Assessment of forest stands condition in Gorce National Park (South Poland) using an Object Based Image Analysis approach of CIR aerial orthophoto and nDSM derived from stereomatchig

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Introduction (1)

Forest cover changes in the mountain environment

Deforestations:

Factors:
- abiotic: climate, wind, water, snow, temperature, fire, landslides, avalanches;
- biotic: insects, fungi;
- anthropogenic: clear cutings, fire, air pollution.

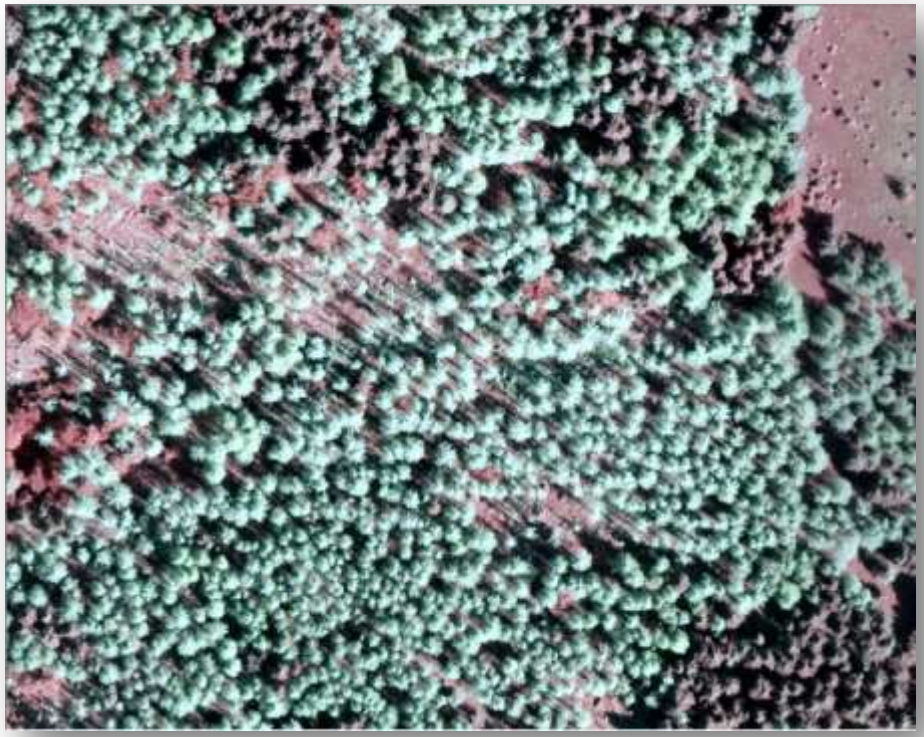
Afforestations:

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

Introduction (2)

Forest change

Deforestation



Dead Norway spruce stands (CIR image 2009

Afforestation

Secondary forest succession (CIR 1997)

Study area
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.)

Landscape transformations in Gorce

Stawieniec meadow – year 1938

Stawieniec meadow in 2011 – M. Mucha (Photo)

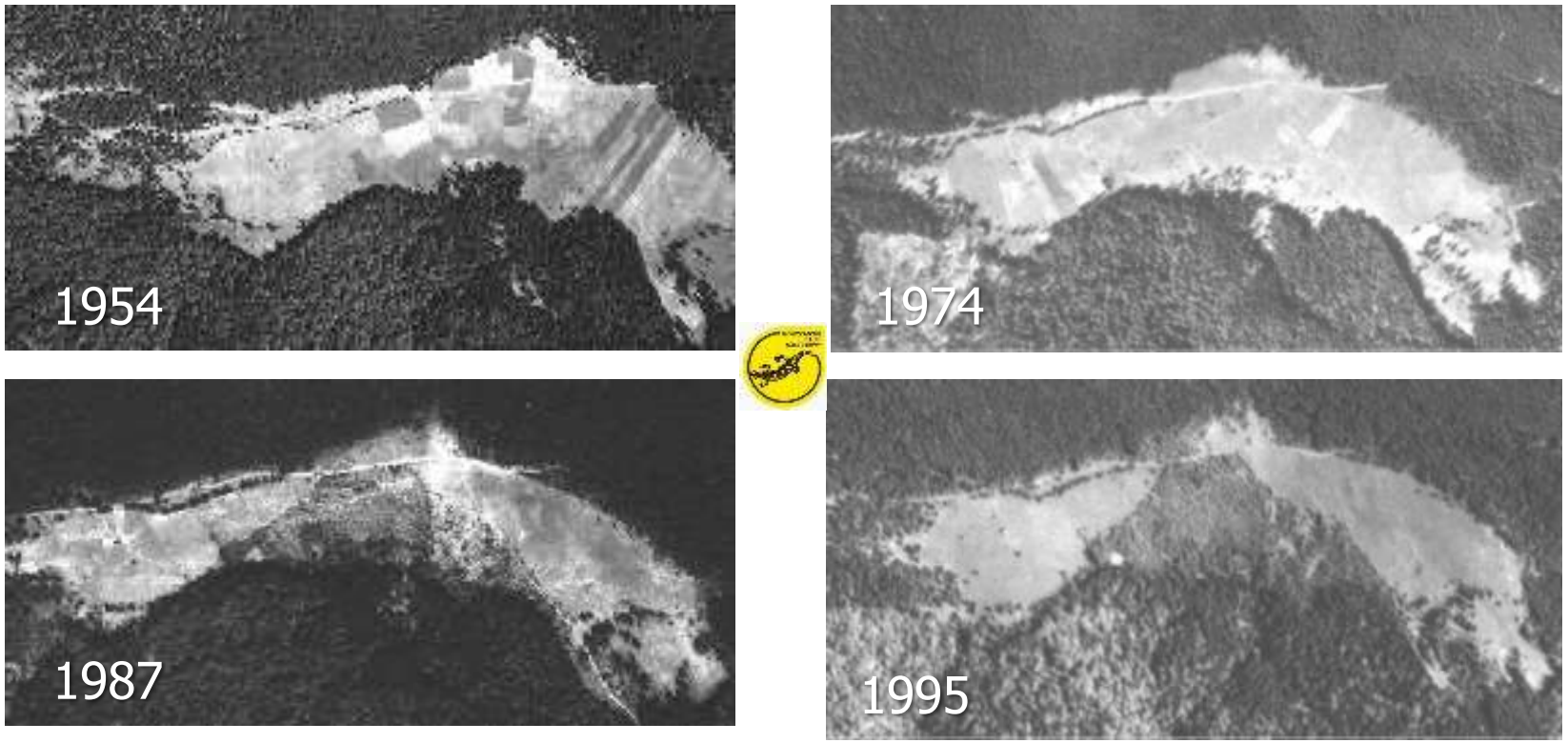
http://www.gorczanskipark.pl

Stawieniec – 2008; Akpol, M. Szelest

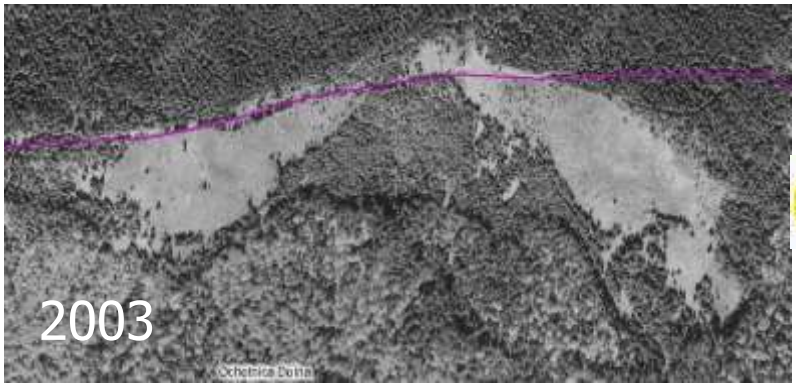
Archive aerial photographs as input data

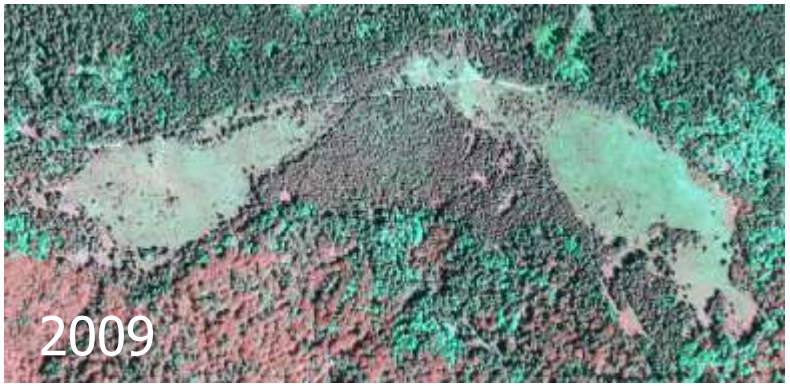
In the Polish archives of aerial photographs (civil and military), the different materials from years: 1946-2012 can be found like: analogue black and white (B&W), color (RGB) and Color InfraRed (CIR) and digital imagery (4 bands) as well.

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



Archive aerial photographs as input data

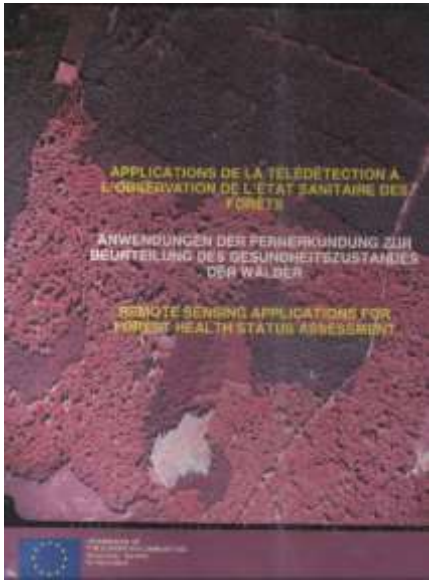




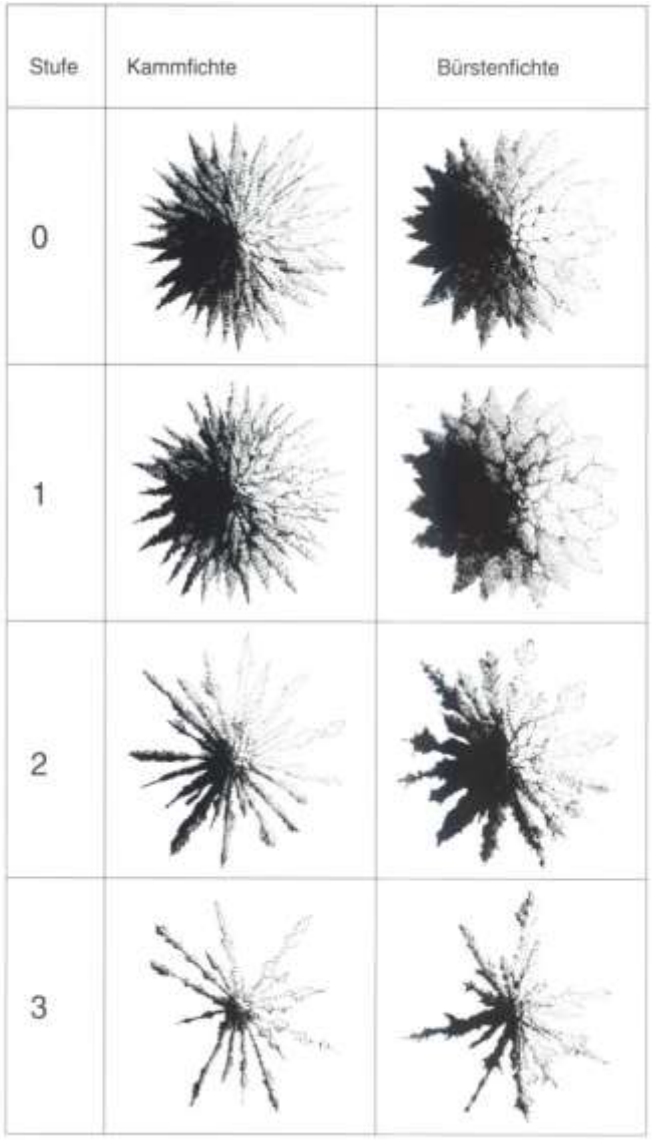
Photointerpretation key

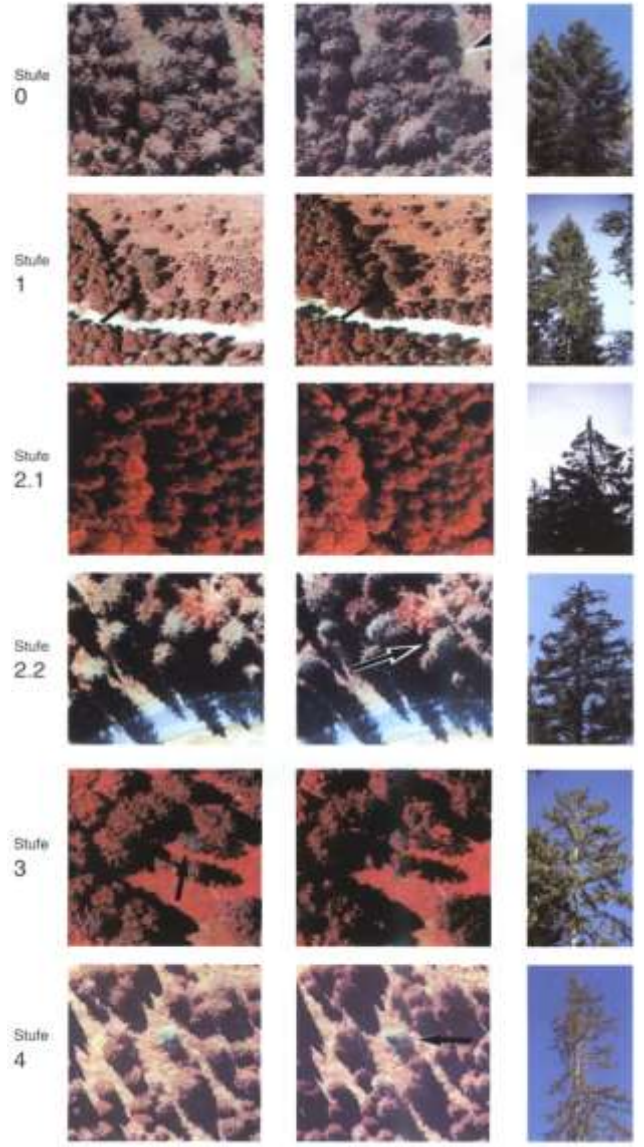
CIR aerial photos

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.



