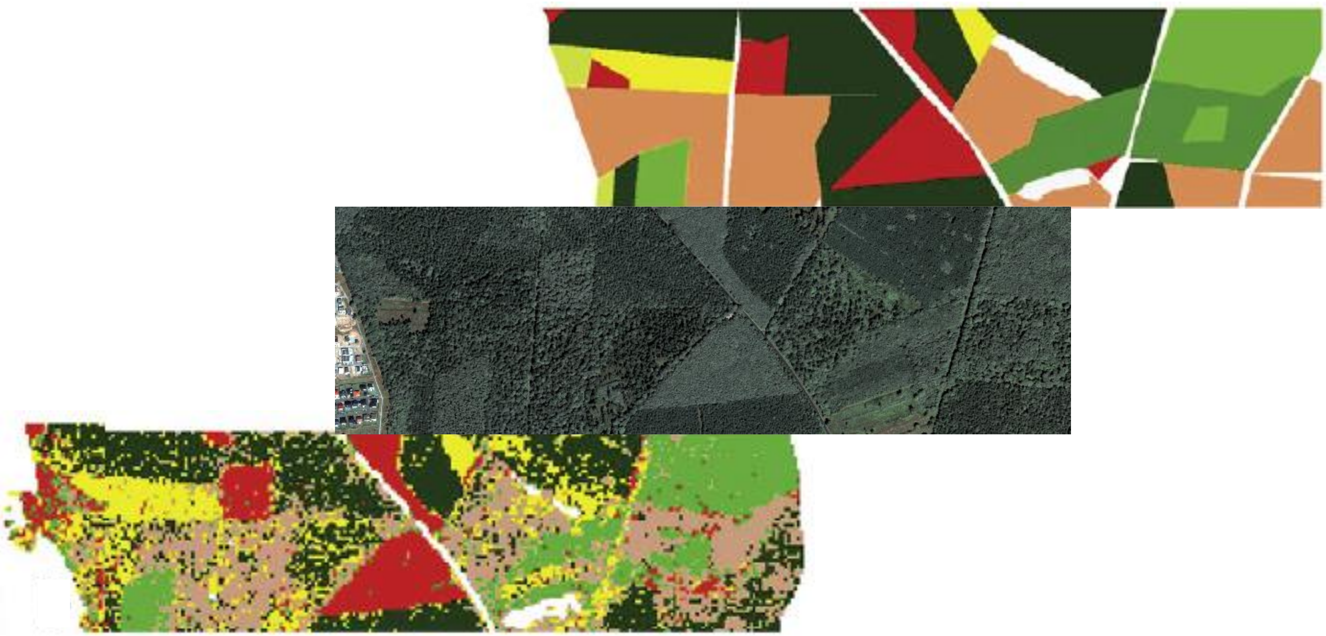
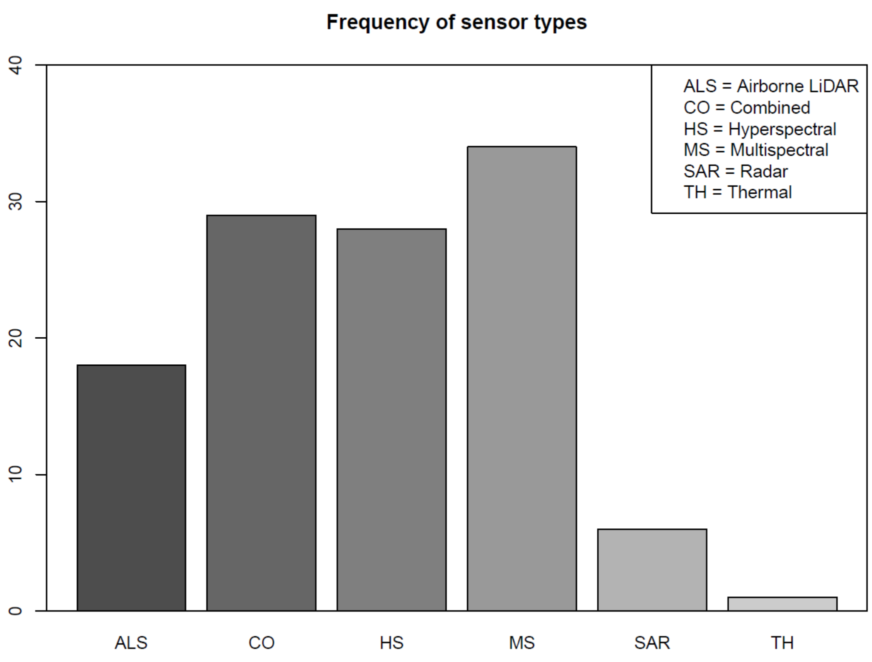
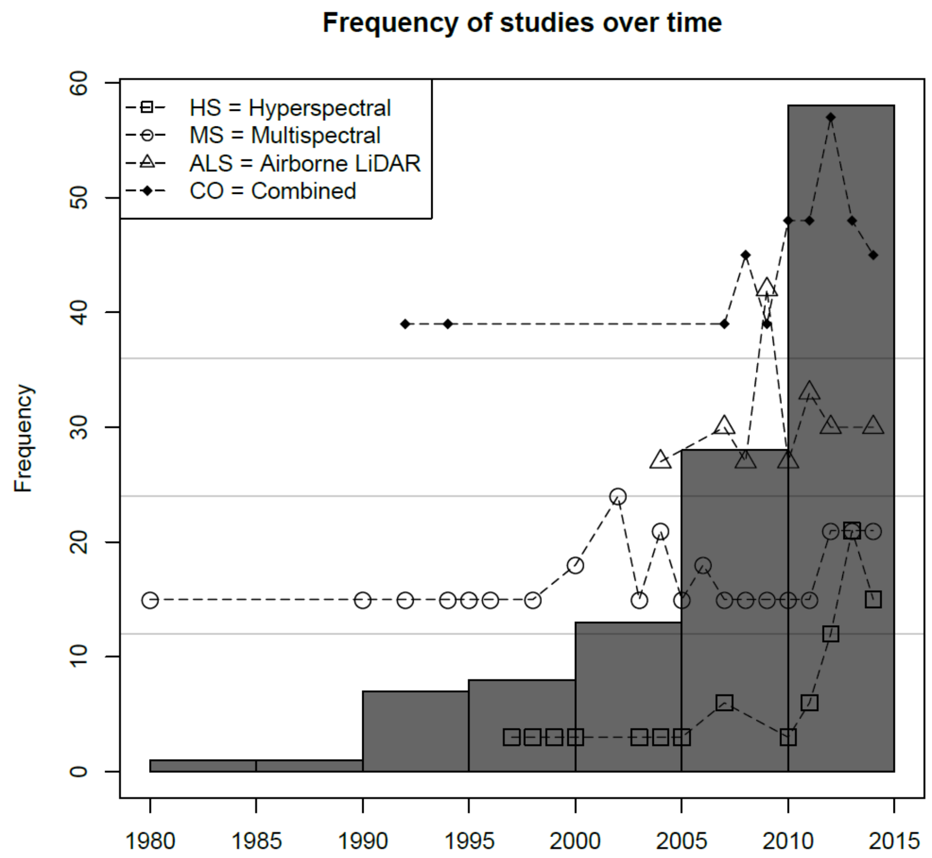
Mapping tree species from combined hyperspectral and LiDAR data - thoughts on **spectral resolution** and **scale**



