The potential of Sentinel-2 data to classify tree species

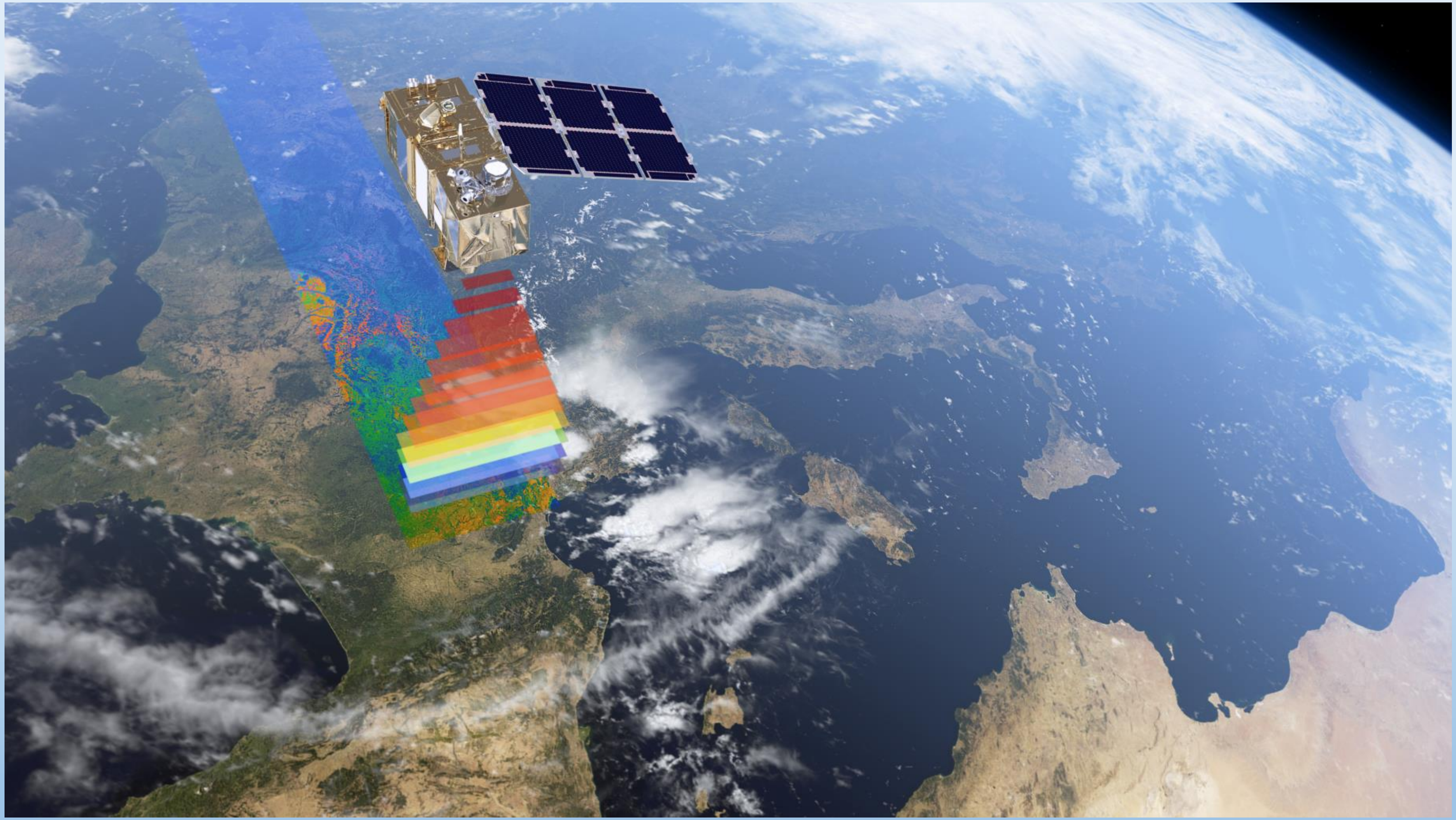
Wessel, M., Brandmeier, M., Tiede, D.

September 2017

Outline of Presentation

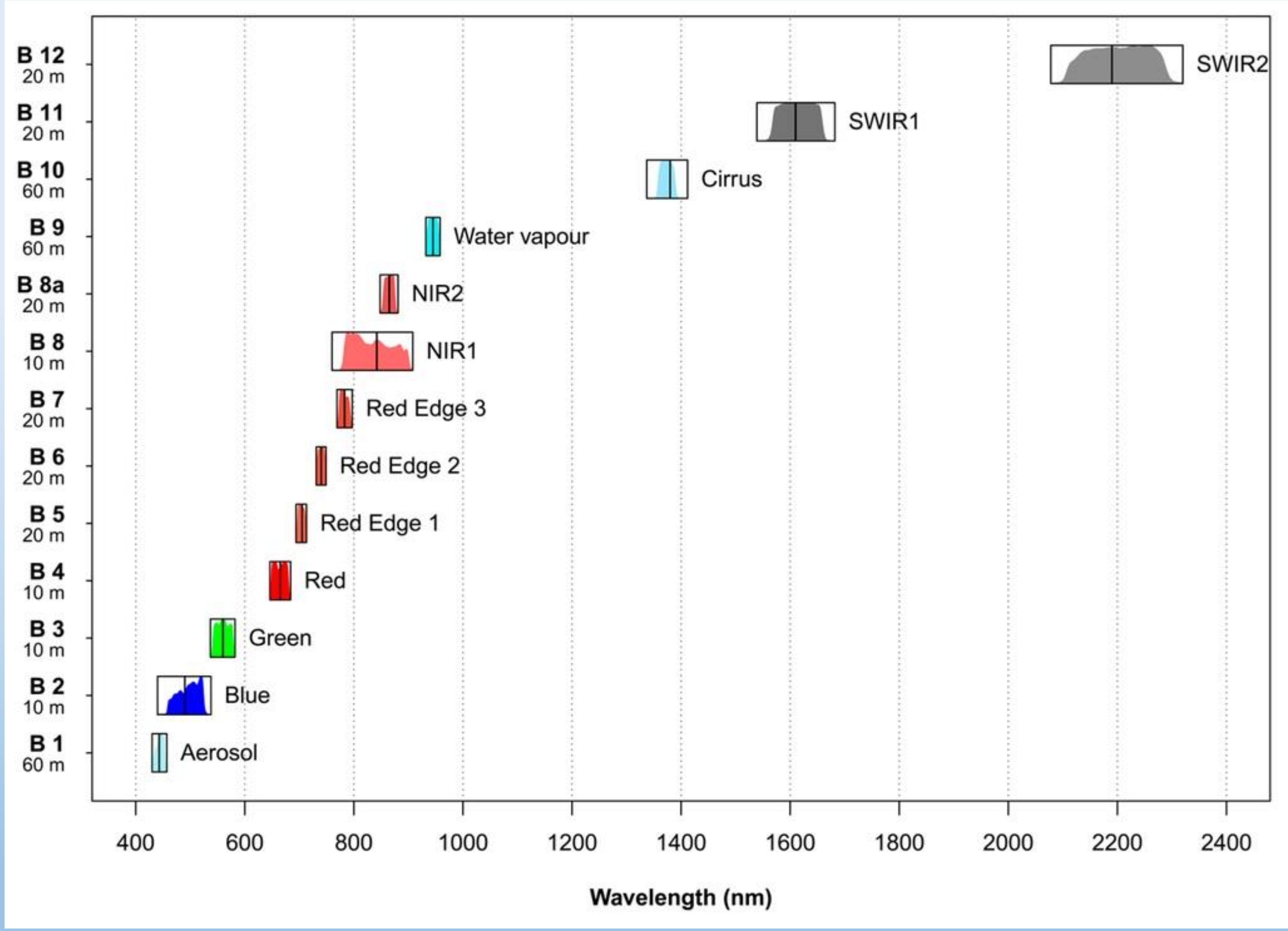
1. Introduction
2. Classification and Machine Learning Approaches
3. Accuracy Assessment and Transferability
4. Conclusions

1. Introduction



http://blog.astronomieschule.de/2015/06/23/sentinel-2a-erfolgreich-gestartet/

1. Introduction



http://www.mdpi.com/remotesensing/remotesensing-08-00166/article_deploy/html/images/remotesensing-08-00166-g002-1024.png

1. Introduction

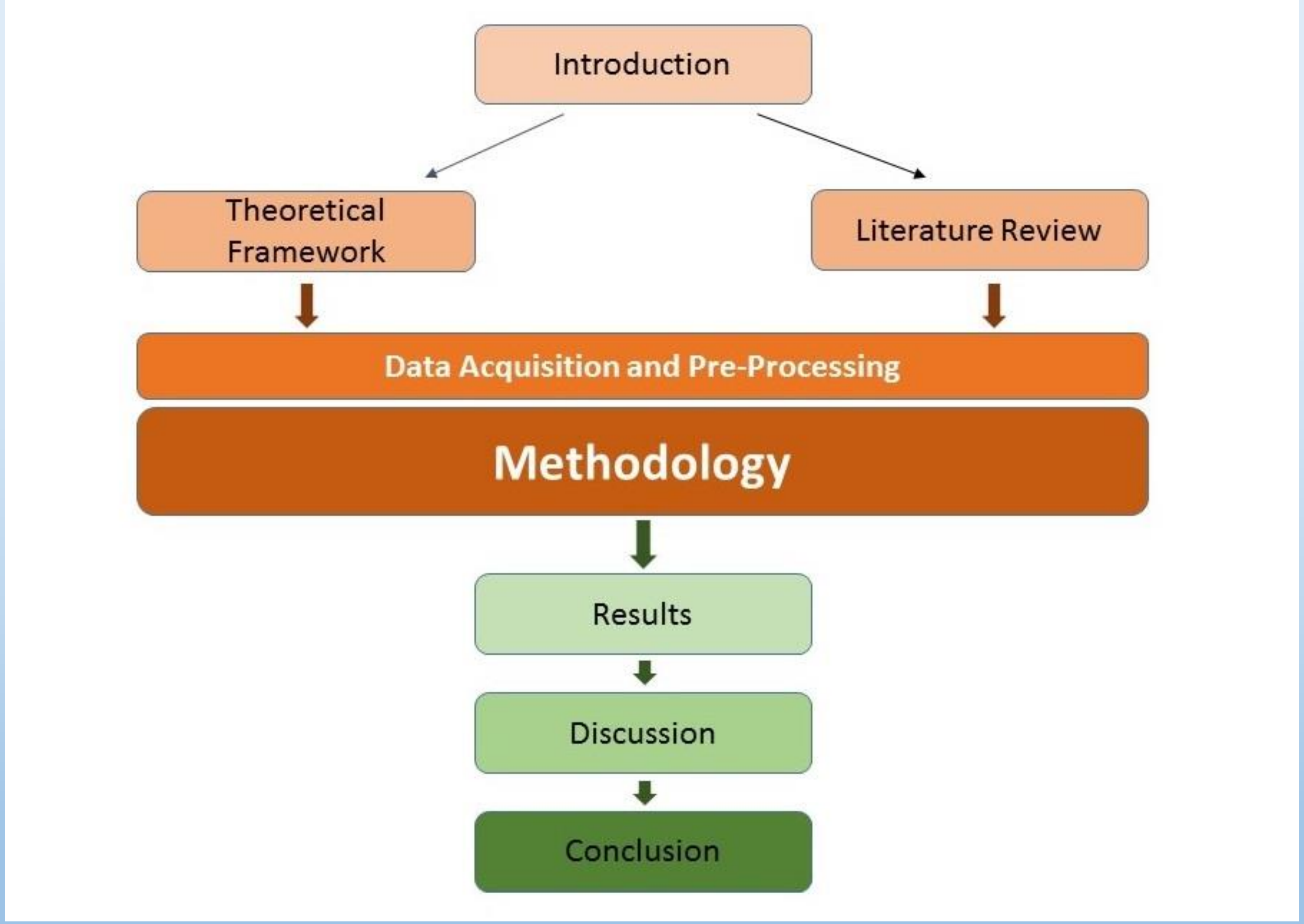
*“How valuable is the **potential** of **Sentinel-2 data** to **classify tree species** using **GIS software**?”*

Which role does the red edge part play?