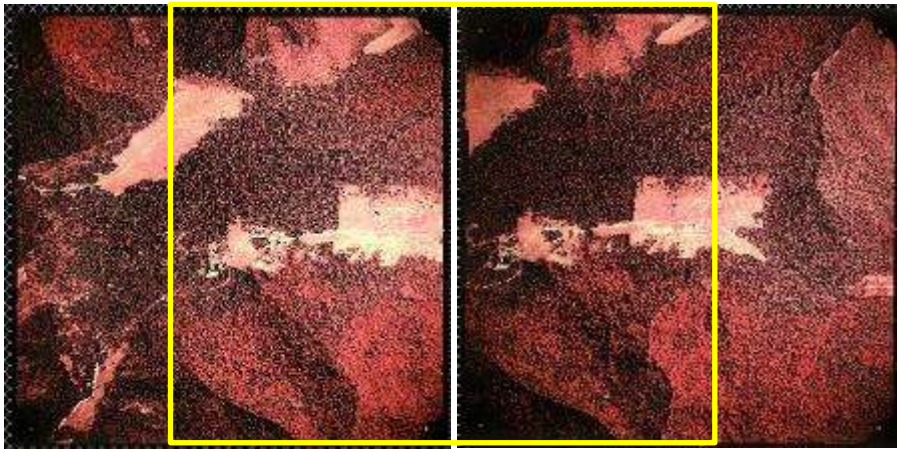
EU guidelines'





Forest inventory

Photogrametry 3D / 2D



CIR aerial photos

- 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

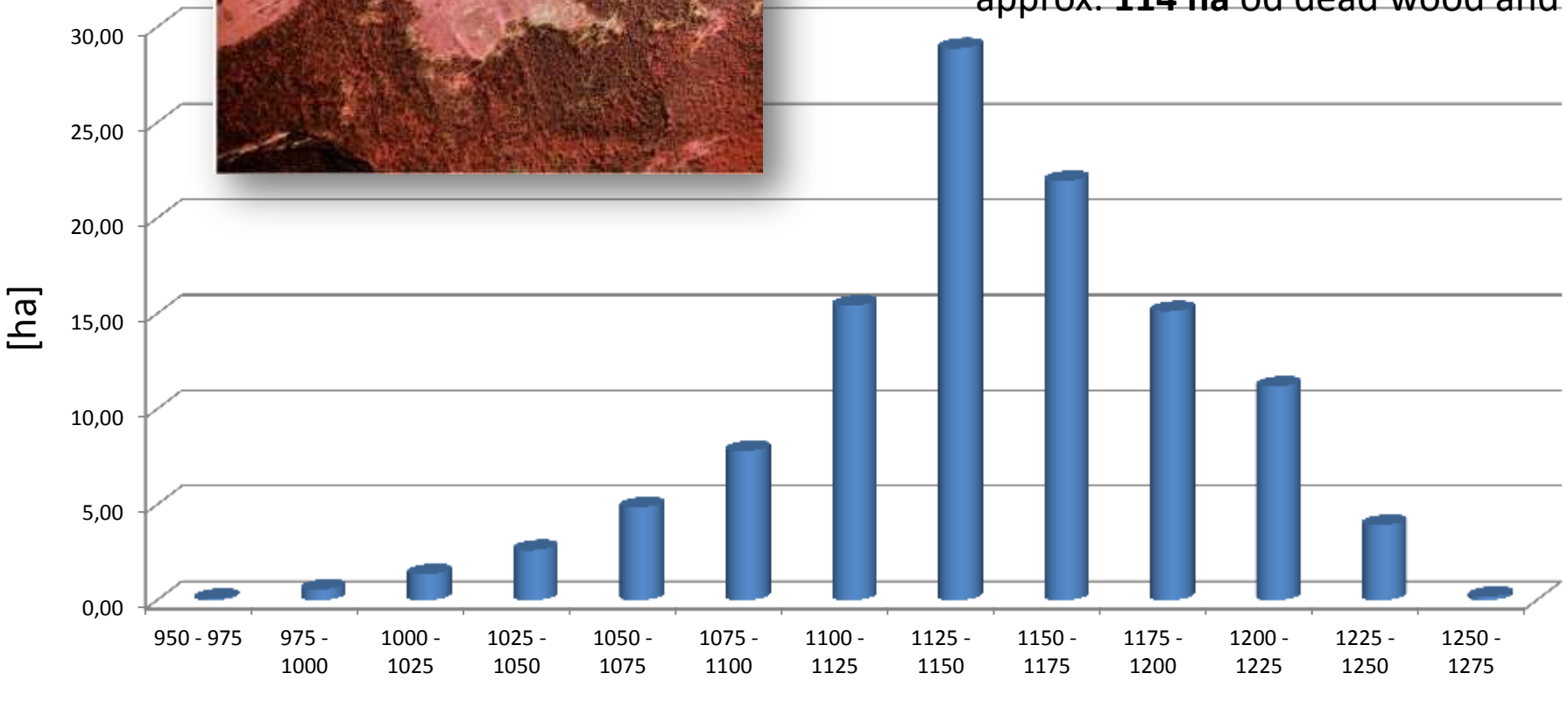
CIR aerial orthophotomaps:

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

Material and methods

Photogrametry 3D (VSD-AGH) CIR 1997

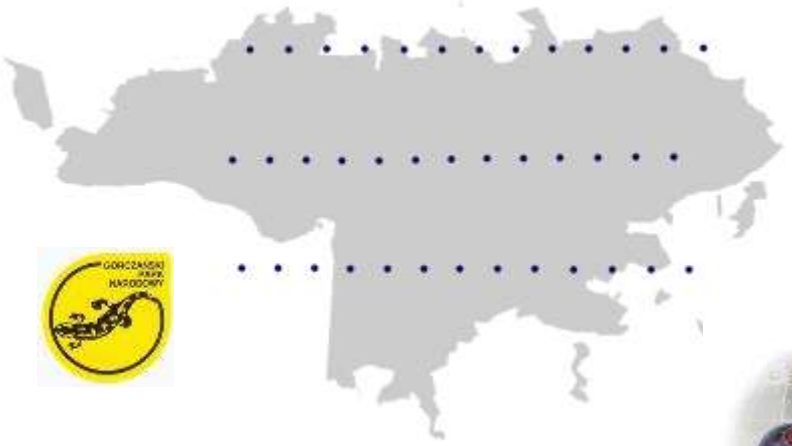
In Aug. 1997 the analogue CIR Kodak Aerochrome 2443 aerial photos was taken. Later the steropairs were elaborated in 3-D mode using VSD-AGH Soft Copy Station. Mapping of dead Norway spruce stands. approx. **114 ha** od dead wood and gaps

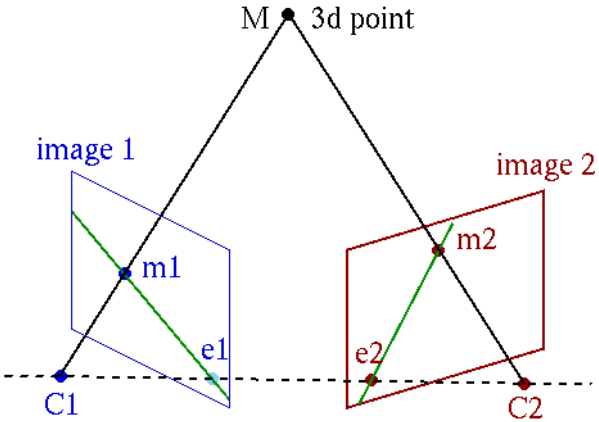


Material and methods

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

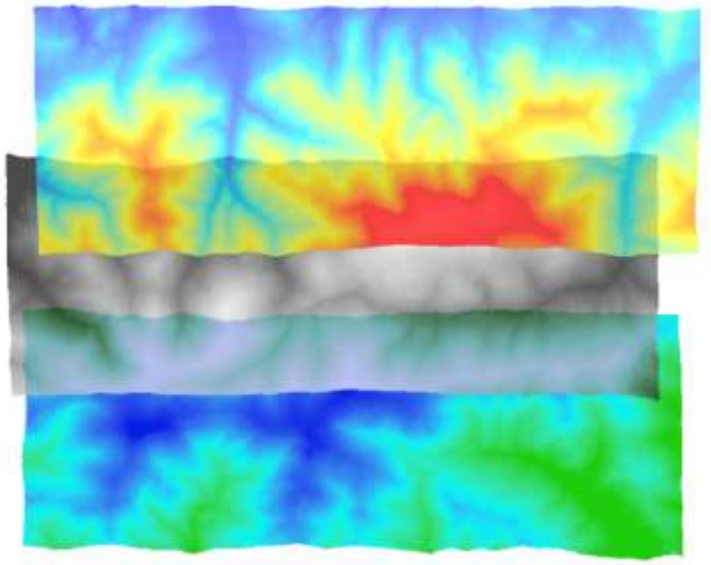




Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track	67.860mm	11310pixel
	cross track	103.860mm	17310pixel
Image Extent		(-33.91, -51.93)mm	(33.91, 51.93)mm
Pixel Size		6.000µm*6.000µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_pp	0.120 mm	± 0.002mm
	Y_pp	0.180 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