Fabian Ewald Fassnacht, Institute of Geography and Geoecology, Karlsruhe Institute of Technology

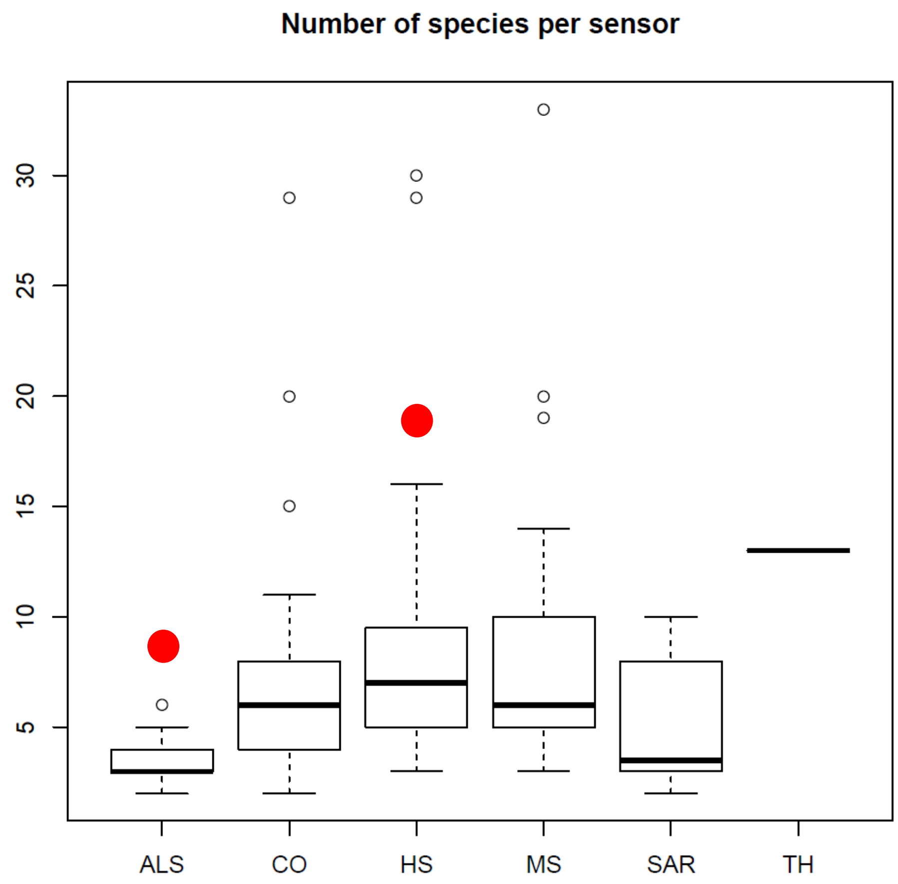
Overview





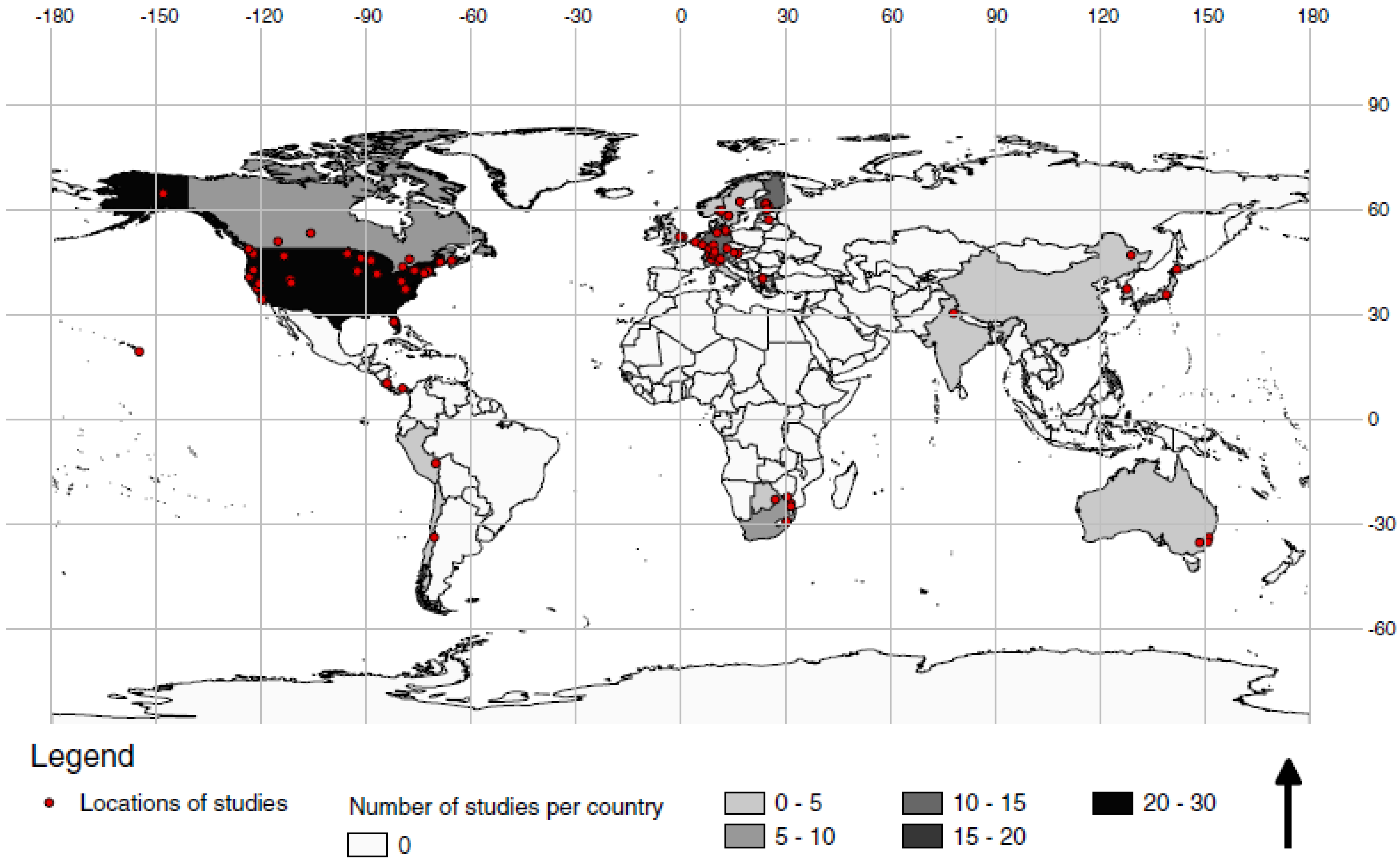
Descriptive statistics compiled from 116 selected **studies focusing on tree species mapping**

