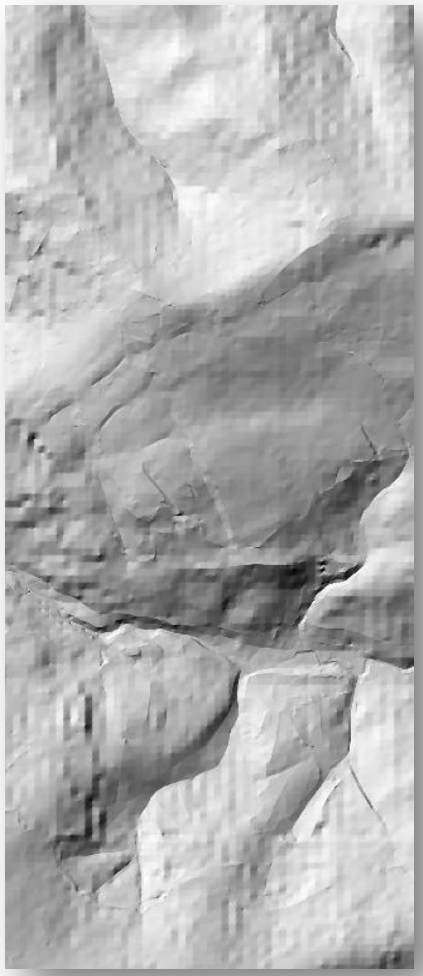
Methods

Derriving nDSM from stereomathing using reference DTM



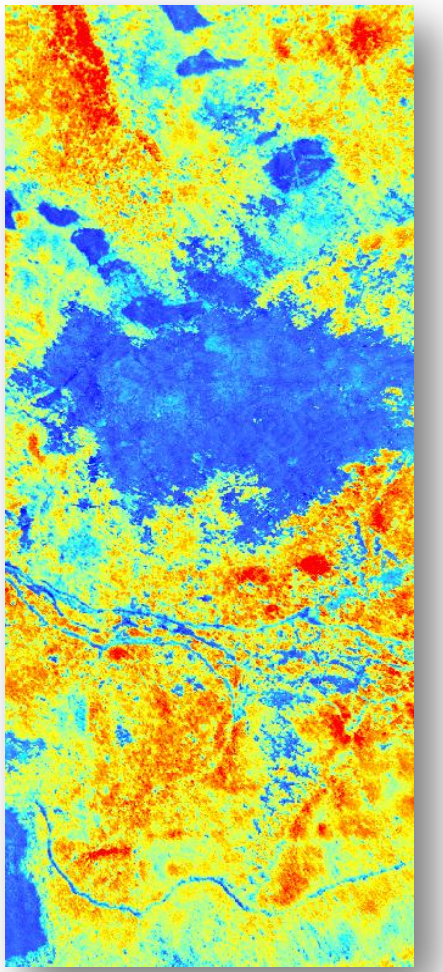
DSM stereo-machting
(832-1288 m a.s.l.)

DSM
minus
DTM



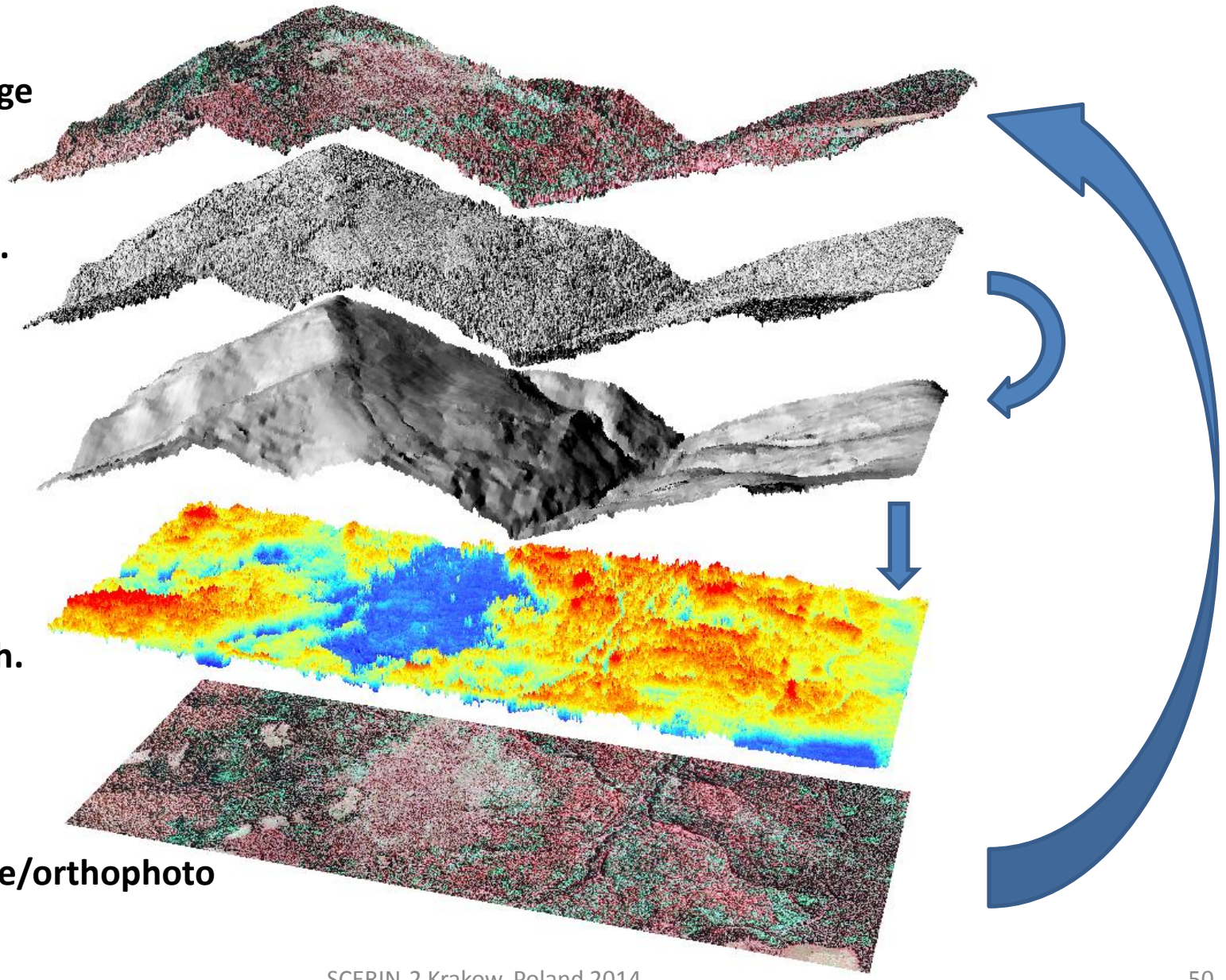
DTM (LPIS) reference
(864-1273 m a.s.l.)

=



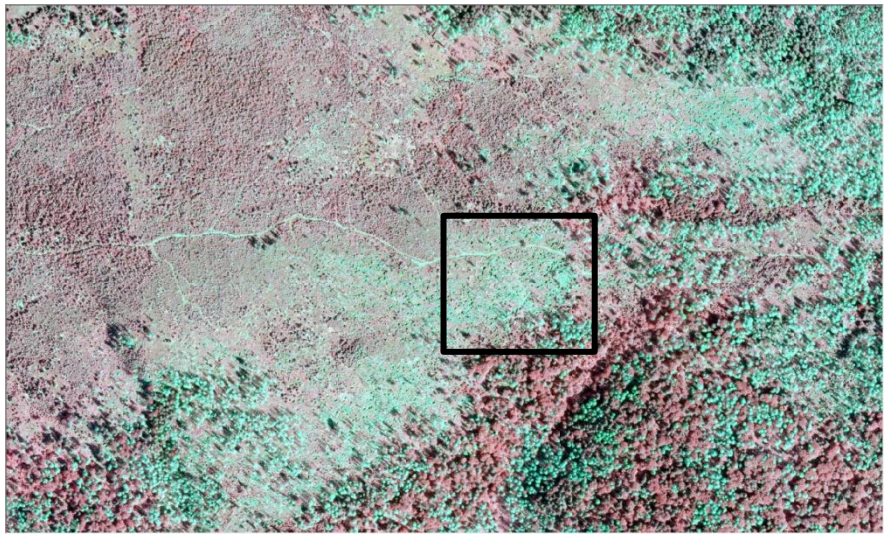
nDSM stereomatching
(0-42m)

