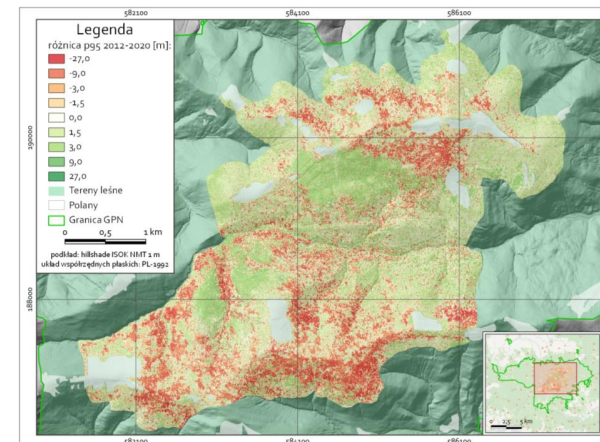
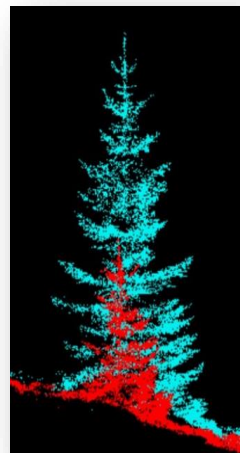
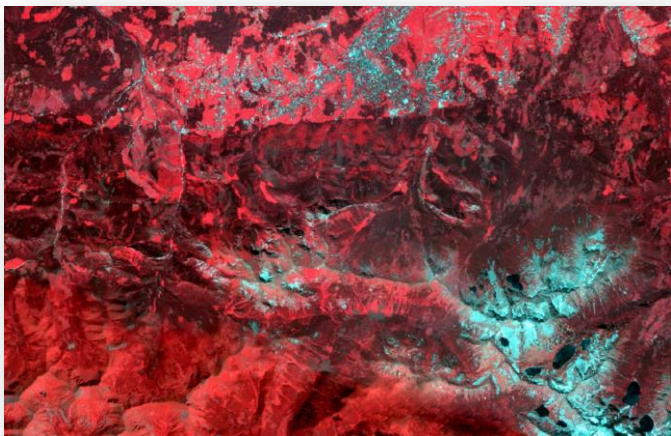




# Wykorzystanie teledetekcji w analizach od 2D do 4D obszarów chronionych



**Piotr Węzyk prof. URK, Wojciech Krawczyk, dr Karolina Zięba-Kulawik, Marta Szostak  
prof. URK, dr Paweł Hawryło, Krzysztof Baś, Piotr Rysiak, Jakub Mischyszyn i in.**

**Katedra Zarządzania Zasobami Leśnymi, Wydział Leśny  
Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie**



***Teledetekcja i GIS w zarządzaniu obszarami chronionymi***





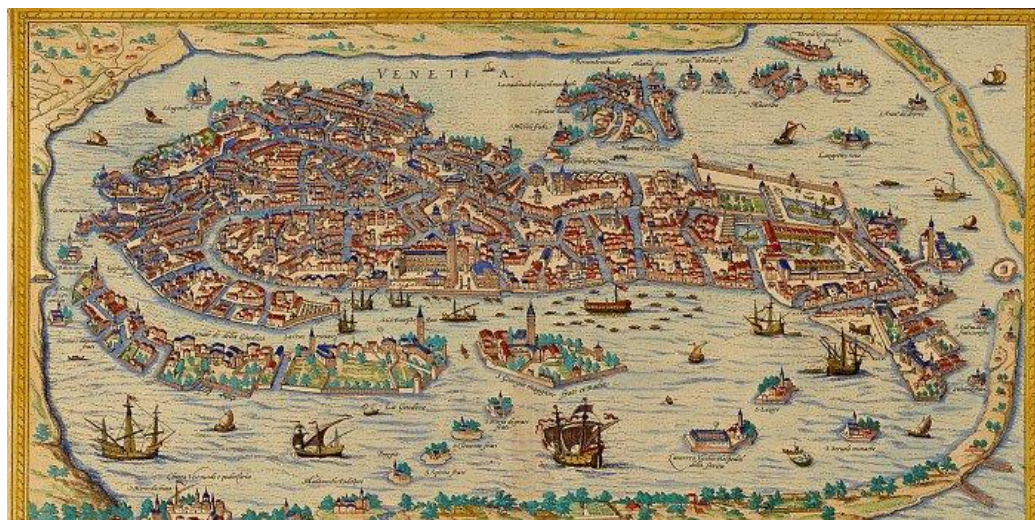
# Historia pomiarów i analiz 2D – 2.5D – 3D – 4D



Mapy archiwalne 2D – 2.5D



Mapa topograficzna 2D + pikiety



Mapy archiwalne 2.5D – Wenecja 1588 r.

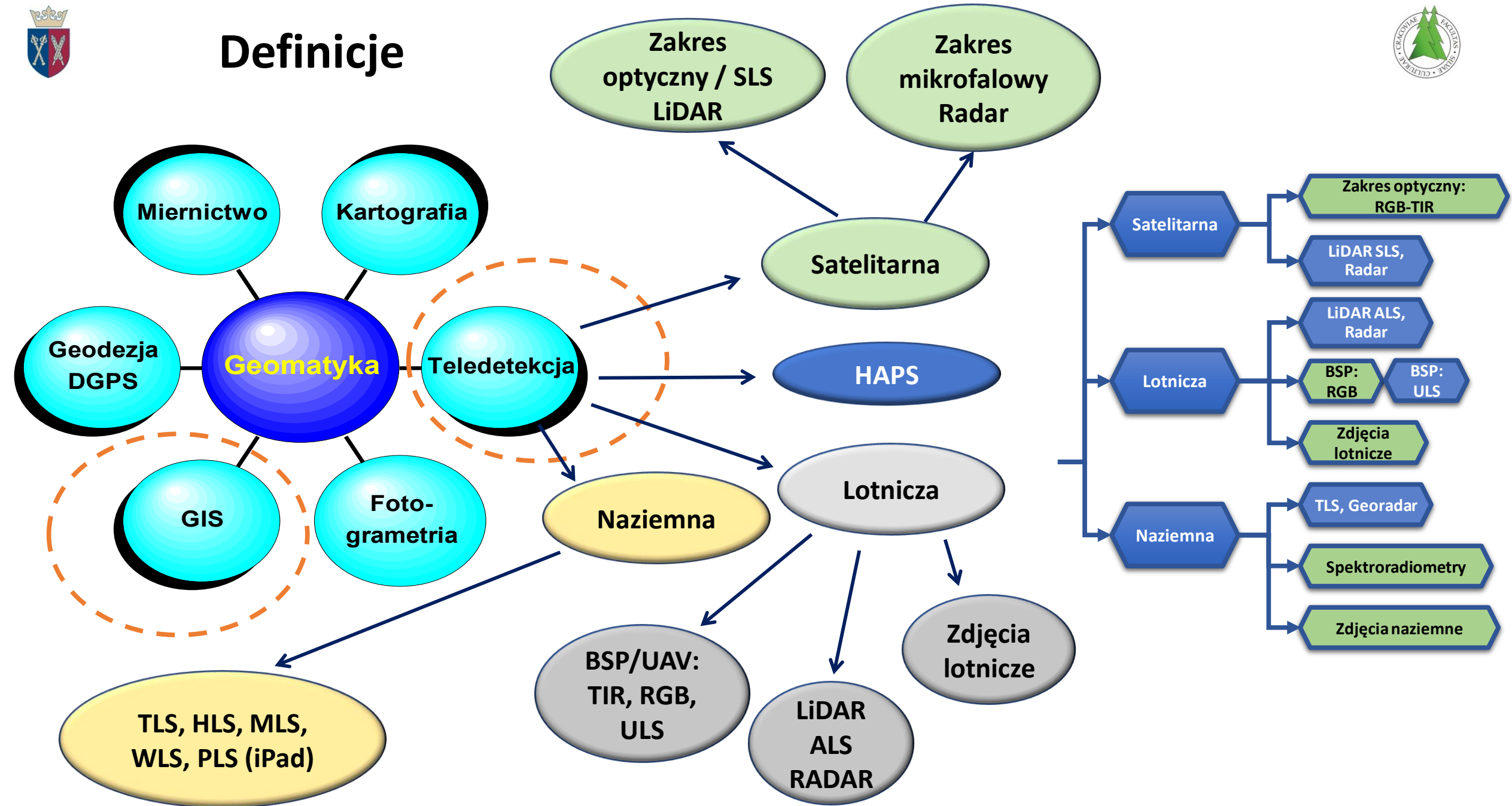


Ortofotomapy lotnicze 2D





# Definicje



# Historia pomiarów z platform „lotniczych”



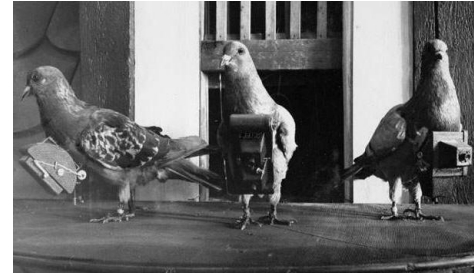
latawce



balony



Zeppelin



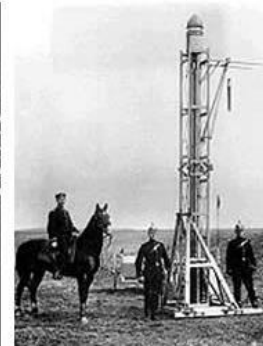
gołębce zwiadowcze



HAPS AIRBUS



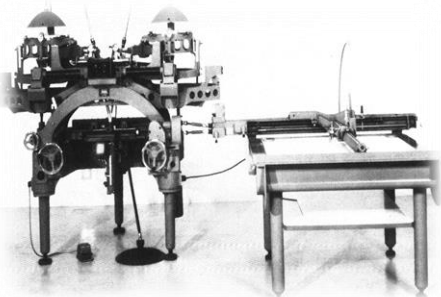
rakiety



zdjęcia lotnicze prawie pionowe



HAPS Zephyr



autografy



samoloty



satelity



BSP



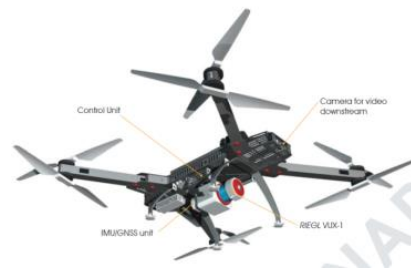
BSP (UAV)



# Typy technologii pomiarowych LiDAR 3D - 4D

## Platformy LiDAR (Light Detection And Ranging)

- **SLS** – Satellite Laser Scanning;
- **ALS** - Airborne Laser Scanning;
- **ALH** – Airborne Laser Hydrography;
- **ULS** – Unmanned Laser Scanning;
- **TLS** - Terrestrial Laser Scanning or Ground Based Scanning;
  - **MLS** - Mobile Laser Scanning;
  - **ILS** - Industrial Laser Scanning;
  - **HLS** – Hand-held Laser Scanning (HMLS; PLS);
  - **WLS** – Wearable Laser Scanning (backpack's).



source:RIEGL



Source: FARO



photo. P. Wężyk

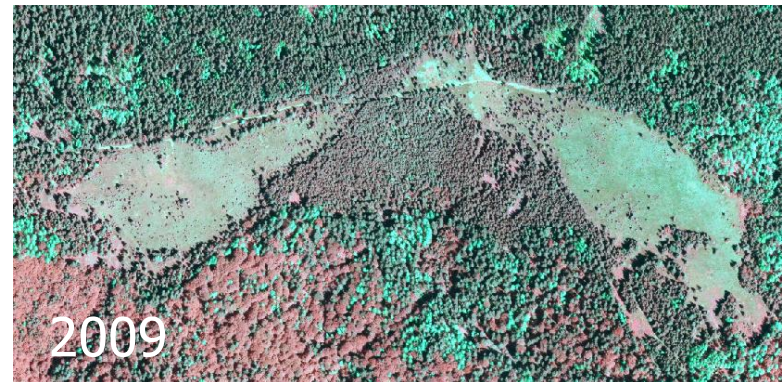
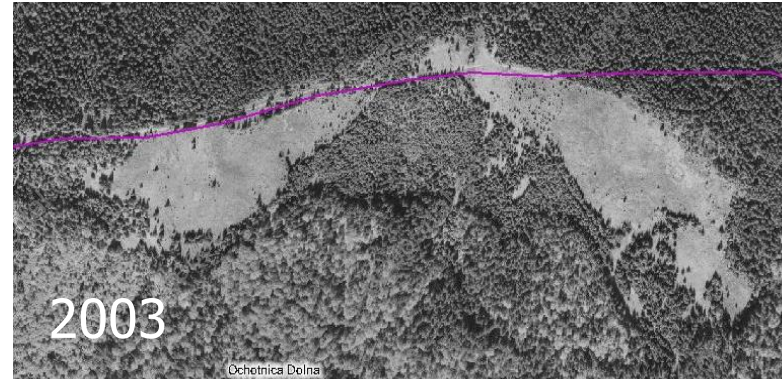


photo. P. Wężyk





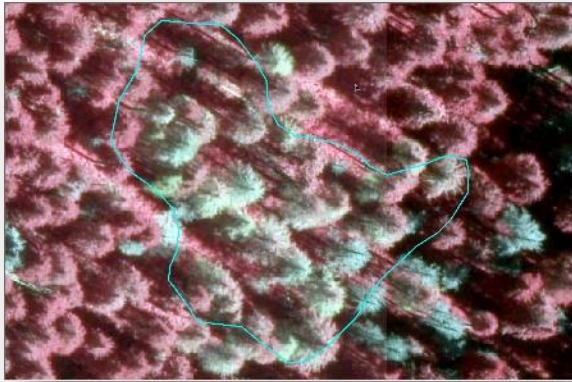
# Fotogrametria 2D - 3D. Archiwalne zdjęcia



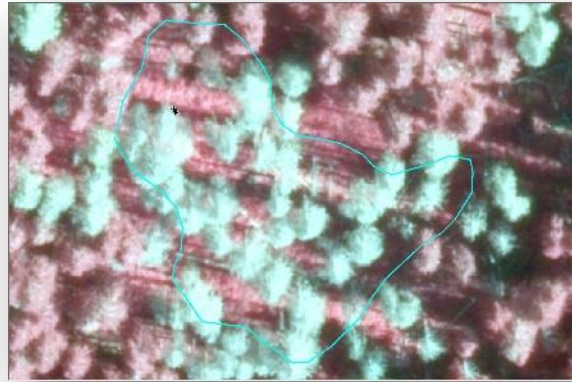


# Fotogrametria cyfrowa – ortofotomapy 2D

## CIR aerial orthophotos GSD 10 cm (Sept. 04, 2019)

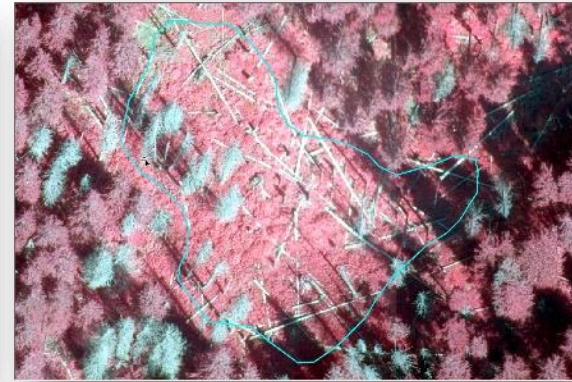


2012

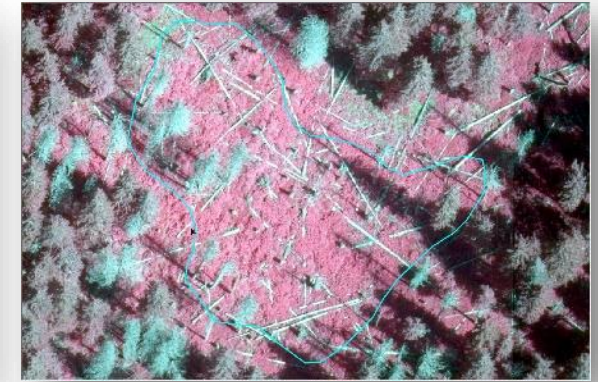


2014

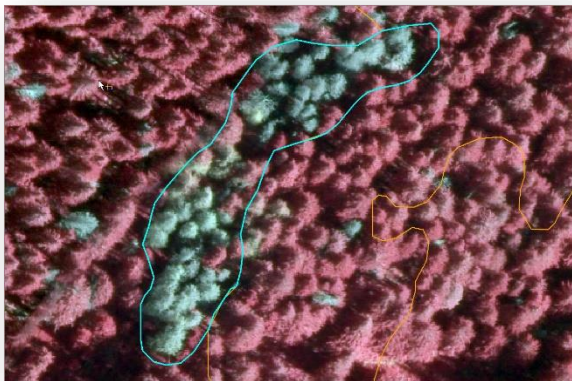
Test site 2



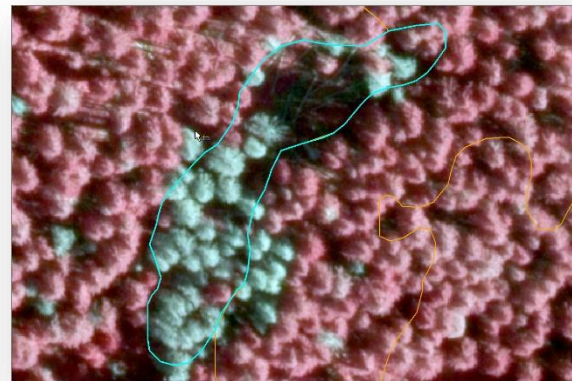
2019



2020

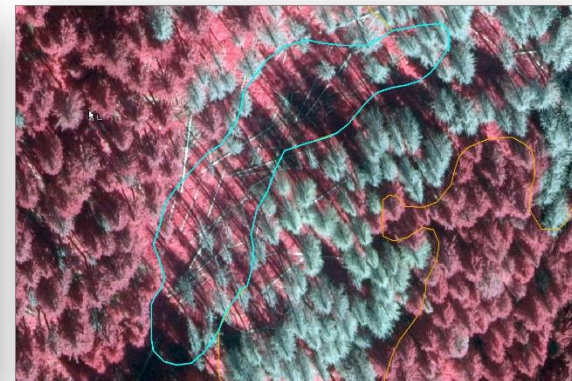


2012

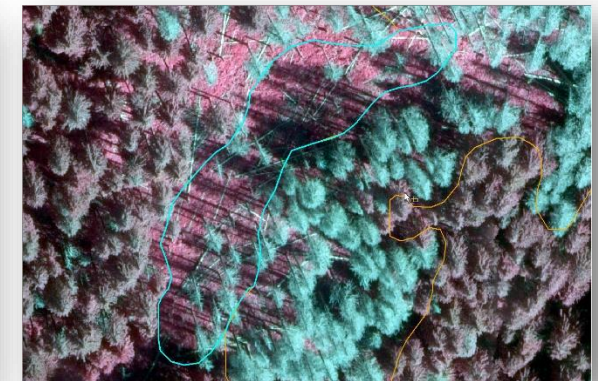


2014

Test site 5



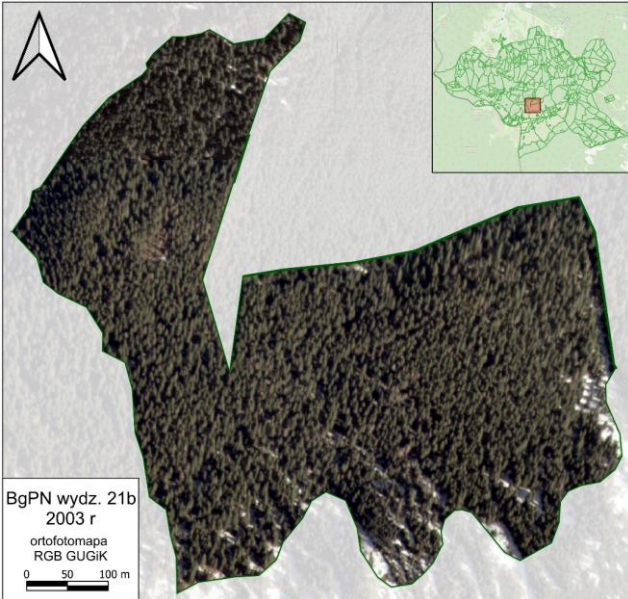
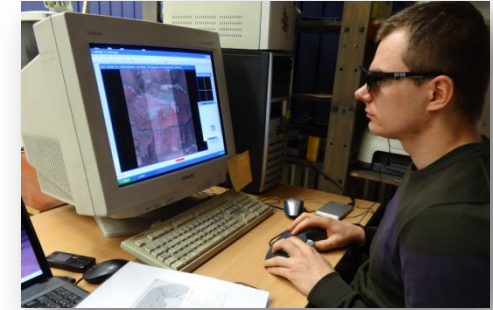
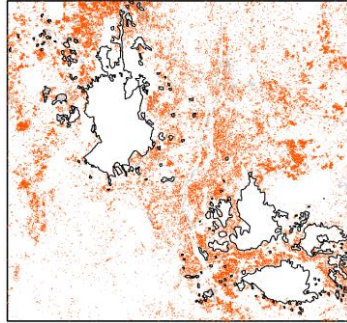
2019



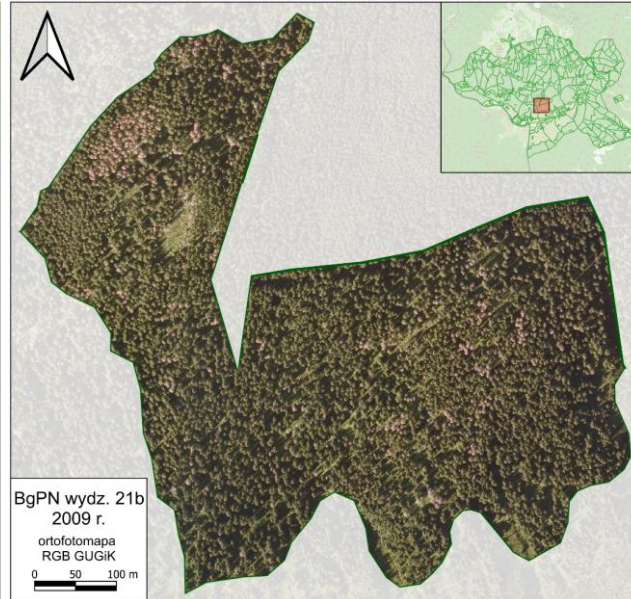
2020



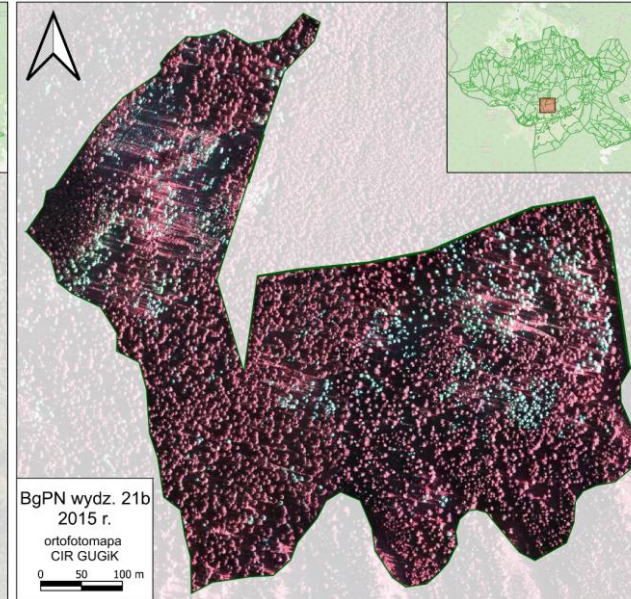
# Fotogrametria – Ortofotomapy 2D Babiogórski Park Narodowy



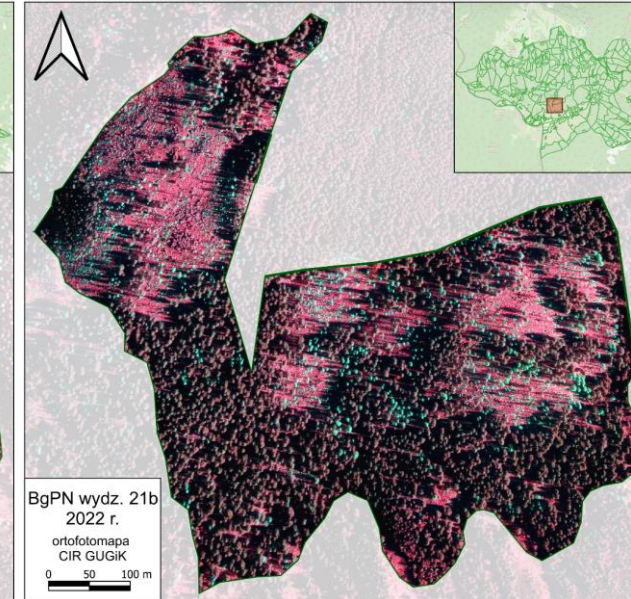
2003



2009



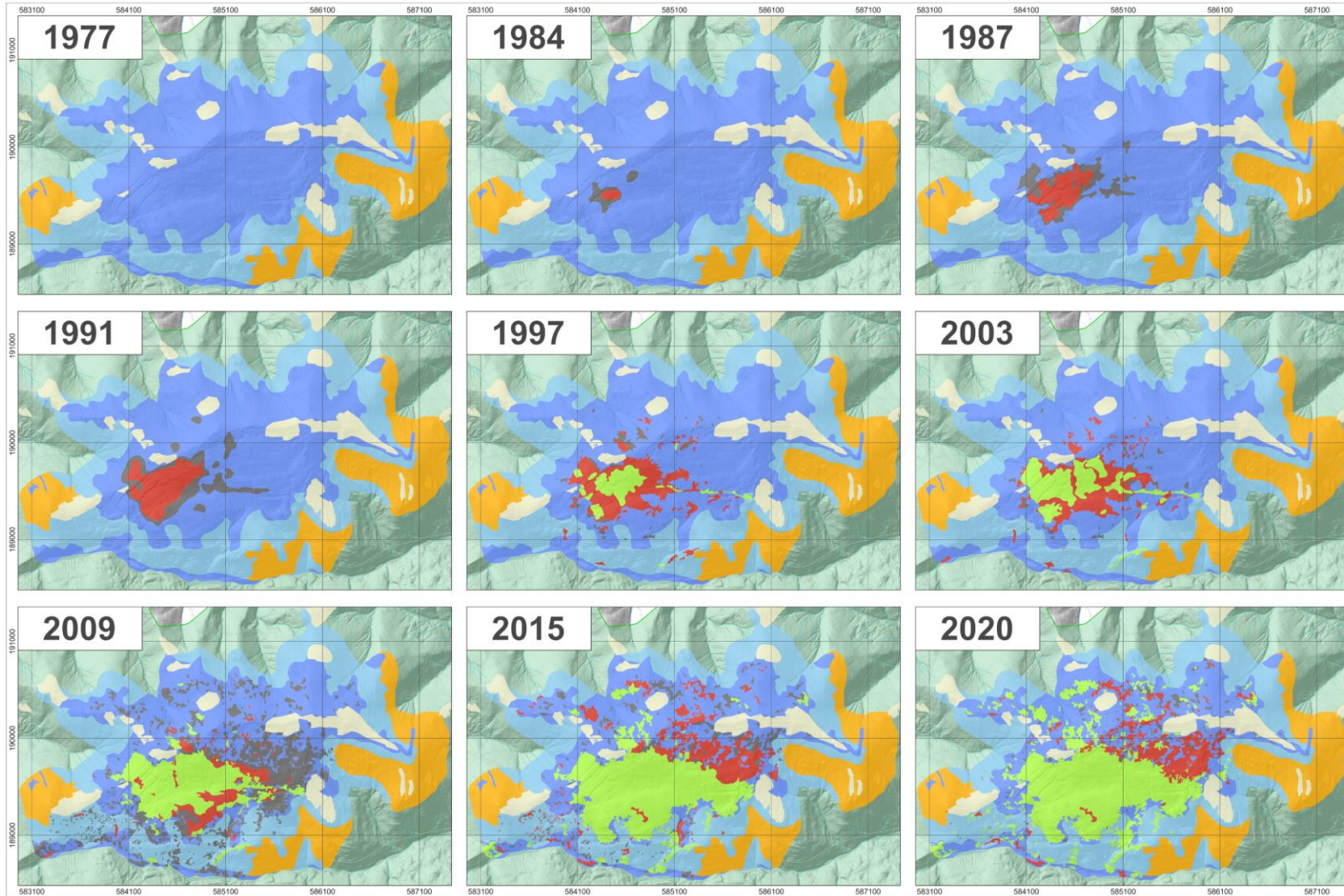
2015



2022

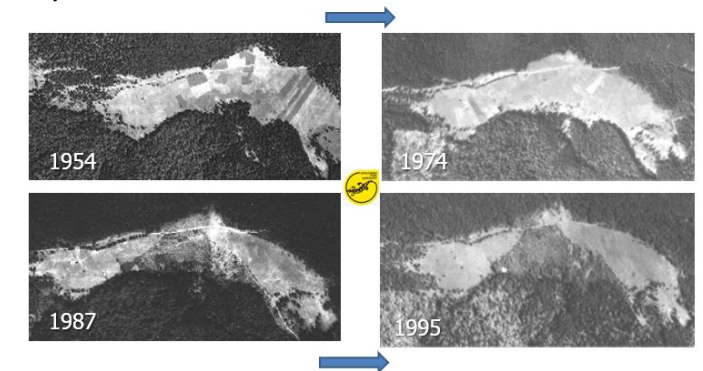


# Monitoring teledetekcyjny drzewostanów Gorczańskiego PN



Year of Acquisition	Spectral Composition	Ground Sampling Distance [m]	Source
1977	B&W	0.50	GNP archive *
1987	B&W	0.75	GNP archive *
1997	CIR	0.25	GNP archive *
2003	B&W	0.25	GUGiK
2009	RGB	0.25	GUGiK
2015	RGB and CIR	0.25	GUGiK
2020	RGB and CIR	0.05	GNP archive

Satellite data (NASA): Landsat-4 on 04.05.1984 (MSS instrument, 4 spectral bands, CIR composition; 60.0 m GSD) and Landsat-5 on 05.09.1991 (TM instrument, 7 spectral bands, CIR composition, 30.0 m GSD).





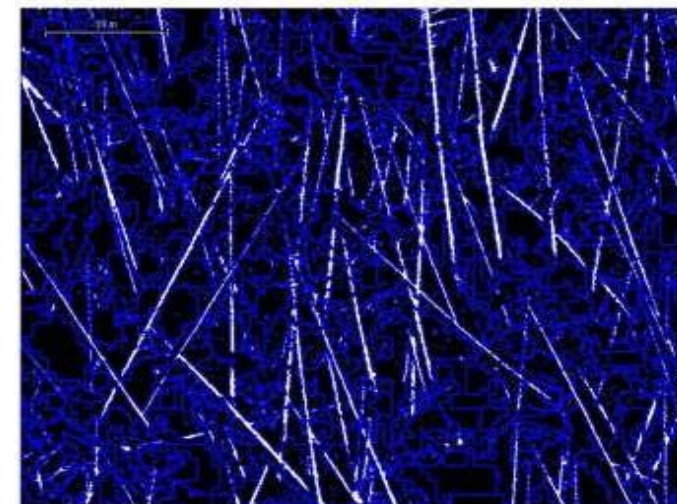
# Fotogrametria cyfrowa 2D > 3D. Matching & GEOBIA



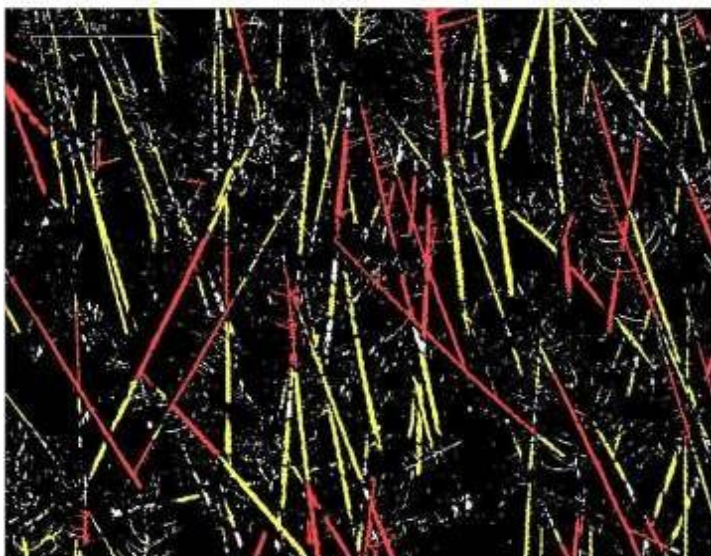
RGB digital aerial photo



Image enhancement



Segmentation stage

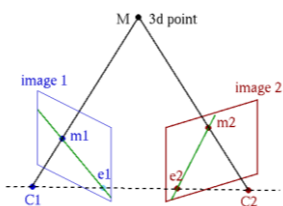
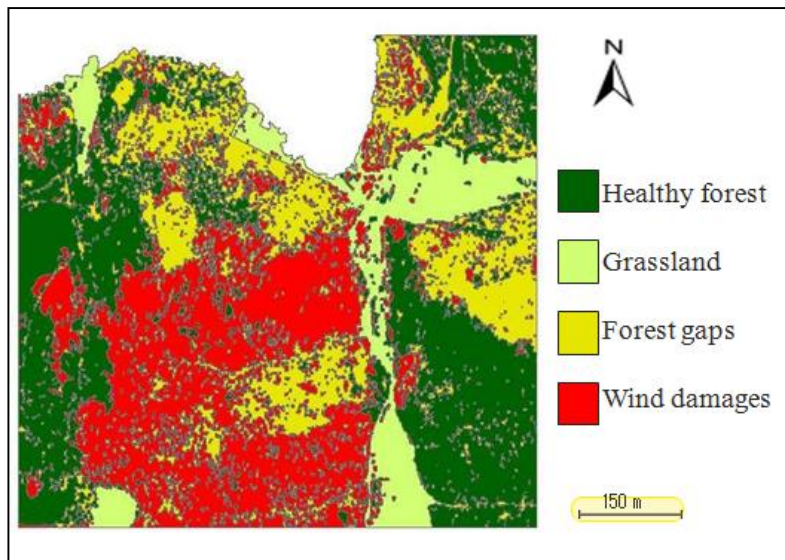


Classification



Vectorized stems

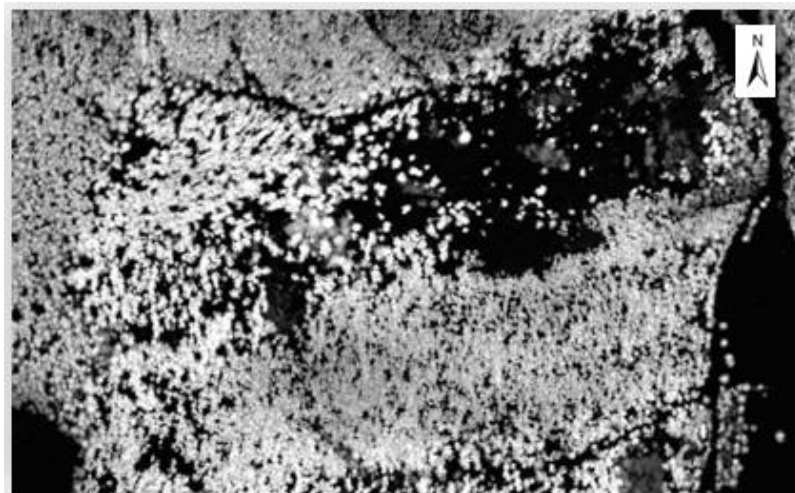
# Fotogrametria cyfrowa. Matching + GEOBIA



Land Cover map of Kościeliska Valley based on nDSM classification

Aspect	Detected logs (n)	Mean wind azimuth (°)
N	1 569	1,0
NE	4 196	-2,4
E	7 239	2,6
SE	2 320	-1,7
S	302	-8,5
SW	107	-6,5
W	205	-16,1
NW	253	0,7

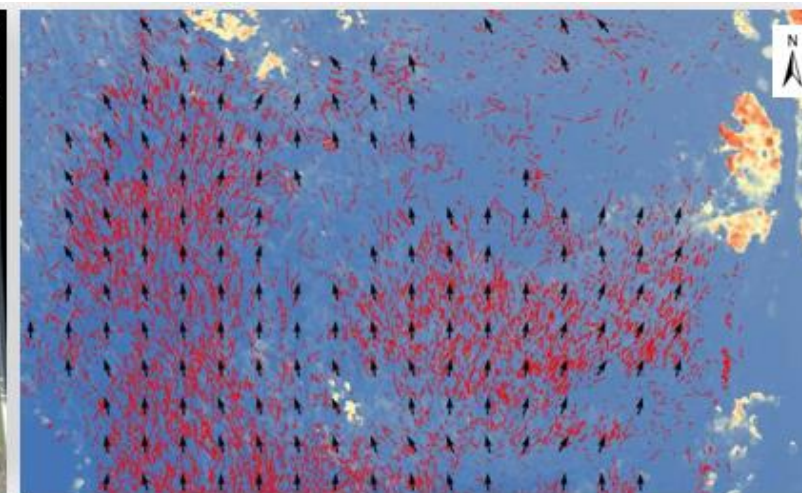
\*0 (North) / 90 (East) / -90 (West)



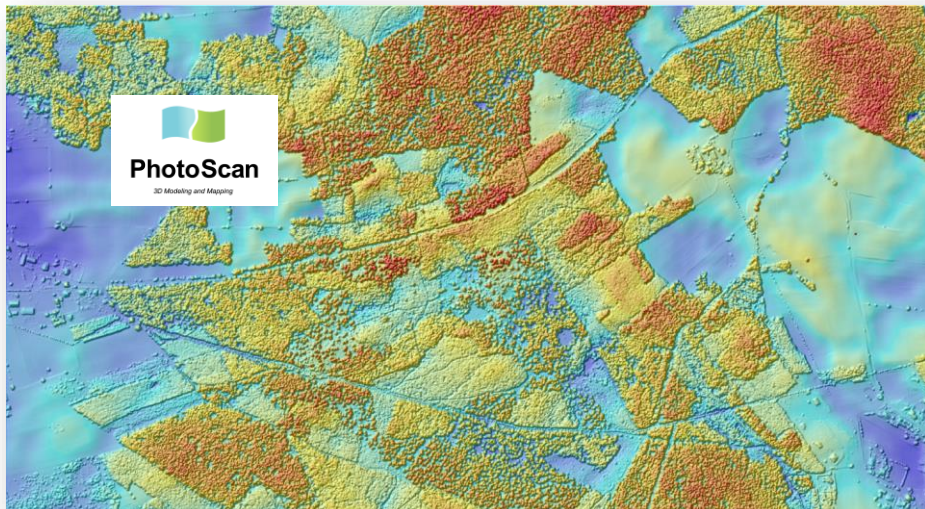
nDSM from ALS data (2012)



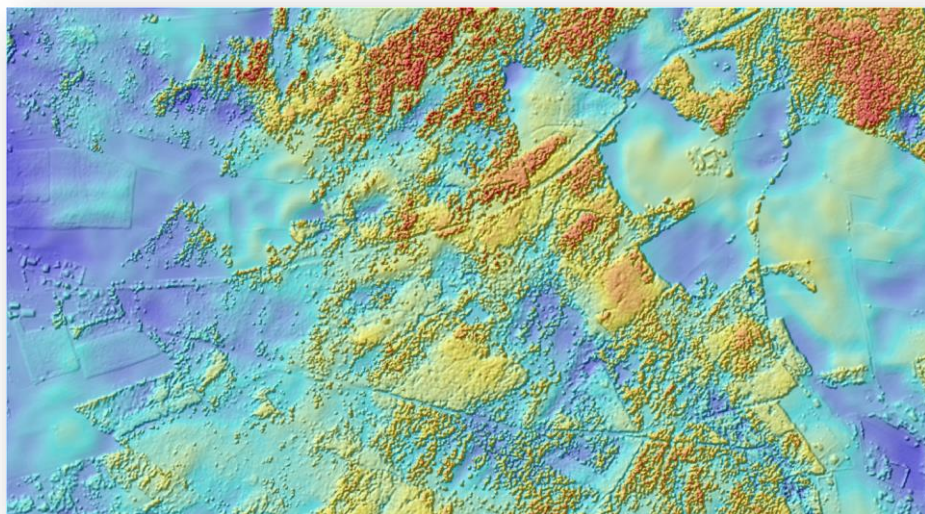
Orthophoto (GSD 7cm) generated using DSM from stereo-matching (2014)



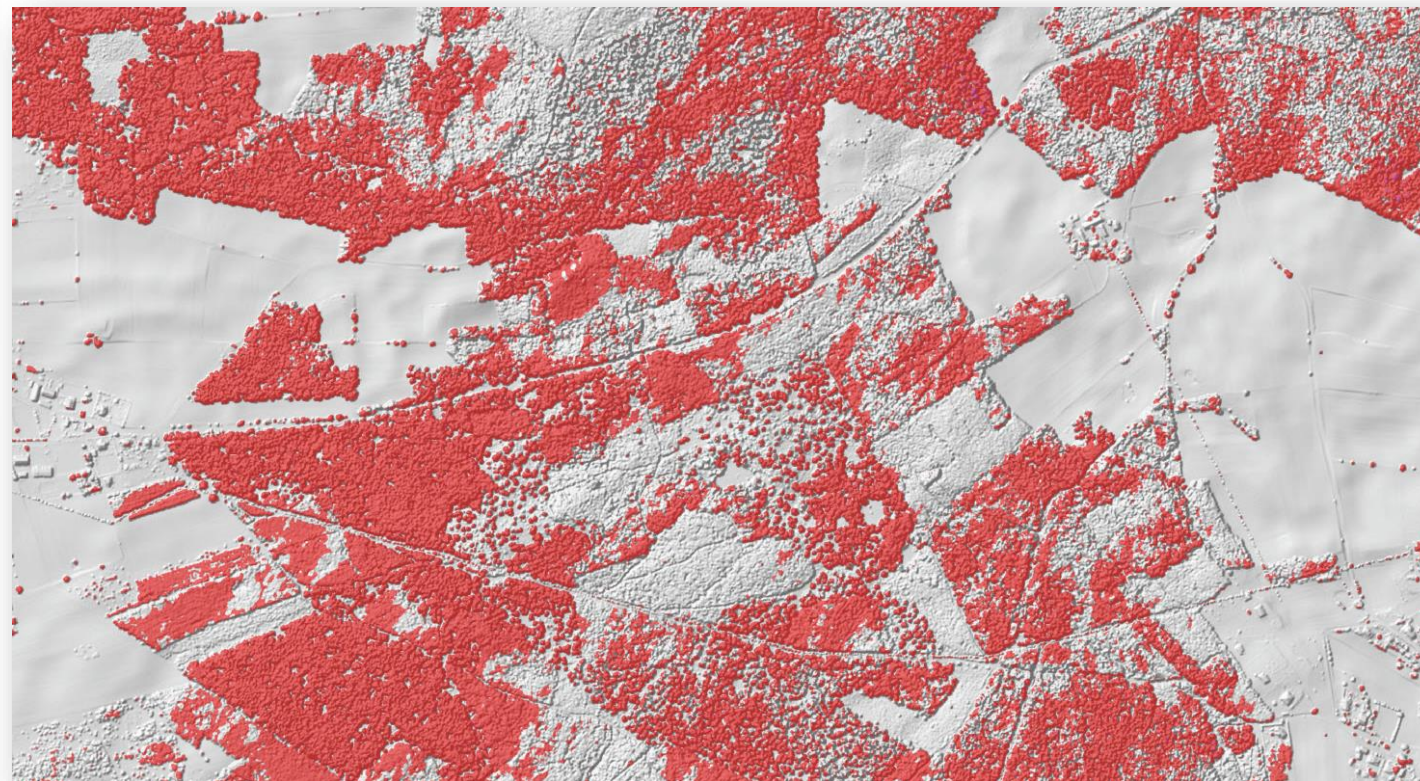
nDSM\_2014 based on stereo-matching detected stems ↑ mean direction of stems