Overview



Descriptive statistics compiled from 116 selected **studies focusing on tree species mapping**

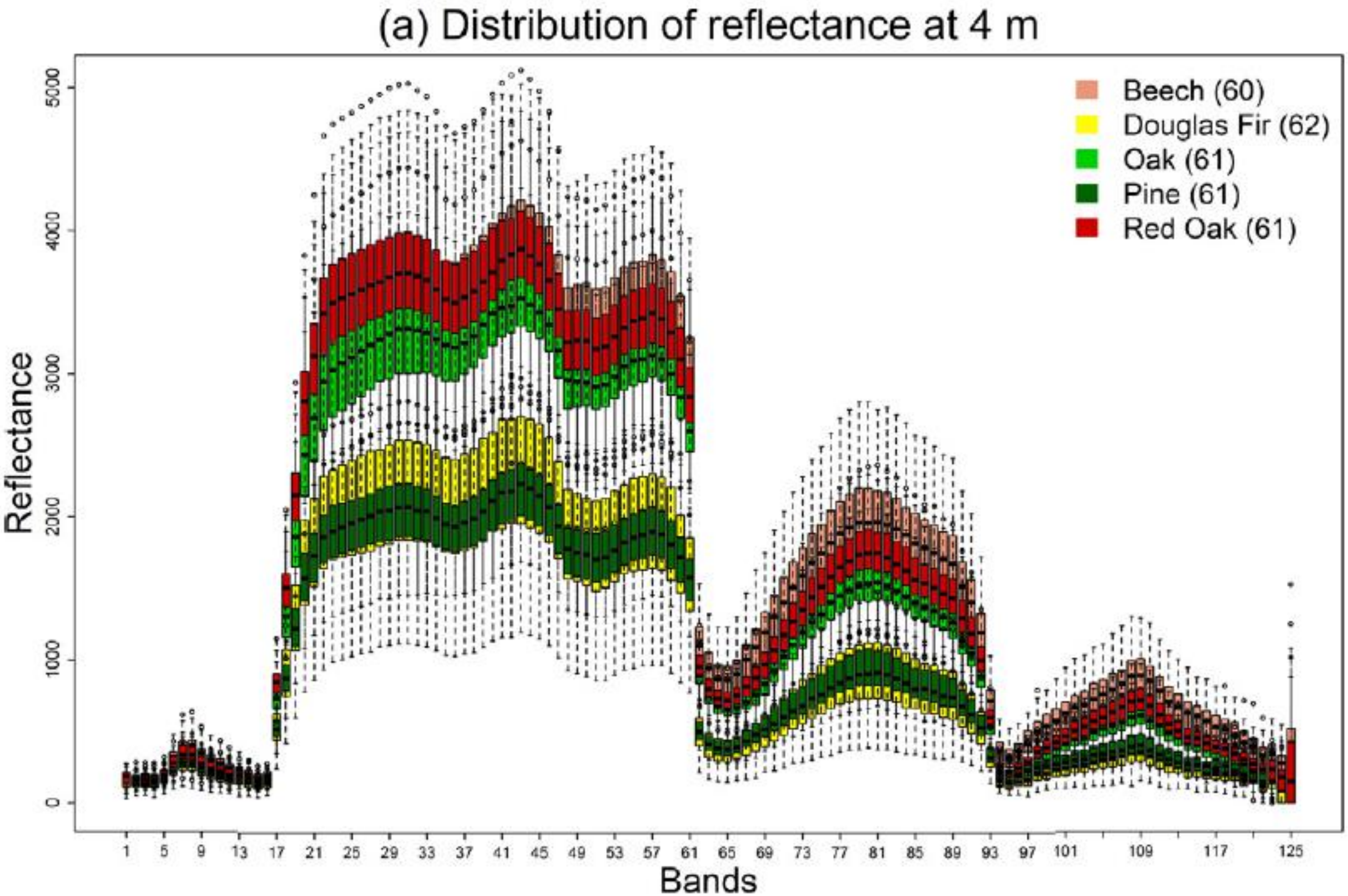
Overview



-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
90
60
30
0
-30
-60
Legend
Locations of studies
Number of studies per country
0
0 - 5
5 - 10
10 - 15
15 - 20
20 - 30