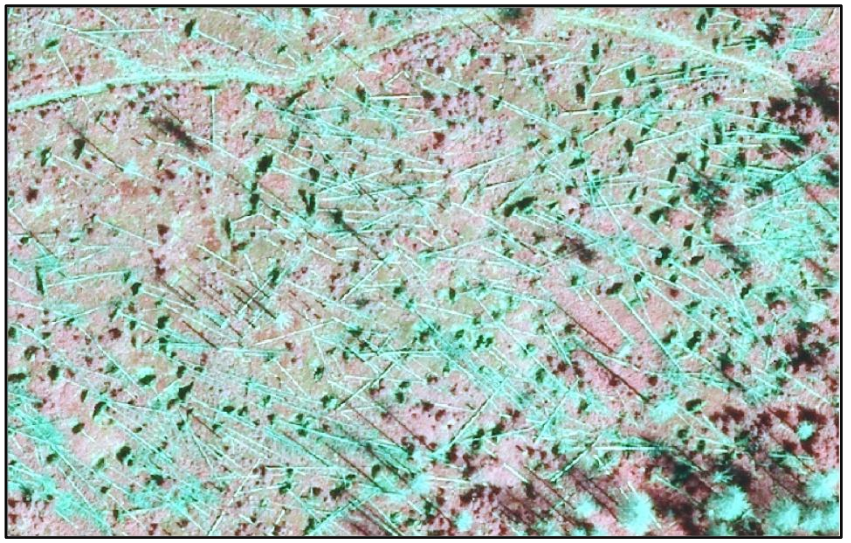
Different models and images used

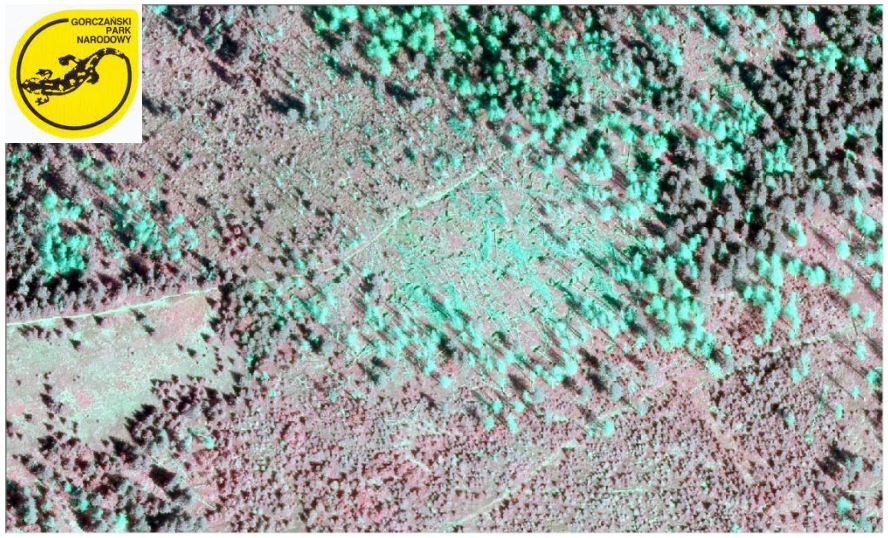


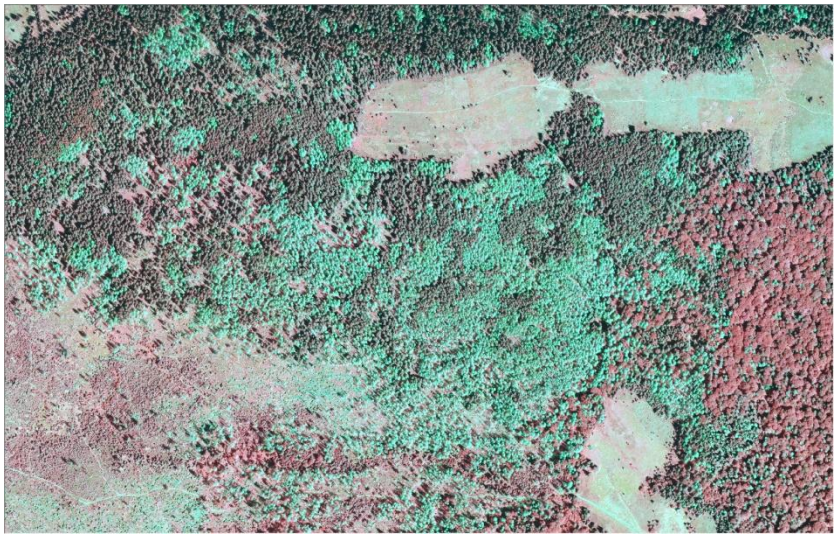
Material

Dead Norway spruce stands on CIR aerial orthophoto 2009

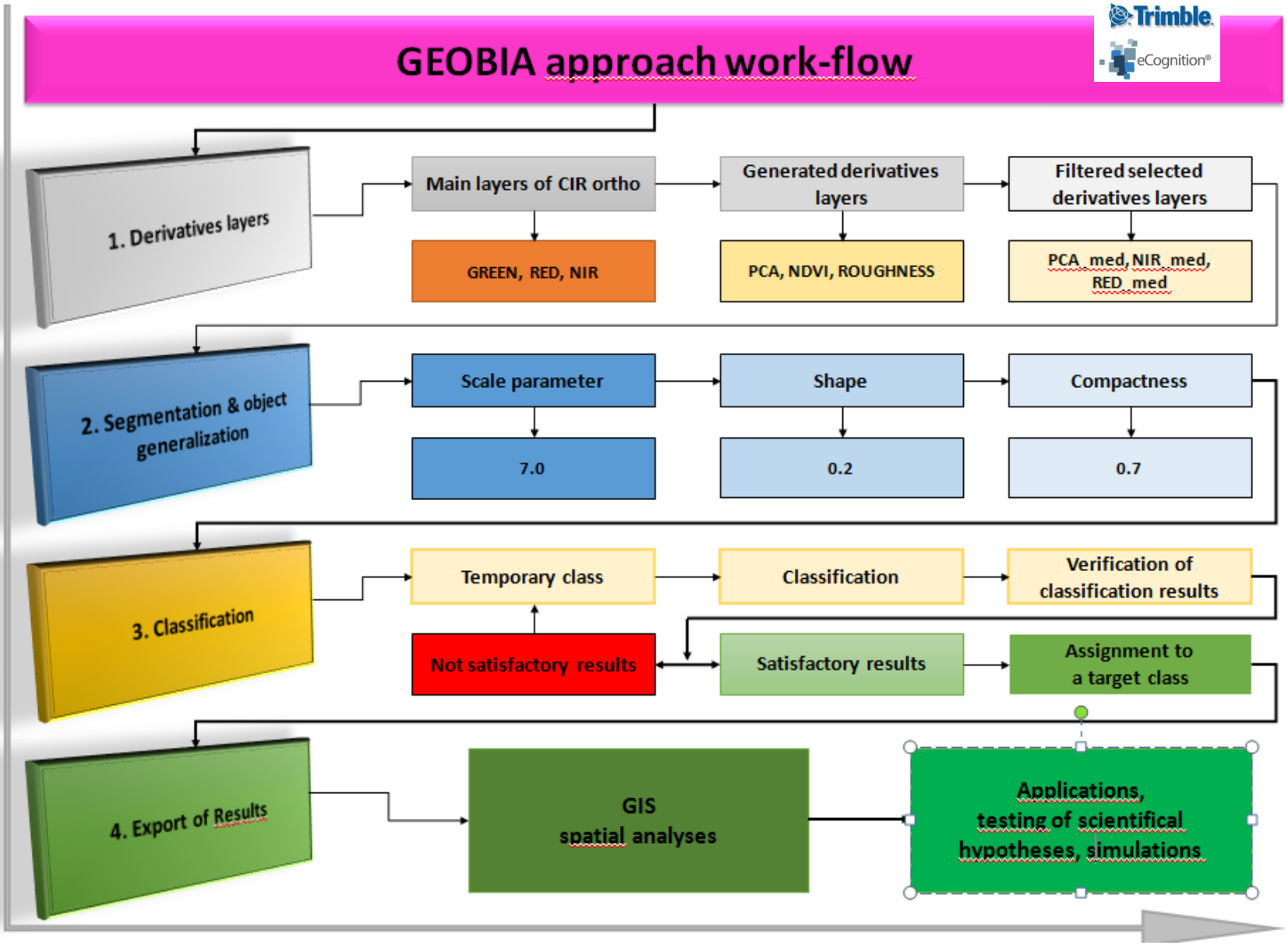








Methods - GEOBIA (0)