**zNMPT - LiDAR ALS 2012**



**zNMPT - IPC 2017**



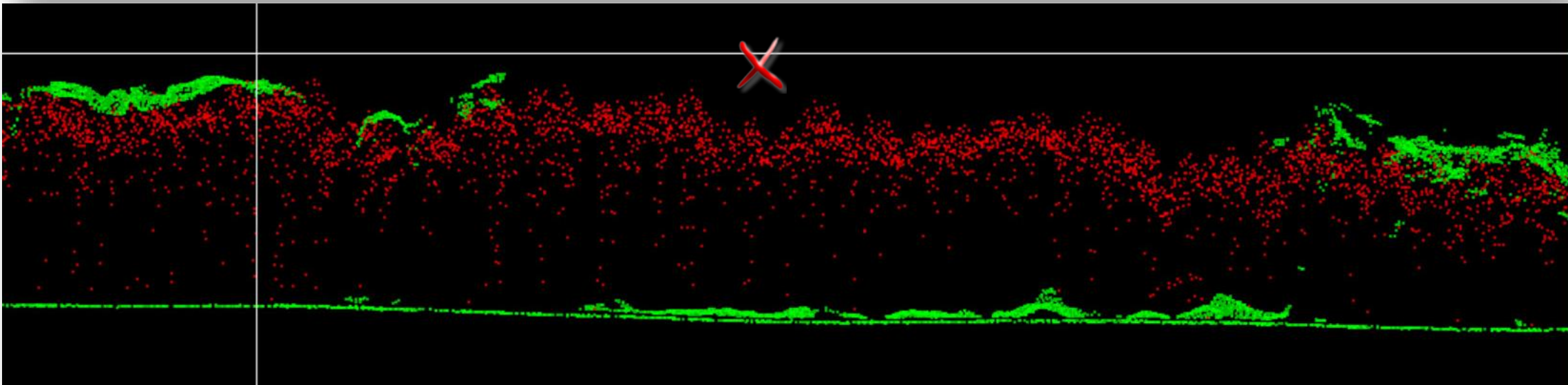
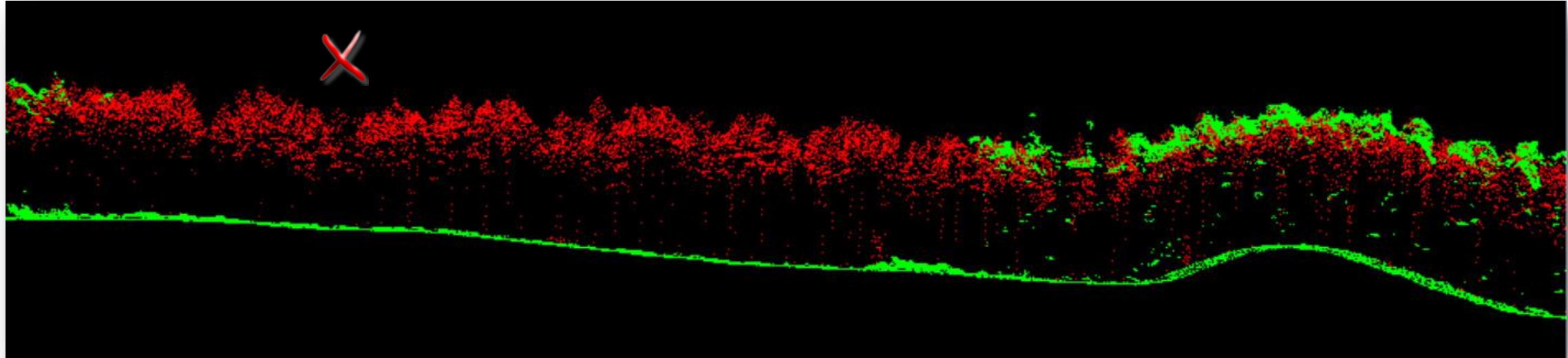
**Mapa zmian zNMPT w okresie 2012-2017**



# Integracja IPC (dense matching) oraz ALS LIDAR



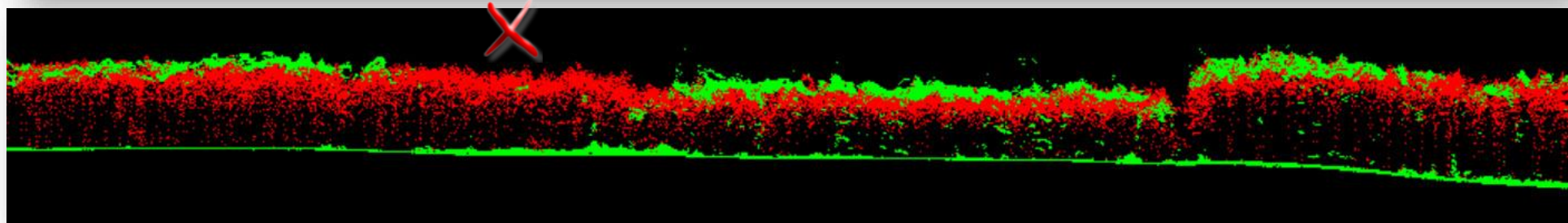
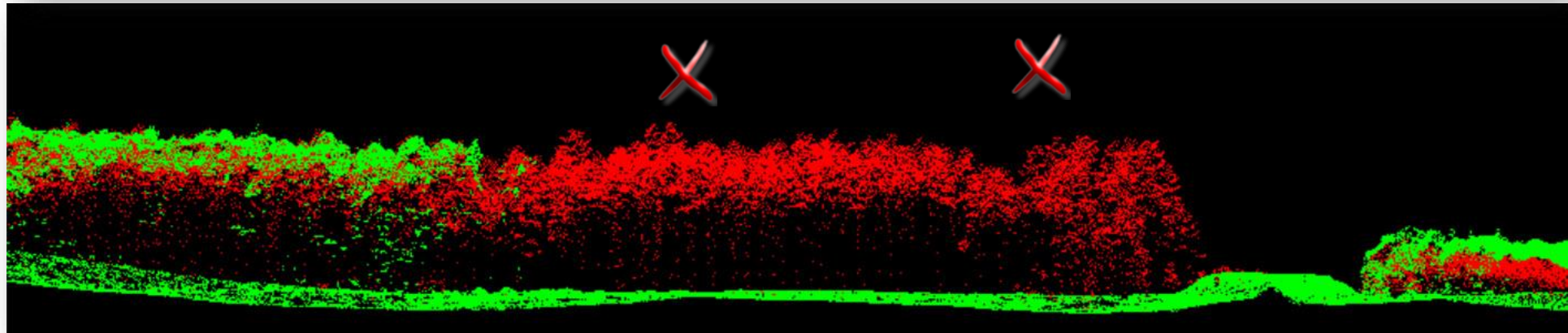
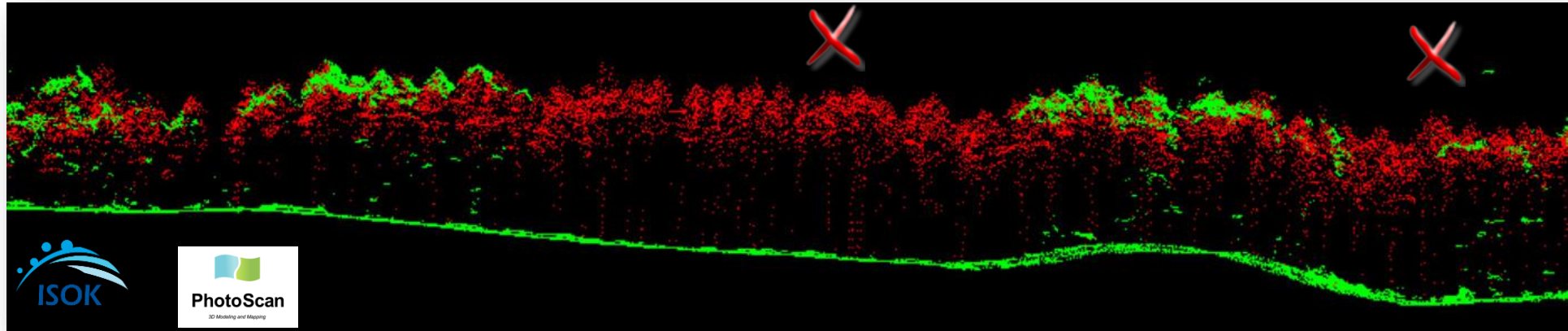
Kolor czerwony – ISOK ALS 2012; Zielony – IPC 2017 zdjęcia lotnicze





# Integracja IPC (dense matching) oraz ALS LIDAR

Kolor czerwony – ISOK ALS 2012; Zielony – IPC 2017 zdjęcia lotnicze

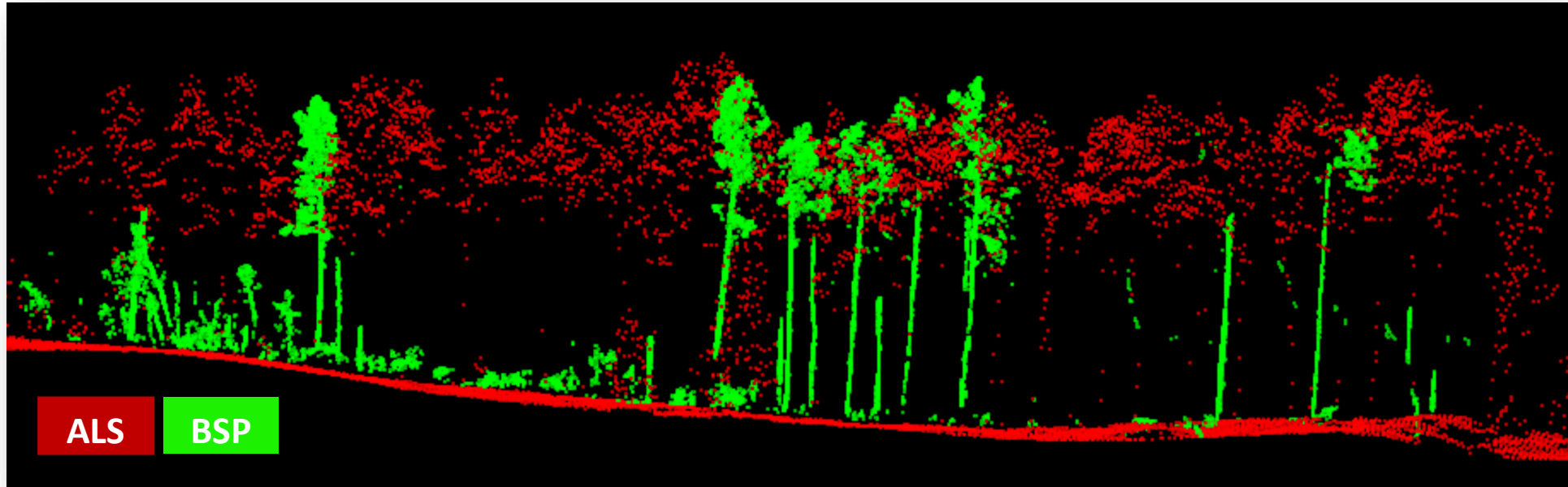




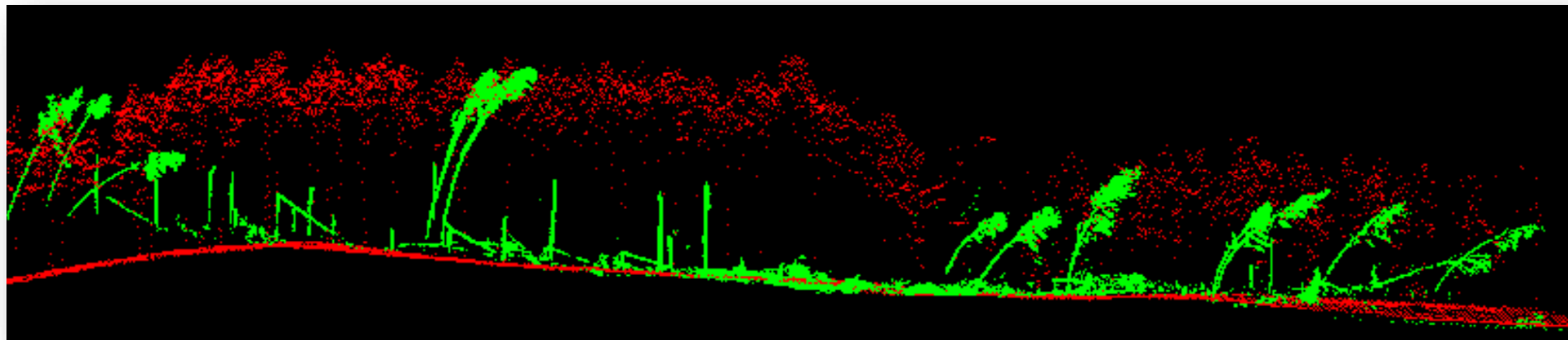
# Integracja BSP IPC (dense matching) oraz ALS LIDAR



Kolor czerwony – ISOK ALS 2012; Zielony – IPC 2017 zdjęcia BSP



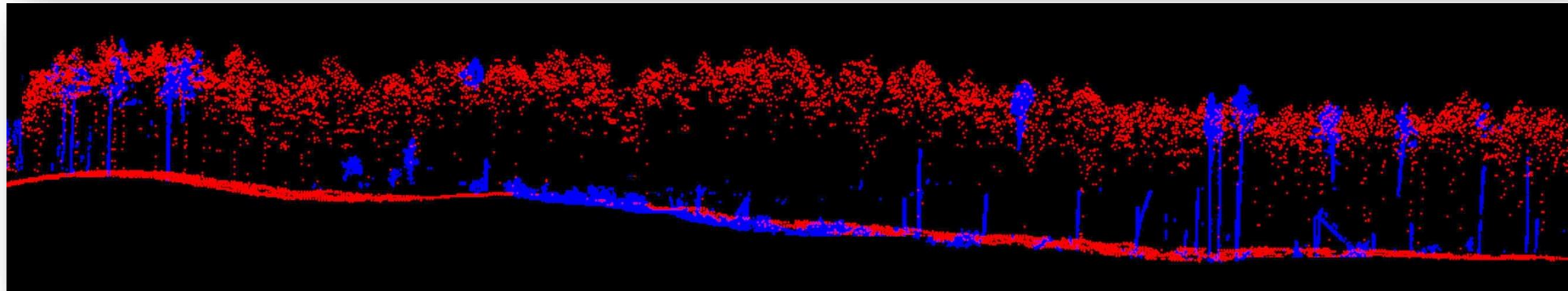
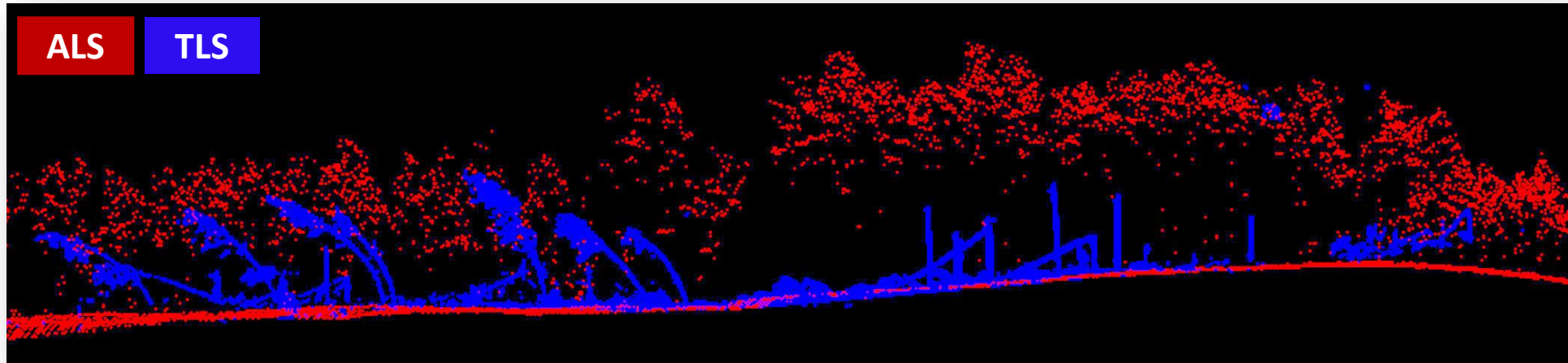
Point cloud: RED – ALS (2012); GREEN – UAV (2017)





# Integracja LiDAR ALS (2012) oraz TLS (2017)

## Bory Tucholskie

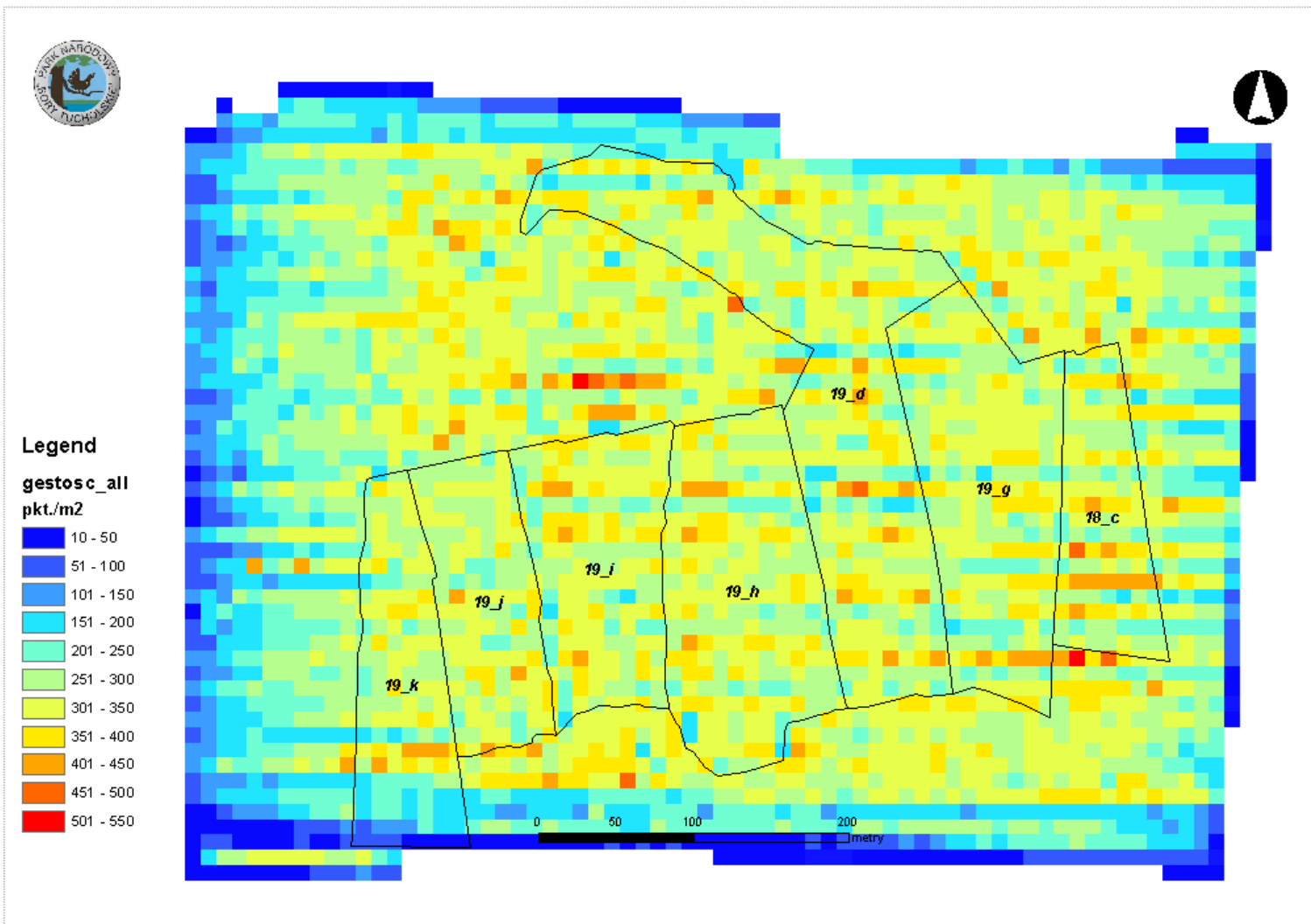






# ULS LiDAR – BSP

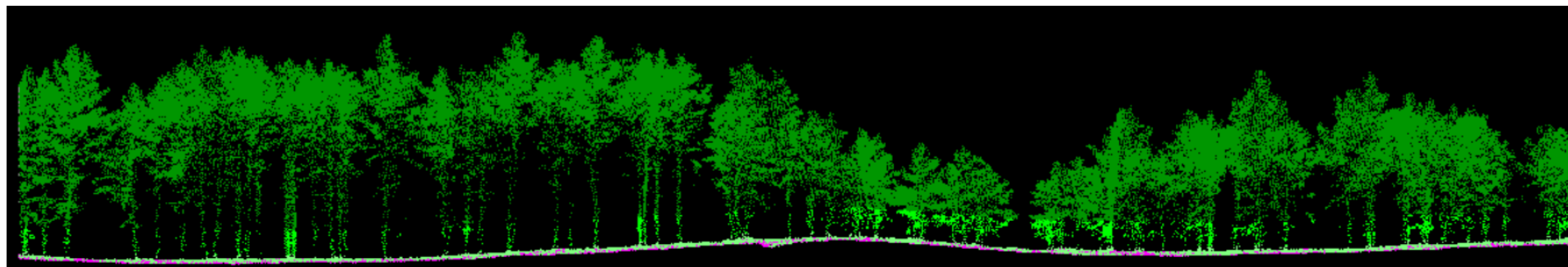
## Park Narodowy Borów Tucholskich



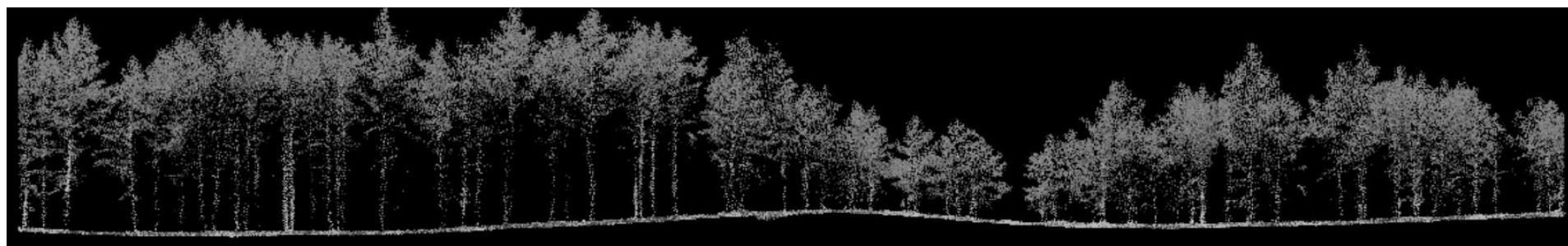
RICOPTER oraz skaner VUX-1  
(RIEGL)



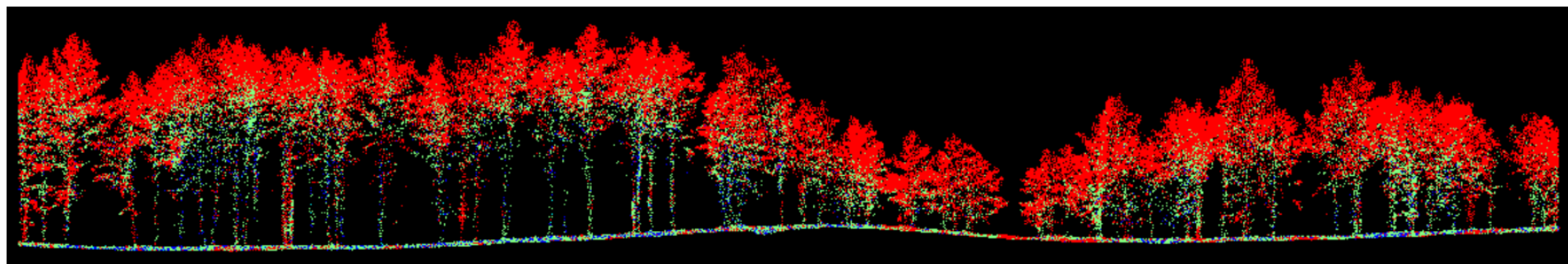
# Chmura punktów ULS LiDAR 2018



Klasy punktów ALS (APSR)



Intensywność



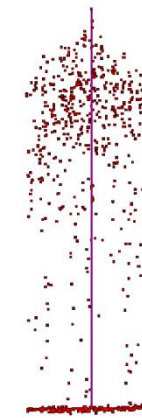
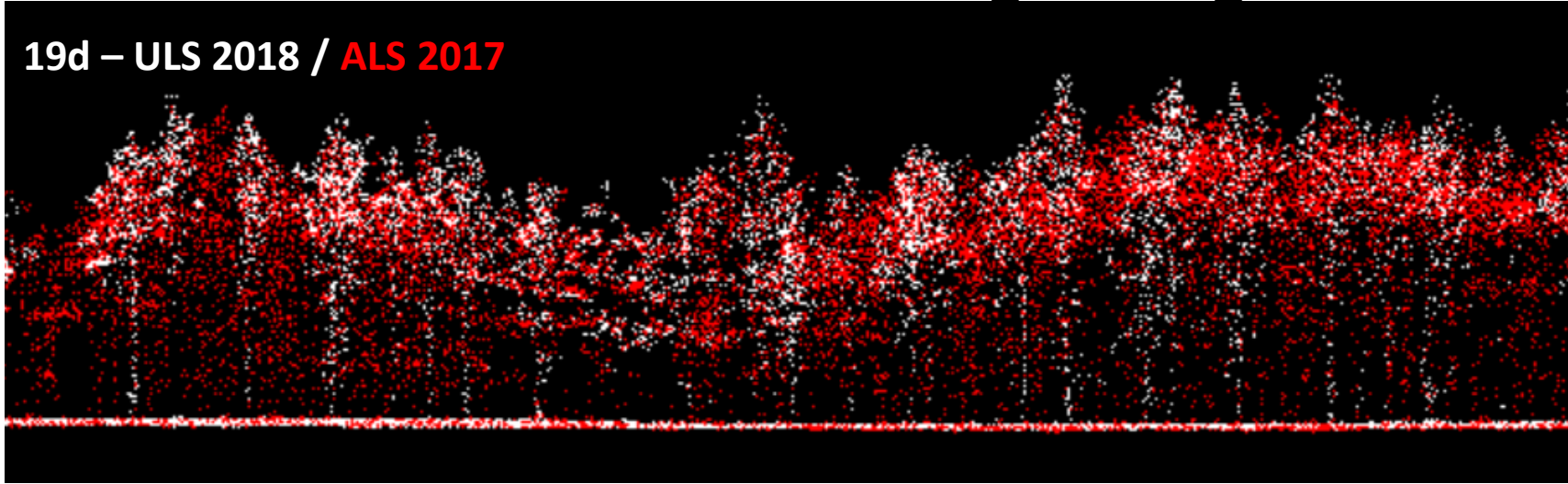
Echa (kolejności odbić)



# LiDAR ALS (2017) i ULS (2018) Monitoring zabiegów trzebieży



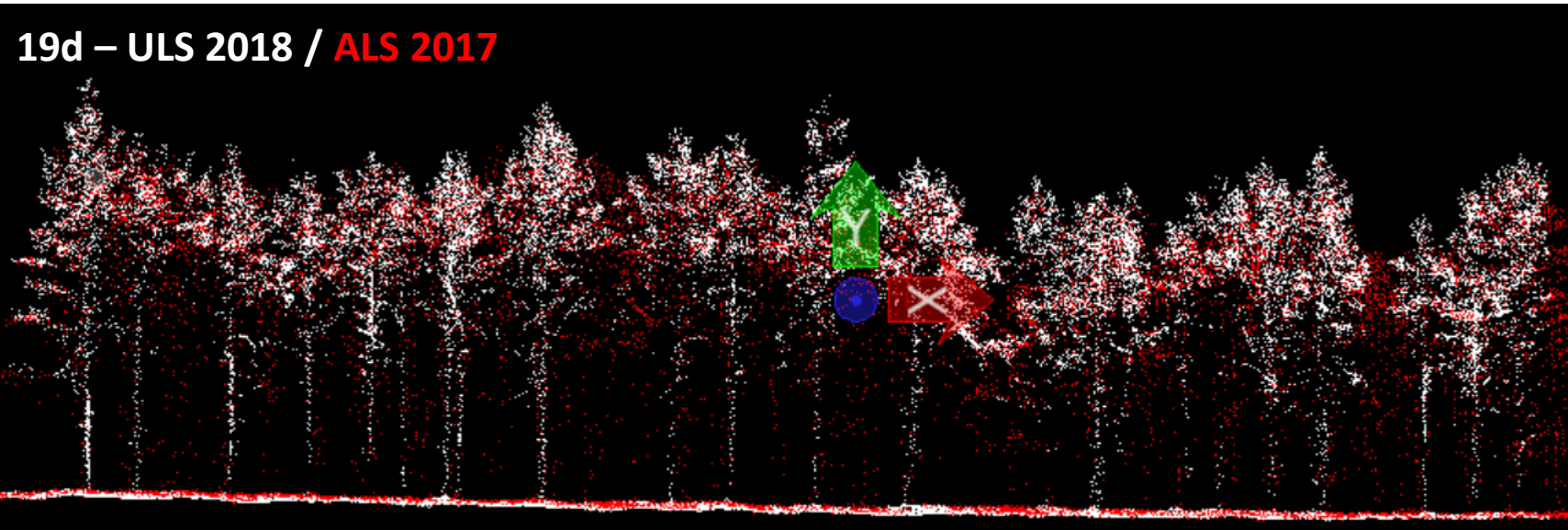
19d – ULS 2018 / ALS 2017



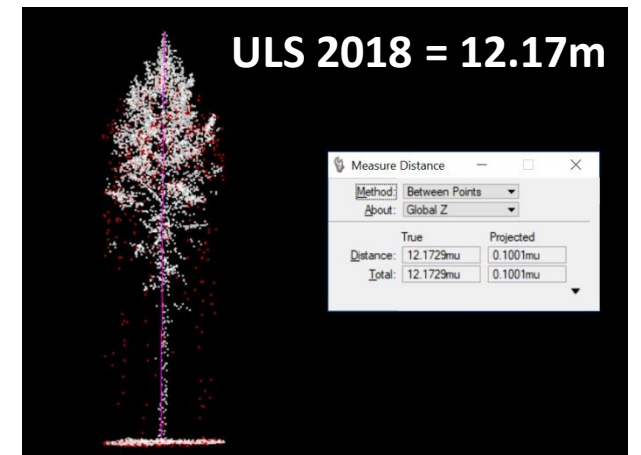
Measure Distance	
Method:	Between Points
About:	Global Z
Distance:	11.4931mu
Total:	11.4931mu

ALS 2017 = 11.49m

19d – ULS 2018 / ALS 2017



Przyrost wysokości  
2017-2018 = 28 cm

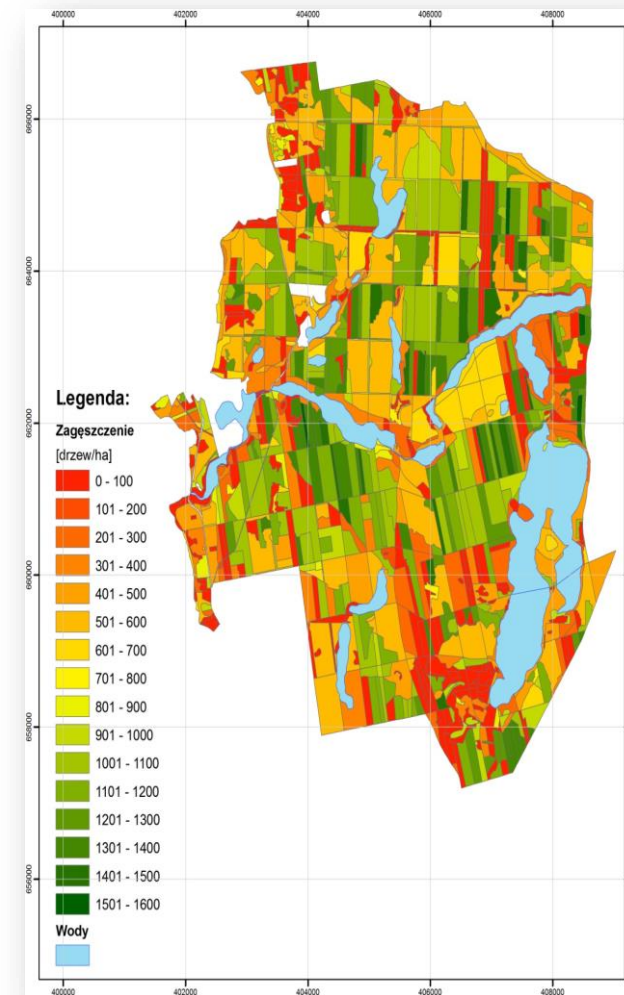
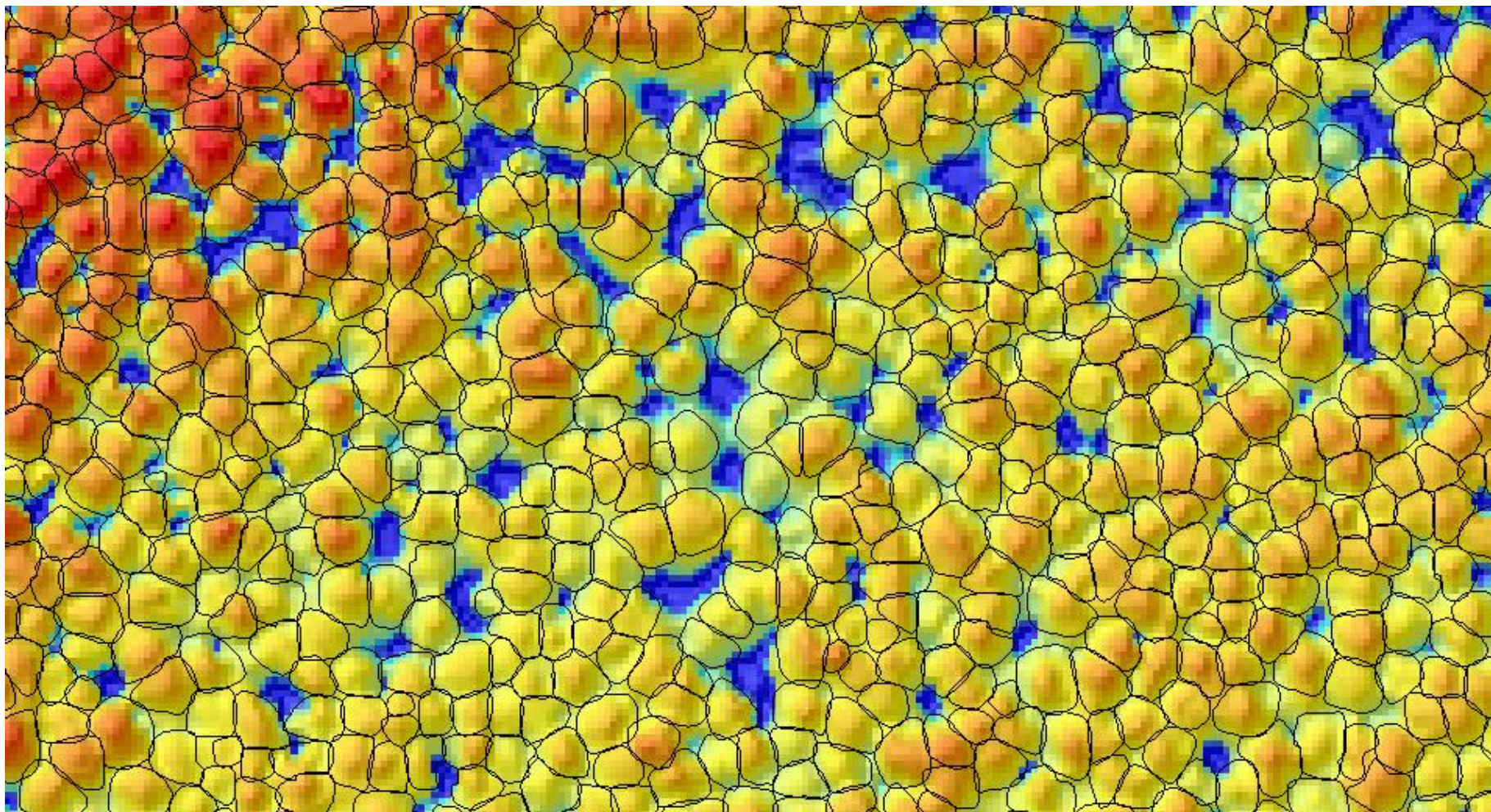


ULS 2018 = 12.17m

Measure Distance	
Method:	Between Points
About:	Global Z
Distance:	12.1729mu
Total:	12.1729mu



# Segmentacja koron drzew w drzewostanach PN Bory Tucholskie



Results of crown segmentation based on CHM\_ALS (12pt/sqm background – CHM\_ALS; ISOK project)

# Detekcja zmian w strukturze pionowej rozpadających się świerczyn. Gorczański Park Narodowy

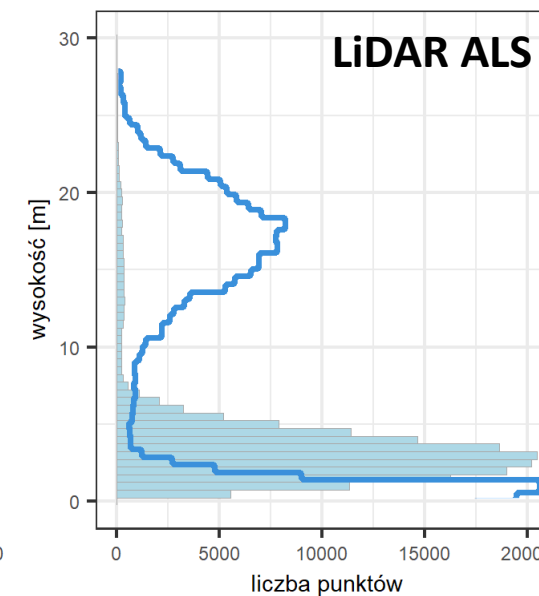
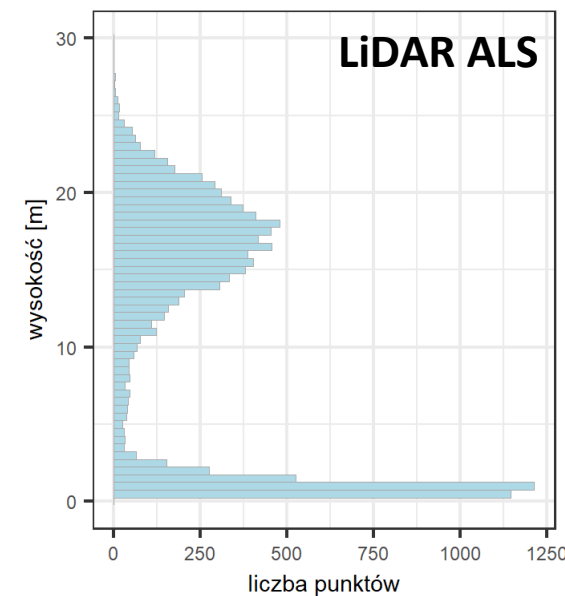
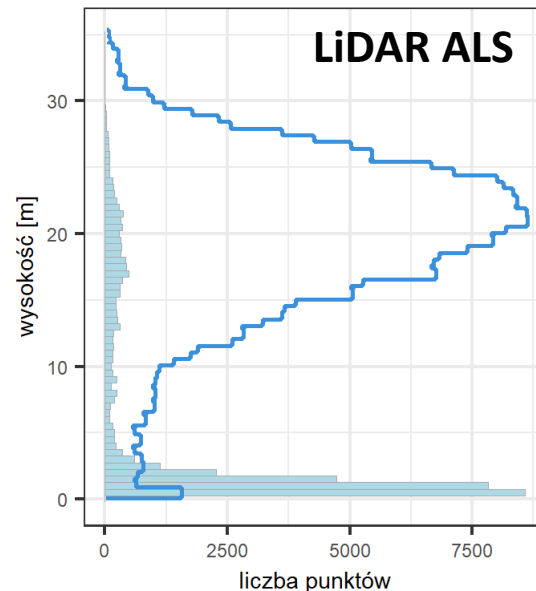
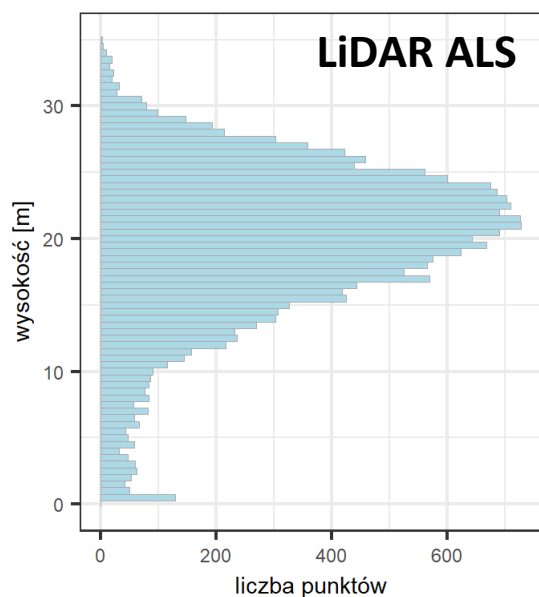