Hyperspectral data

Hyperspectral data



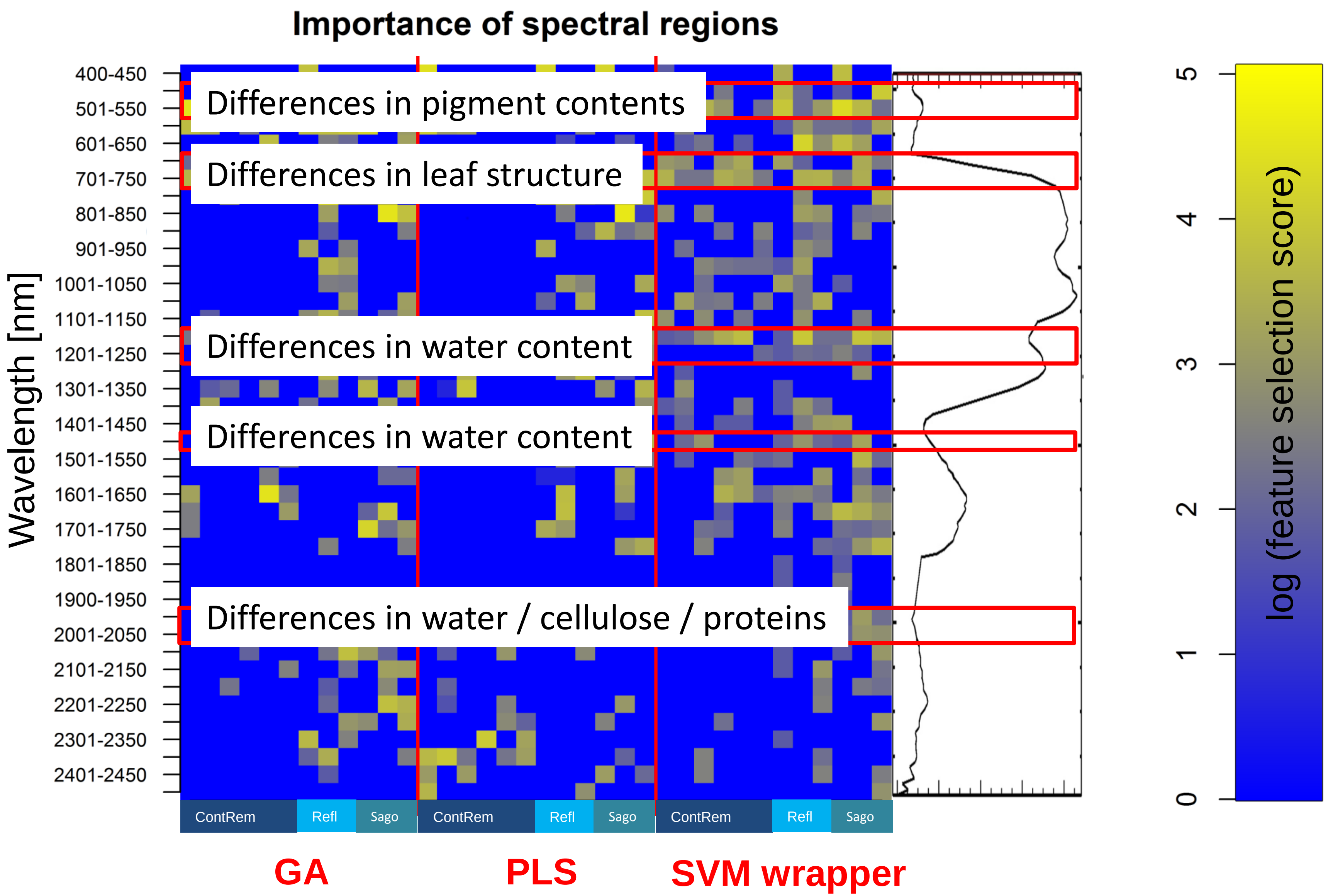
Spectral resolution and range

Spectral Resolution

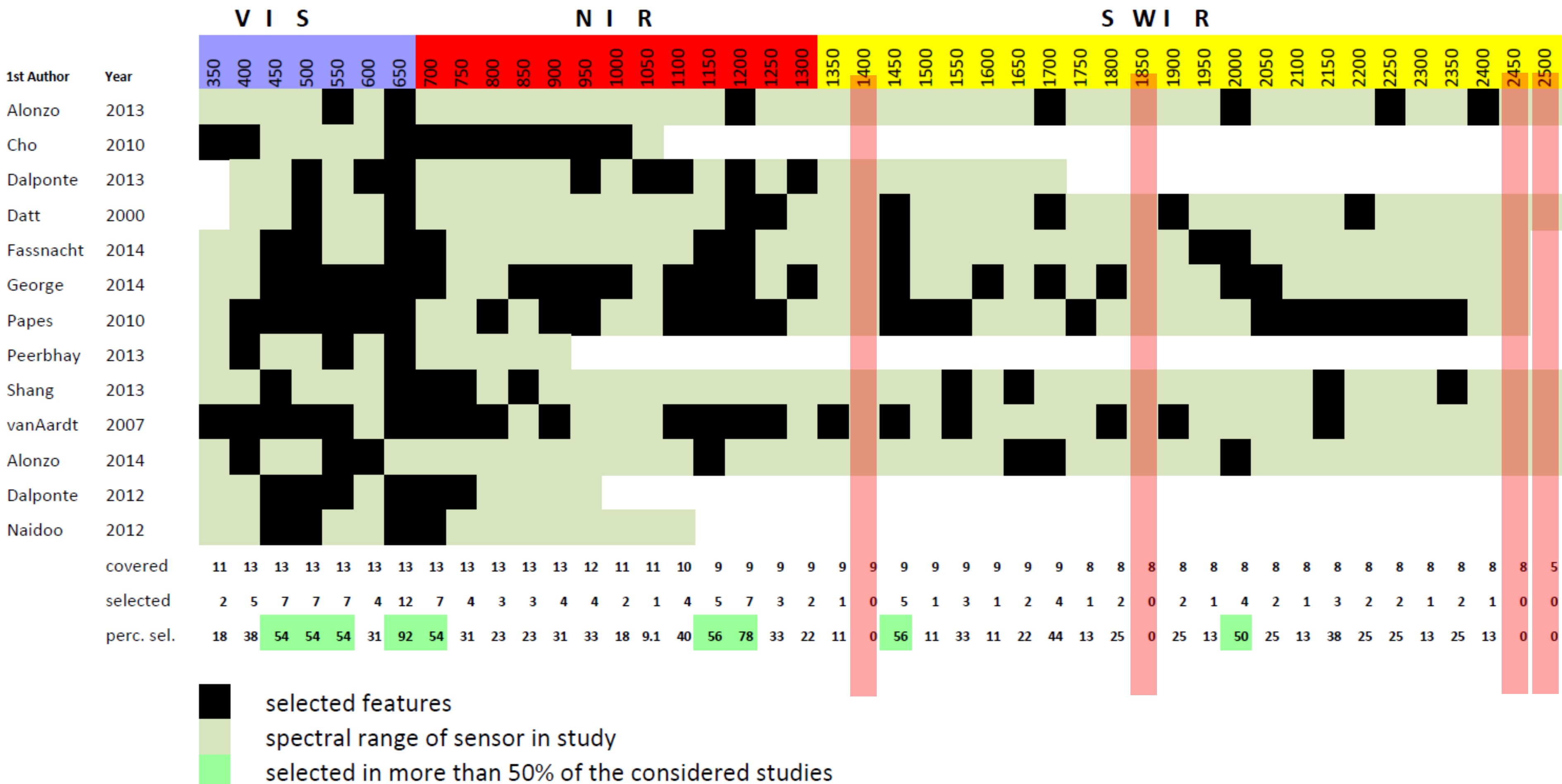
Do we need to cover the full VIS-SWIR region?