Can S-2 compete with high resolution, cost-intense hyperspectral earth monitoring satellite data?

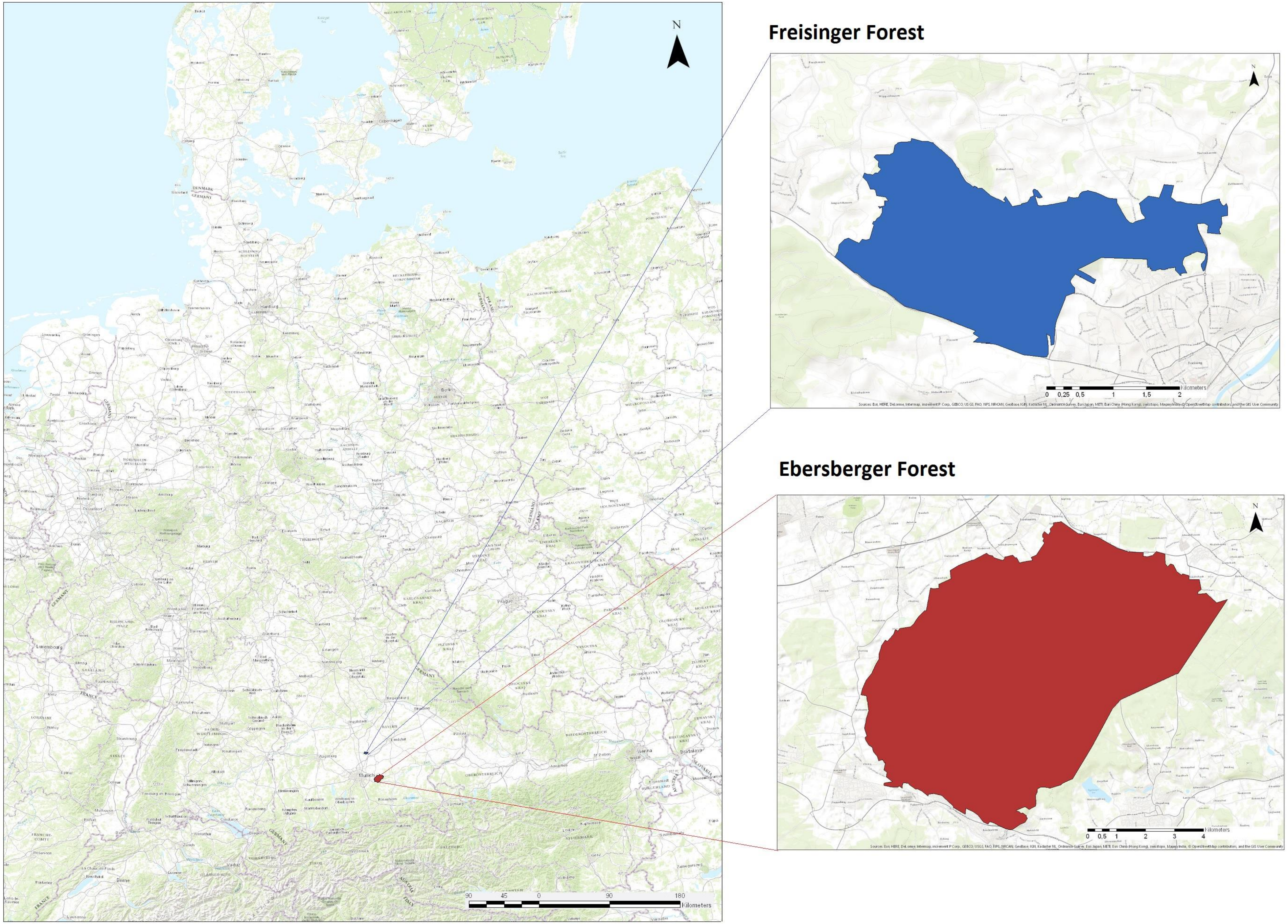
Is the resolution sufficient enough for detailed forest / tree species classifications?

1. Introduction



1. Introduction

- Primarily use of statistical machine learning classifiers (SVM and RF)
- Use of ArcGIS Pro
- Focus on scientific relevance (arrangements and discussions with the LWF „Landesanstalt für Wald und Forstwirtschaft Bayern“)
- Importance of Validation Procedure



Freisinger Forest
Ebersberger Forest
N
90 45 0 90 180
Kilometers
0 0,25 0,5 1 1,5 2
Kilometers
0 0,5 1 2 3 4
Kilometers

2. Classification and Machine Learning Approaches

Data Aquisition

a) Sentinel-2 data

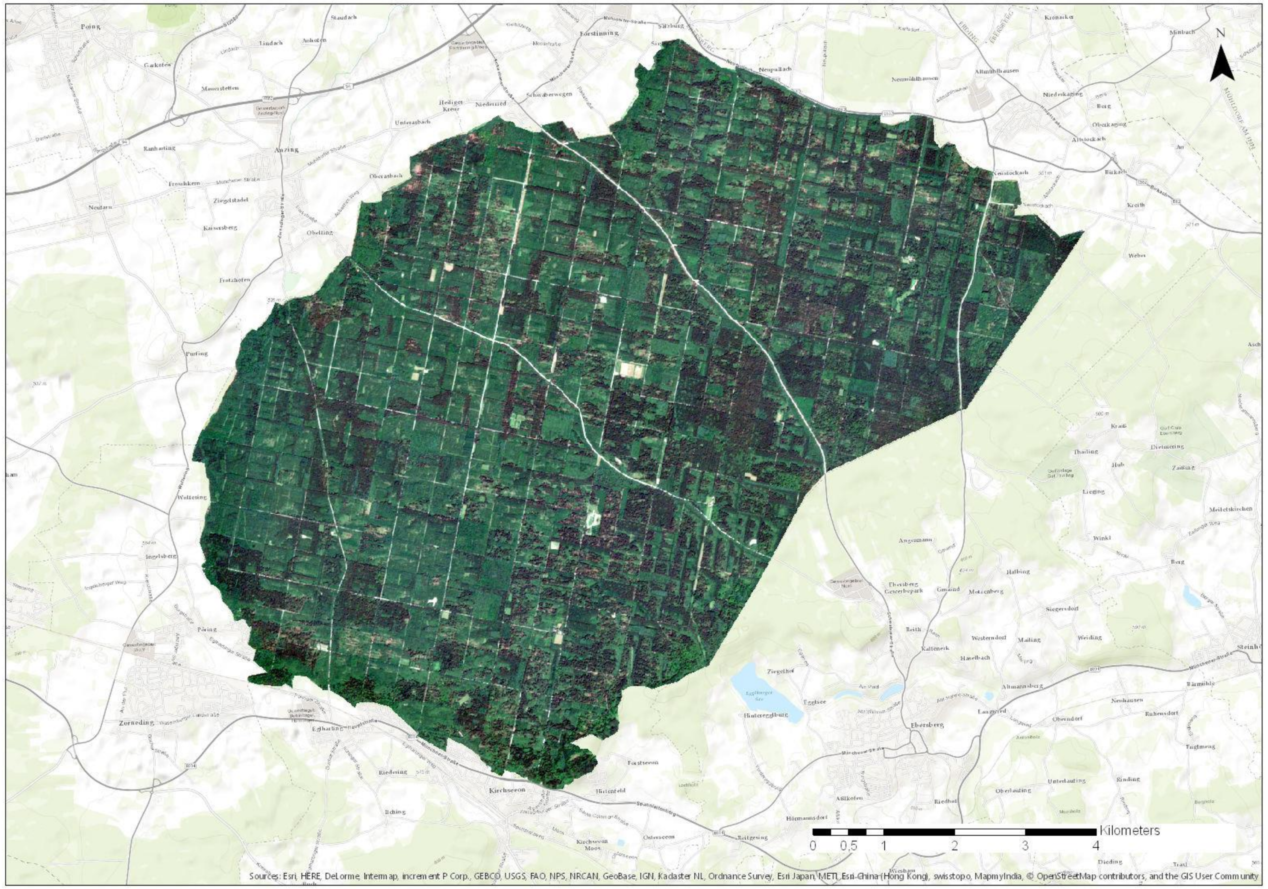
- Freely available in the „Copernicus Open Access Hub“ (non-atmosphere corrected level 1C data)

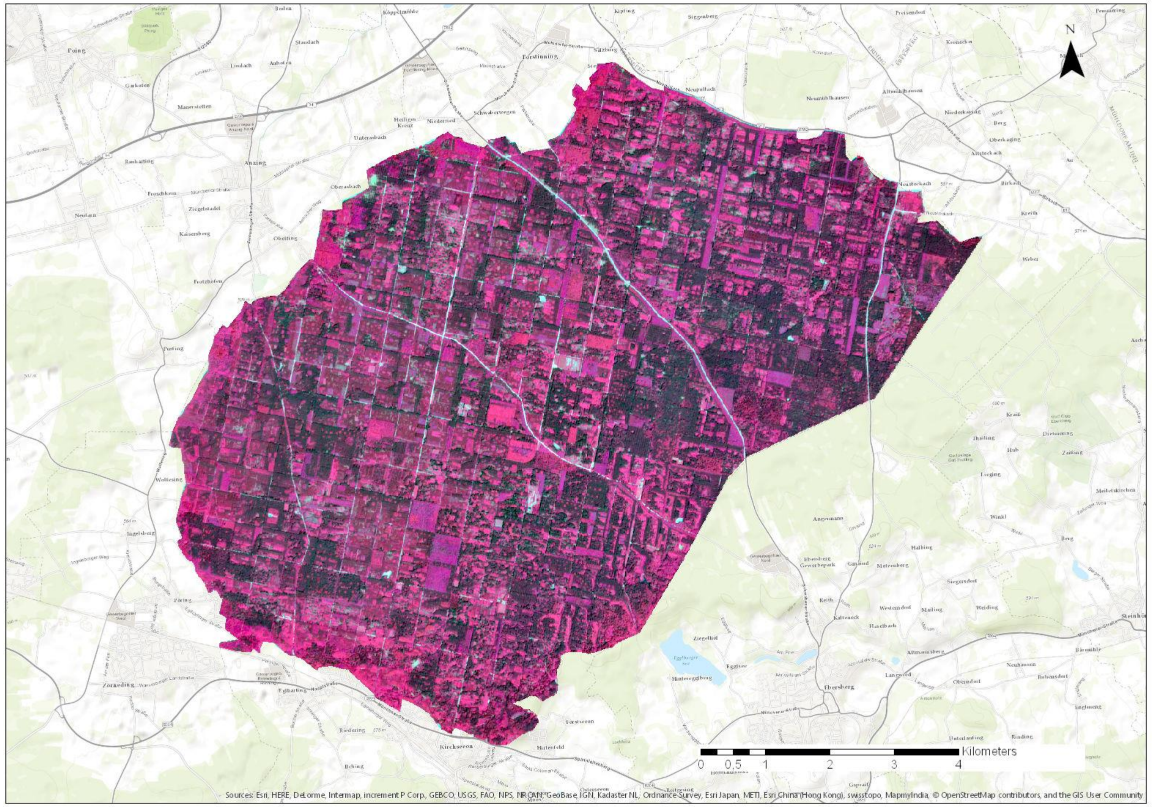
https://scihub.copernicus.eu/dhus/#/home