2012 r. - klasa dst\_sw

2020 r. - klasa wylesienie

2012 r. - klasa martwe\_sto

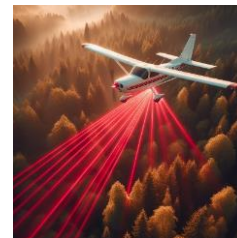
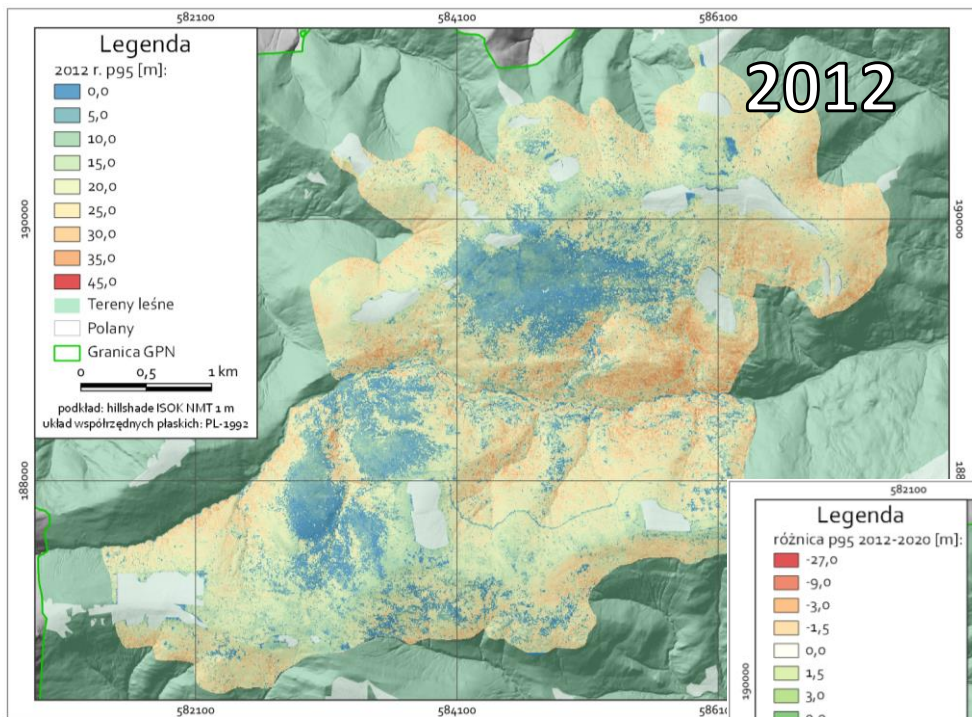
2020 r. - klasa sukcesja



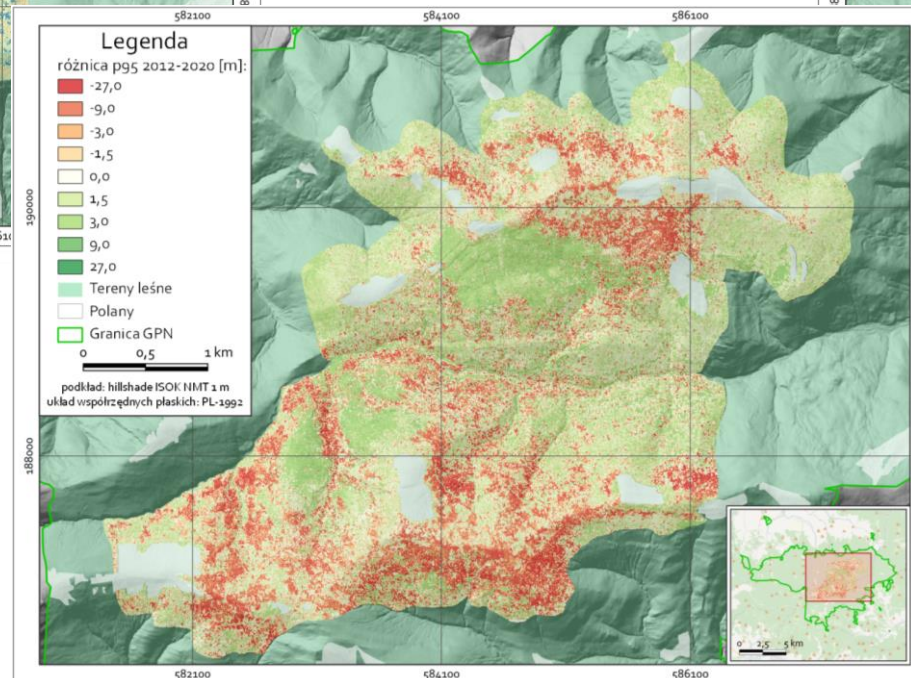
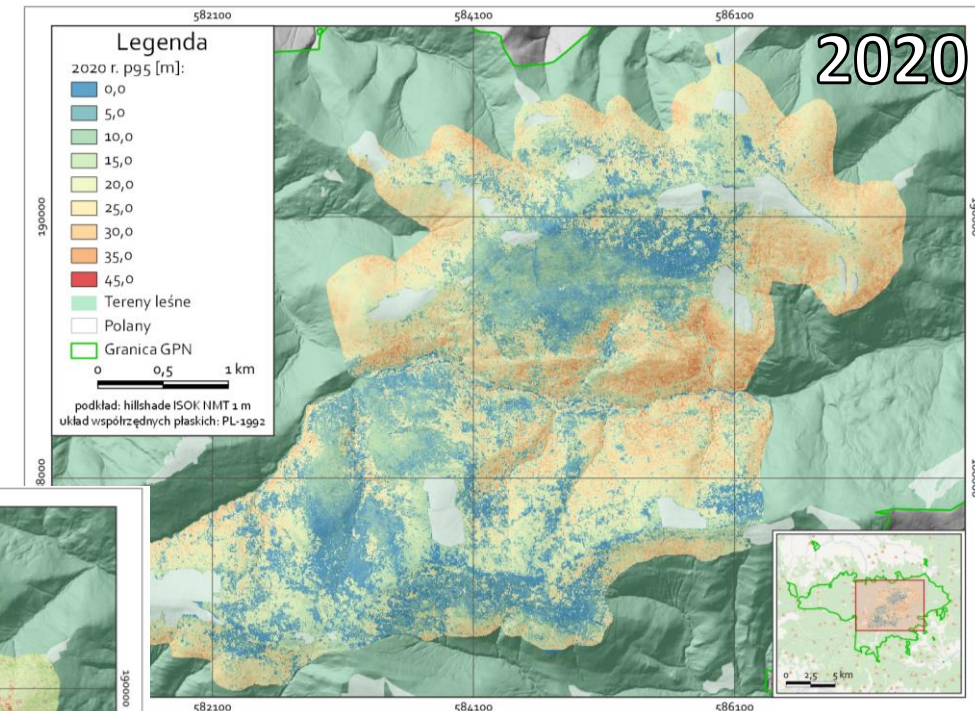
Histogramy obszaru, na którym w latach 2012-2020 zmarł i rozpadł się drzewostan świerkowy, pozostawiając otwartą powierzchnię.

Histogramy obszaru, na którym w latach 2012-2020 stojące martwe świerki zostały powalone przez wiatr i pojawiła się wtórna sukcesja leśna.

# Dynamika wysokości drzewostanów GPN



**LiDAR ALS**



Dynamika zmian wysokości drzewostanów w okresie 2012-2020 w masywie: Kudłonia i Jaworzyny Kamienickiej w Gorcach (GPN).

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Article  
Using Satellite Imagery and Aerial Orthophotos for the Multi-Decade Monitoring of Subalpine Norway Spruce Stands Changes in Gorce National Park, Poland

Wojciech Krawczyk and Piotr Wężyk

# ALS LiDAR – Analizy 4D parametrów biometrycznych drzewostanów 2012 i 2023

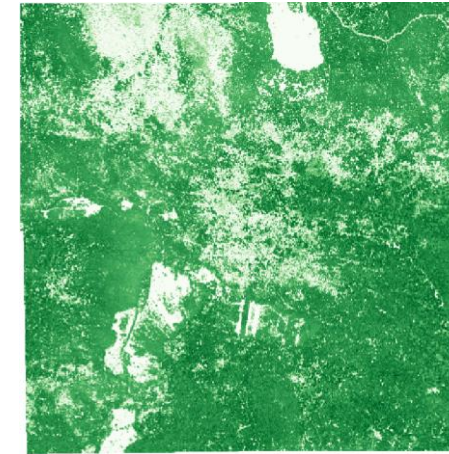
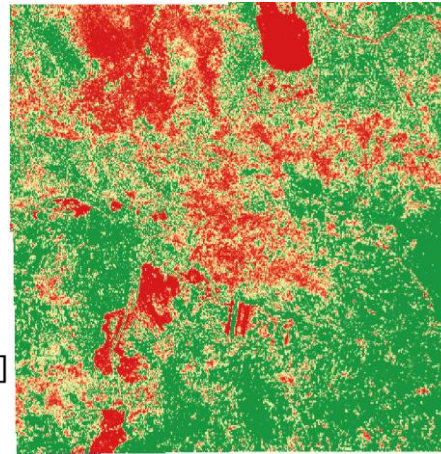


Model Koron Drzew

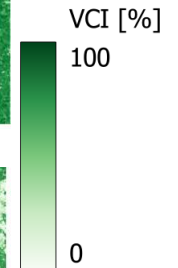
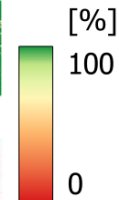
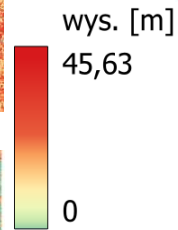
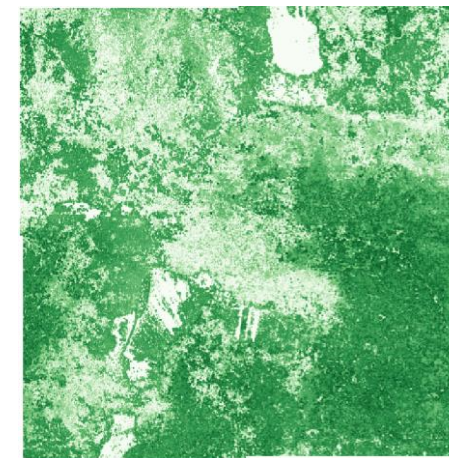
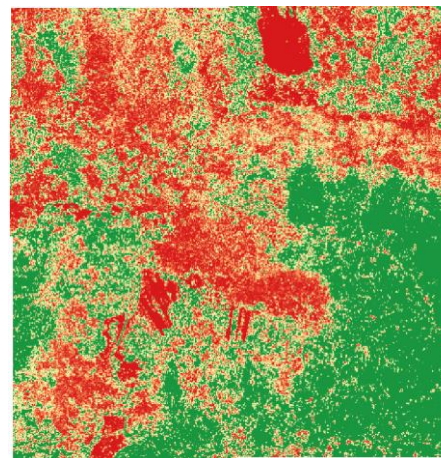
Zwarcie Poziome

Zwarcie Pionowe (VCI)

2012



2023

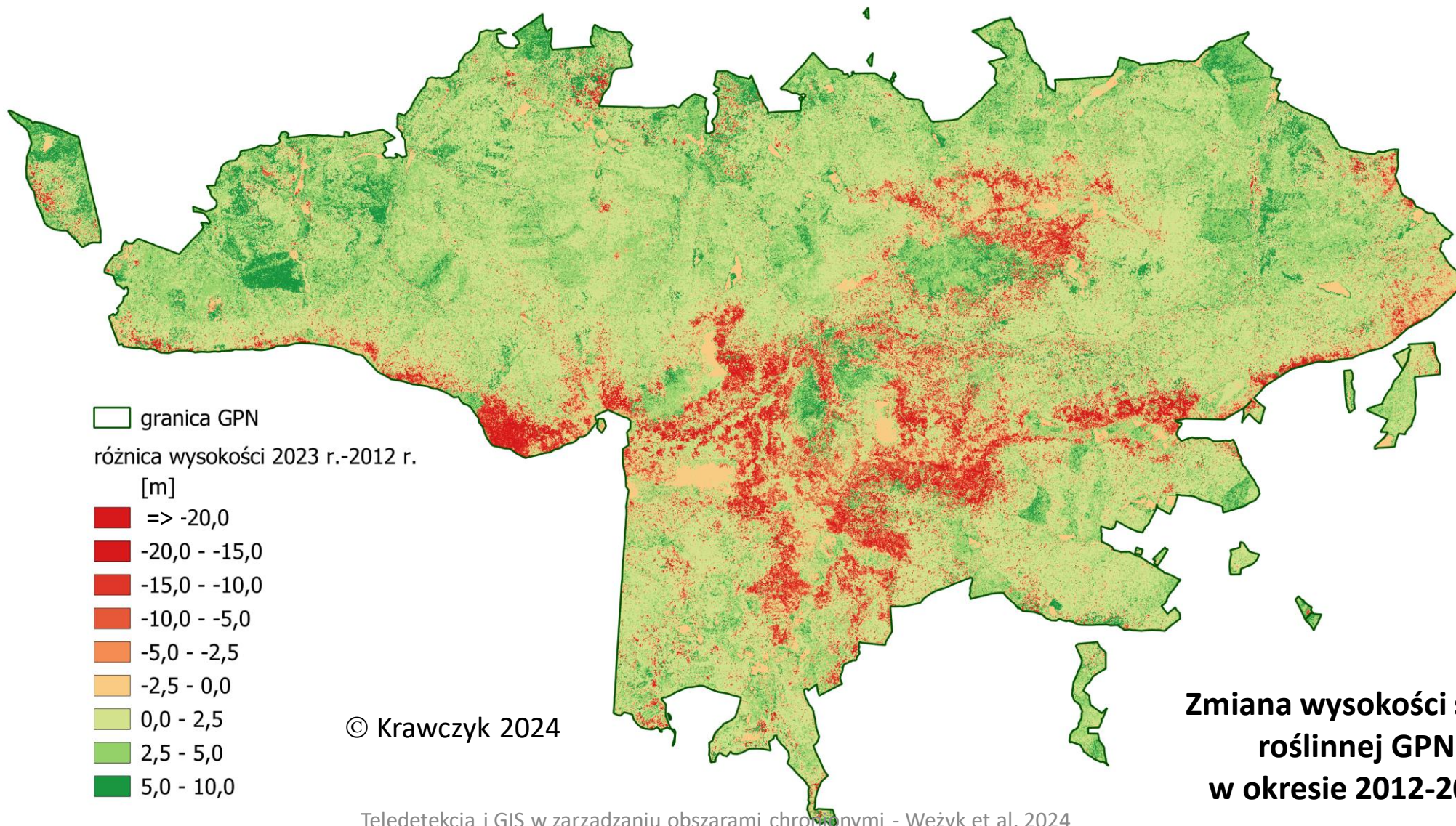
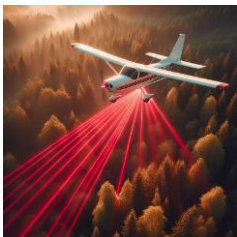


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# Dynamika wysokości drzewostanów GPN

## ALS LiDAR p95

### LiDAR ALS



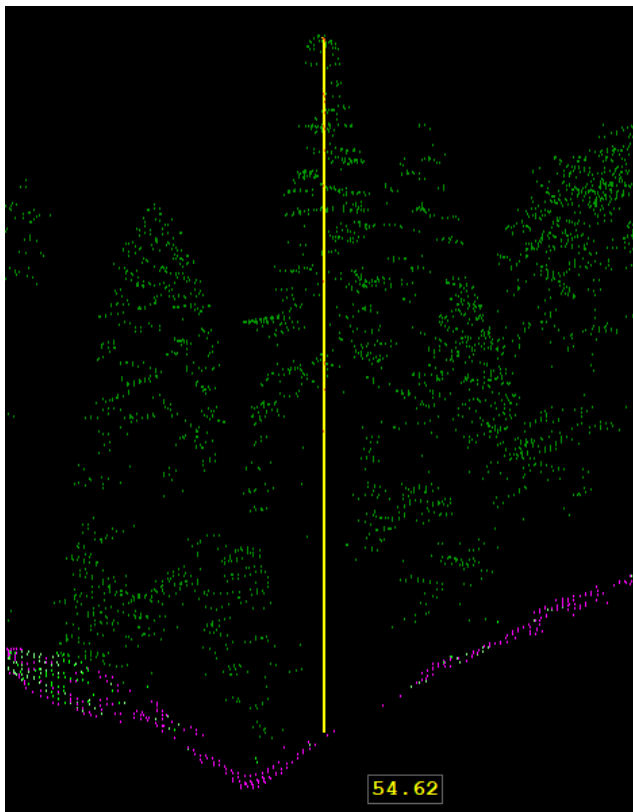
**Zmiana wysokości szaty  
roślinnej GPN  
w okresie 2012-2023**



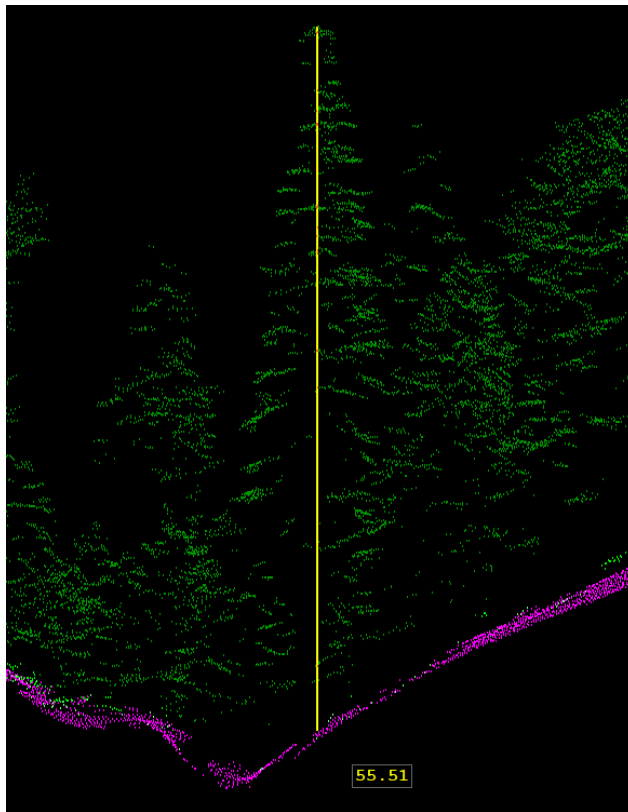


# Gdzie rośnie najwyższe drzewo?

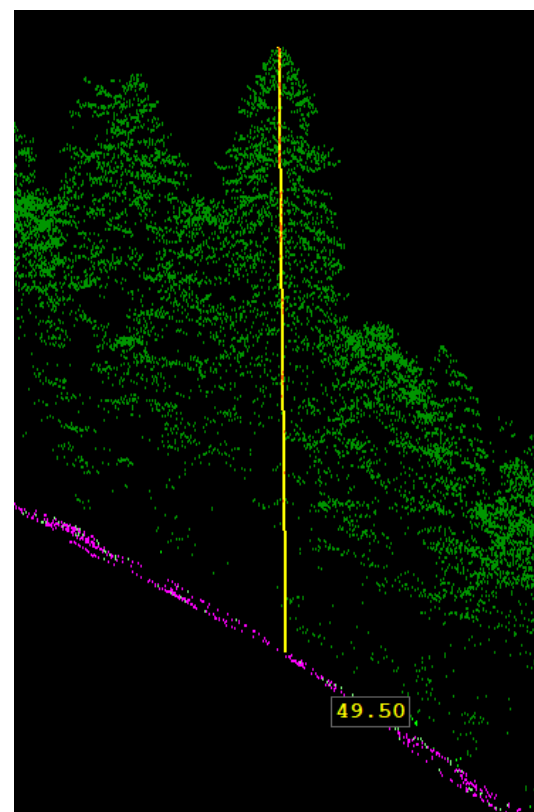
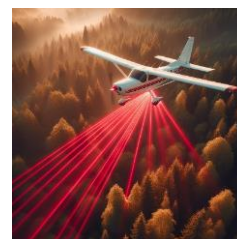
## LiDAR ALS



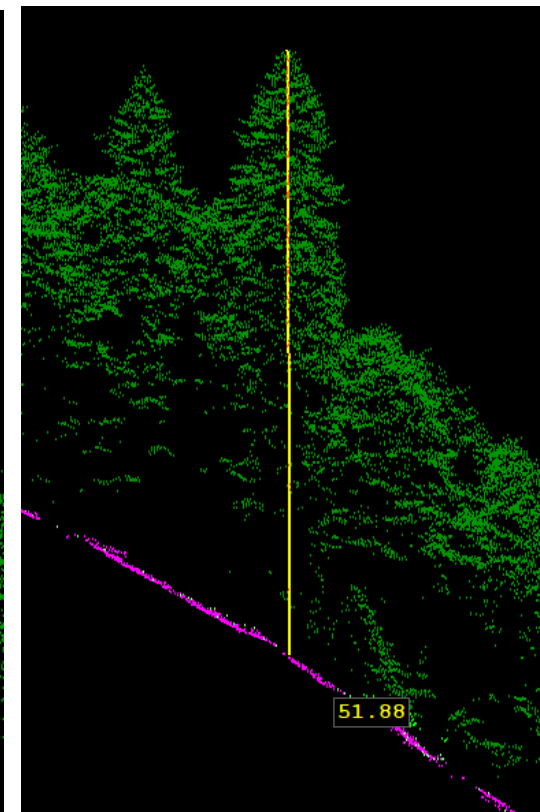
ALS LiDAR GUGiK 2012 r.  
H = 54.6 m



ALS LiDAR GUGiK 2023 r.  
H = 55.5 m



ALS LiDAR GUGiK 2012 r.  
H = 49.5 m m



ALS LiDAR GUGiK 2023 r.  
H = 51.9 m

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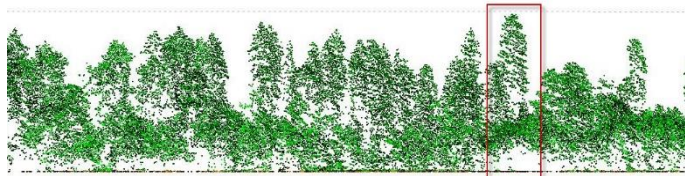
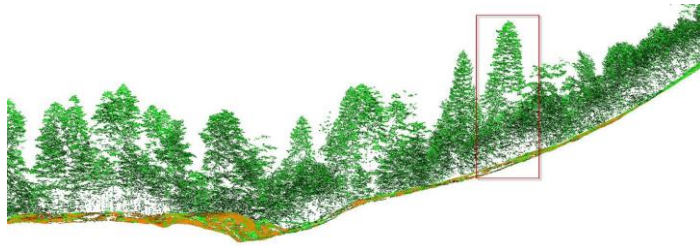


# Gdzie rośnie najwyższe drzewo?

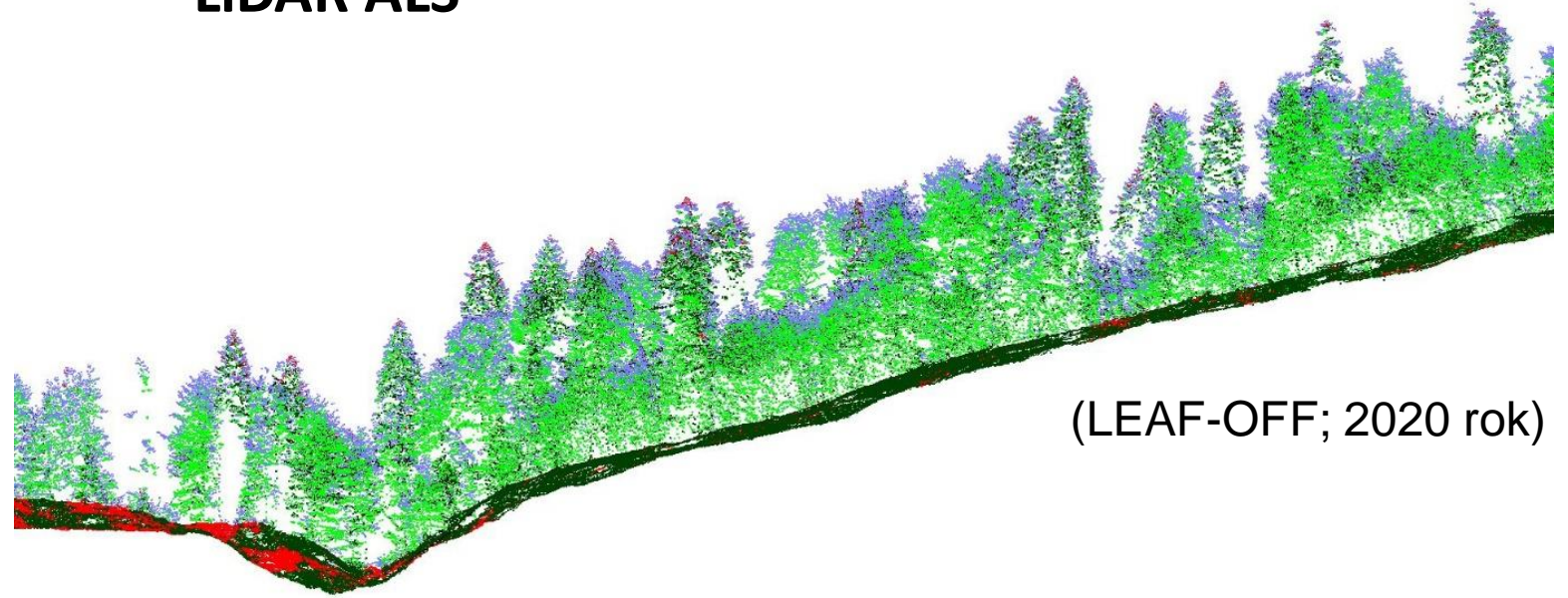
## LiDAR ALS

ALS LiDAR BgPN 2019

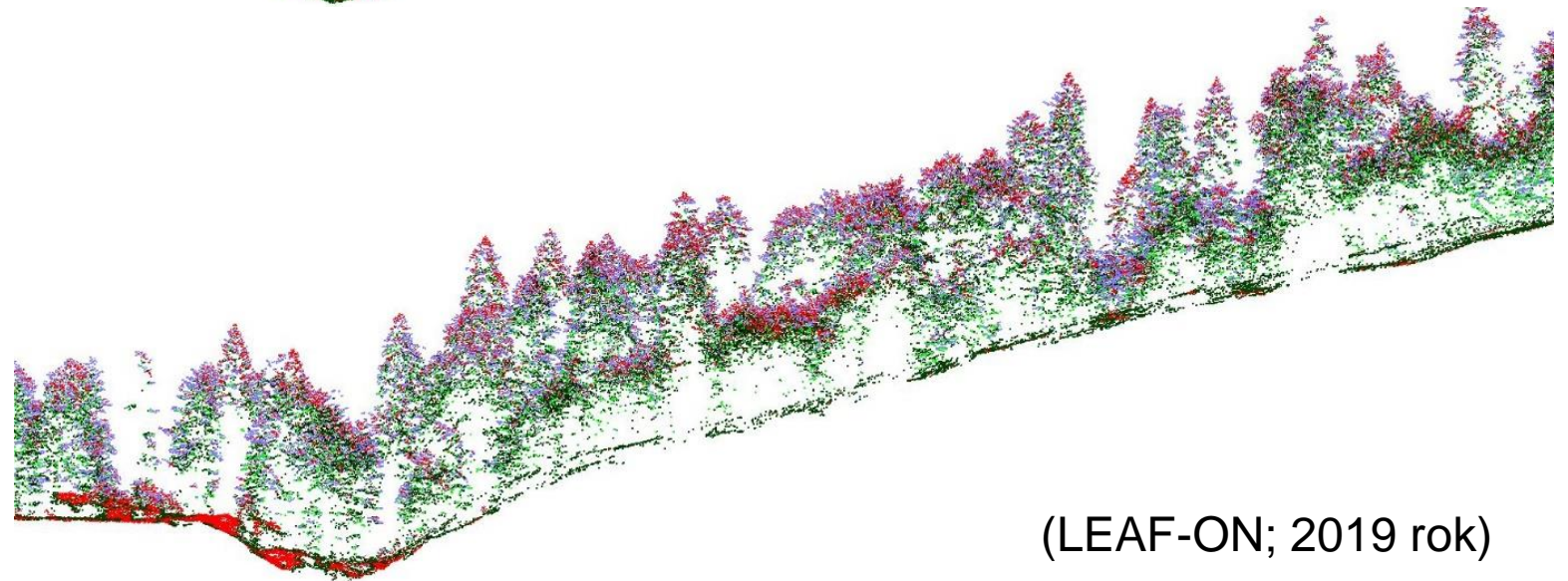
H = 49,56 m



ALS po normalizacji



(LEAF-OFF; 2020 rok)

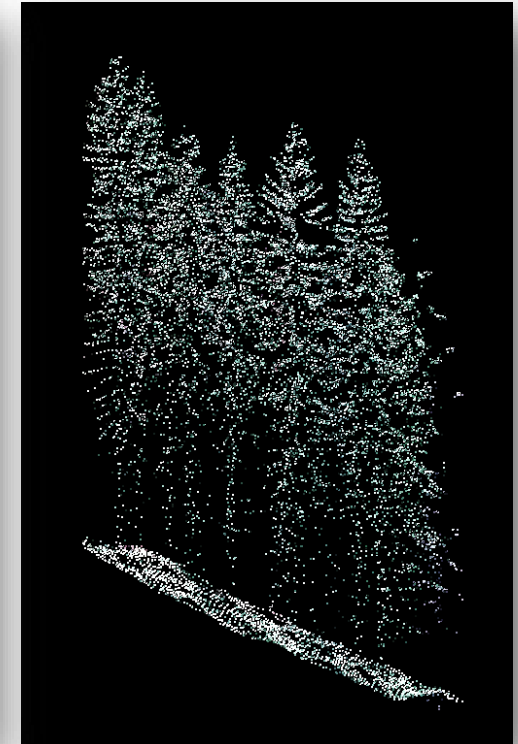
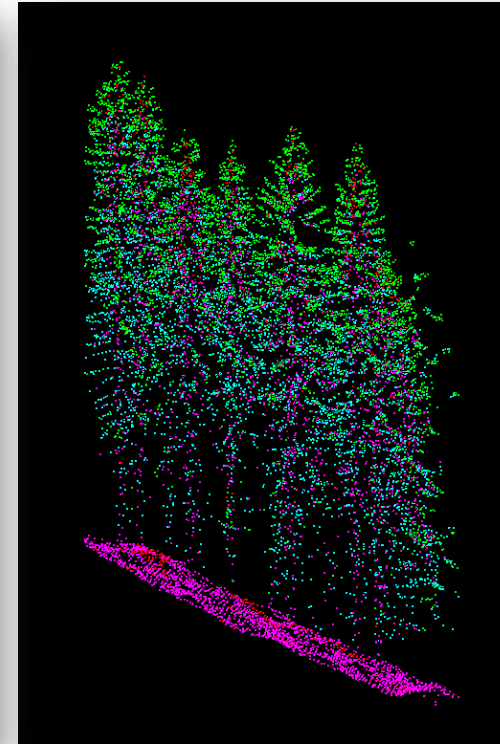
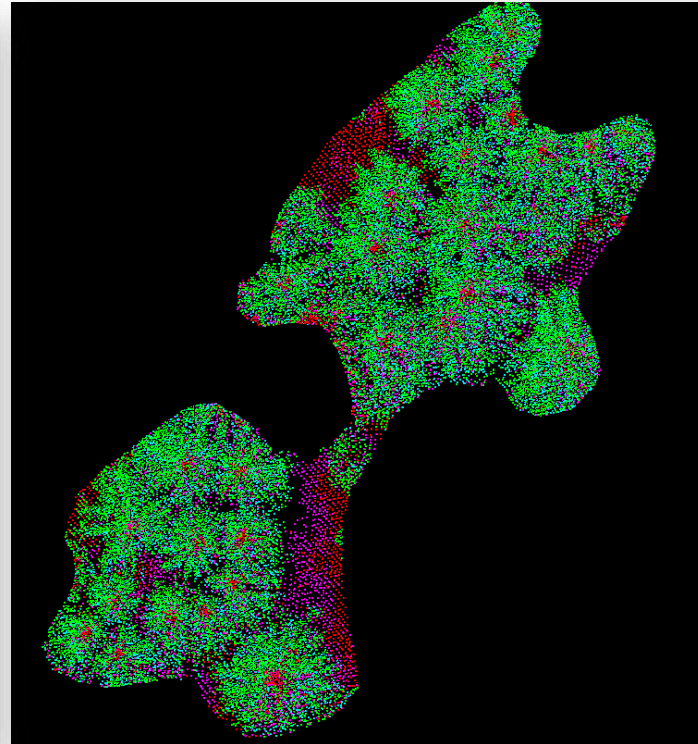
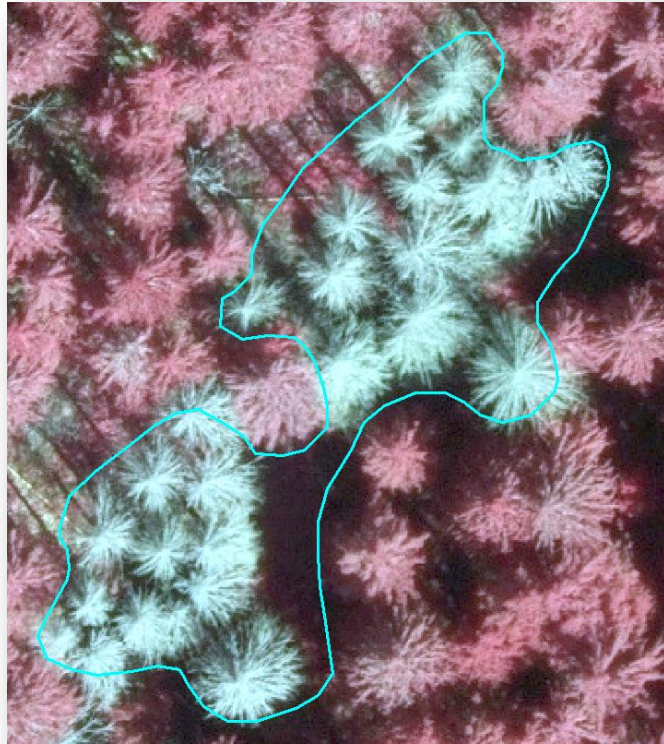


(LEAF-ON; 2019 rok)



# ALS LiDAR & CIR orthophoto

## Echo (Return) visualisation – TerraScan (Terrasolid)



CIR orthophoto 10cm GSD



ALS Echo (TOP)

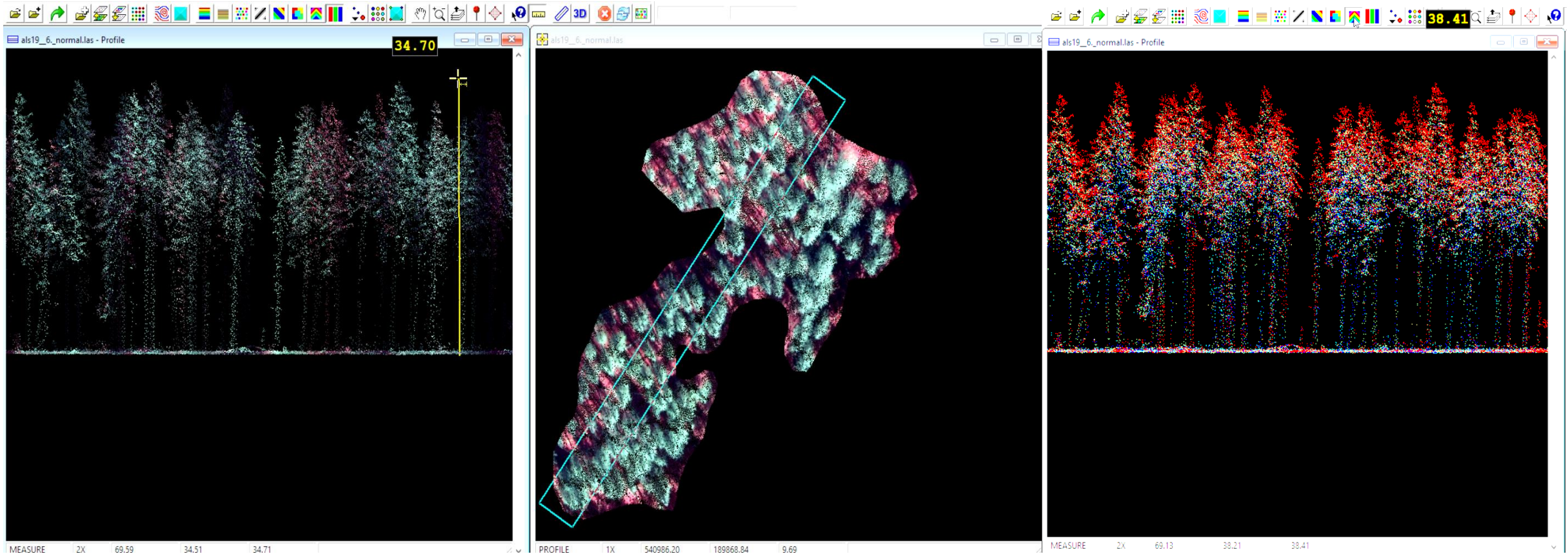
ALS Echo (cross-section)

ALS Intensity

The loss of the assimilation apparatus by dying spruce trees causes a greater penetration of the laser beam through the tree crowns and thus a greater number of indirect reflections (echoes) before the laser beam reaches the ground. This feature allows for better detection of places with increased density (richer structure of laser-illuminated branches)

# ALS LiDAR point density & echos

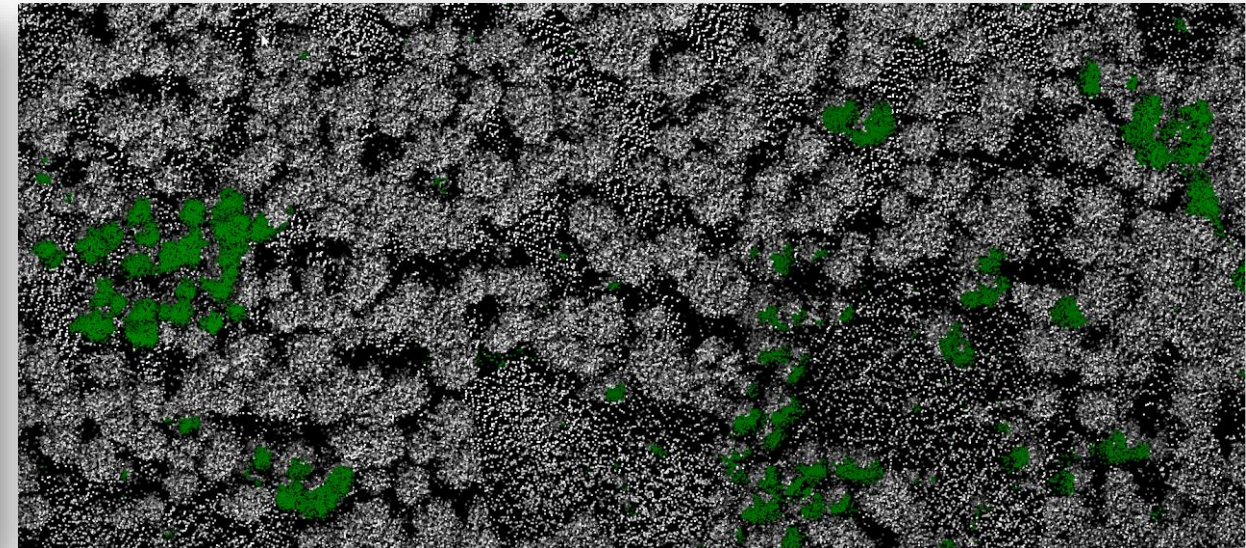
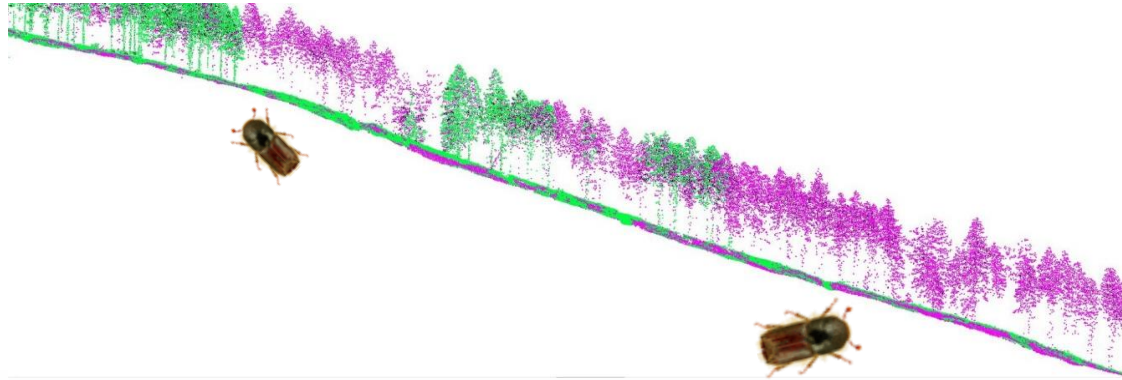
## Dead Norway spruce



Dead forest Norway spruce stands after bark beetle attack. Lef: Cross-section trough the normalised ALS pointcloud (Sept. 2019; density > 70 pts sqm); right: different echos in the full tree crown range



