Department of Geoinformatics and Remote Sensing
Faculty of Geography and Regional Studies
Warsaw University, Poland

Vegetation mapping of the High Tatras and the Karkonosze Mts. using hyperspectral images and neural networks

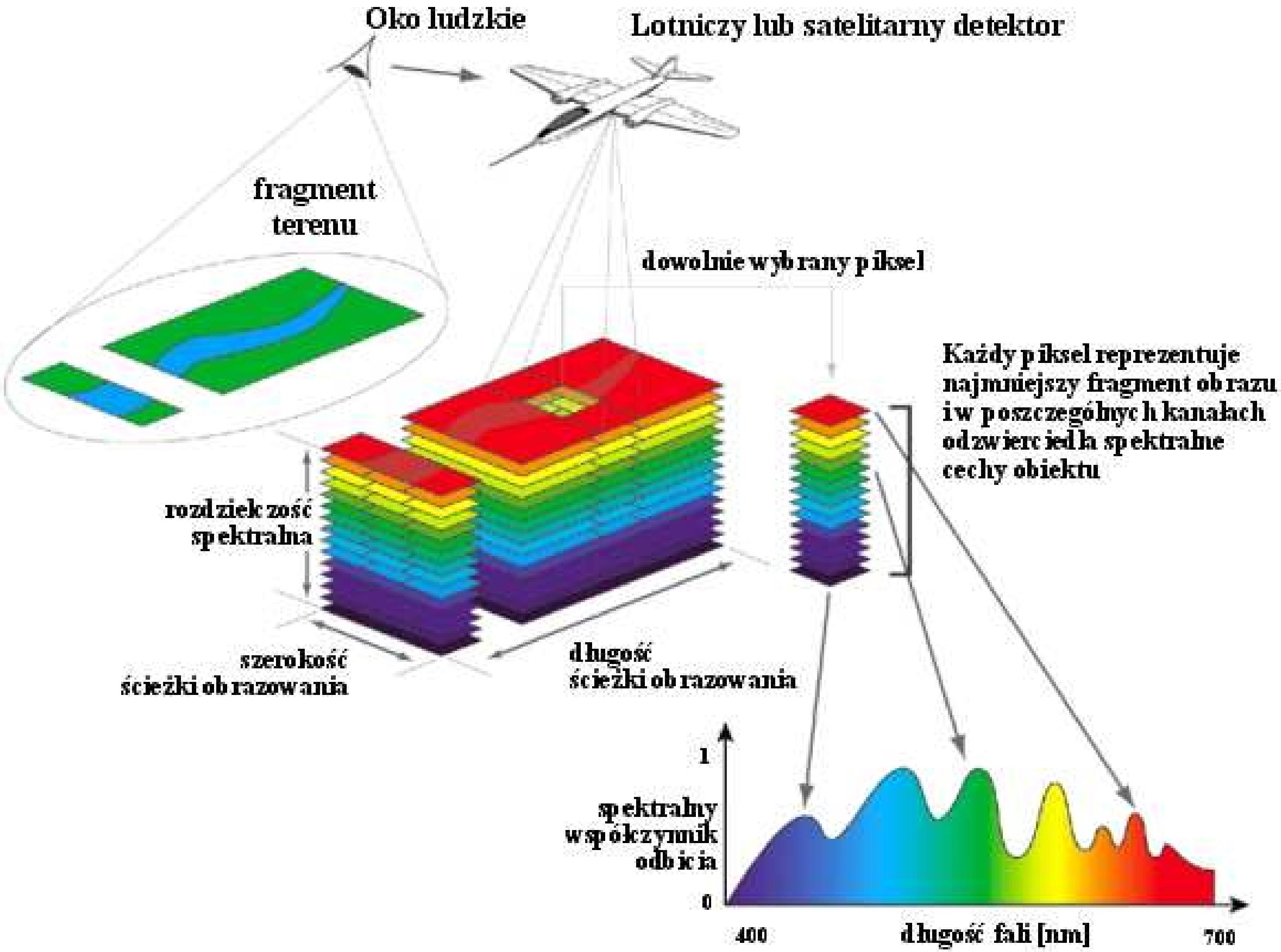
2013-07-23

Bogdan ZAGAJEWSKI

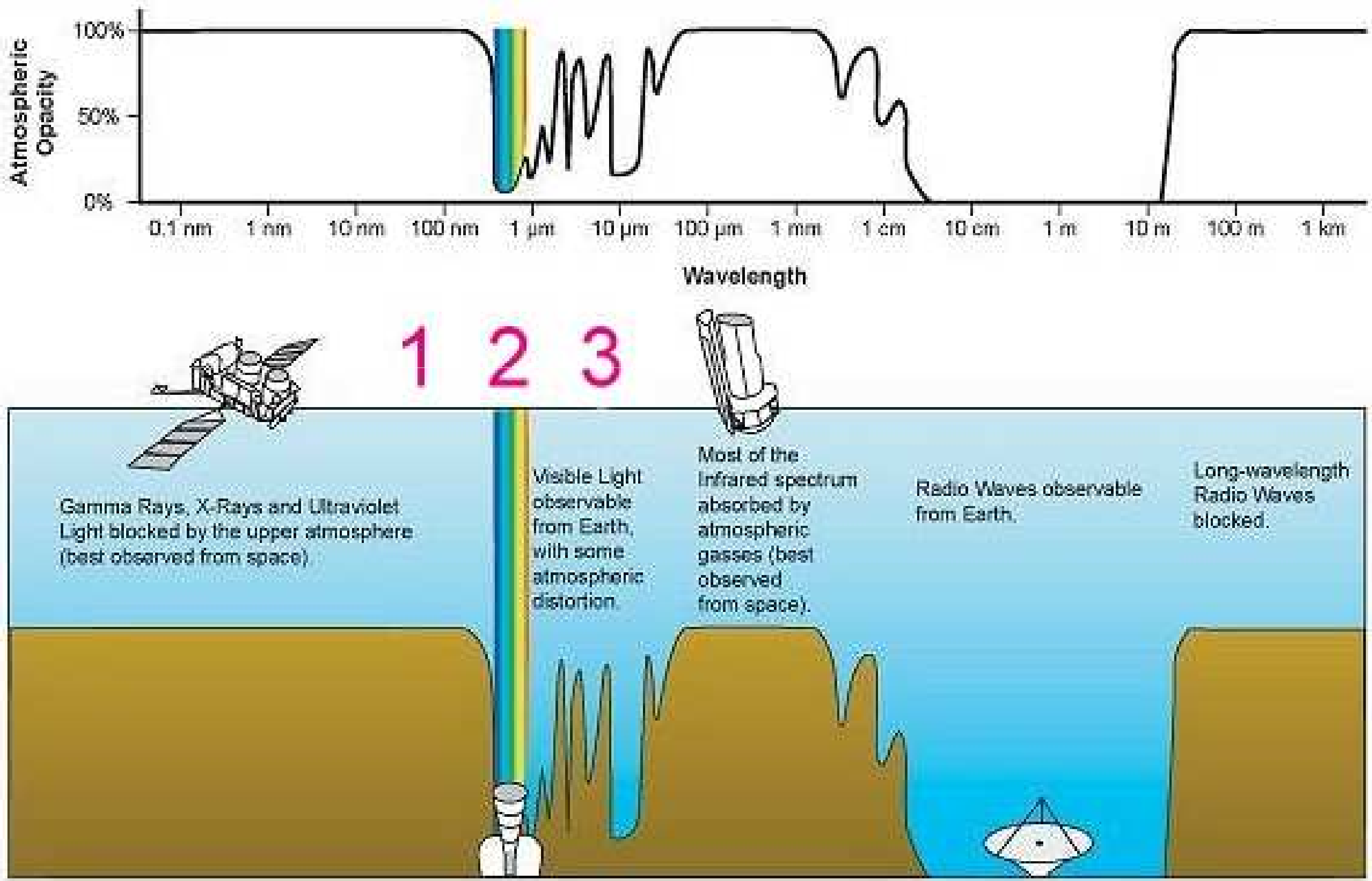
The study aims at:

- Mountain ecosystem mapping
- Plant communities identification,
- Image classification using fuzzy ARTMAP and SVM methods,
- Analysis of airborne hyperspectral data potential for vegetation monitoring
- Presenting the HySens (the Tatras) and HyMountEcos (Krkonose/Karkonosze) projects.

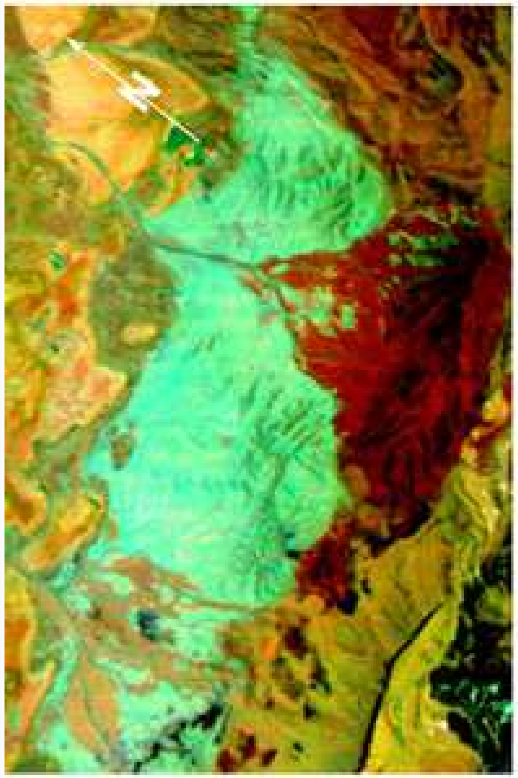
Idea of remote sensing



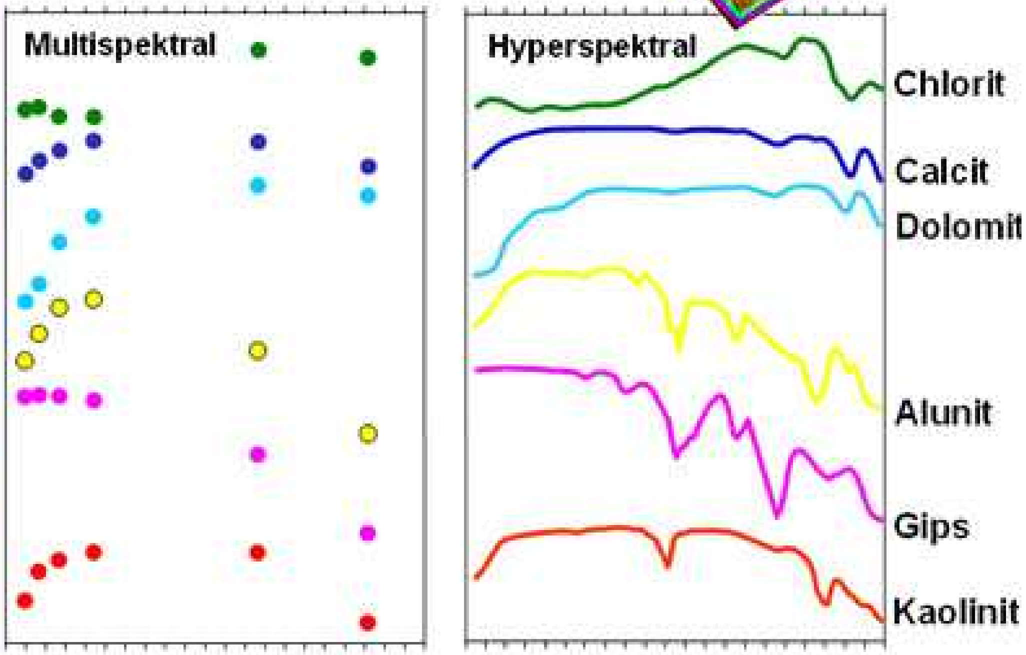
Spectral ranges of remote sensing of environment



