Assessment of vegetation conditions on natural parks by using hyperspectral data

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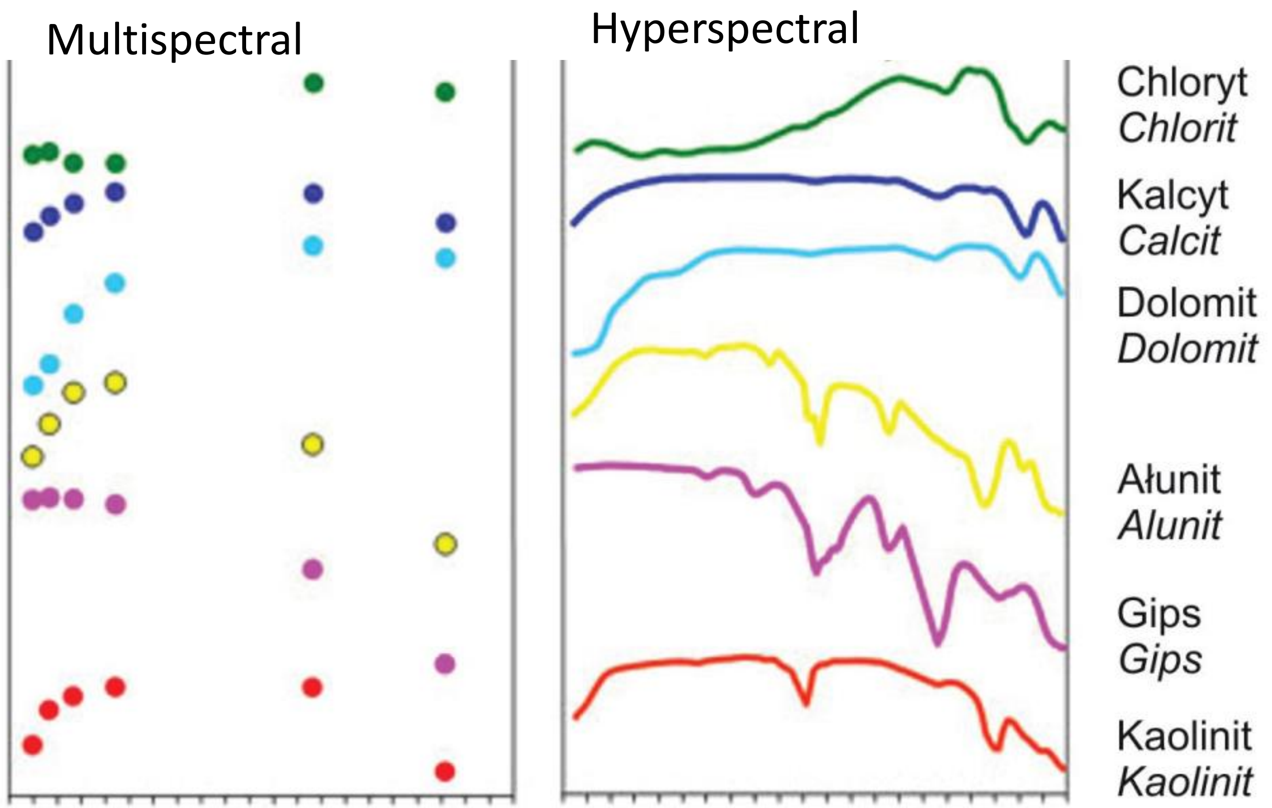
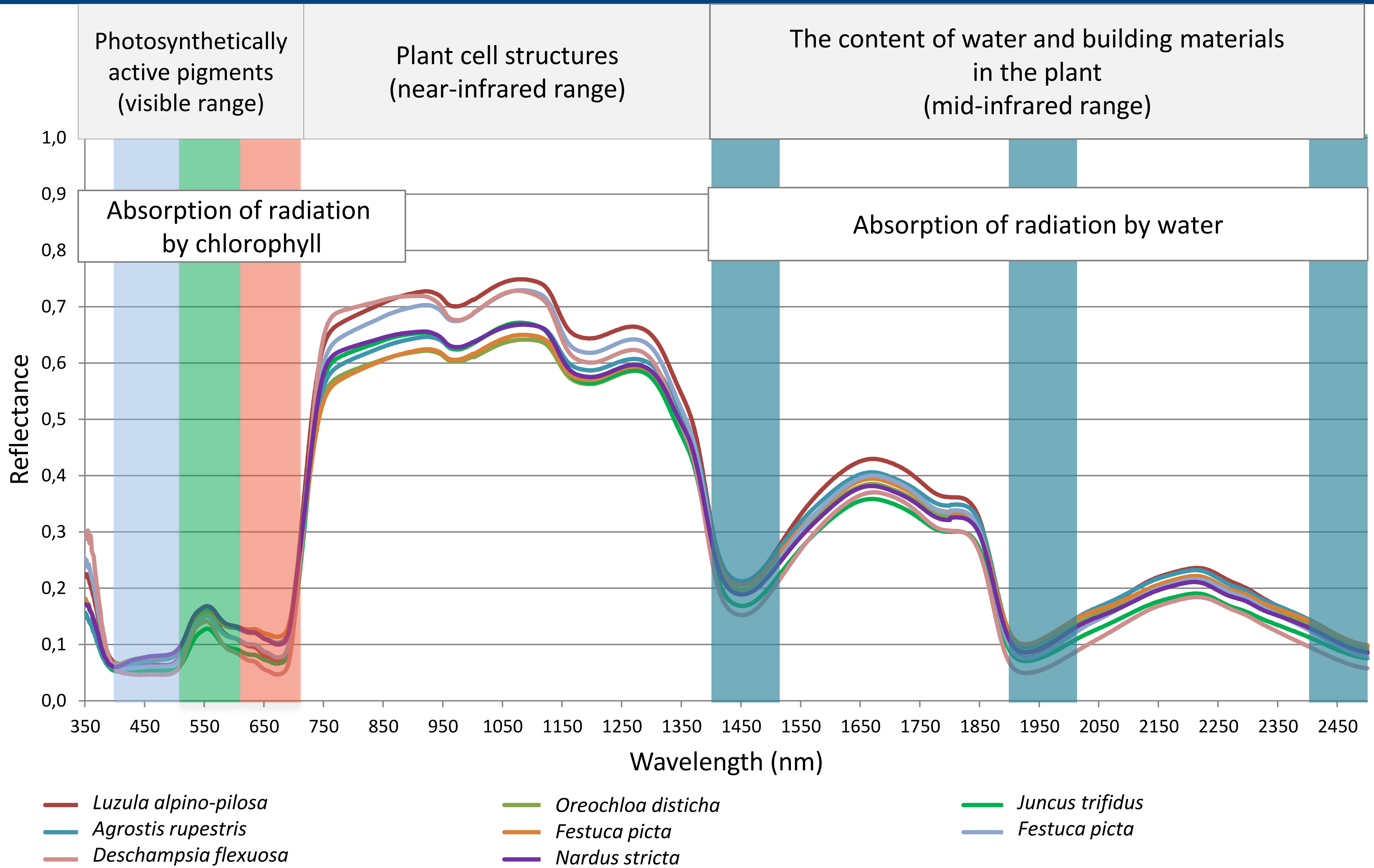
Introduction

Hyperspectral remote sensing

Remote sensing data comprising over 40 spectrally continuous bands with a half width of between 10 and 20 nm (Goetz et al. 1985).



The spectral characteristics of vegetation



Remote sensing vegetation indicators (1)

Application	Symbol	Name	Formula	Source of information
Assessment of the general state of vegetation	WRDVI	*Wide Dynamic Range Vegetation Index*	WRDVI=(0,2* R860- R650)/(0,2* R860+ R650)	Gitelson, 2004
	ARVI	*Atmospherically Resistant Vegetation Index*	ARVI={[R860-(2* R650- R470)]/[R860+(R650-R470)]}	Kaufman, Tanre 1992
	TVI	*Triangular Vegetation Index*	TVI = 0,5 * [120 * (R750- R550) – 200 * (R670-R550)]	Broge i Leblanc, 2000
	NMDI	*Normalized Multi-band Drought Index*	NMDI={[R860-(R1640-R2130)]/[R860+(R1640-R2130)]}	Wang, Qu 2007, Zhang i in. 2009
	GNDVI	*Green Normalized Difference Vegetation Index*	GNDVI=(R860- R550)/ (R860+ R550)	Gitelson i in., 1996
Assessment of the amount of photosynthetic dyes	mNDVI705	*Modified Normalized Difference Vegetation Index 705*	mNDVI705=(R750-R705)/[R750+R705-(2*R445)]	Sims i Gamon, 2002
	VREI2	*Vogelmann Red Edge Index 2*	VREI2=(R734-R747)/(R715+R726)	Vogelmann i in., 1993
	REPI	*Red Edge Position Index*	REPI = 700 + 40* {[(R670 + R780)/2 – R700]/(R740 – R700)}	Dawson i Curran 1998
	SRPI	*Simple ratio pigment index*	SRPI=R800/R635	Peñuelas i in., 1995
	CRI2	*Carotenoid Reflectance Index 2*	CRI2=(1/R510)-(1/R700)	Gitelson i in., 2002
	ARI2	*Anthocyanin Reflectance Index 2*	ARI2=R800*[(1/R550)-(1/R700)]	Gitelson i in., 2001
	CTR2	*Carter*	CTR2 = R695 / R760	Carter i in., 1996
	LIC2	*Lichtenthaler*	LIC2 = R440 / R690	Lichtenthaler i in., 1996
	GM2	*Gitelson i Merzlyak*	GM2 = R750 / R700	Gitelson i Merzlyak 1997
	GI	*Greenness Index*	GI = R554 / R677	Zarco-Tejada i in.,2004
	XES	*Xantophyll epoxidation state*	XES=R531	Gamon i in., 1990
	SI	*Stress Index*	SI=R710/R810	Jiang i Carrow, 2007
	RGR	*Red/Green Ratio; Antocyjany/chlorofil*	RGR=(R600-R699)/(R500-R599)	Fuentes i in., 2001
	RARSa	*Ratio analysis of reflectance spectra algorithm chlorophyll a*	RARSa=R675/R700	Chappelle i in., 1992
	RARSb	*Ratio analysis of reflectance spectra algorithm chlorophyll b*	RARSb=R675/(R650*R700)	Chappelle i in., 1992
	RARSc	*Ratio analysis of reflectance spectra algorithm carotenoind*	RARSc=R760/R500	Chappelle i in., 1992

Remote sensing vegetation indicators (2)

Application	Symbol	Name	Formula	Source of information
Assessment of nitrogen content	NDNI	*Normalized Difference Nitrogen Index*	NDNI=[LOG(1/R1510)-LOG(1/R1680)]/[LOG(1/R1510)+LOG(1/R1680)]	Serrano i in., 2002
Assessment of the amount of light used in photosynthesis	PRI	*Photochemical Reflectance Index*	PRI=(R531-R570)/(R531+R570)	Gamon i in., 1992
	SIPI	*Structure Insensitive Pigment Index*	SIPI=(R800-R445)/(R800-R680)	Penuelas i in., 1995
	NPQI	*Normalized Phaeophytinization Index*	NPQI = (R415-R435)/(R415 + R435)	Barnes i in., 1992
	ZMI	*Zarco-Tejada & Miller*	ZMI = R750/R710	Zarco-Tejada i in., 2001
Assessment of the amount of dry biomass and coal	PSRI	*Plant Senescence Reflectance Index*	PSRI=(R680-R500)/R750	Merzlyak i in., 1999
	NDLI	*Normalized Difference Lignin Index*	NDLI=[LOG(1/R1754)-LOG(1/R1680)]/[LOG(1/R1754)+LOG(1/R1680)]	Serrano i in., 2002
	CAI	*Cellulose Absorption Index*	CAI=[0,5*(R2000+R2200)]-R2100	Daughtry, 2001
Assessment of water content	WBI	*Water Band Index*	WBI=R970/R900	Penuelas i in., 1995
	NDWI	*Normalized Difference Water Index*	NDWI=(R857-R1241)/(R857+R1241)	Gao, 1995
	RWC	*Relative Water Content*	RWC=R1483 / R1650	Linke i in., 2008
	AWC	*Actual water content*	AWC=R1121 / R1430	Linke i in., 2008
	RMP	*Relative leaf moisture percentage on fresh weight basis*	RMP=R2200 / R1430	Yu i in., 2000
	DSWI	*Disease water stress*	DSWI=(R802+R547)/(R1657+R682)	Galvão i in., 2005

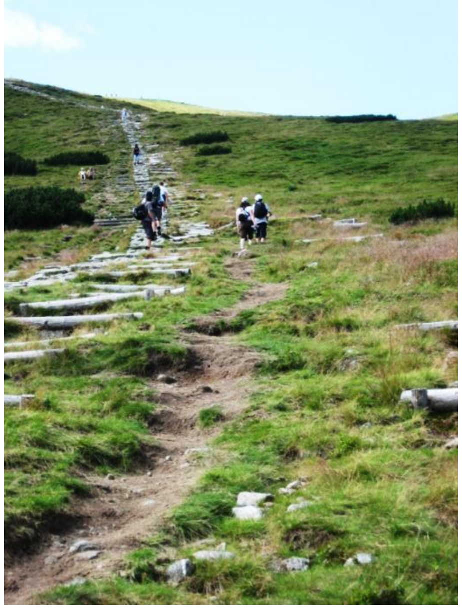
Hyperspectral remote sensing for monitoring of alpine trampled species

Motivations and object of research

- The purpose of the study is to determine changes in alpine swards, caused by stressors (e.g. **trampling** caused by increased tourist traffic)
- Integration of **hyperspectral tools** with plant **physiology methods** (fluorescence and chlorophyll content).