# NDVI point cloud classification of dead trees

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$$


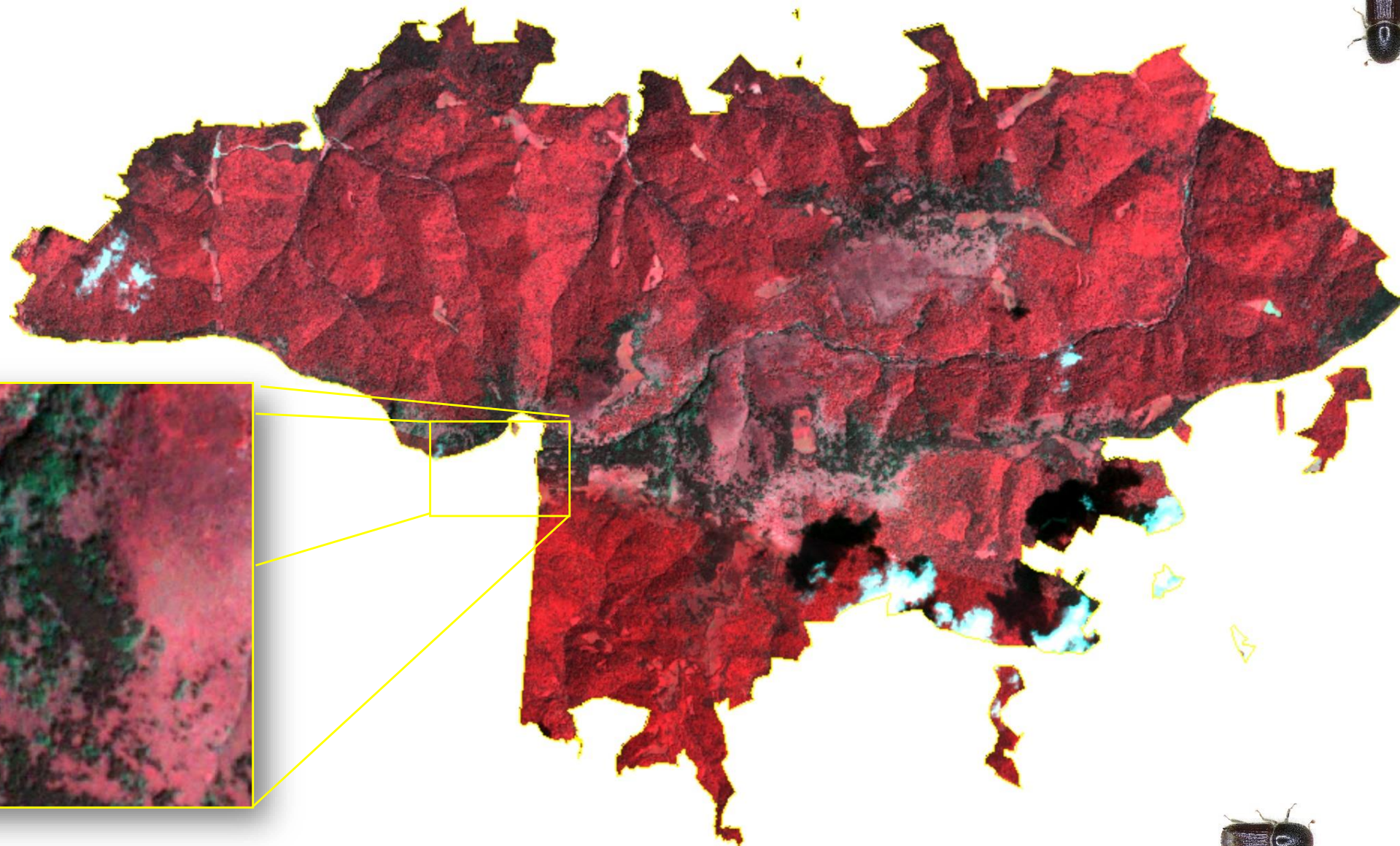
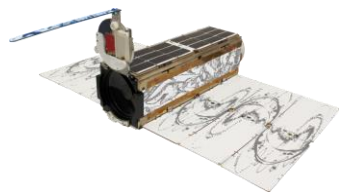
ALS LiDAR dense cloud (> 70 ppsqm) coloured with aerial photographs

ALS LiDAR dense cloud (> 70 ppsqm) visualisation using the NDVI ratio



# Teledetekcja satelitarna monitoring drzewostanów w GPN

PlanetScope Dove – kompozycja CIR (30.07.2017 r.; GSD 3.0 m)

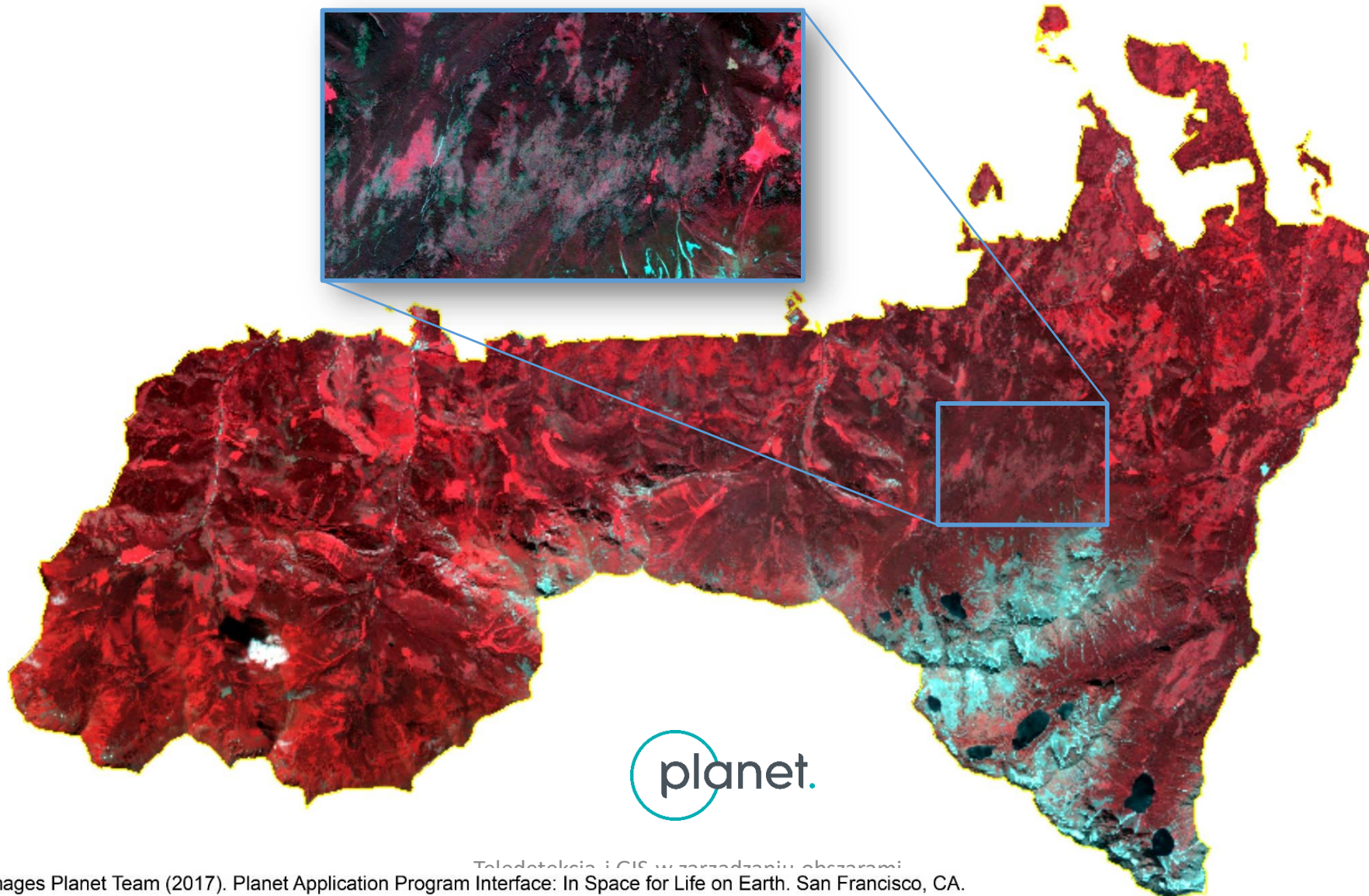
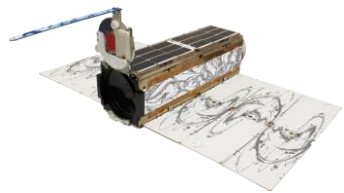




# Teledetekcja satelitarna monitoring d-stanów w TPN 2017



PlanetScope Dove – kompozycja CIR (24.08.2017 r.; GSD 3,0 m)

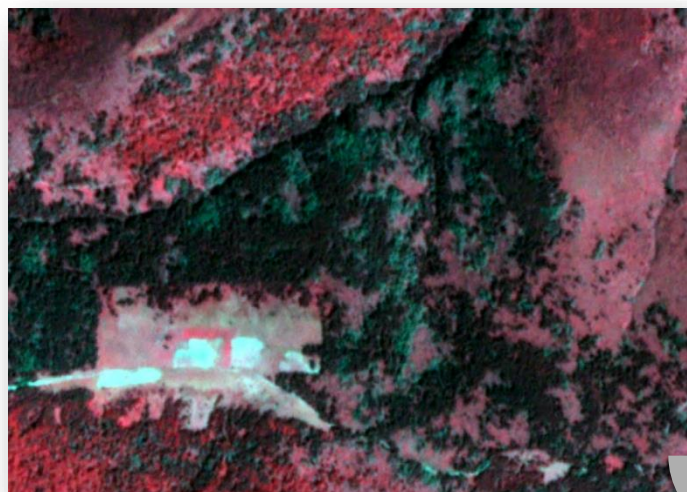


Teledetekcja i GIS w zarządzaniu obszarami  
Satellite images Planet Team (2017). Planet Application Program Interface: In Space for Life on Earth. San Francisco, CA.  
Cichonowicz et al. 2024

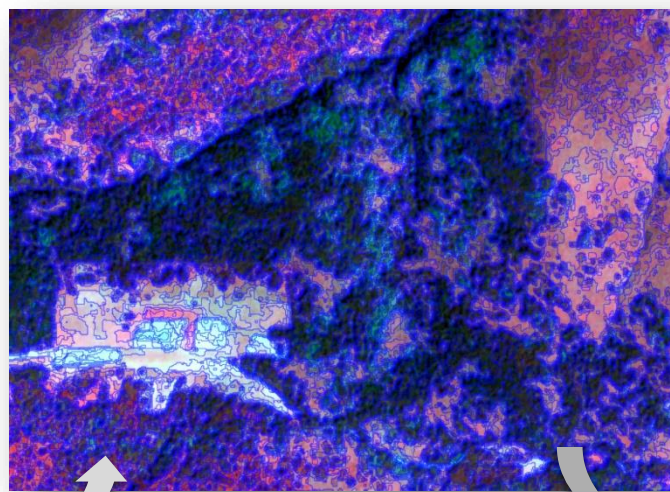
# Klasyfikacja obiektowa (GEOBIA)

## Automatyczna detekcja martwych drzew

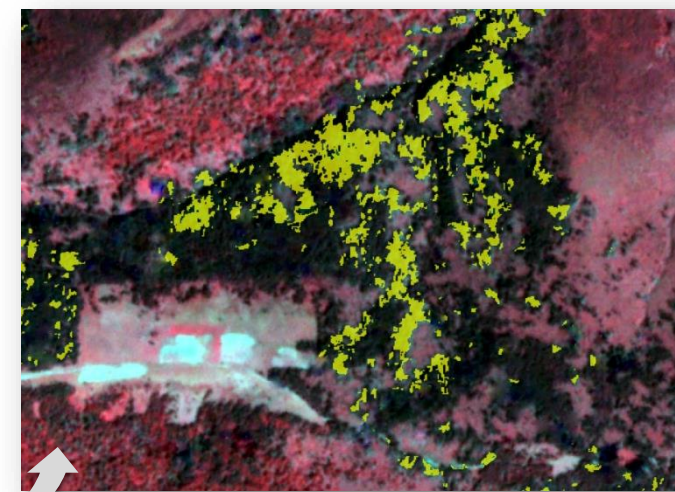
### GEOBIA – *Geographic-Object-Based Image Analysis*



PlanteScope - CIR (2017)



Segmentacja



Wstępna klasyfikacja



Klasyfikację GEOBIA obrazów satelitarnych przeprowadzono w oprogramowaniu eCognition Developer (TRIMBLE).

- warstwy wejściowe: trzy kanały PlanetScope – podczerwony (NIR), czerwony (R) i zielony (G),
- algorytm: multiresolution segmentation,
- parametry: Scale=50, Shape=0.2, Compactness=0.5,
- łączenie sąsiadujących segmentów o różnicy spektralnej  $DN < 50$ .

- wartość średnia w kanale podczerwonym:  $SP \geq 3500$  i  $SP \leq 6000$ ;
- wartość średnia w kanale czerwonym:  $SC \geq 1800$  i  $SC \leq 3400$ ;
- wartość wskaźnika wegetacji  $NDVI < 0.3$ .

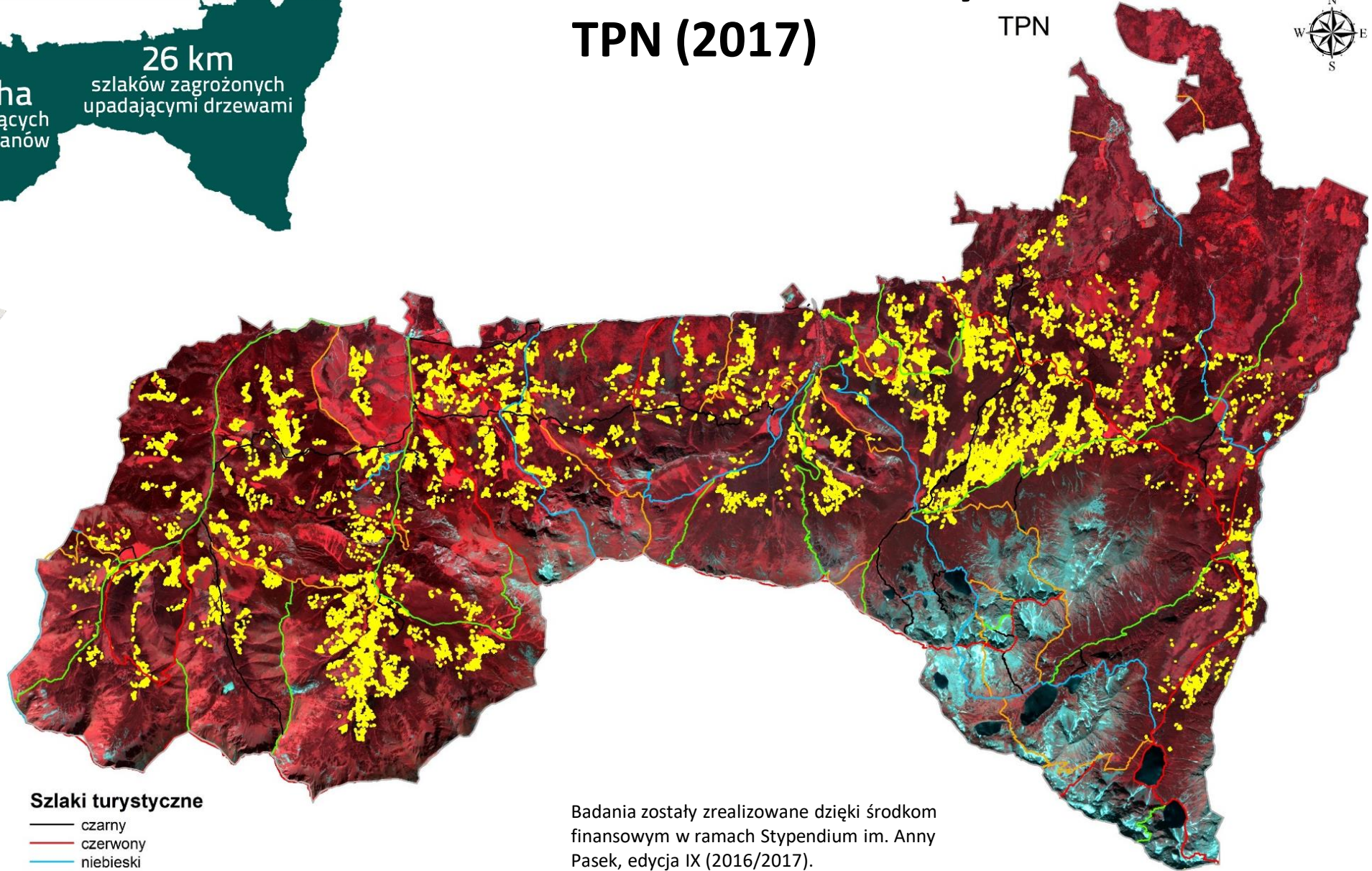
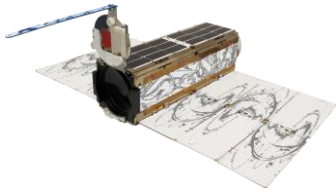




Tatrzański Park Narodowy

# RS - Martwe drzewostany TPN (2017)

TPN



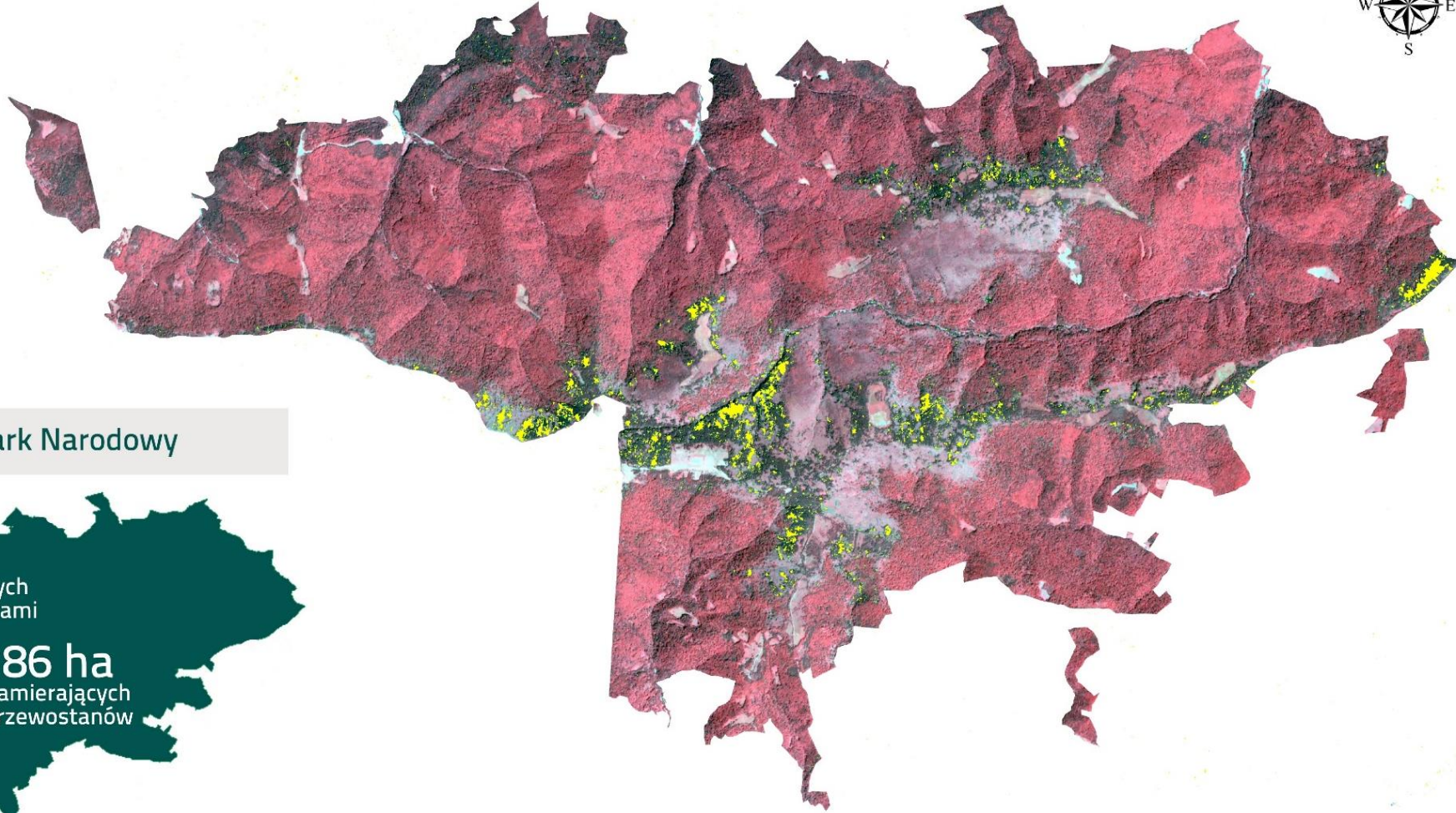
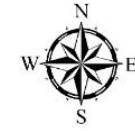
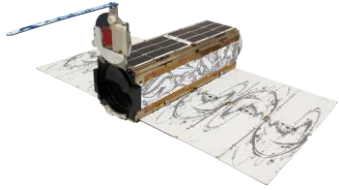
### Szlaki turystyczne

- czarny
- czerwony
- niebieski
- zielony
- żółty
- Obszary zagrożone

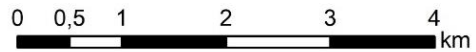
Badania zostały zrealizowane dzięki środkom finansowym w ramach Stypendium im. Anny Pasek, edycja IX (2016/2017).



# Martwe drzewostany w GPN (2017)

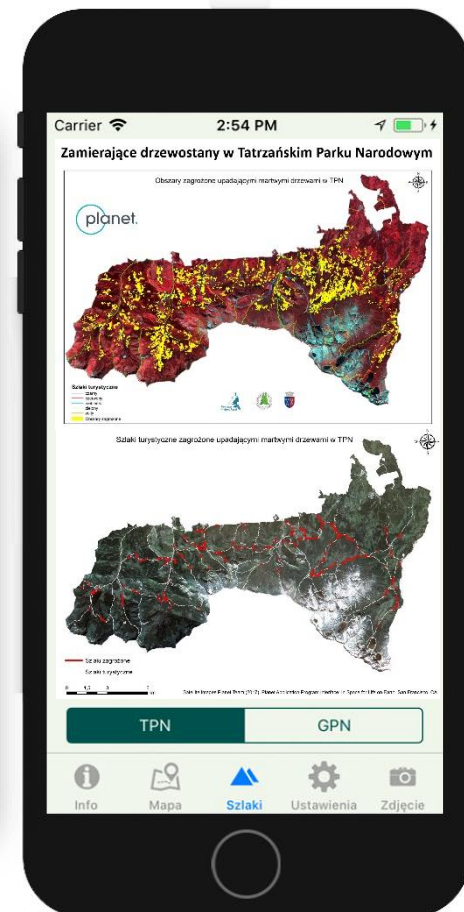
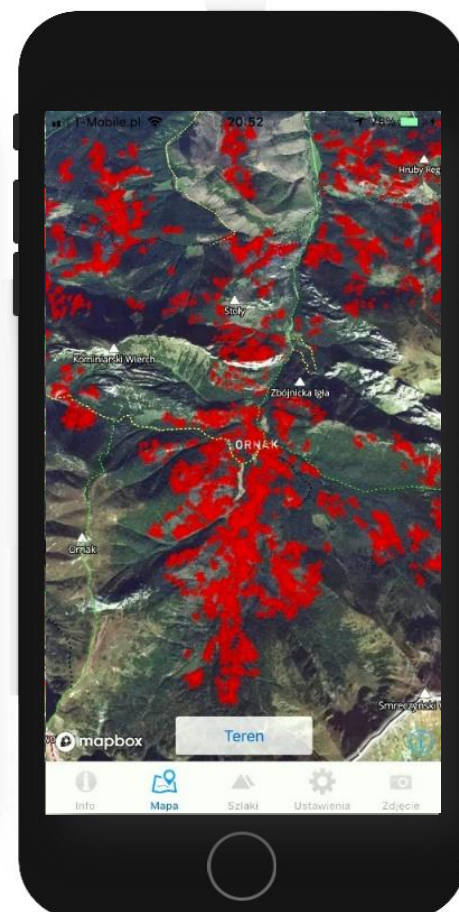
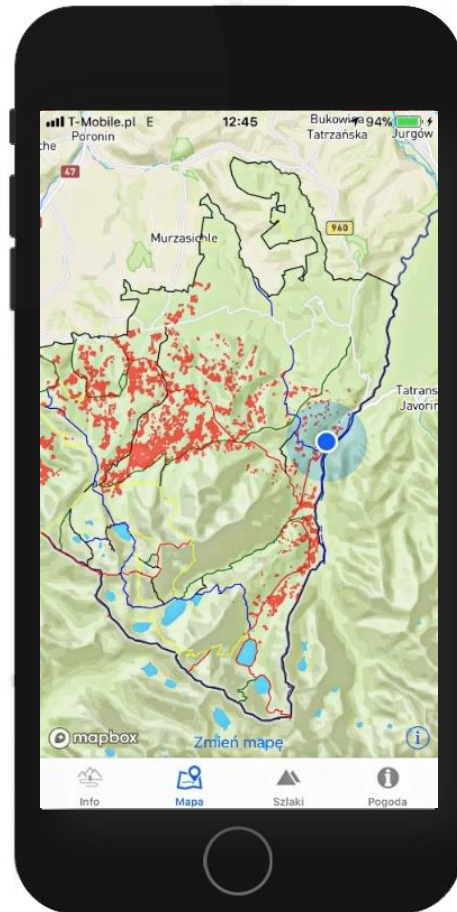


 Gorczański Park Narodowy





# Mobilna aplikacja „Bezpieczny Szlak”



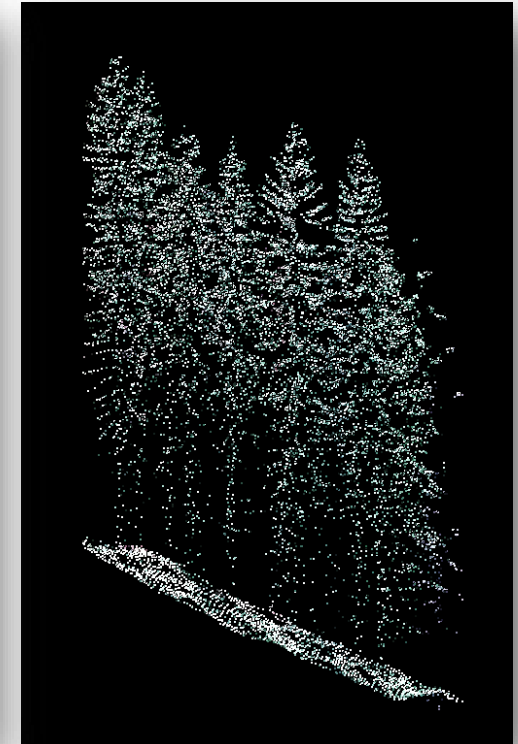
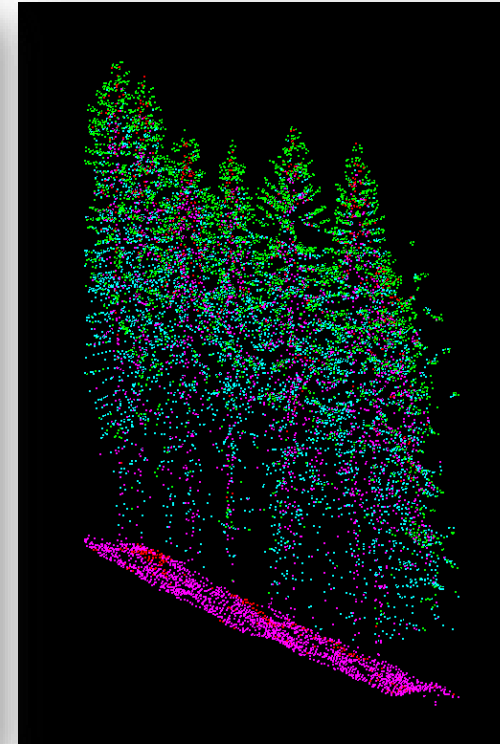
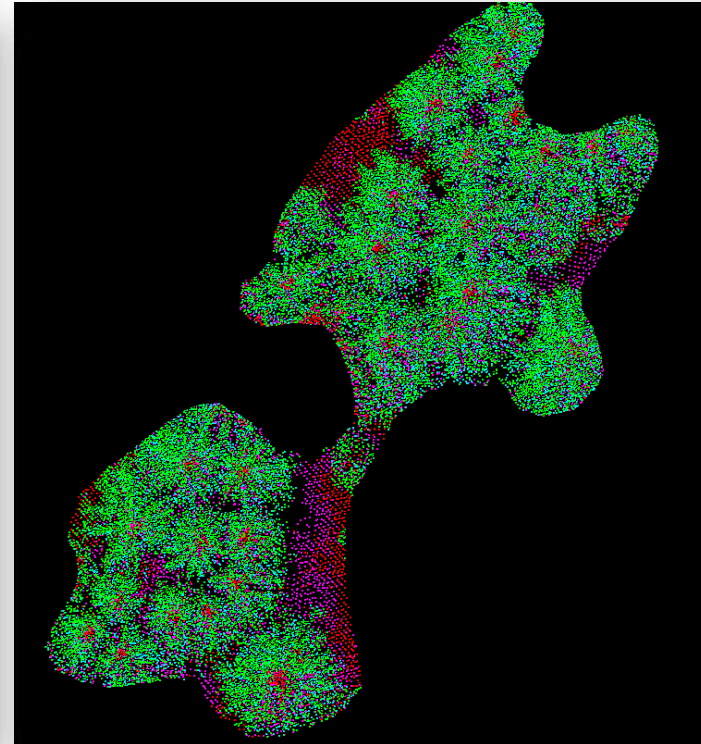
- Jest bezpłatna; zawiera mapę topograficzną i satelitarną oraz warstwę szlaków w TPN i GPN do użytku online i offline;
- Ostrzega przed niebezpiecznymi miejscami na szlaku (dźwięki lub alerty), pokazuje obszary zagrożenia;
- Informuje o aktualnej pozycji (współrzędne GPS), które szybko można wysłać jako SMS, e-mail do znajomych lub TOPR;
- Umożliwia przekazanie informacji o zdarzeniach niebezpiecznych na szlaku i wezwanie pomocy; umożliwia robienie zdjęć; opisy zawierają ogólne informacje na temat bezpieczeństwa w górach oraz telefony alarmowe.





# ALS LiDAR very dense point cloud - case study 2018

## Echo (Return) visualisation – TerraScan (Terrasolid)



CIR orthophoto 10cm GSD



ALS Echo (TOP)

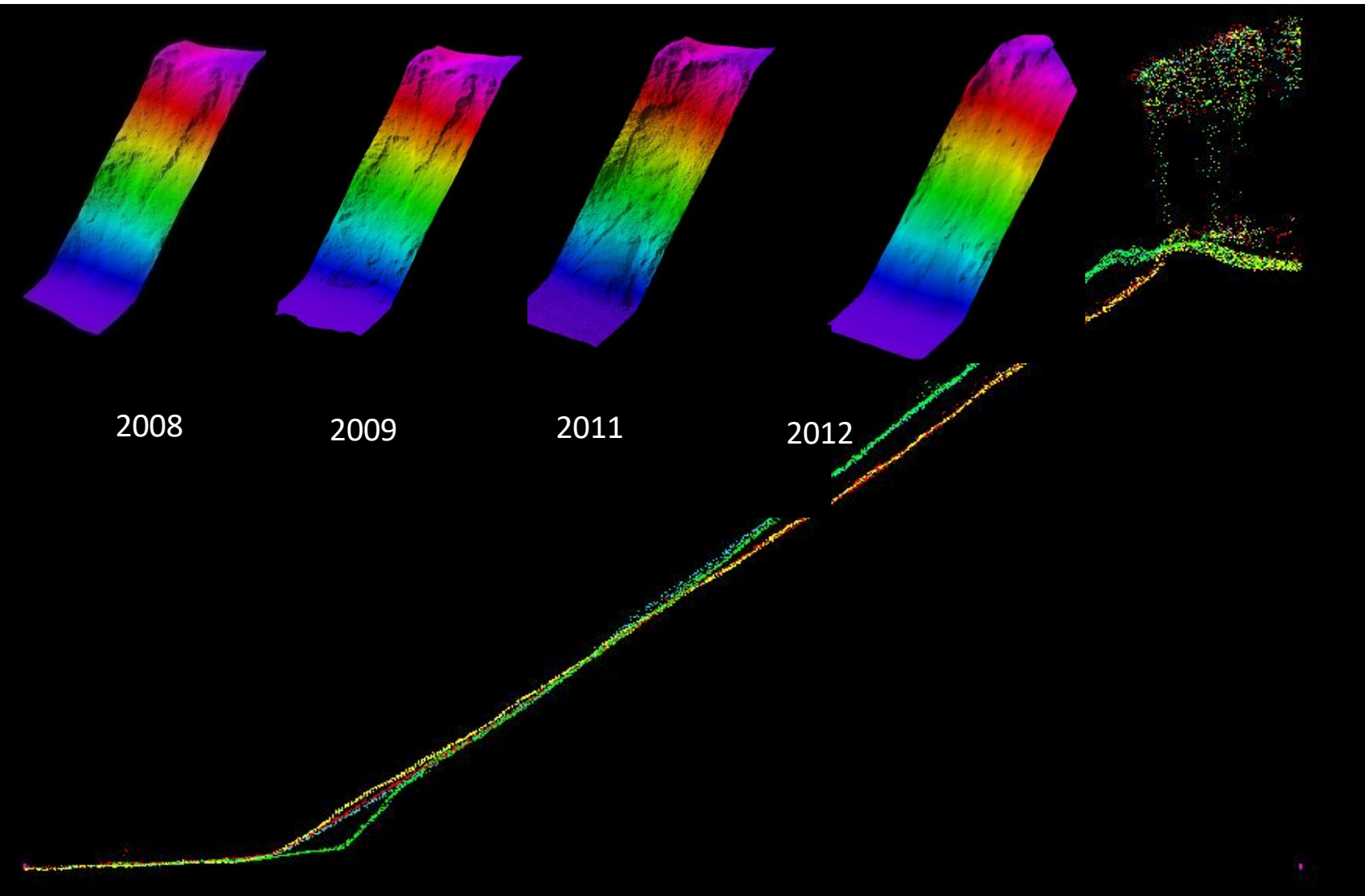
ALS Echo (cross-section)

ALS Intensity

The loss of the assimilation apparatus by dying spruce trees causes a greater penetration of the laser beam through the tree crowns and thus a greater number of indirect reflections (echoes) before the laser beam reaches the ground. This feature allows for better detection of places with increased density (richer structure of laser-illuminated branches)



# ALS LiDAR i monitoring 4D NMT Woliński PN

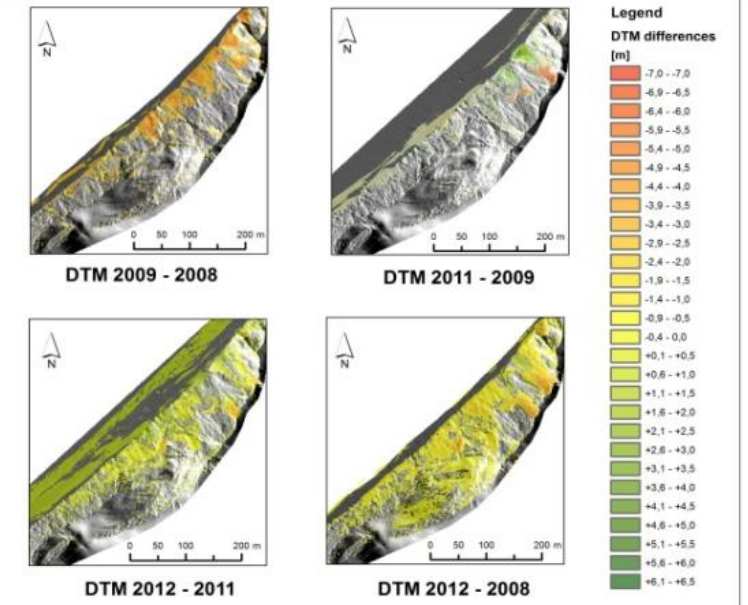
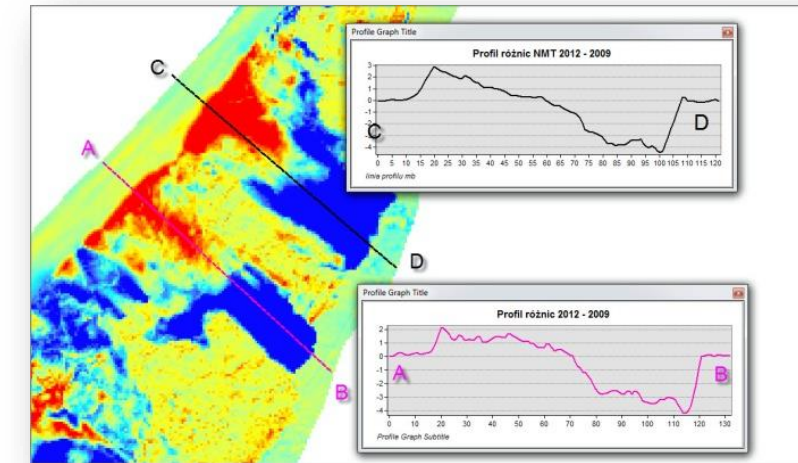


2008

2009

2011

2012



*Dudzińska-Nowak J., Wężyk P., 2013*

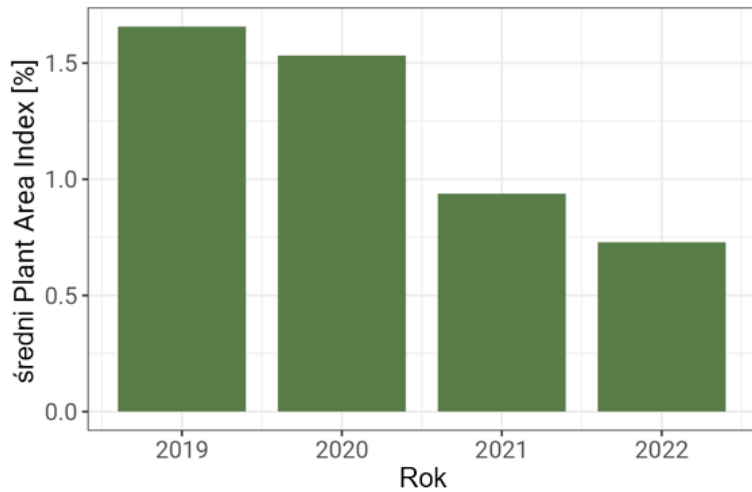


# LiDAR SLS – GEDI (NASA) – Tatrzański PN

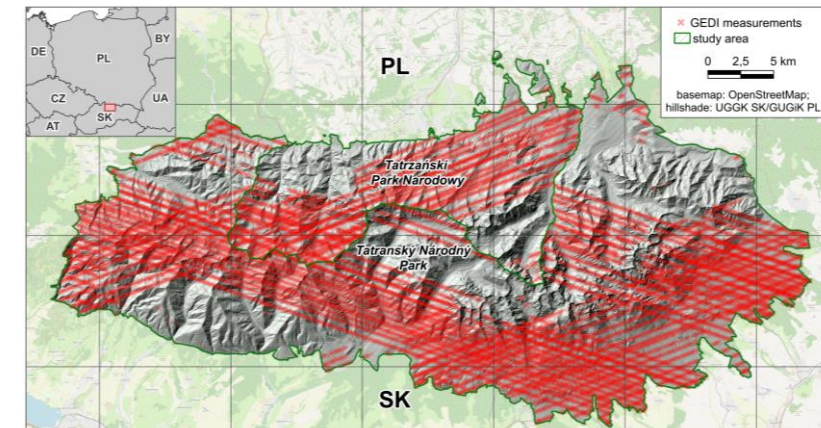
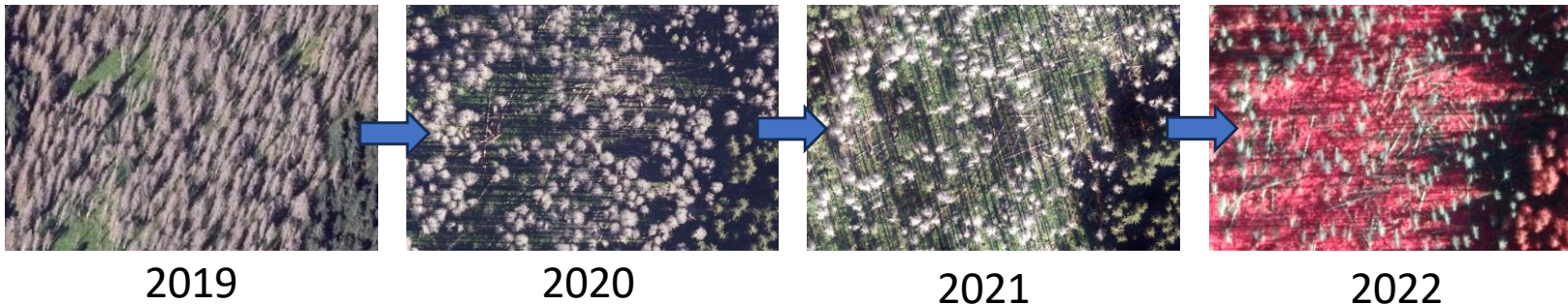
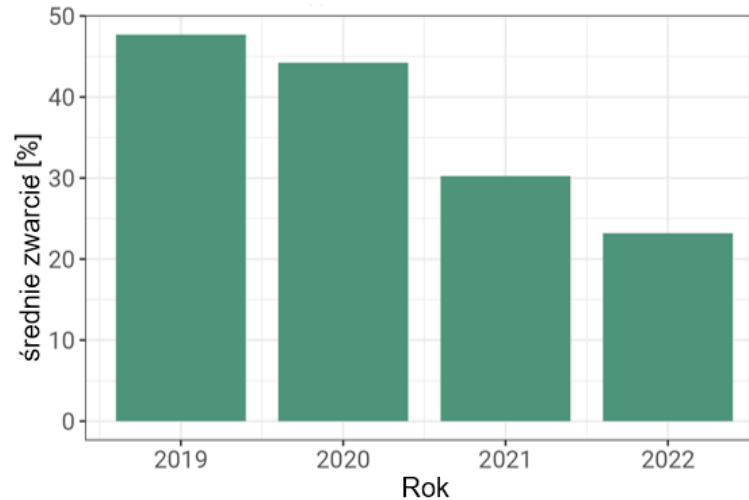


Pomiary SLS GEDI NASA w monitorowaniu dynamiki rozpadu świerczyn w TPN – mgr inż. W. Krawczyk (doktorat)  
Spadek wartości parametrów struktury poziomej pionowej **martwych d-stanów** w serii czasowej pomiarów GEDI.