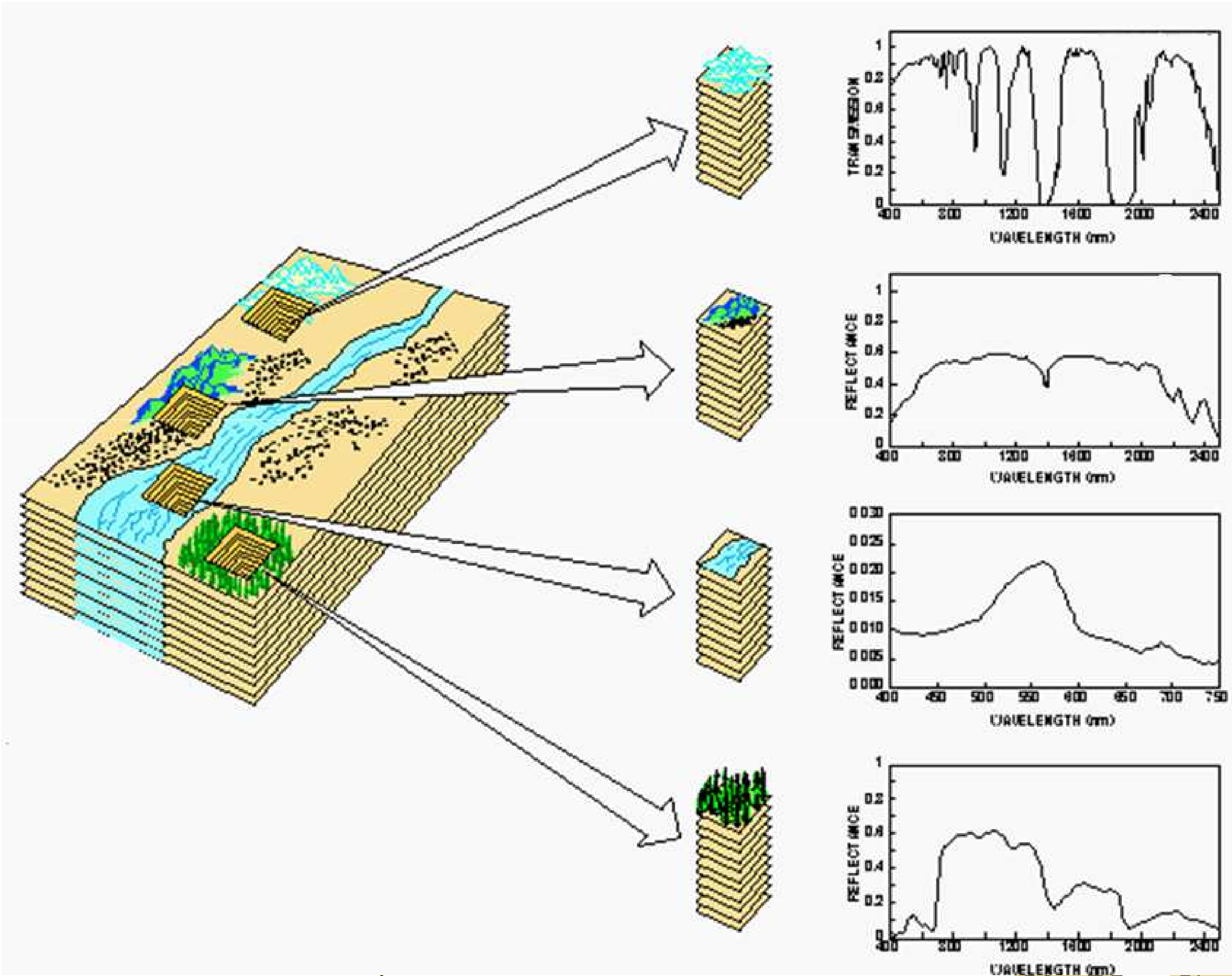
Multi-, hyperspectral remote sensing



Makhtesh Ramon/Israel
Farbdarstellung der Bänder 1, 20, 48



Data acquisition



High Tatras

(Tatra National Park, M&B reserve)

2013-07-23

Research objects (1)

(42 classes)

- *cryptogamic plant communities on scree – initial phase*
- *epilitic lichen communities*
- *scree communities*
- *snow-bed communities*
- *subnivale swards*
- *alpine swards*
- *peaty and boggy communities*
- *avalanche meadows*
- *tall herb communities*
- *grassland communities after grazing*
- *subalpine dwarf scrub communities*
- *willow thicket*
- *mountain-pine scrub on silikat substrate*
- *mountain-pine scrub on calcareus substrate*
- *montane spruce forest*
- *lakes*