- 0% cloud coverage as important factor
- 3 different dates for multitemporal analysis (May, August, September)

Sentinel-2 data:

Date	Product Name	Cloud Coverage %	Product Level
22 May 2016	S2A_OPER_PRD_MSIL1C_PDMC_20160522T182438_R065_V20160522T102029_20160522T102029.SAFE	28.7	1C
09 August 2016	S2A_OPER_PRD_MSIL1C_PDMC_20160809T050727_R022_V20150704T101337_20150704T101337.SAFE	4.5	1C
29 September 2016 EF*	S2A_OPER_PRD_MSIL1C_PDMC_20160929T185141_R065_V20160929T102022_20160929T102344.SAFE	0.0	1C
29 September 2016 FF* EF = Ebersberger Forest FF = Freisinger Forest	S2A_OPER_PRD_MSIL1C_PDMC_20160929T181908_R065_V20160929T102022_20160929T102344.SAFE	0.0	1C

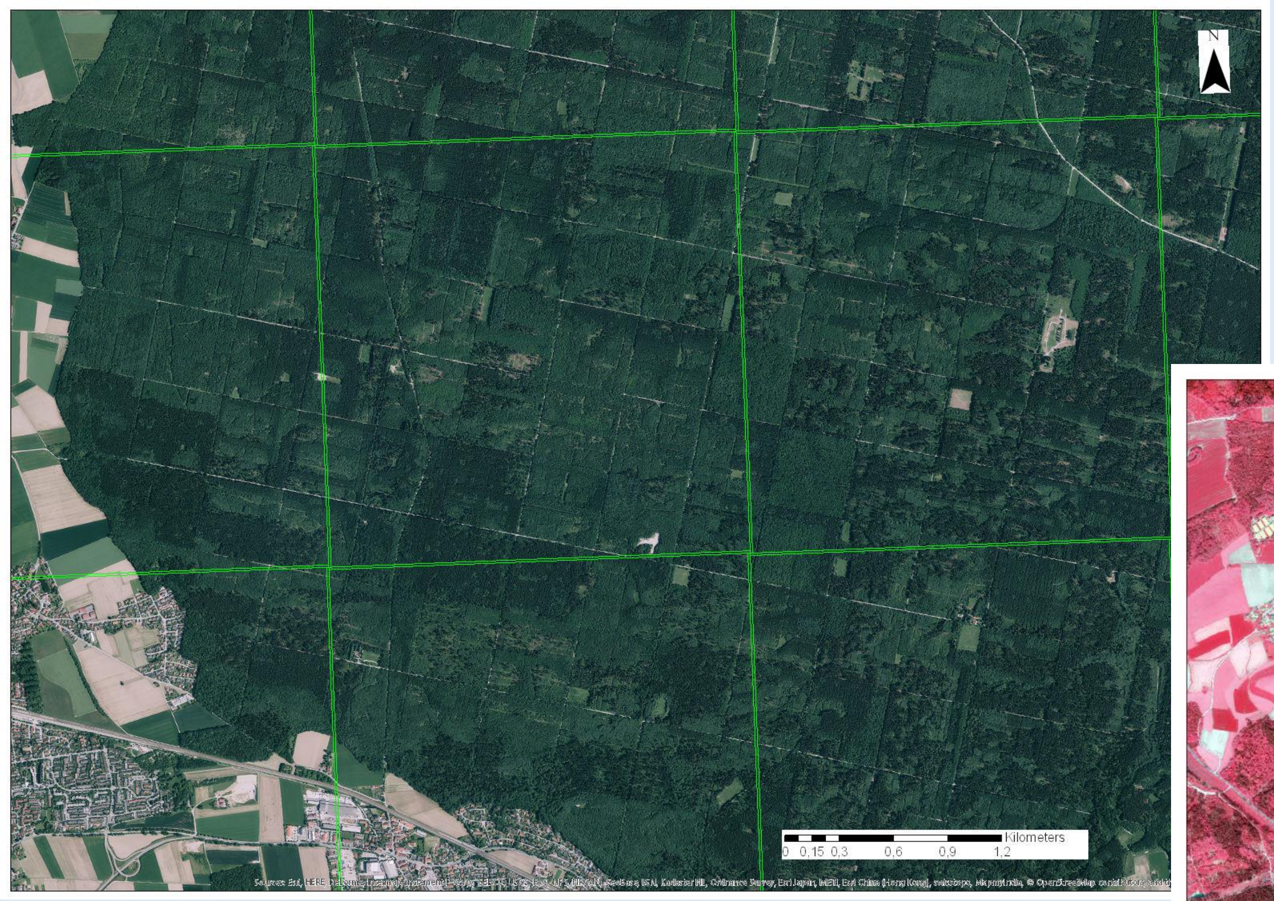

N
Kilometers
0 0,5 1 2 3 4
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

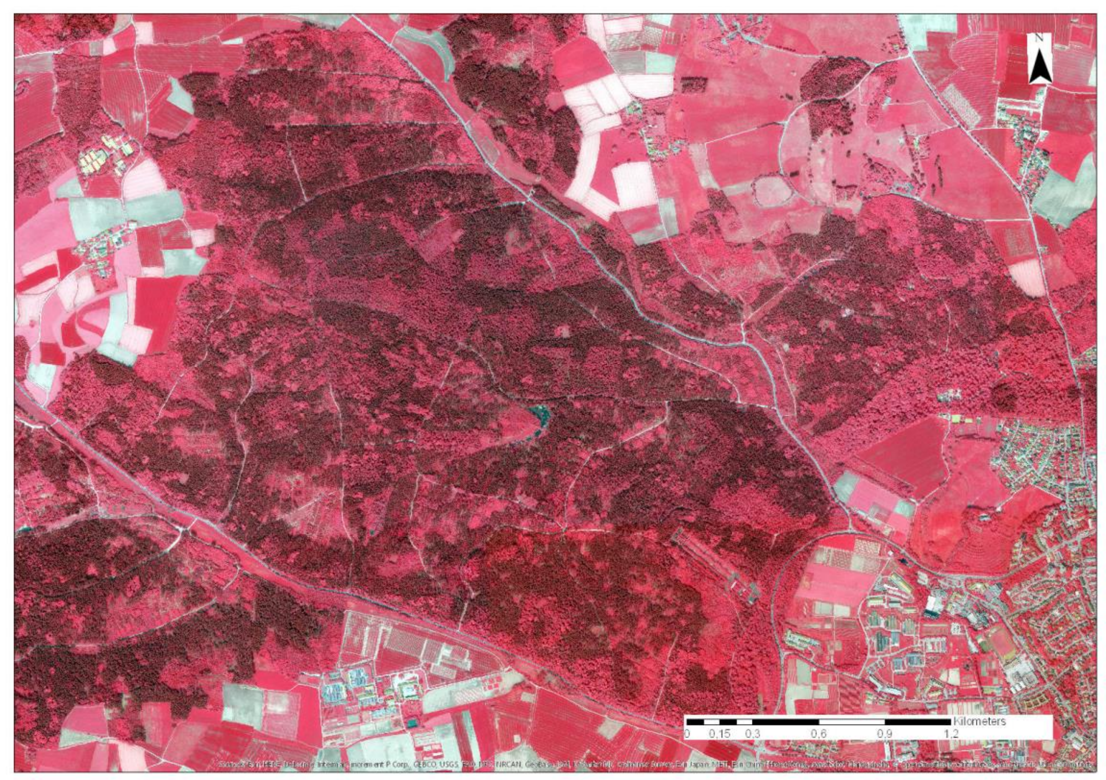

N
Kilometers
0 0,5 1 2 3 4
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

2. Classification and Machine Learning Approaches

b) Aerial Images

- RGB and CIR with a 20cm resolution
- Useful for validation analysis and classification steps
- Sensed in January 2016 and May 2015



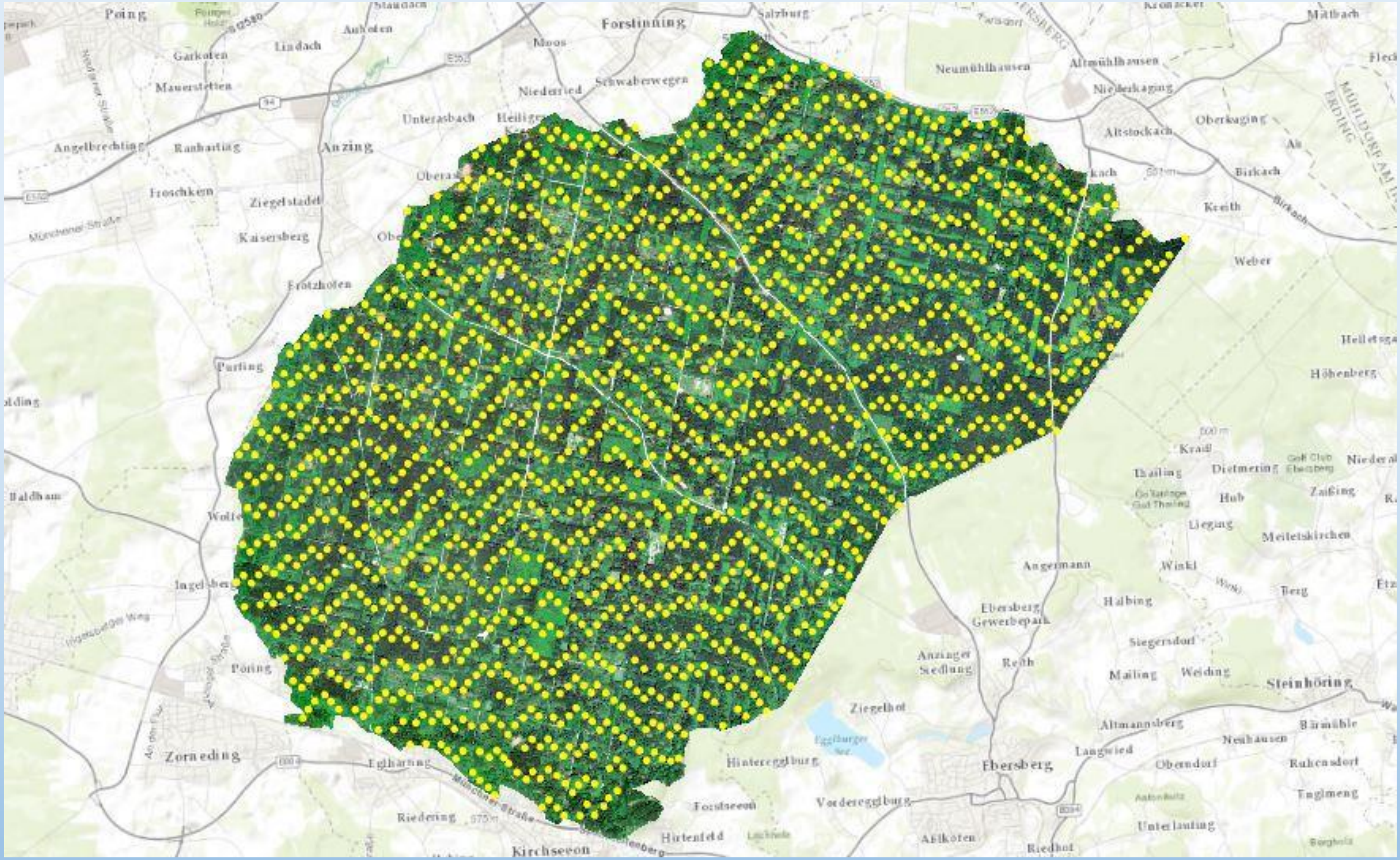


(Geobasisdaten © Bayerische Vermessungsverwaltung)