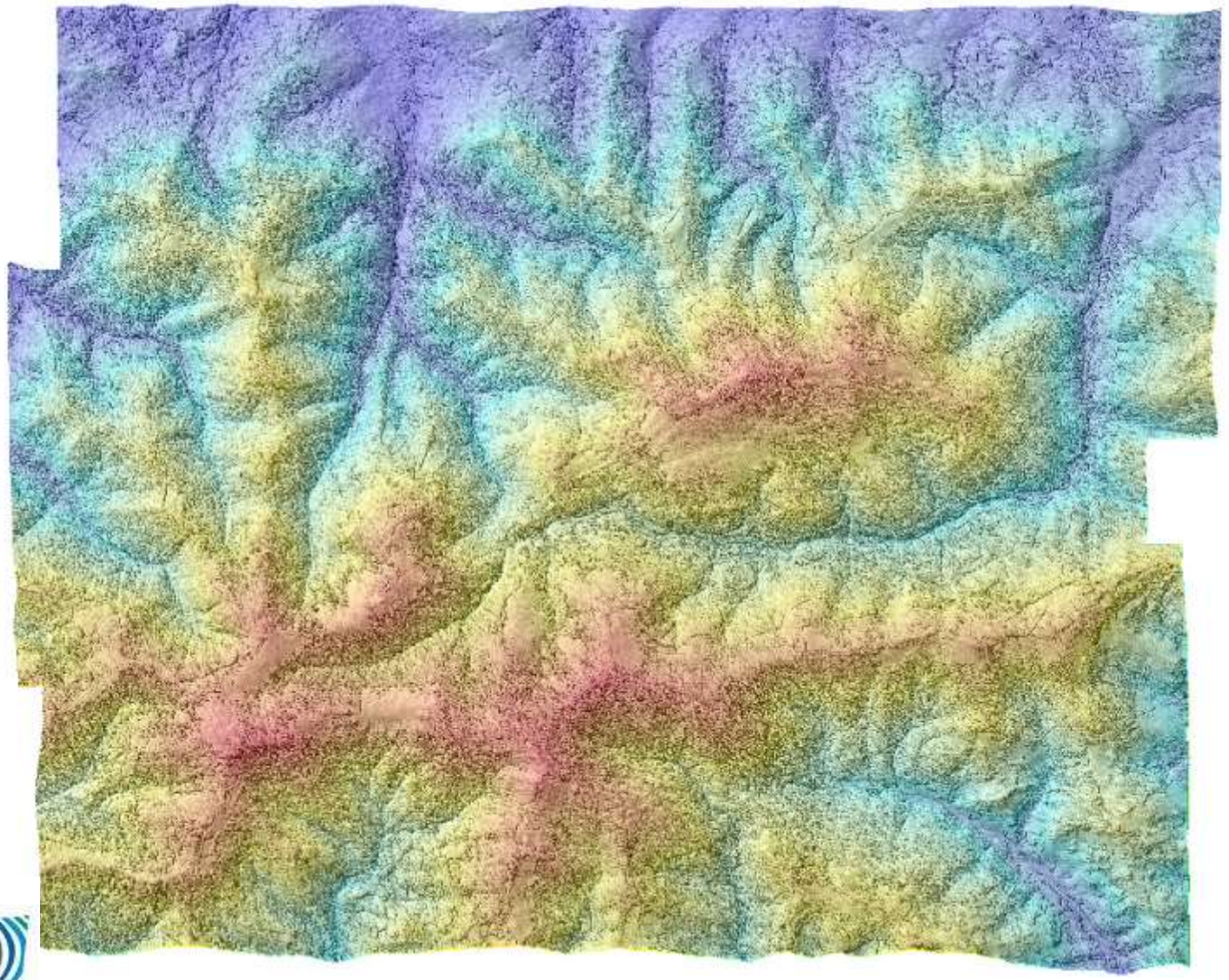


generation map of disparity using Semi-Global Matching

Stereomatching - DSM mosaick

Material and methods

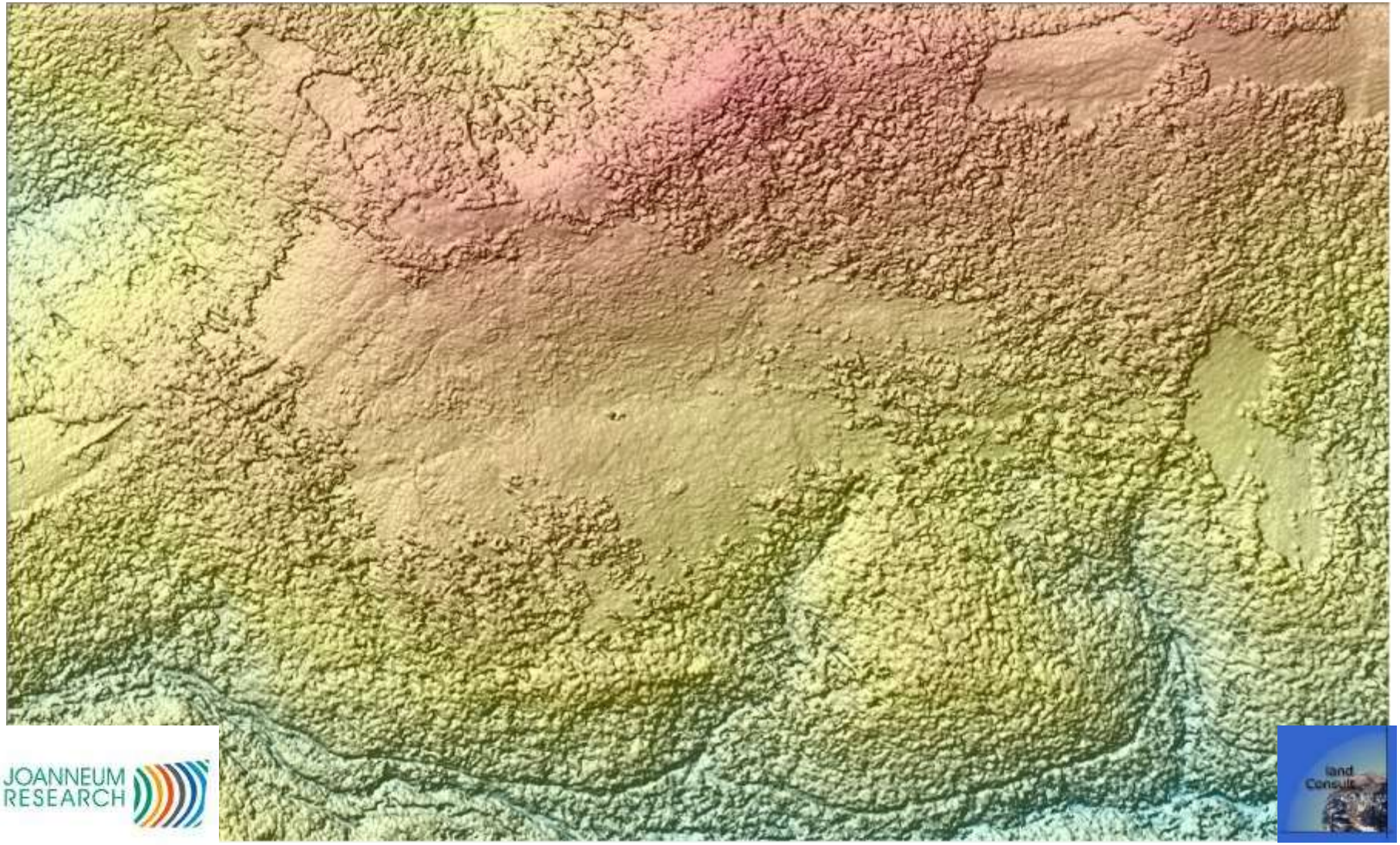
Stereomatching approach – SGM



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

Material and methods

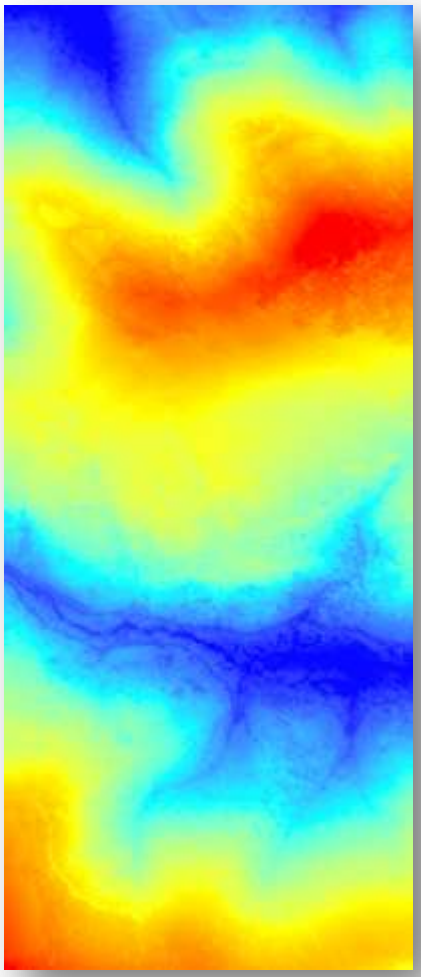
Stereomatching approach – SGM



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

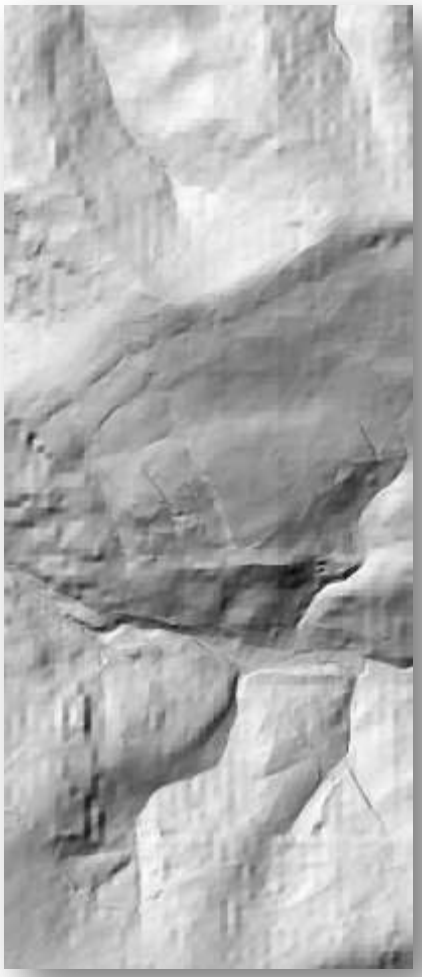
Methods

Derriving nDSM from stereomathing using reference DTM



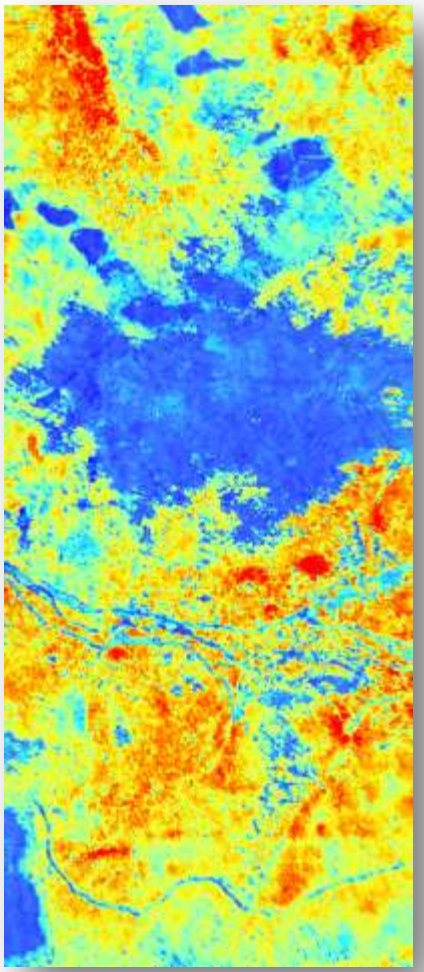
DSM stereo-machting
(832-1288 m a.s.l.)

DSM
minus
DTM



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

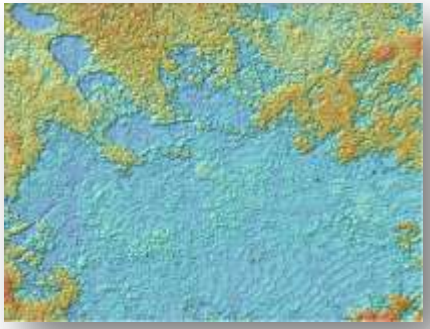
=



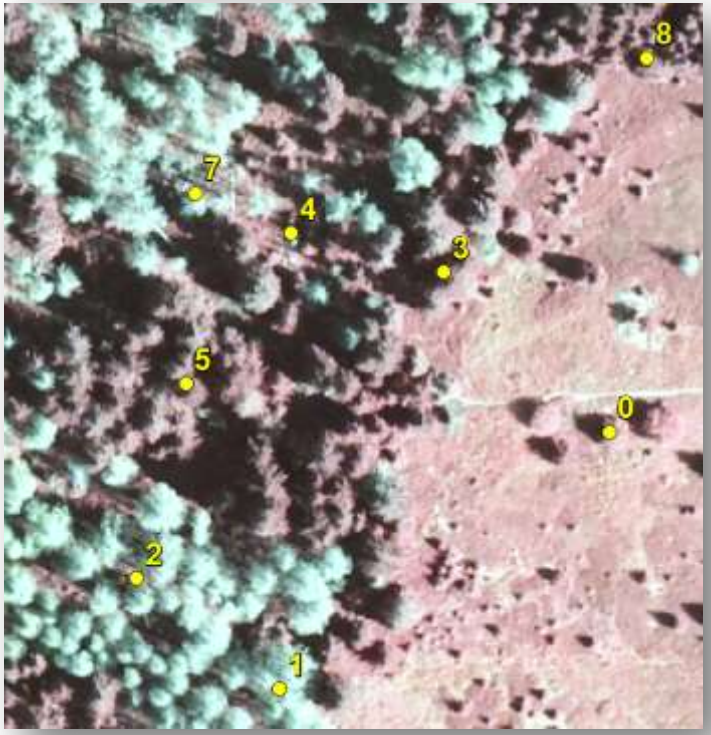
nDSM (stereomatching)
(0-42m)

Methods

nDSM Quallity Control



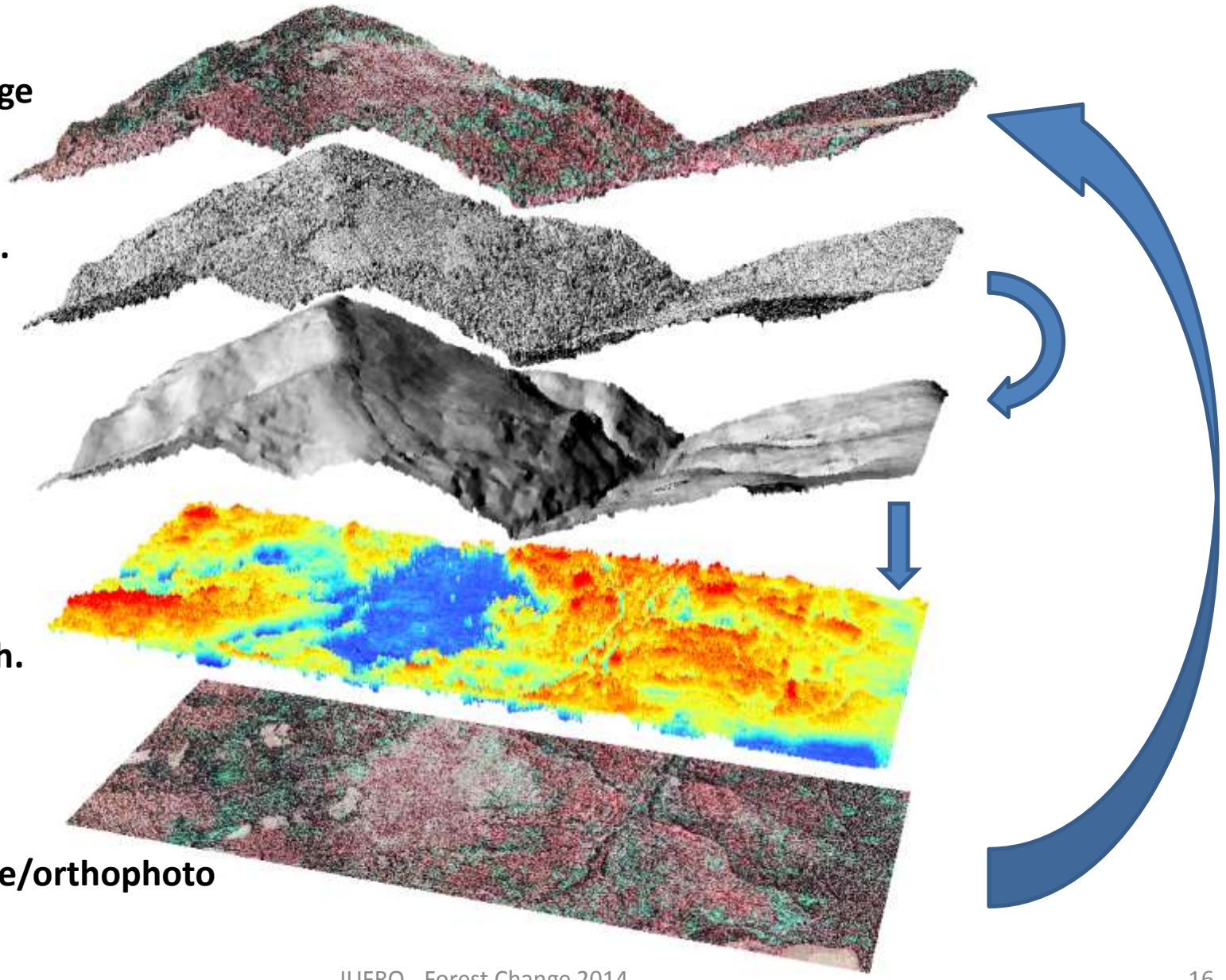
The Quallity Control was performed using the 3D photogrammetric workout based on the DEPHOS SoftCopy Station and the stereopairs.