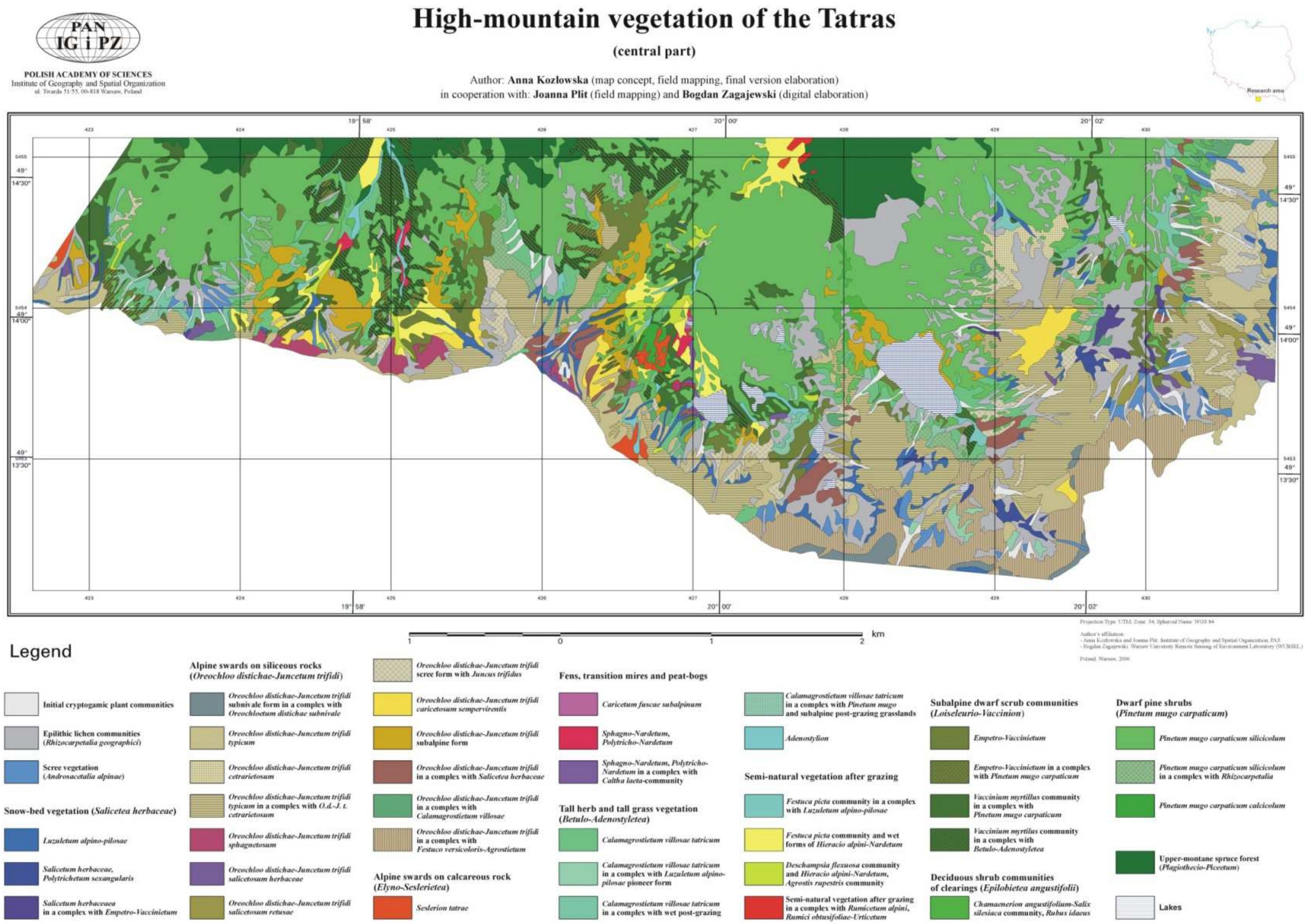








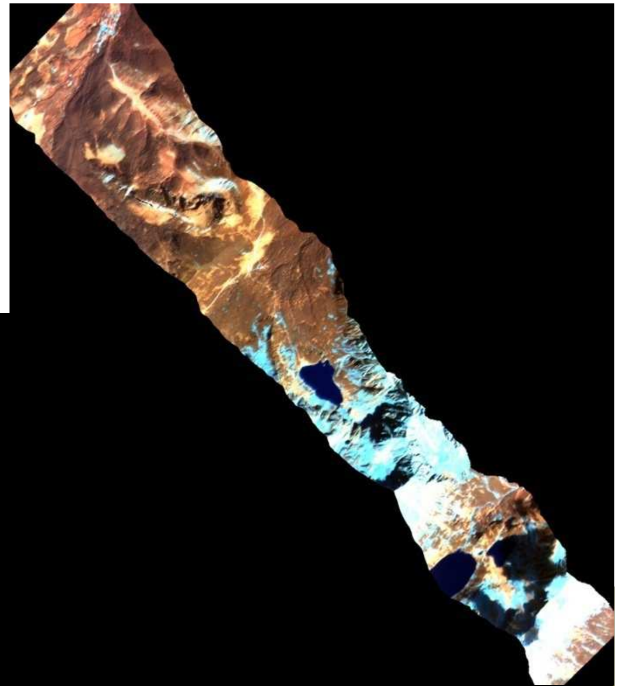


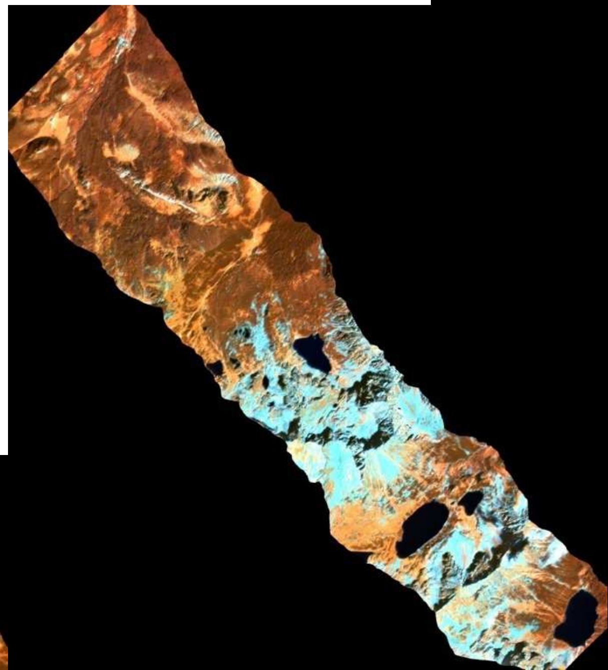



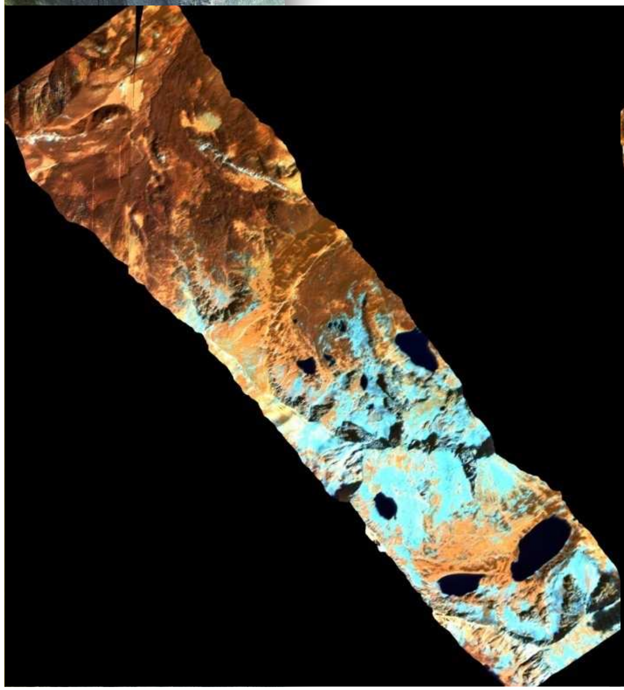
PAN
IG i PZ
POLISH ACADEMY OF SCIENCES
Institute of Geography and Spatial Organization
High-mountain vegetation of the Tatras
(central part)
Author: Anna Kozłowska (map concept, field mapping, final version elaboration)
in cooperation with: Joanna Plit (field mapping) and Bogdan Zagajewski (digital elaboration)
Research area
km
Legend
Initial cryptogamic plant communities
Epilithic lichen communities (Rhizocarpetalia geographici)
Scree vegetation (Androsacetalia alpinae)
Snow-bed vegetation (Salicetea herbaceae)
Luzuletum alpino-pilosae
Salicetum herbaceae, Polytrichetum sexangularis
Salicetum herbaceaea in a complex with Empetro-Vaccinietum
Alpine swards on siliceous rocks (Oreochloo distichae-Juncetum trifidi)
Oreochloo distichae-Juncetum trifidi subnivale form in a complex with Oreochloetum distichae subnivale
Oreochloo distichae-Juncetum trifidi typicum
Oreochloo distichae-Juncetum trifidi cetrarietosum
Oreochloo distichae-Juncetum trifidi typicum in a complex with O.d.-J. t. cetrarietosum
Oreochloo distichae-Juncetum trifidi sphagnetosum
Oreochloo distichae-Juncetum trifidi salicetosum herbaceae
Oreochloo distichae-Juncetum trifidi salicetosum retusae
Oreochloo distichae-Juncetum trifidi scree form with Juncus trifidus
Oreochloo distichae-Juncetum trifidi caricetosum sempervirentis
Oreochloo distichae-Juncetum trifidi subalpine form
Oreochloo distichae-Juncetum trifidi in a complex with Salicetea herbaceae
Oreochloo distichae-Juncetum trifidi in a complex with Calamagrostietum villosae
Oreochloo distichae-Juncetum trifidi in a complex with Festuco versicoloris-Agrostietum
Alpine swards on calcareous rock (Elyno-Seslerietea)
Seslerion tatrae
Fens, transition mires and peat-bogs
Caricetum fuscae subalpinum
Sphagno-Nardetum, Polytricho-Nardetum
Sphagno-Nardetum, Polytricho-Nardetum in a complex with Caltha laeta-community
Tall herb and tall grass vegetation (Betulo-Adenostyletea)
Calamagrostietum villosae tatricum
Calamagrostietum villosae tatricum in a complex with Luzuletum alpino-pilosae pioneer form
Calamagrostietum villosae tatricum in a complex with wet post-grazing
Calamagrostietum villosae tatricum in a complex with Pinetum mugo and subalpine post-grazing grasslands
Adenostylion
Semi-natural vegetation after grazing
Festuca picta community in a complex with Luzuletum alpino-pilosae
Festuca picta community and wet forms of Hieracio alpini-Nardetum
Deschampsia flexuosa community and Hieracio alpini-Nardetum, Agrostis rupestris community
Semi-natural vegetation after grazing in a complex with Rumicetum alpini, Rumici obtusifoliae-Urticetum
Subalpine dwarf scrub communities (Loiseleurio-Vaccinion)
Empetro-Vaccinietum
Empetro-Vaccinietum in a complex with Pinetum mugo carpaticum
Vaccinium myrtillus community in a complex with Pinetum mugo carpaticum
Vaccinium myrtilus community in a complex with Betulo-Adenostyletea
Deciduous shrub communities of clearings (Epilobietea angustifolii)
Chamaenerion angustifolium-Salix silesiaca community, Rubus idaeus
Dwarf pine shrubs (Pinetum mugo carpaticum)
Pinetum mugo carpaticum silicicolum
Pinetum mugo carpaticum silicicolum in a complex with Rhizocarpetalia
Pinetum mugo carpaticum calcicolum
Upper-montane spruce forest (Plagiothecio-Piceetum)
Lakes