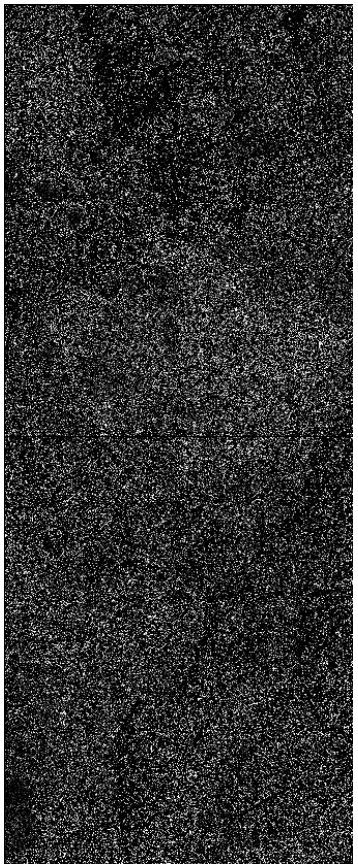


Methods - GEOBIA (1)

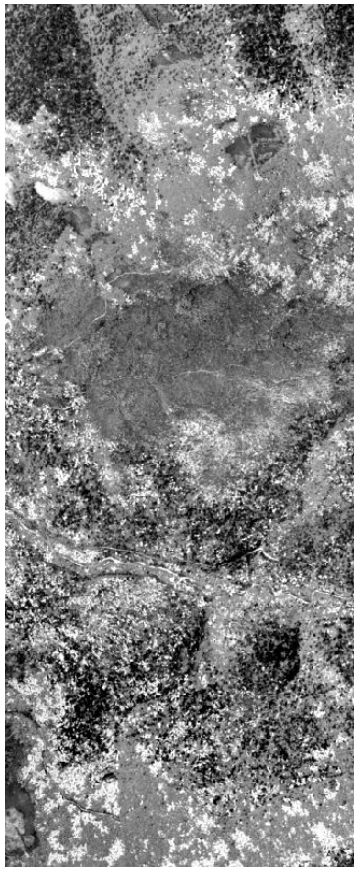
Data input - derrivative layers NDVI, Roughness

CIR
2009

NDVI
2009



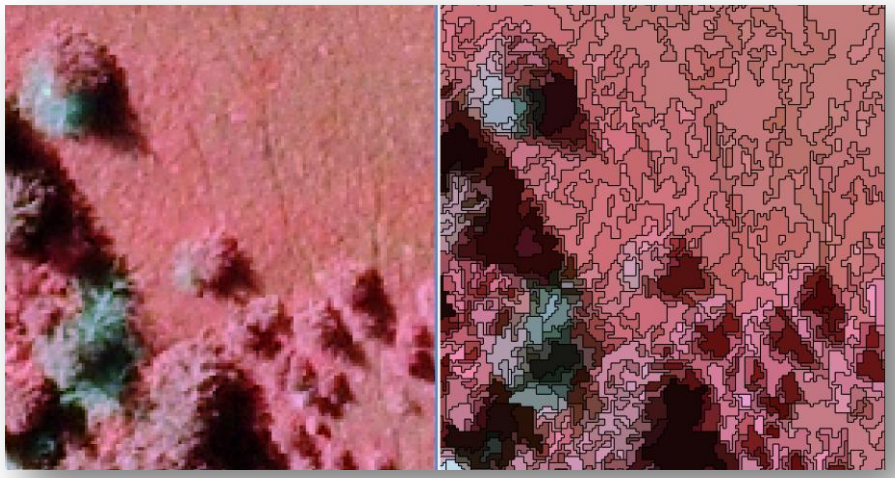
Lee Sigma Bright
2009



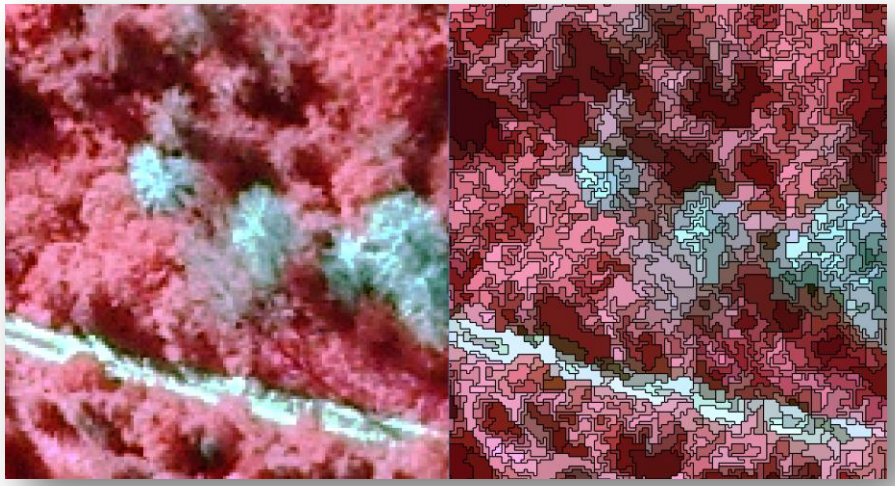
Roughness
2009

Methods - GEOBIA (2)

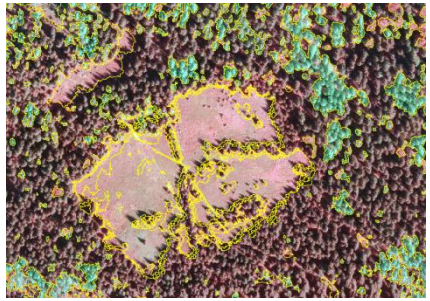
Rule-set



examples of segmentation



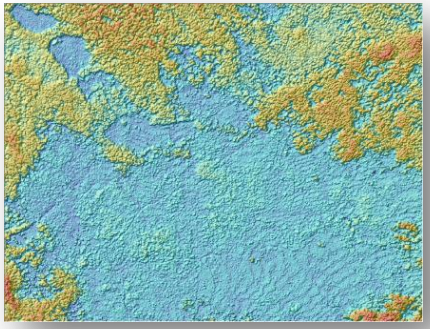
- Gorce 2009
  - set rule set options
  - temporary layers
    - if Existence of image layer ndvi = 0 : layer arithmetics (val "(CIR1 - CIR2)\(CIR1 + CIR2)", layer ndvi[float])
    - if Existence of image layer CIR1_median = 0 : median filter (7 x 1): 'CIR1' => 'CIR1_median'
    - if Existence of image layer roughness = 0
      - roughness
  - Segmentation
    - 7 [shape:0.2 compct.:0.7] creating 'New Level'
  - Classification
    - Shadows
    - Dead forest
      - unclassified with Mean ndvi <= 0 and Mean ndvi <= 0.05 at New Level: temp1
      - loop: temp1 at New Level: grow into unclassified where ndvi<=0.07 and rel. area of temp1 pixels in (5 x 5) >=0.2
      - Shadow direction
      - Super objects
      - temp1 at New Level: brak_wegetacji
      - loop: martwe_drzewa at New Level: grow into unclassified with Mean nDSM >= 4 where ndvi<0.25 and CIR2>=140 and rel. area of mar
      - loop: martwe_drzewa at New Level: grow into unclassified with Mean nDSM >= 4 where ndvi<0.1 and rel. area of martwe_drzewa pixels
      - martwe_drzewa with Mean nDSM <= 5 at New Level: brak_wegetacji
      - unclassified with Area <= 12 Pxl at New Level: enclosed by martwe_drzewa: martwe_drzewa +
      - martwe_drzewa with Area <= 12 Pxl and Rel. border to martwe_drzewa = 0 at New Level: unclassified
      - martwe_drzewa at New Level: opening: martwe_drzewa
      - martwe_drzewa at New Level: grow into unclassified with Mean CIR1 >= 90 where rel. area of martwe_drzewa pixels in (5 x 5) >=0.3
      - do
    - Forest
    - Meadows
    - Sucession
    - Coniferous and Decidious
    - Generalization
  - Export



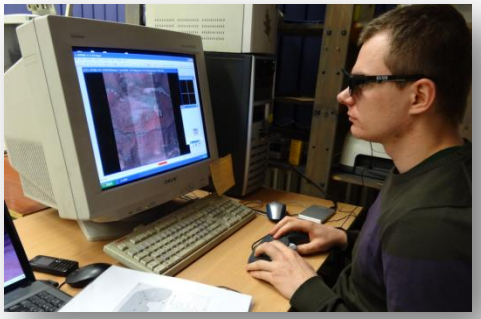
Trimble.