How narrow should the bands be?

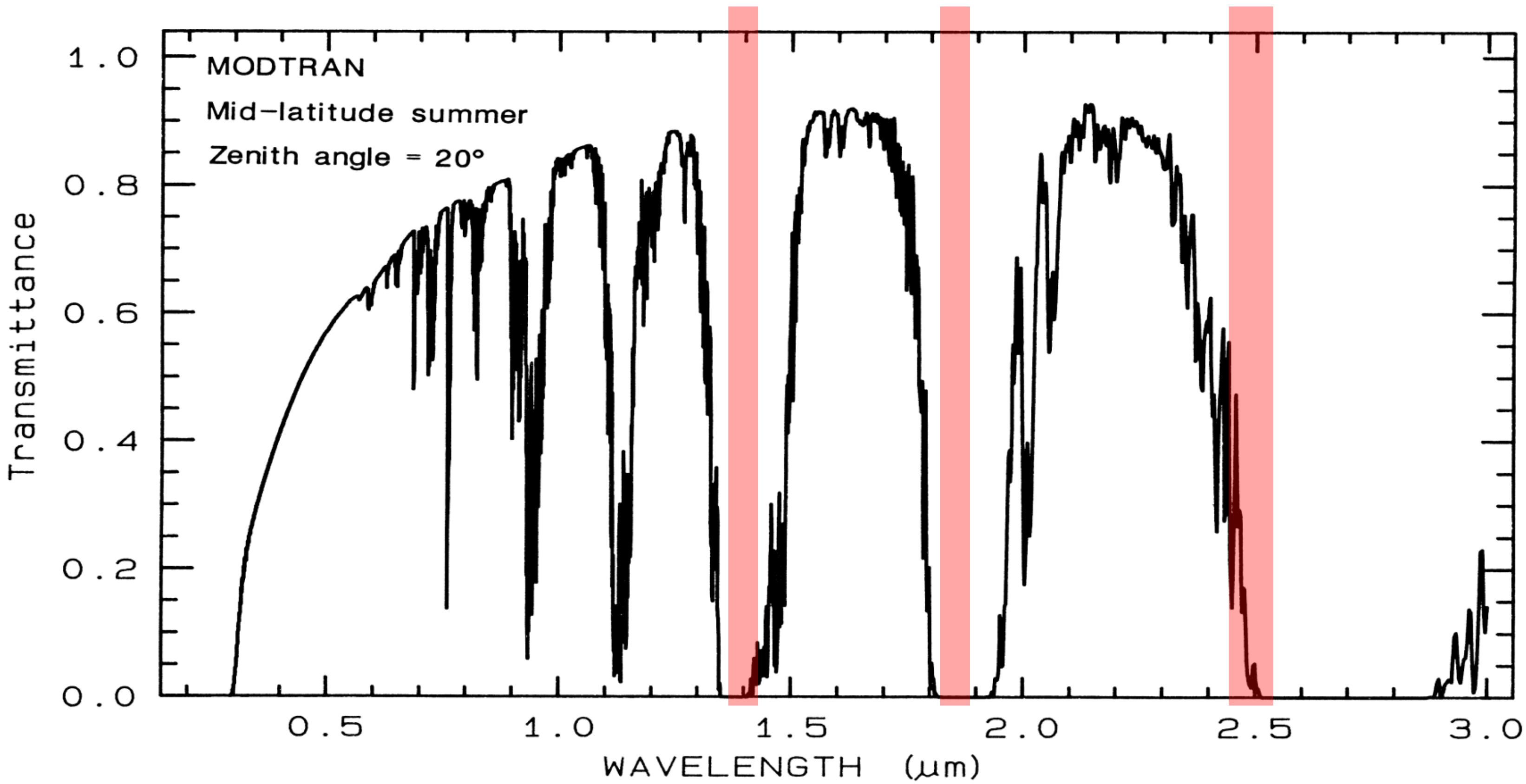
How to deal with spectral resolution in an operational approach?



Fassnacht, F. E. et al. (2014): Comparison of Feature Reduction Algorithms for Classifying Tree Species With Hyperspectral Data on Three Central European Test Sites. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (J-STARS) 7(6), pp. 2547–2561.



Summary of important wavelength regions as identified by 13 studies making use of hyperspectral data and feature selection approaches. Covered = number of studies that covered the wavelength region; selected = number of studies that selected the wavelength region as being relevant for tree species discrimination.



http://speclab.cr.usgs.gov/PAPERS.refl-mrs/giff/300dpi/fig3a3.gif

Spectral Resolution

Do we need to cover the full VIS-SWIR region?

Based on the studies so far: Yes!

But: some regions are more important than others

➔ optimize processing speed?