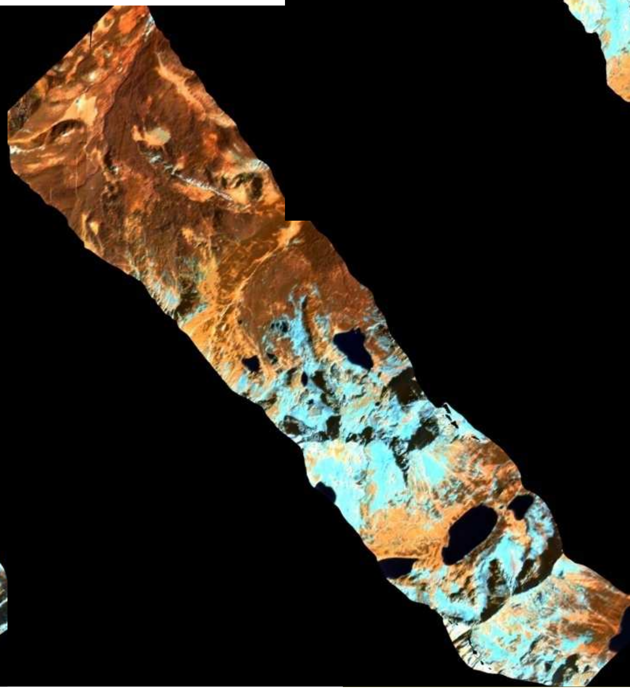
DAIS 7915 images

4 flight lines
79 bands,
15 bit,
3 m pixel size,

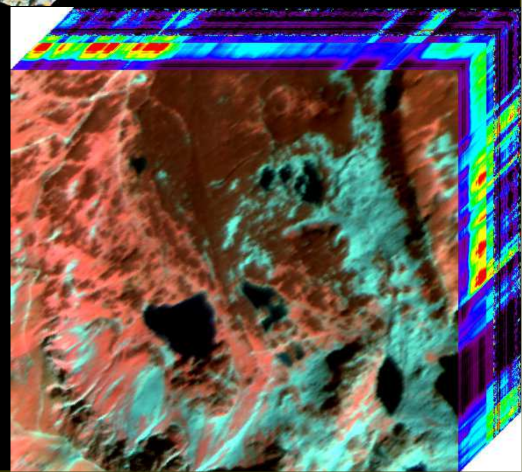






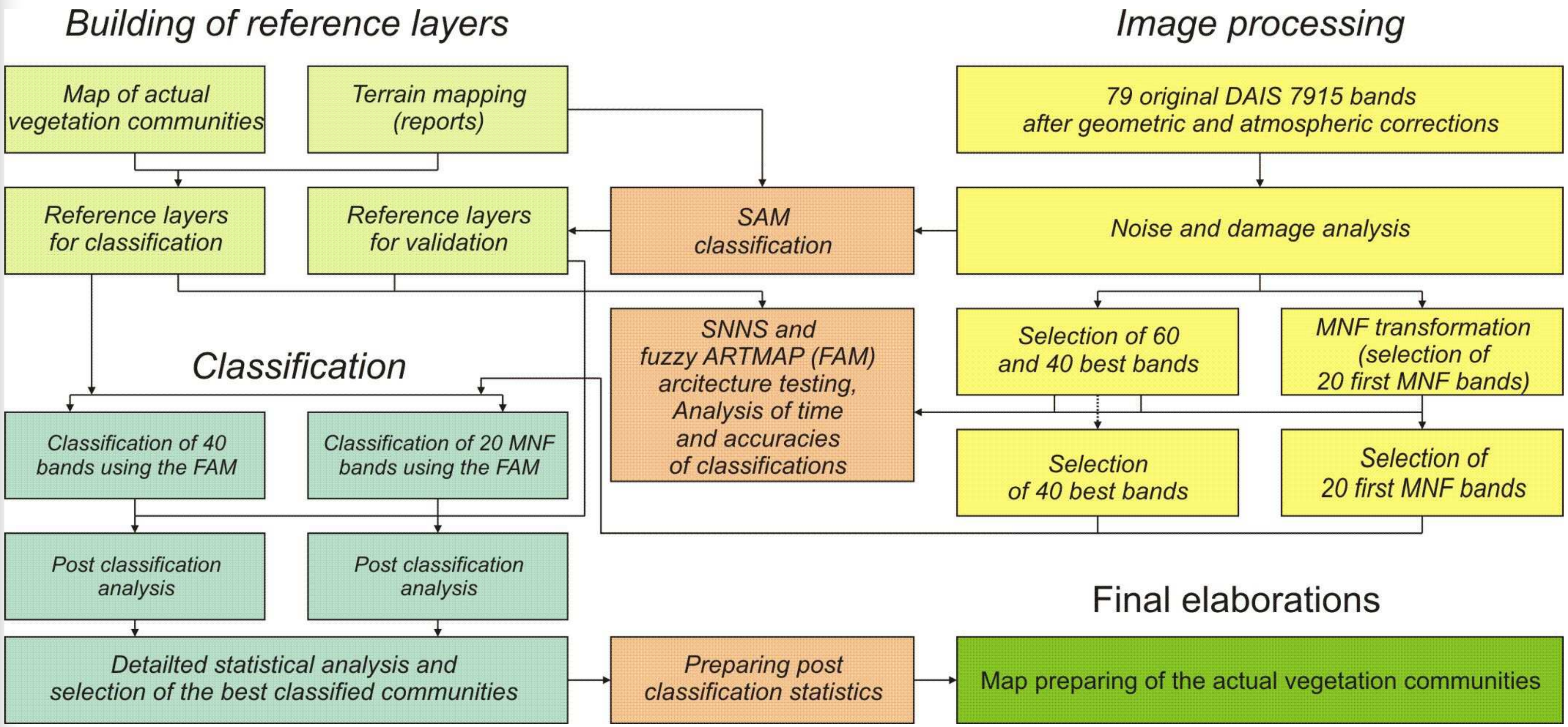


DAIS 7915 RGB 22, 12, 1 compositions
of flight lines 2., 4., 5. and 6.

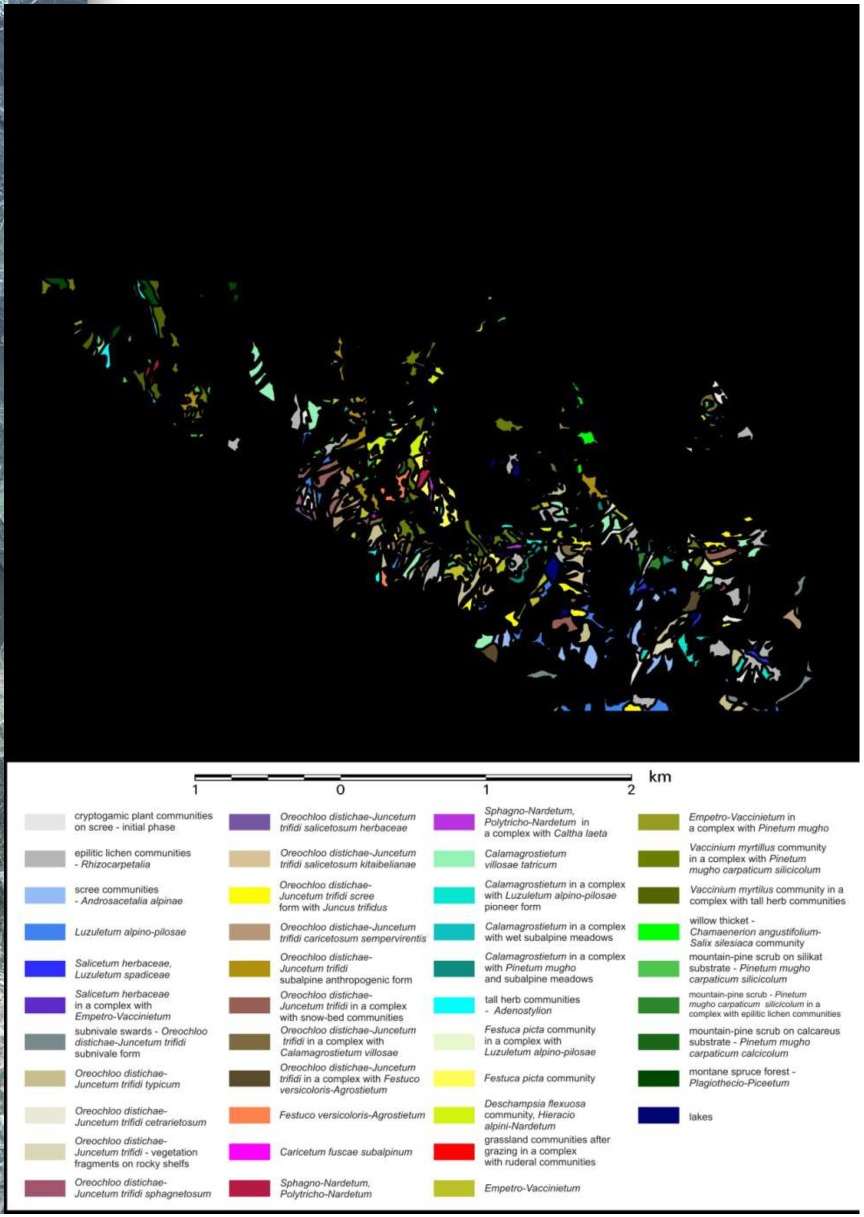


Data cube
of the Gasienicowa Valley
(central part of the test area)

Research algorithm



Teaching and validation sets
(on the base of field mapping and SAM classification)



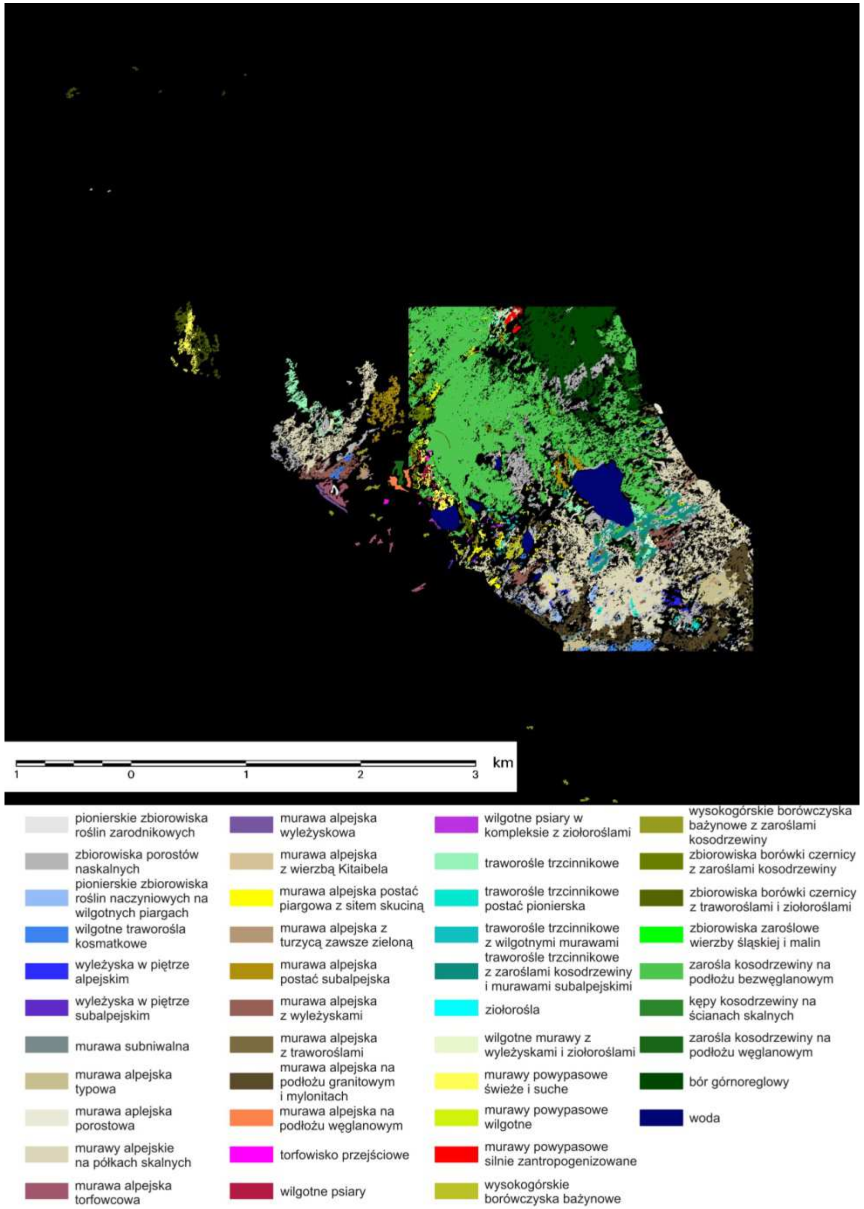
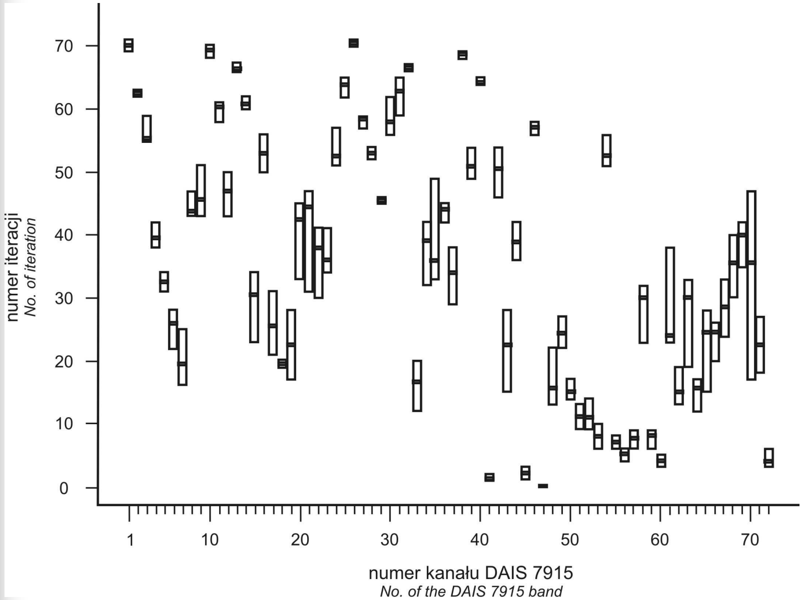
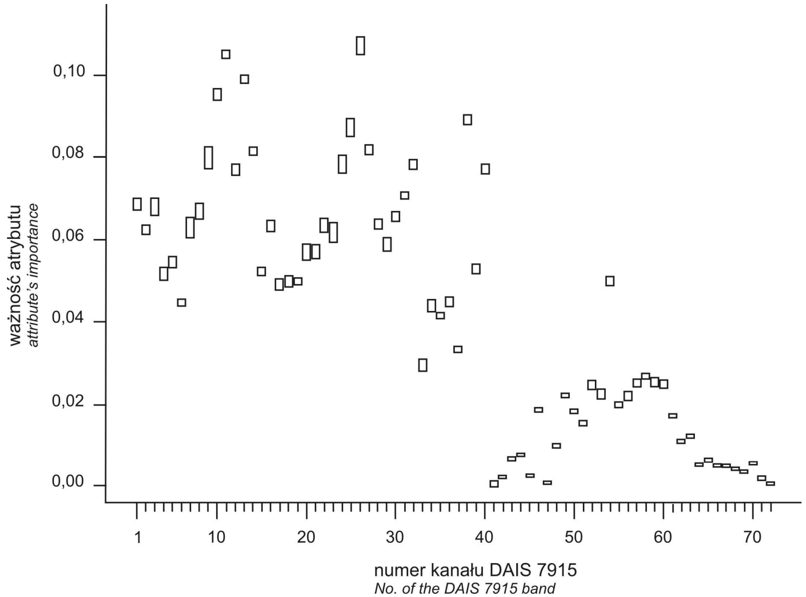