Measurements was performed on dominant species of alpine swards in Polish mountains (**Tatra National Park**, TPN) - Kasprowy Peak and Red Peaks in Tatras (**UNESCO M&B Reserve and National Park**).

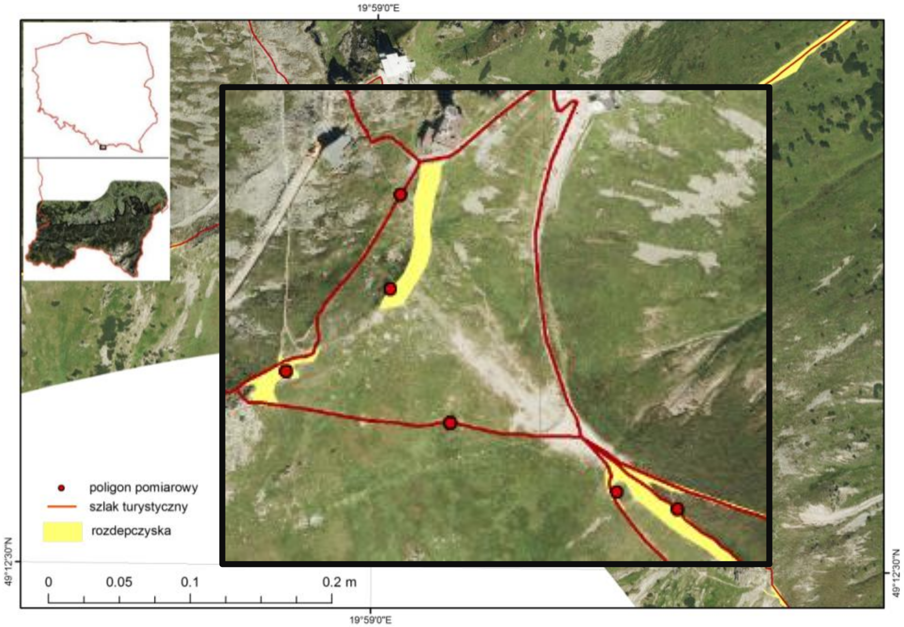
Photo. M. Kycko



Motivations and object of research

- **natural attractiveness** of the Tatra National Park,
- intense tourist traffic - **anthropogenic impact**,
- remote sensing tools - allow precise (**qualitative, quantitative and reproducible in time**) and non-invasive analysis of the condition of plant.

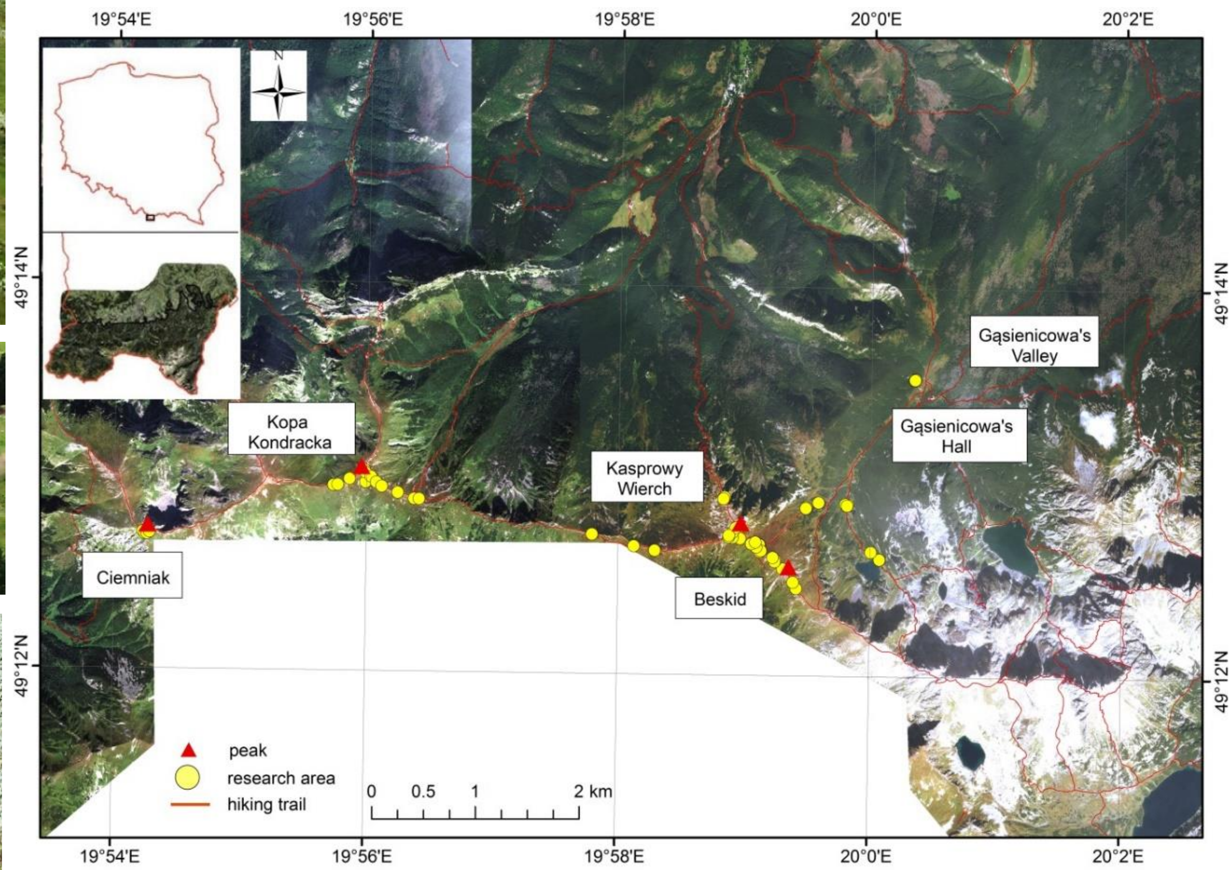
Photo. M. Kycko



Selection of research areas

Type of measurements polygons:
- Dense alpine swards (reference)
- Vulnerable to trampling alpine swards (near the trails)
- Alpine swards areas subjected to restoration

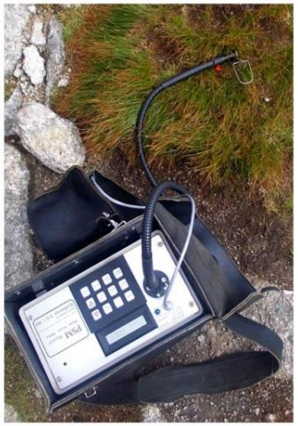
Photo. M. Kycko



Research methods

Field measurements:

- **spectrometric measurements** using the ASD FieldSpec 3/4 + ASD PlantProbe
- **chlorophyll content** (CCM-200),
- **water stres** (pyrometer IRtec MiniRay),
- **accumulation of photosynthetically active radiation** (AccuPAR)
- **fluorescence** - fluorescence measurements were made with adaptation to the darkness (Biomonitor Plant Stress Meter II fluorometer),
- **GPS** coordinates and documentation.



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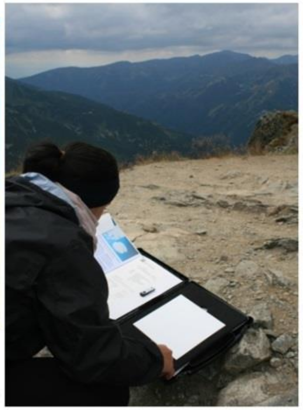

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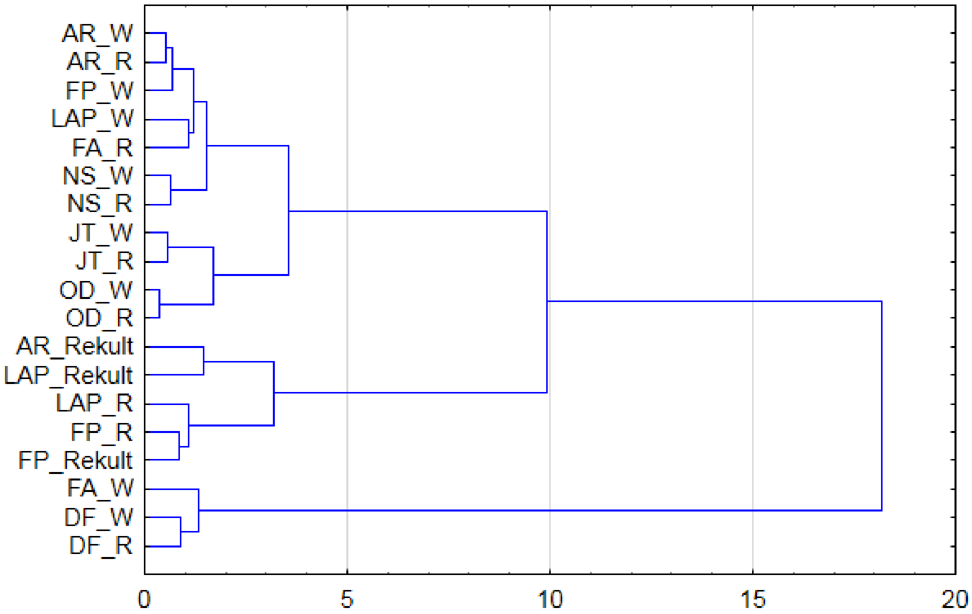
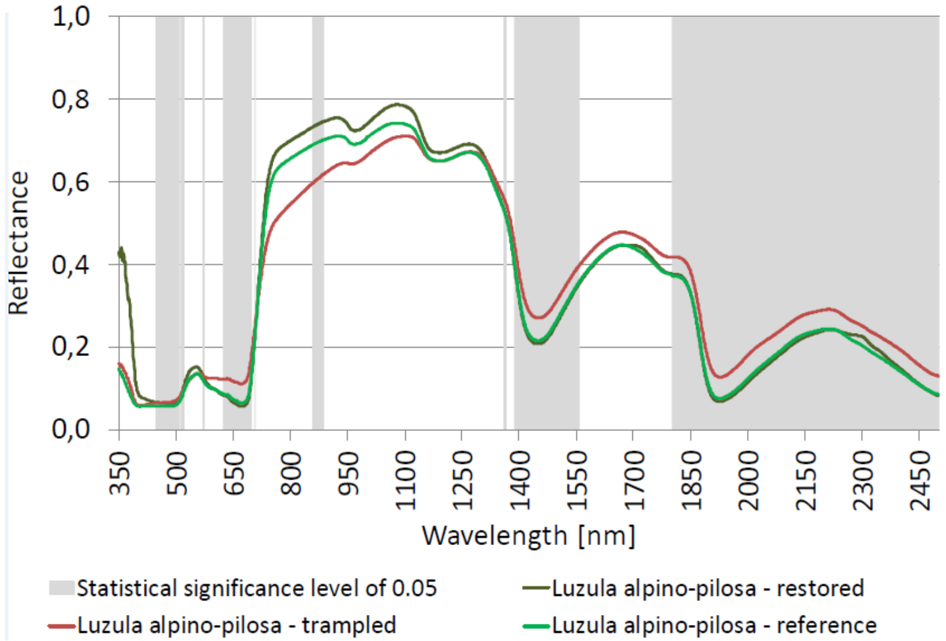
Research methods

<u>Laboratory analyses of:</u>

- spectral curves for each alpine sward species were analyzed using ANOVA,
- vegetation indices were calculated,
- fluorescence parameters,
- statistical analysis the data [significance level of 0.05; Mann–Whitney U test; Spearman correlation; Ward's method].