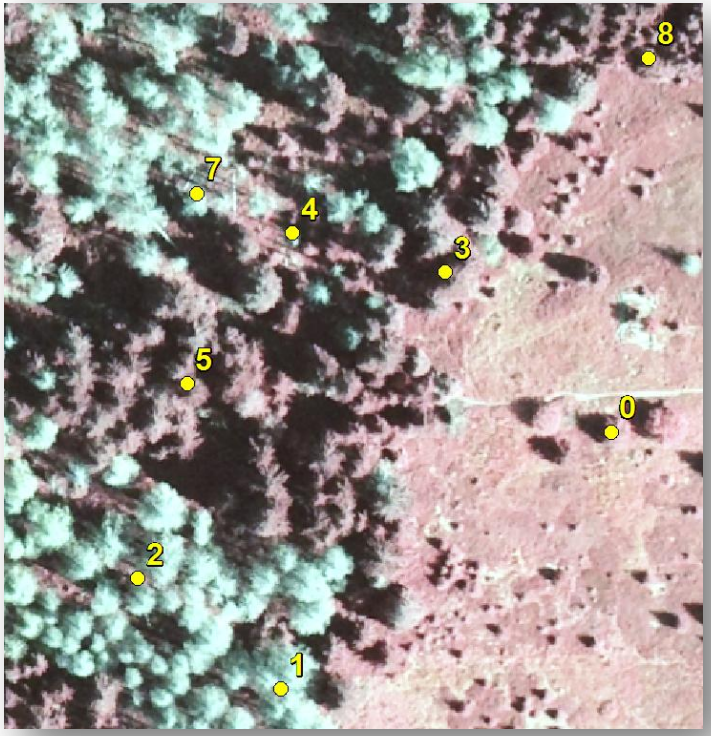
eCognition®

Results (1)
nDSM Quallity Control



The Quallity Control was performed using the 3D photogrammetric workout based on the DEPHOS SoftCopy Station and the stereopairs.





Id	Rel. hight Photo 3D [m]	Hight nDSM stereomatching [m]	Differences Photo 3D – nDSM [m]
0	6,2	3,2	3,00
1	24,6	21,81	2,79
2	20,7	20,7	0,00
3	13,4	11,32	2,08
4	14,5	11,95	2,55
5	20,2	14,48	5,72
6	20,7	18,74	1,96
7	14,5	11,57	2,93
8	10,5	9,02	1,48

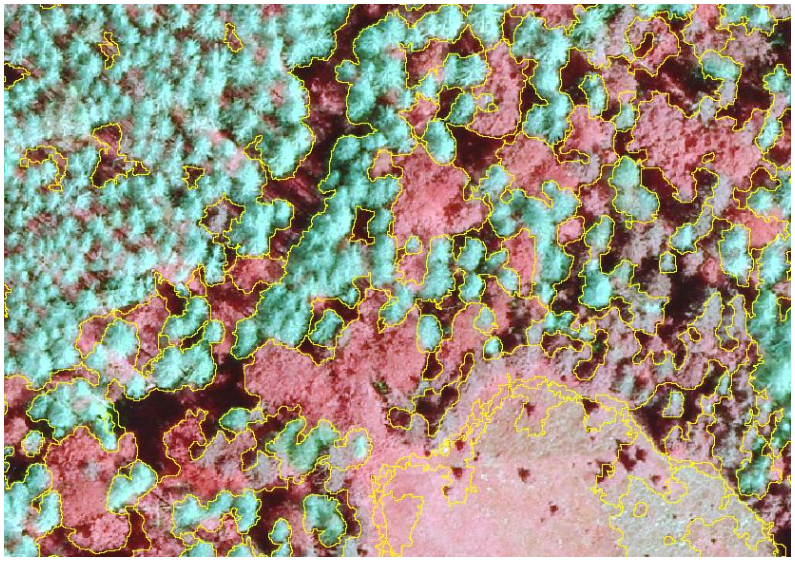
mean difference = 2,51 m

Results (2)