Image data quality analysis

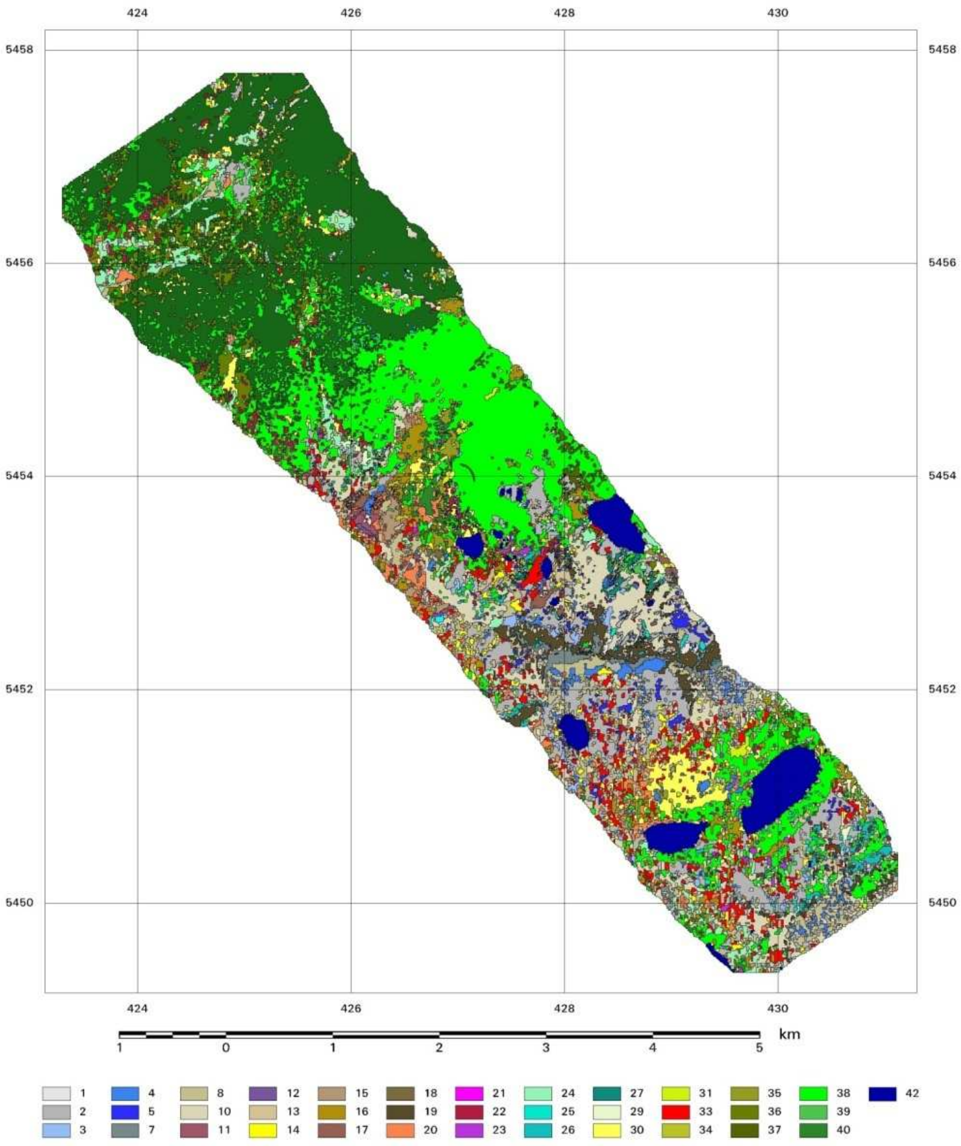




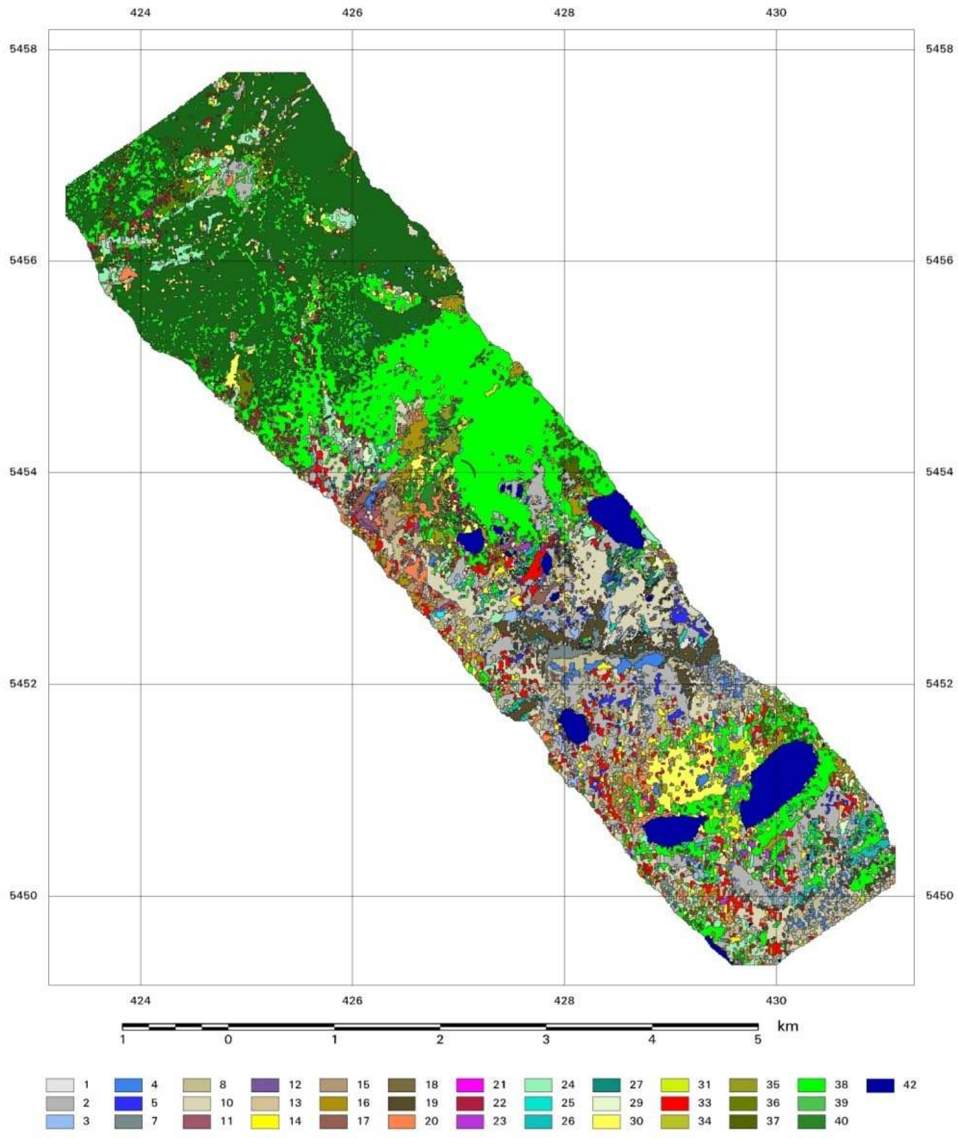
Quality of DAIS 7915 bands: 26, 1, 10, 38, 13, 32, 40, 25, 31, 2, 14, 11, 30, 27, 3, 46, 24, 16, 28, 54, 39, 42, 12, 9, 29, 8, 36, 69, 20, 35, 21, 4, 44, 22, 34, 23, 68, 70, 37, 5, 67, 15, 61, 58, 63, 17, 6, 49, 66, 71, 19, 43, 65, 18, 7, 48, 62, 33, 64, 50, 52, 51, 53, 57, 59, 55, 56, 72, 60, 45