Vegetation indices

Remote sensing vegetation indices:

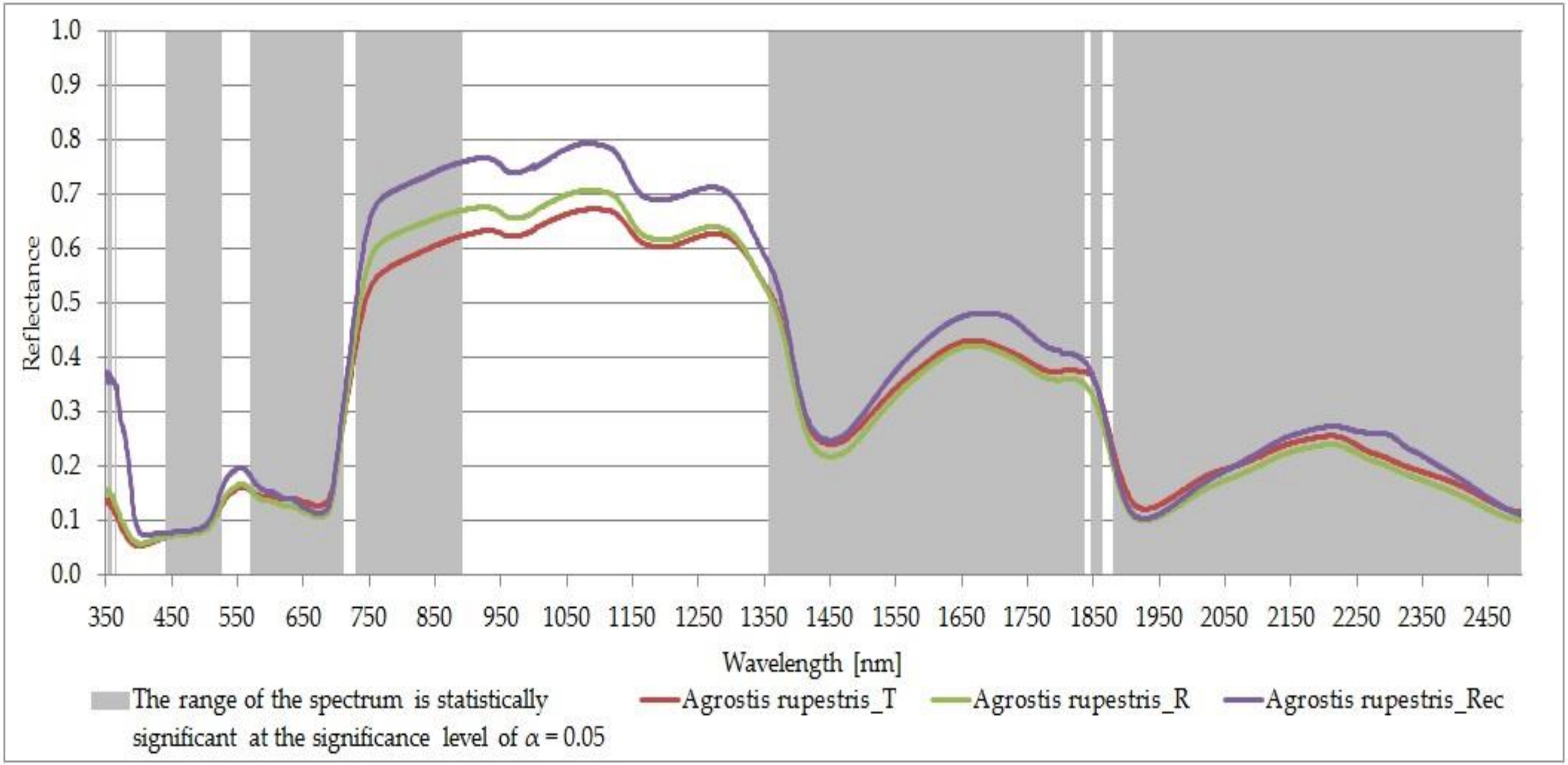
- General plant vigor (NDVI, ARVI, WDRVI),
- Chlorophyll content and structure (NDVI705, NPCI, MCARI, TCARI),
- Amount of light absorbed in photosynthesis (PRI, SIPI),
- Nitrogen content (NDNI),
- Amount of carbon contained in cellulose and lignin (NDLI, PSRI),
- Carotenoids (SRPI, CRI2),
- Amount of water in the plant (MSI, NDWI, NDII),
- ts-ta (water stress).

Fluorescence parameters:

Fv/Fm: The ratio of variable fluorescence to maximal fluorescence.

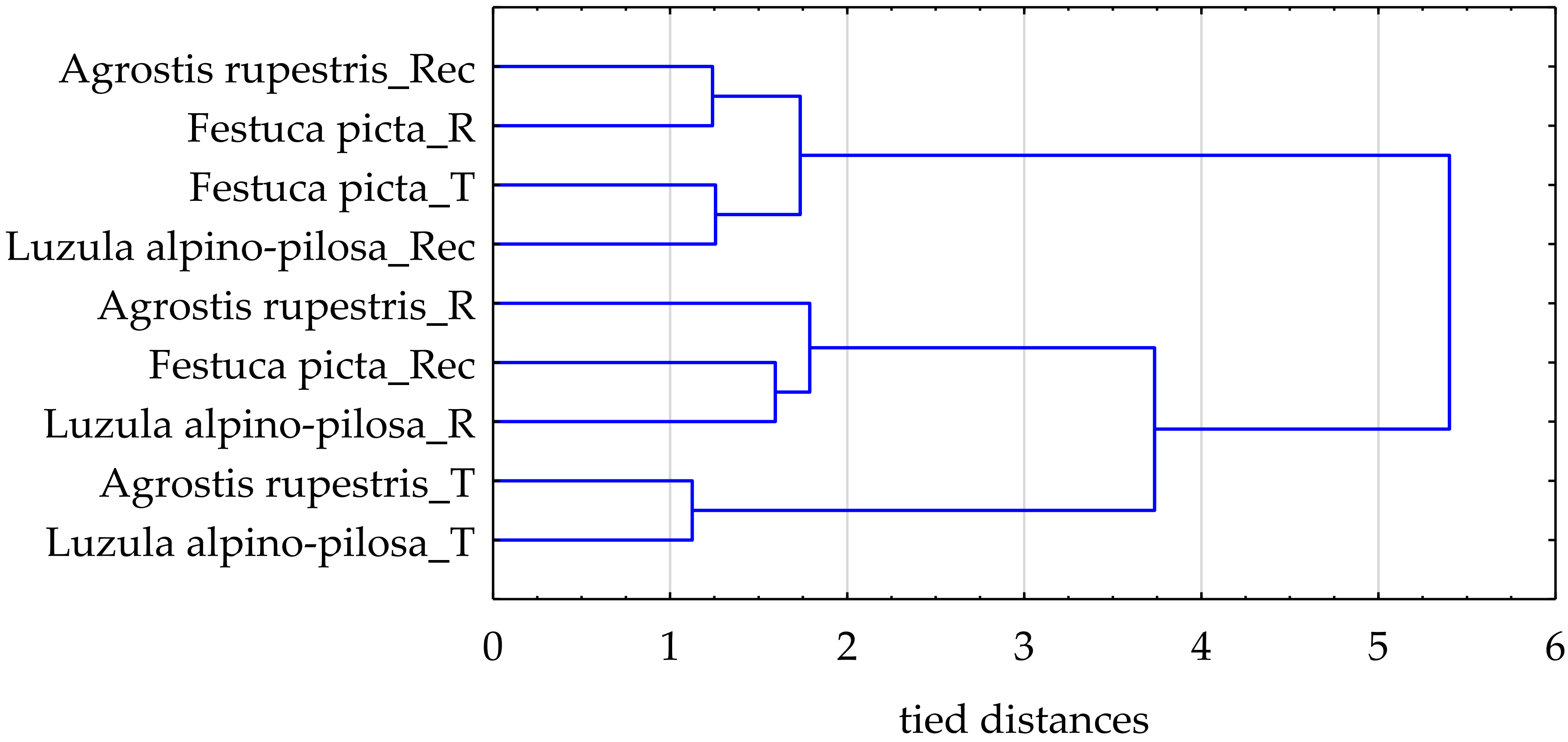
T 1/2: Half rise time from **F0** to **Fm**.

Results



Mean value for the spectral properties of the tested species with the shaded parts of the electromagnetic spectrum indicating where a significant statistical relationship at the 0.05 level was found (test ANOVA, α=0.05), n=49 375

Results



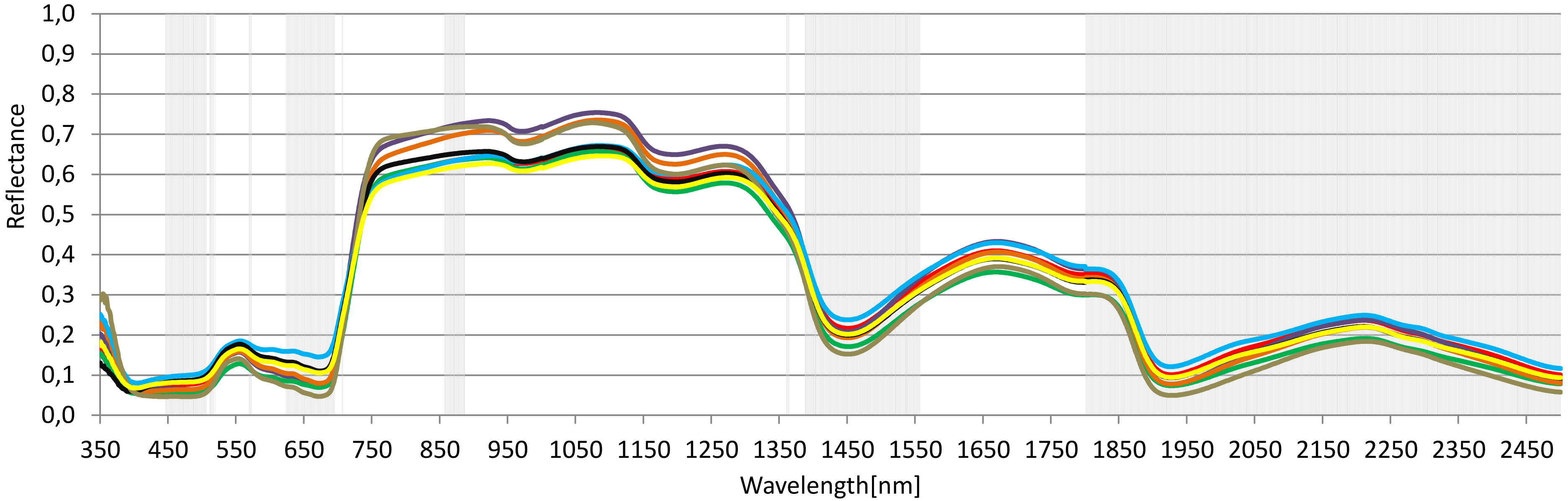
Agglomeration of spectral curves in the electromagnetic spectrum (350–2500 nm; Ward's method) acquired in 2012-2014 for dominant species, n=102 875.

Explanations: _T – trampled, _R – reference, _Rec – recultivated,

Results

• to determine, which species exhibited the largest/smallest indicator variation,

• all the species threatened by **trampling** have **a worse condition** by about **10-30%**; taking into account all the statistically significant analysed indicators,



Spectrum ranges	Width of the range (nm)	Description of the plant characteristics
448-514	26	The amount of photosynthetically active pigments
581-707	126	
1385-1556	171	Vegetation cellular structures
1801-1835	34	Water content, dry matter content, absorption of proteins and nitrogen compounds
1845-1862	17	
1879-2500	621	

Results

Application	Index		% cases statistically significant for a given indicator
Assessment of the general state of vegetation	**NMDI**	***Normalized Multi-band Drought Index***	**88**
	ARVI	***Atmospherically Resistant Vegetation Index***	**78**
	WRDVI	*Wide Dynamic Range Vegetation Index*	77
	TVI	*Triangular Vegetation Index*	75
	Green NDVI	*Green Normalized Difference Vegetation Index*	45
Assessment of the amount of photosynthetic dyes	**RARSa**	***Ratio Analysis of Reflectance Spectra algorithm chlorophyll a***	**80**
	GI	***Greenness Index***	**77**
	RARSc	*Ratio analysis of reflectance spectra algorithm carotenoind*	71
	LIC 2	*Lichtenthaler Index*	70
	mNDVI 705	*Modified Normalized Difference Vegetation Index 705*	70
	RARSb	*Ratio Analysis of Reflectance Spectra algorithm chlorophyll b*	70
	RGR	*Red/Green Ratio; Antocyjany/chlorofil*	70
	SRPI	*Simple Ratio Pigment Index*	70
	GM 2	*Gitelson & Merzlyak 2 Index*	69
	CRI 2	*Carotenoid Reflectance Index 2*	68
	CTR 2	*Carter Index*	66
	VREI2	*Vogelmann Red Edge Index 2*	66
	XES	*Xantophyll epoxidation state Index*	66
	SI	*Stress Index*	62
	ARI 2	*Anthocyanin Reflectance Index 2*	58
	REPI2	*Red Edge Position Index 2*	52

Results

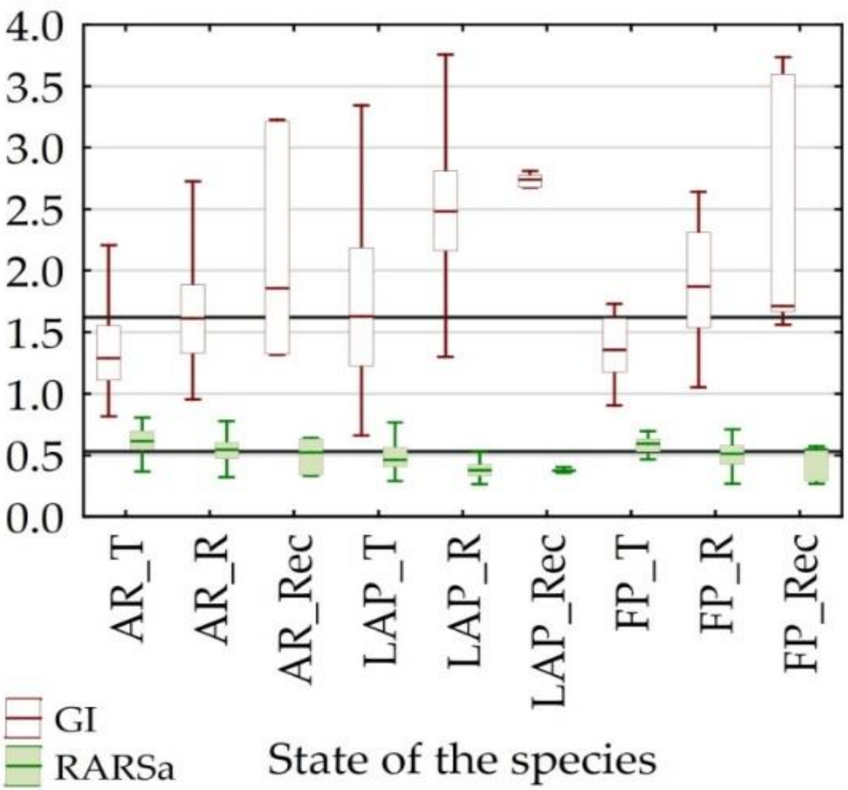
Application	Index		% cases statistically significant for a given indicator
Assessment of nitrogen content	**NDNI**	***Normalized Difference Nitrogen Index***	**73**
Assessment of the amount of light used in photosynthesis	**SIPI**	***Structure Insensitive Pigment Index***	**70**
	PRI	***Photochemical Reflectance Index***	**65**
	ZMI	*Zarco-Tejada & Miller Index*	62
	NPQI	*Normalized Phaeophytinization Index,*	44
Assessment of the amount of dry biomass and coal	**CAI**	***Cellulose Absorption Index***	**71**
	PSRI	***Plant Senescence Reflectance Index***	**70**
	NDLI	*Normalized Difference Lignin Index*	52
Assessment of water content	**NDWI**	***Normalized Difference Water Index***	**92**
	WBI	***Water Band Index***	**92**
	AWC	*Actual Water Content*	77
	DSWI	*Disease Water Stress*	77
	RWC	*Relative Water Content*	74
	RMP	*Relative leaf moisture percentage on fresh weight basis*	69