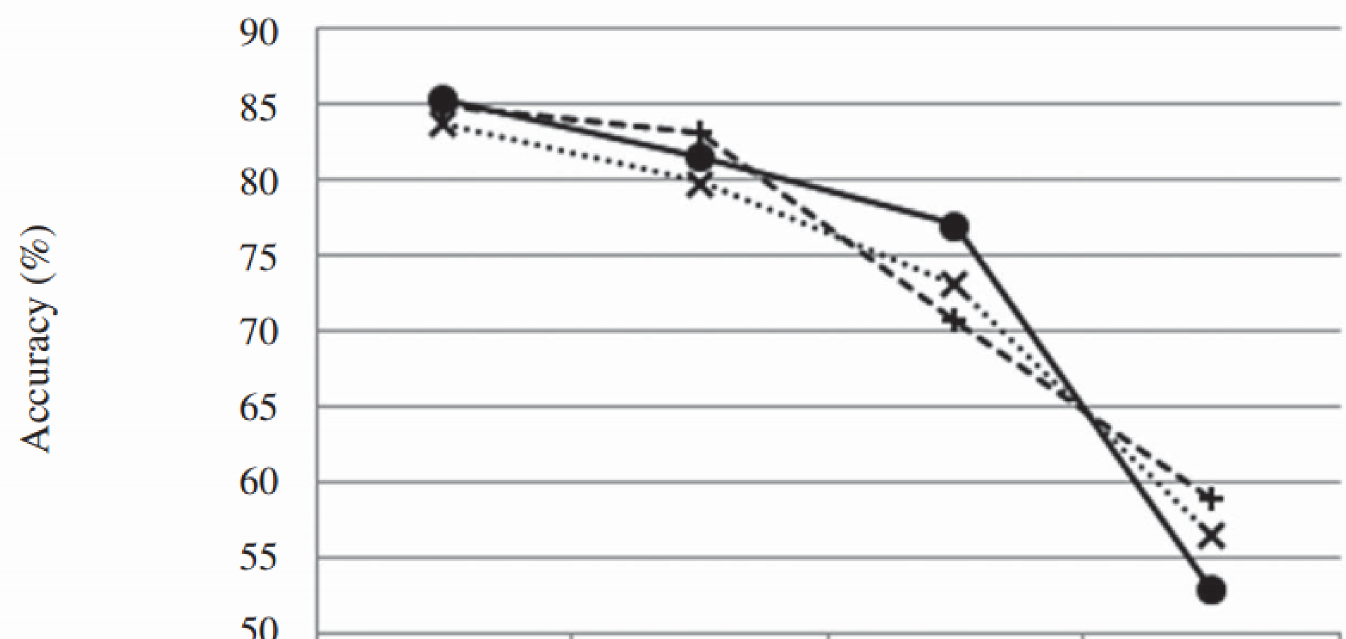
Spectral Resolution

How narrow should the bands be?

Question is connected to processing speed (number of predictors)

Radiometric noise vs. ability to capture subtle absorption features

Hardly any systematic investigation available so far



	0.3 m	0.6 m	1.2 m	2.4 m
160 bands	85.3	81.5	77.0	52.9
79 bands	83.8	79.8	73.1	56.5
39 bands	84.8	83.1	70.7	59.0

Results for SAM classifier applied to noise-reduced image (MNF)

Pena, M.A., Cruz, P. & Roig, M. (2014). The effect of spectral and spatial degradation of hyperspectral imagery for the Sclerophyll tree species classification. Int. J. of Rem. Sens., 34(20), 7113-7130.

Spectral Resolution

How narrow should the bands be?

“Gut feeling / hypothesis”:

A sensor with 100-150 narrow bands (VIS-SWIR) should do the job

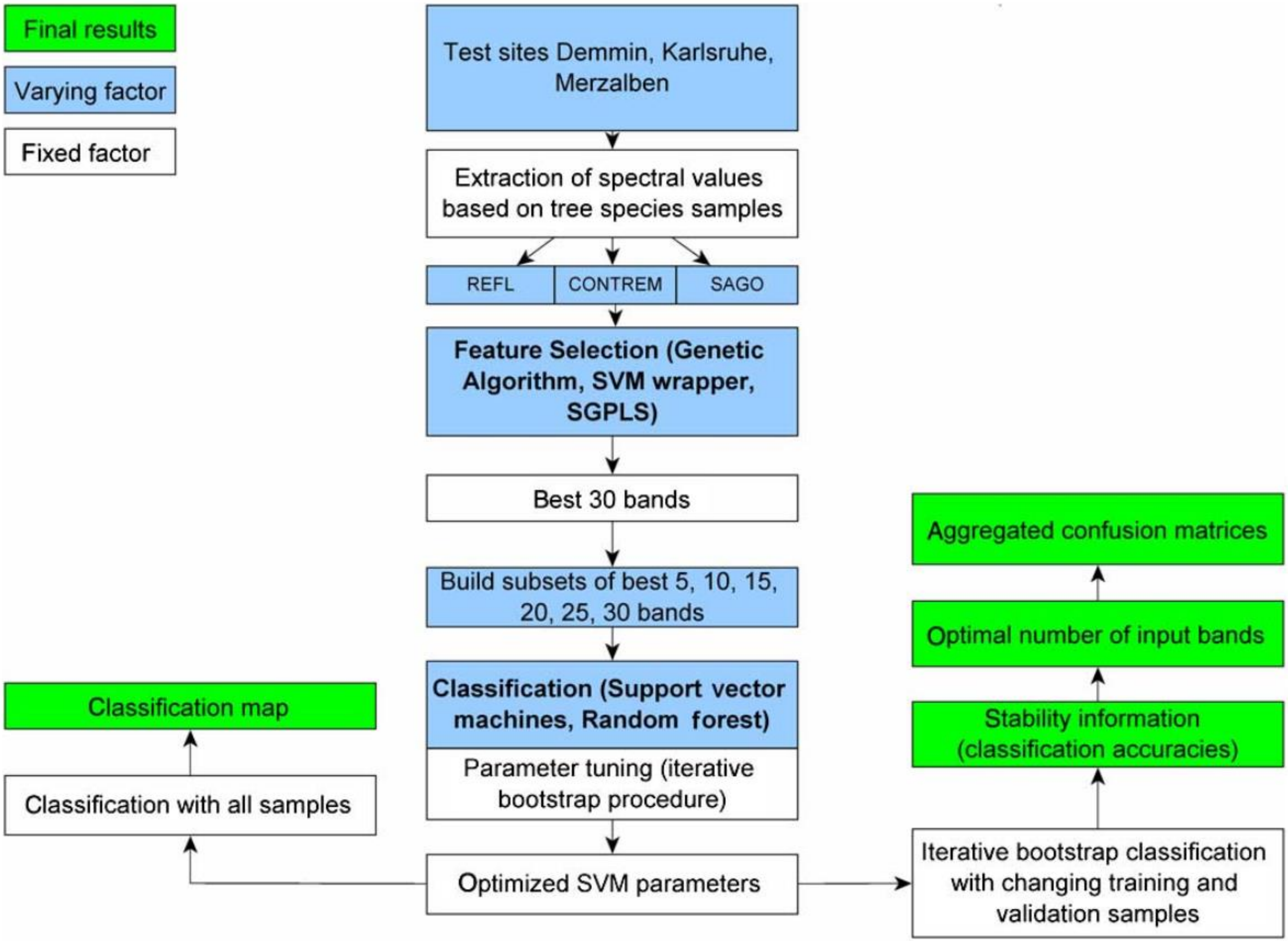
Having very narrow 400 bands won’t add a lot of useful information in a classification problem (co-linearity)