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

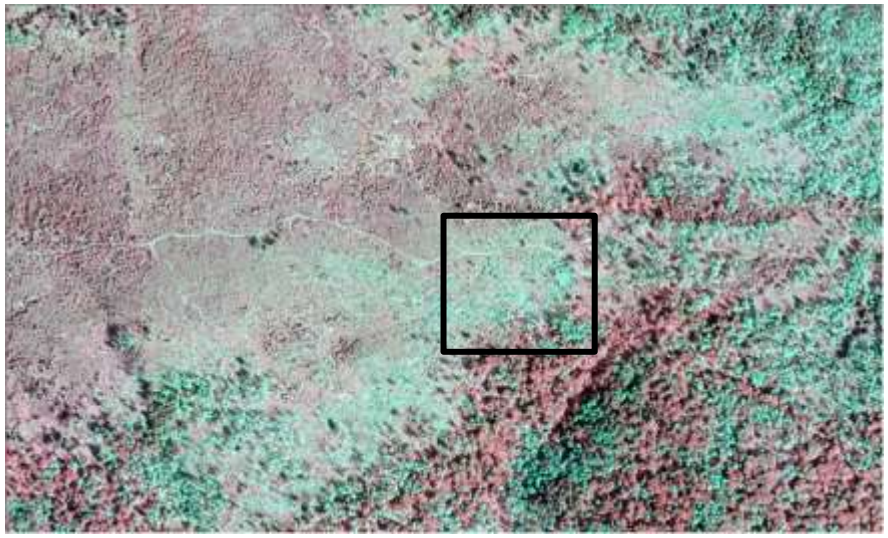
mean difference = 2,51 m

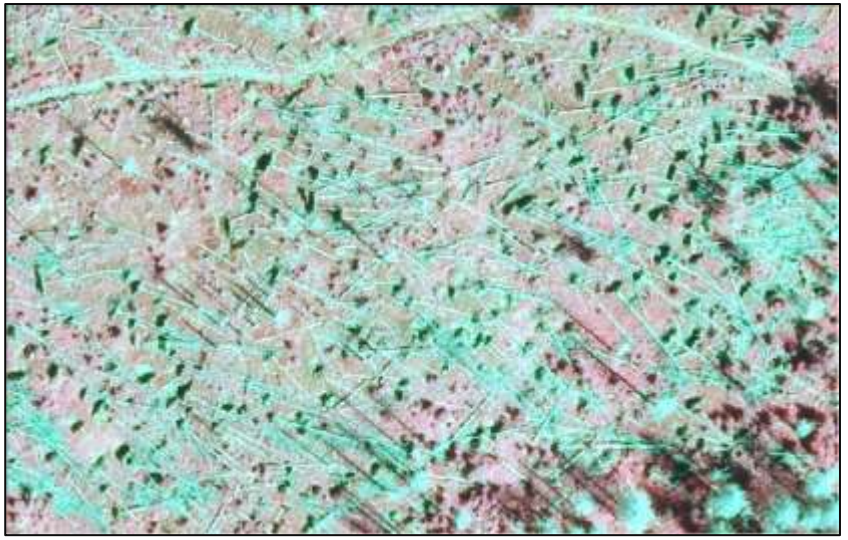
Different models and images used

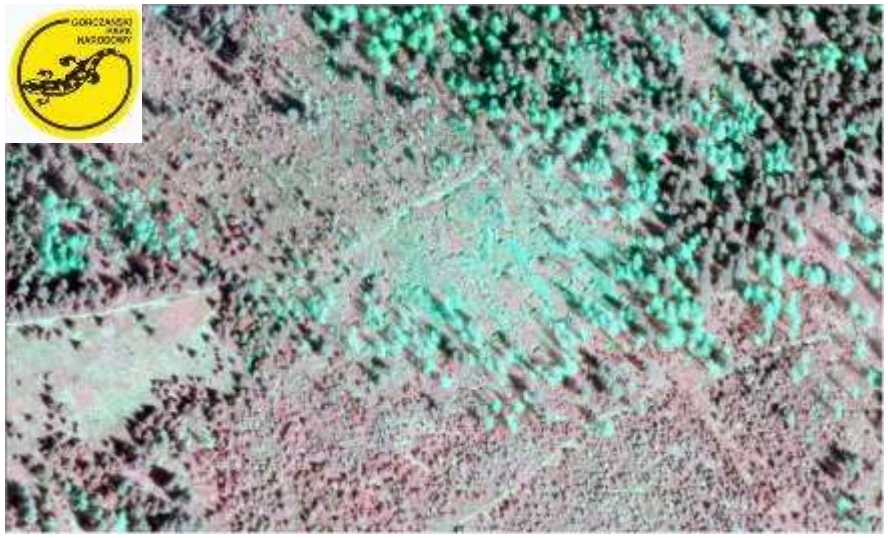


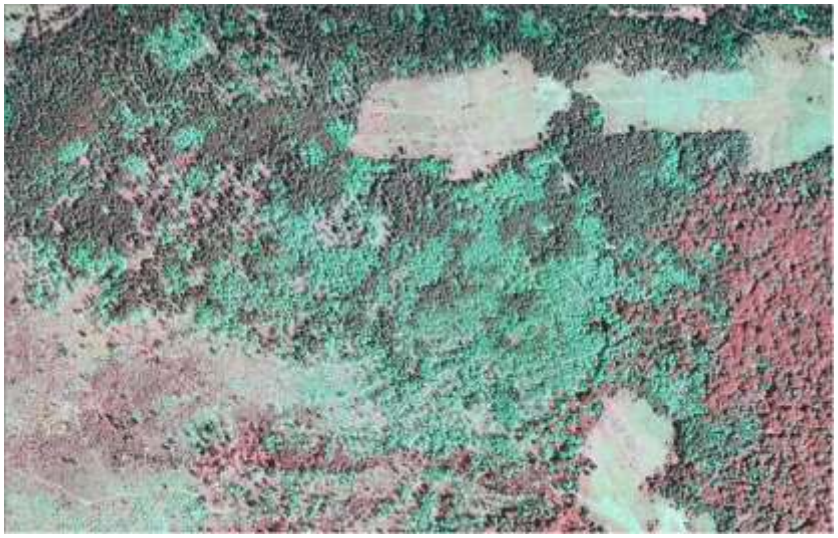
Material

Dead Norway spruce stands on CIR aerial orthophoto 2009

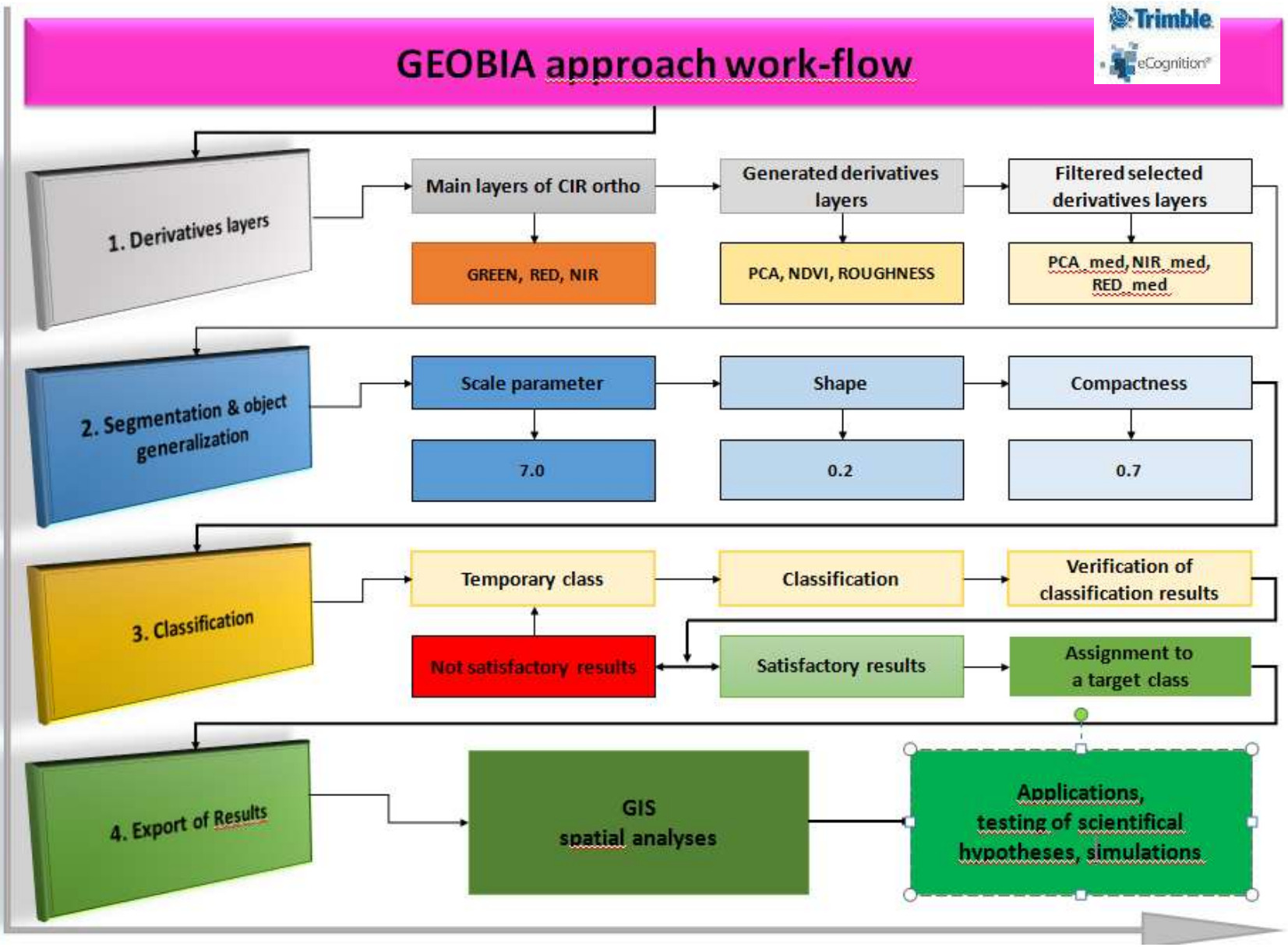








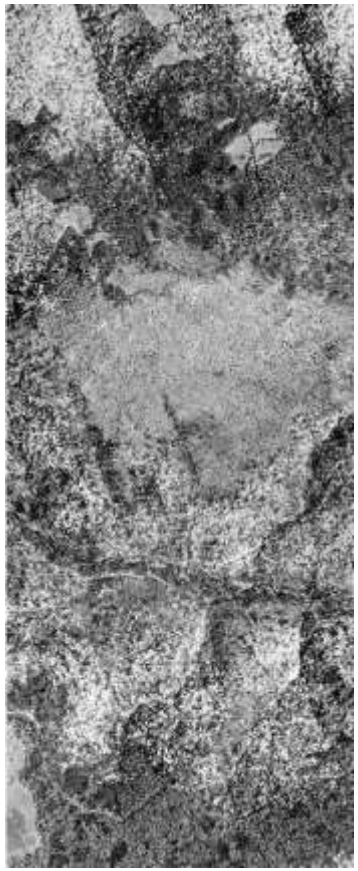
Methods - GEOBIA (0)



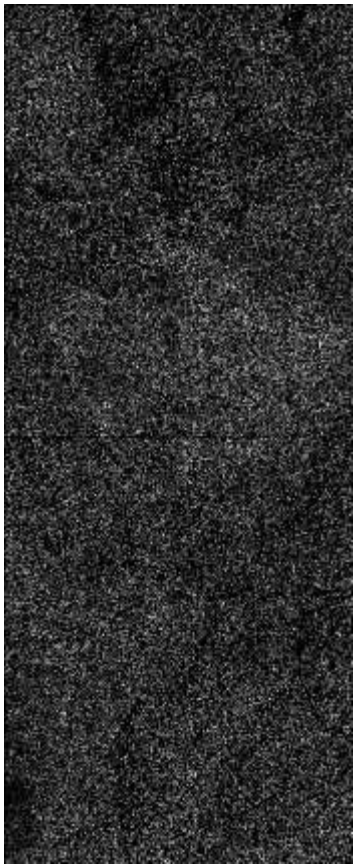
Methods - GEOBIA (1)

Data input - derrivative layers NDVI, Roughness

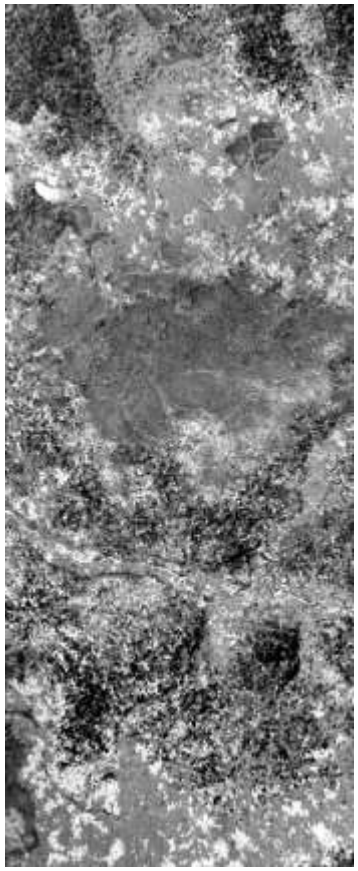
CIR
2009



NDVI
2009



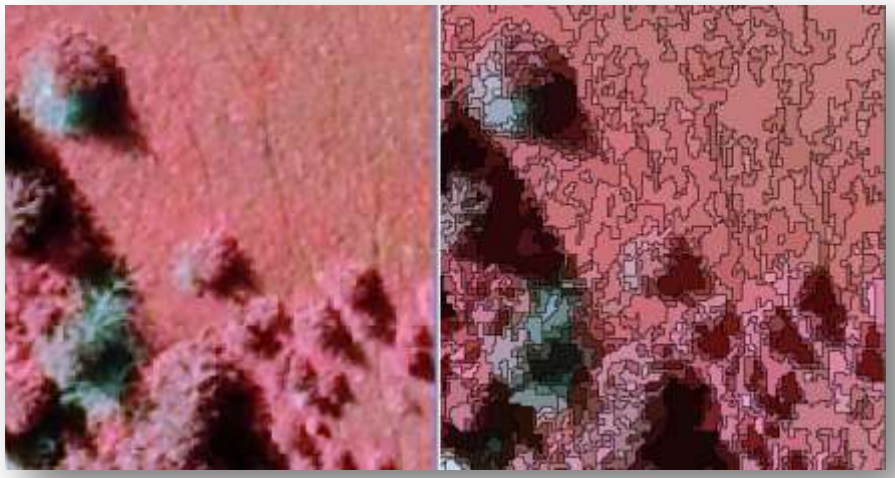
Lee Sigma Bright
2009



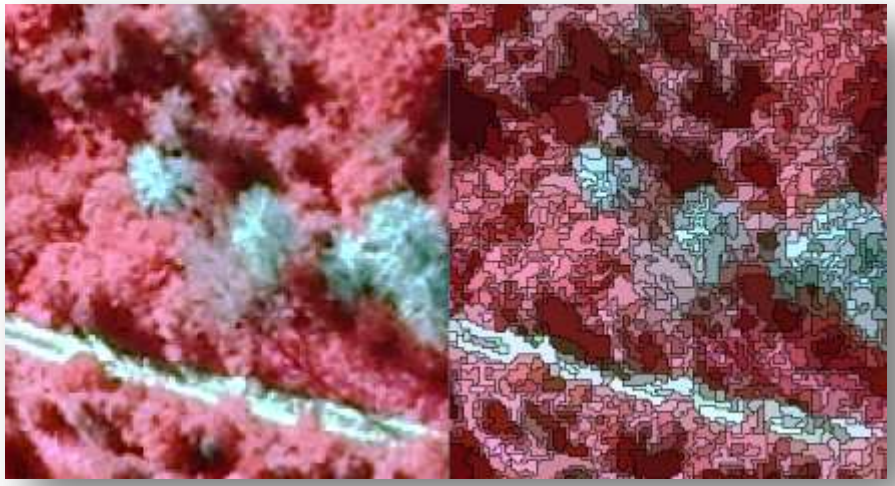
Roughness
2009

Methods - GEOBIA (2)

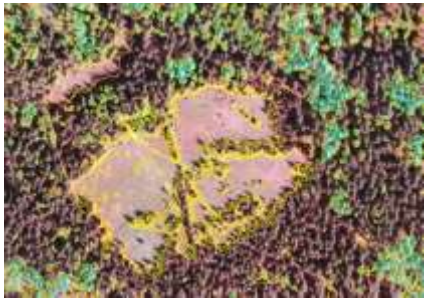
Rule-set



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 pixel
      - 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



Trimble.

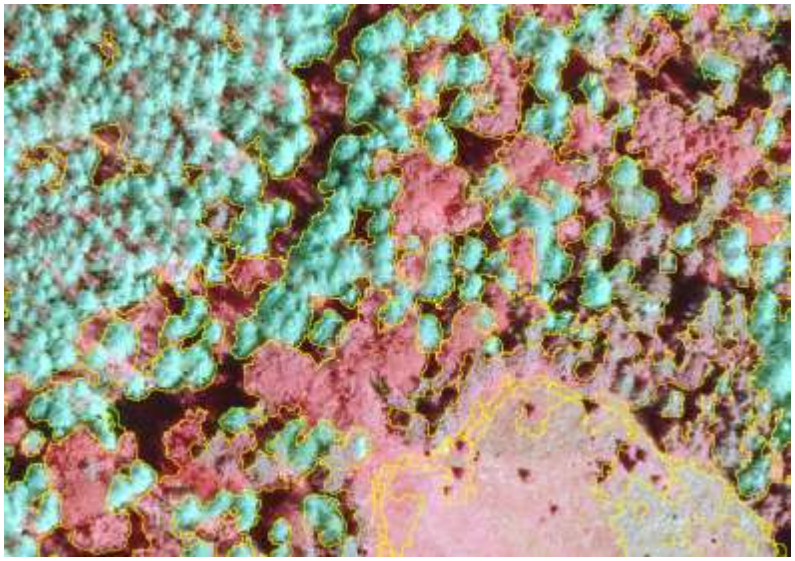
eCognition®

Results (1)