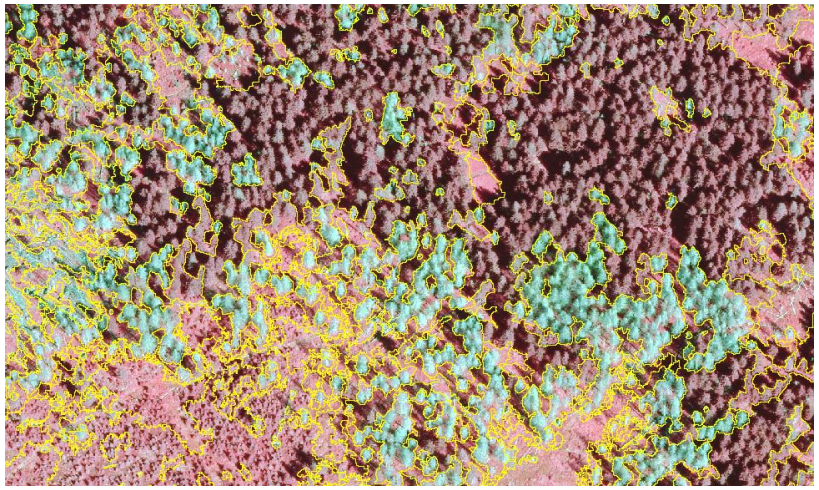
GEOBIA objects / classes

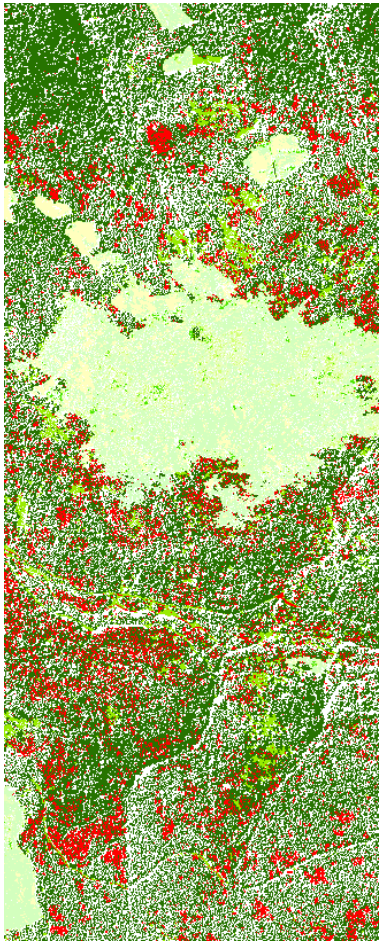
CIR 2009

Trimble eCognition®



GEOBIA segmentation

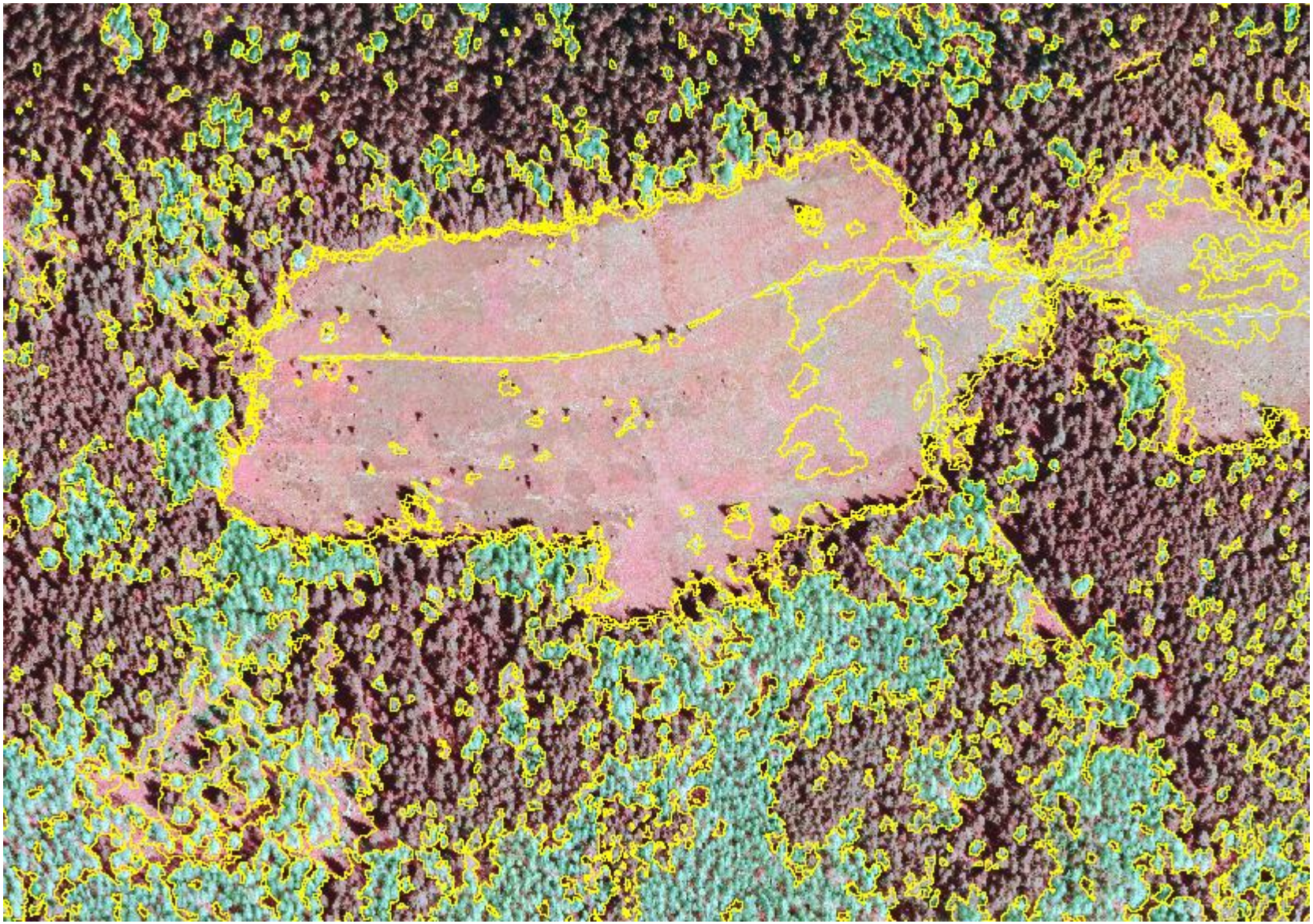




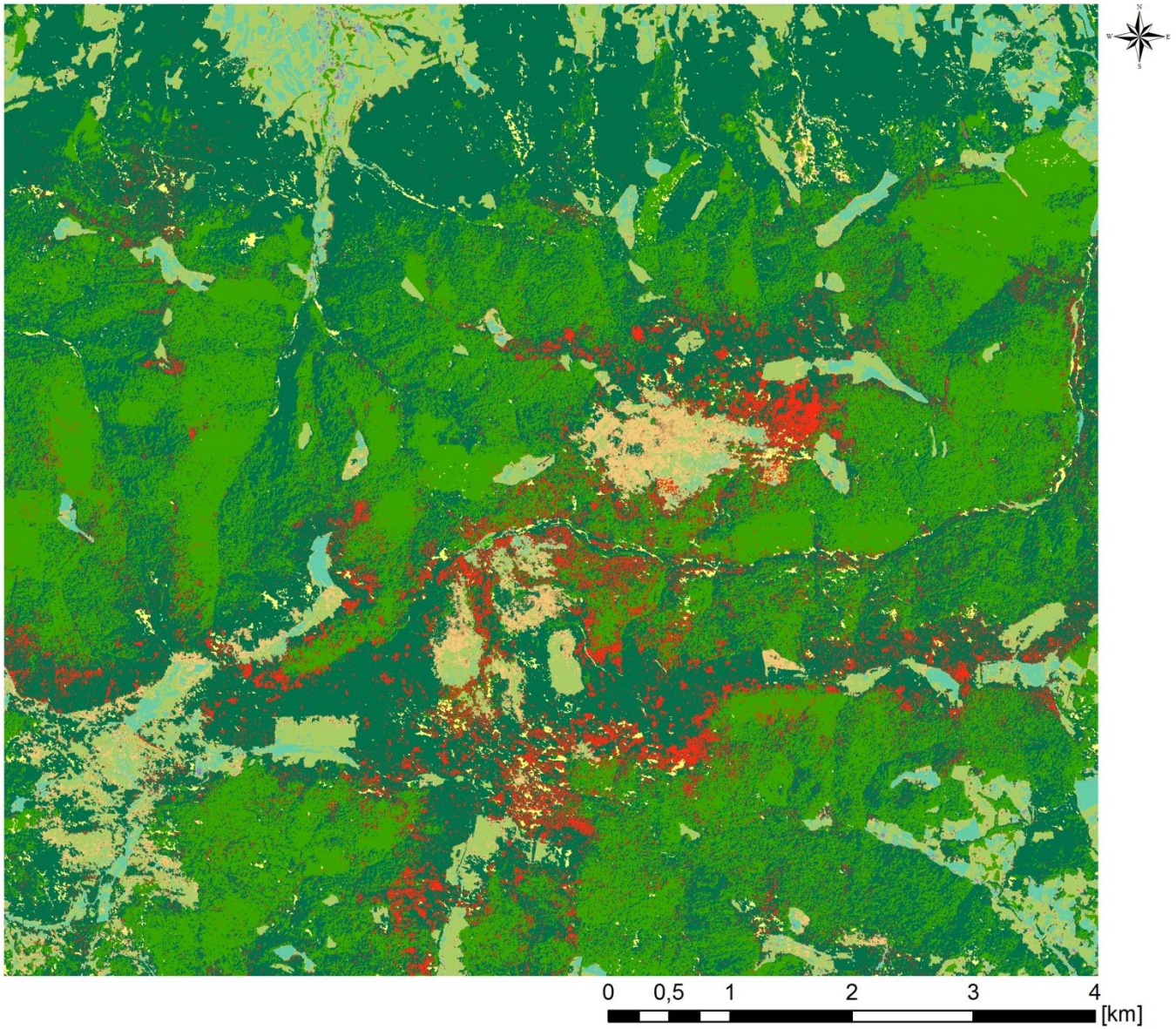
Results for year 2009

Results (3)

GEOBIA segemntation/objects/classes



Results (4)
GEOBIA LULC map



Results (5)

GEOBIA objects / classes

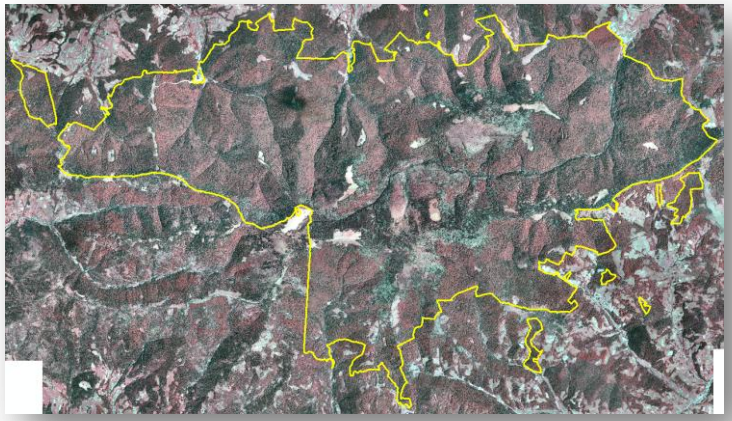
LULC class	area [ha]	area [%]
deciduous forest	2.204,3	30,6
health coniferous stands	3.380,5	47,0
dead coniferous forest (Norway spruce)	465,5	6,5
gaps in the canopy	111,1	1,5
secondary forest succession (Σ 3 classes: >2m + >4m + >6m)	256,6	3,6
meadows and open areas covered by low vegetation	577,8	8,0
meadows and open areas without vegetation	204,1	2,8
Total	7.200,0	100,0

Results (6)

GIS analyses

Analyses inside Gorce NP area:

- **dead Norway spruce stands: 440,41 ha**
- **gaps : 67,24 ha**
- health coniferous stands : 2.227,18 ha
- health decidous stands: 1.965,63 ha
- meadow vegetation: 201,37 ha
- **secondary forest succession > 2.0 m: 99,37 ha**
- **secondary forest succession > 4.0 m: 25,69 ha**
- **secondary forest succession > 6.0 m 10,98 ha**