Spectral Resolution

How to deal with spectral resolution in an operational approach?

Experiences from a case study conducted over three test sites in Germany

Characteristics		Site 1 (Demmin)	Site 2 (Karlsruhe)	Site 3 (Merzalben)
Bio-geographical	General	North of Germany, shows properties of a riparian forest; flat terrain	Relatively warm climate due to the influence of the Upper-Rhine; more continental than typical German conditions; flat terrain	Typical low mountain range; relative humid and cool climate; mountainous terrain
	Dominant tree species	Black Alder (*Alnus, glutinosa*); Willow , (*Salix caprea*), Birch , (*Betula pendula*), Ash (*Fraxinus excelsior*), European Beech (*Fagus , sylvatica*), Norway Spruce (*Picea Abies* (L.) Karst)	Scots Pine (*Pinus sylvestris*), European Beech Sessile Oak (*Quercus petreae*), Pedunculate Oak (*Quercus robur*), Douglas Fir (*Pseudo-tsuga menziesii*), Norway, Spruce, Larch (*Larix sp.*)	European Beech, Sessile Oak, Pedunculate Oak, Scots Pine Norway Spruce, Douglas Fir, Larch (small occurrences)
Hyper-spectral dataset	Sensor; (spectral range); date	AISA Eagle & Hawk; (400–2450 nm); 29/06/2011	HyMap; (450–2480 nm); 20/08/2010 (Cocks et al. ([43]))	HyMap; (450–2480 nm); 05/08/2009
	Pixel size	3 m	4 m	5 m
	Processing level	Destriped and atmospherically and geographically corrected by the GFZ using ATCOR4 software	Atmospherically and topographically corrected by DLR using ATCOR4 and ORTHO software	Atmospherically and topographically corrected by DLR using ATCOR 4 and ORTHO software


Final results
Varying factor
Fixed factor
Test sites Demmin, Karlsruhe, Merzalben
Extraction of spectral values based on tree species samples
REFL
CONTREM
SAGO
Feature Selection (Genetic Algorithm, SVM wrapper, SGPLS)
Best 30 bands
Build subsets of best 5, 10, 15, 20, 25, 30 bands
Classification (Support vector machines, Random forest)
Parameter tuning (iterative bootstrap procedure)
Optimized SVM parameters
Classification with all samples
Classification map
Iterative bootstrap classification with changing training and validation samples
Stability information (classification accuracies)
Optimal number of input bands
Aggregated confusion matrices

	PLS feature selection	SVM wrapper	Genetic Algorithm	Reference all bands	Reference MNF
Demmin					
Input dataset	REFL	CONTREM	CONTREM		MNF
Classifier	SVM	SVM	SVM	SVM	SVM
Nr. of bands	20	15	20	125	20
Min.	0.650	0.750	0.723	0.729	0.848
Median	0.729	**0 .816**	0.802	0.798	**0.910**
Max.	0.807	0.891	0.875	0.862	0.923
Karlsruhe					
Input dataset	SAGO	CONTREM	SAGO		MNF
Classifier	SVM	SVM	SVM	SVM	SVM
Nr. of bands	20	20	20	125	10
Min.	0.710	0.725	0.726	0.680	0.924
Median	0.806	0.817	**0.826**	0.783	**0.960**
Max.	0.889	0.886	0.916	0.875	1.0
Merzalben					
Input dataset	CONTREM	SAGO	SAGO		MNF
Classifier	RF	SVM	SVM	SVM	RF
Nr. of bands	25	15	15	125	10
Min.	0.365	0.441	0.396	0.375	0.507
Median	0.513	**0.559**	0.528	0.510	**0.629**
Max.	0.629	0.675	0.678	0.623	0.724

Spectral Resolution

How to deal with spectral resolution in an operational approach?