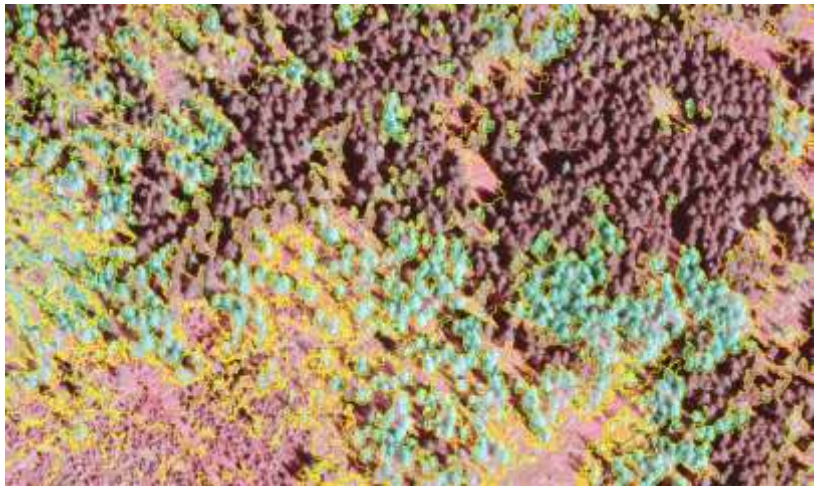
GEOBIA objects / classes

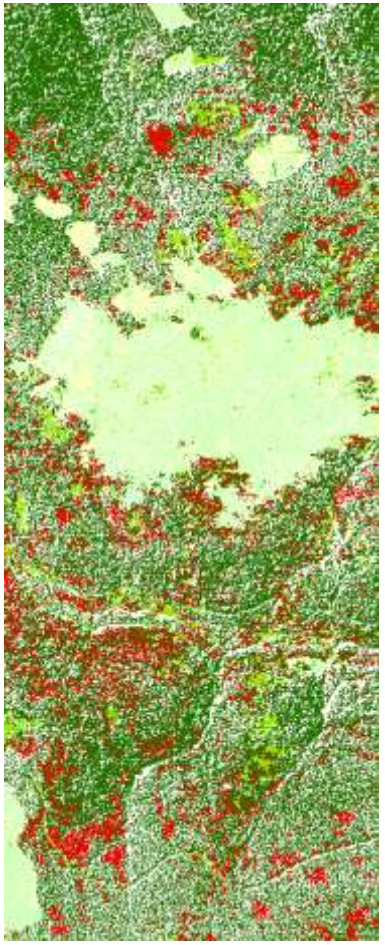
CIR 2009

Trimble eCognition



GEOBIA segmentation

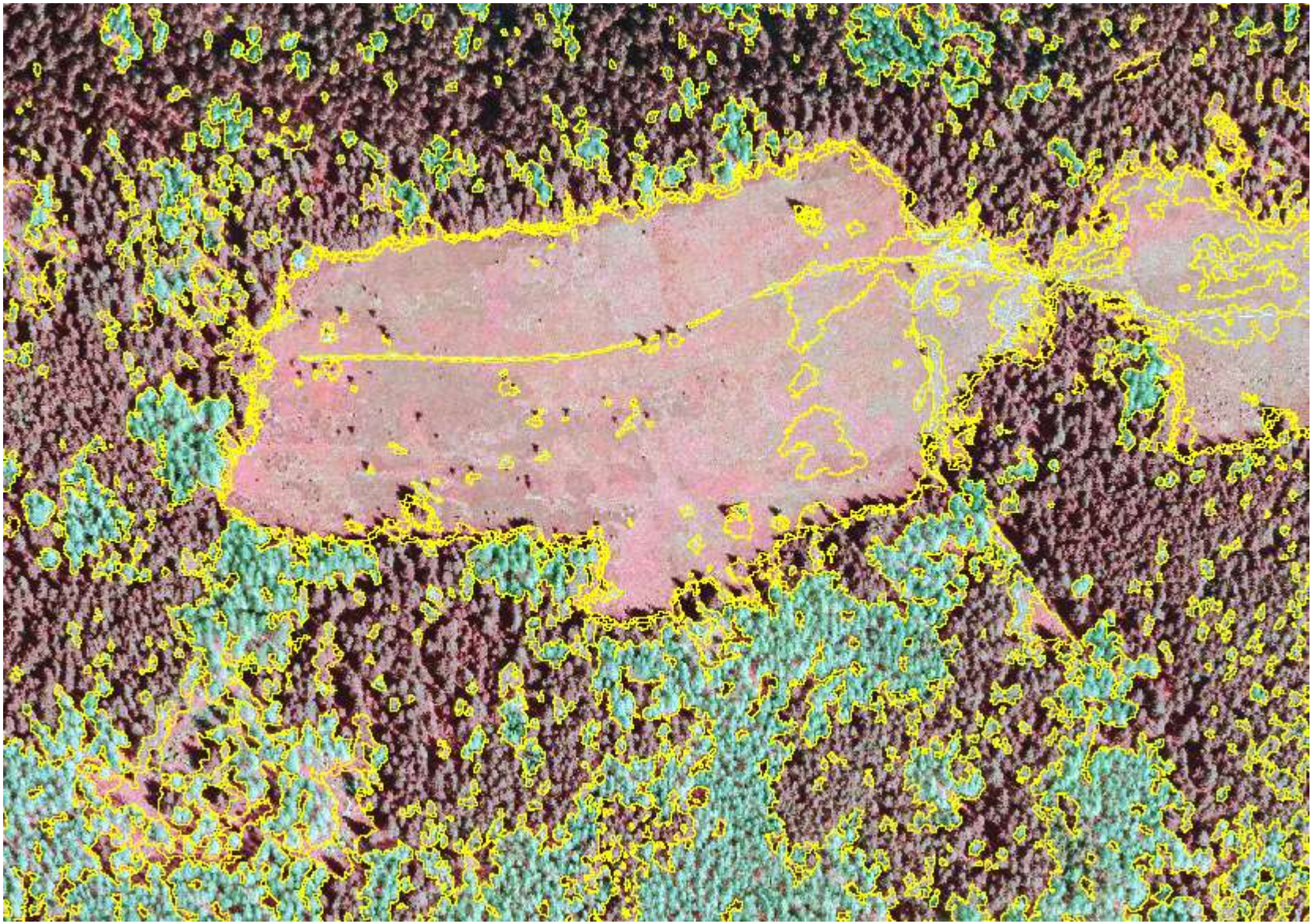




Results for year 2009

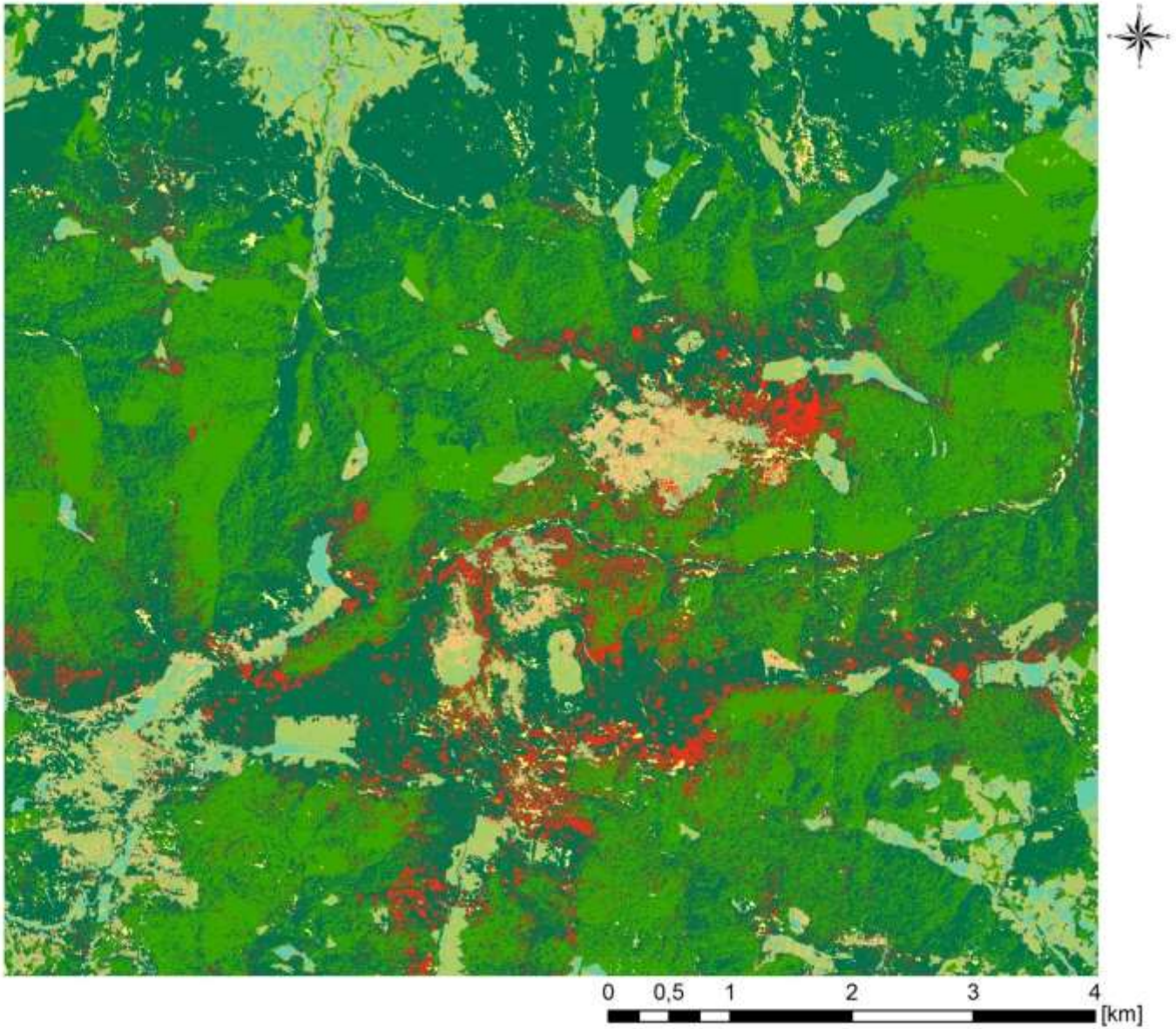
Results (2)

GEOBIA objects / classes



Results (4)

GEOBIA LULC map



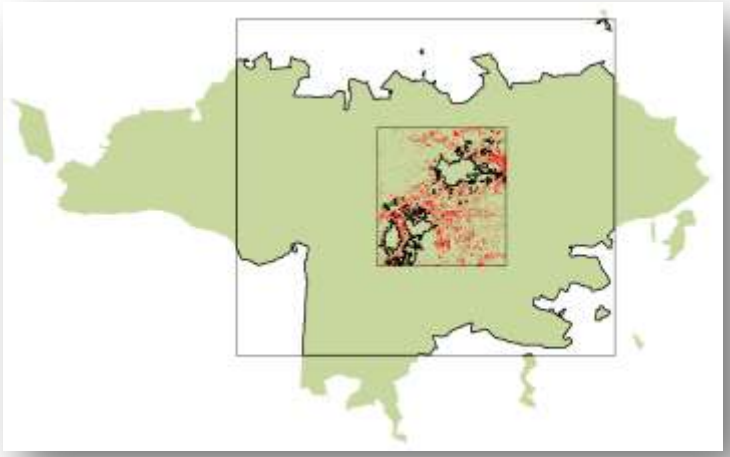
Results (5)

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 (3 classes: >2 m + >4 m + >6 m)	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)

Basic statistics based on GIS



Analysis inside Gorce NP:

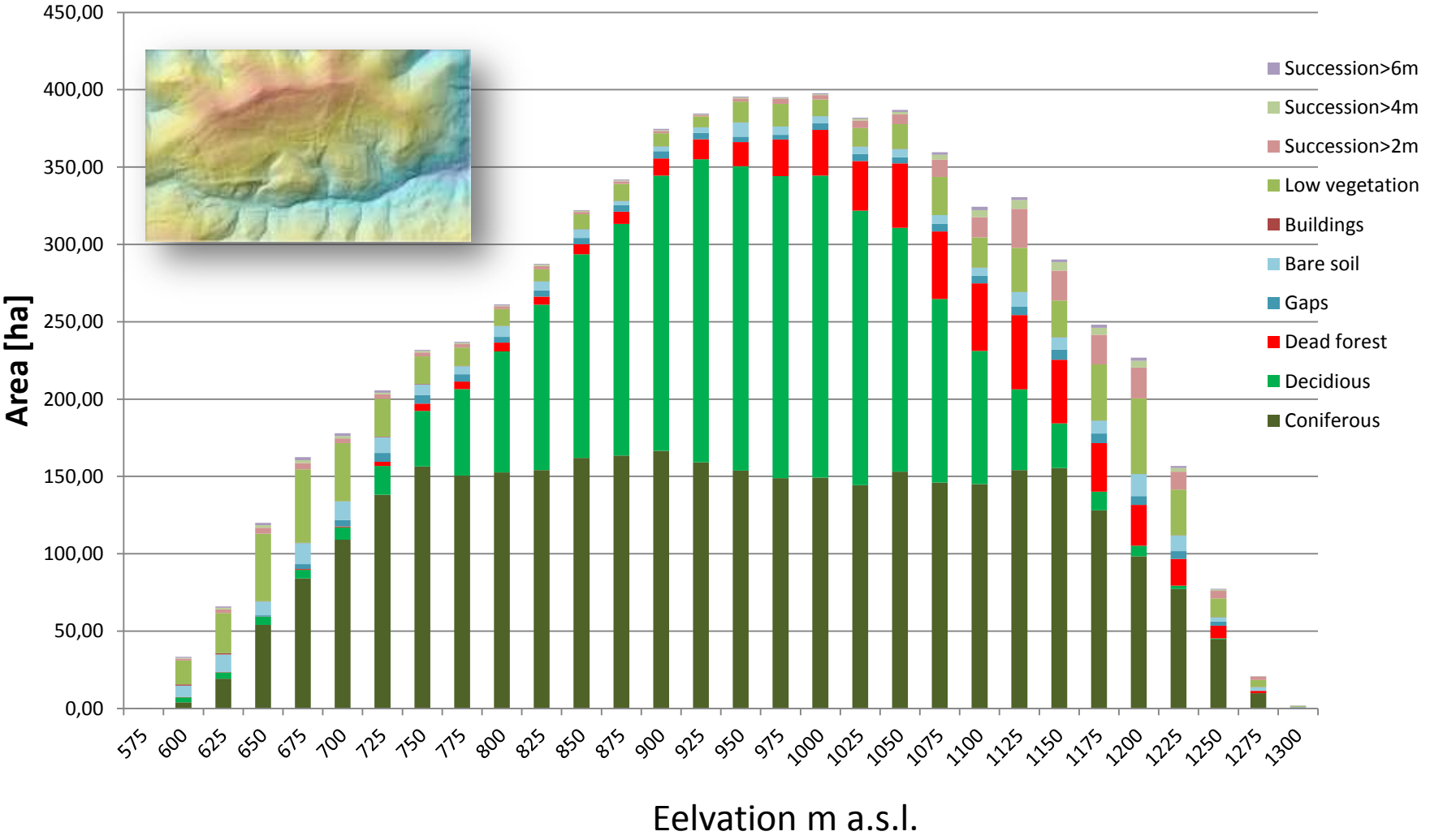
- dead Norway spruce stands: 440,41 ha
- gaps : 67,24 ha
- health coniferous stands : 2.227,18 ha
- health decidous stands: 1.965,63 ha
- meadow vegetation: 201,37 ha
- secondary forest succession > 2.0 m: 99,37 ha
- secondary forest succession > 4.0 m: 25,69 ha
- secondary forest succession > 6.0 m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