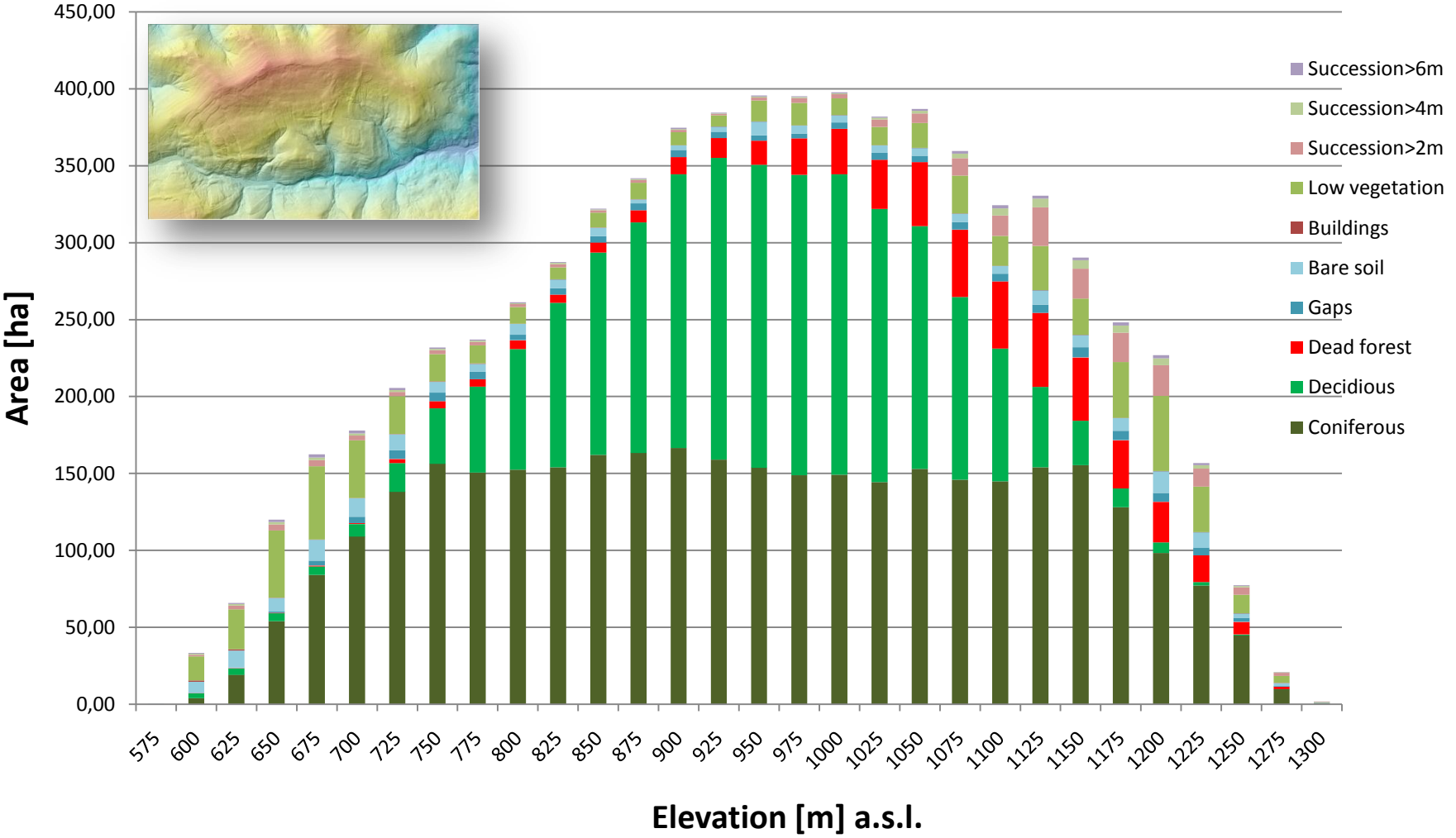


Analysis outside Gorce NP:

- **dead Norway spruce stands: 25,07 ha**
- **gaps : 43,90 ha**
- health coniferous stands: 1.102,22 ha
- health decidous stands: 238,65 ha
- meadow vegetation: 376,33 ha
- **secondary forest succession > 2.0 m: 77,85 ha**
- **secondary forest succession > 4.0 m: 22,90 ha**
- **secondary forest succession > 6.0 m 19,58 ha**

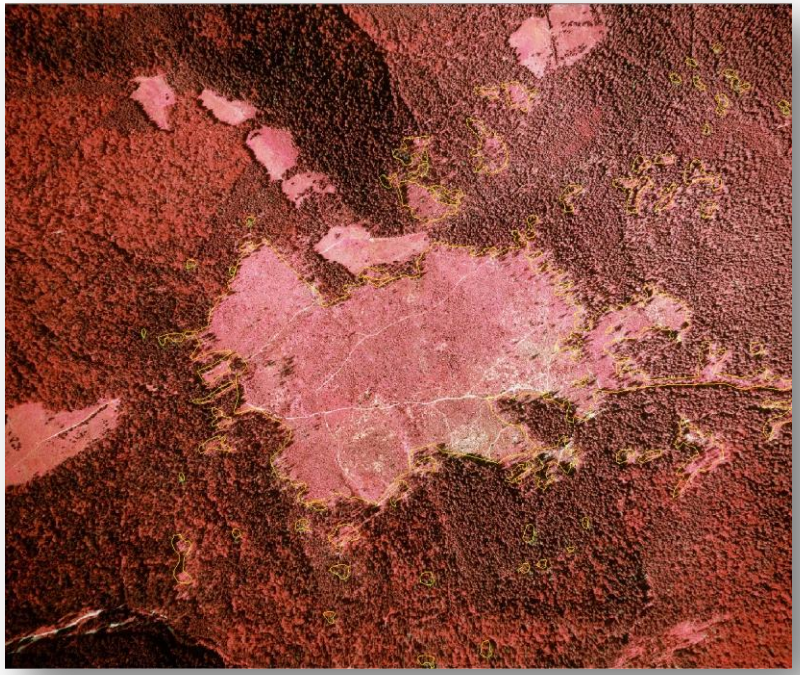
Results (7)

GIS - vertical distribution of LULC classes

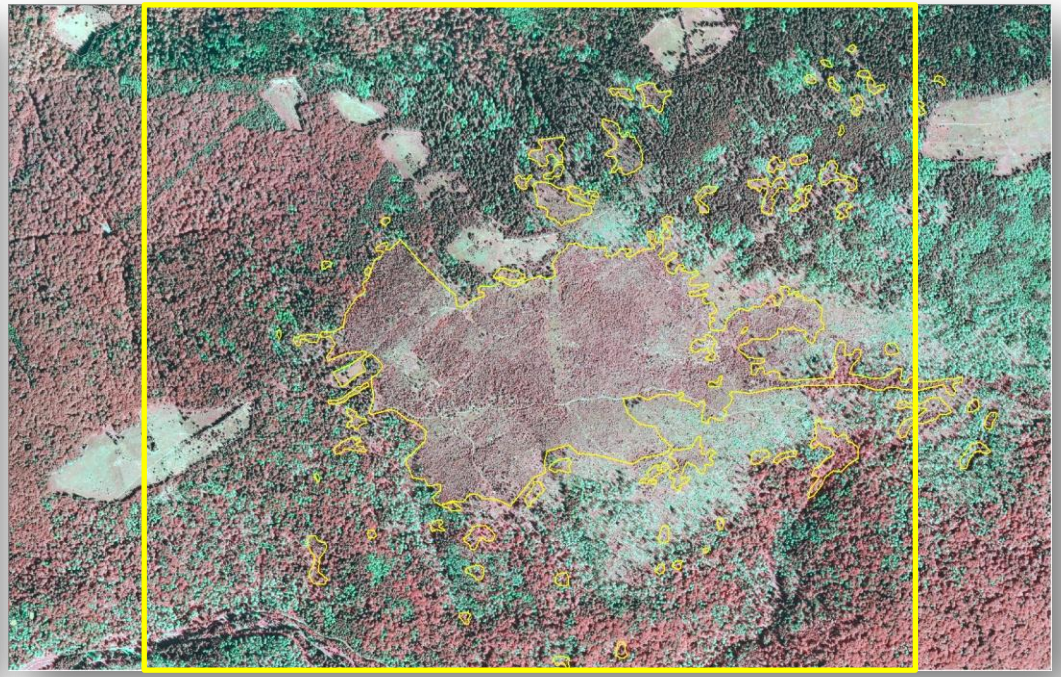


Results (8)