Seria czasowa pomiarów GEDI - wskaźnik Plant Area Index



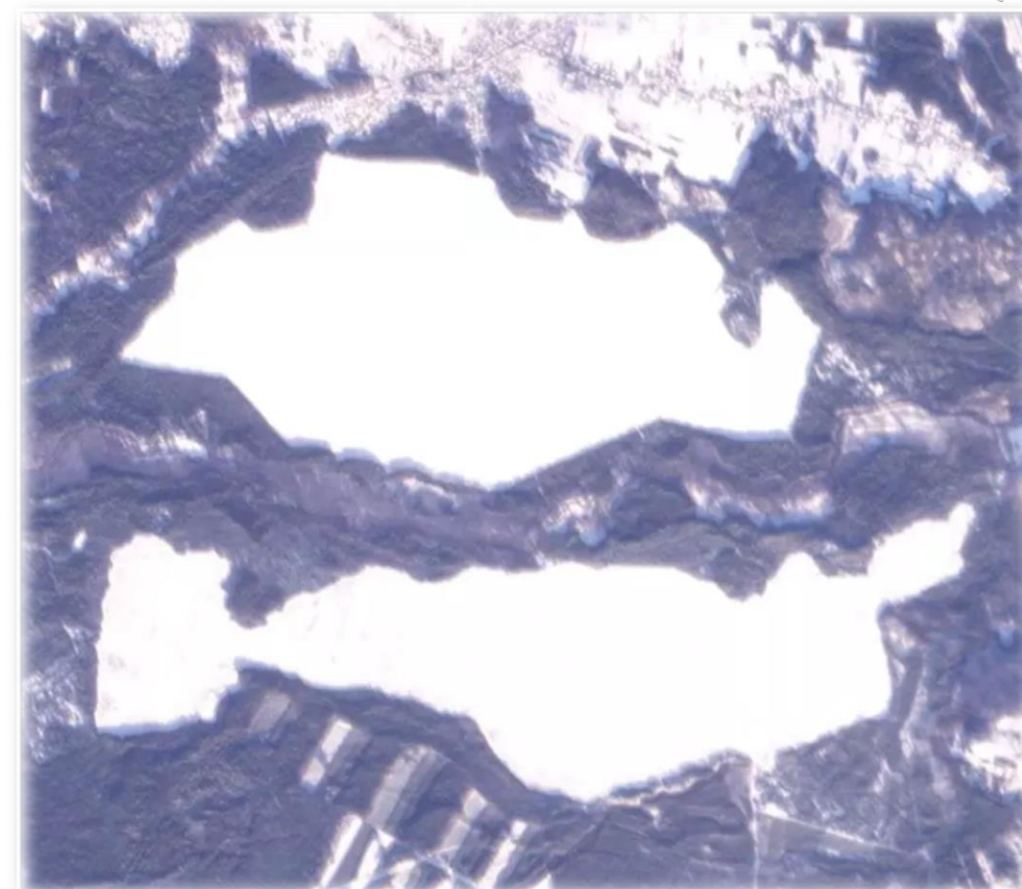
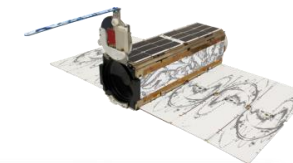
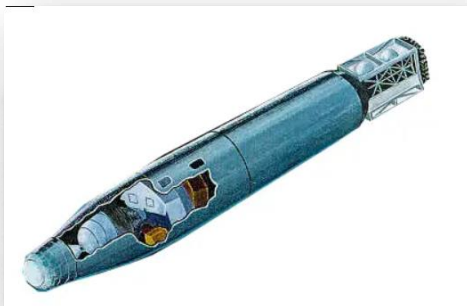
Seria czasowa pomiarów GEDI – zwarcie poziome





# Teledetekcja satelitarna 2D

## CORONA KH-9 Pustynia Błędowska 1974

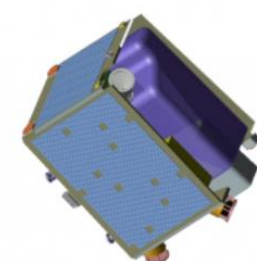


**PlanetScope Super Dove 10.01.2024**



# Teledetekcja satelitarna 2D - RapidEye

## CORONA KH-9 Pustynia Błędowska 1974



QUAESTIONES GEOGRAPHICAE 55(3) • 2016

**MONITORING THE SECONDARY FOREST SUCCESSION AND LAND COVER/USE CHANGES OF THE BŁĘDÓW DESERT (POLAND) USING GEOSPATIAL ANALYSES**

MARTA SZOSTAK, PIOTR WĘZYK, PAWEŁ HAWRYŁO, MARTA PUCHAŁA  
 Institute of Forest Resources Management, University of Agriculture in Krakow, Poland

Manuscript received: November 27, 2015  
 Revised version: May 23, 2016

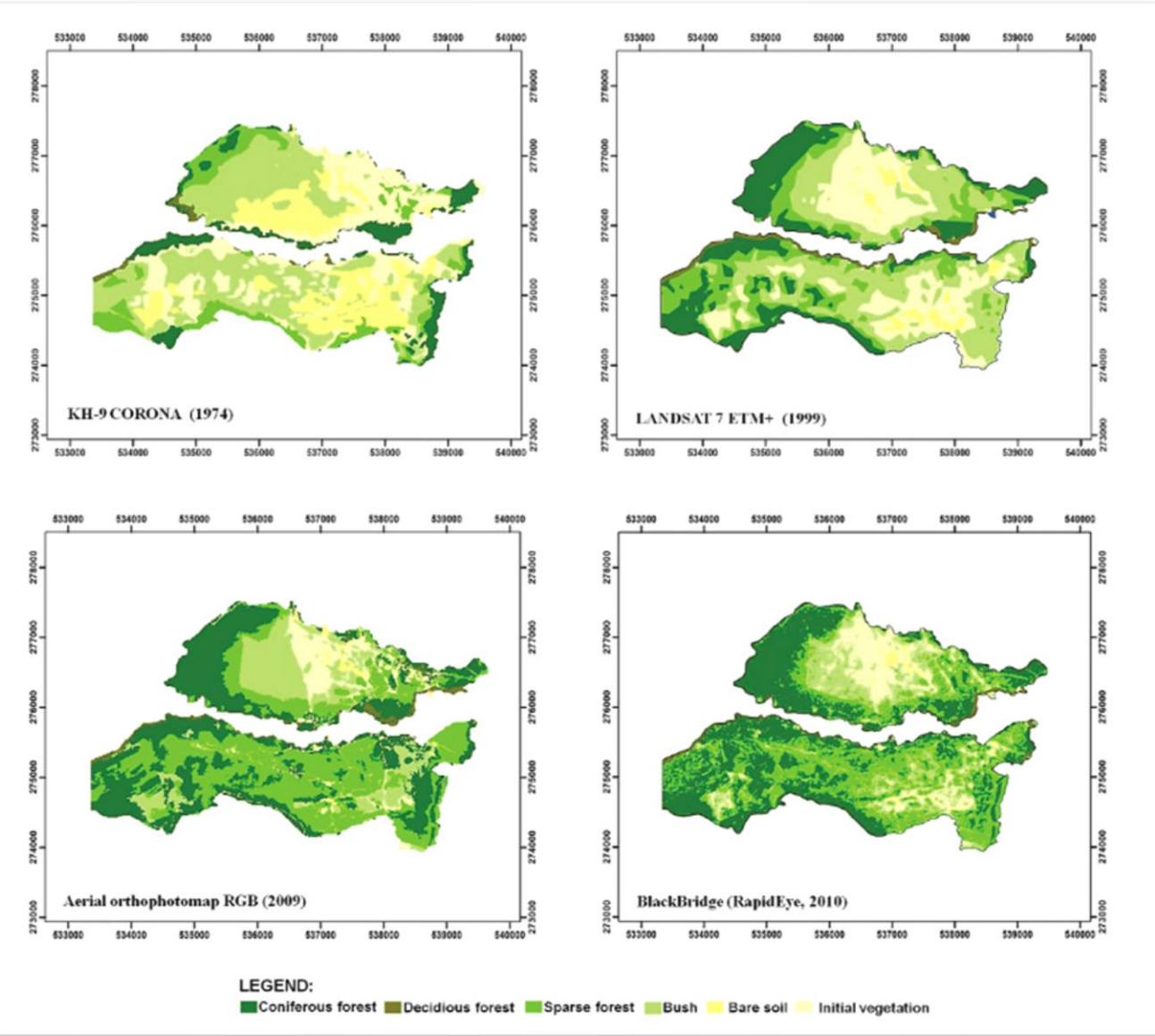
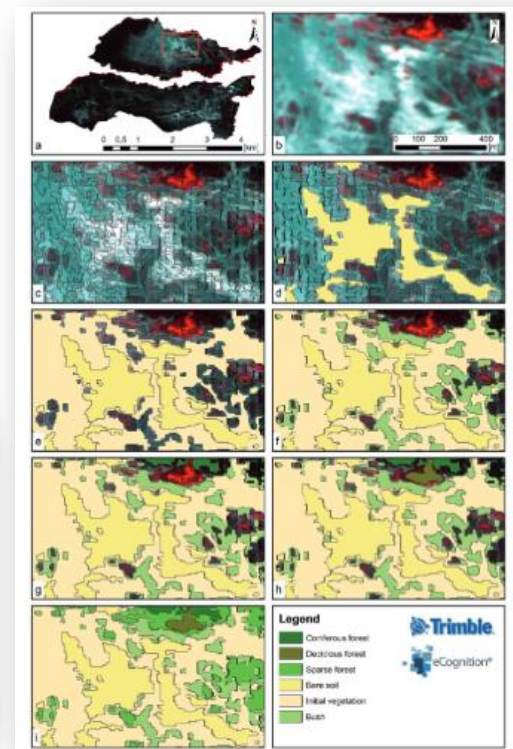


Table 1. The distribution of LULC classes in the test area.

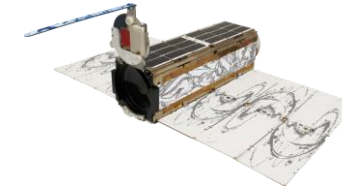
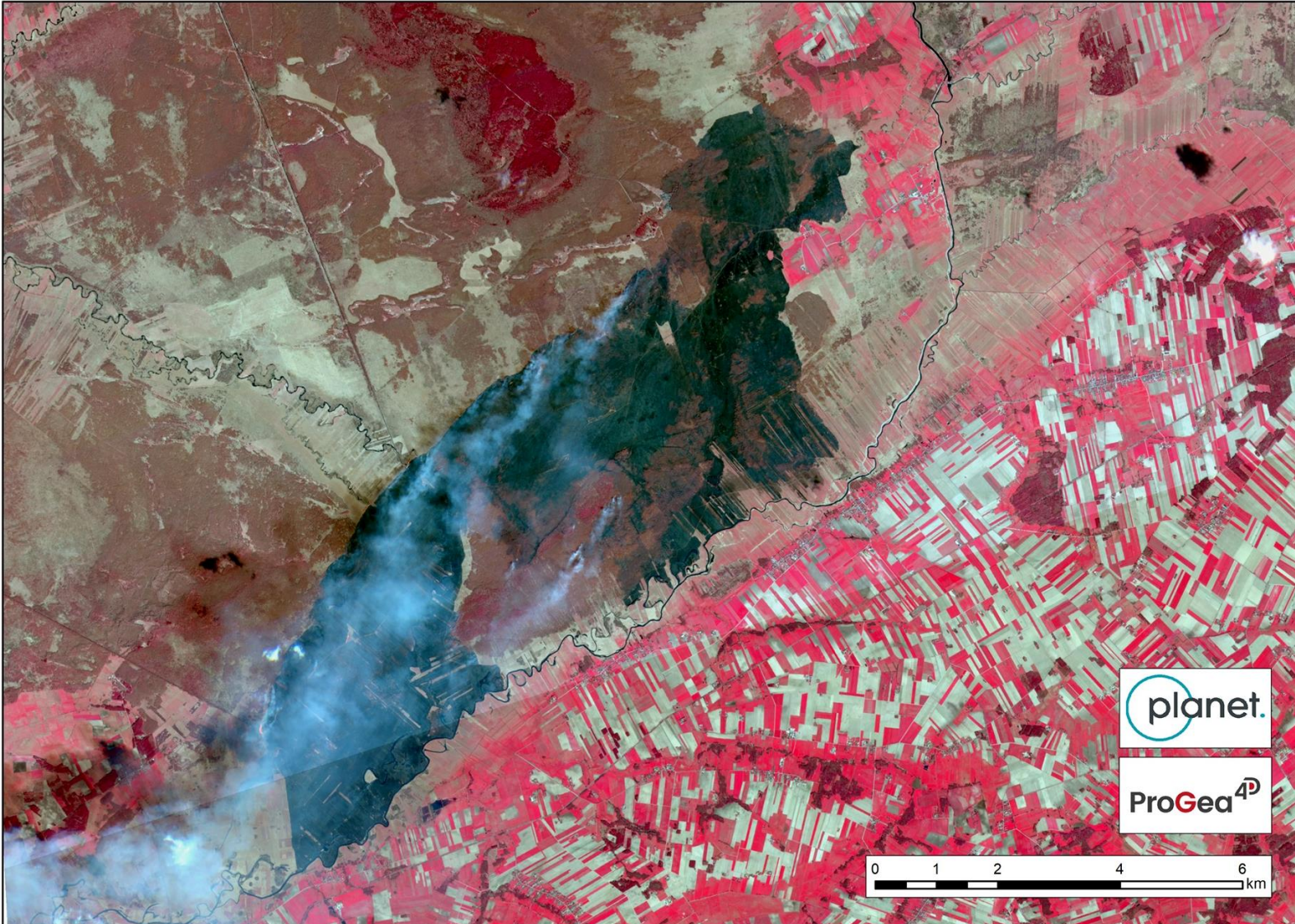
Method	Photointerpretation and on-screen vectorization								Image classification			
	KH-9 (1974)		LANDSAT 7 (1999)		ORTHO/RapidEye (2009/2010)		LULC changes		RapidEye GEOBIA (2010)		RapidEye pixel-bas.c.l. (2010)	
	[ha]	%	[ha]	%	[ha]	%	1974 -2009/10	1999 -2009/10	[ha]	%	[ha]	%
Coniferous forest	126.3	10.4	258.4	21.3	402.9	33.3	22.9	12.0	406.5	33.5	464.2	38.4
Deciduous forest	14.4	1.2	35.3	2.9	28.8	2.4	1.2	-0.5	41.3	3.4	22.2	1.8
Sparse forest	187.2	15.5	206.9	17.1	468.9	38.7	23.2	21.6	390.1	32.2	369.7	30.5
Bush	369.6	30.5	398.4	32.9	191.4	15.8	-14.7	-17.1	203.8	16.9	215.6	17.8
Initial vegetation	280.0	23.1	272.8	22.5	105.5	8.7	-14.4	-13.8	145.0	12.0	126.8	10.5
Bare soil	233.0	19.3	38.7	3.2	13.0	1.1	-18.2	-2.1	23.9	2.0	12.0	1.0
Test area	1210.5 ha / 100%											



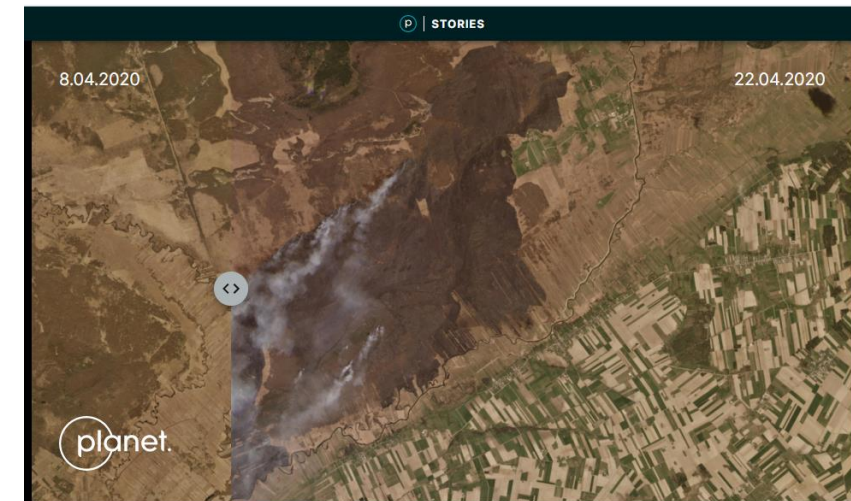


# Teledetekcja satelitarna HRS - Monitoring 2D

## Pożar w Biebrzańskim PN – 04.2020



<https://www.planet.com/stories/pozar-lak-w-biebrzanskim-parku-narodowym-kwiecien--SqaybL3Zg>



**Pożar łąk w Biebrzańskim Parku Narodowym - kwiecień 2020**  
by Piotr Weżyk

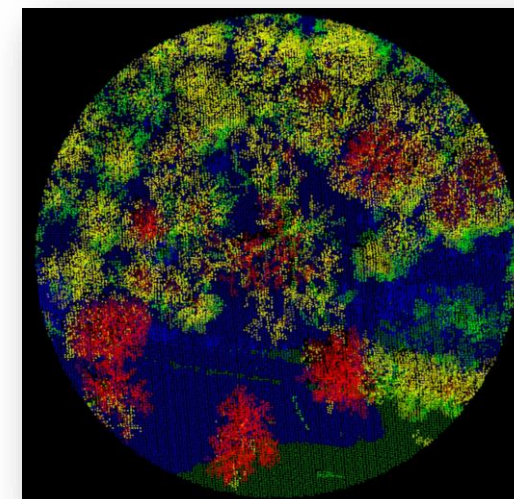
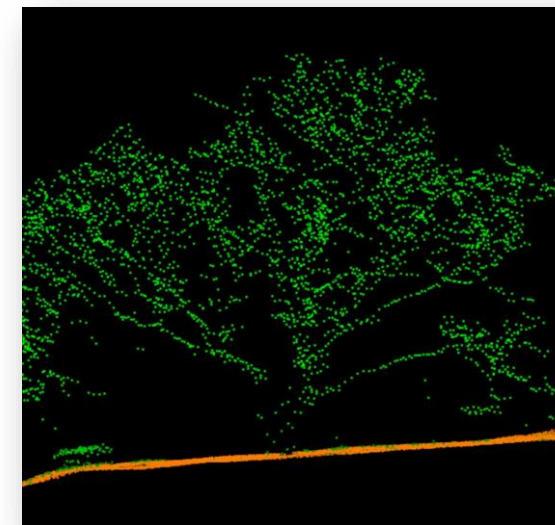
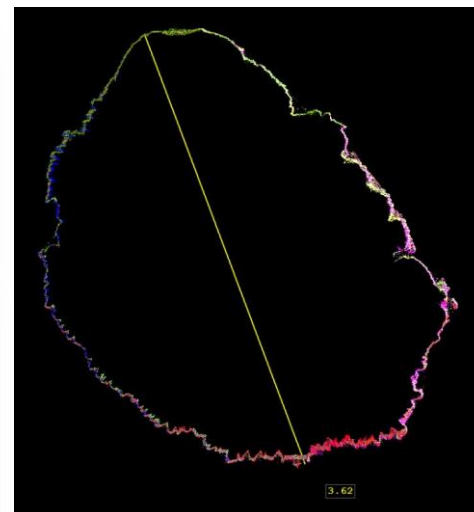
Published on Apr 23, 2020

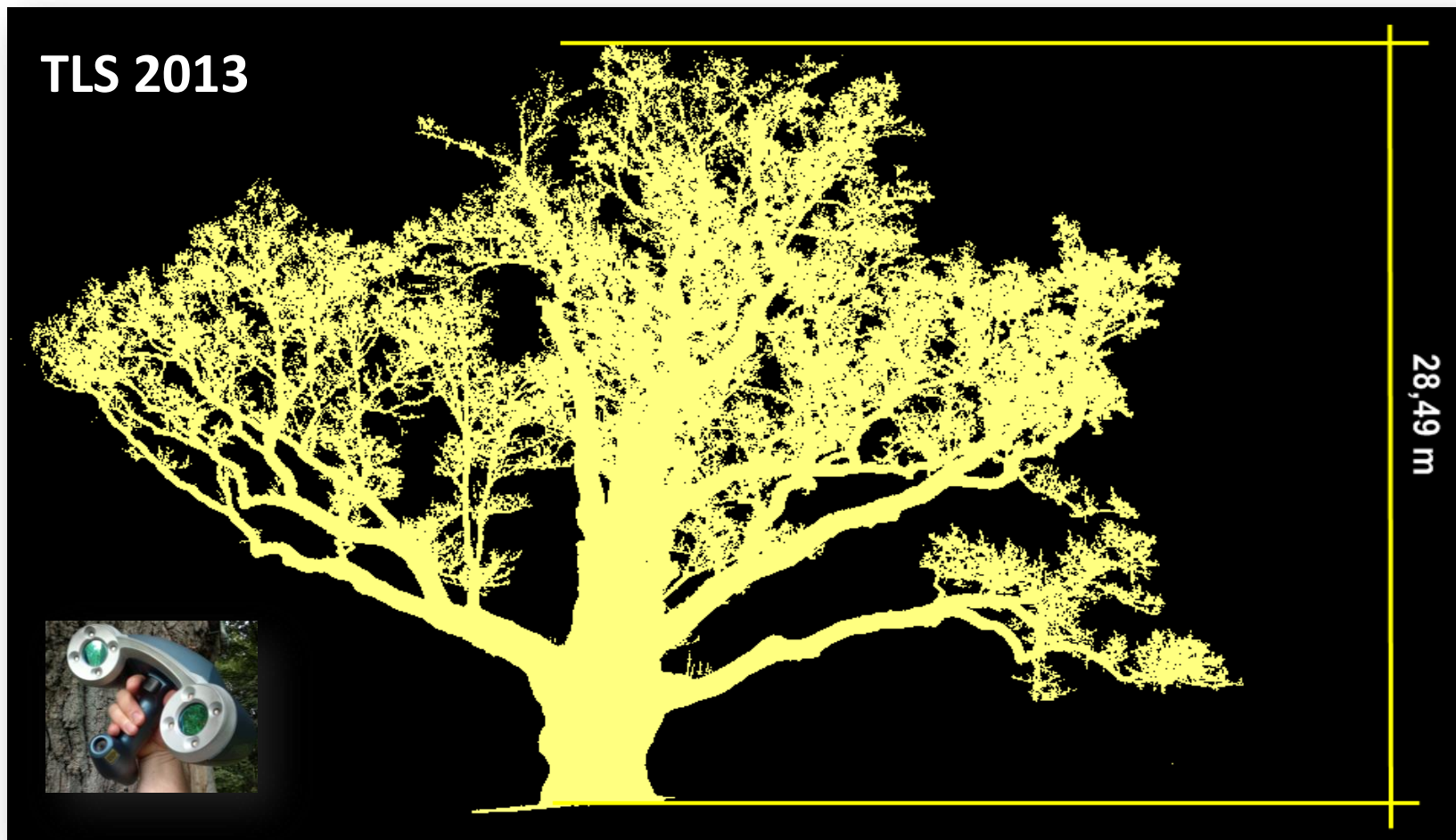
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pożar trwał do 19-22.04.2020



# Dąb Bartek 3D w Zagnańsku – TLS LiDAR





Height of tree from the point cloud TLS  $H = 28.49$  m  
(-1, 51 m lower then official data 30.0 m)

Vertex H altimeter measurement = **29.31 m** (+ 0.82 m higher then TLS)



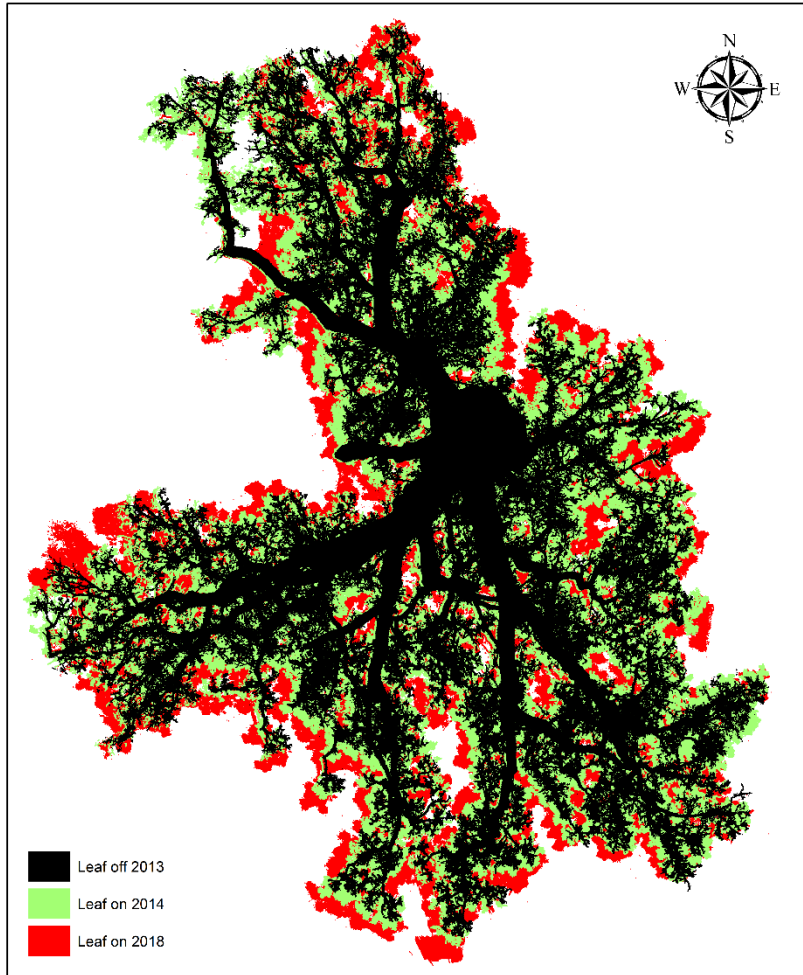
# Dąb Bartek 3D w Zagnańsku – TLS LiDAR





# Dąb Bartek 3D w Zagnańsku – TLS LiDAR

## Monitoring powierzchni rzutu korony 2013-2018



Date	Scanner type	Crown area [m <sup>2</sup> ]	Difference	
			[m <sup>2</sup> ]	[%]
19.04.2013	FARO Focus <sup>3D</sup>	243,46	Ref.	Ref.
02.07.2013	FARO Focus <sup>3D</sup>	401,55	+158,09	64,93
22.04.2014	FARO Focus <sup>3D</sup>	208,01	-35,45	-14,56
21.10.2014	Riegl VZ-400	380,39	+136,93	56,25
19.03.2016	FARO Focus <sup>3D</sup>	345,53	+102,07	41,92
01.08.2018	FARO Focus <sup>3D</sup>	496,58	+253,12	103,97



# TLS LiDAR - Dąb Bartek 3D w Zagnańsku

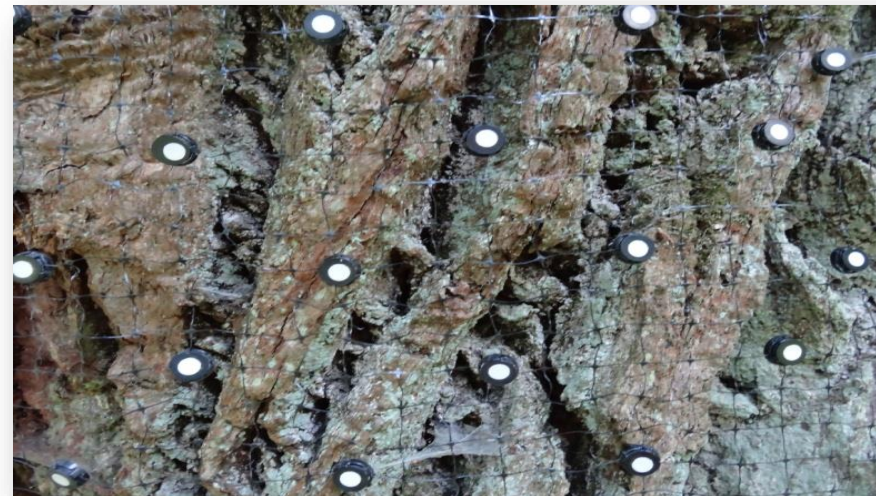
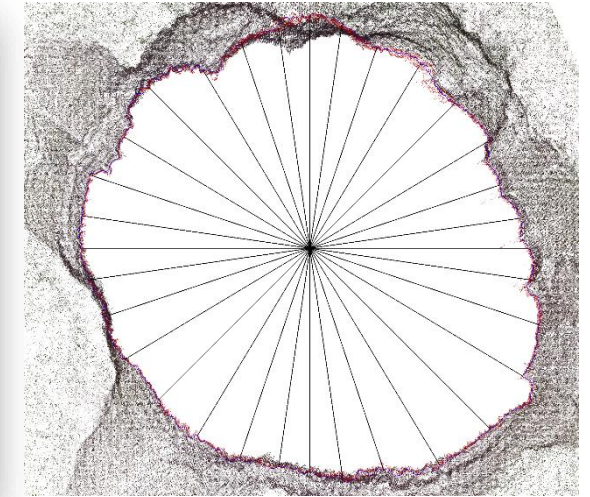
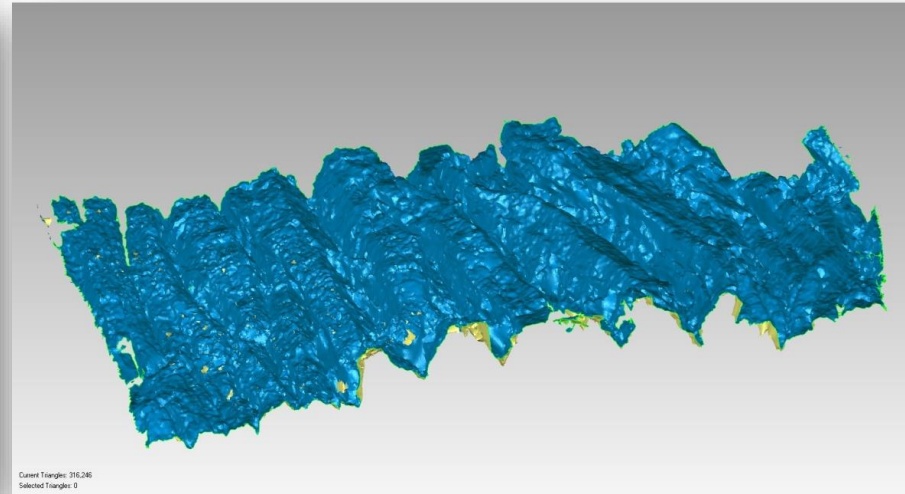


3D STL Model of Oak „Bartek” LEAF-OFF (left) and LEAF-ON (right)



# HLS - Monitoring 4-D

## HLS (Hand-Held) RevScan scanner July 2013





# TLS LiDAR - Dąb Bartek 3D & Dąb Józef – modele STL/OBJ i wydruk 3D

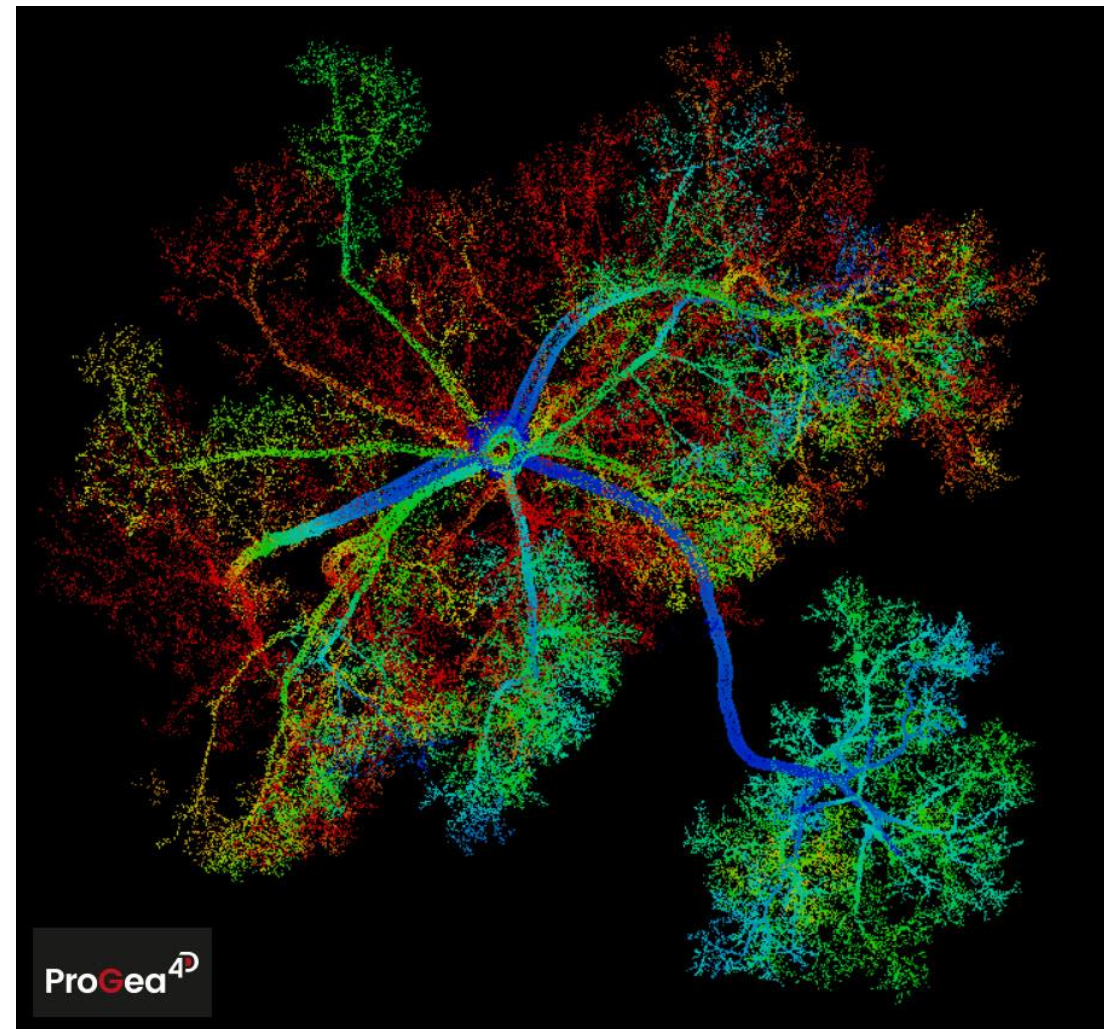
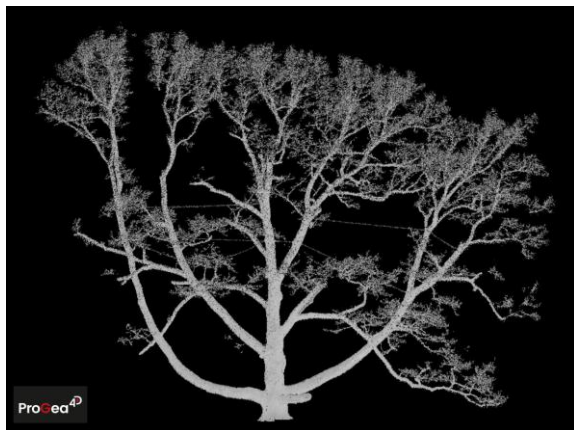


**Dąb Józef** - dąb szypułkowy (*Quercus robur* L.) - Europejskie Drzewo Roku 2017 rośnie na terenie zespołu parkowo-dworskiego w Wiśniowej w województwie podkarpackim. Dąb jest częścią wieloobiektowego pomnika przyrody (kod INSPIRE: PL.ZIPOP. 1393.PP.1819052.1647), ustanowionego w 1954 roku, który tworzy grupa sześciu drzew. Wysokość 30 metrów, pierśnica 215 cm, obwód 675 cm, szacowany wiek 650 lat





# TLS LiDAR - Dąb Fabrykant w Łodzi Drzewo Roku 2023





# Park Narodowy Bory Tucholskie

## Aktywna ochrona chrobotków - 2018



(c) Michał Węgrzyn

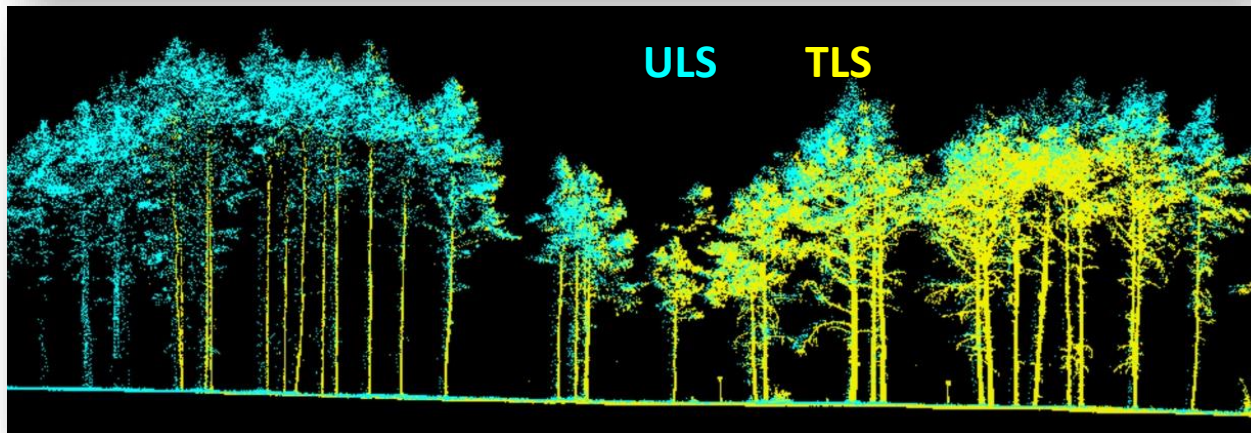
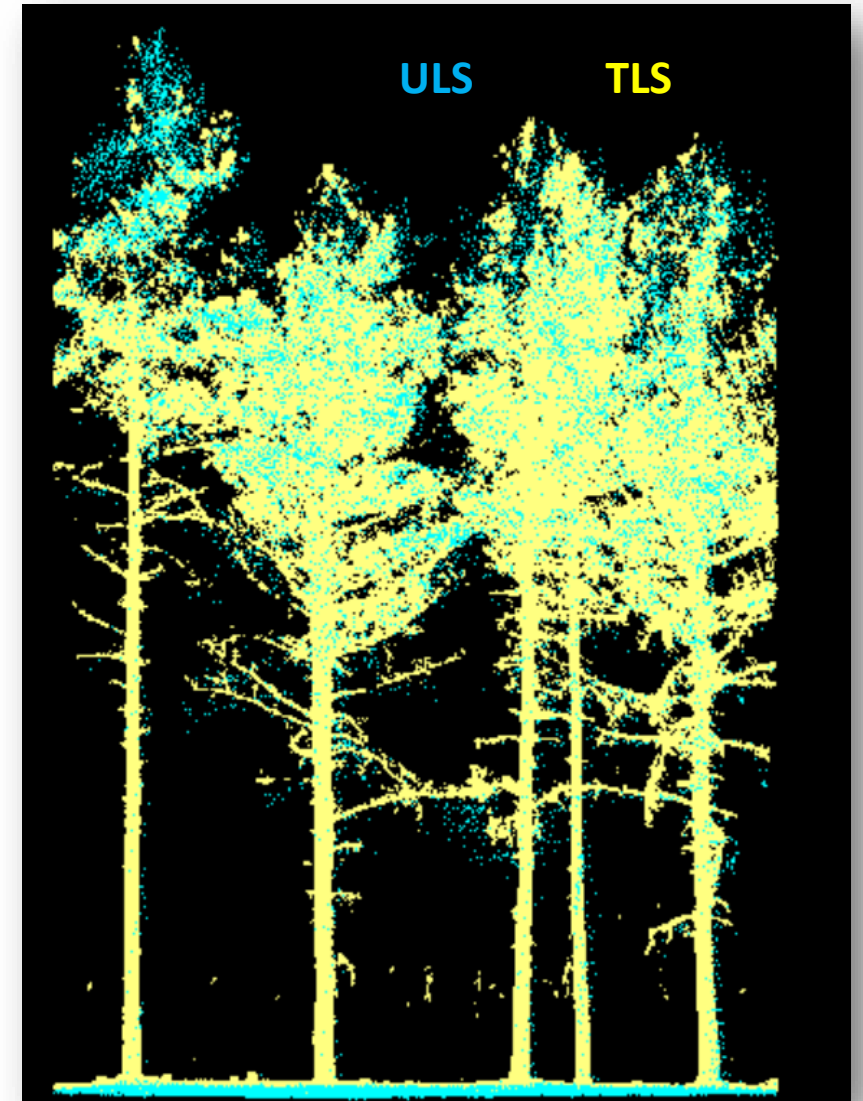
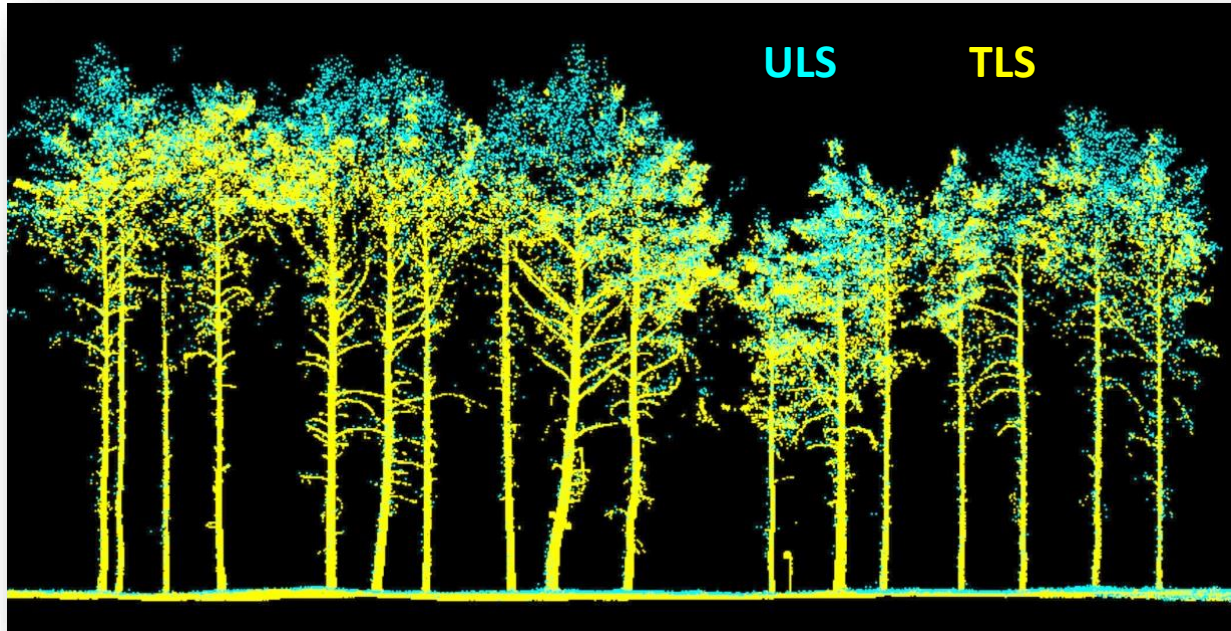
28