2. Classification and Machine Learning Approaches

c) **Inventory Data**

- Inventory data consists of circles with a procentual distribution of different tree species (11-12m circle radius)
- Only usage of circles which contain a 100% dominance of a single tree type
- Actual data from January/November 2016



(Inventory Data@Bayerische Staatsforsten)

2. Classification and Machine Learning Approaches

Challenge: No linear distribution of tree species!

Tree Type	Ebersberger Forest	Freisinger Forest
Spruce	777	70
Pine	2	1
Larch	6	2
Fir	1	2
Other Coniferous	8	2
Beech	75	4
Oak	21	2
Other Deciduous	63	11

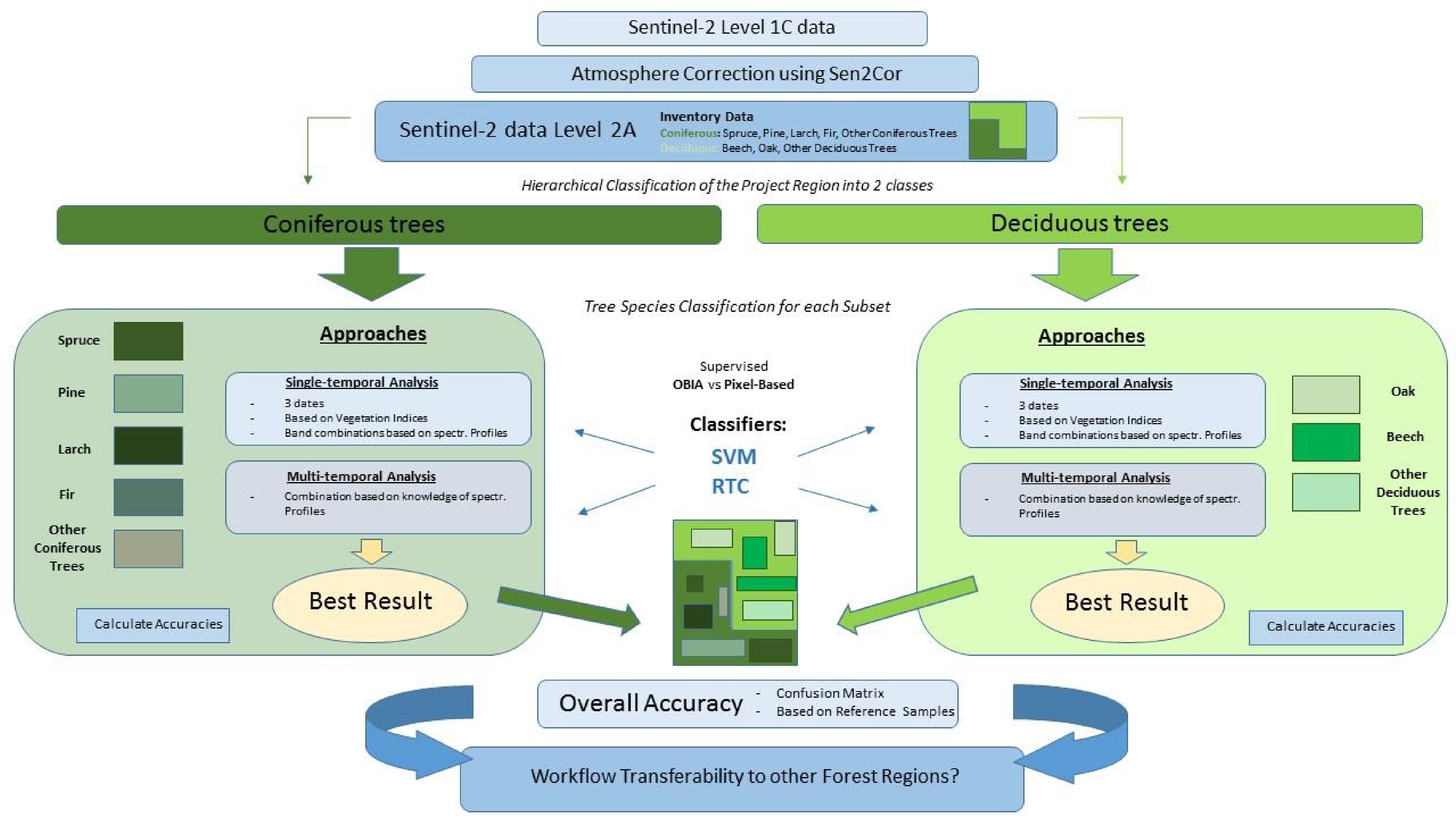
2. Classification and Machine Learning Approaches

Atmosphere Correction:

Tool: Sen2Cor (not undisputed by researchers)
Alternate tools: ATCOR

Sen2Cor can be used within SNAP or with Python Anaconda

<u>Main aim:</u>
Top of Atmosphere (TOA) Reflectance → Bottom of Atmosphere (BOA) Reflectance
Level 1C → Level 2A


Sentinel-2 Level 1C data
Atmosphere Correction using Sen2Cor
Sentinel-2 data Level 2A
Inventory Data
Coniferous: Spruce, Pine, Larch, Fir, Other Coniferous Trees
Deciduous: Beech, Oak, Other Deciduous Trees
Hierarchical Classification of the Project Region into 2 classes
Coniferous trees
Deciduous trees
Tree Species Classification for each Subset
Spruce
Pine
Larch
Fir
Other Coniferous Trees
Approaches
Single-temporal Analysis
- 3 dates
- Based on Vegetation Indices
- Band combinations based on spectr. Profiles
Multi-temporal Analysis
- Combination based on knowledge of spectr. Profiles
Best Result
Calculate Accuracies
Supervised
OBIA vs Pixel-Based
Classifiers:
SVM
RTC
Approaches
Single-temporal Analysis
- 3 dates
- Based on Vegetation Indices
- Band combinations based on spectr. Profiles
Multi-temporal Analysis
- Combination based on knowledge of spectr. Profiles
Oak
Beech
Other Deciduous Trees
Best Result
Calculate Accuracies
Overall Accuracy
- Confusion Matrix
- Based on Reference Samples
Workflow Transferability to other Forest Regions?

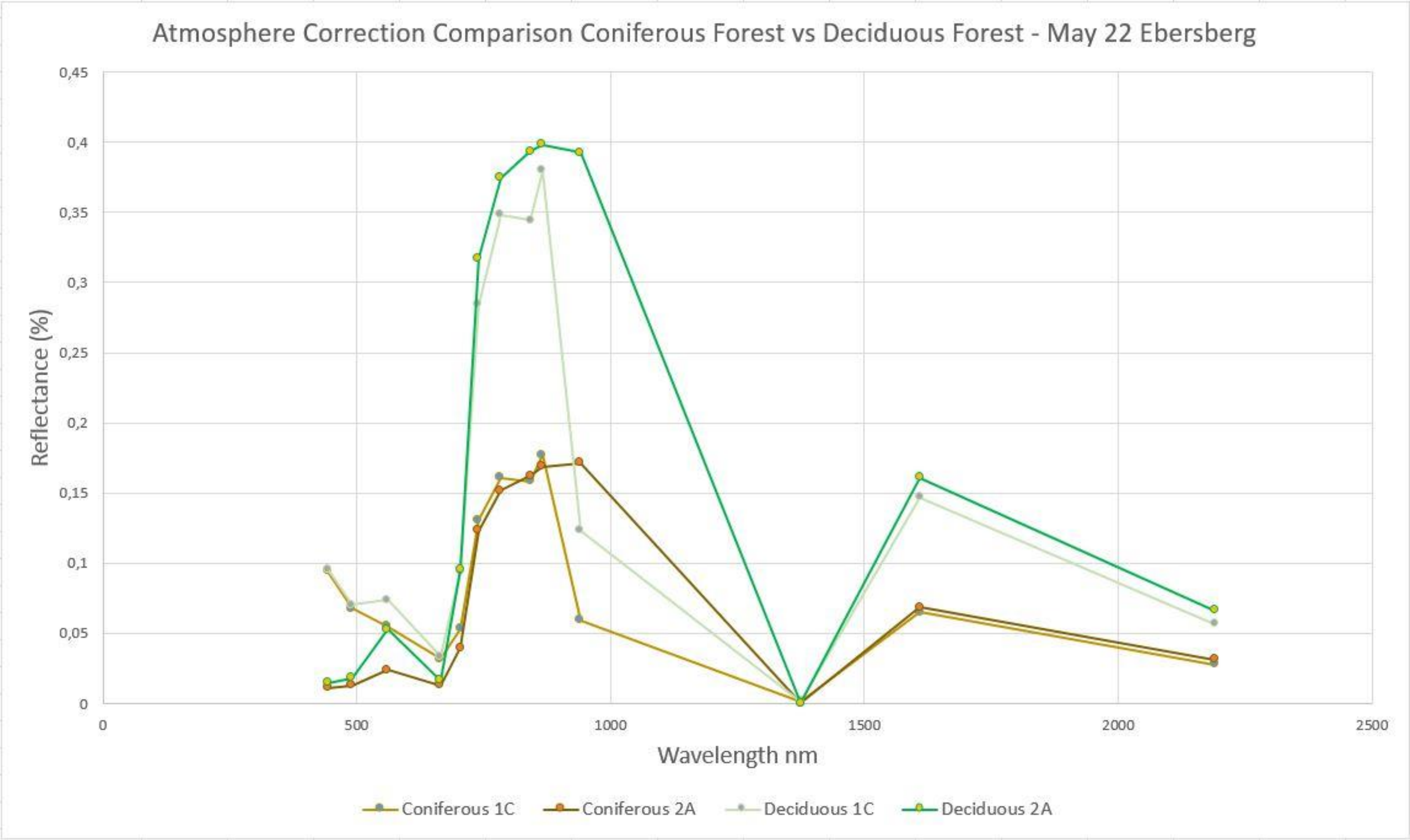
2. Classification and Machine Learning Approaches