Forest cover changes: 1997-2011
Kudłon - test site



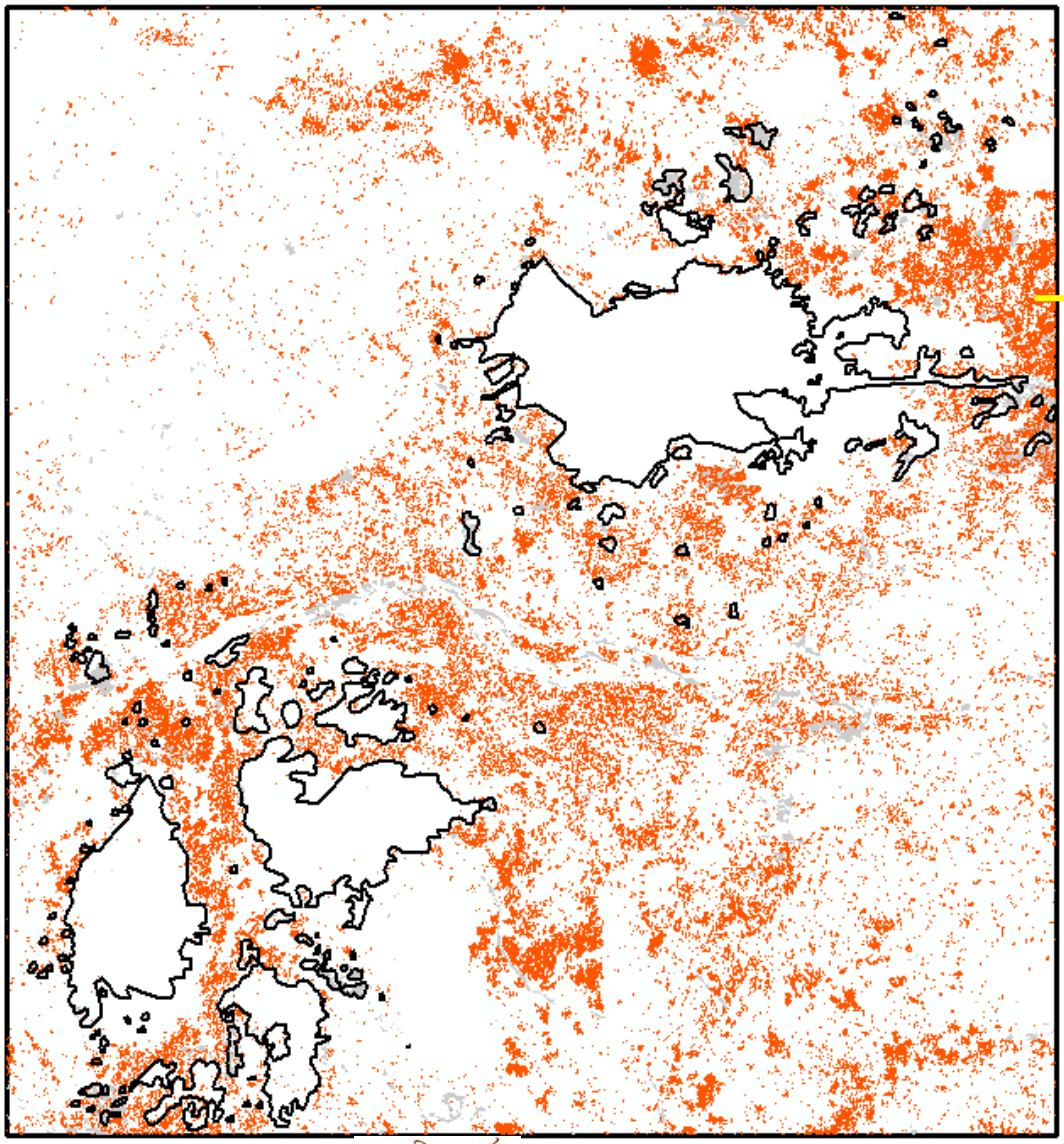
CIR aerial photos from year 1997
yellow vector – 3D stereo-mapping (VSD)
114,11 ha of dead or destroyed Norway spruce stands (*Plagiothecio-Piceetum)*



CIR digital aerial orthophoto from 2009.
yellow vector – 3D mapping from 1997
158,39 ha ha od dead forest (*Plagiothecio-Piceetum)* and gaps.

Results (9)

Dead conifreous stands



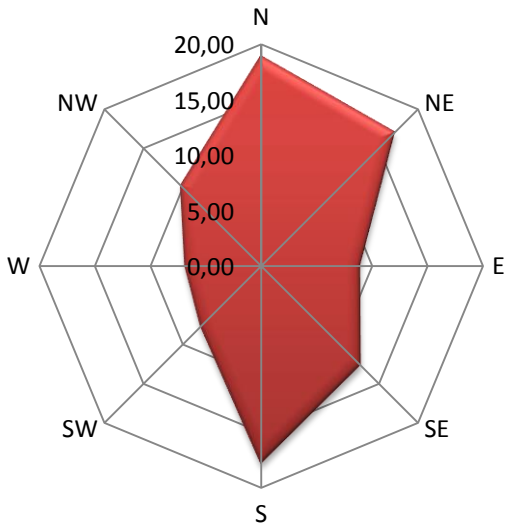
Changes on the „dead forest" class and gaps using GIS spatial analyses in the boundary box form 1997:

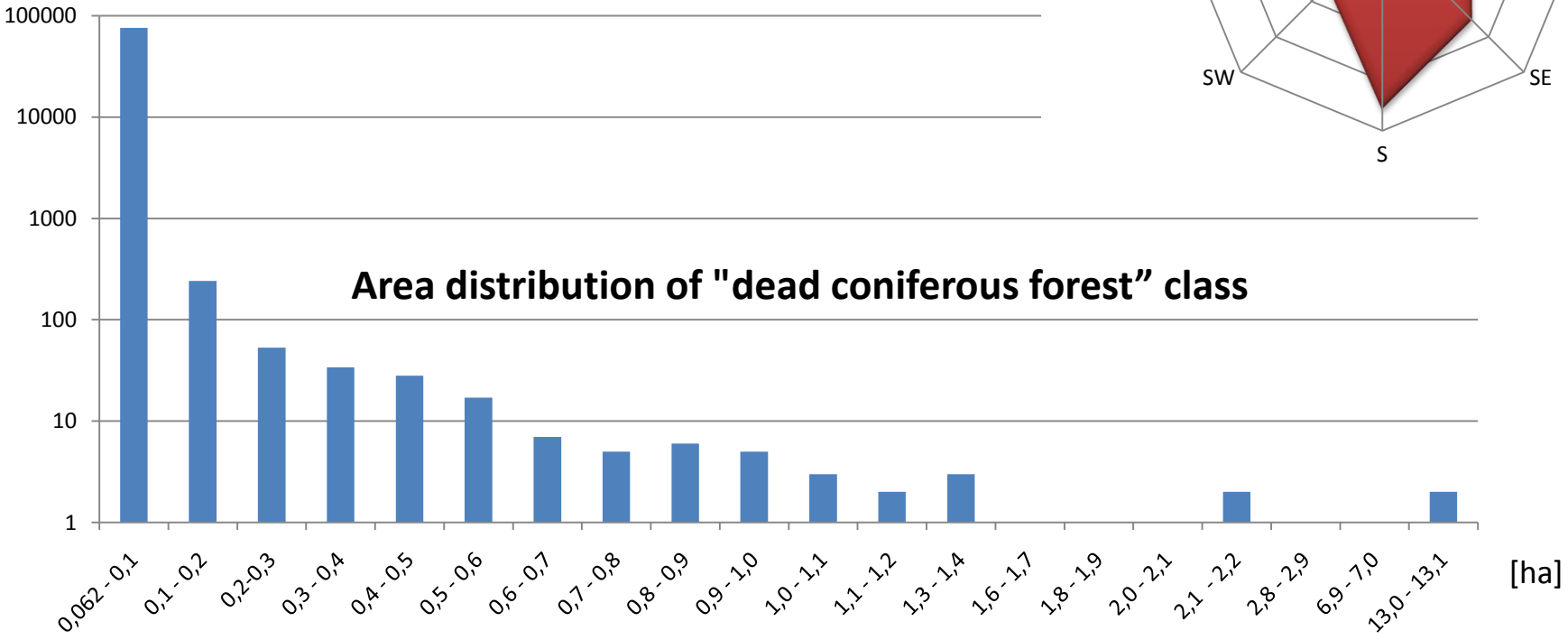
- **Aug. 1997 = 114,05 ha**
- **Aug. 2009 = 158,39 ha**

Difference: +44,34 ha (+38,87%) increase of dead and destroyed forests. **Approx. 93% of dead forest area from 1997 is covered by young forest regeneration!**

Results (10)

Dead Norway spruce stands





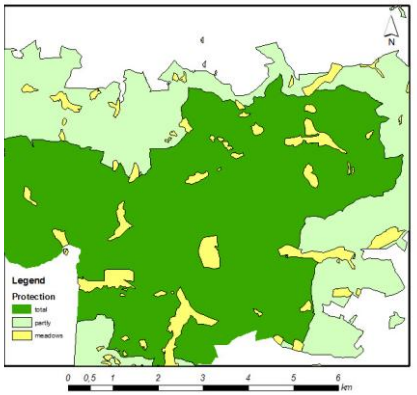
Results (11)

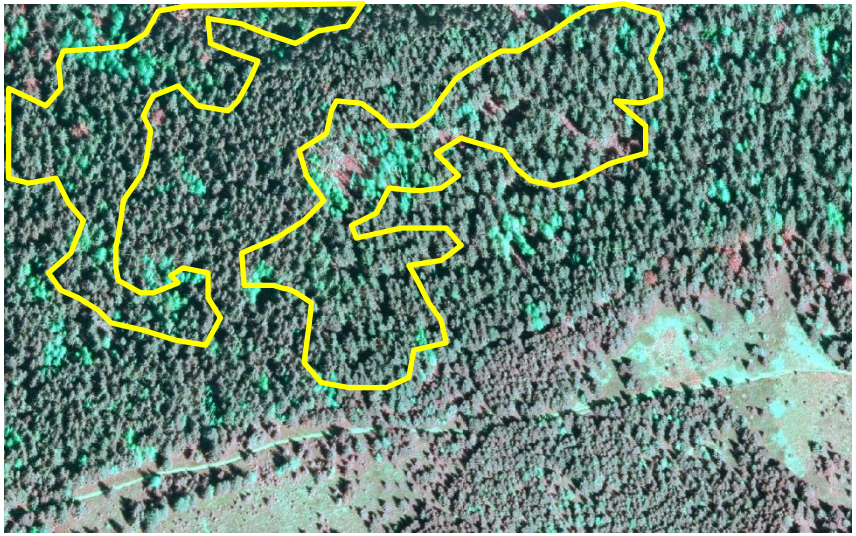
dead Norway spruce stands – vertical distribution