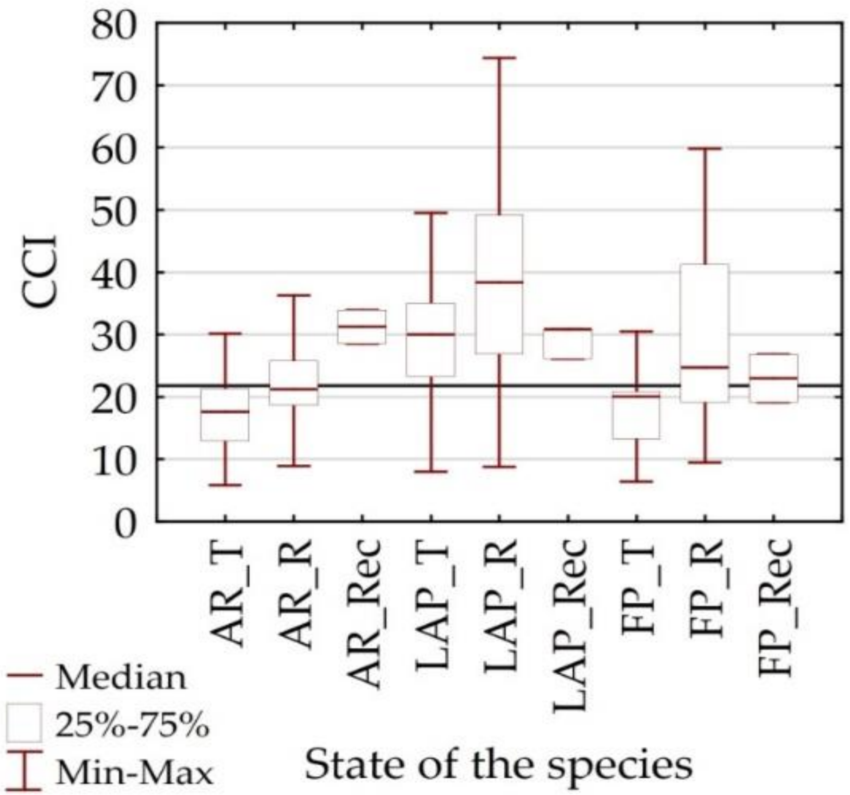
Results

Vegetation indices			Reference			Trampled			Recultivated		
Application	Index		*A. rupestris*	*L. alpino-pilosa*	*F. picta*	*A. rupestris*	*L. alpino-pilosa*	*F. picta*	*A. rupestris*	*L. alpino-pilosa*	*F. picta*
General condition of vegetation	NMDI	Median	**0.53**	**0.54**	**0.54**	**0.53**	**0.51**	**0.51**	**0.54**	**0.54**	**0.53**
		± st. Dev.	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.00
	ARVI	Median	0.27	0.45	0.40	0.25	0.33	0.27	0.38	0.30	0.41
		± st. Dev.	0.07	0.05	0.05	0.06	0.06	0.03	0.14	0.03	0.08
Amount of photosynthetically active pigments	GI	Median	1.65	2.35	2.20	1.45	1.70	1.54	1.73	2.57	2.43
		± st. Dev.	0.22	0.28	0.40	0.29	0.13	0.20	0.77	0.10	0.98
	RARSa	Median	0.56	0.40	0.46	0.60	0.49	0.55	0.16	0.09	0.11
		± st. Dev.	0.05	0.03	0.060	0.06	0.01	0.05	0.08	0.01	0.04
Nitrogen content	NDNI	Median	0.19	0.22	0.21	0.19	0.20	0.20	0.23	0.17	0.22
		± st. Dev.	0.02	0.01	0.01	0.01	0.02	0.00	0.01	0.00	0.02
Amount of light used in photosynthesis	PRI	Median	-0.03	-0.02	-0.02	-0.04	-0.04	-0.04	-0.02	0.01	-0.01
		± st. Dev.	0.01	0.01	0.01	0.01	0.01	0.00	0.04	0.00	0.00
	SIPI	Median	1.08	1.02	1.04	1.12	1.07	1.08	1.06	0.99	1.02
		± st. Dev.	0.05	0.02	0.02	0.05	0.03	0.01	0.07	0.00	0.04
Amount of dry biomass and carbon	PSRI	Median	0.05	0.01	0.03	0.07	0.05	0.05	0.04	-0.01	0.00
		± st. Dev.	0.02	0.02	0.01	0.03	0.02	0.01	0.05	0.00	0.03
	CAI	Median	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
		± st. Dev.	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Canopy water content	WBI	Median	1.02	1.03	1.03	1.01	1.00	1.00	1.03	1.03	1.04
		± st. Dev.	0.01	0.02	0.01	0.01	0.01	0.00	0.02	0.01	0.01
	NDWI	Median	0.02	0.03	0.03	0.01	-0.02	-0.01	0.03	0.03	0.05
		± st. Dev.	0.02	0.03	0.01	0.02	0.02	0.01	0.03	0.01	0.01
Biometrical variables	Fv/Fm	Median	0.67	0.71	0.66	0.65	0.62	0.64	0.72	0.77	0.71
		± st. Dev.	0.03	0.00	0.06	0.00	0.05	0.04	0.05	0.05	0.05
	Fv/Fm'	Median	0.39	0.46	0.40	0.37	0.40	0.31	0.42	0.52	0.49
		± st. Dev.	0.02	0.07	0.05	0.01	0.02	0.01	0.03	0.05	0.05
	CCI	Median	19.63	36.50	29.03	17.85	31.67	17.53	31.27	28.53	22.98
		± st. Dev.	5.51	8.57	4.17	1.96	5.62	2.59	3.00	3.50	6.50
	ts-ta	Median	-2.49	-3.63	-3.06	-2.18	-4.17	-0.42	-3.80	-3.12	-2.40
		± st. Dev.	0.90	0.70	1.56	1.06	2.07	1.70	2.68	2.38	1.83
	fAPAR	Median	0.72	0.71	0.78	0.64	0.75	0.60	0.91	0.91	0.91
		± st. Dev.	0.05	0.10	0.13	0.11	0.15	0.07	0.05	0.10	0.03

Results: Assessment of the amount of photosynthetic dyes

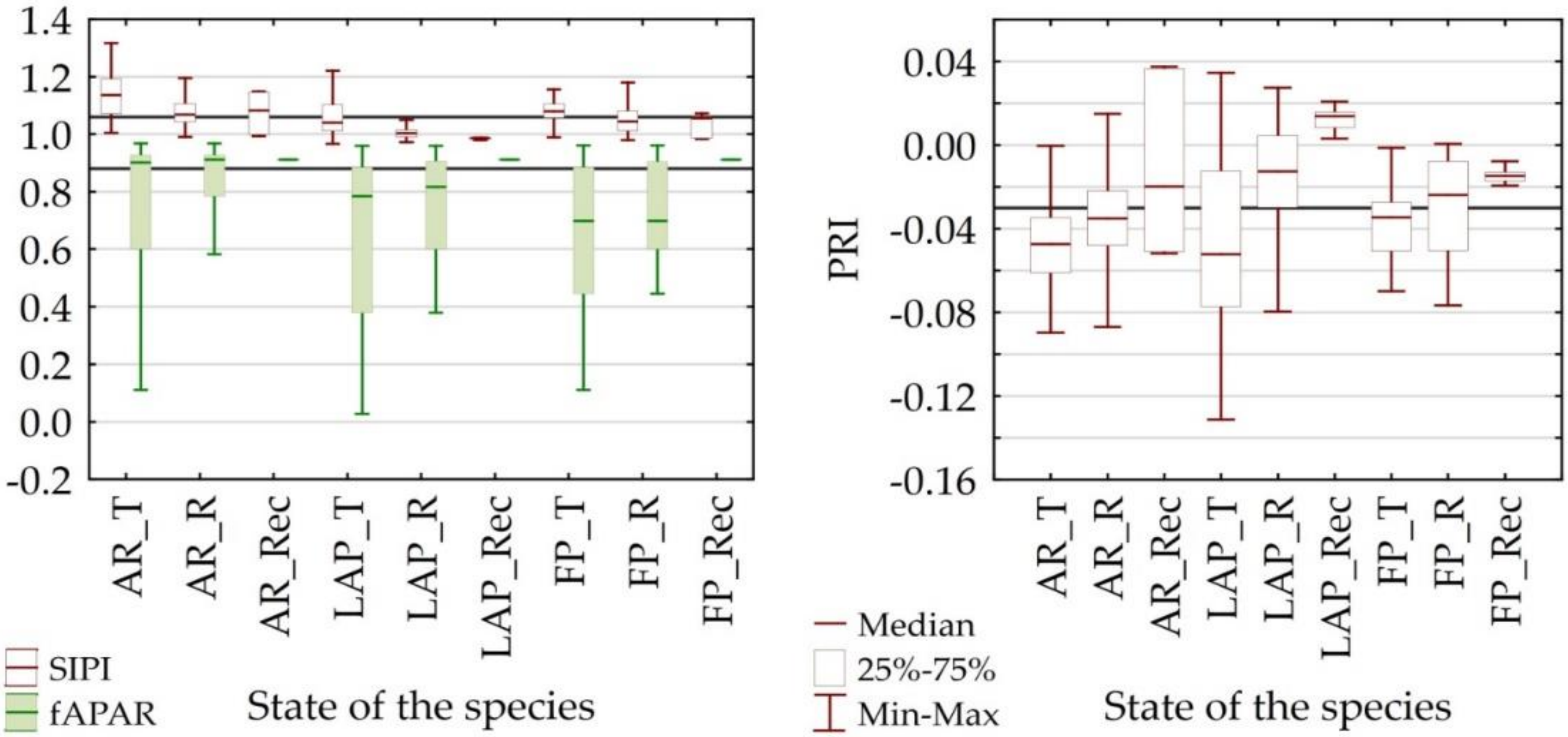
Species	State	CCI
Festuca picta	Trampled	ARVI [0.80], WBI [0.70], CAI [-0.65], NWDI [0.60], NDNI [0.50]
	Reference	NMDI [0.84], PRI [0.78], NDWI [0.76], PSRI [-0.76], ARVI [0.61], WBI [0.56]
	Recultivated	-
Luzula alpino-pilosa	Trampled	CAI [-0.73], WBI [-0.45]
	Reference	NMDI [0.41], GI [0.40]
	Recultivated	-
Agrostis rupestris	Trampled	PRI [0.75], WBI [0.71], PSRI [-0.65], NMDI [-0.52], GI [-0.42]
	Reference	NDNI [0.60], PRI [0.54],WBI [0.42]
	Recultivated	-