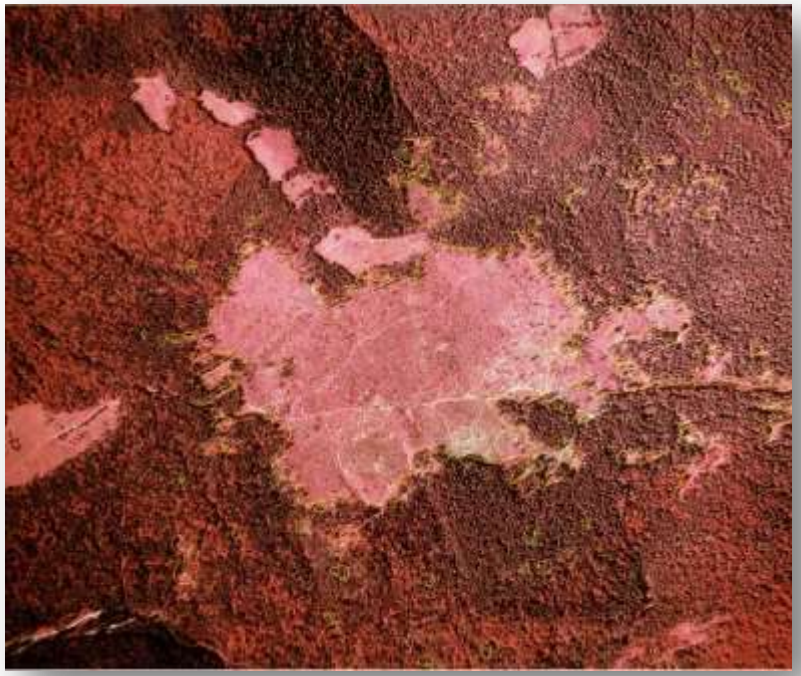
Vertical distribution of LULC classes

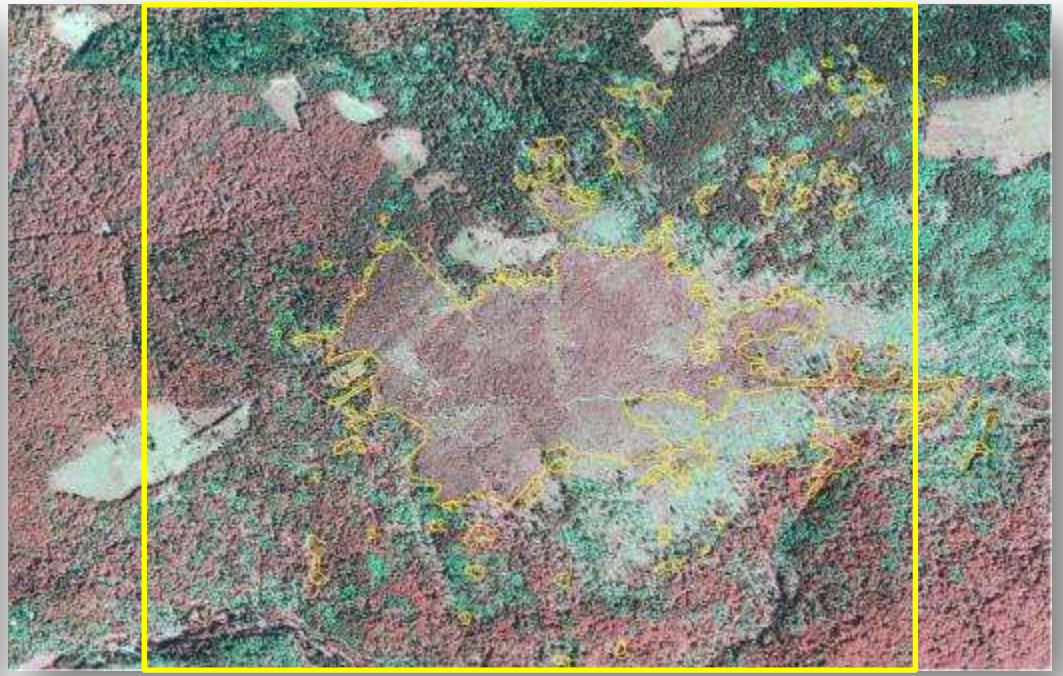


Results (8)

Forest cover changes: 1997-2011

Kudłon - test site



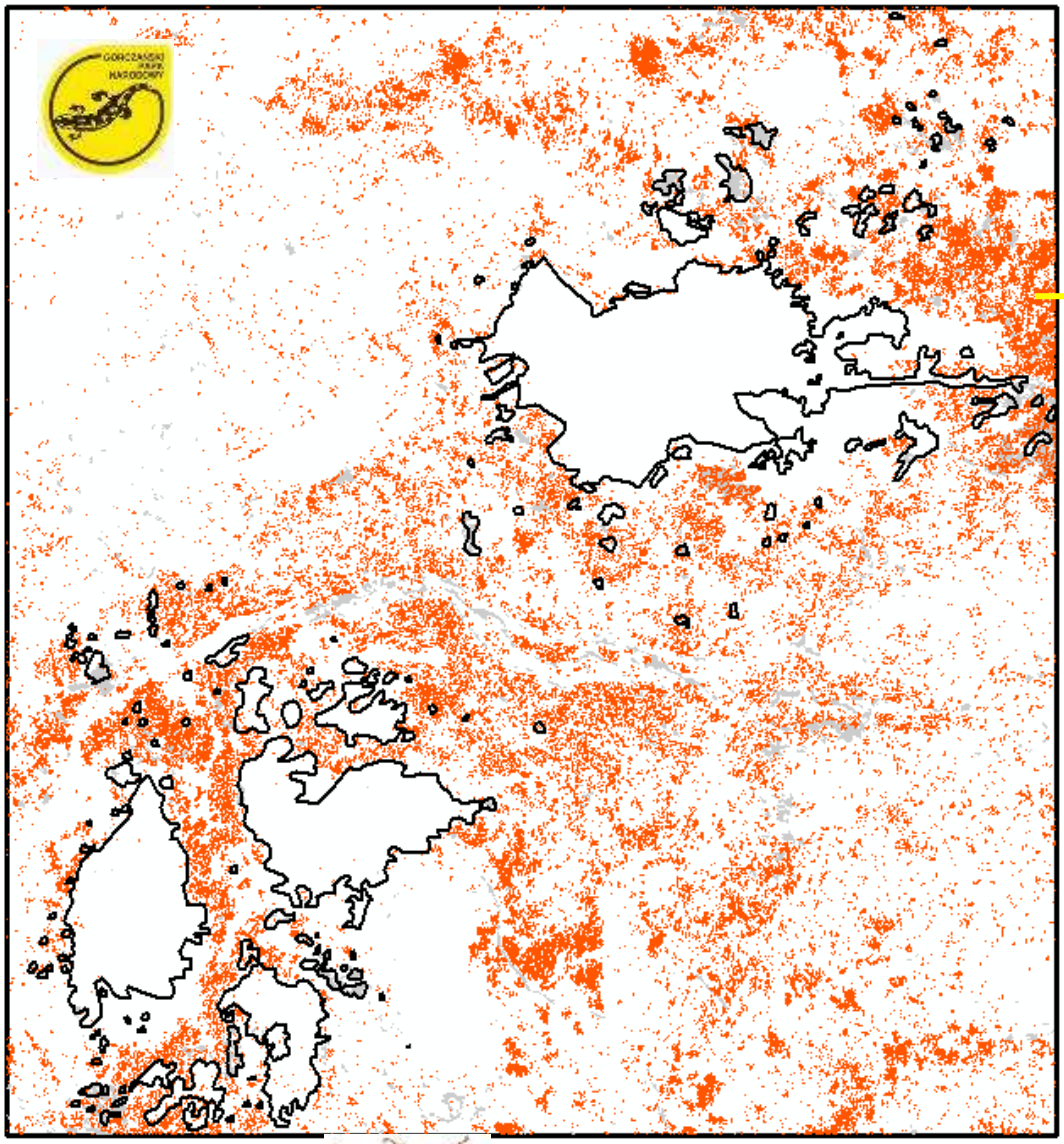


CIR aerial orthophoto from year 1997
yellow vector – 3D stereo-mapping (VSD)
114,11 ha of dead or destroyed Norway spruce stands (*Plagiothecio-Piceetum)*

CIR digital aerial orthophoto from 2009.
yellow vector – 3D mapping from 1997
158,39 ha ha od dead forest and gaps

Results (9)

Dead conifreous stands



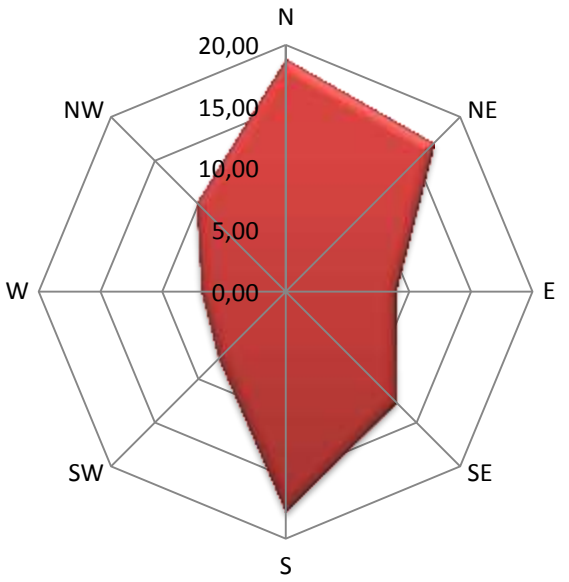
Changes on the „dead forest" class and gaps using GIS spatial analyses in the boundary box form 1997:

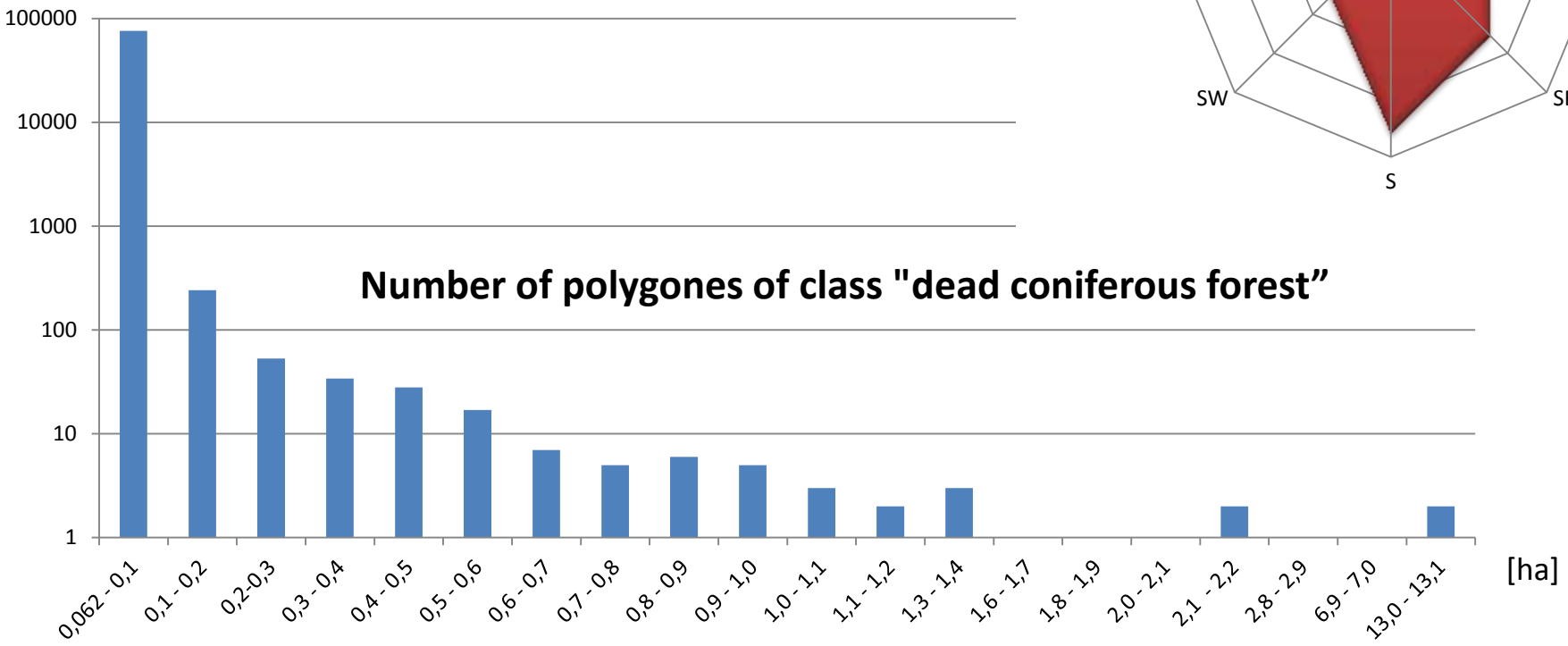
- Aug. 1997 = 114,05 ha
- Aug. 2009 = 158,39 ha

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

Results (10)

Dead Norway spruce stands





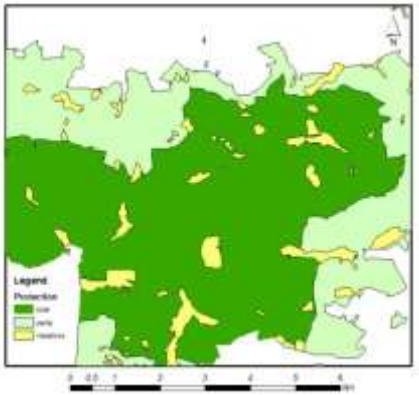
Results (11)

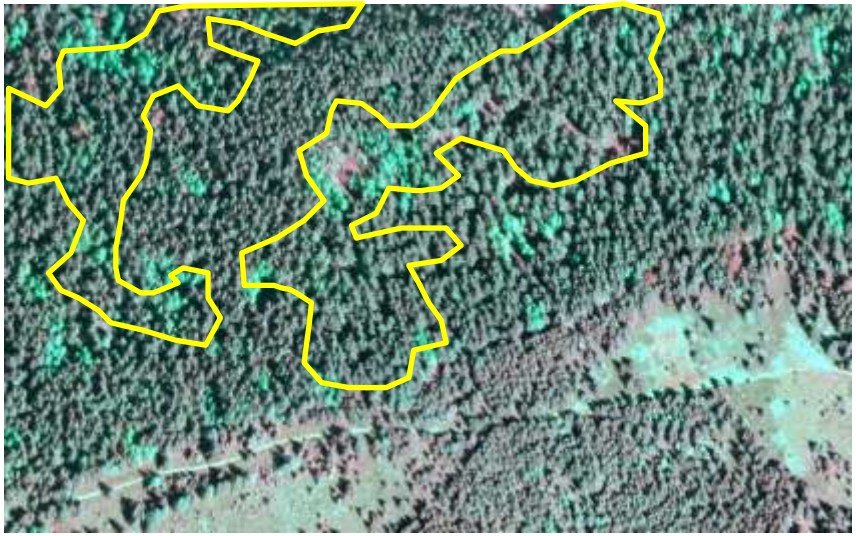
dead Norway spruce stands – vertical distribution

Results (12)