Results (line #5, 5000 iterations)

40 bands



20 MNF bands



	Band #6				Band #5				Band #4		Band #2			
	40 bands		**20 MNF bands**		**40 bands**		**20 MNF bands**		**40 bands**		**40 bands**		**20 MNF bands**	
Overall Accuracy	**87.40%** (362757/415058)		**86.48%** (358569/414637)		**86.96%** (286175/329088)		**85.46%** (281235/329065)		**89.07%** (224941/252538)		**88.79%** (352691/397228)		**84.45%** (335445/397228)	
Kappa Coefficient	**0.8429**		**0.8310**		**0.8425**		**0.8248**		**0.8581**		**0.8634**		**0.8103**	
Class	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.	Prod. Acc.	User Acc.
Class #1	87.8	75.1	88.3	73.9	92.4	80.1	92.4	80.1	-	-	88.9	69.4	83.3	65.37
Class #2	78.5	74.3	78.9	72.9	83.6	82.5	79.0	81.6	84.1	68.7	79.6	82.0	75.13	76.39
Class #3	96.0	54.9	90.7	53.5	92.8	73.2	92.8	71.7	-	-	96.5	66.8	93.73	61.7
Class #4	97.4	68.0	97.5	67.7	93.5	79.1	93.5	78.8	95.8	70.7	93.8	76.5	90.31	45.14
Class #5	95.6	72.1	95.6	72.1	95.2	57.3	95.2	53.4	-	-	89.9	74.5	75.7	70.02
Class #7	90.7	65.9	90.7	64.1	95.8	53.2	94.6	52.9	-	-	90.1	75.5	87.06	64.67
Class #8	89.4	74.8	89.5	74.2	89.1	79.1	89.2	76.9	94.0	93.0	92.2	81.0	89.43	73.07
Class #9	-	-	-	-	-	-	-	-	98.3	66.6	-	-	-	-
Class #10	73.3	92.6	73.4	91.7	80.7	94.9	77.9	94.6	86.5	89.3	78.7	95.2	73.45	93.93
Class #11	-	-	-	-	91.4	98.1	91.4	97.1	-	-	-	-	-	-
Class #12	-	-	-	-	90.5	89.3	90.5	89.3	-	-	-	-	-	-
Class #13	91.7	73.0	80.5	69.0	94.9	45.2	94.9	45.2	-	-	89.9	81.8	73.33	76.02
Class #14	82.2	64.0	54.4	52.9	78.6	80.5	78.6	80.5	94.4	32.3	83.8	77.1	75.34	59.61
Class #15	87.9	83.2	70.7	82.1	79.4	68.4	79.4	68.2	97.9	63.6	87.1	81.6	59.1	72.76
Class #16	76.2	94.4	65.0	94.7	78.5	83.4	78.5	81.9	90.6	77.6	83.9	91.6	80.15	88.77
Class #17	81.4	82.5	68.9	80.1	68.8	91.4	68.9	88.3	95.0	90.6	91.3	72.2	87.02	65.3
Class #18	85.9	73.6	86.0	71.5	71.5	93.2	71.5	93.2	95.4	84.0	81.7	72.5	76.16	67.77
Class #19	84.8	76.8	84.8	76.2	72.8	86.3	72.8	85.4	90.1	88.4	90.4	82.6	85.69	77.46
Class #20	95.1	85.2	61.8	86.3	89.8	66.6	83.2	63.8	-	-	91.9	89.1	83.7	87.22
Class #21	-	-	-	-	95.7	84.6	95.7	84.6	-	-	97.8	83.5	88.89	85.71
Class #22	85.6	80.7	74.0	75.2	90.8	56.4	87.8	55.7	-	-	91.3	84.0	87.78	80.63
Class #23	93.8	78.2	83.5	67.4	94.1	55.1	94.1	54.5	-	-	84.9	85.3	73.14	85.09
Class #24	82.1	73.4	78.2	71.9	73.7	84.6	73.8	81.6	91.0	70.0	80.3	71.2	66.55	60.86
Class #25	95.8	67.9	91.6	65.8	86.0	63.0	86.0	58.1	-	-	93.6	70.0	89.45	61.91
Class #26	89.7	67.5	73.8	63.8	97.8	30.8	97.8	27.5	-	-	91.1	81.4	77.13	80.44
Class #27	-	-	-	-	83.7	87.5	83.8	87.1	-	-	76.5	84.5	38.02	72.89
Class #28	83.9	79.5	64.4	76.5	-	-	-	-	-	-	87.2	72.4	88.27	71.57
Class #29	97.8	73.9	91.8	73.4	84.0	67.5	84.3	65.1	92.7	89.8	76.9	78.5	76.56	67.43
Class #30	80.8	57.4	74.8	48.5	76.7	80.6	76.7	79.1	-	-	87.9	60.0	82.75	53.85
Class #31	85.5	71.0	69.7	66.5	81.7	76.4	81.7	76.4	80.1	59.1	89.4	59.6	79.8	47.8
Class #33	96.1	75.9	96.6	73.9	96.5	64.3	95.7	59.5	98.8	63.3	93.5	66.7	94.21	60.23
Class #34	-	-	-	-	85.6	96.2	85.6	96.2	-	-	-	-	-	-
Class #35	84.8	72.0	85.7	67.6	81.4	82.7	81.5	81.7	98.1	50.5	86.8	69.5	78.5	63.75
Class #36	75.3	73.7	63.6	73.3	73.8	84.0	66.0	78.5	68.4	76.4	71.1	78.5	62.06	61.84
Class #37	92.6	66.0	63.3	60.4	94.3	28.3	95.1	18.7	74.7	51.1	92.4	49.6	65.56	38.72
Class #38	95.8	93.9	96.0	93.4	93.4	96.2	92.3	95.3	91.8	92.1	94.6	96.8	94.09	95.04
Class #39	85.2	72.6	85.4	71.9	91.1	67.2	91.1	67.2	-	-	93.8	67.7	89.97	60.01
Class #40	-	-	-	-	95.9	37.4	95.9	37.2	-	-	96.0	86.0	92.02	76.38
Class #41	81.3	97.0	81.4	97.0	-	-	-	-	80.9	96.0	87.7	96.0	77.16	96.16
Class #42	97.4	98.1	97.5	98.0	97.8	97.8	97.8	97.8	98.7	99.6	96.7	98.3	96.78	97.85

Conclusions

- Hyperspectral remote sensing techniques and ANN show potential for mountainous vegetation mapping in large scales, what can bu used for monitoring of high-mountain ecosystems ,
- 39 of 41 vegetation classes were classified,
- The best results (producer and user accuracies > 90%) are observed for: #8 *Oreochloo distichae-Juncetum trifidi typicum*; #11 *Oreochloo distichae-Juncetum trifidi sphagnetosum*; #16 *Oreochloo distichae-Juncetum trifidi* subalpine anthropogenic form; #17 *Oreochloo distichae-Juncetum trifidi* in a complex with snow-bed communities; #18 *Oreochloo distichae-Juncetum trifidi* in a complex with *Calamagrostietum villosae*; #38 mountain-pine scrub on silicate substrate - *Pinetum mugho carpaticum silicicolum*; #42 lakes
- The best average fourty-band set’s results: 92.8% (producer accuracy) and 84,2% (user acc.). The worst: 84.2% and 67.5%.
- The best average twenty-MNF-band set’s results: 86.1% and 79.9%, and the worst 74.7% and 63.7%
- The best results are observed for: oat crops (99,8 %), stubbles (96,6 %), grasslands (94,8 %), deciduous forest (93,9 %), and the worst for tree clumps (38,8 %), orchards (44,7 %) and side roads (56,1 %),
- Twenty-MNF-band set achieves ~7-9% worst results, but classifications were 2-3 times faster

Hyperspectral remote sensing for Karkonosze ecosystems – EUFAR's HyMountEcos Project

Zagajewski B., Kupkova L., Markowicz K.M., Kozłowska A., Adamczyk J., Albrechtova J., Będkowski K., Bilip M., Chiliñski M., Jarocińska A., Kycko M., Lhotakova Z., Marcinkowska A., Mierczyk M., Nasiłowska S., Ochtyra A., Knapik R., Oprządek M., Pabjanek P., Potuckova M., Przewoźnik L., Raczko E., Sendyk A., Slacikova J., Stachlewska I.S., Tobiasz M., Wojtuń B., Zawadzka O., Żołnierz L.

HyMountEcos project

- Project acronym **HyMountEcos**
- Project title **Hyperspectral Remote Sensing for Mountain Ecosystems**
- Type **Scientific project**
- Scientific theme **Assessment of the hyperspectral techniques potential for mountain ecosystems monitoring**
- Main scientific field and Specific discipline **Earth Sciences & Environment / Ecosystems & Biodiversity**