# Integracja TLS & ULS - PNB

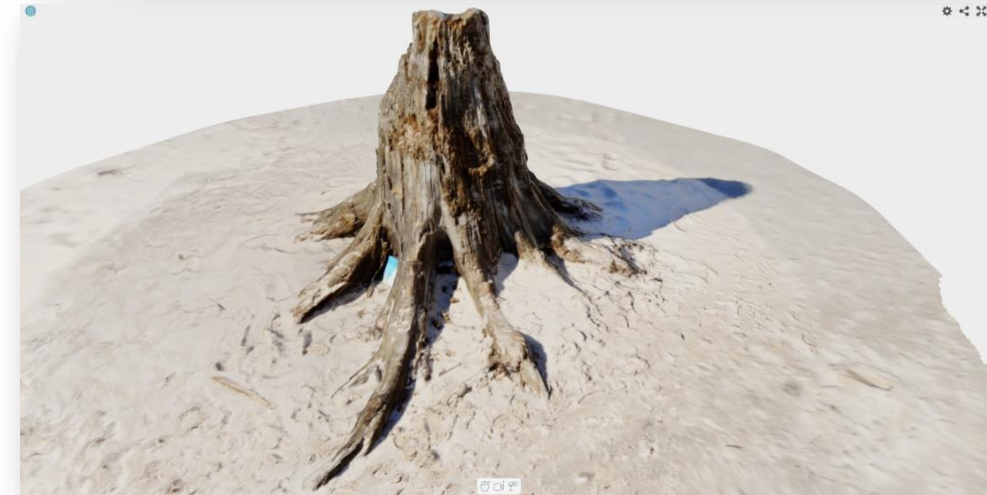
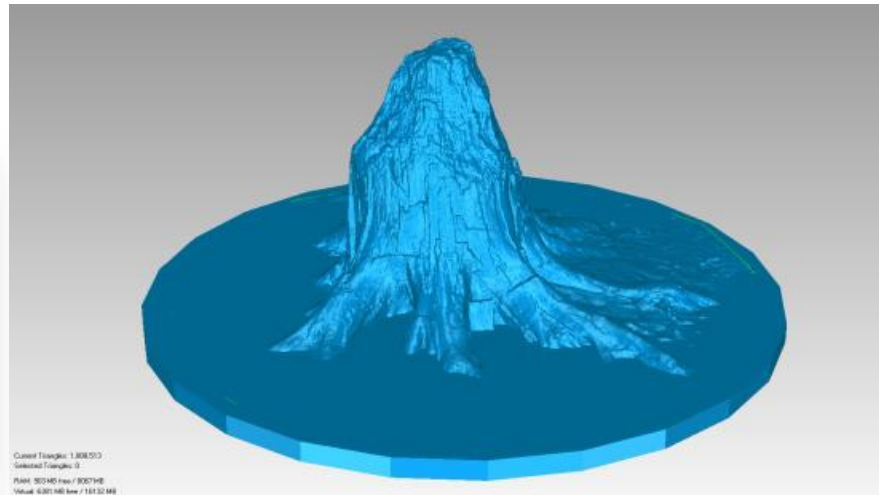
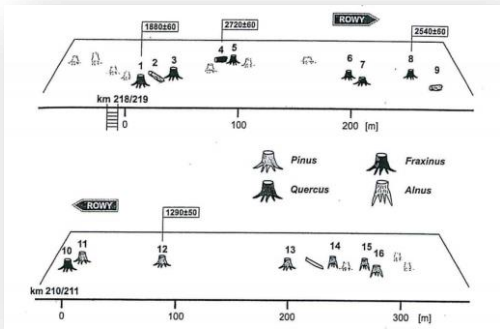
## Aktywna ochrona chrobotków - 2018



ULS (blue) & TLS (yellow) point clouds



# TLS LiDAR - Las fosylny 3D w Słowinskim PN





# TLS LiDAR - Inwentaryzacja drewna martwego w Rezerwacie Lipówka (Puszcza Niepołomska) rok 2006



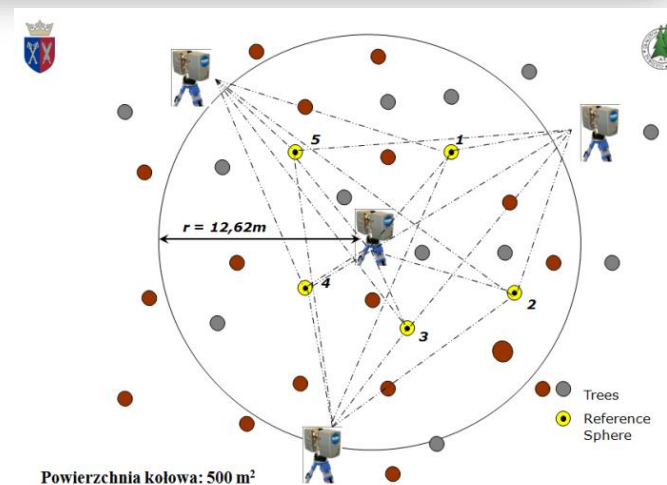
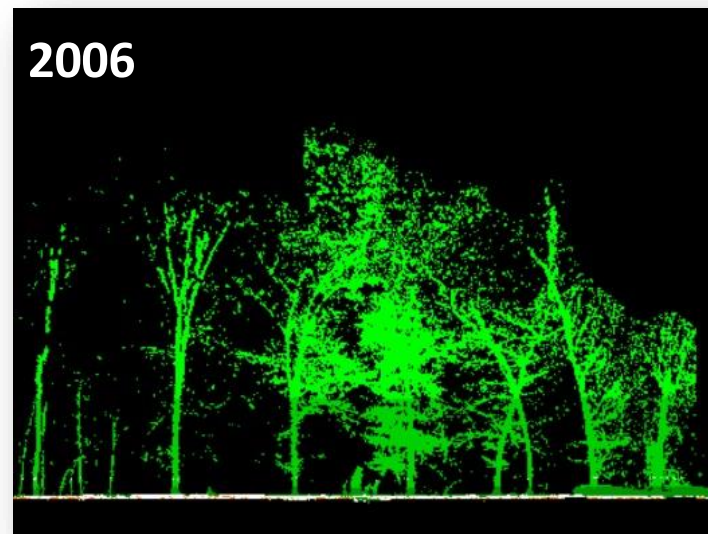
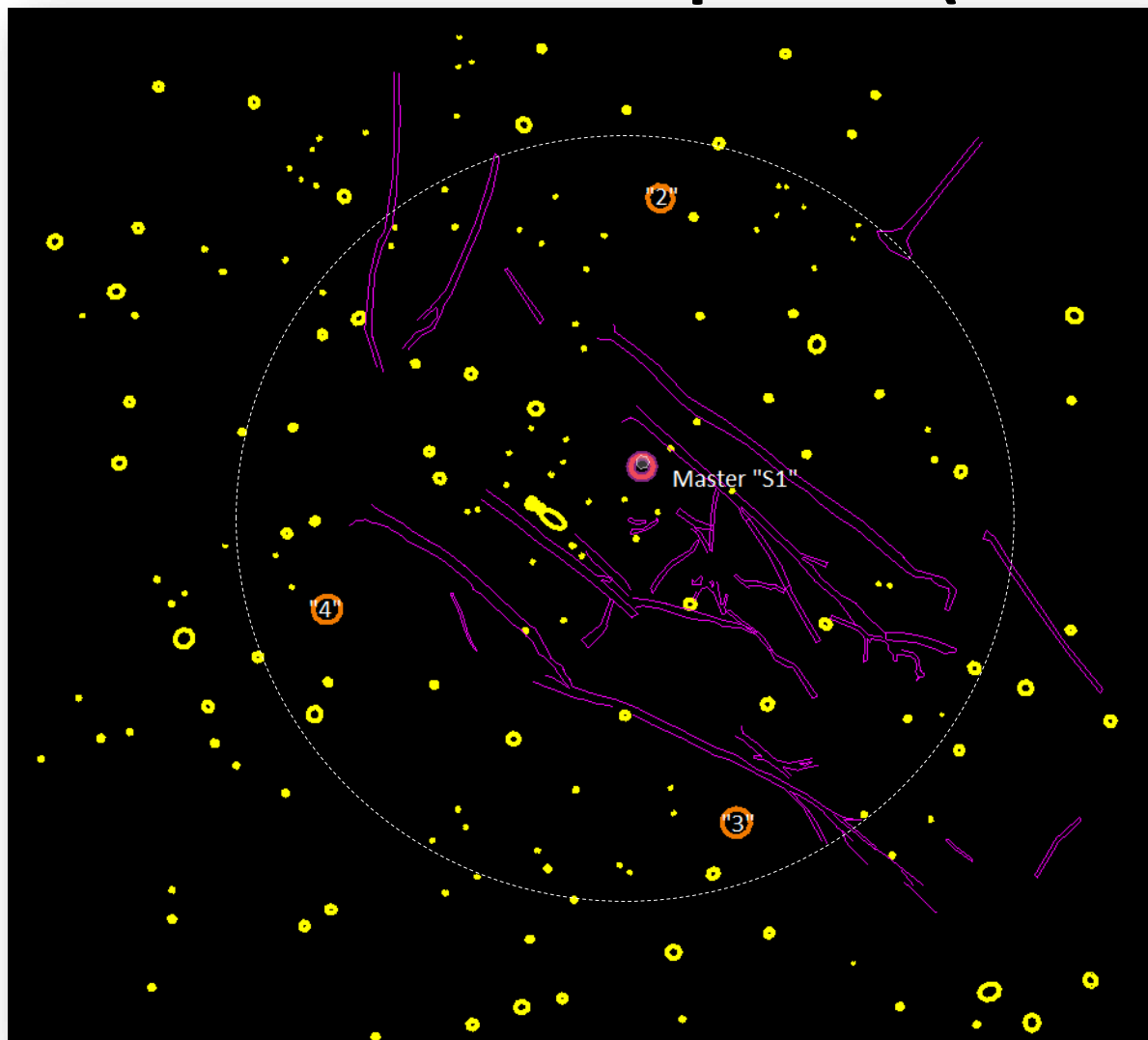
**TLS 2006**  
**Scanner Faro LS 880**



**TLS 2016**  
**Scanner Faro FOCUS 3D**



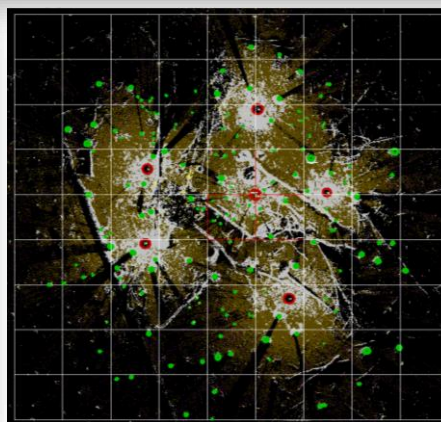
# TLS LiDAR - Inwentaryzacja drewna martwego w Rezerwacie Lipówka (Puszcza Niepołomska) rok 2006

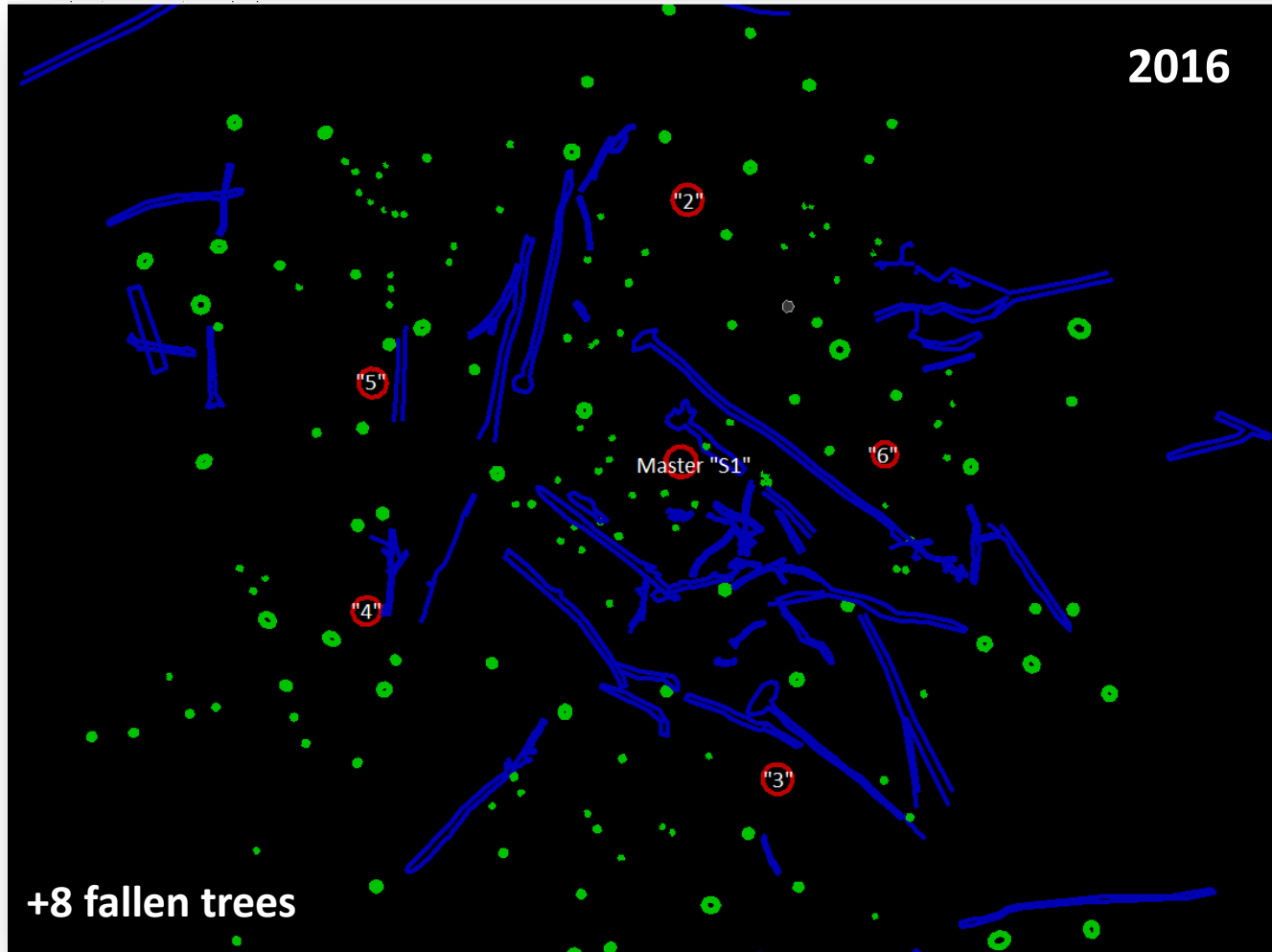


TLS 2006 - tree trunks (yellow); dead wood / logs (purple), scanner positions (orange)

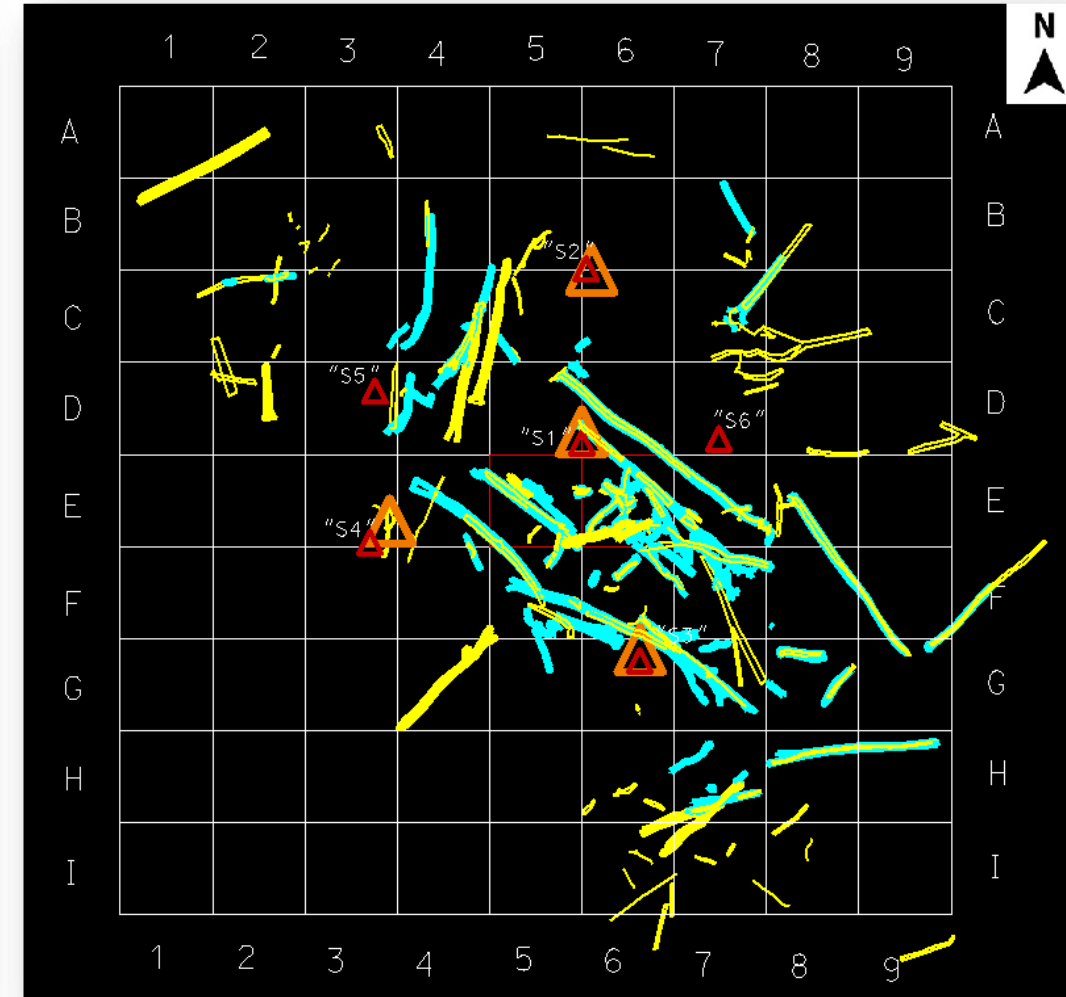


# TLS LiDAR - Rezerwat Lipówka rok 2016



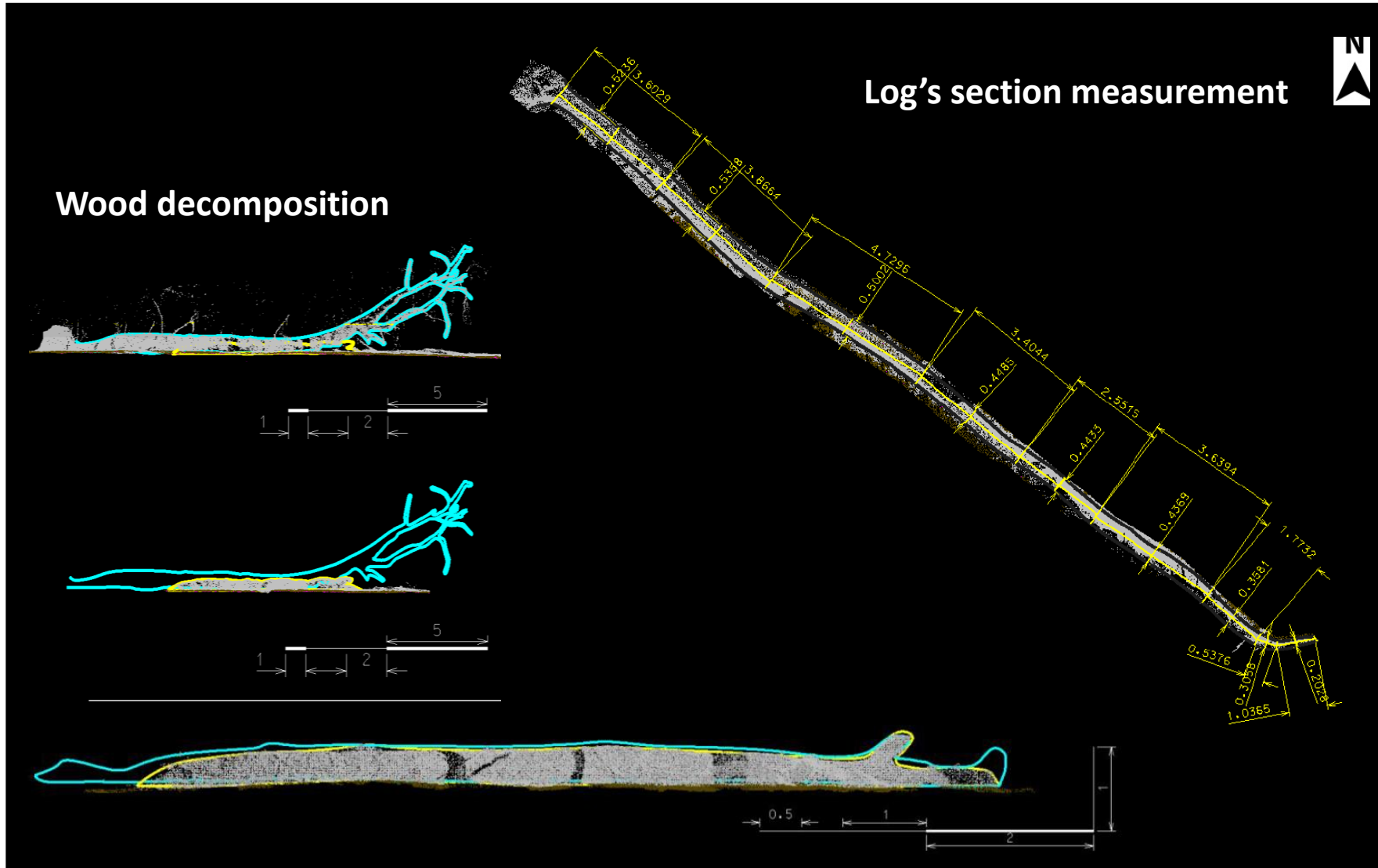


TLS 2016 – trees (green); dead wood / logs (blue); scanner stations (red)



Leżące kłody w 2006 (kolor niebieski)  
Leżące kłody w 2016 (kolor żółty)





The amount of dead wood in period 2006-2016 has increased from **31.7 m<sup>3</sup>** to **51.8 m<sup>3</sup>** (> 60%).



# Methods: HLS LiDAR (ZEB HORIZON) SLAM 15.11.2019





# TLS LiDAR – 4D dead wood monitoring – Lipówka Reserve





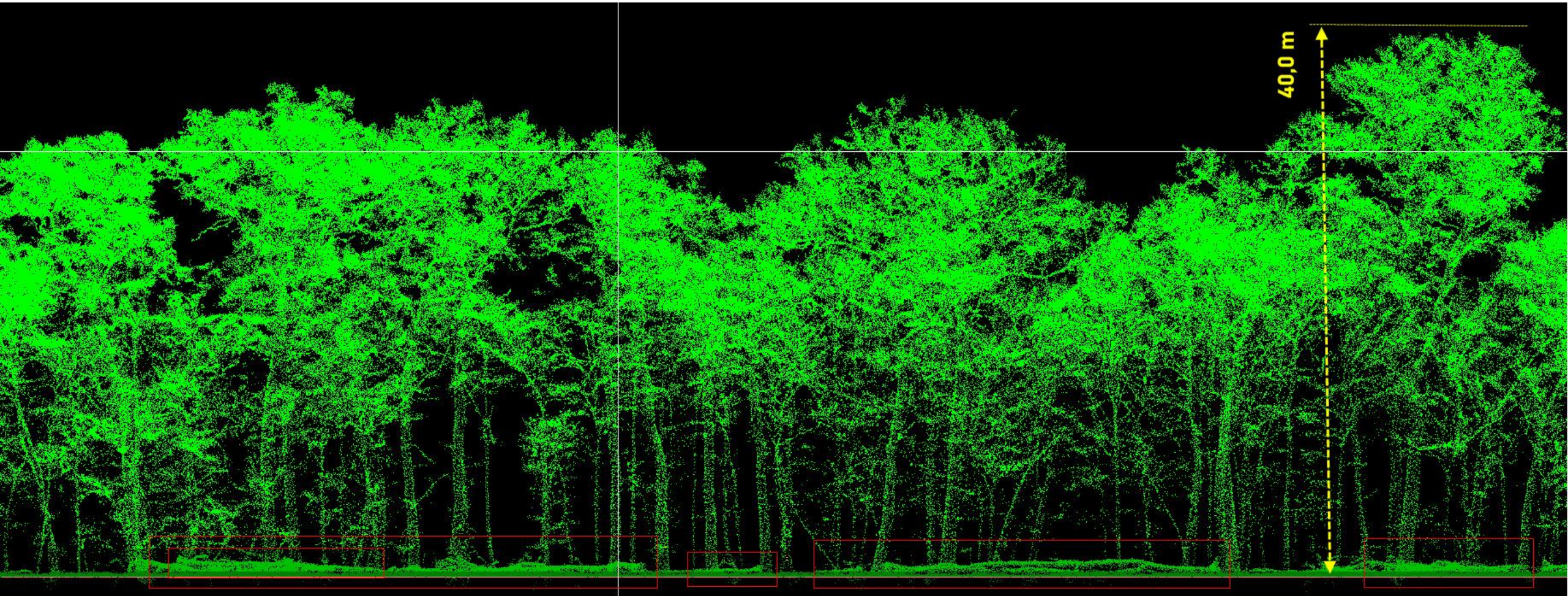
# MHLS - ZEB Horizon



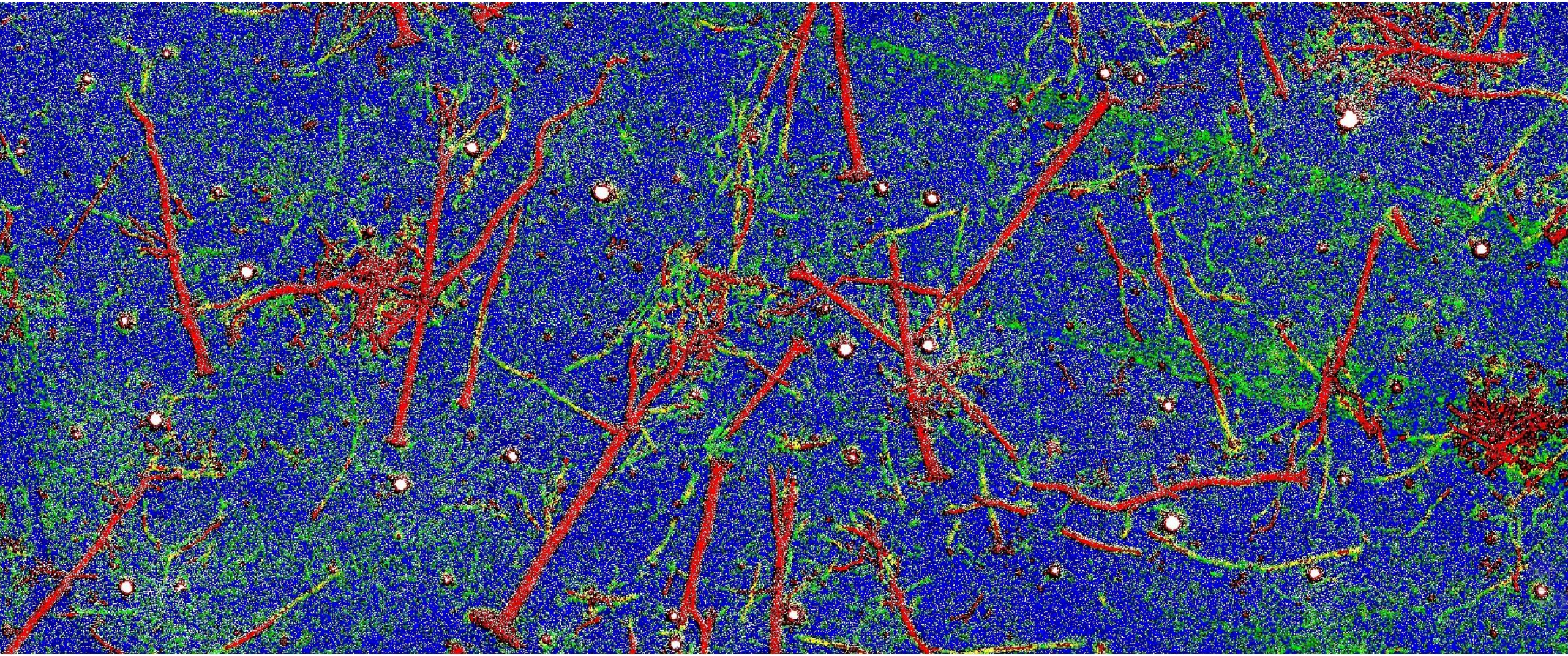


# ALS LiDAR (RIEGL VQ780i )

## LEAF-OFF period (Nov. 2020) – reference point cloud



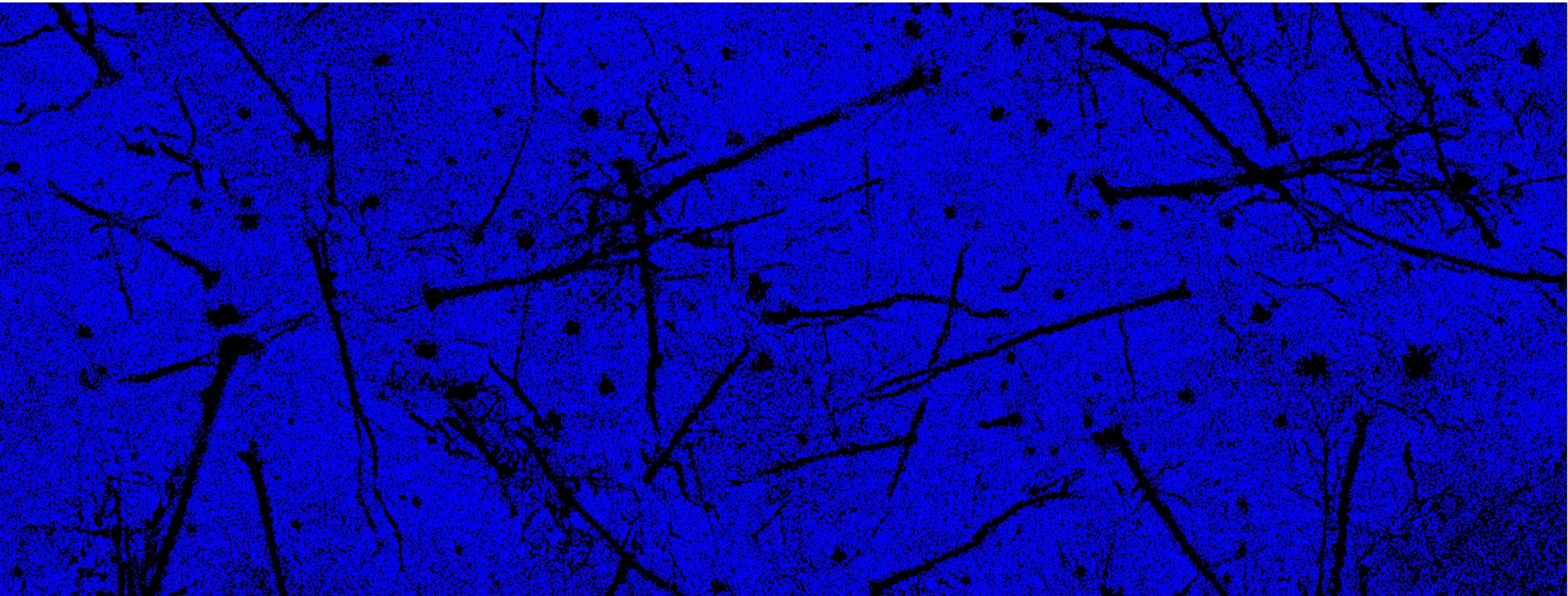
**ALS dense point cloud. Mean density: 560 pts/m<sup>2</sup> (all points). Tree height up to 40.0 m**



**ALS dense point cloud – mean density : 560 pts/m<sup>2</sup> of all points (120 pts/m<sup>2</sup> ground class)**



# Methods: Alignment(point pairs picking)

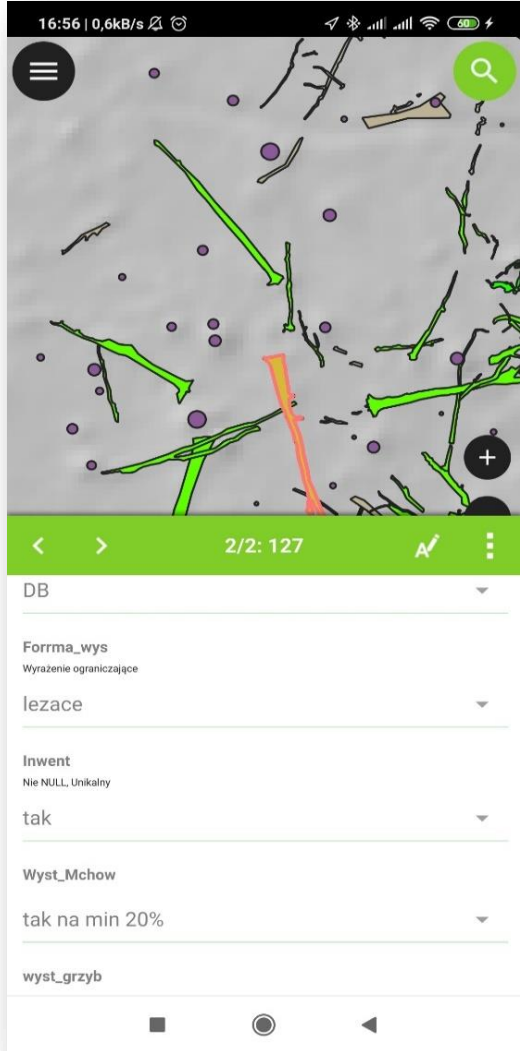


**ALS Class ground (2) in blue. The missing points (black areas) are shadows from lying dead wood logs.**

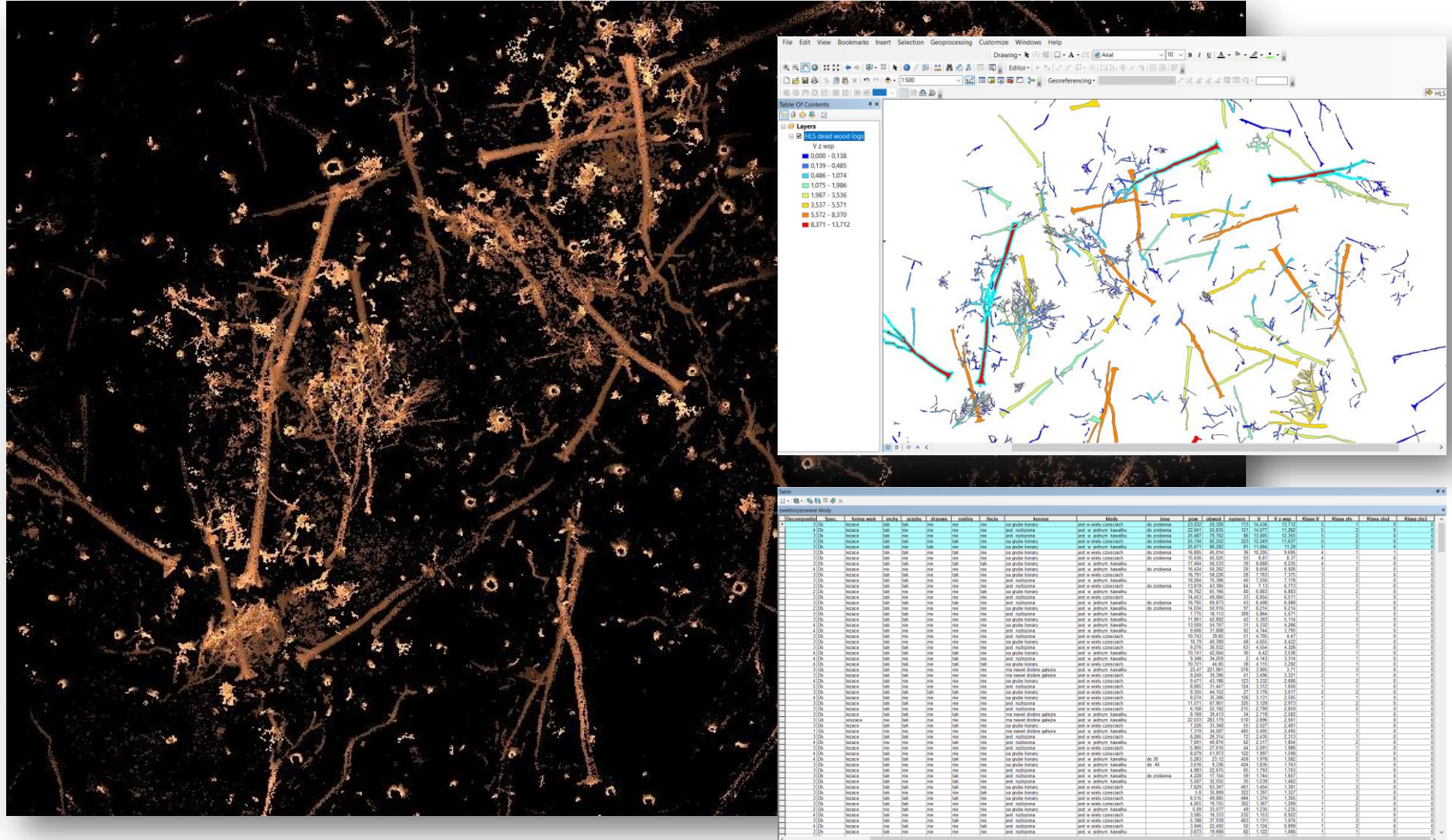


# Methods: Mapping the logs

## QFiled (OpenGIS.ch) – Mobile GIS solution



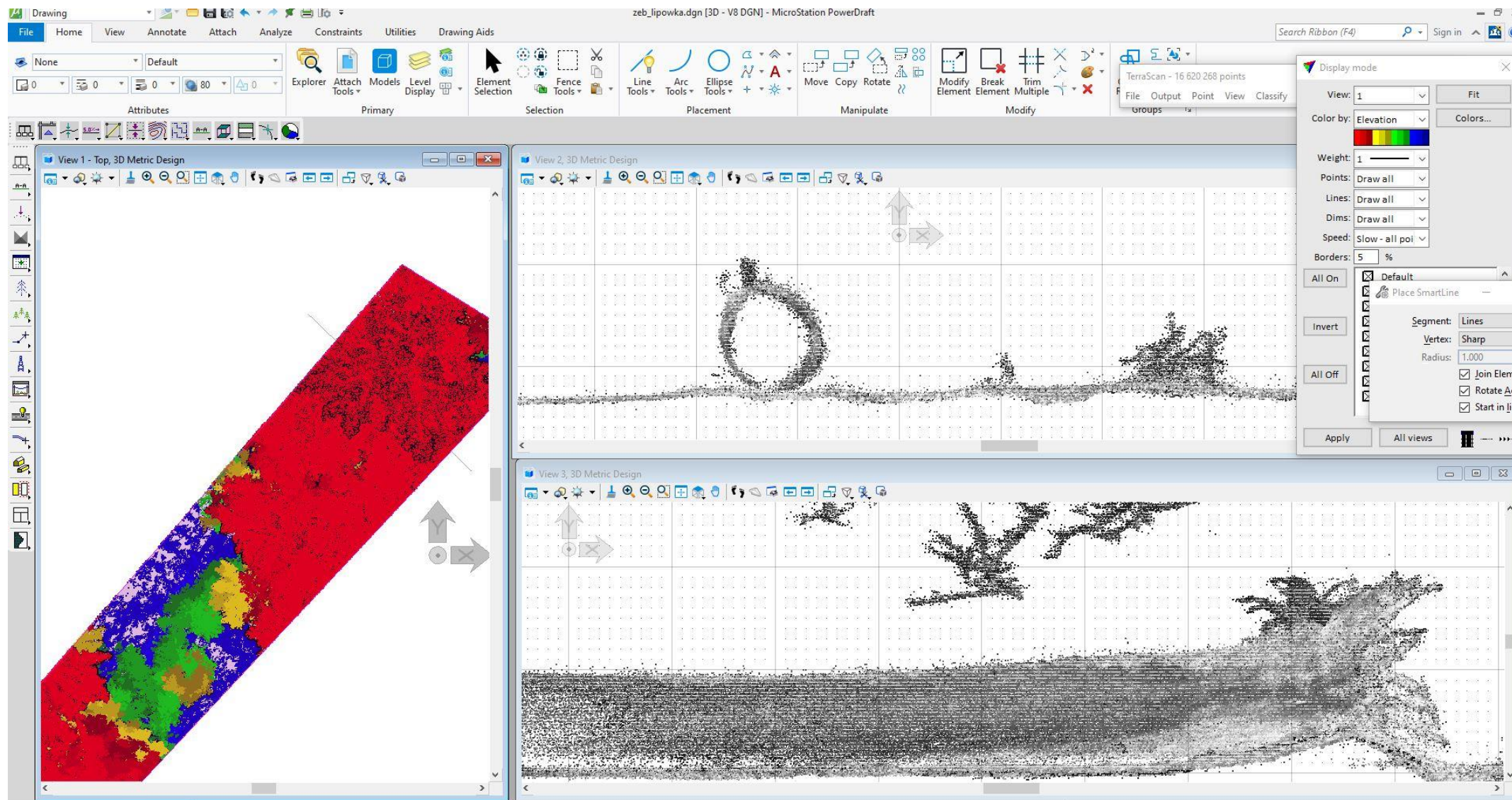
QFiled





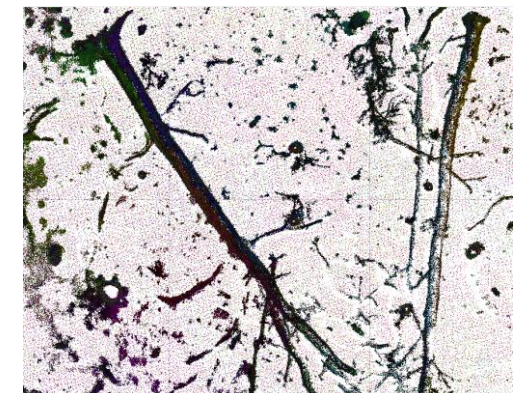
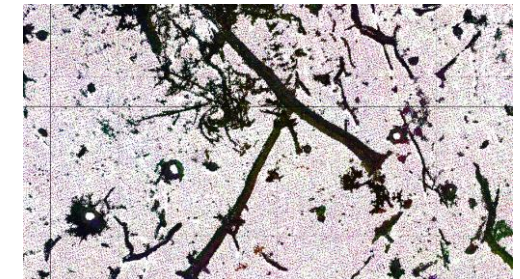
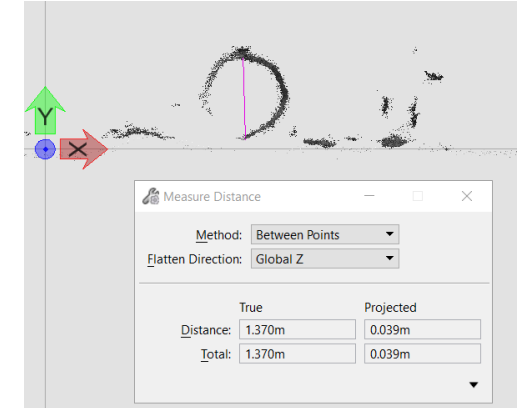
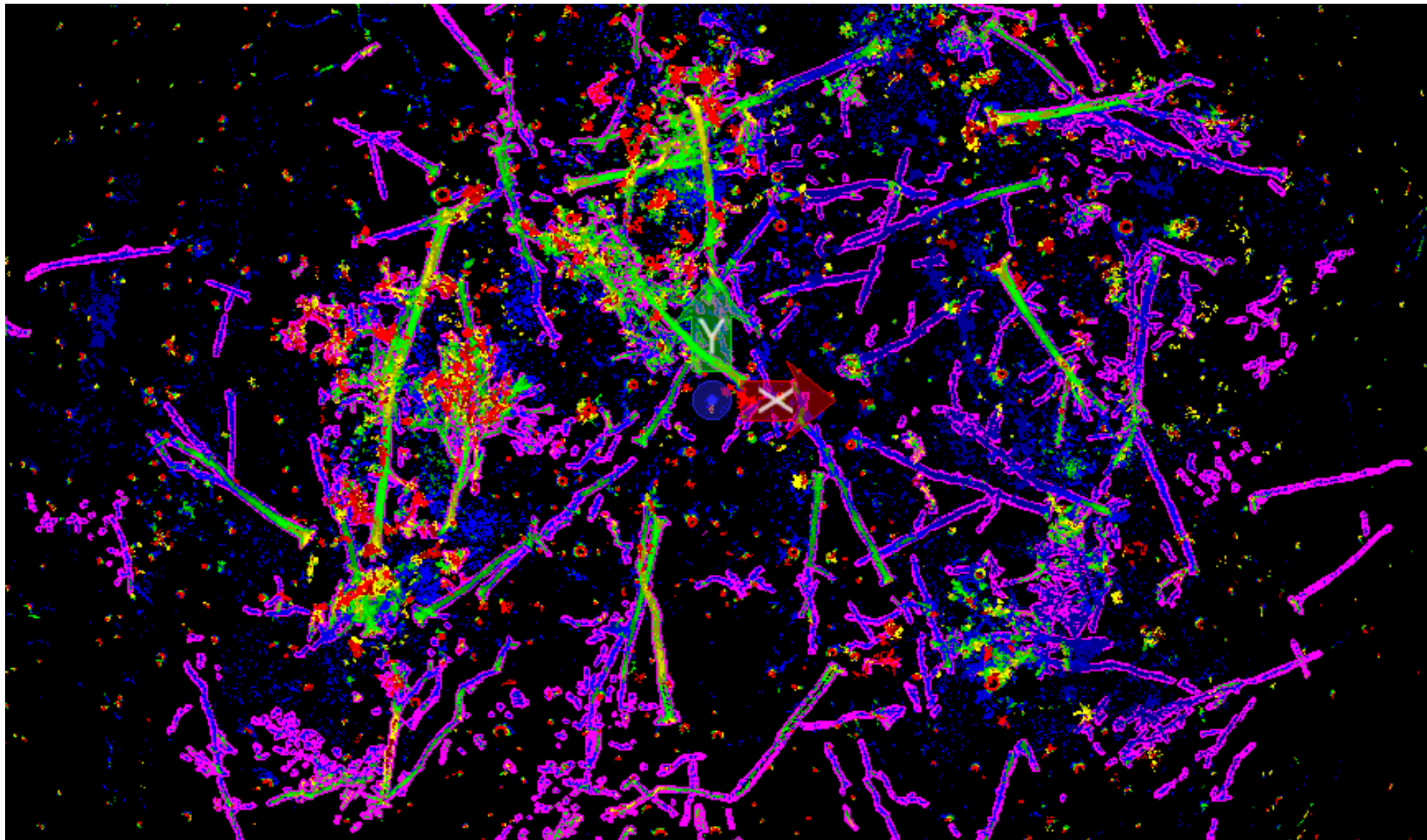