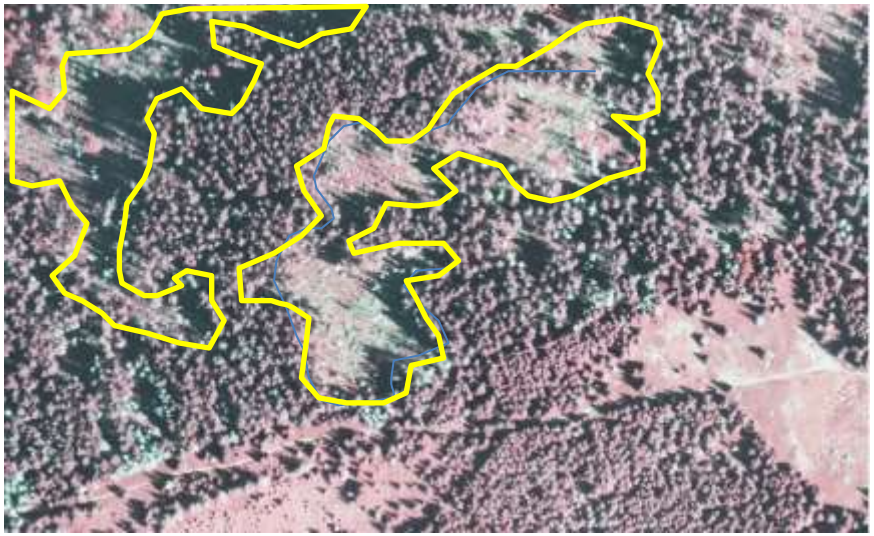
Protection: strict / partly

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)

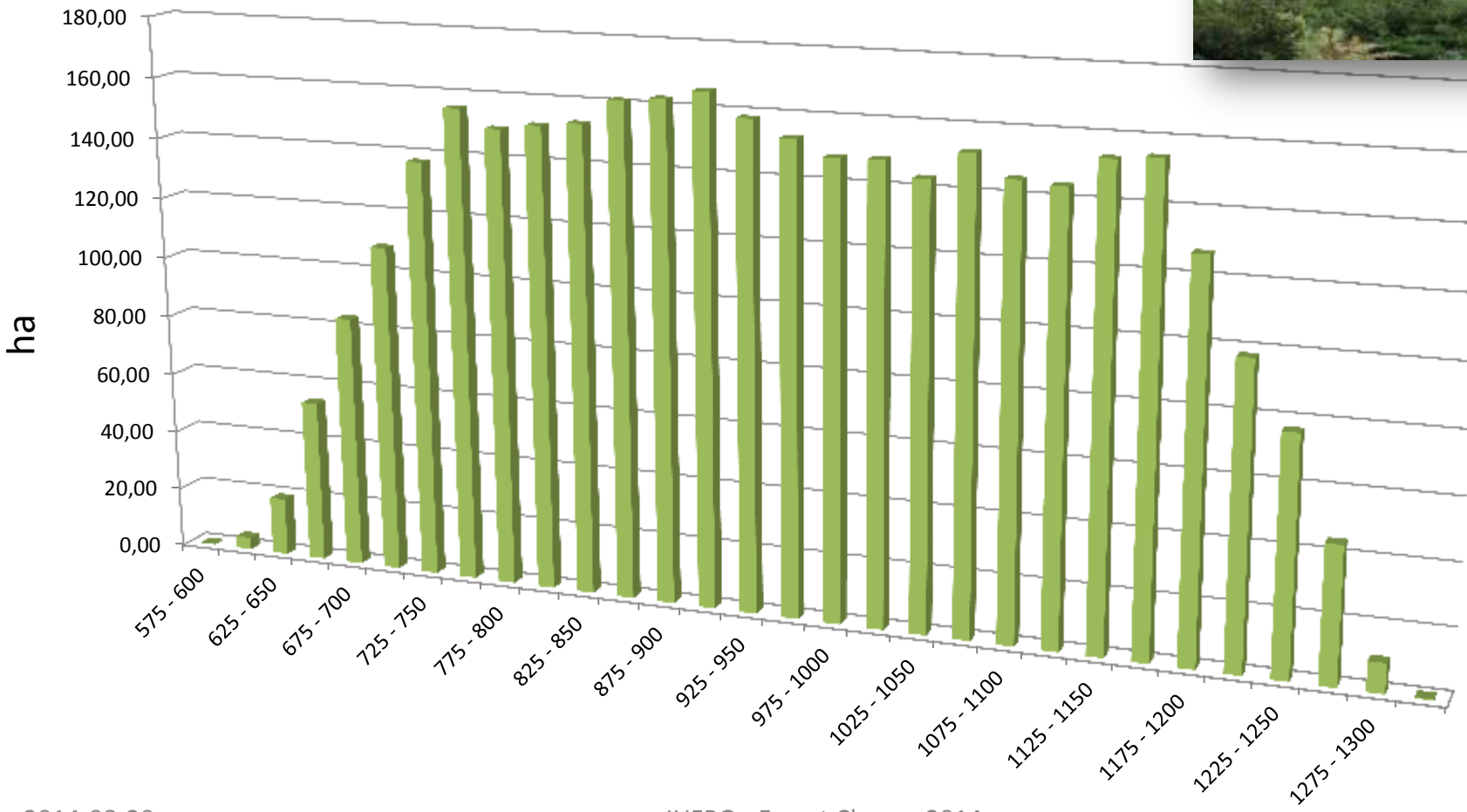
Results (13)
secondary forest succession

Results (14)

health Norway spruce stands

Test area inside Gorce N.P. = 2.227,18 ha

Test area outside Gorce N.P. = 1.102,22 ha



Conclusions (1)

- In the Gorce NP there 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 hectares of dead Norway spruce stands and 67,24 gaps - identified on CIR aerial orthophotos from 2009. The Norway spruce dieback occurs mainly as a result of abiotic factors (wind, drought) and bark beetle (Ips typographus) outbreaks.

- a high risk of further Norway spruce dieback in Gorce NP exist, becaouse of alive coniferous stands covering approx. 3.380,5 ha (almost half of the study area). Less threatened are forest stands lies on lower mountain belt. The European Beech (*Fagus silvatica*) begins to be dominat tree species in Gorce NP

- In areas where 10-15 years, the dead or dying trees were not removed from the forest ecosystem, there is observed now the dynamic process of natural forest regeneration. Young trees are protected from deer damages by thicket and mazes created by dead and broken trees, roots system and branches. Left dead wood positively influence on soil reachnes and microclimate conditions.

Conclusions (2)

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

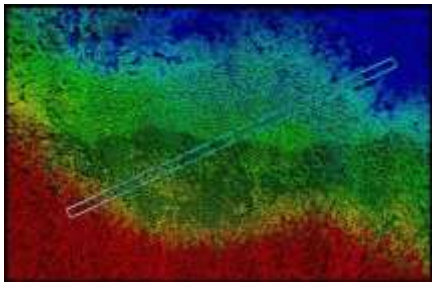
- Usage of the nDSM derived using Semi Global Matching algorithm (RSG software; Remote Sensing Graz; Joanneum Research Graz) enabled reliable and accurate classification of different LULC classes a specially different forest regeneration stages.

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

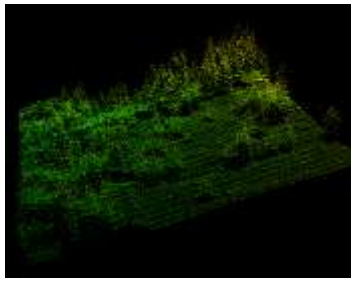
- digital elevation models (like CHM, nDSM) and other derivates maps (e.g. density, 95 percentile etc) based on ALS point clouds, will significantly improve classification accuracy of GEOBIA approach.

Thanks for your the attention !!!

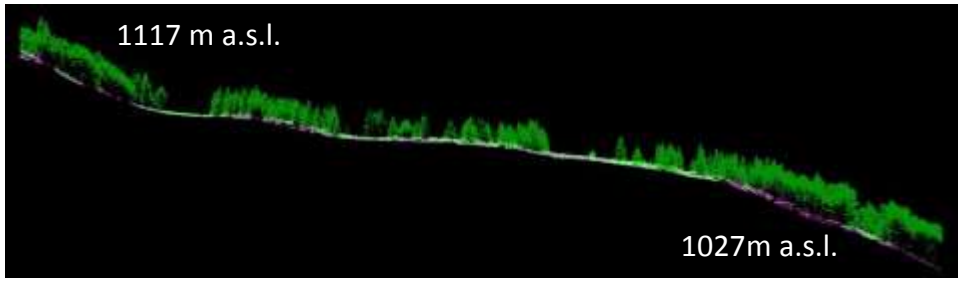
ALS (1)
Point cloud and derivatives



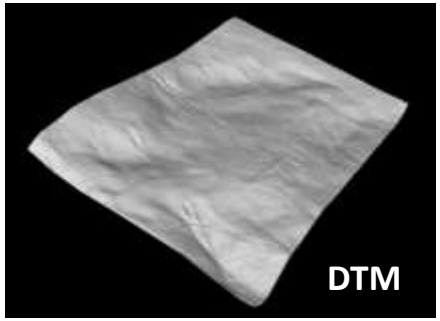
ALS

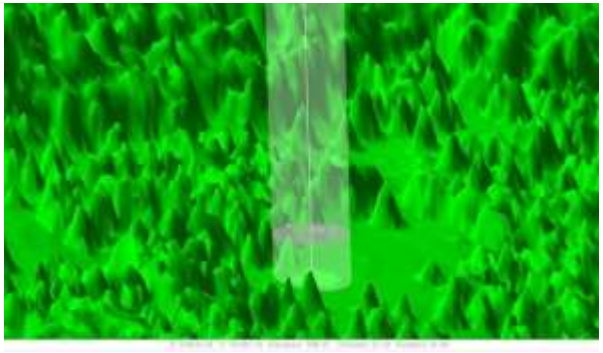


ALS 2.5D

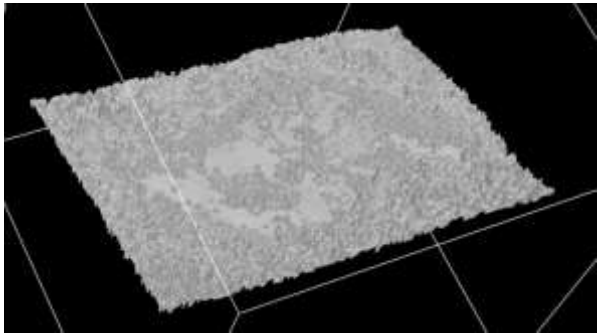


ALS profile





DSM (FUSION)



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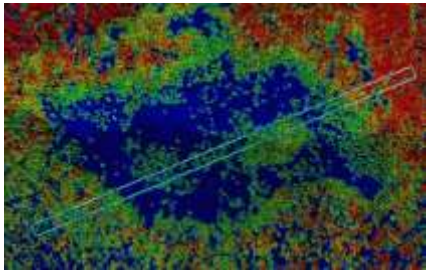


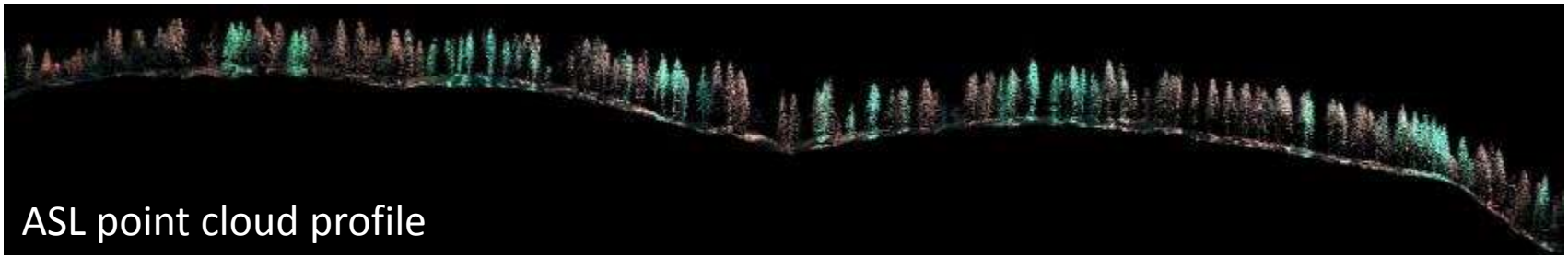
normalised ALS

0 m a.s.l.

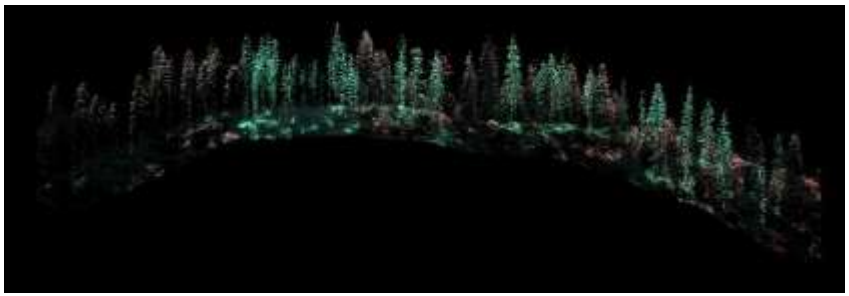
nALS profile

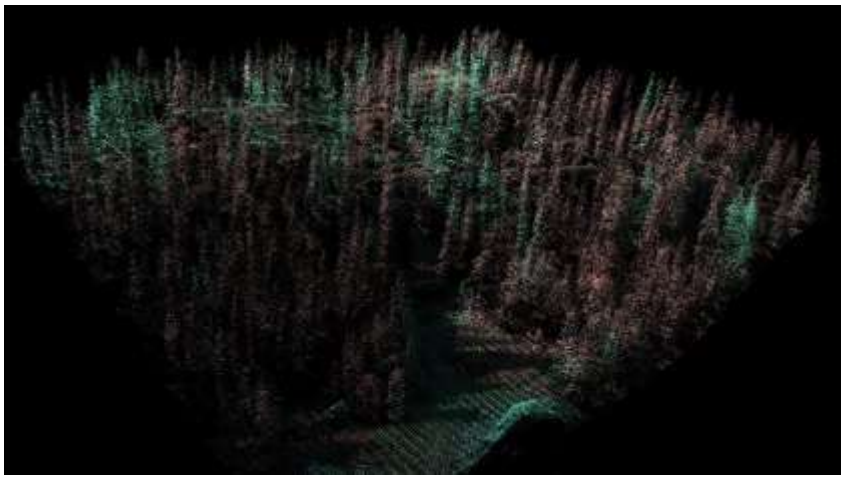
What next - ALS

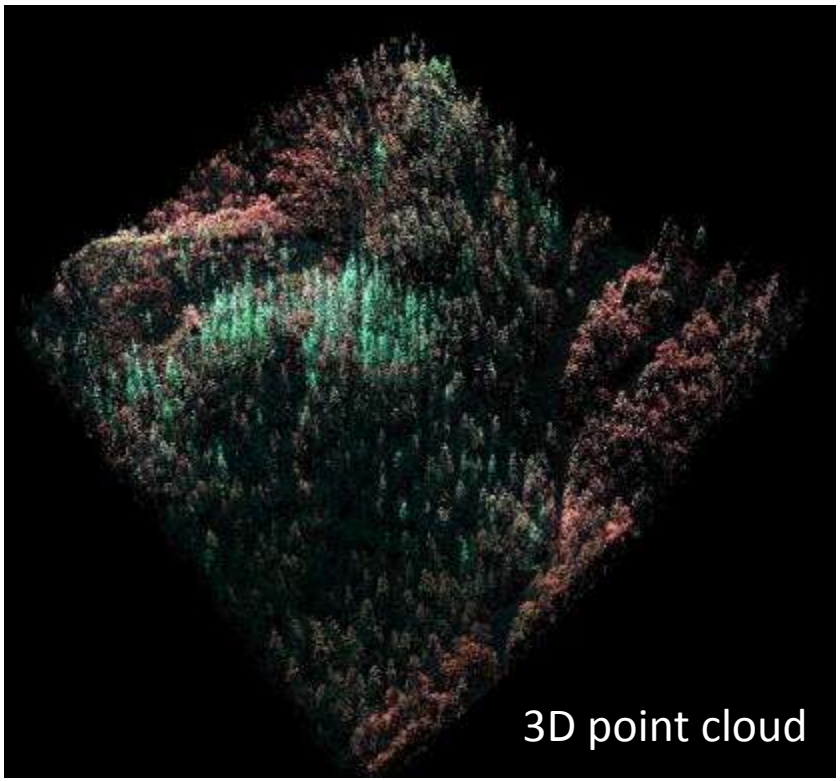
Profiles. Color points RGB (CIR)