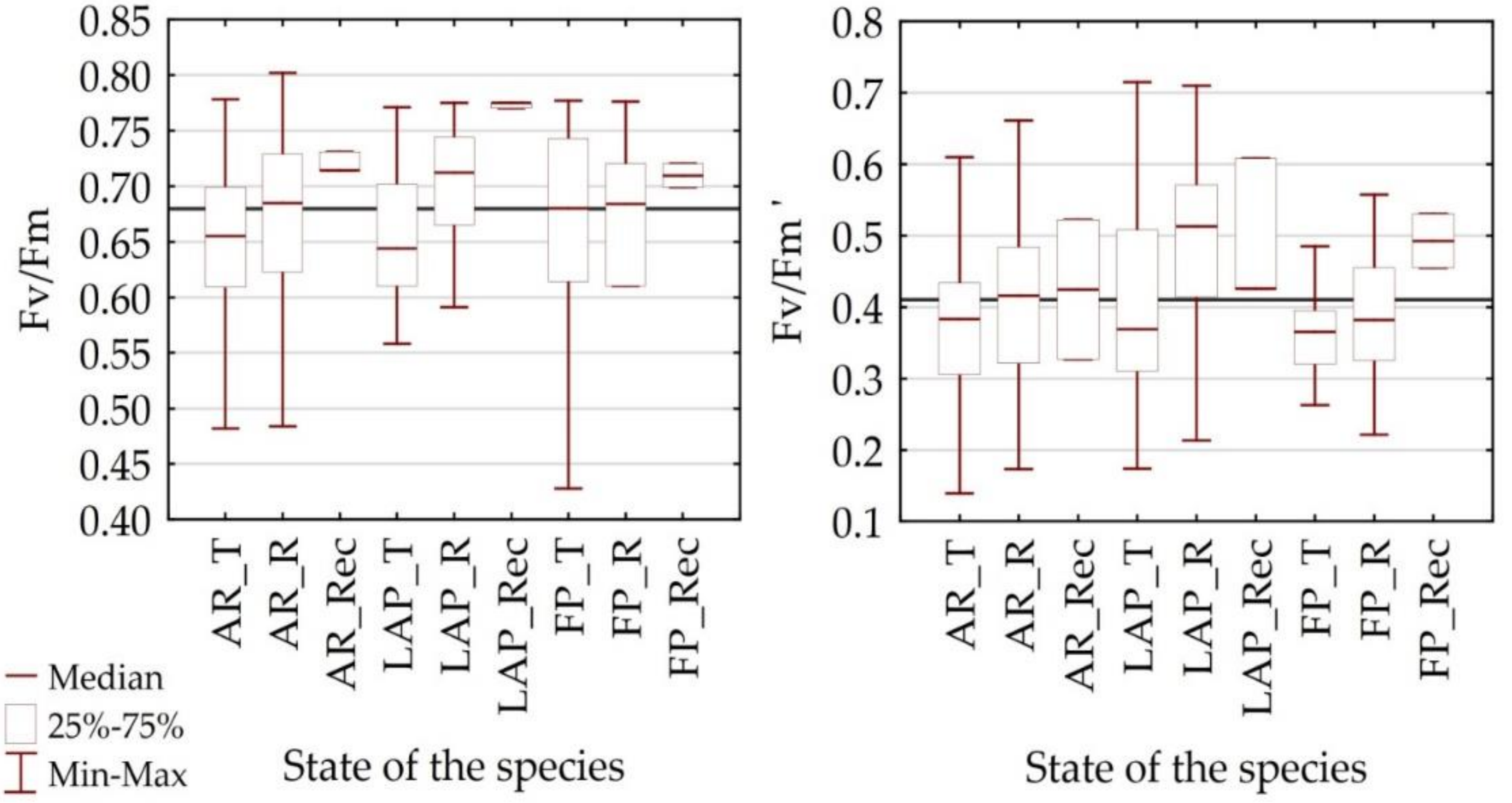


Results: Assessment of the amount of light used in photosynthesis

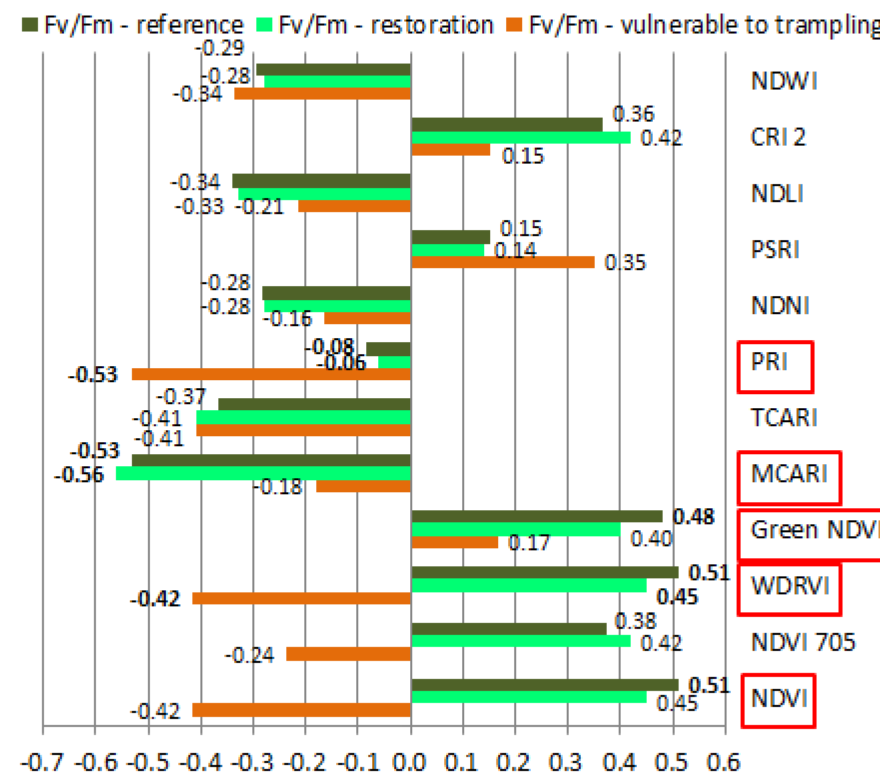
Species	State	fAPAR
Festuca picta	Trampled	NDWI [0.52], PRI [0.51], NDWI [-0.41]
	Reference	NMDI [-0.74], CAI [0.54], SIPI [0.53], PSRI [0.52], GI [0.44]
	Recultivated	-
Luzula alpino-pilosa	Trampled	-
	Reference	ARVI [0.74], RARSa [-0.72], NDNI [0.47], NMDI [0.44]
	Recultivated	-
Agrostis rupestris	Trampled	PRI [-0.55], SIPI [0.42]
	Reference	NDWI [-0.43]
	Recultivated	-



Results: Assessment of the amount of light used in photosynthesis



Results: Assessment of the amount of light used in photosynthesis

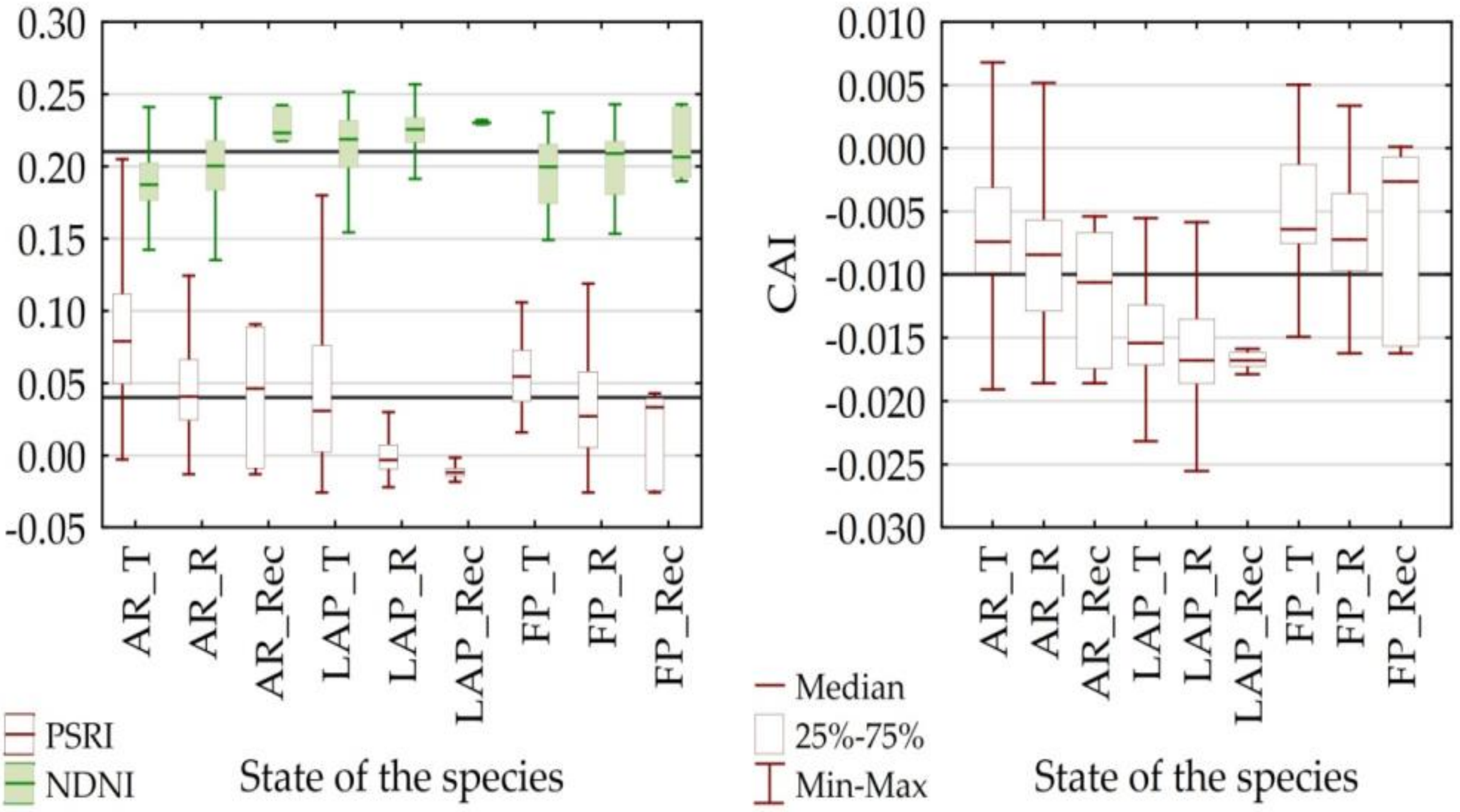


Correlation of fluorescence values with vegetation indices.

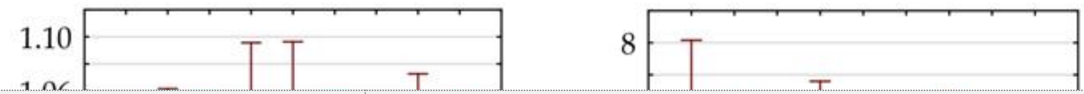
Vulnerable to trampling	with adaptation to darkness	Fv/Fm	607,7
		t ½	108,0
	without adaptation to darkness	Fv/Fm'	397,7
		t ½'	23,8
Reference	with adaptation to darkness	Fv/Fm	706,6
		t ½	78,6
	without adaptation to darkness	Fv/Fm'	486,7
		t ½'	25,2
Restoration	with adaptation to darkness	Fv/Fm	722,5
		t ½	96,0
	without adaptation to darkness	Fv/Fm'	569,3
		t ½	50,5

Species	State	Fv/Fm	Fv/Fm '
Festuca picta	Trampled	-	PRI [0.40]
	Reference	PRI [0.65], WBI [0.51], NMDI [0.51], ARVI [0.48]	PRI [0.60], NDNI [0.49]
	Recultivated	-	-
Luzula alpino-pilosa	Trampled	RARSa [0.53], GI [0.40], GI [-0.45]	ARVI [-0.51], WBI [-0.44]
	Reference	SIPI [-0.58], WBI [0.44]	CAI [-0.41]
	Recultivated	-	-
Agrostis rupestris	Trampled	PRI [0.40], NMDI [0.40]	CAI [-0.51], RARSa [-0.47]
	Reference	NMDI [0.70], NDWI [0.61], ARVI [0.48]	-
	Recultivated	-	-

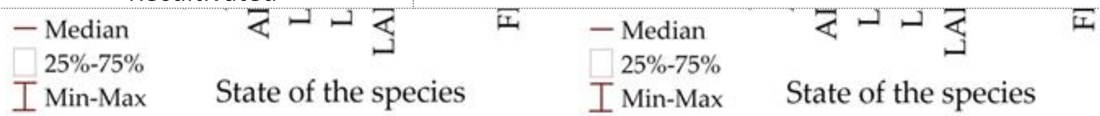
Results: Assessment of the amount of dry biomass and coal, and nitrogen