Results (12)

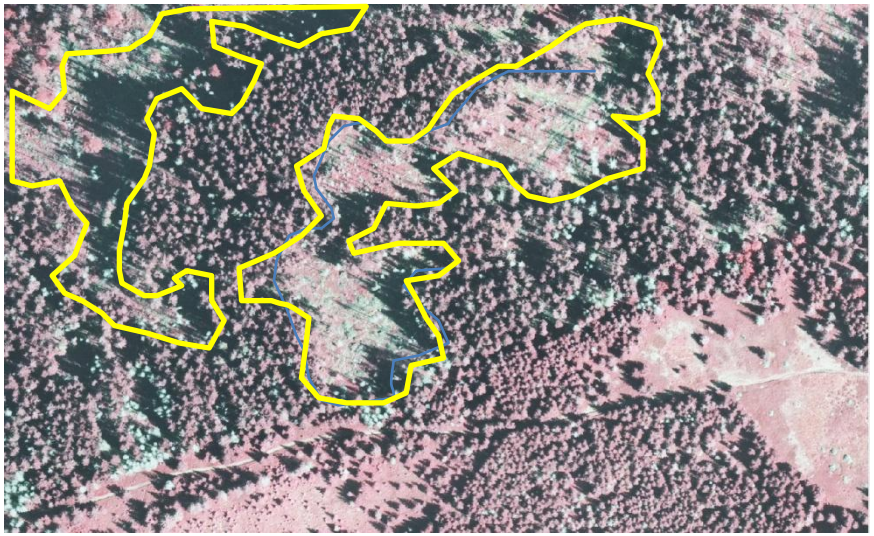
GIS analysis: Protection status: strict / partly

LULC class	strict/pasive protection ha	strict/pasive protection %	partly/active protection ha	partly/active protection %
Decidous stands	1.249,78	39,62	696,73	42,99
Coniferous stands	1.355,32	42,97	810,83	50,03
Dead trees / dead coniferous stands	350,9	11,13	78,77	4,86
Gaps and shadow	42,62	1,35	18,26	1,13
Secondary forest succession h> 2m	68,94	2,19	2,09	0,13
Secondary forest succession h> 4m	18,23	0,58	0,82	0,05
Secondary forest succession h>6m	5,26	0,17	1,18	0,07
Meadows/open areas with low vegetation	50,07	1,59	7,89	0,49
Meadows/open areas without vegetation cover	12,97	0,41	3,93	0,24





CIR orthophoto: 2009 (GPN)



CIR orthophoto: 2011 (GPN)

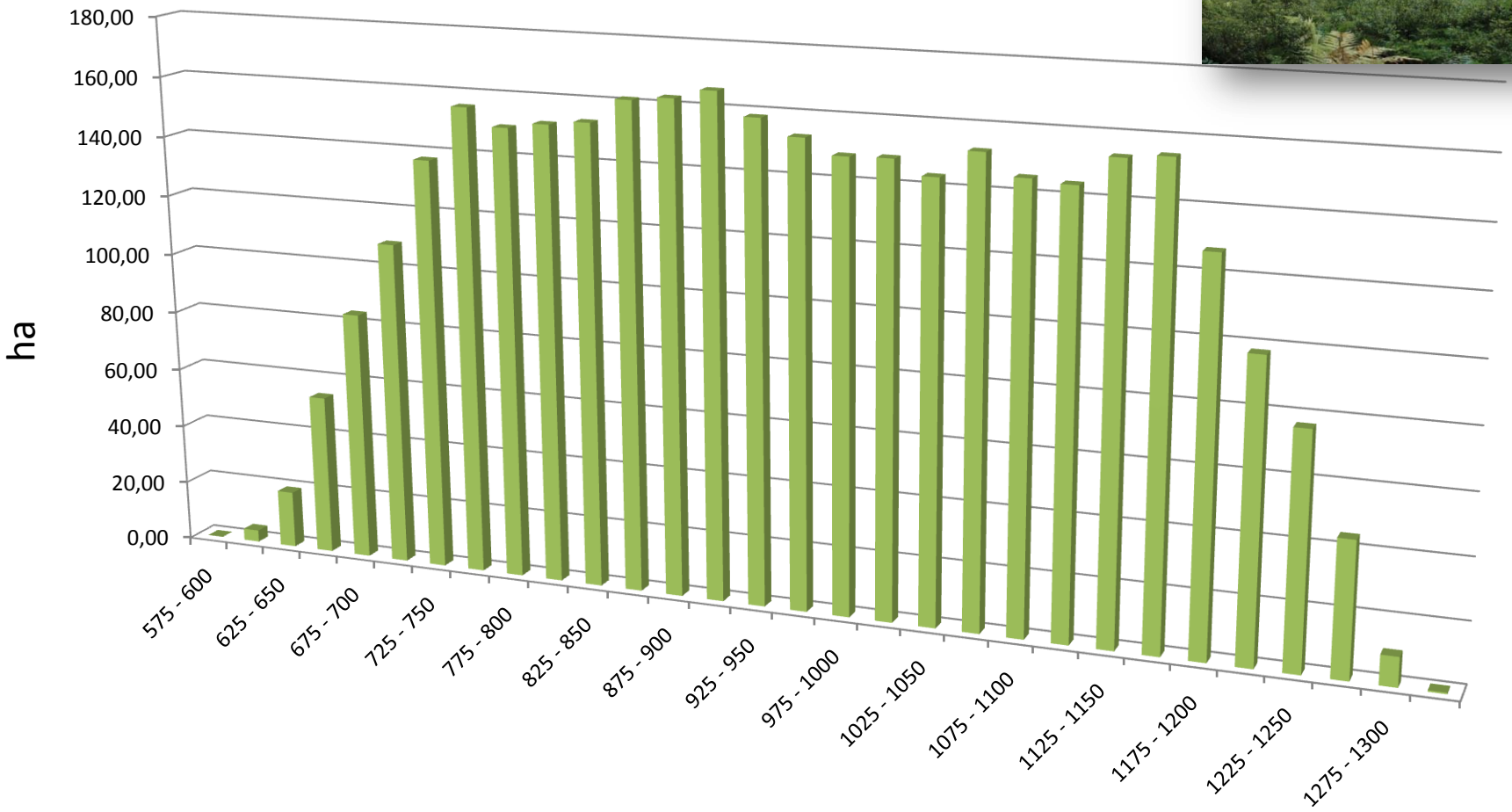
Results (13)

GIS analysis - secondary forest succession

Results (14)

GIS analysis - health Norway spruce stands

inside Gorce N.P. = 2.227,18 ha
outside Gorce N.P. = 1.102,22 ha



Conclusions (1)

- In the Gorce NP the dynamic processes of Norway spruce dieback started in 1980 can be still observed. This ongoing process of Norway spruce regress can be confirmed by the 440.4 ha of dead Norway spruce stands and 67,24 ha of gaps - identified on CIR aerial orthophotos from 2009. The Norway spruce dieback occurs mainly as a result of abiotic factors (wind, drought) and biotic factors: bark beetle (*Ips typographus*) outbreaks.

- A high risk of further Norway spruce dieback in Gorce NP exist, because of occuring health coniferous stands on the area of 3.380,5 ha (almost 50% of the study area). Less threatened are forest stands lies on lower mountain belt. The European Beech (*Fagus silvatica*) begins to be dominant tree species in Gorce NP.

- In areas where 10-15 years ago the dead or dying trees <u>were not removed</u> from the forest ecosystem, the dynamic process of natural forest regeneration is observed. Young trees are protected from deer damages by thicket and mazes created by dead and broken trees, overturned roots system and branches. Dead wood positively influence the reachness of elements and physically properties of the soil.

Conclusions (2)

- GEOBIA approach turned out to be robust and objective method for Norway spruce dieback mapping in the mountains environment.

- Usage of the nDSM derived using Semi Global Matching algorithm (RSG software; Remote Sensing Graz; Joanneum Research Graz) enabled reliable and accurate classification of different LULC classes a specially different forest regeneration stages.

- Designed GEOBIA workflow (rule-set) after some adjustments can be used for further projects based on aerial CIR orthophotomaps from 2011 and 2012.

- Digital Elevation Models (like: CHM, nDSM) and other derivates maps (e.g. density, 95 percentile etc) based on ALS point clouds, will significantly improve classification accuracy of GEOBIA approach.

Thanks for your attention !!!

ISOK Project 2013 – just got it!