# MHLS classification and logs measurement



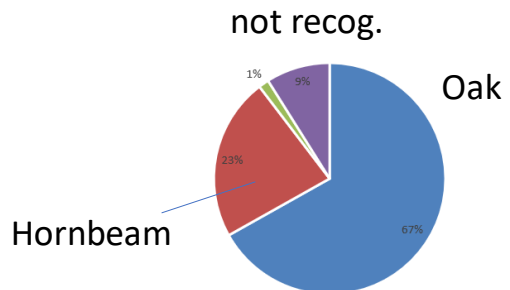
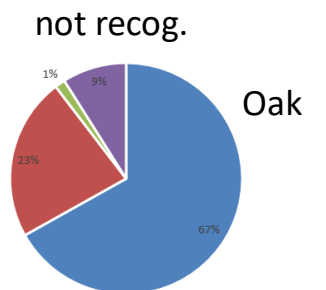


# MHLS - Wektoryzacja 3D



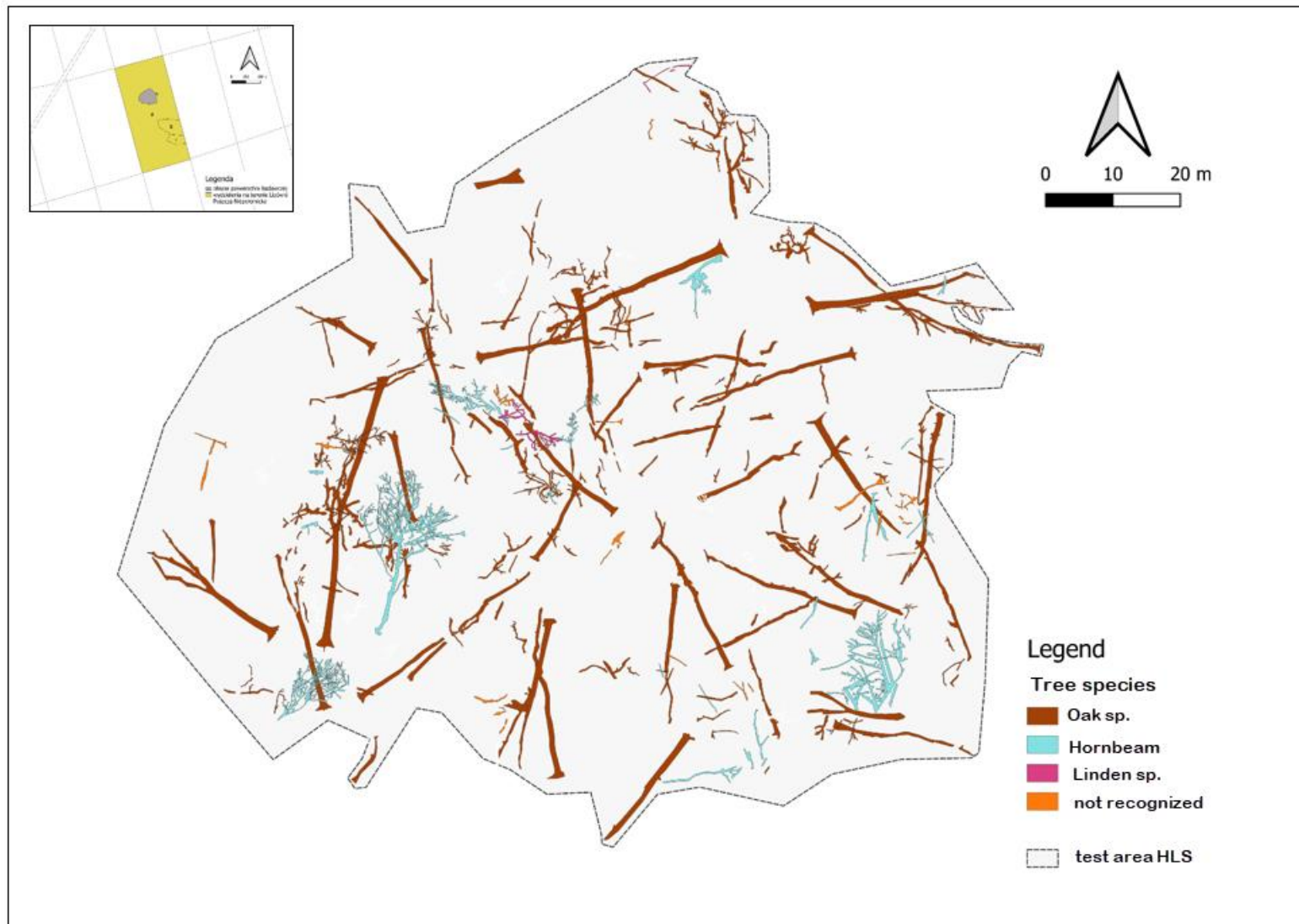
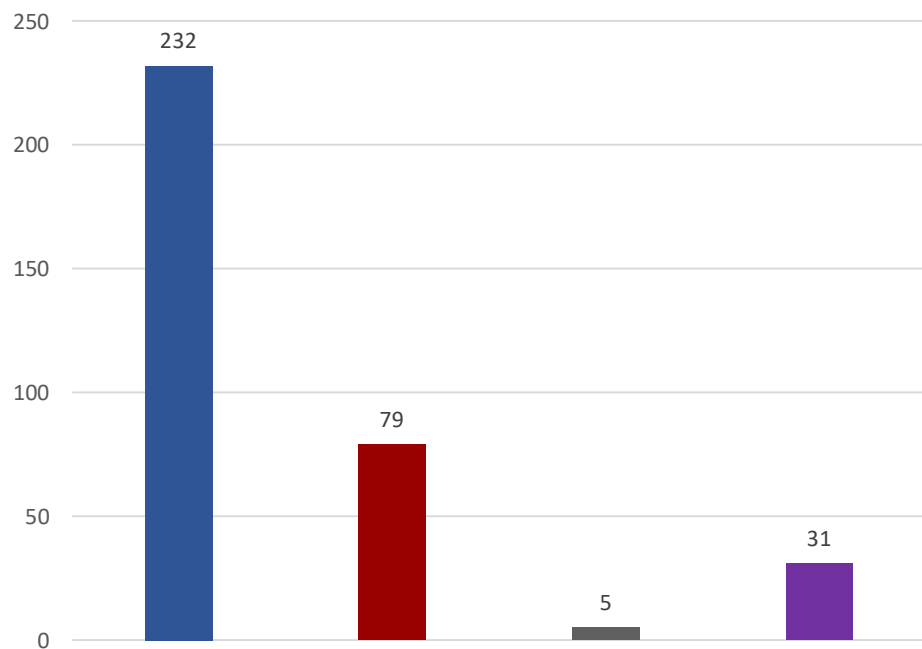


# Gatunki drewna martwego leżącego



Share in quantity [%]

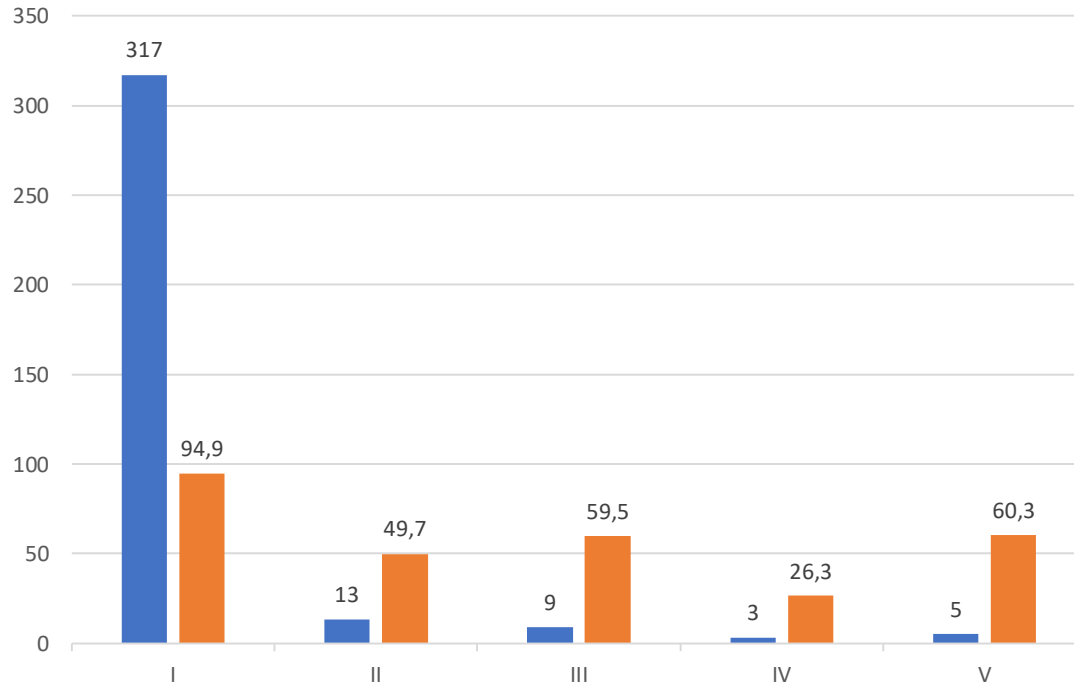
Share in Voume [%]



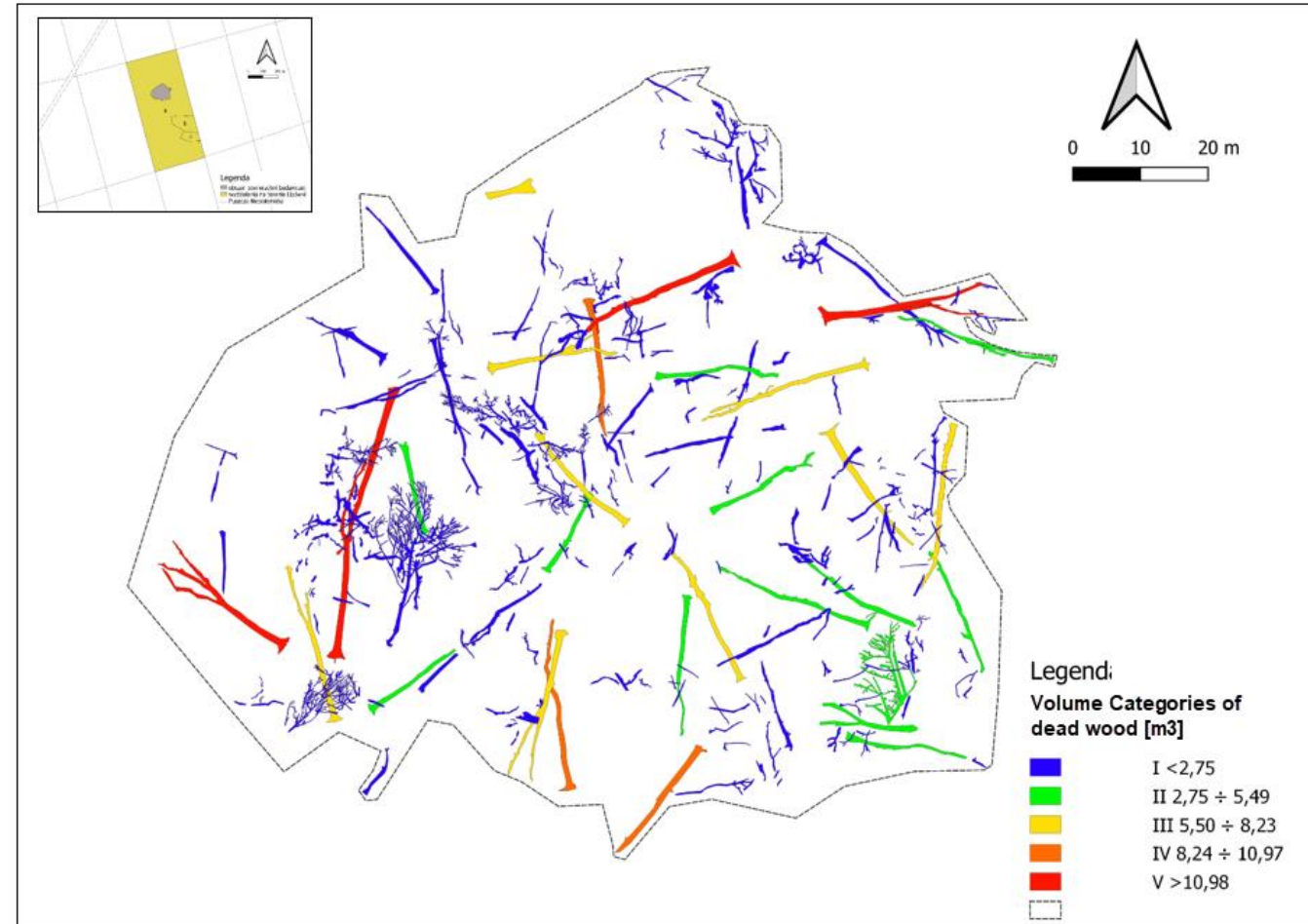
# Klasy miąższości kłód

- Category I:  $V < 2.75 \text{ m}^3$ ;  $n = 317 \text{ pcs. (91\%)}$ ,  $\Sigma V = 94,9 \text{ m}^3 \text{ (33\%)}$
- Category II:  $V 2.76 \div 5.49 \text{ m}^3$ ; 13 pcs.,  $\Sigma V = 49,7 \text{ m}^3$
- Category III:  $V 5.50 \text{ m}^3 \div 8.23 \text{ m}^3$ ; 9 pcs.,  $\Sigma V = 59,5 \text{ m}^3$
- Category IV:  $V 8.24 \text{ m}^3 \div 10.97 \text{ m}^3$ ; 3 pcs.,  $\Sigma V = 26,3 \text{ m}^3$
- Category V:  $V > 10.98 \text{ m}^3$ ; 5 pcs.,  $\Sigma V = 60,3 \text{ m}^3$

$$\Sigma V_{dw} = 290,66 \text{ m}^3$$



Logs volume categories



# Klasy dekompozycji drewna leżacego



1.



2.



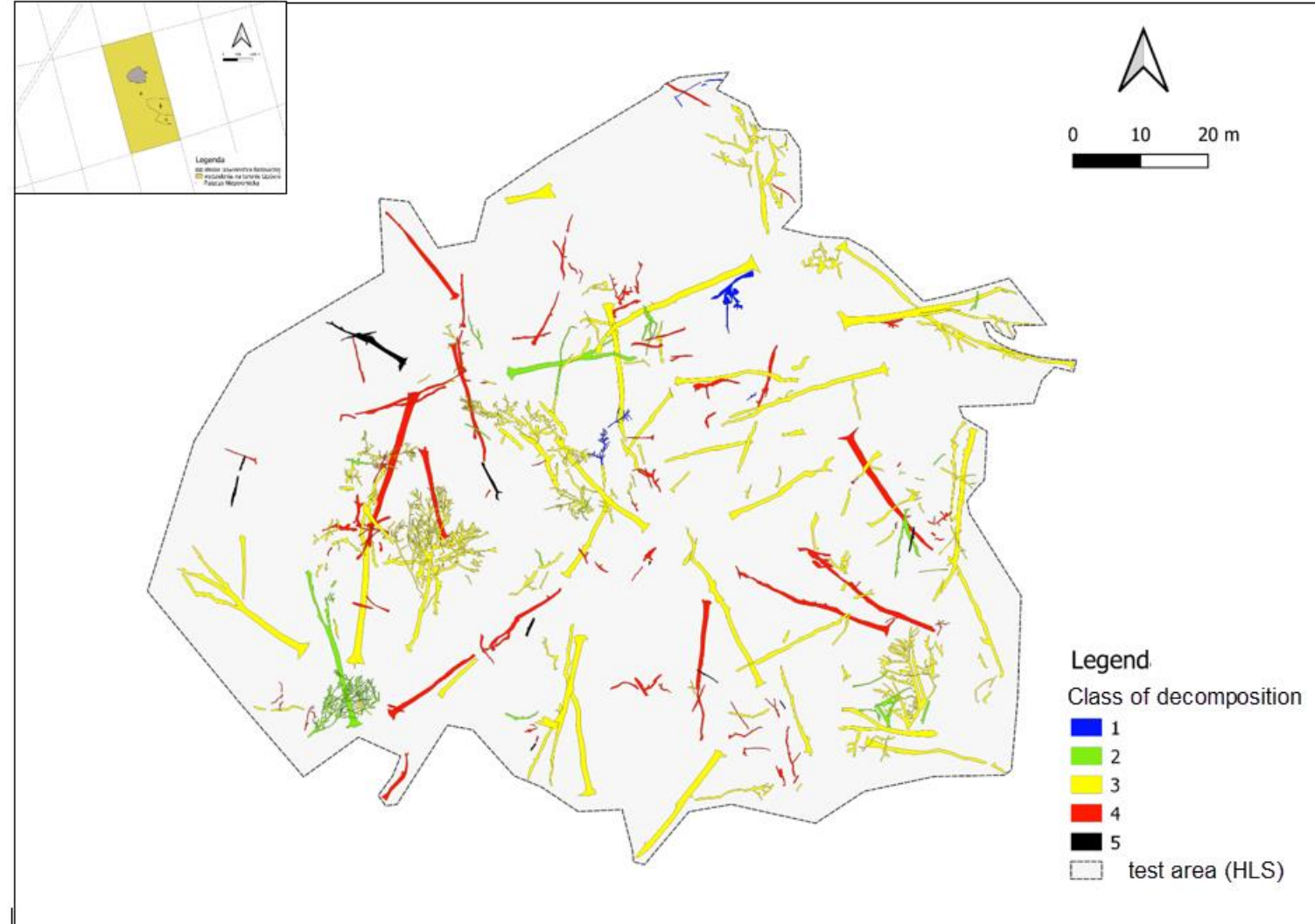
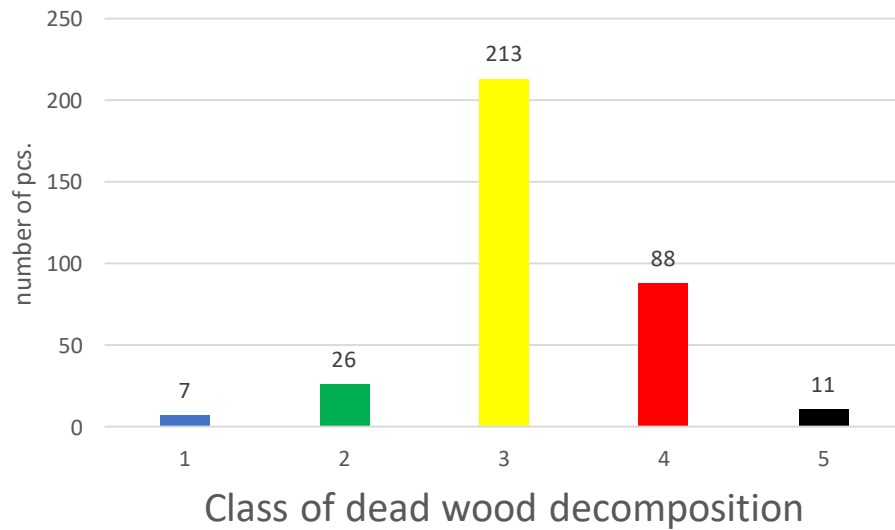
3.



4.



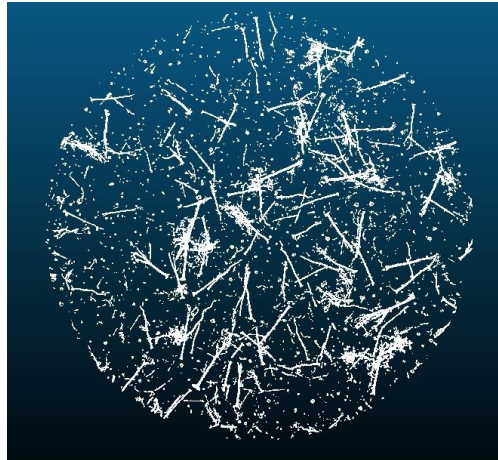
5.





# Outlook - ongoing works - automatisisation

HMLS



Note: All four steps are performed automatically by a software developed by PIFDL



Private Institute for  
General Dynamic Logic  
www.pifdl.eu

Step 2:  
Clustering of the lying trees  
and recording of each  
individual log

Step 3:  
Result of the cluster.  
LAS file and XYZ file for each  
trunk

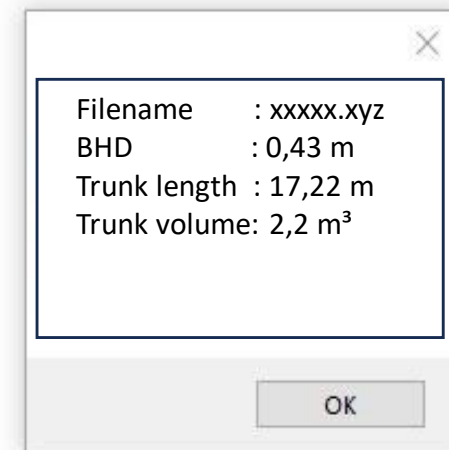
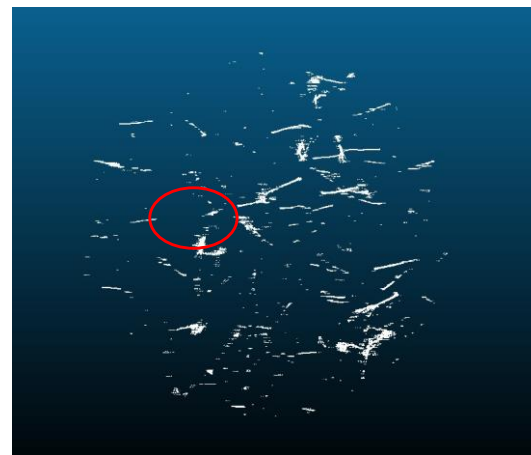
Step 4:  
Analysis of the tree data  
using its xyz data

Step 1: Conversion  
LAZ to XYZ data

```

428106.024 1252154.645 -0.62
428106.024 1252154.645 -0.62
428106.049 1252154.645 -0.58
428106.049 1252154.645 -0.56
428106.027 1252154.645 -0.53
428106.026 1252154.645 -0.50
428106.044 1252154.645 0.12
428106.052 1252154.645 0.15
428106.024 1252154.645 0.16
428106.024 1252154.645 0.17
428106.024 1252154.645 0.17
428106.024 1252154.645 0.17
428106.054 1252154.645 0.17
428106.023 1252154.645 0.17

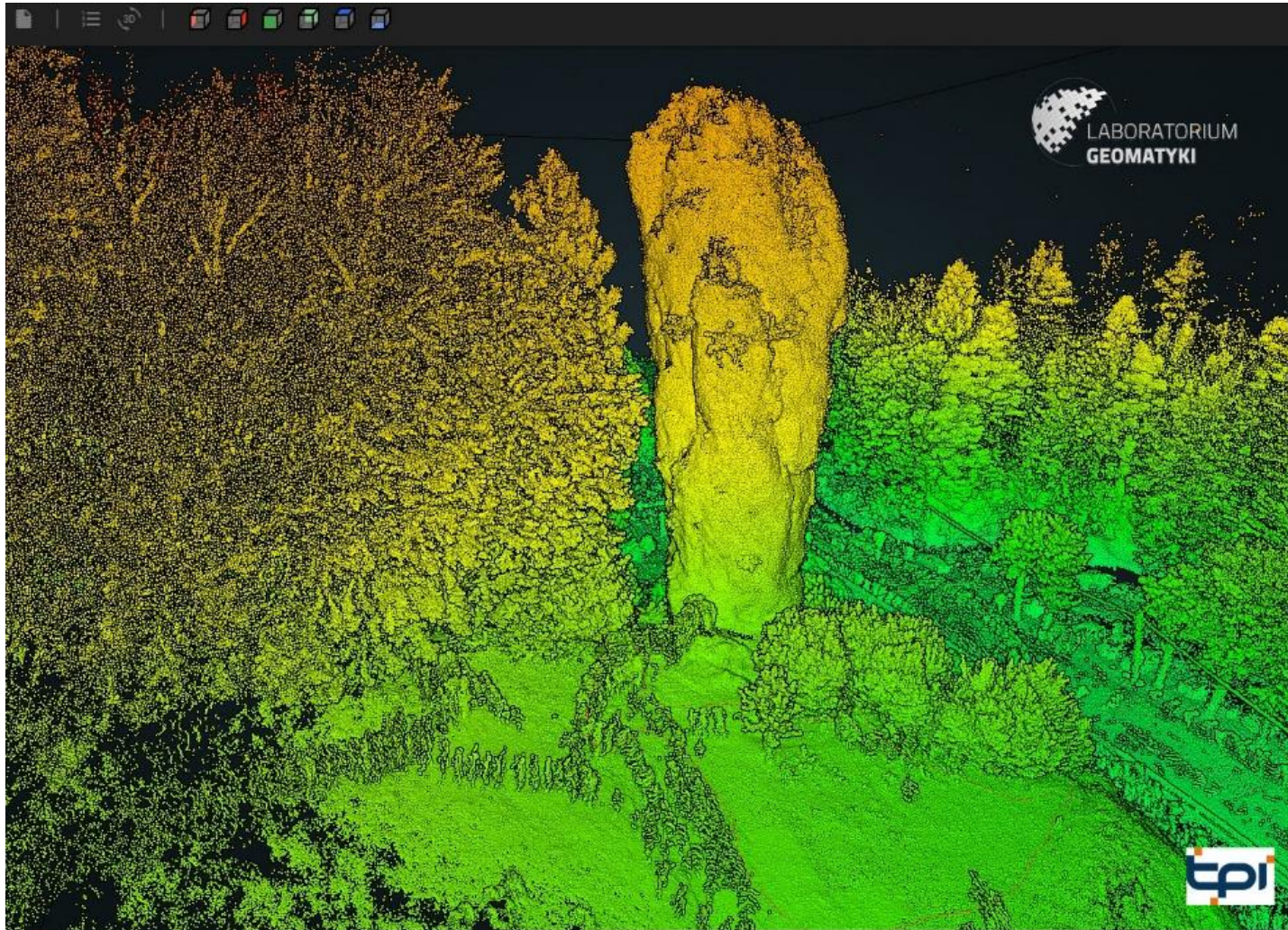
```





# LiDAR MHLS ZEB HORIZON GEOSLAM

## Maczuga Herkulesa – Ojcowski PN

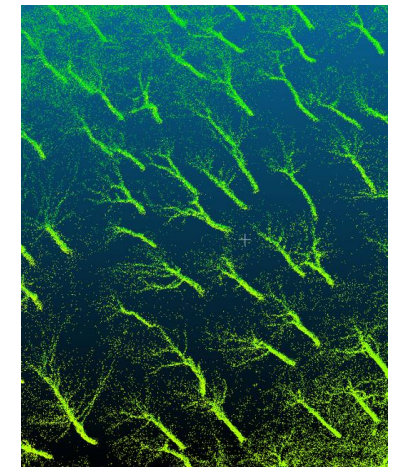
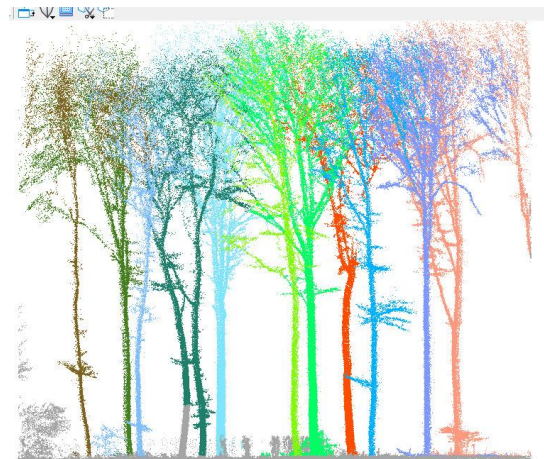
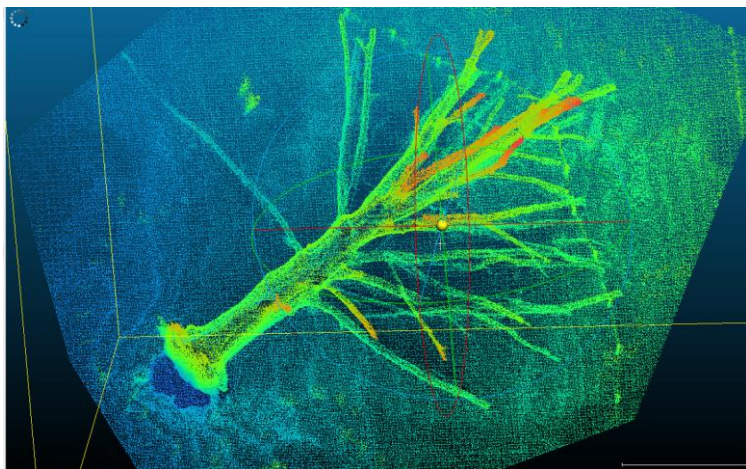




# Hand-Held Laser Scanning (HLS) ZEB HORIZON



Transekt przez d-stan bukowy (*Fagus silvatica* L.)





# TLS LiDAR 3D tree stand structure monitoring Gorce National Park (2012-2018)



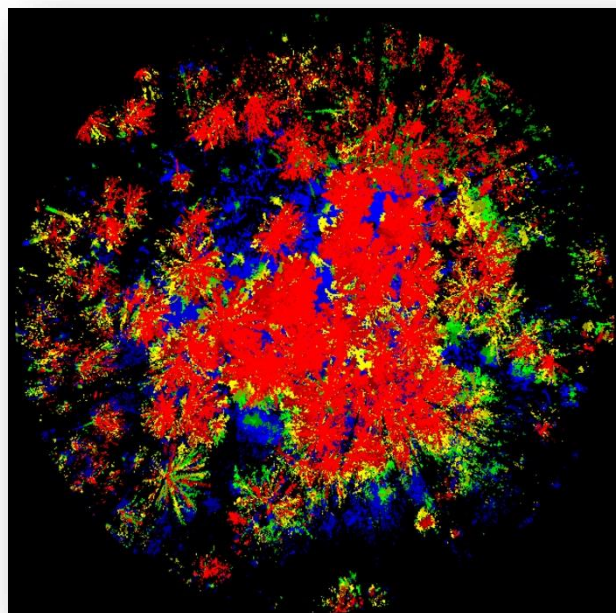
2012



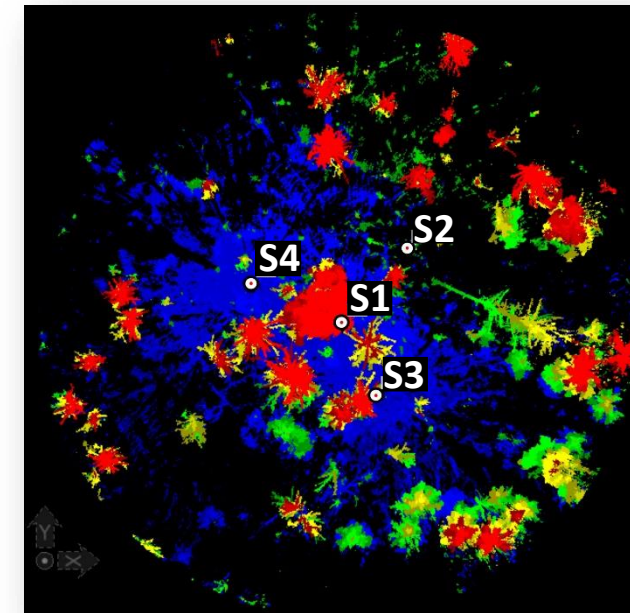
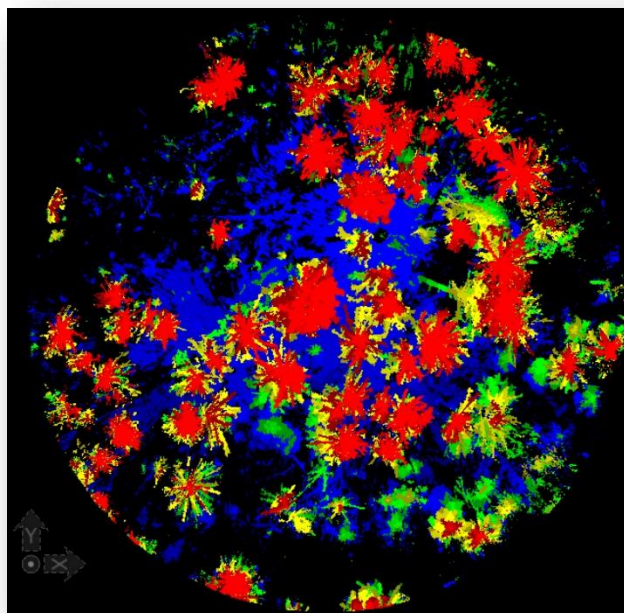
2016



2018



22.01.2024





# LiDAR TLS point cloud 2016 (RGB) Gorce National Park



TLS point cloud (2016) – color by RGB

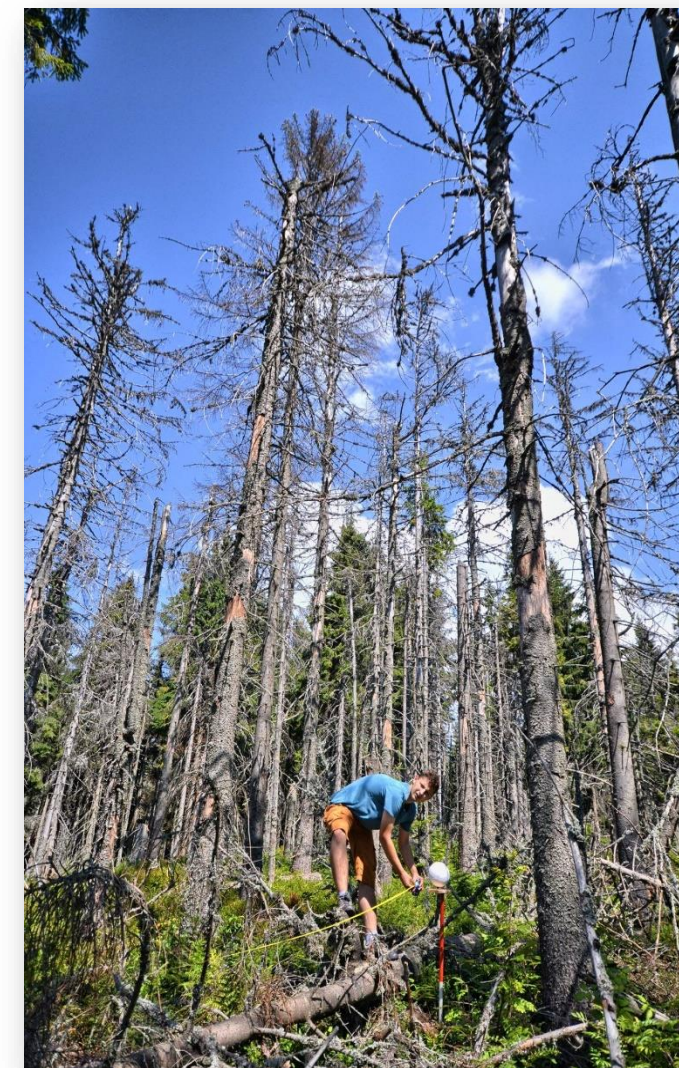
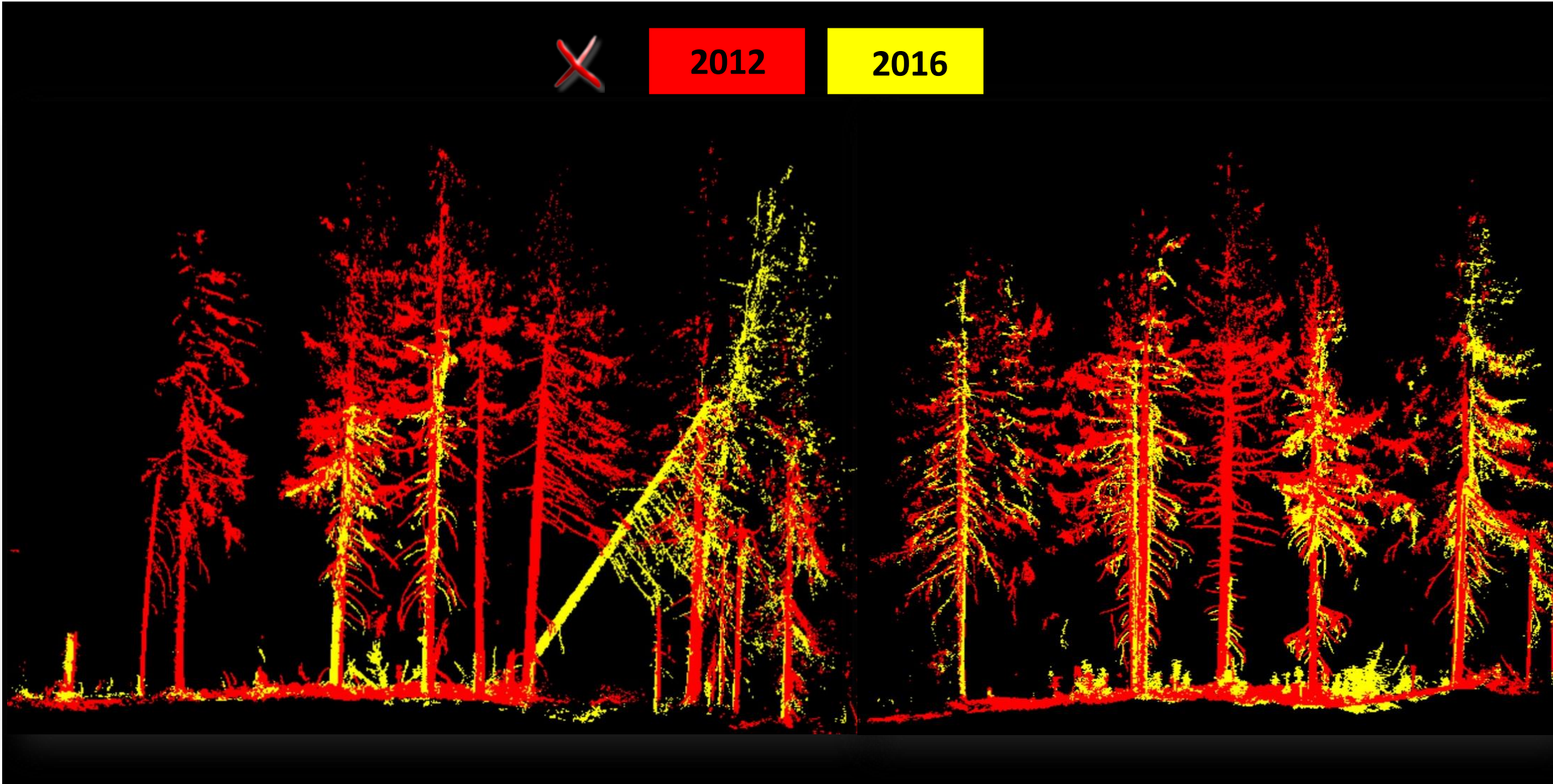