Scientific problems

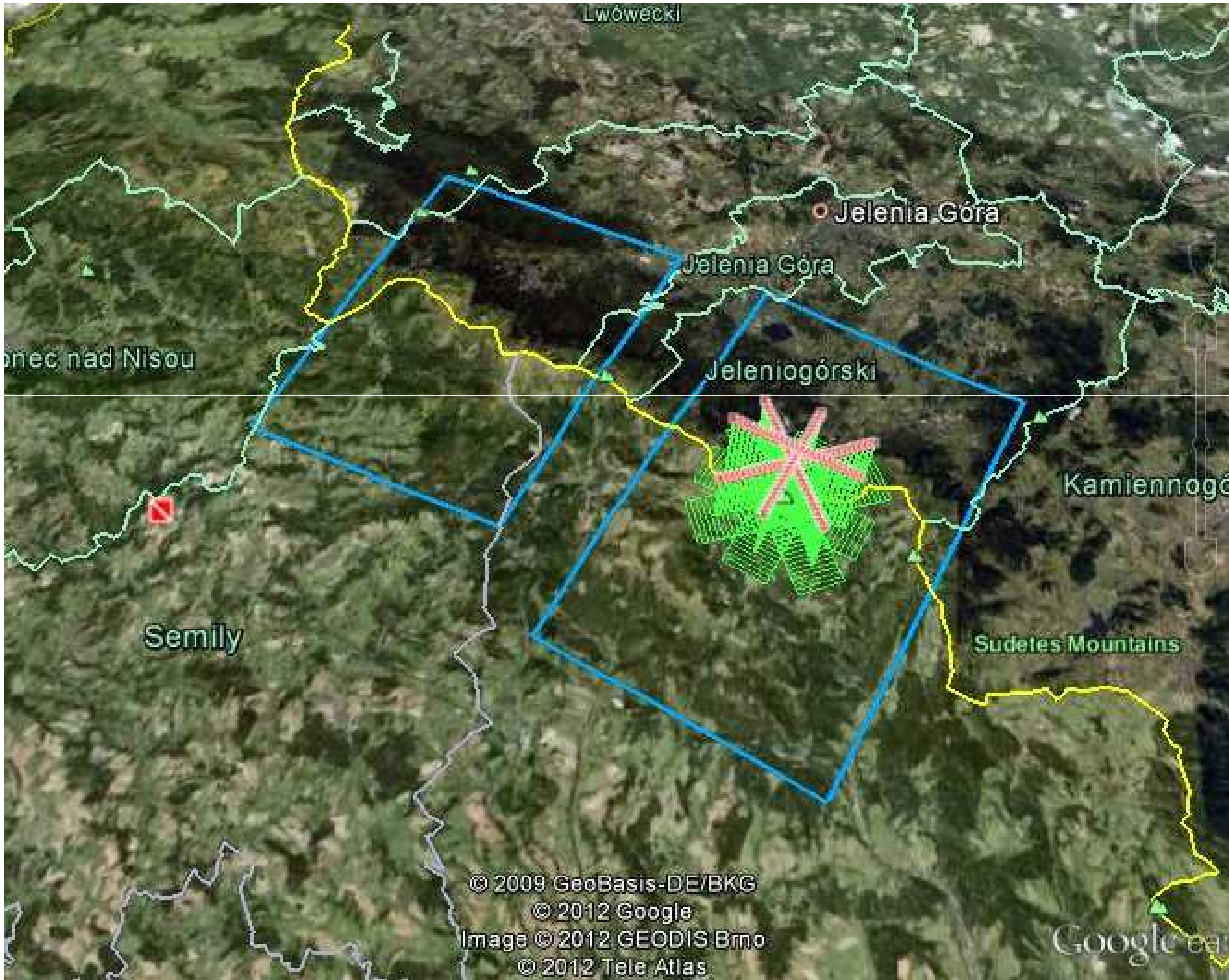
- monitoring of mountain ecosystems of the Giant Mountains (Karkonosze/Krkonoše) National Park
- to assess influence of management practice.
- mountain ecosystems mapping and inventarization,
- an analyses and evaluation of forest ecosystems conditions/health,
- an analyses of ecosystems species composition and invasive species introduction
- an analysis of soil contamination.

APEX Performance

- Spectral Range 380.5 – 971.7 nm VNIR 941.2 – 2501.5 nm SWIR
- Spectral Bands Up to 532 (Default: 312)
- SSI 0.45 – 7.5 nm   5 – 10 nm
- FWHM 0.7 – 9.7 nm   6.2 – 12 nm
- Spatial 1000 Pixel
- Ground Resolution 0.5 – 1.75m @ 1000 – 3500m AGL
- FOV 28 Degrees

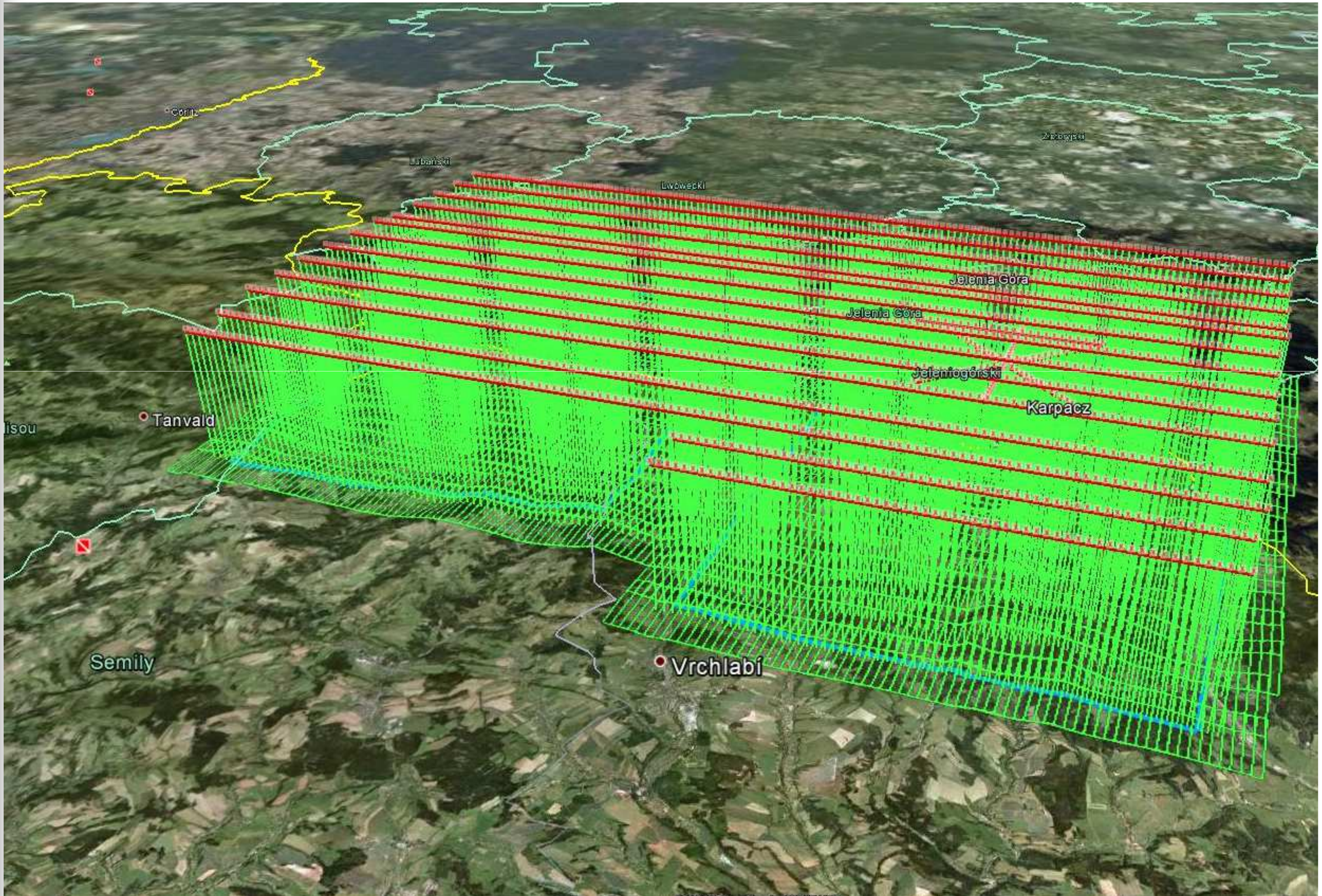
Data acquisition (10.09.2012)

Flight plan (BRDF)