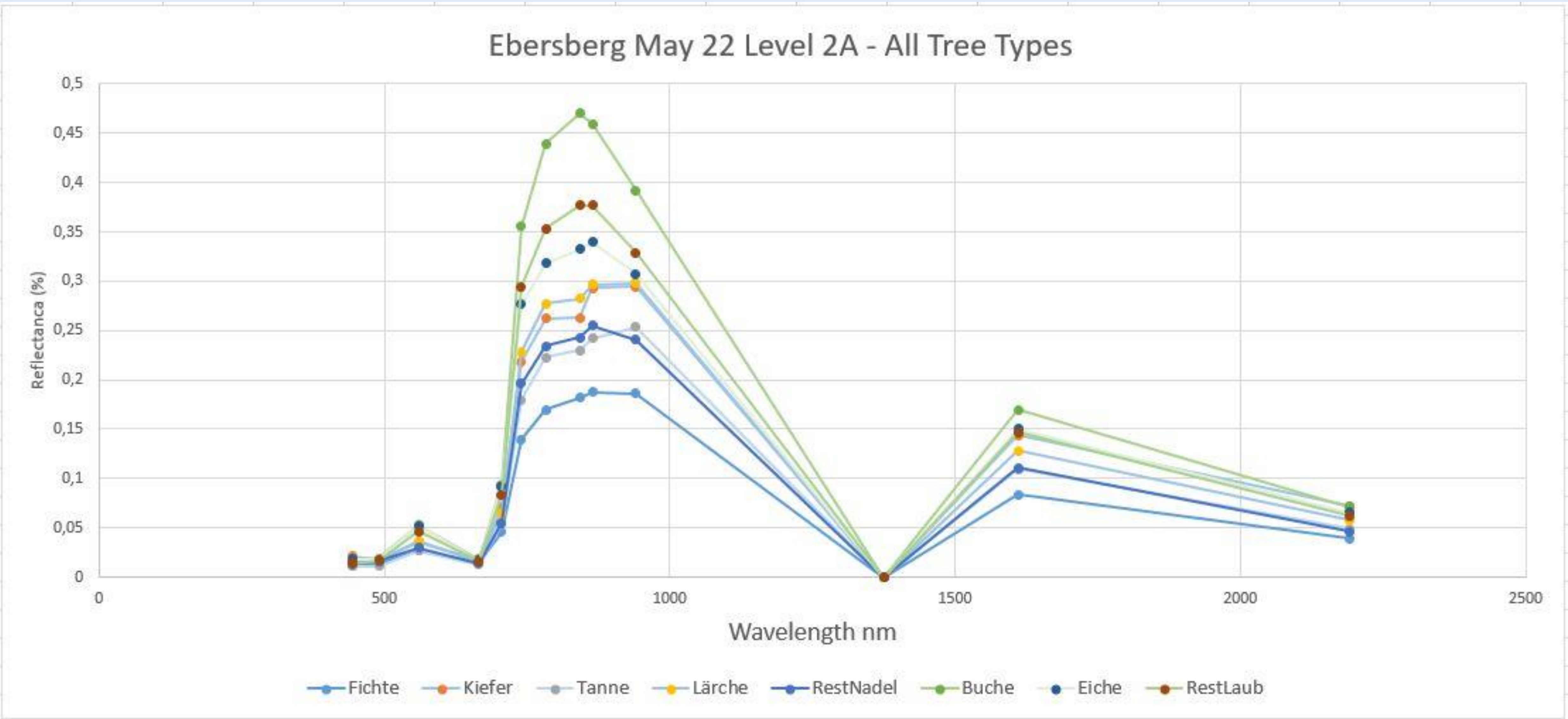
Spectral Profiles:

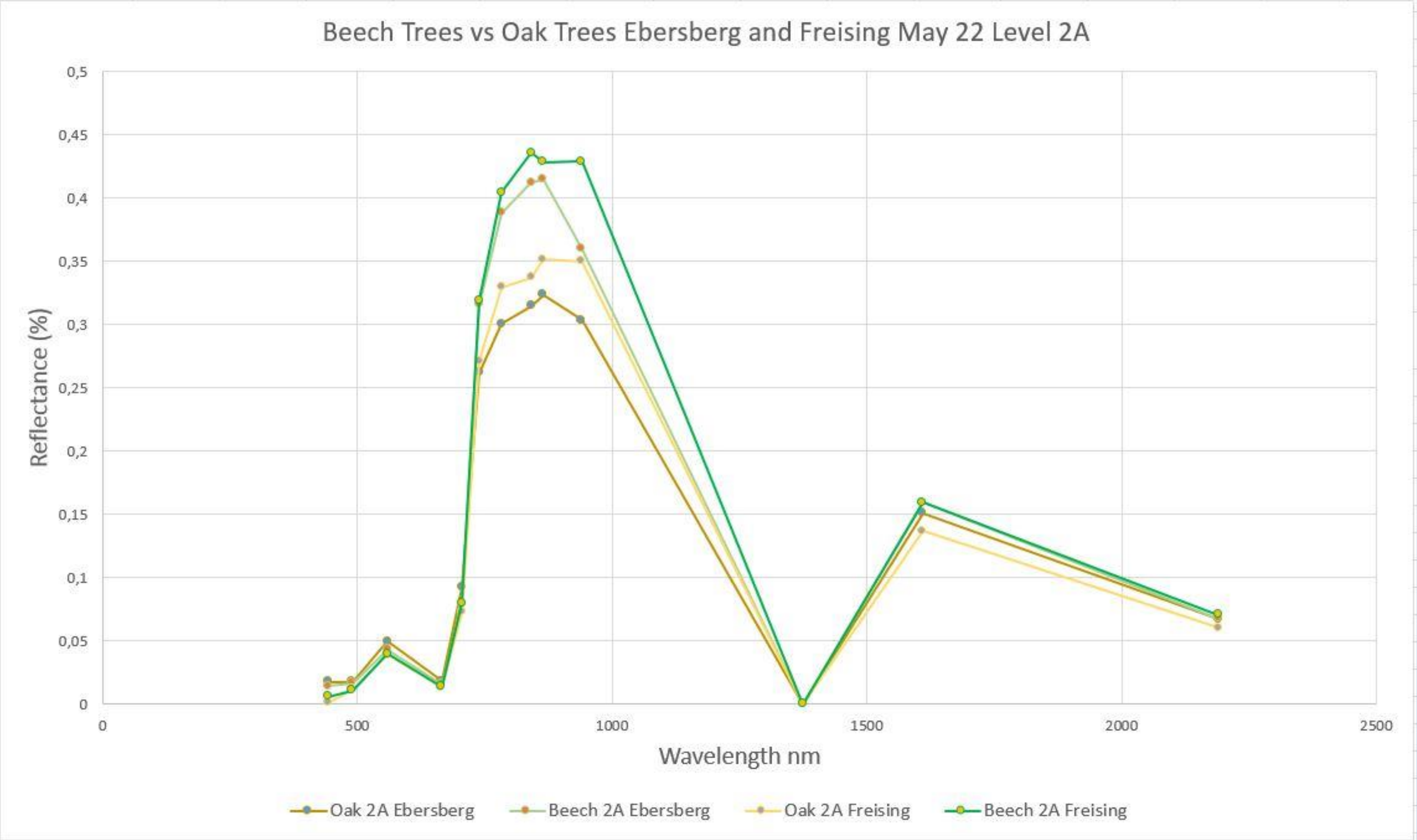
Why is it useful to use spectral profiles?

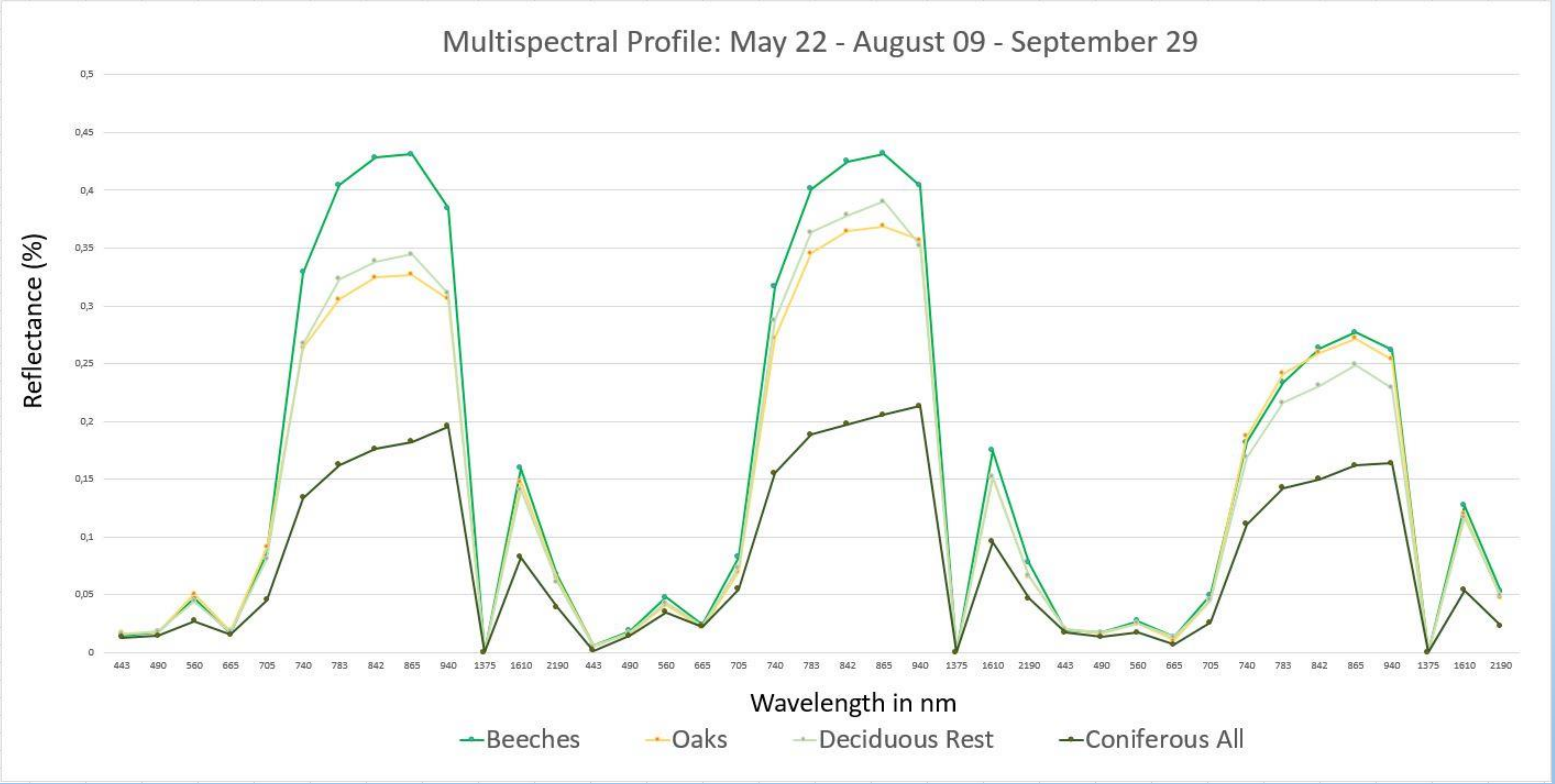
→Important wavelength regions (bands) can be estimated by displaying reflectance values