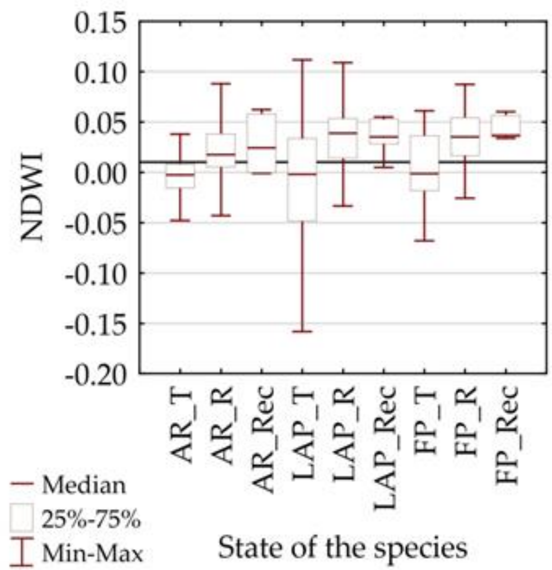


Results: Assessment of water content

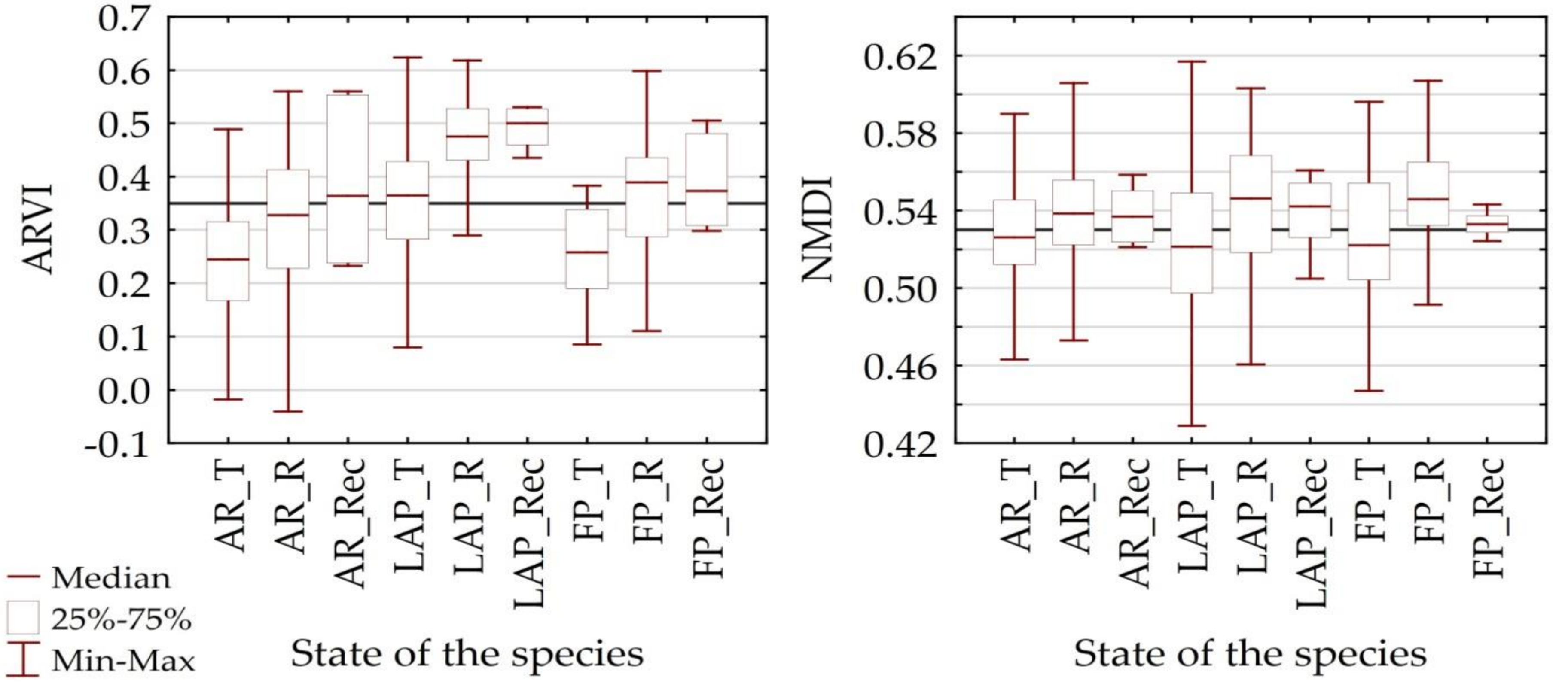


Species	State	ts-ta
Festuca picta	Trampled	CAI [0.89], ARVI [-0.71], WBI [-0.70], NDWI [-0.60], RARSa [0.40]
	Reference	CAI [0.77], NMDI [-0.75], RARSa [0.61], SIPI [0.56], NDWI [-0.55], NDNI [-0.46]
	Recultivated	-
Luzula alpino-pilosa	Trampled	WBI [-0.65], RARSa [0.57], GI [-0.43], ARVI [-0.40]
	Reference	NWDI [0.92], WBI [0.88], RARSa [-0.70], GI [0.53]
	Recultivated	-
Agrostis rupestris	Trampled	PSRI [0.64], SIPI [0.62], WBI [0.50], RARSa [-0.49]
	Reference	NMDI [-0.70], NDWI [0.57], PSRI [-0.55], CAI [0.45],
	Recultivated	-





Results: Assessment of the general state of vegetation



Results

Range of the spectrum (nm) – this research	Wavelength (nm)	Application	Source of information
448-514	463	analysis of b-carotene absorption	[76]
	470	analysis of the absorption of total carotenoids	[76]
581-707	530-630	analysis of chlorophyll content	[77]
	650	chlorosis analysis	[81]
	663.2	analysis of absorption of chlorophyll-a	[82]
	646.8	analysis of absorption of chlorophyll-b	[82]
	670	soil effect normalization and AVI analysis, bands for the analysis of small amounts of chlorophyll	[77,83,84]
	680	analysis of chlorophyll absorption	[85]
	695	analysis of plant stress PSI (760/695 nm)	[86]
	1450	analysis of water absorption in leaves	[87]
	1510	analysis of the absorption of proteins and nitrogen compounds in conifers	[88]
1801-1835, 1879-2500	1650-1850	analysis of water content in cereals (wheat)	[89]
	1870	analysis of dry matter content	[78]
	1910	plant turgor analysis (water content)	[78]
	2160	analysis of dry matter content	[78]
	2180	analysis of the absorption of proteins and nitrogen compounds	[88]
	2310	analysis of dry leaves, absorption of hydrocarbons	[78,90]

Conclusions and remarks (1)

- The use of hyperspectral data allowed register spectral properties, physiological, **morphological and anatomical characteristics** of tested species,
- **remote sensing vegetation indicators and verification measurements** (including chlorophyll content, fluorescence, evapotranspiration and energy storage) **confirmed changes in plants**,
- **the condition of the plants is good** (it was in the optimal ranges or slightly below),
- the parameters of the leaves, the plants being trampled are lowered, e.g.
  - **the chlorophyll content is less by about 10-20% in relation to the reference polygons;**
  - **water content by approx. 10-30%;**
  - **the amount of light used in the photosynthesis process is about 10-40%;**
  - **general reduction of plant health by about 10-40%;**
- worse values of indicators (> 80% of statistically significant changes) were characterized by: ***Luzula alpino-pilosa, Festuca Picta*** (species susceptible to trampling),
- ***Agrostis rupestris*** (55%) showed similar spectral characteristics of trampled and reference plants,
- **recultivated species have similar values to reference values, and changes caused by trampling are regenerating,**

Conclusions and remarks (2)

- The intervals of the electromagnetic spectrum statistically significant in the study of changes in the condition of vegetation mainly concern the determining range:
  - **content of chlorophyll, photosynthetic dyes** (446-506, 511-519, 569-573, 623-695, 706-707 nm),
  - **cell structures** (857-996 nm),
  - **amount of water and building elements** (1360-1364, 1388-1557, 1801-2500 nm),

- The following indicators are **optimal for assessing the condition** of high-mountainous grasslands :
  - **general condition: ARVI** (*Atmospherically Resistant Vegetation Index;* 78%), **NMDI** (*Normalized Multi-band Drought Index;* 88%),
  - **content and state of chlorophyll: RARSa** (*Ratio analysis of reflectance spectra algorithm chlorophyll a;* 80%), **GI** (*Greenness Index; 77%*),
  - **the amount of light used in photosynthesis: SIPI** (*Structure Insensitive Pigment Index;* 70%), **PRI** (*Photochemical Reflectance Index;* 65%),
  - **amount of dry matter**: **PSRI** (*Plant Senescence Reflectance Index;* 70%), **CAI** (*Cellulose Absorption Index;* 71%),
  - **water content : WBI** (*Water Band Index;* 92%), **NDWI** (*Normalized Difference Water Index;* 92%),

- Hyperspectral remote sensing methods (ground level) allow to distinguish vegetation damaged by trampling of vegetation reference in **75%,**

- The integration of field measurement and hyperspectral biometrics allows for non-invasive monitoring of vegetation, as well as the transfer this analysis on the level of air and satellite.

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Classification of High-Mountain Vegetation Communities within a Diverse Giant Mountains Ecosystem Using Airborne APEX Hyperspectral Imagery

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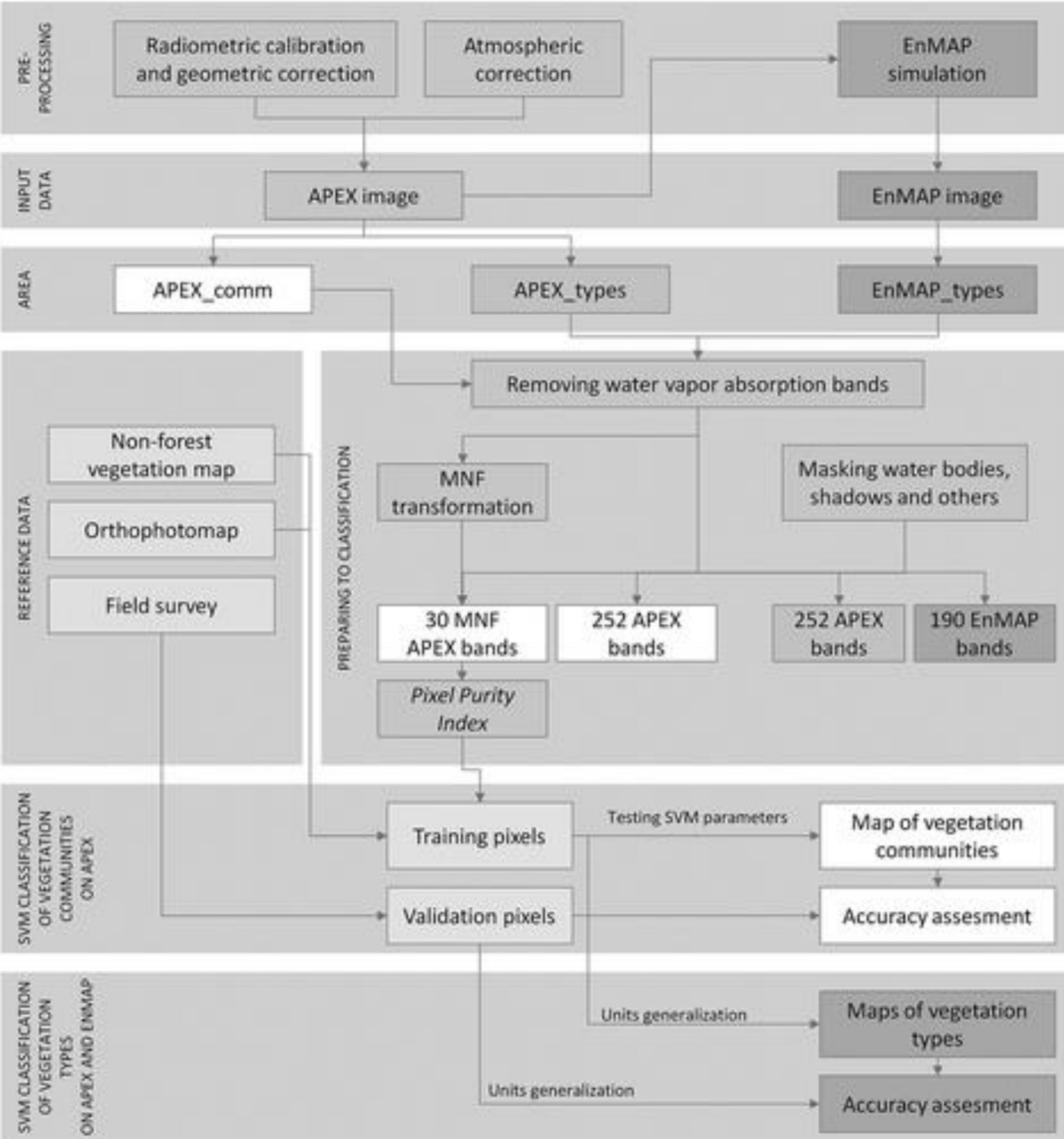

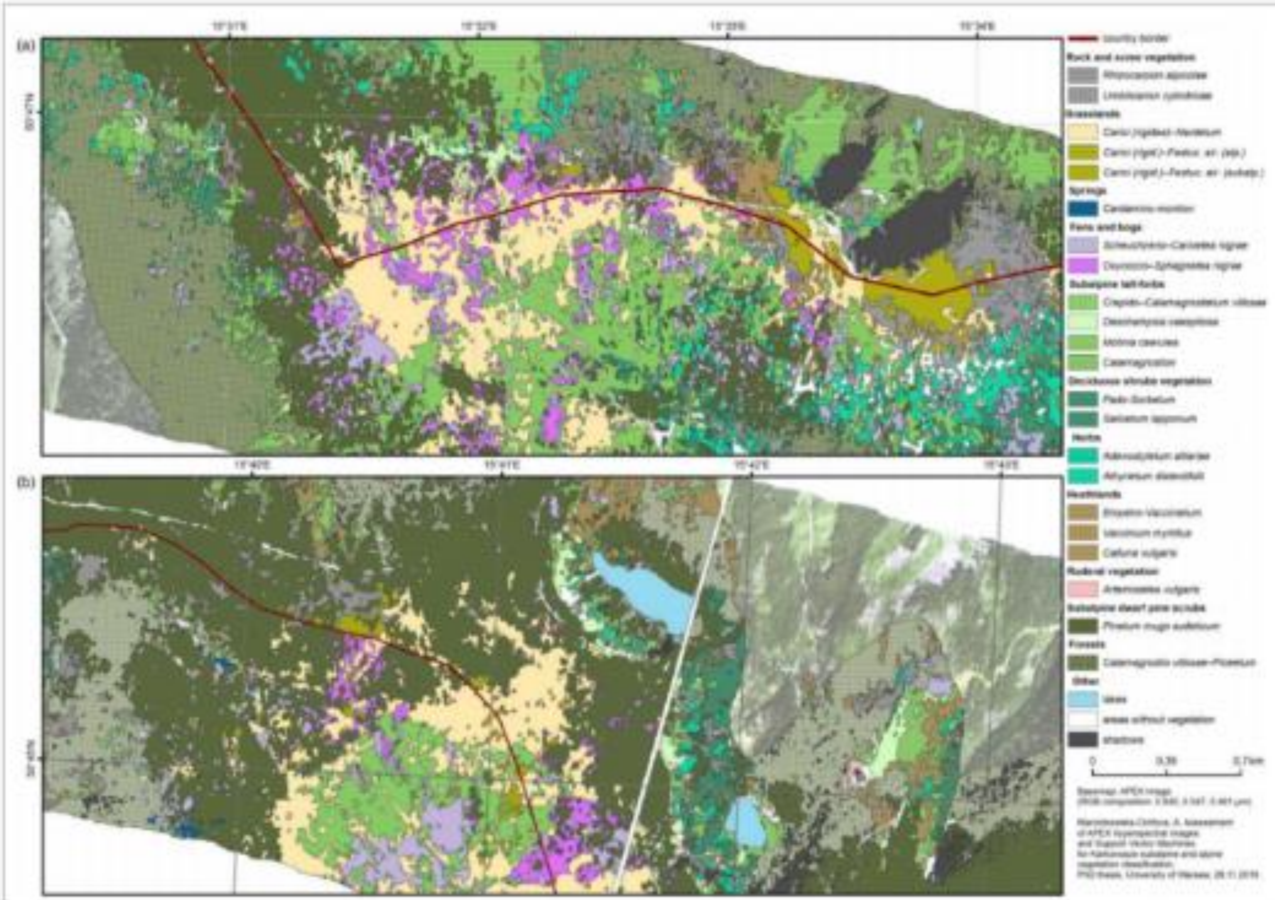

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Map of vegetation communities of the Giant Mountains: (**a**) western part, (**b**) eastern part.