ASL point cloud profile







3D point cloud

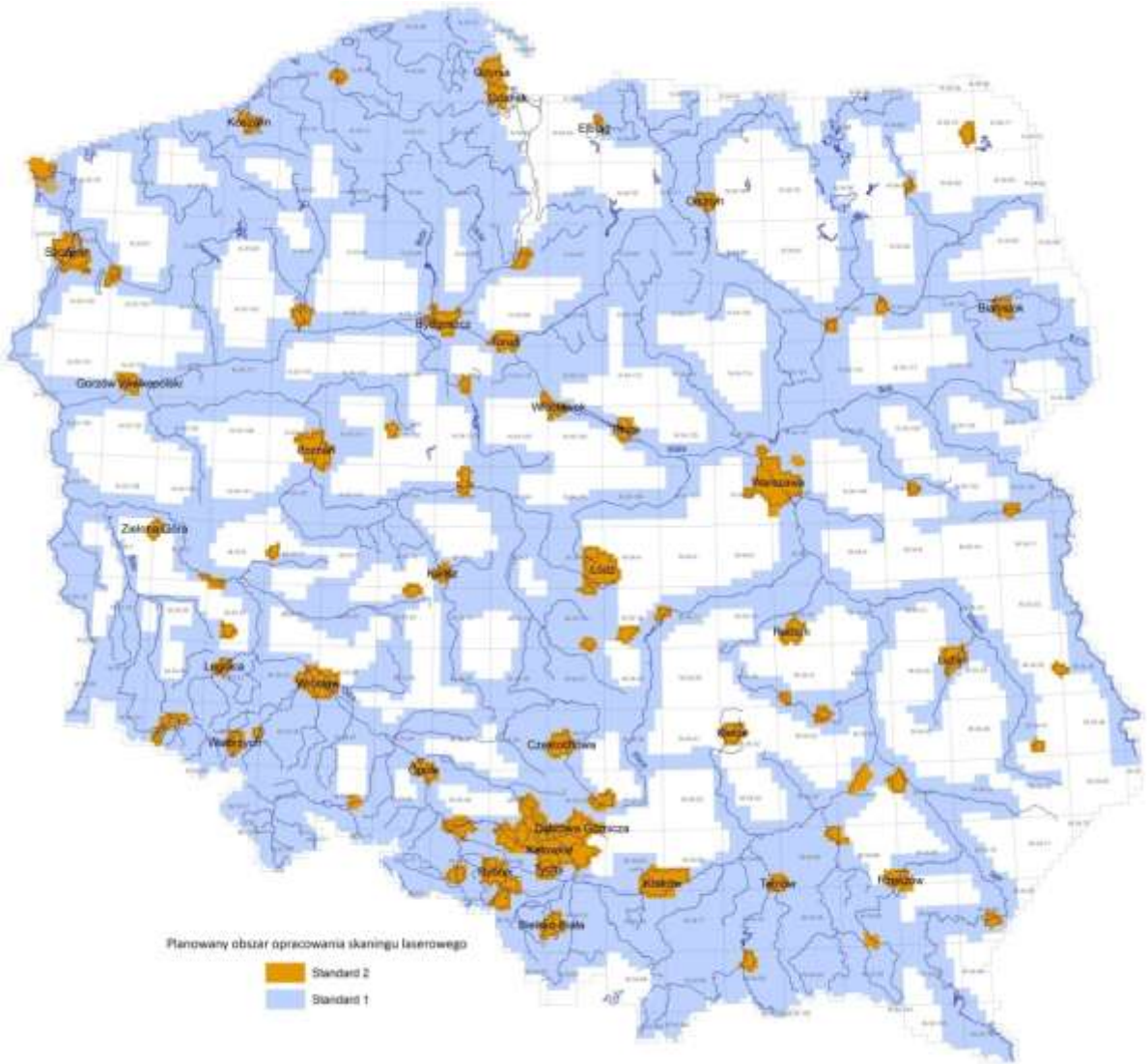
ISOK Project 2011-2013

HEAD OFFICE OF GEODESY AND CARTOGRAPHY

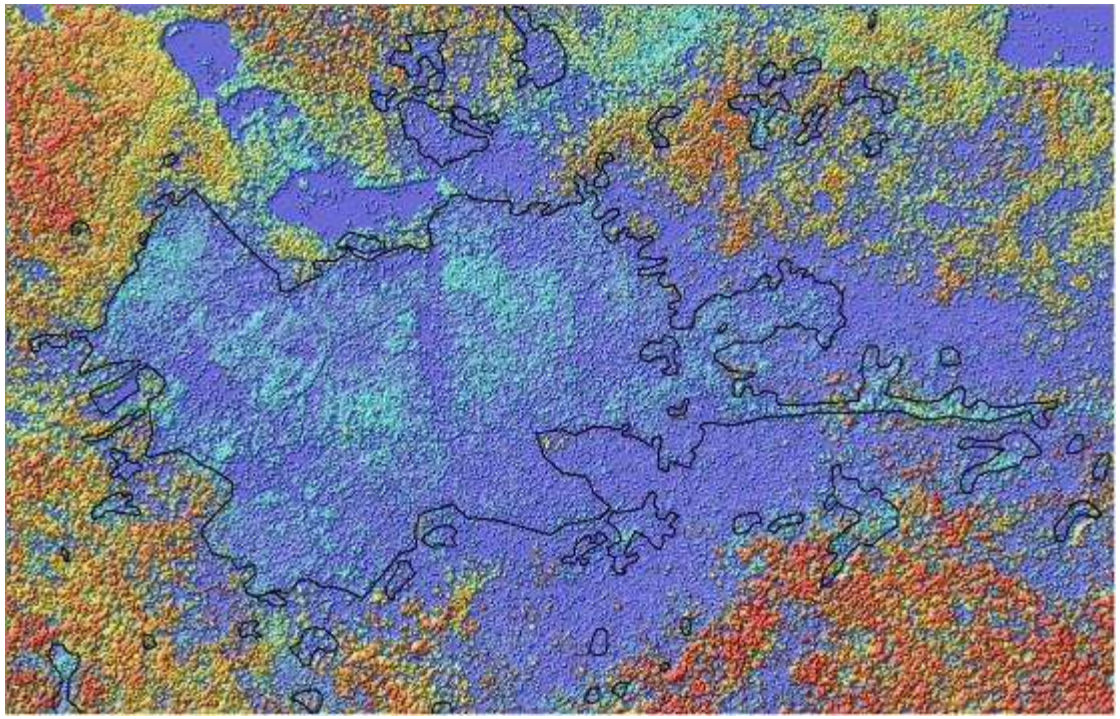
S I 4p/m² 177 000 km²

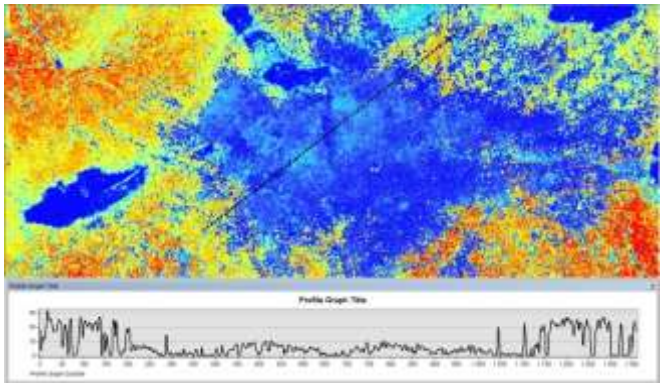
S II 12p/m² **14 000 km²**

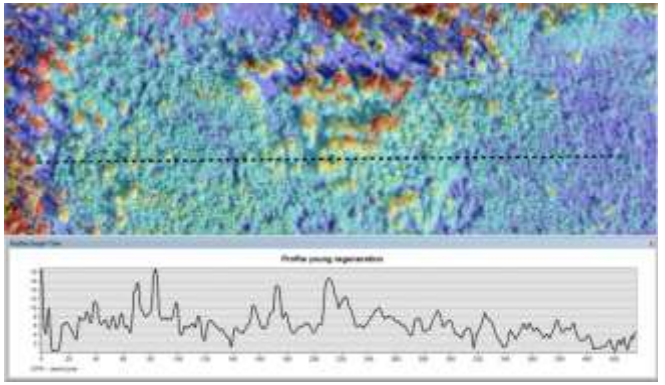
Total area: 191 000 km²
in 26 months

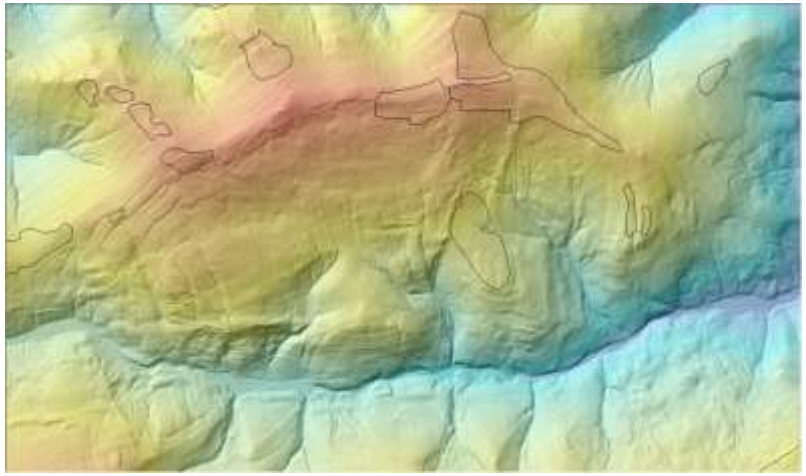


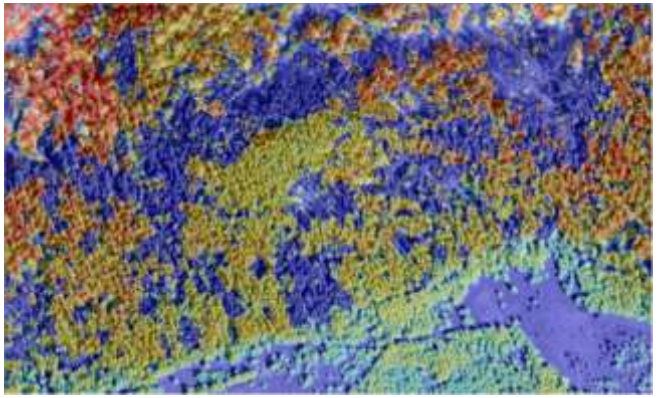
ISOK Project 2013 – just got it!





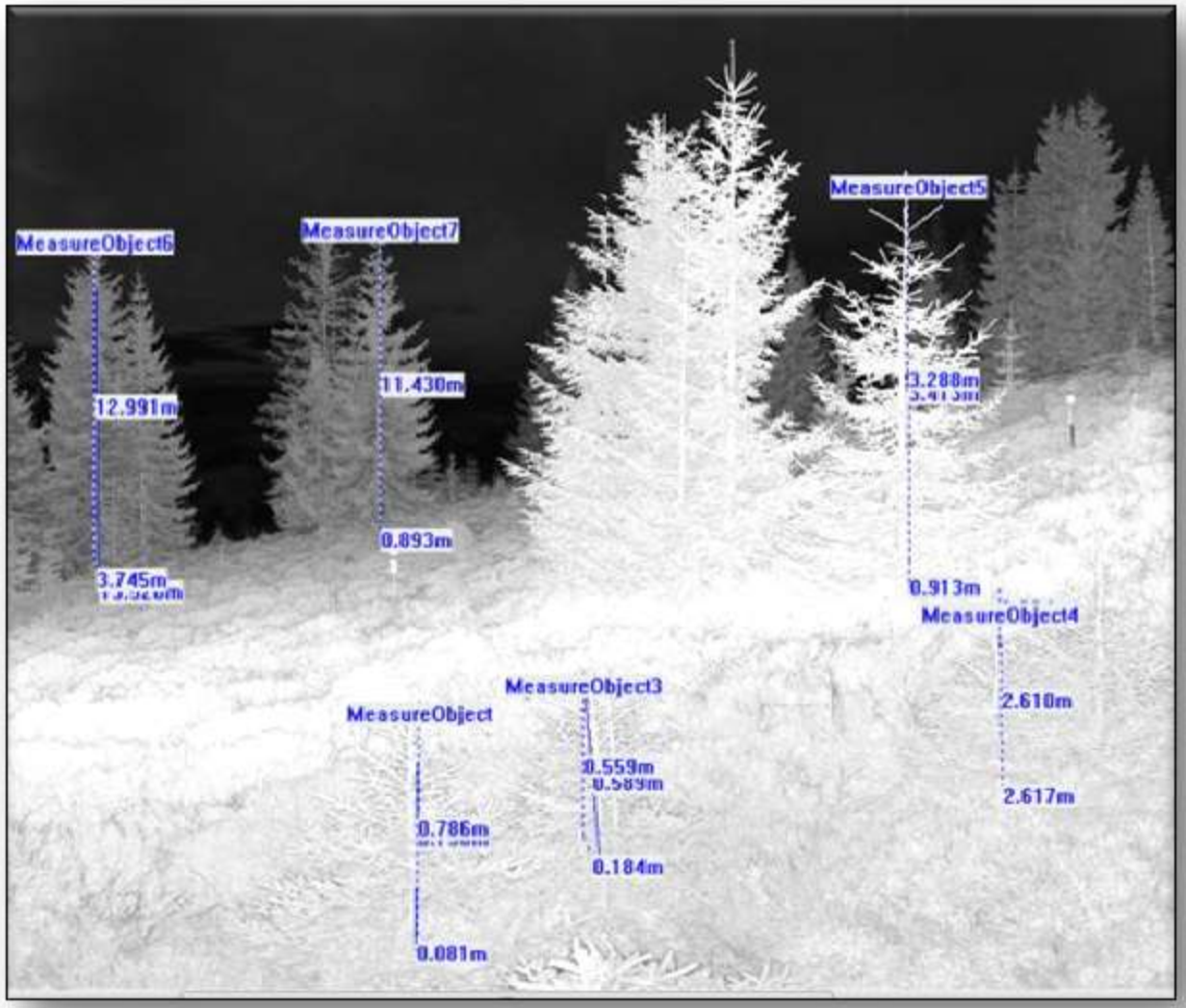






Outlook - TLS monitoring of the secondary forest succession

Outlook - TLS monitoring of the secondary forest succession



TLS inventory of „bark beetle nest”