- Based on training samples (based on inventory data)
- Can be easily exported and displayed within e.g. Word
- Multitemporal profiles can be created

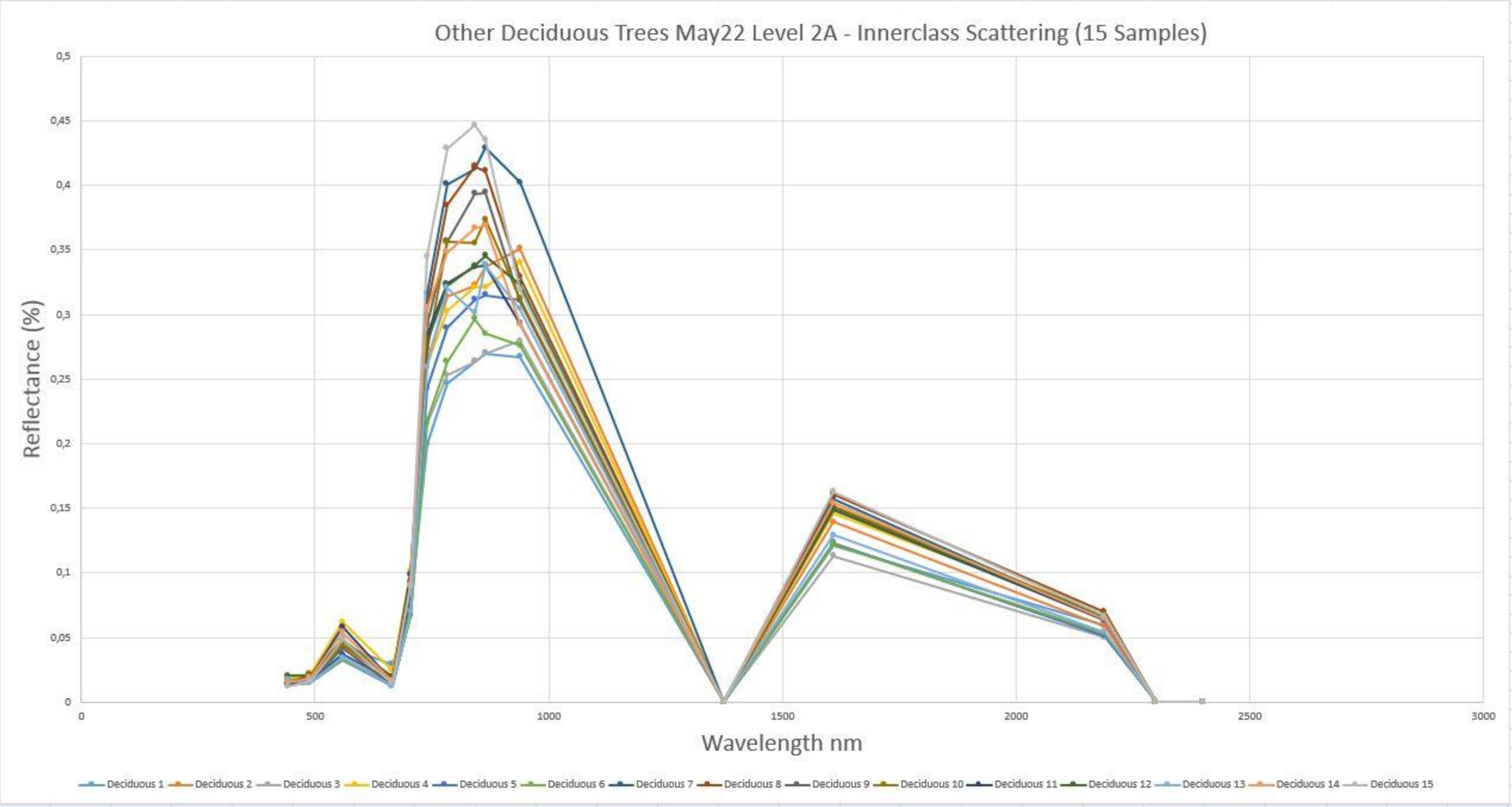

Atmosphere Correction Comparison Coniferous Forest vs Deciduous Forest - May 22 Ebersberg
Reflectance (%)
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
500
1000
1500
2000
2500
Wavelength nm
Coniferous 1C
Coniferous 2A
Deciduous 1C
Deciduous 2A


Ebersberg May 22 Level 2A - All Tree Types
Reflectanca (%)
0,5
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
500
1000
1500
2000
2500
Wavelength nm
Fichte
Kiefer
Tanne
Lärche
RestNadel
Buche
Eiche
RestLaub


Beech Trees vs Oak Trees Ebersberg and Freising May 22 Level 2A
Reflectance (%)
0,5
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
500
1000
1500
2000
2500
Wavelength nm
Oak 2A Ebersberg
Beech 2A Ebersberg
Oak 2A Freising
Beech 2A Freising



Multispectral Profile: May 22 - August 09 - September 29
Reflectance (%)
0,5
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
443 490 560 665 705 740 783 842 865 940 1375 1610 2190 443 490 560 665 705 740 783 842 865 940 1375 1610 2190 443 490 560 665 705 740 783 842 865 940 1375 1610 2190
Wavelength in nm
Beeches
Oaks
Deciduous Rest
Coniferous All


Other Deciduous Trees May22 Level 2A - Innerclass Scattering (15 Samples)
Reflectance (%)
Wavelength nm
0
0,05
0,1
0,15
0,2
0,25
0,3
0,35
0,4
0,45
0,5
0
500
1000
1500
2000
2500
3000
Deciduous 1
Deciduous 2
Deciduous 3
Deciduous 4
Deciduous 5
Deciduous 6
Deciduous 7
Deciduous 8
Deciduous 9
Deciduous 10
Deciduous 11
Deciduous 12
Deciduous 13
Deciduous 14
Deciduous 15

2. Classification and Machine Learning Approaches

Coniferous- and Deciduous Forest Classification

Method: supervised classification, pixel-based and object-based

Classifier: SVM, RT

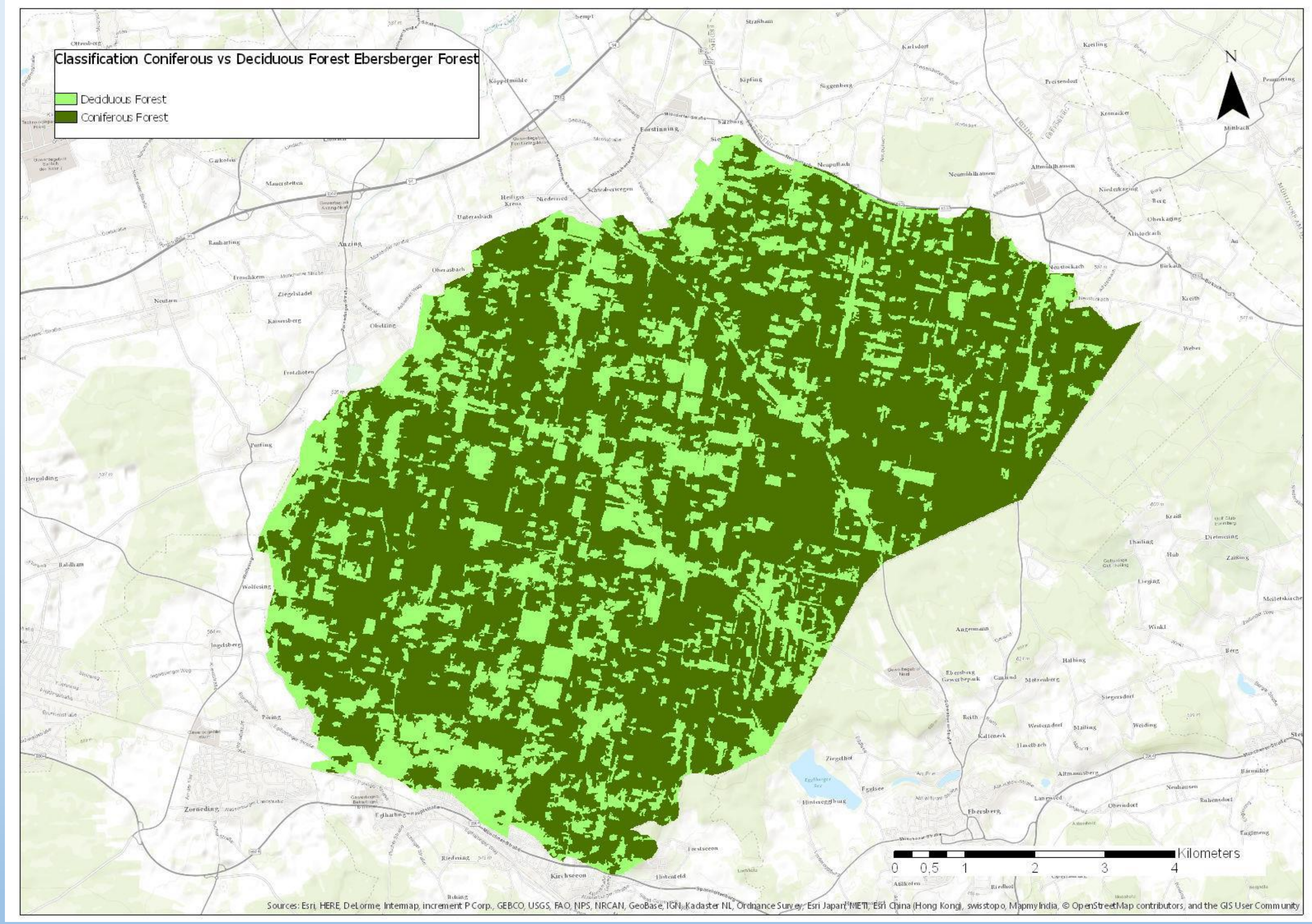
Segmentation knowledge based on spectral profiles information

Coniferous- and Deciduous Forest Classification

Workflow Classification Coniferous Forest vs. Deciduous Forest

Accuracy	Method	Classifier	Segmented Image	Segmentation Settings
95,2	OBIA	SVM	May22 / bands 8 7 6	DS
86,8	OBIA	RTC	May22 / bands 8 7 6	DS
92,3	PB	SVM	May22 / bands 8 7 6	DS
90,2	OBIA	SVM	May 22 / bands 8 4 3	DS
74	OBIA	RTC	May 22 / bands 8 4 3	DS
97	PB	SVM	May 22 / bands 8 4 3	DS
87	OBIA	SVM	May 22 / bands 8 4 3	SegSize 5
85	OBIA	SVM	Multitemporal / May 3, Aug 8, Sept 7	DS
86,6	OBIA	RTC	Multitemporal / May 3, Aug 8, Sept 7	DS
83	PB	SVM	Multitemporal / May 3, Aug 8, Sept 7	DS
97,2	OBIA	SVM	Multitemporal / May 8, Aug 8, Sept 8	DS
92,4	OBIA	SVM	Multitemporal / May 8, Aug 8, Sept 8	SegSize 5
81,6	OBIA	RTC	Multitemporal / May 8, Aug 8, Sept 8	DS
89,8	PB	SVM	Multitemporal / May 8, Aug 8, Sept 8	DS