Table 2. Overall accuracies obtained for different datasets and two kernel functions. PCA: Principal Component Analysis; MNF: Minimum Noise Fraction.

Dataset	Overall accuracy (OA, %)		File Size (MB)
	Linear	Radial	
252 spectral bands	82.69	83.11	465
40 PCA bands	81.04	84.49	65
30 MNF bands	80.76	82.02	48
70 spectral bands *	76.68	77.16	113
18 spectral bands *	68.14	69.01	31

* backward elimination approach.

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Tree Species Classification of the UNESCO Man and the Biosphere Karkonoski National Park (Poland) Using Artificial Neural Networks and APEX Hyperspectral Images

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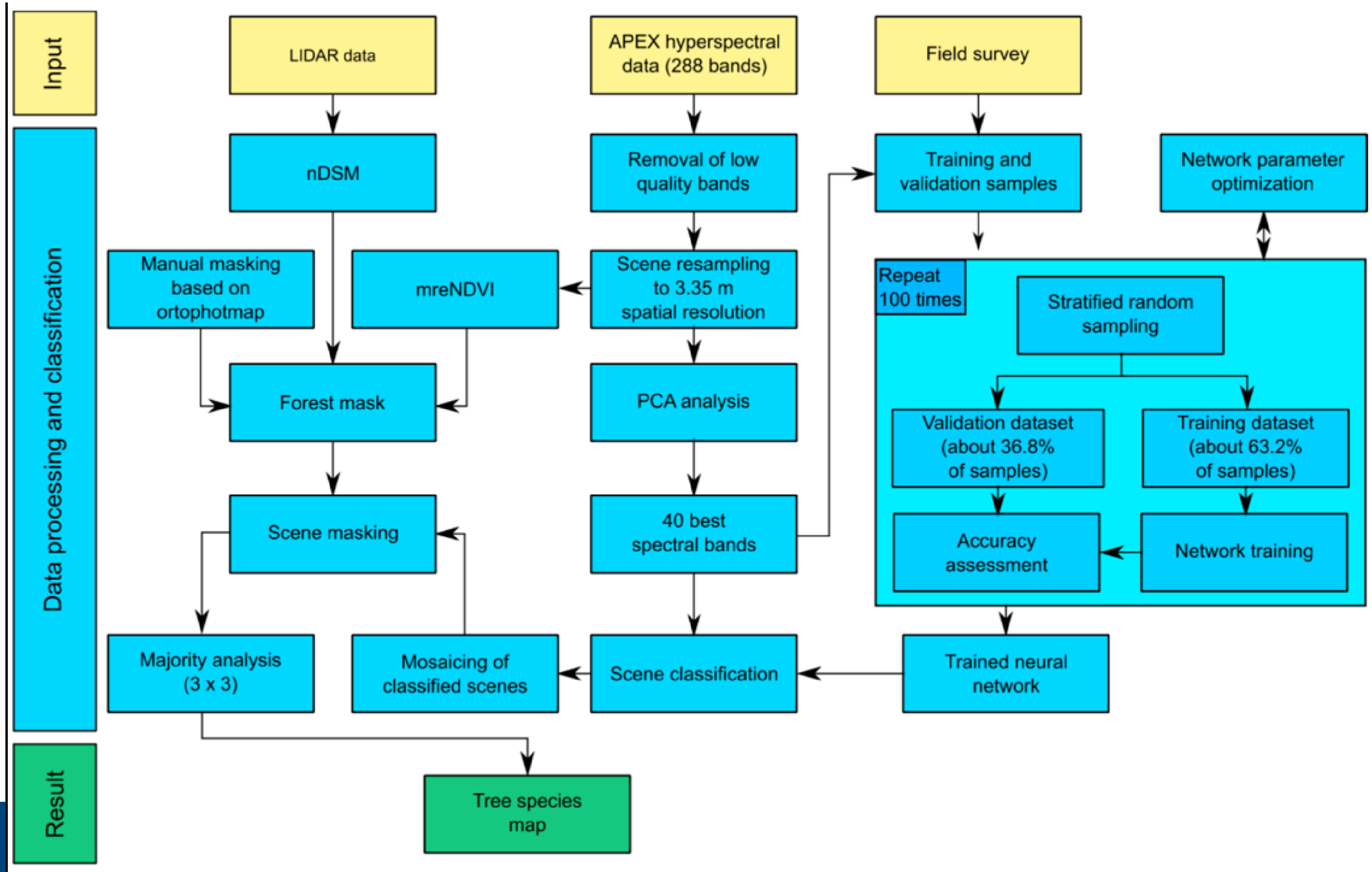
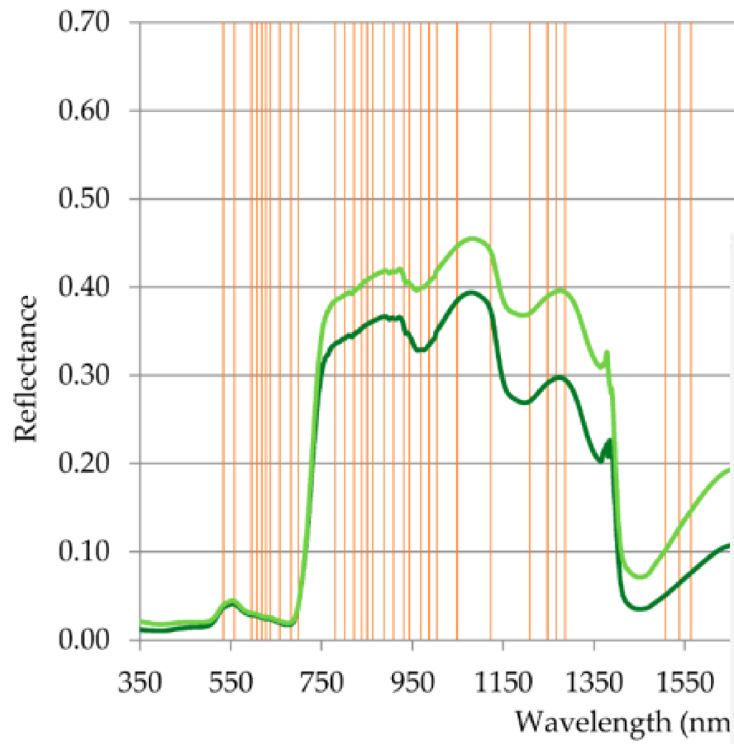
- Are hyperspectral data and artificial neural networks useful for mapping tree species?
- What are the differences between forest inventory and Airborne Prism Experiment (APEX) derived tree species compositions of forest growing in Karkonoski National Park (KNP)?





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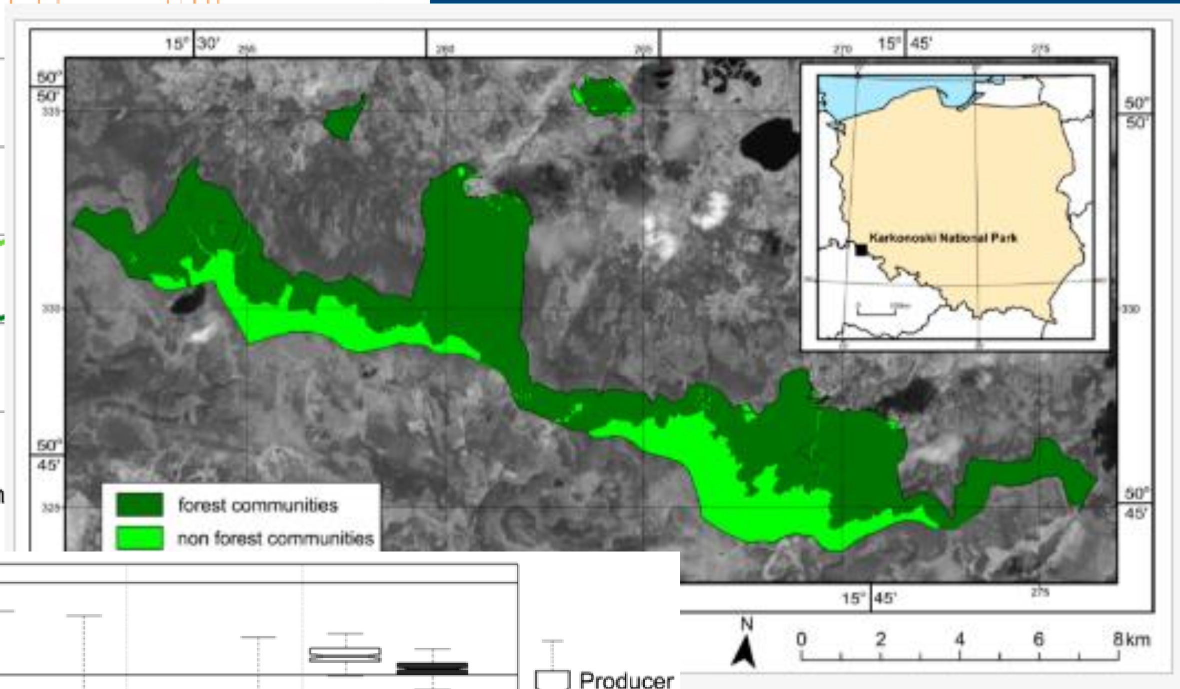