Foto: K. Zieba-Kulawik





# TLS LiDAR 3D tree stand structure monitoring Gorce National Park

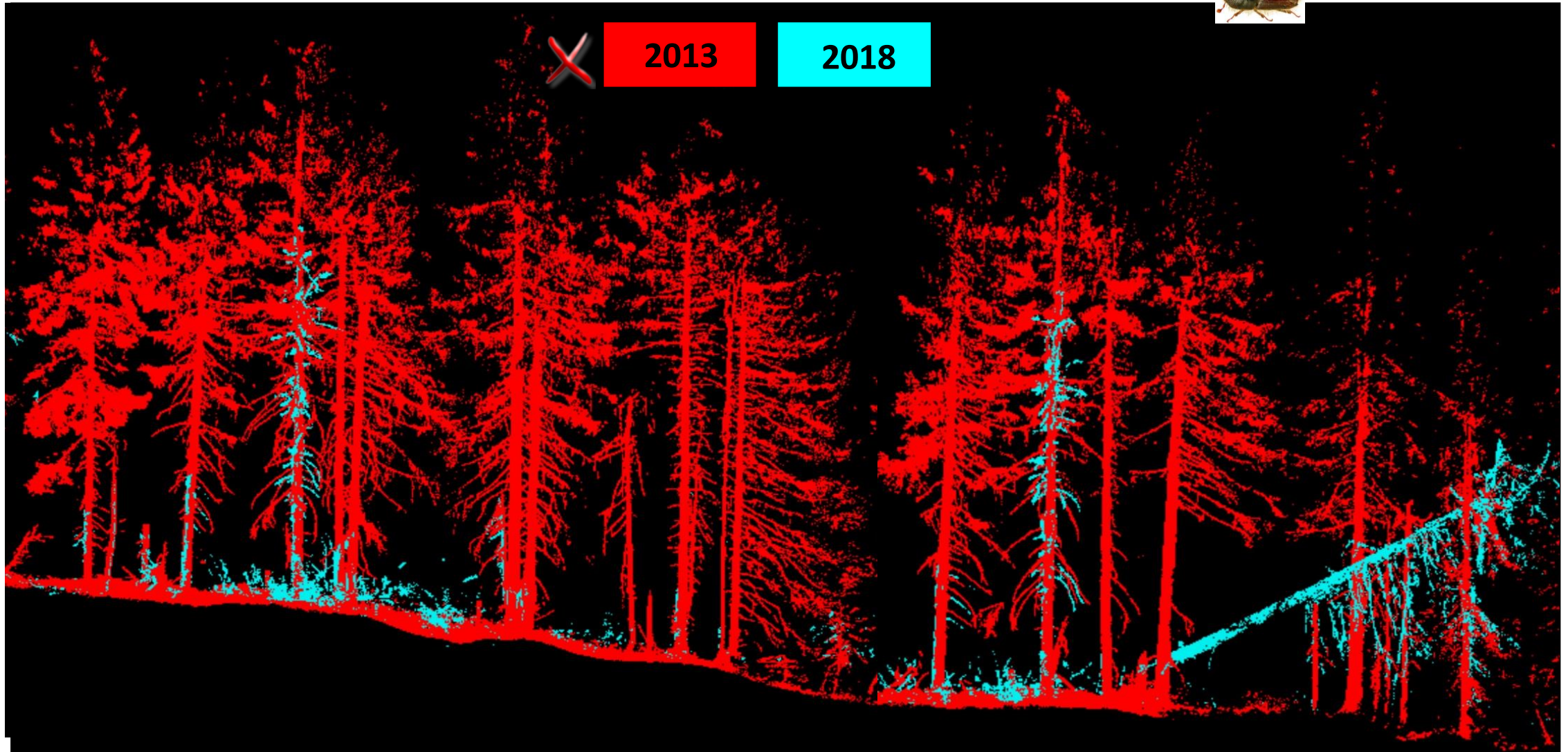


TLS point clouds (red – 2013; yellow – 2016)





# TLS LiDAR 3D tree stand structure monitoring Gorce National Park

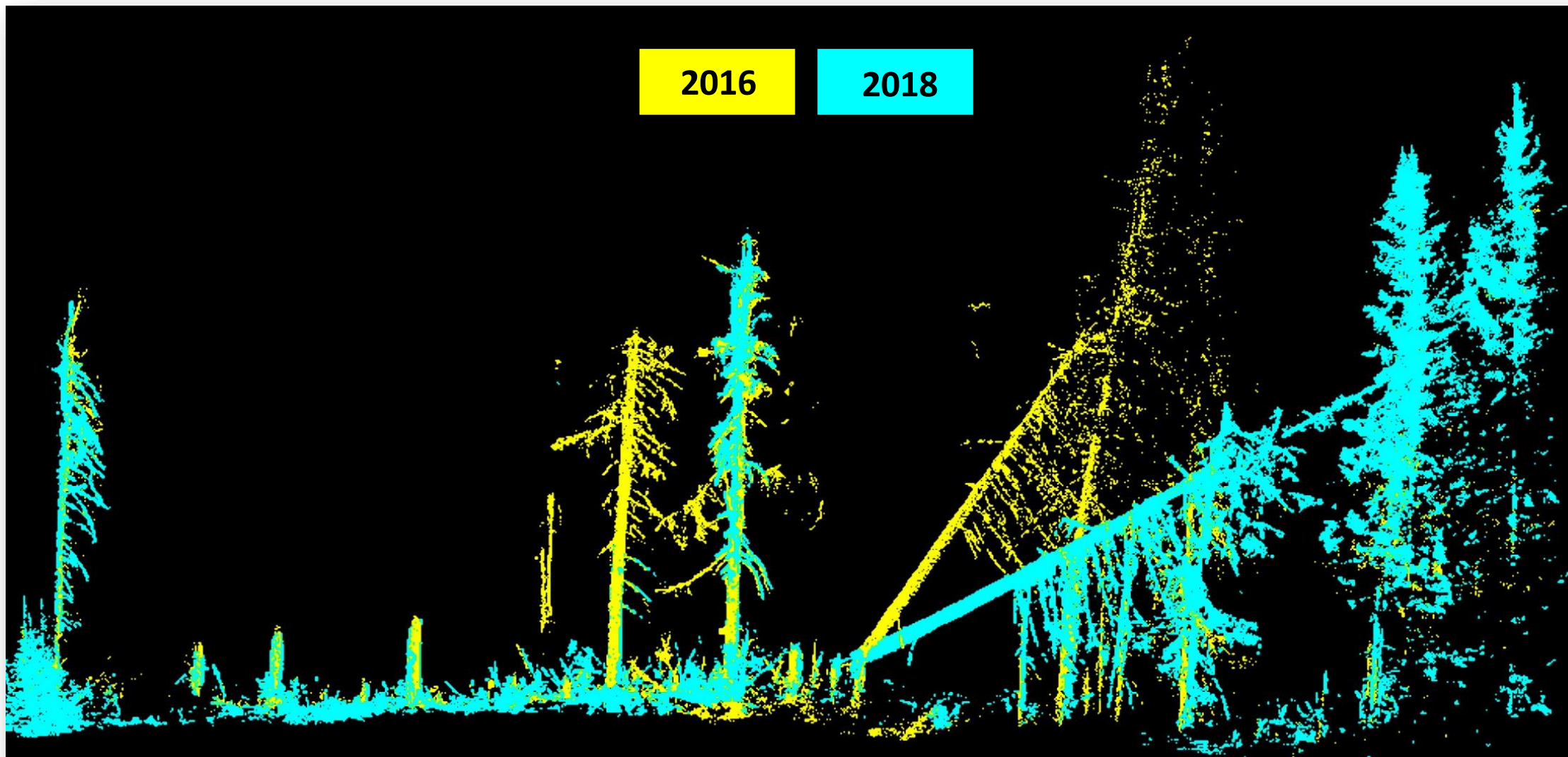


TLS point clouds (red – 2013; blue – 2018)





# TLS LiDAR 3D tree stand structure monitoring Gorce National Park



TLS point clouds (yellow – 2016; blue – 2018)

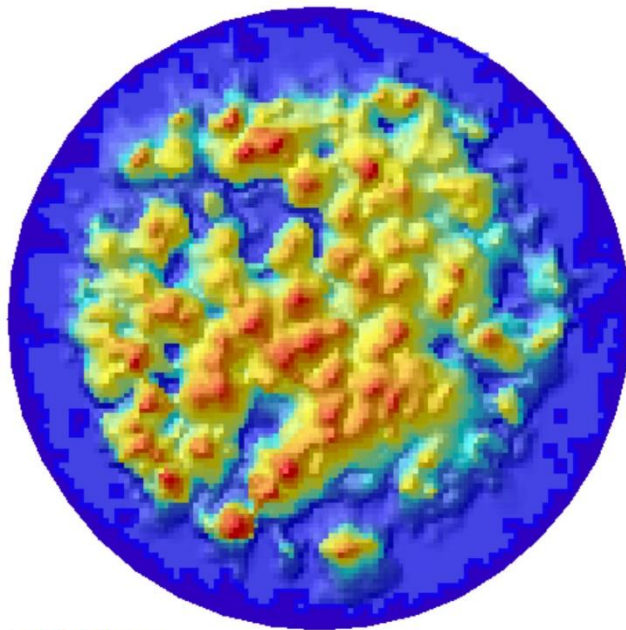
# TLS LiDAR 3D tree stand structure monitoring Gorce National Park

## Canopy Height Model (CHM)

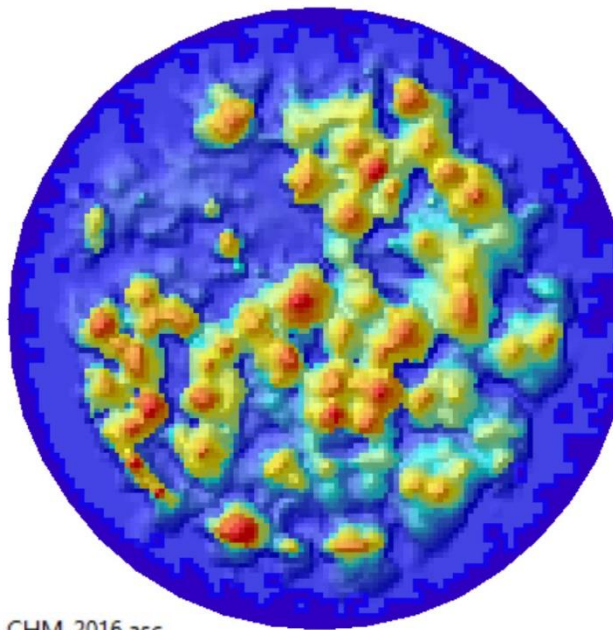
2012

2016

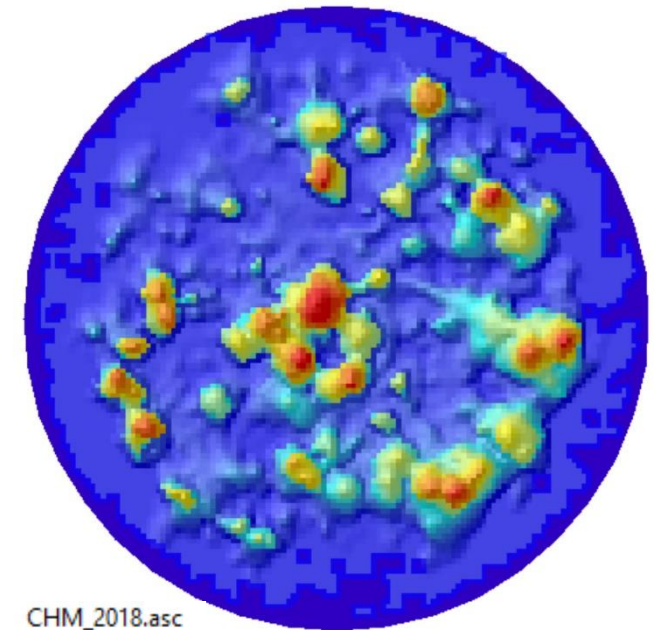
2018



CHM\_2013.asc  
Value  
High : 21,18  
Low : 0



CHM\_2016.asc  
Value  
High : 21,13  
Low : 0

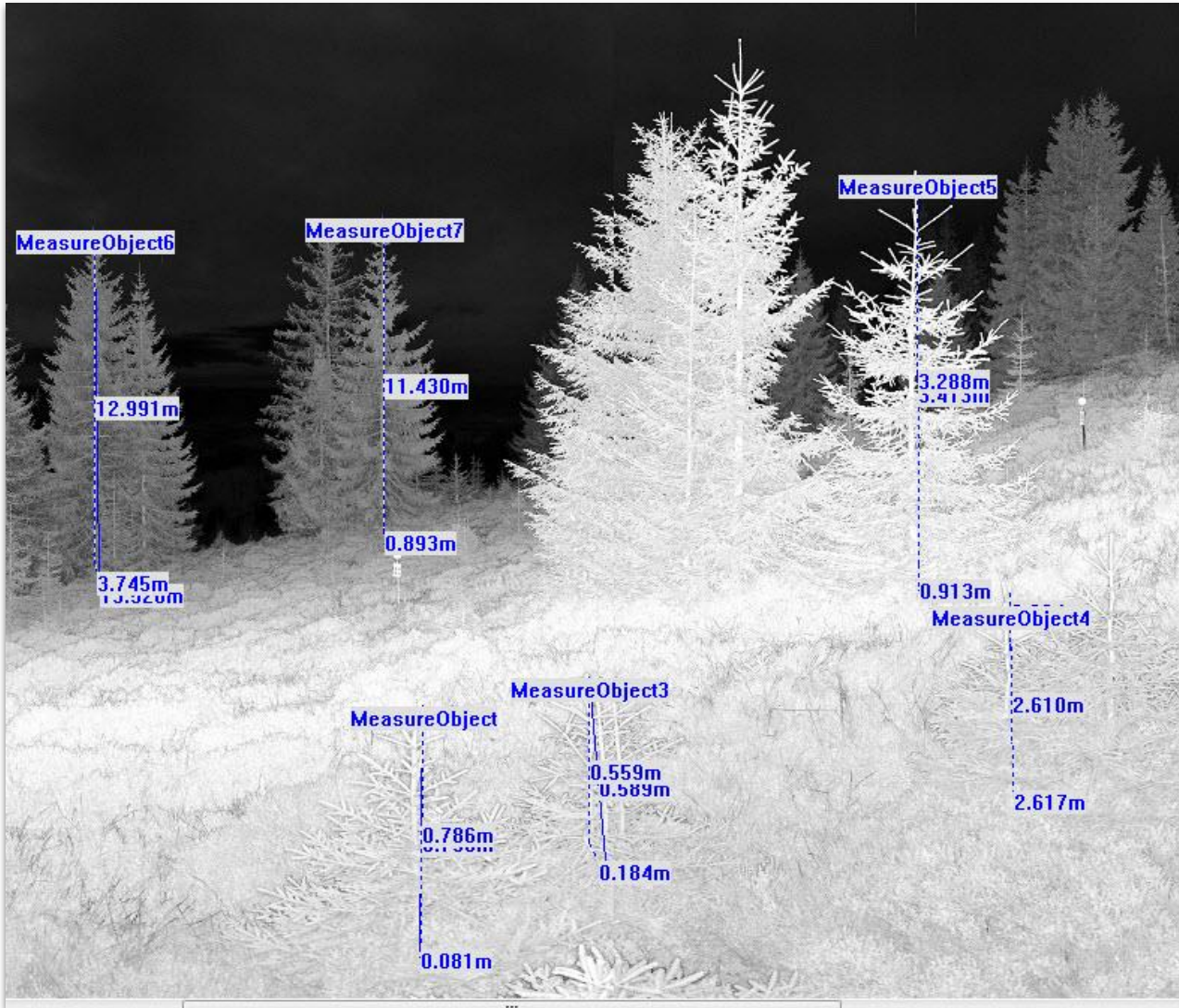


CHM\_2018.asc  
Value  
High : 20,39  
Low : 0

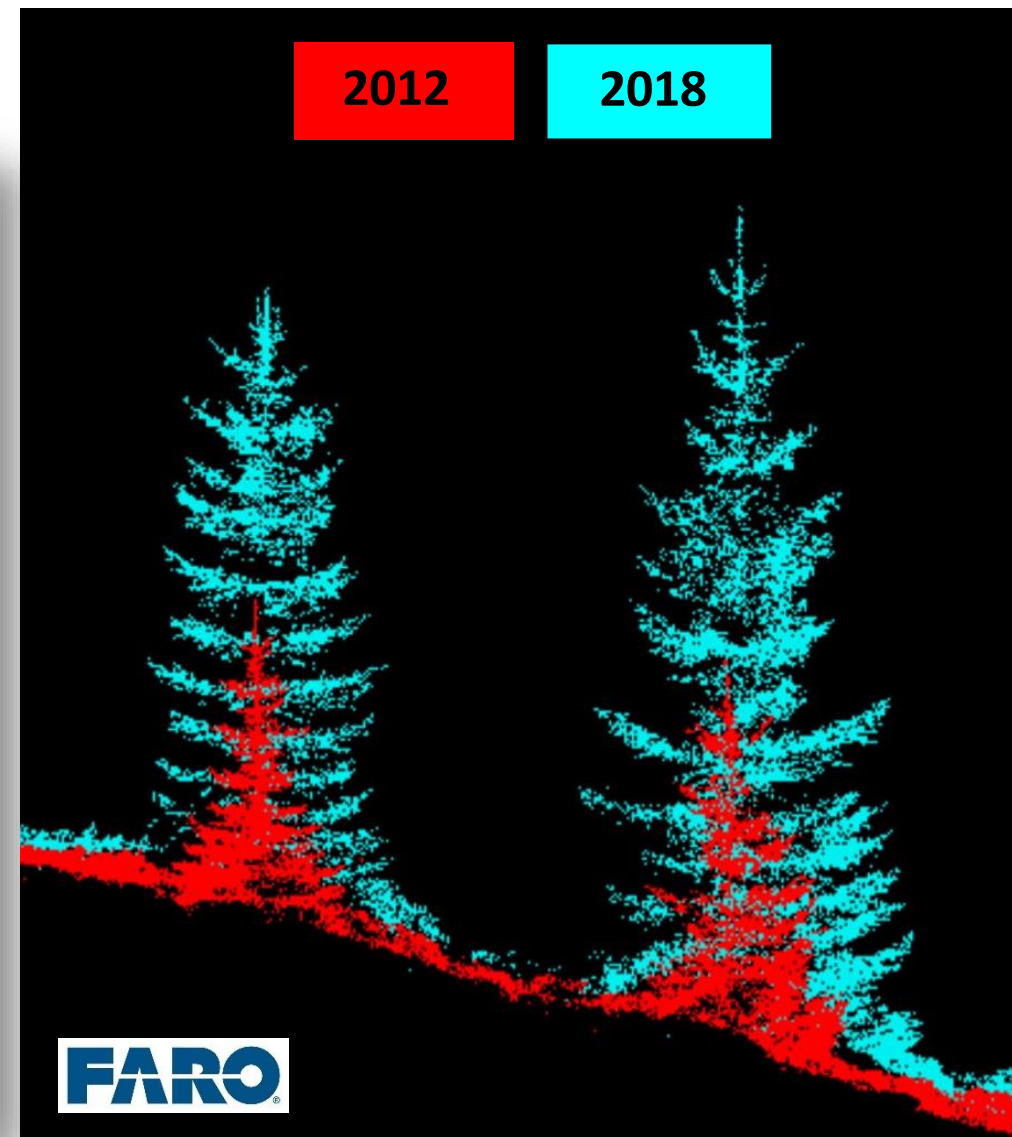
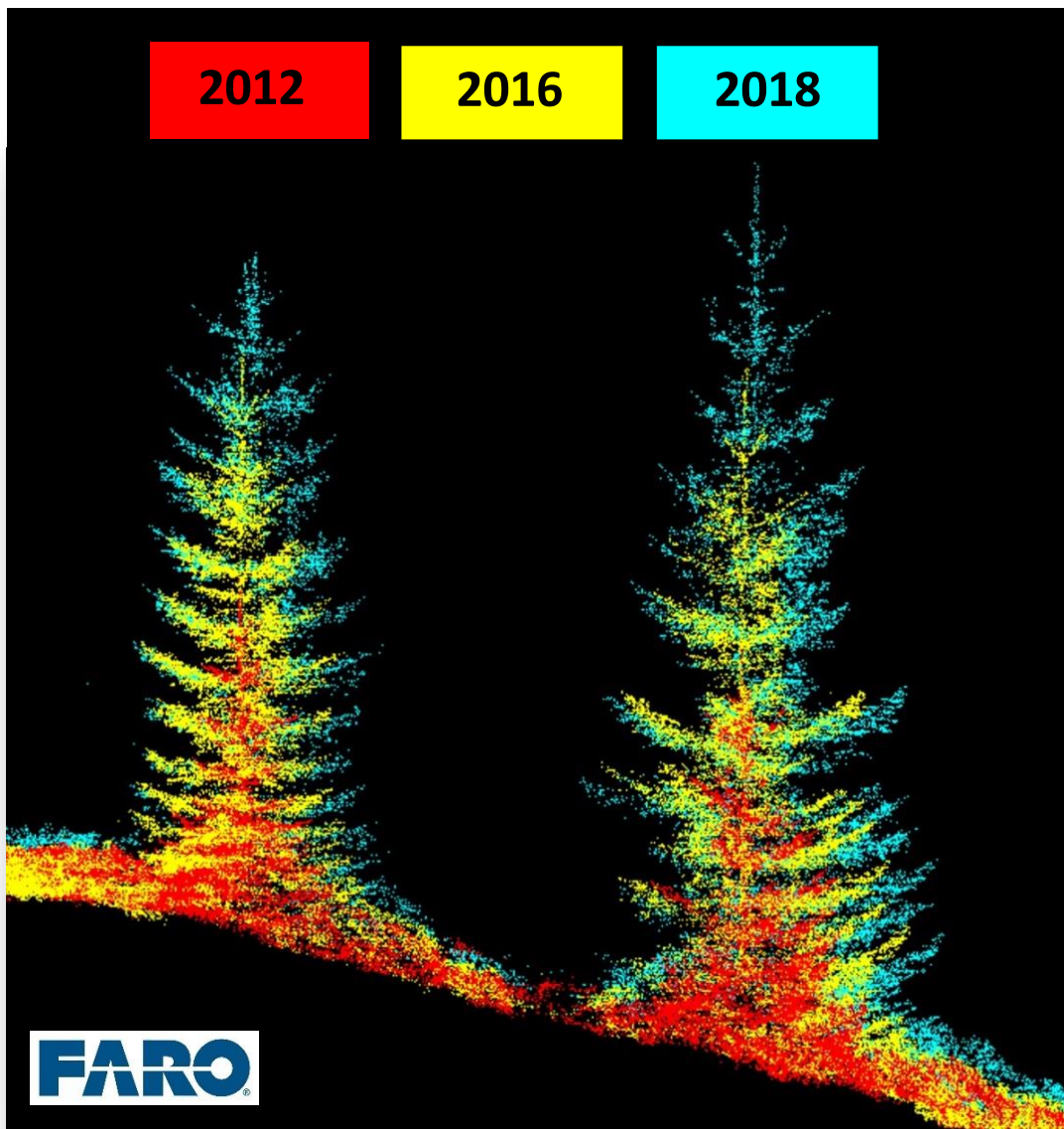
nDSM - Difference between DSM and DTM, which is the height of vegetation



# TLS LiDAR - monitoring wtórnej sukcesji leśnej na polanach regłowych w Gorczańskim PN w latach 2012-2018



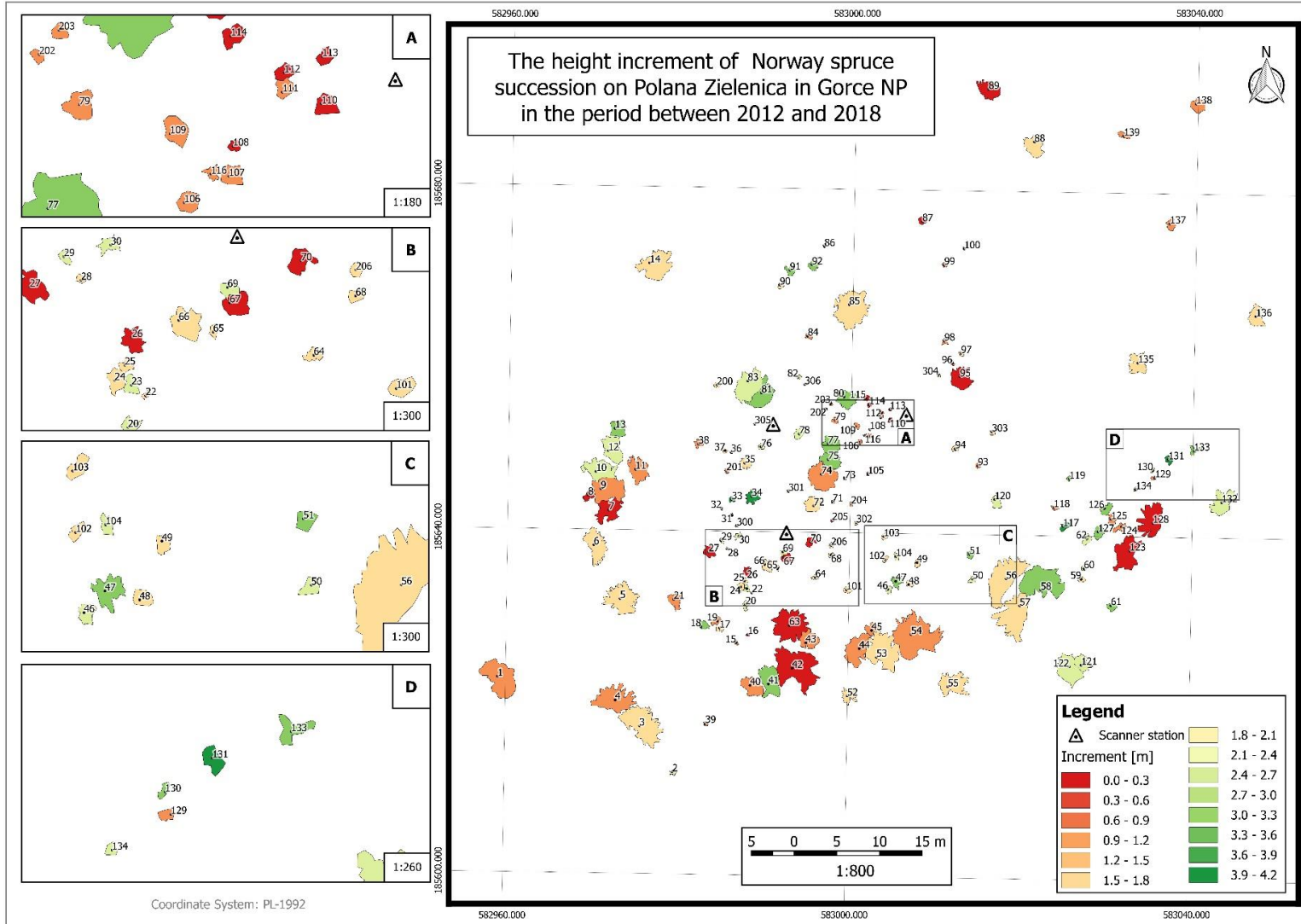
# TLS LiDAR monitoring przyrost świerka na polanie w latach 2012 – 2016 - 2018





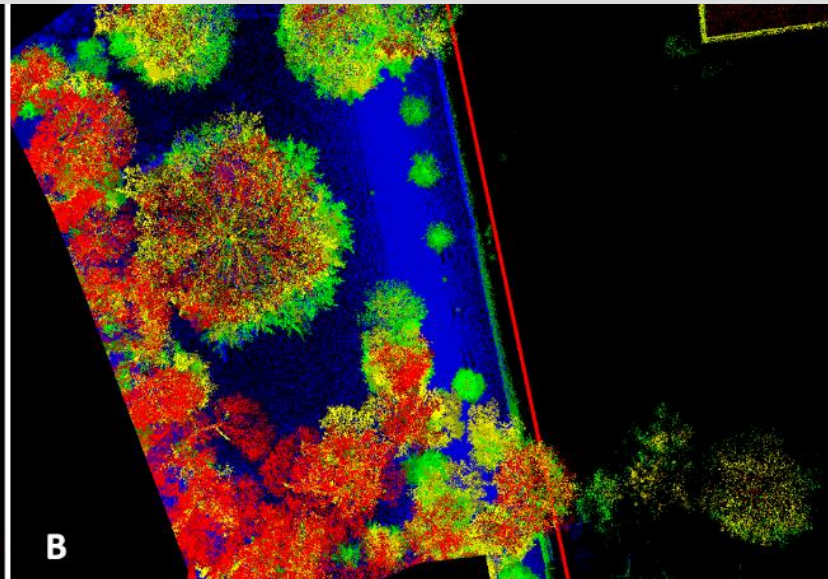
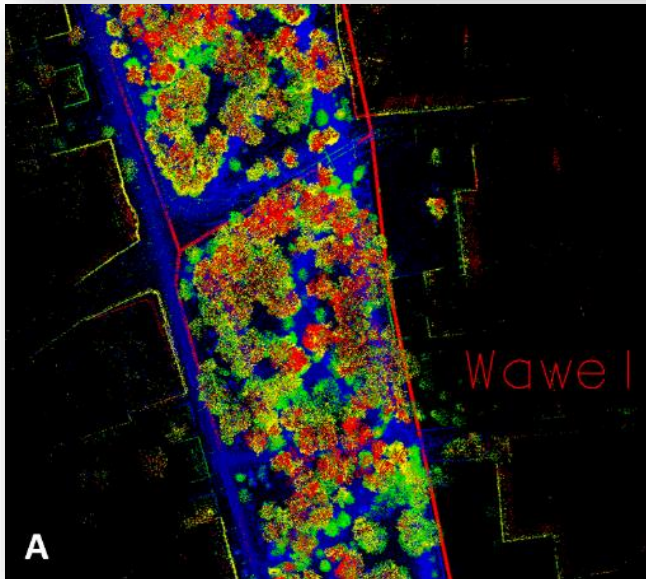
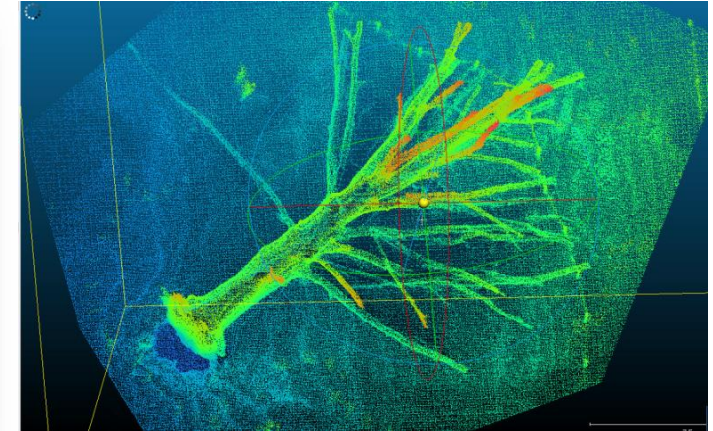


# TLS LiDAR - monitoring wtórnej sukcesji leśnej na polanach regłowych w Gorczańskim PN w latach 2012-2018



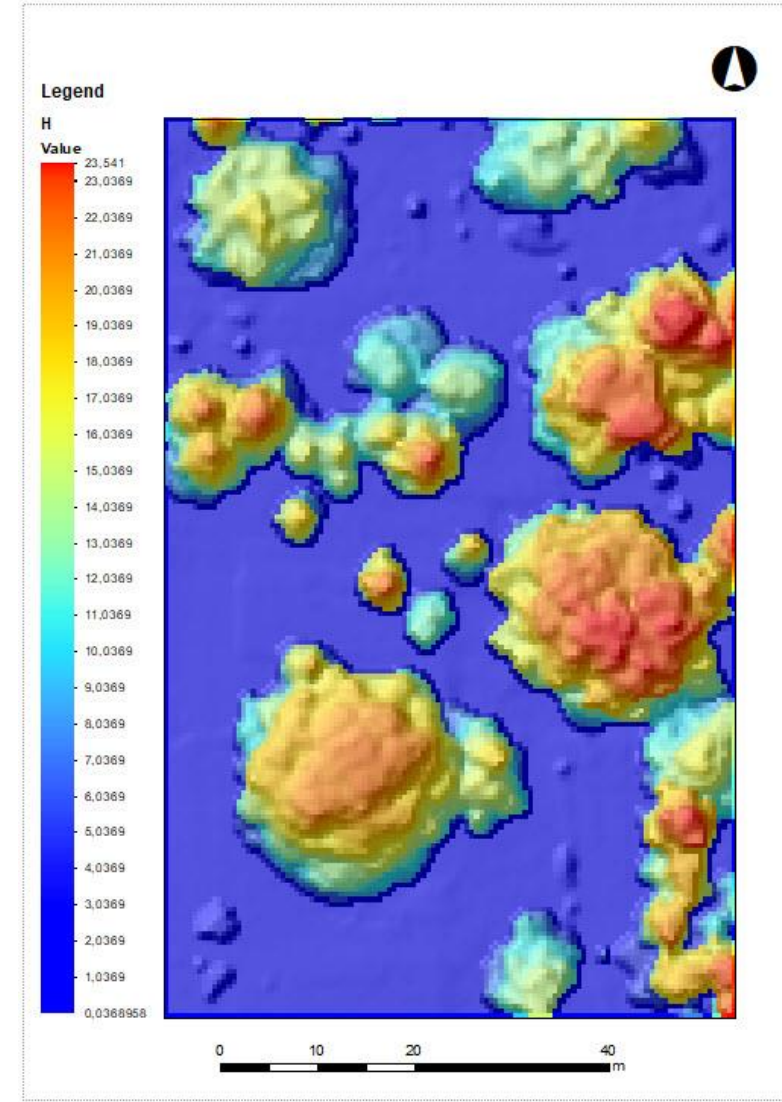
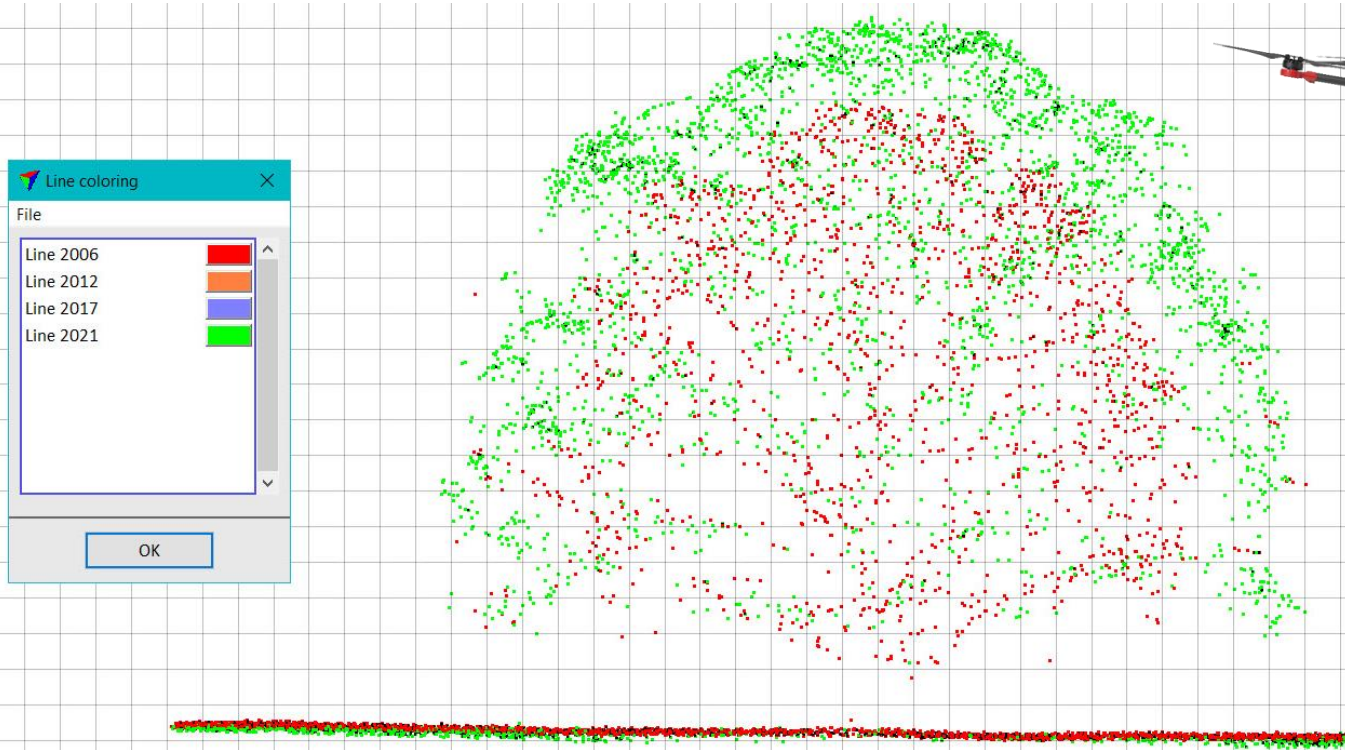
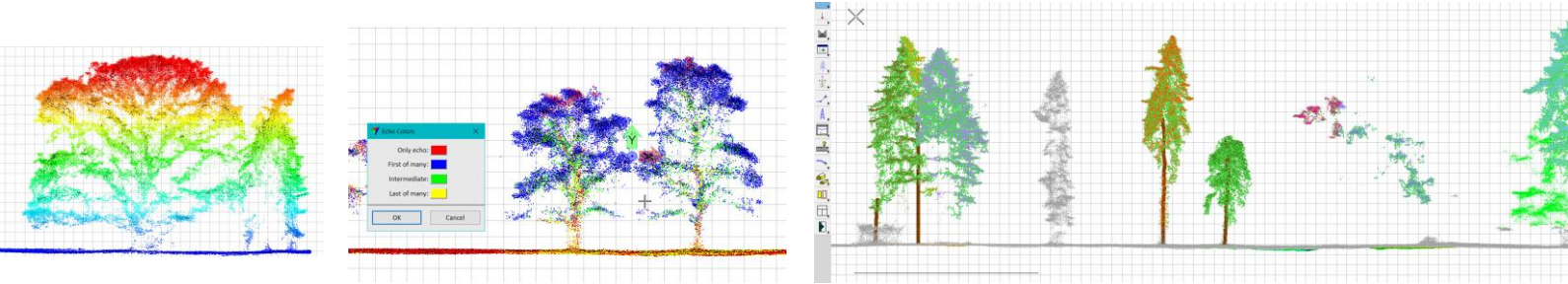


# MLS LiDAR – inwentaryzacja zieleni miejskiej. Pomniki przyrody – miasta, aleje zabytkowe



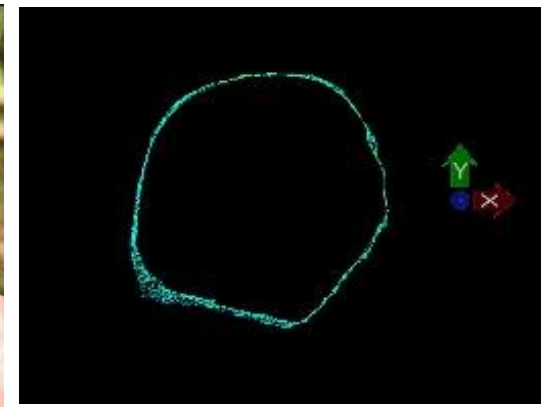
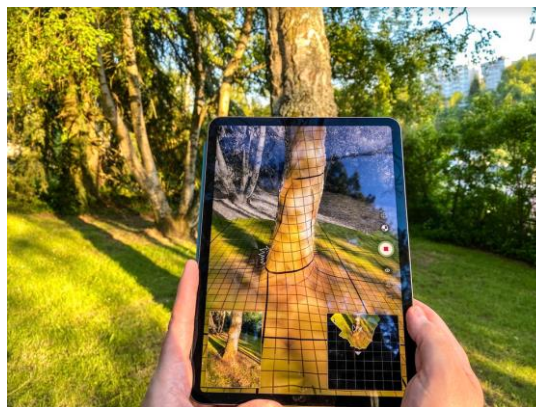


# ULS - Unammed Laser Scanning Monitoring drzew pomnikowych





# HLS/PLS – iPad Pro 2020 – monitoring obiektów



# Dziękuję za uwagę ! Pytania ?