	Method	Classifier	Input Image	Segmented additional Image	Segmentation Settings
92,6	OBIA	SVM	August - all bands	Multitemporal / May 8, Aug 8, Sept 8	DS
97,2	OBIA	SVM	August PCA 1 to 4	Multitemporal / May 8, Aug 8, Sept 8	DS



97.2% accuracy

Best results with:
OBIA
SVM
Multitemporal approach (IR bands)

2. Classification and Machine Learning Approaches

Deciduous Tree Species Classification: Beech, Oak, Other Broadleaf Trees

- Hierarchical analysis of coniferous and deciduous tree types
- Based on polygon masks
- „Segment Mean Shift“ algorithm for a first segmentation (30 in total)
- Best „SMS“ results is used as „additional input image“ in a further segmentation step (all bands of the input image are accounted)
- 3 Broadleaf species: Beech, oak and other deciduous tree types
- 15 training samples are set for each type

2. Classification and Machine Learning Approaches

Workflow Classification Deciduous Trees Segment Mean Shift

Accuracy	Method	Classifier	Segmented Image	Segmentation Settings
63	OBIA	SVM	Multitemporal / May 8, Aug 8, Sept 8	DS
50	OBIA	RTC	Multitemporal / May 8, Aug 8, Sept 8	DS
62	PB	SVM	Multitemporal / May 8, Aug 8, Sept 8	DS
86,8	OBIA	SVM	May 22 - all bands	SegSize 5
64	OBIA	SVM	May22 / bands 8 7 6	DS
61	OBIA	SVM	May 22 / bands 8 4 3	DS
50	OBIA	SVM	May 22 / band 4 3 2	DS
50	PB	SVM	May 22 / band 4 3 2	DS
81	OBIA	SVM	May 22 / bands 8 3 2	DS
87,4	OBIA	SVM	May 22 / bands 8 3 2	SegSize 5
74	OBIA	SVM	May 22 / bands 8 3 2	SegSize 2
46	OBIA	SVM	May 22 / bands 8 3 2	SegSize 10
78	OBIA	SVM	May 22 / bands 8 3 2	SegSize 5/spa/spec 18/18
83,3	OBIA	SVM	May 22 / bands 8 3 2	SegSize 5/spa/spec 10/10
58	OBIA	RTC	May 22 / bands 8 3 2	DS
66	PB	SVM	May 22 / bands 8 3 2	DS
72	OBIA	SVM	May 22 / bands 7 6 5 (Red Edge)	DS
75	OBIA	RTC	May 22 / bands 7 6 5 (Red Edge)	DS
71	OBIA	SVM	May 22 / bands 7 6 5 (Red Edge)	SegSize 5
58	OBIA	RTC	May 22 / bands 7 6 5 (Red Edge)	SegSize 5
35	OBIA	SVM	May 22 / bands 8 4 2	DS
57	OBIA	RTC	May 22 / bands 8 4 2	DS
66	PB	SVM	May 22 / bands 8 4 2	DS
70	OBIA	RTC	May 22 / bands 8 4 2	SegSize 5
69	OBIA	SVM	Aug 09 / bands 8 3 2	DS
60	OBIA	SVM	Aug 09 / bands 8 3 2	SegSize 5
37	OBIA	SVM	Sept 29 / bands 8 3 2	DS
66	OBIA	SVM	Multitemporal / Sept 2, Aug 3, May 8	DS
62	OBIA	RTC	Multitemporal / Sept 2, Aug 3, May 8	DS
38	OBIA	SVM	Multitemporal / Sept 8, Aug 3, May 2	DS

Best SMS result:

May 22

Bands 8, 3, 2

OBIA

SVM

Classification Classify Tool with additional Mean Shift Segmented Input Raster

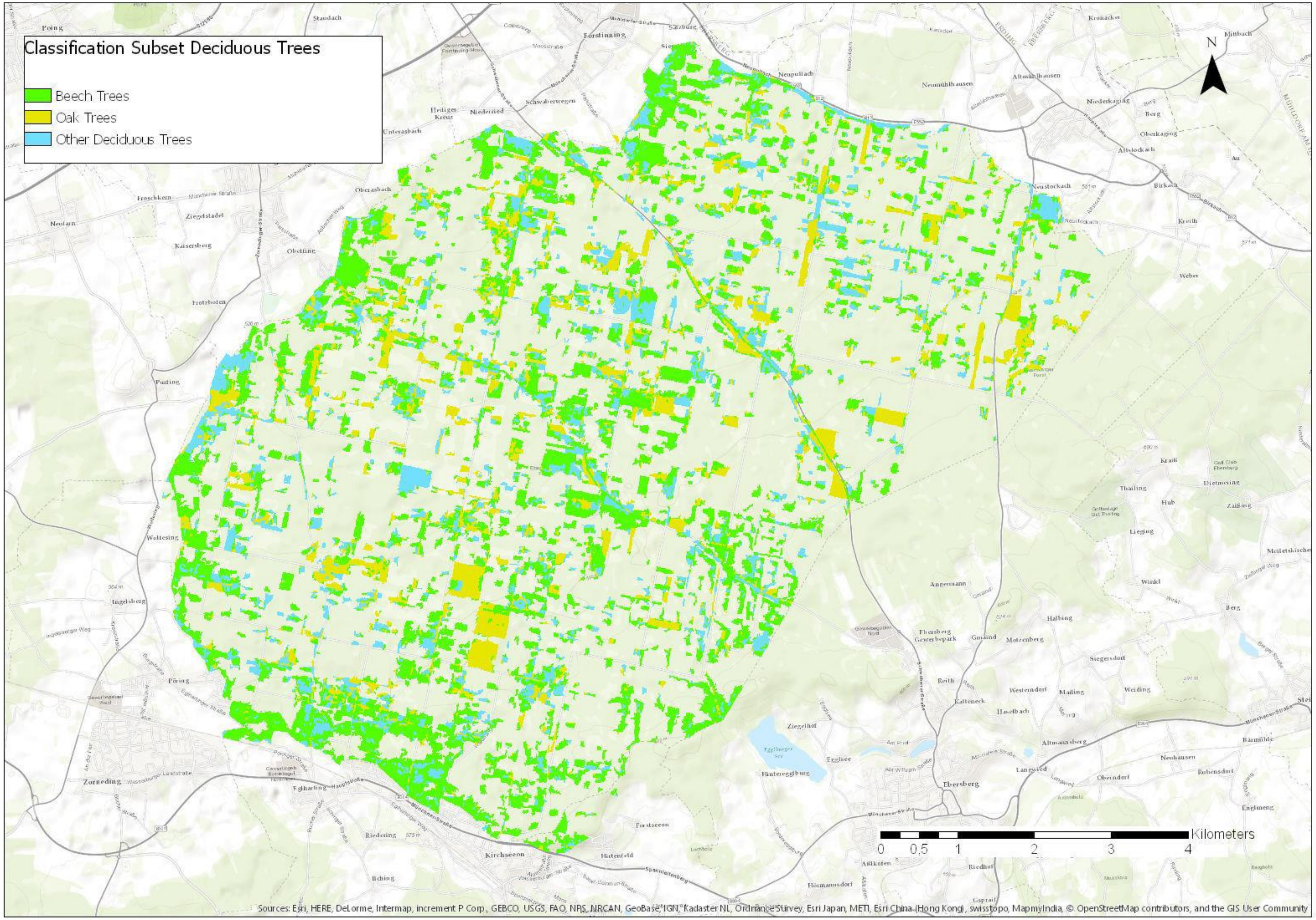
Accuracy	Method	Classifier	Input Image	Segmented additional Image	Segmentation Settings
54,3	OBIA	SVM	S_23456789_PCA1_2	May 22 / bands 8 3 2, segSize 5	SegSize 5
49,4	OBIA	SVM	S_23456789_PCA1_2	May 22 / bands 8 3 2, segSize 5	SegSize5 + SA 1-6
71,7	OBIA	SVM	S_23456789_PCA1-4	May 22 / bands 8 3 2, segSize 5	SegSize 5
67,3	OBIA	SVM	S_23456789_PCA1-5	May 22 / bands 8 3 2, segSize 5	SegSize5 + SA 1-6
59	OBIA	SVM	S_23456789_PCA1-6	May 22 / bands 8 3 2, segSize 5	SegSize5 + SA 1-2-5
61,6	OBIA	RTC	S_23456789_PCA1-7	May 22 / bands 8 3 2, segSize 5	SegSize 5
63,3	PB	SVM	S_23456789_PCA1-8		
76,2	PB	RTC	S_23456789_PCA1-9		
80,7	OBIA	SVM	May_S_832_PCA1-4&NDVI_May	May 22 / bands 8 3 2, segSize 5	SegSize 5
76	OBIA	SVM	May_NDVI&PCA1-4	May 22 / bands 8 3 2, segSize 5	SegSize 5
65	OBIA	SVM	May 832+ NDVI	May 22 / bands 8 3 2, segSize 5	SegSize 5
75,7	OBIA	SVM	May_Sentinel 98732	May 22 / bands 8 3 2, segSize 5	SegSize 5
74,3	OBIA	SVM	May_98732_PCA_1-4_NDVI_May	May 22 / bands 8 3 2, segSize 5	SegSize 5
55	PB	SVM	May_98732_PCA_1-4_NDVI_May		
75,1	PB	RTC	May_98732_PCA_1-4_NDVI_May		
87,2	OBIA	SVM	May 765	May 22 / bands 8 3 2, segSize 5	SegSize 5
59,9	OBIA	SVM	May 765 & PCA 1_4	May 22 / bands 8 3 2, segSize 5	SegSize 5
78,8	OBIA	SVM	May 765	May 22 / bands 8 3 2, segSize 5	SegSize5 + SA 1-2-3-4
53,7	PB	SVM	May 765		
67,1	OBIA	RTC	May 765	May 22 / bands 8 3 2, segSize 5	SegSize 5
87,2	OBIA	SVM	May 765 & NDVI	May 22 / bands 8 3 2, segSize 5	SegSize 5
87,2	OBIA	SVM	May 7654	May 22 / bands 8 3 2, segSize 5	SegSize 5
62,5	OBIA	RTC	May 7654	May 22 / bands 8 3 2, segSize 5	SegSize 5
80,3	OBIA	SVM	May 7, Aug 6, May5	May 22 / bands 8 3 2, segSize 5	SegSize 5
61,8	OBIA	SVM	May - all bands	May 22 / bands 8 3 2, segSize 5	SegSize 5
89,1	OBIA	SVM	August - all bands	May 22 / bands 8 3 2, segSize 5	SegSize 5
63,1	OBIA	RTC	August - all bands	May 22 / bands 8 3 2, segSize 5	SegSize 5
46	PB	SVM	August - all bands		
65,2	OBIA	SVM	August - all bands & PCA May 1-4	May 22 / bands 8 3 2, segSize 5	SegSize 5
80,5	OBIA	SVM	Aug 765	May 22 / bands 8 3 2, segSize 5	SegSize 5
80,7	OBIA	SVM	Aug 832	May 22 / bands 8 3 2, segSize 5	SegSize 5
60,9	OBIA	SVM	Sept - all bands	May 22 / bands 8 3 2, segSize 5	SegSize 5
63,3	OBIA	SVM	May PCA 1-12	May 22 / bands 8 3 2, segSize 5	SegSize 5
60	OBIA	SVM	May all bands & May PCA 1-4	May 22 / bands 8 3 2, segSize 5	SegSize 5
90,9	OBIA	SVM	August PCA 1-12	May 22 / bands 8 3 2, segSize 5	SegSize 5
78,3	OBIA	SVM	August - PCA1	May 22 / bands 8 3 2, segSize 5	SegSize 5
86,3	OBIA	SVM	August PCA 1-4	May 22 / bands 8 3 2, segSize 5	SegSize 5
53,3	OBIA	RTC	August PCA 1-4	May 22 / bands 8 3 2, segSize 5	SegSize 5
51	PB	SVM	August PCA 1-4		
90,5	OBIA	SVM	August PCA 1-5	May 22 / bands 8 3 2, segSize 5	SegSize 5
84,5	OBIA	SVM	August PCA 1-6	May 22 / bands 8 3 2, segSize 5	SegSize 5
85,2	OBIA	SVM	August PCA 1-7	May 22 / bands 8 3 2, segSize 5	SegSize 5
80,8	OBIA	SVM	august pca 1-10	May 22 / bands 8 3 2, segSize 5	SegSize 5
81,9	OBIA	SVM	august pca 1-11	May 22 / bands 8 3 2, segSize 5	SegSize 5
90,9	OBIA	SVM	august pca 1-12	May 22 / bands 8 3 2, segSize 5	SegSize 5
72,3	OBIA	SVM	August PCA 1 & 4	May 22 / bands 8 3 2, segSize 5	SegSize 5
74,8	OBIA	SVM	August PCA 2-3-4	May 22 / bands 8 3 2, segSize 5	SegSize 5
78,3	OBIA	SVM	August PCA 1 only	May 22 / bands 8 3 2, segSize 5	SegSize 5
82,3	OBIA	SVM	PCA May all - PCA Aug all	May 22 / bands 8 3 2, segSize 5	SegSize 5
77,2	OBIA	SVM	PCA all Aug - PCA allSep	May 22 / bands 8 3 2, segSize 5	SegSize 5
66	OBIA	SVM	PCA all May - PCA 1-12 Aug - PCA 1-12 Sep	May 22 / bands 8 3 2, segSize 5	SegSize 5
67,7	OBIA	SVM	PCA 1-12 Sept	May 22 / bands 8 3 2, segSize 5	SegSize 5
80,8	OBIA	SVM	NDVI August	May 22 / bands 8 3 2, segSize 5	SegSize 5
73,5	OBIA	SVM	August PCA 1-12 & NDVI	May 22 / bands 8 3 2, segSize 5	SegSize 5