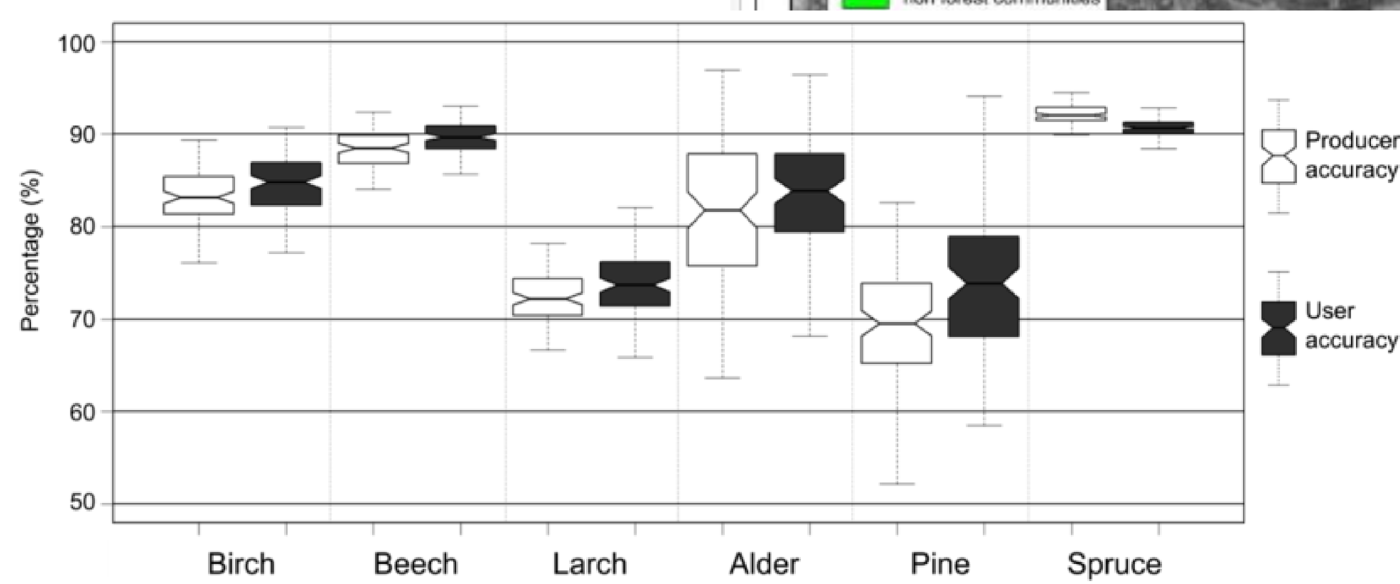

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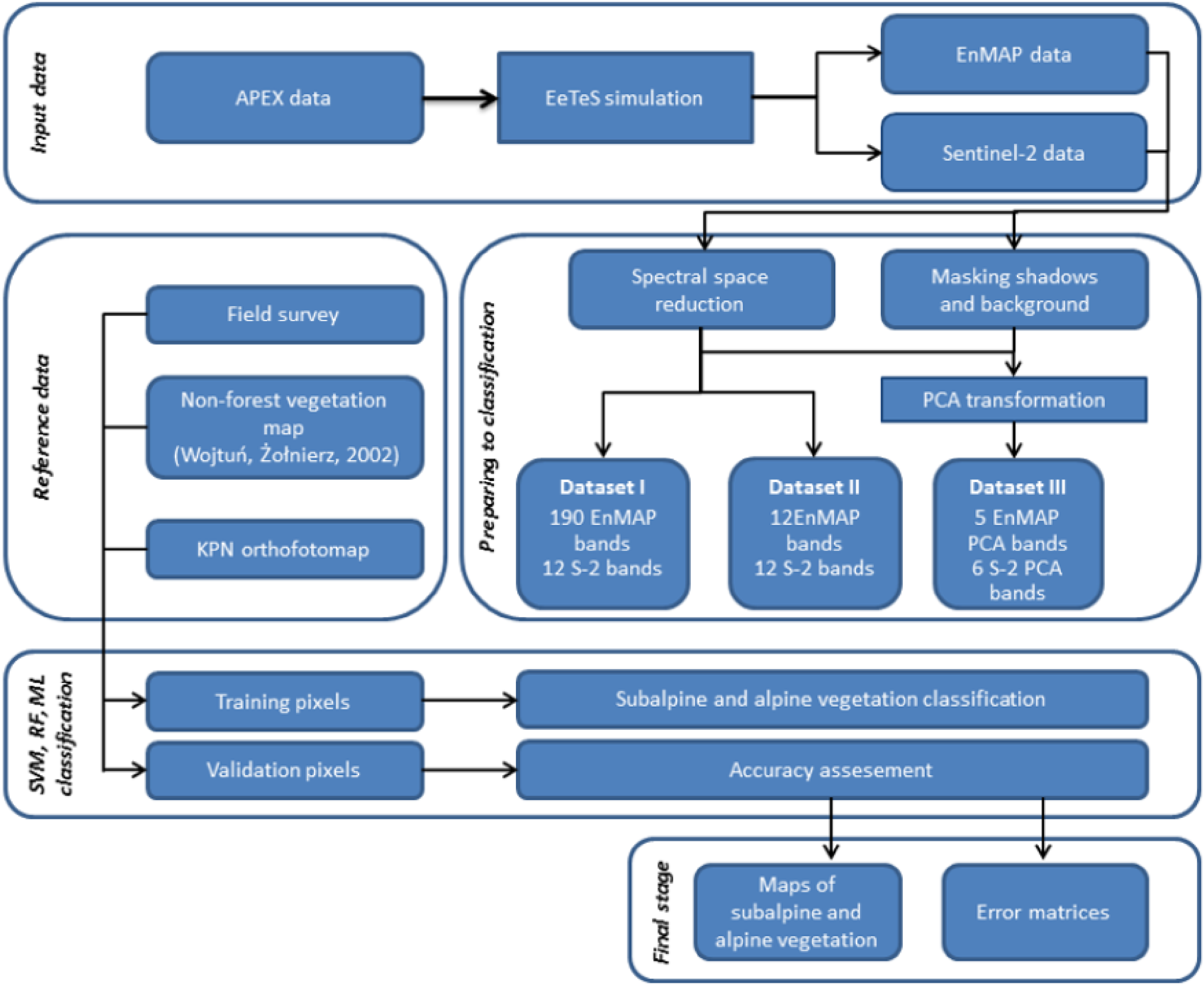
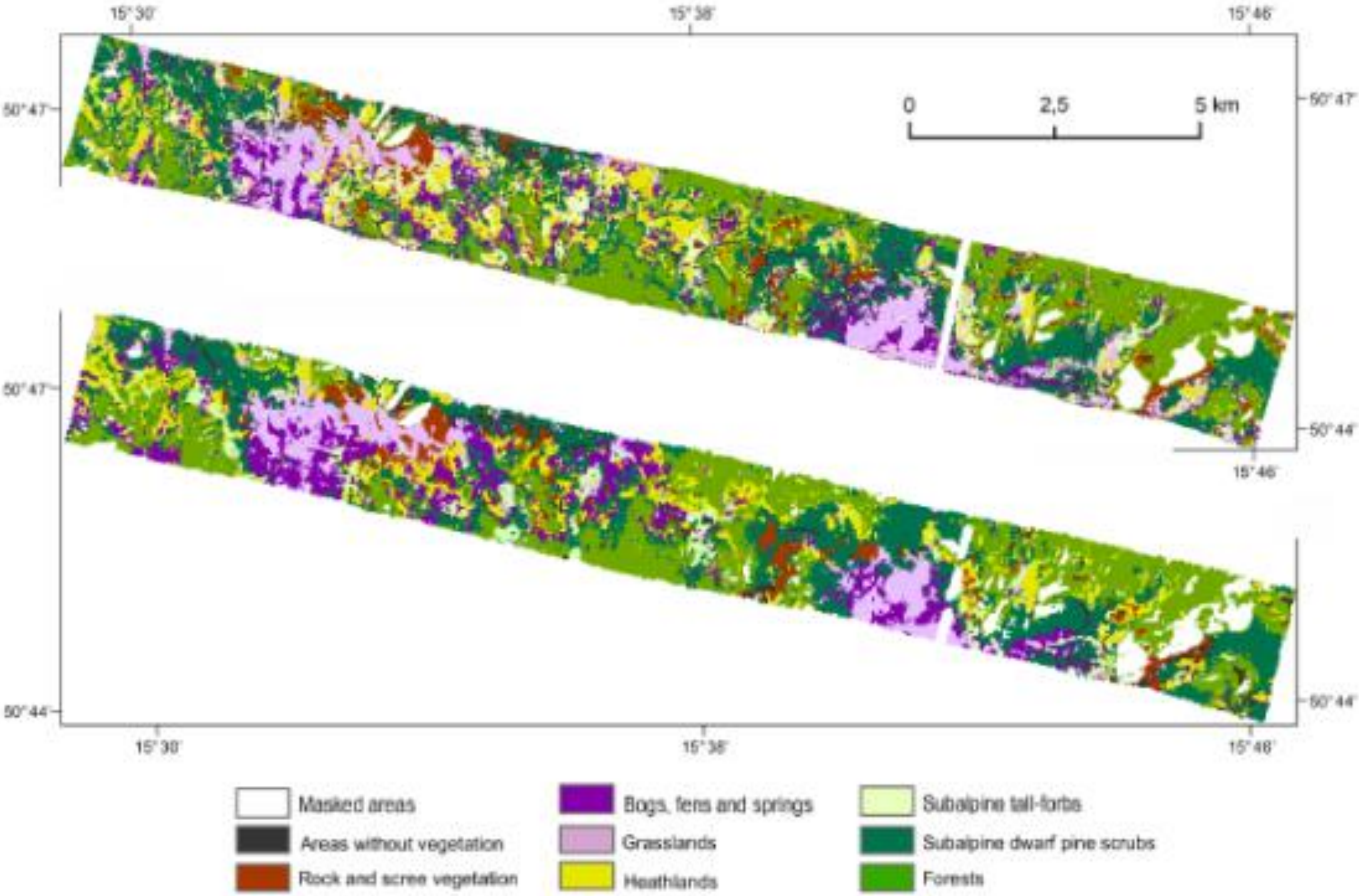
Application of Sentinel-2 and EnMAP new satellite data to the mapping of alpine vegetation of the Karkonosze Mountains


Input data
APEX data
EeTeS simulation
EnMAP data
Sentinel-2 data
Reference data
Field survey
Non-forest vegetation map (Wojtuń, Żołnierz, 2002)
KPN orthofotomap
Preparing to classification
Spectral space reduction
Masking shadows and background
PCA transformation
Dataset I
190 EnMAP bands
12 S-2 bands
Dataset II
12EnMAP bands
12 S-2 bands
Dataset III
5 EnMAP PCA bands
6 S-2 PCA bands
SVM, RF, ML classification
Training pixels
Subalpine and alpine vegetation classification
Validation pixels
Accuracy assesement
Final stage
Maps of subalpine and alpine vegetation
Error matrices



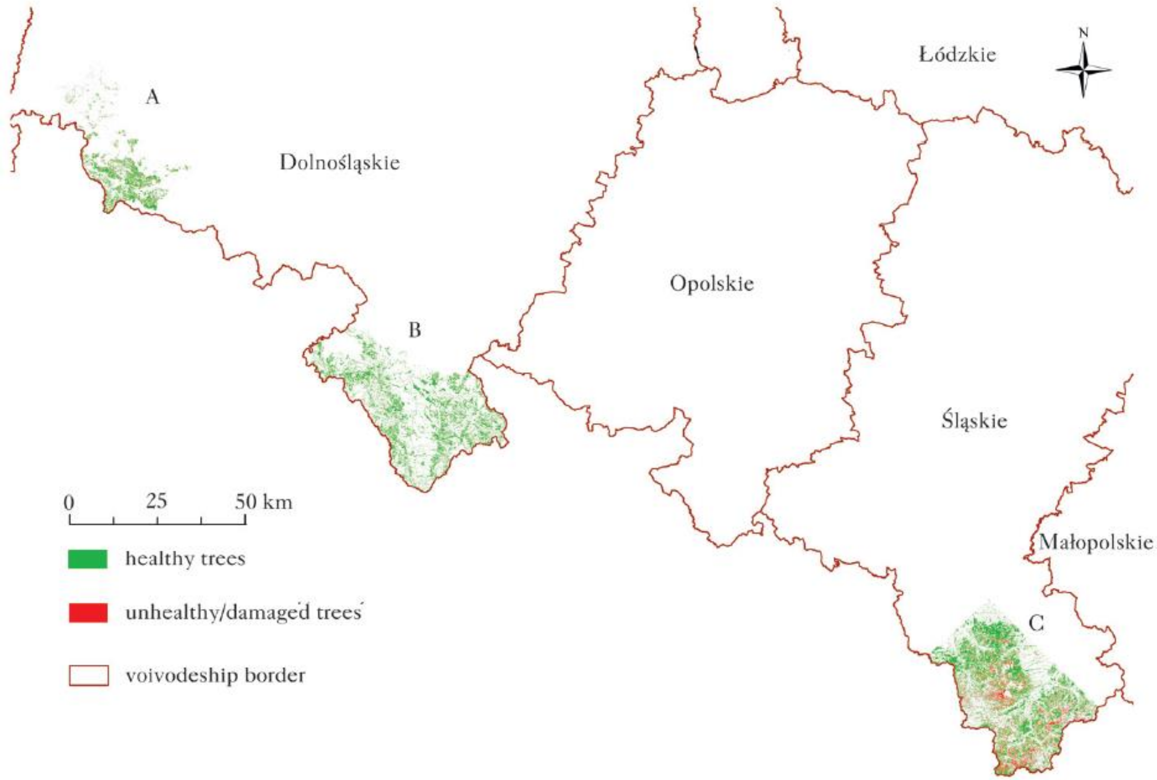
Error matrix for EnMAP classification using SVM (overall accuracy 82,92%)

Class	Correctly classified pixels (%)							
	1	2	3	4	5	6	7	8
1. Subalpine dwarf pine scrubs	**81**	0	0	0	4	4	11	0
2. Heathlands	0	**68**	0	8	13	0	4	7
3. Grasslands	0	0	**96**	0	0	0	0	4
4. Bogs, fens and springs	0	2	0	**90**	2	0	6	0
5. Subalpine tall-forbs	0	4	1	6	**69**	1	19	0
6. Areas without vegetation	0	0	0	4	0	**96**	0	0
7. Rock and scree vegetation	6	7	0	5	11	0	**71**	0
8. Forests	0	13	3	1	0	1	1	**80**

Error matrix for Sentinel-2 classification using SVM (overall accuracy 78,33%)

Class	Correctly classified pixels (%)							
	1	2	3	4	5	6	7	8
1. Subalpine dwarf pine scrubs	**90**	2	0	10	1	2	0	5
2. Heathlands	1	**54**	2	7	23	5	2	1
3. Grasslands	0	18	**79**	3	20	5	0	0
4. Bogs, fens and springs	3	6	10	**73**	8	5	0	0
5. Subalpine tall-forbs	1	18	7	6	**41**	9	0	0
6. Areas without vegetation	0	3	3	0	6	**64**	6	0
7. Rock and scree vegetation	0	0	1	1	1	11	**91**	1
8. Forests	5	0	0	0	0	0	0	**91**

Detection of bark beetle infected trees with BlackBridge image on the example of the Sudety and the Beskidy mountains



Orthofotomap from 2012 with regard to trees over 1 m of theight

Classification RapidEye imaging - Maximum Likelihood

ːBridge image

classification

	Świeradów, Szklarska Poręba				Bystrzyca Kłodzka, Zdroje, Międzylesie, Lądek Zdrój				Bielsko (częściowo), Jeleśnia (częściowo), Ujsoły (częściowo), Ustroń, Węgierska Górka, Wisła			
Date	08.07.2012		15.05.2013		09.09.2012		19.05.2013		24.07.2012		24.07.2013	
I_{CP}	0,54		0,72		0,52		0,63		0,53		0,72	
Kappa	0,02		0,44		0,02		0,02		0,01		0,44	
Klasa	1	2	1	2	1	2	1	2	1	2	1	2
A_P	0,95	0,51	0,44	0,69	0,93	0,52	0,92	0,52	0,95	0,51	0,45	0,69
A_U	0,07	0,08	0,27	0,71	0,13	0,16	0,13	0,16	0,07	0,08	0,27	0,72

Klasa: 1 – healthy trees, 2 – weakened or dead trees

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Thank you for your attention

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