Flight plan 2

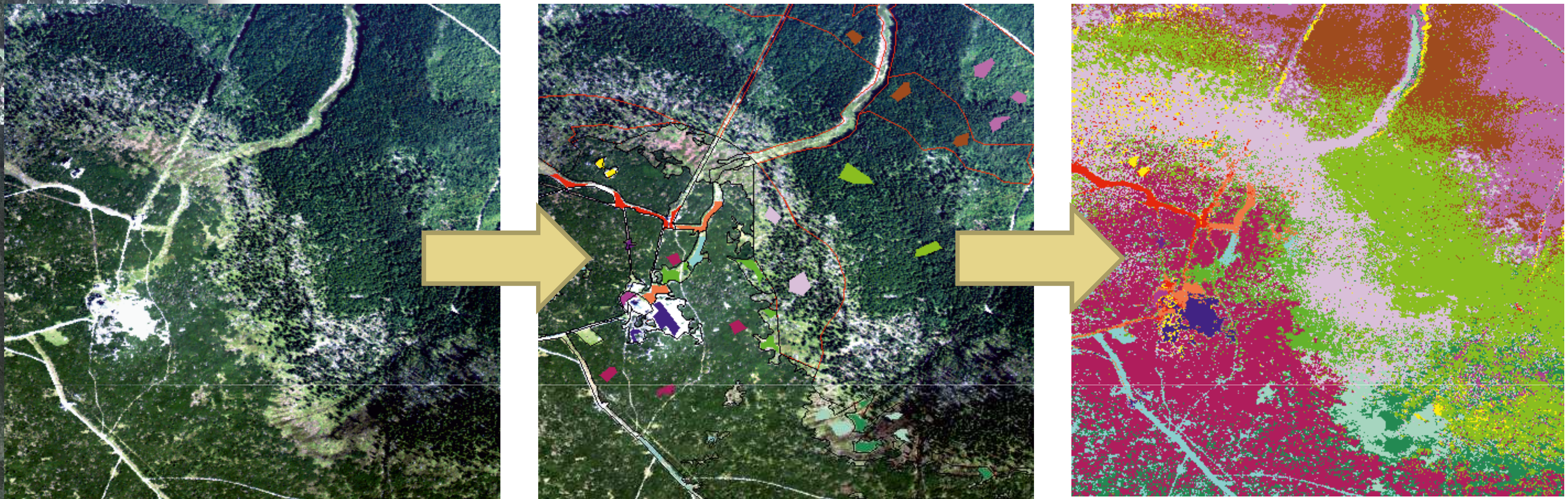
Flight plan 3



Output of the project

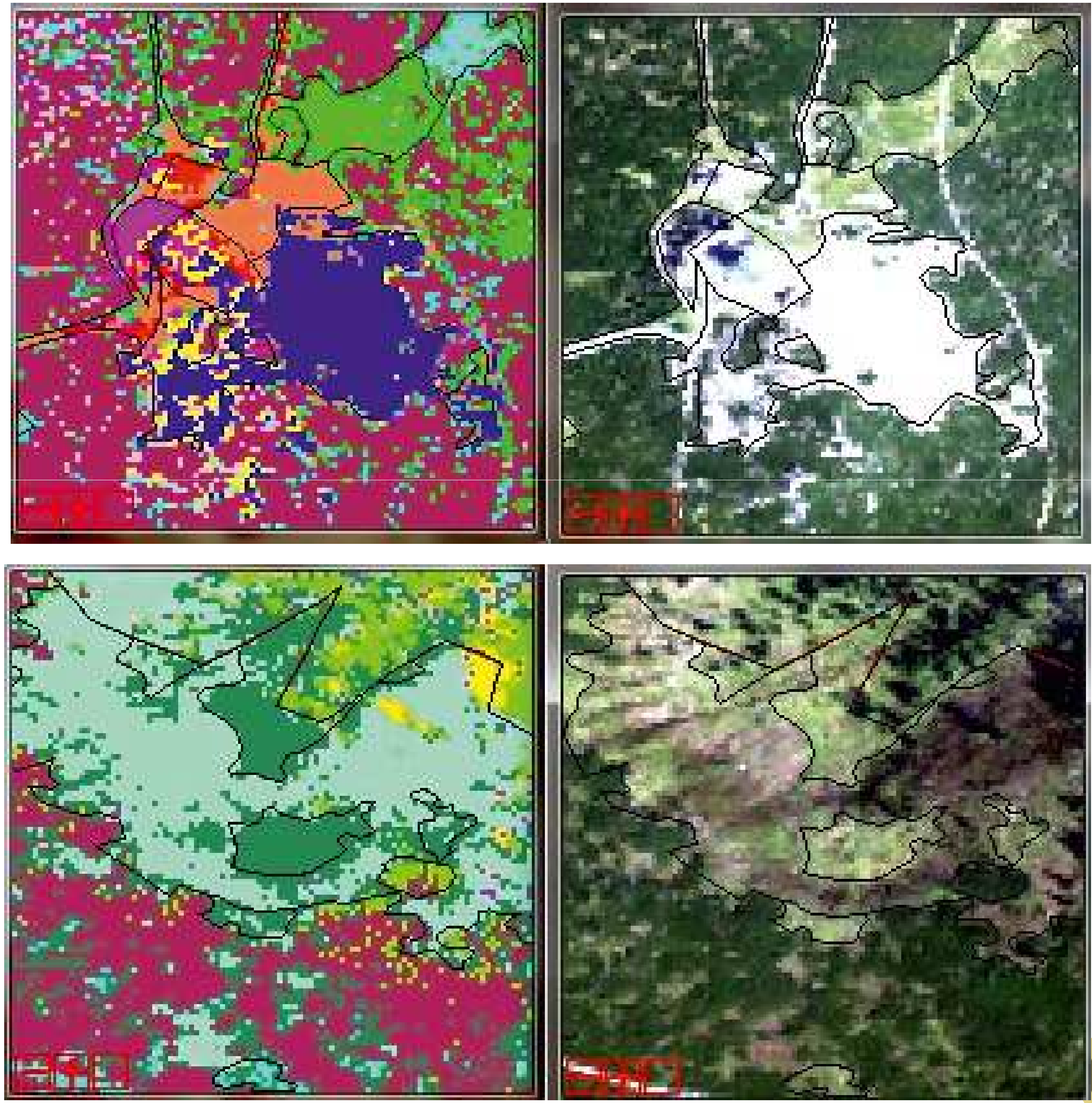
- Mountain ecosystems mapping and inventarization,
- Analyses of ecosystems species composition and invasive species introduction,
- Analyses and evaluation of forest ecosystems conditions/health (biophysical parameters like chlorophyll content, LAI, water content).
- Processing chain for mountain ecosytems monitoring using hyperspectral technologies and potential/feasibility assessment of hyperspectral data/technologies for the mountain ecosystems analysis and monitoring.

Vegetation mapping



1. Vaccinium myrtillus, 2. Associations from Rhizocarpion alpicolae alliance, 3. Associations from Umbilicarion cylindricae alliance, 4. Carici (rigidae)-Nardetum, 5. Associations from Artemisietea vulgaris class, 6. Pinetum mugo sudeticum, 7. Associations from Calamagrostion alliance, 8. Associations from Scheuchzerio-Caricetea nigrae class, 9. Deschampsia caespitosa, 10. Athyrietum distentifolii, 11. Luzulo nemorosae-Fagetum (typical), 12. Abieti-Piceetum (montanum), 13. Calamagrostio villosae-Piceetum (division of fern), 14. Calamagrostio villosae-Piceetum typicum, 15. Area without vegetation.

Validation process



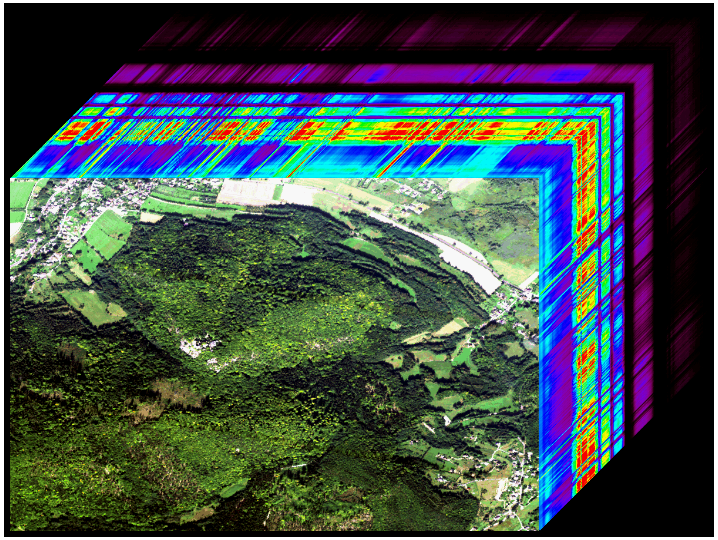
Accuracy analysis

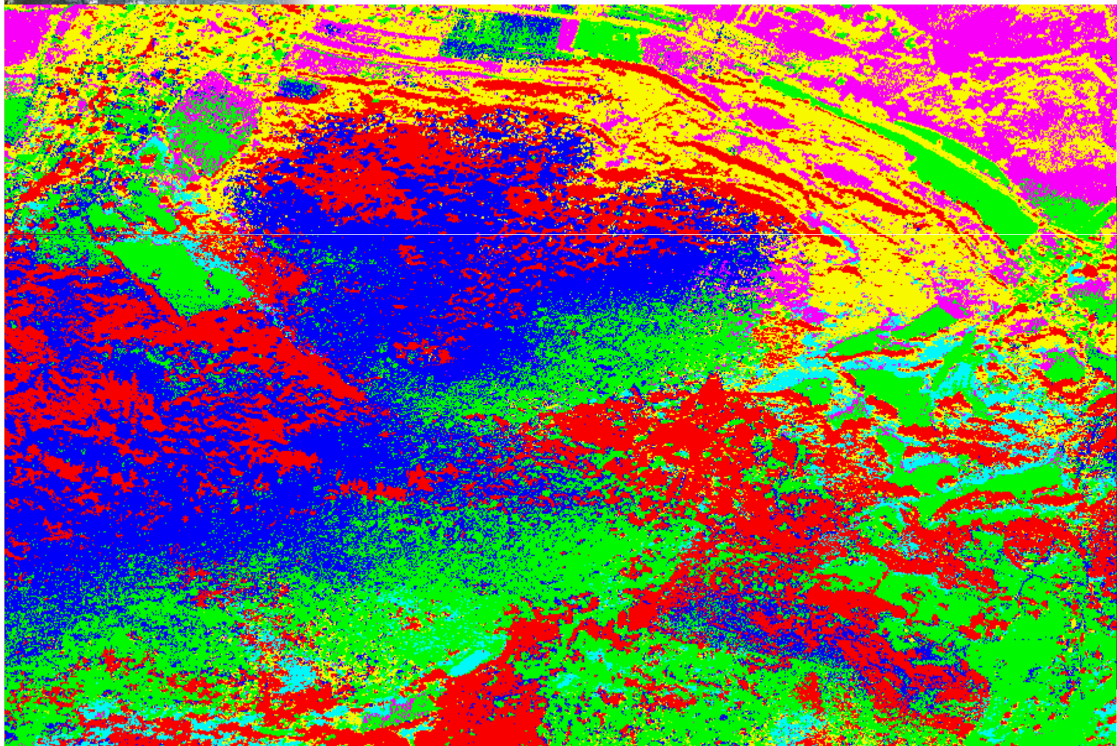
Class	Prod. Acc. (%)	User Acc. (%)	Class	Prod. Acc. (%)	User Acc. (%)
1	77,24	73,85	9	73,23	76,86
2	99,06	99,76	10	0,24	3,23
3	93,33	54,55	11	77,02	77,32
4	89,37	96,35	12	65,63	69,44
5	89,13	94,25	13	99,14	92,74
6	99,14	94,86	14	81,59	45,56
7	93,17	96,22	15	83,76	90,48
8	83,72	97,3			

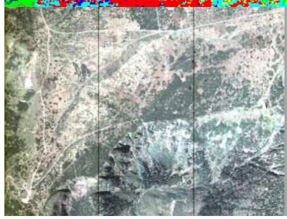
Overall Accuracy = 79,1259%

Kappa Coefficient = 0,7736

Results of tree species classification







Classification test area 2

Class	Pine	Beech	Larch	Adler	Birch	Spruce
Pine	91,71	0,00	0,00	0,00	0,00	0,85
Beech	0,00	88,04	9,87	14,20	10,39	0,47
Larch	0,00	1,15	58,48	4,32	16,23	0,57
Adler	0,00	3,17	3,29	81,48	1,08	0,19
Birch	0,00	7,06	13,16	0,00	59,31	1,32
Spruce	8,29	0,58	15,19	0,00	12,99	96,60

Overall Accuracy: 82,64%

Kappa Coefficient: 0,77

Conclusions

- Dominant (spruce, beech and larch) tree species are usually better classified than those that are sparser.
- Best results were obtained for spruce (above 90% on both areas) and pine (above 80%).
- Worse accuracy for larch was mainly caused by small sample of data from which learning and verification polygons were taken.
- Results for deciduous trees were bit less accurate ranging from 59% for birch to 88% for beech. Given classifications were made on diverse test sites with mixed forest composition
- The best results are observed for associations from Rhizocarpion alpicolae alliance - 99,06 % (prod. a), 99,76% (user a), the worst - Athyrietum distentifolii - 0,24% (p.a.), 3,23 % (u.a.). It was caused e.g. by homogeneity of polygons representing each class.

Thank you very much for your attention

Special thanks to:
- *Lucie Kupkova and colleagues from the Charles University*
- *Andreas Mueller and the DLR team for the DAIS data*
- *Koen Mueleman and the VITO and DLR teams for the APEX data*
- *Paolo Gamba for the fuzzy ARTMAP simulator*
- *Management Boards of the Tatra, Krkonose and Karkonosze National Parks*