Best final accuracy:

S-2 scene for August

PCA 1-12

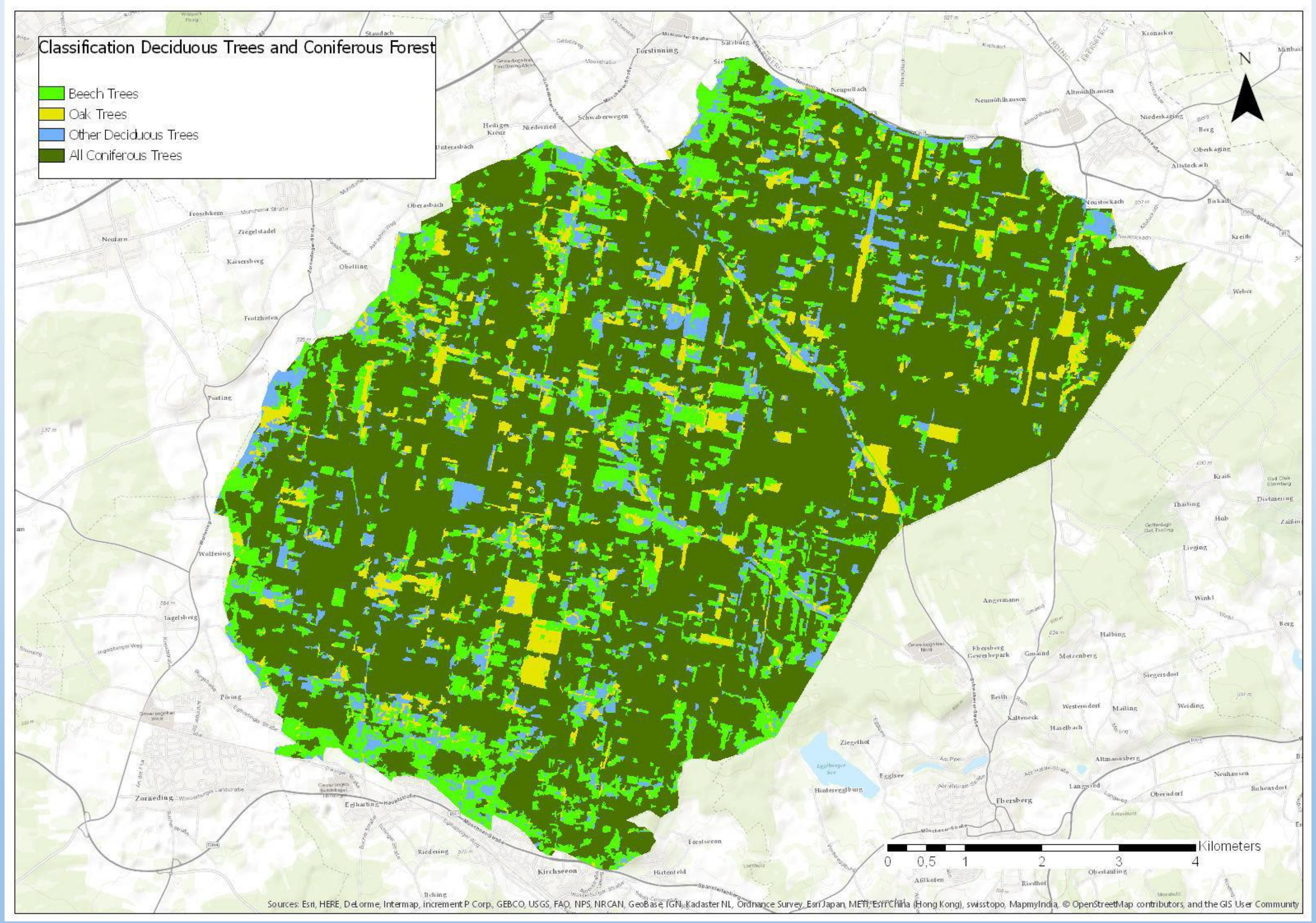
Segmentation min size: 5px



Accuracy of **90.9%**

3. Accuracy Assessment and Transferability

Final Classification



87% accuracy

4 classes:

- Beech
- Oak
- Other deciduous trees
- Coniferous trees

3. Accuracy Assessment and Transferability

- Validation based on training samples with unused inventory circles
- Accuracy Assessment: confusion matrix

→ Calculation of Users´s (UA), Producer´s (PA) and Overall Accuracy (OA)

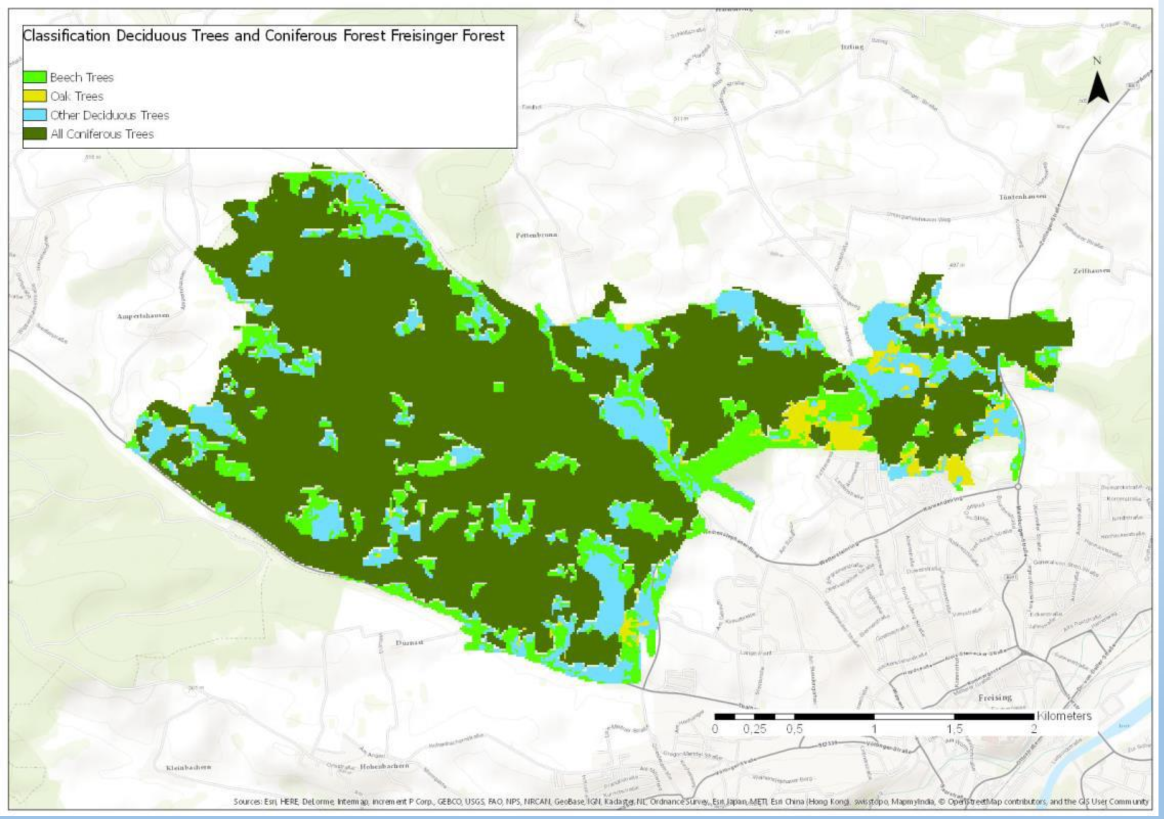
- Cohens Kappa is not highlighted due to ist controversial character

(Death to Kappa)

3. Accuracy Assessment and Transferability

Transferability:

To test, if conditions in one region are transferable to similar other regions (based on new invenory samples and new input data)



<u>Freisinger Forest:</u>

Seperation of Coniferous/Deciduous Forests: **91.2%** (cf. 97.2%)

Broadleaf Tree Species: **79.4%** (cf. 90.9%)

Overall Accuracy: **85%** (cf. 87%)

3. Accuracy Assessment and Transferability

Validation with tools (Collector for ArcGIS)

Visual in-field validation to control input data:

- Inventory data can be inaccurate!

4. Conclusions

- Results are strongly dependant of the quality (and also quantity) of input data
- Usage of visual and infrared 10m bands was most efficient for the analysis
- Red Edge region showed great potential but the resolution is to low for single tree types classification issues
- Results are only marginal worse compared to expensive commercial high resoltuion data

Thank you for listening! ☺

Contact Information:

Mathias Wessel:

wesselma1988@gmail.com

Melanie Brandmeier:

m.brandmeier@esri.de