All bands → MNF (feature extraction) → Classification

By far best approach on all three test sites

Reduced set of predictors but almost all information is preserved

Spectral Resolution

Scale

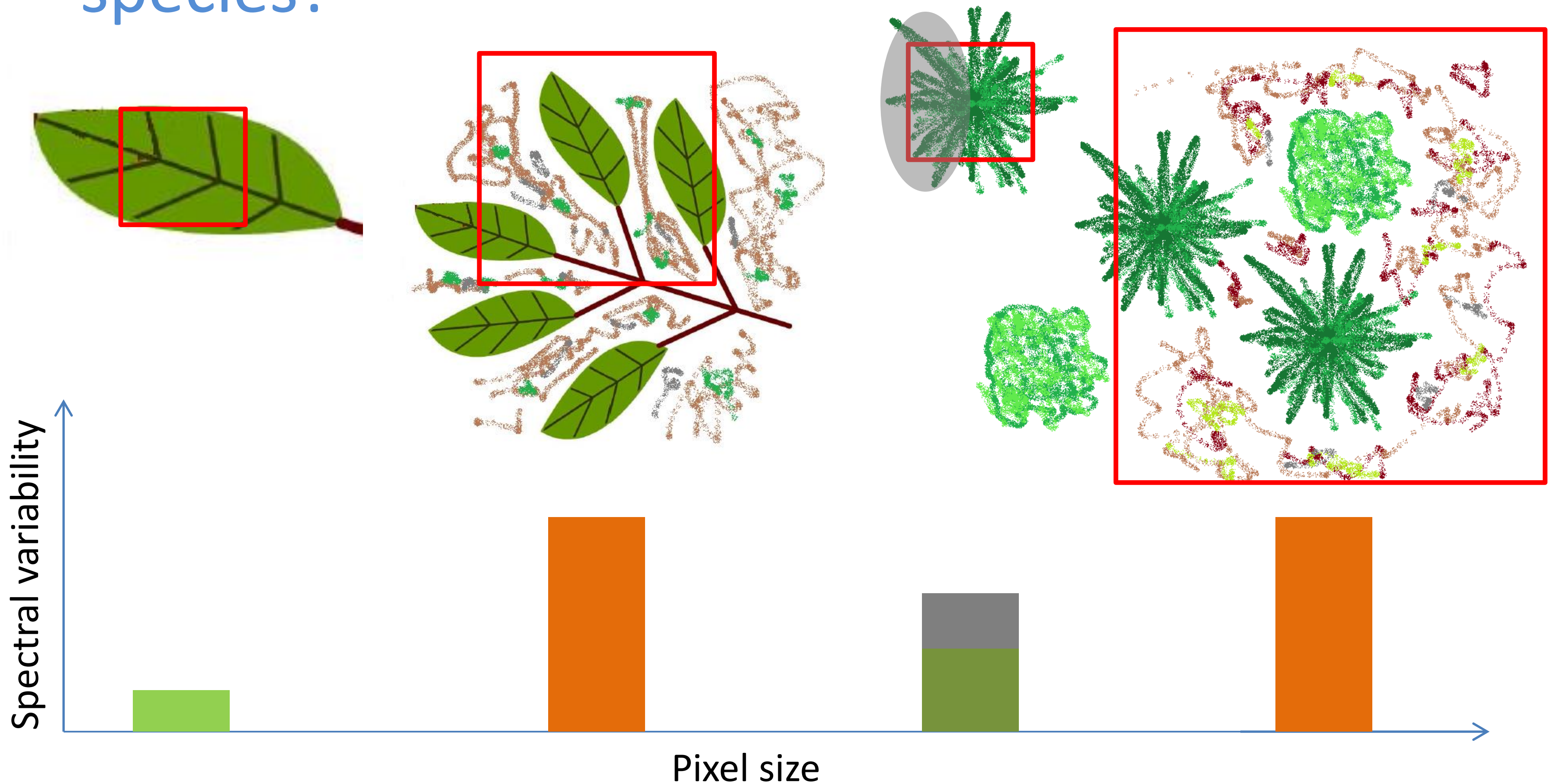
Spectral Resolution

What is the optimal pixel size for classifying tree species?

Was is the optimal spatial unit to obtain species information?

Spectral Resolution

What is the optimal pixel size for classifying tree species?



What is the optimal pixel size for classifying tree species?

Experiences from case studies (I)

Sensor	Classifier	Num. of Features	OA (%)	K
Hyspex VNIR 1600	SVM	160	92.6	0.869
		52	**92.8**	**0.873**
	RF	160	89.7	0.816
		52	90.1	0.823
	GML	160	-	-
		52	87.0	0.777
Hyspex SWIR 320i	SVM	130	**81.7**	**0.680**
		42	80.9	0.665
	RF	130	75.9	0.571
		42	77.0	0.590
	GML	130	-	-
		42	67.3	0.398
Hyspex VNIR 1600 + Hyspex SWIR 320i	SVM	290	**92.4**	**0.867**
		64	91.8	0.855
	RF	290	87.9	0.785
		64	82.5	0.687
	GML	290	-	-
		64	83.5	0.703

0.4 m Pixel Size <-

OA (%)	K
78.0	**0.604**
77.3	0.590
75.7	0.564
73.6	0.523
-	-
-	-
63.3	0.341
65.4	0.377
65.0	0.378
65.4	**0.390**
-	-
56.4	0.223
77.0	**0.589**
75.5	0.560
74.8	0.555
71.5	0.497
-	-
-	-

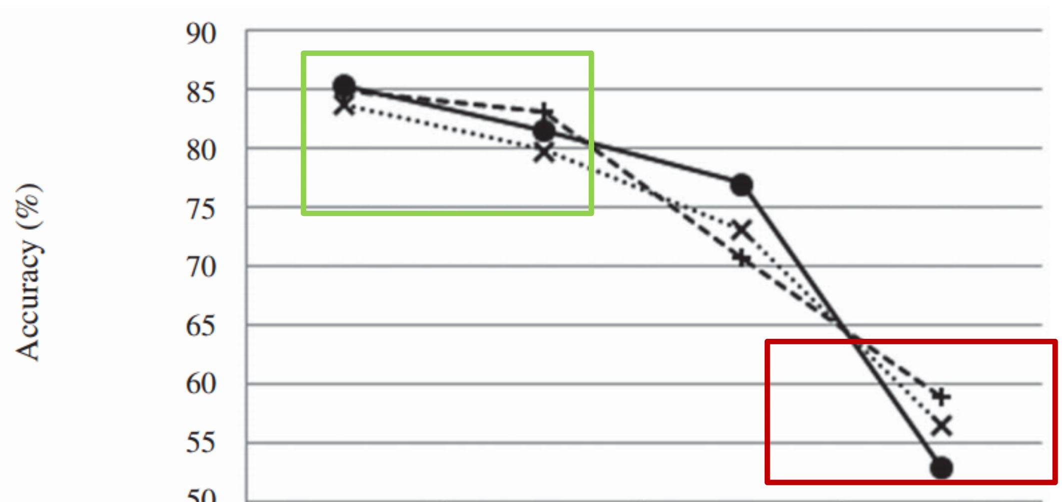
1.5 m Pixel Size <-

Dalponte et al. (2013). Tree Species Classification in Boreal Forests With Hyperspectral Data. IEEE Trans. On GeoSc. And Rem. Sens., 51(5), 2632-2645.

Spectral Resolution

What is the optimal pixel size for classifying tree species?

Experiences from case studies (II)



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Spectral Resolution

What is the optimal pixel size for classifying tree species?

Experiences from case studies (III)

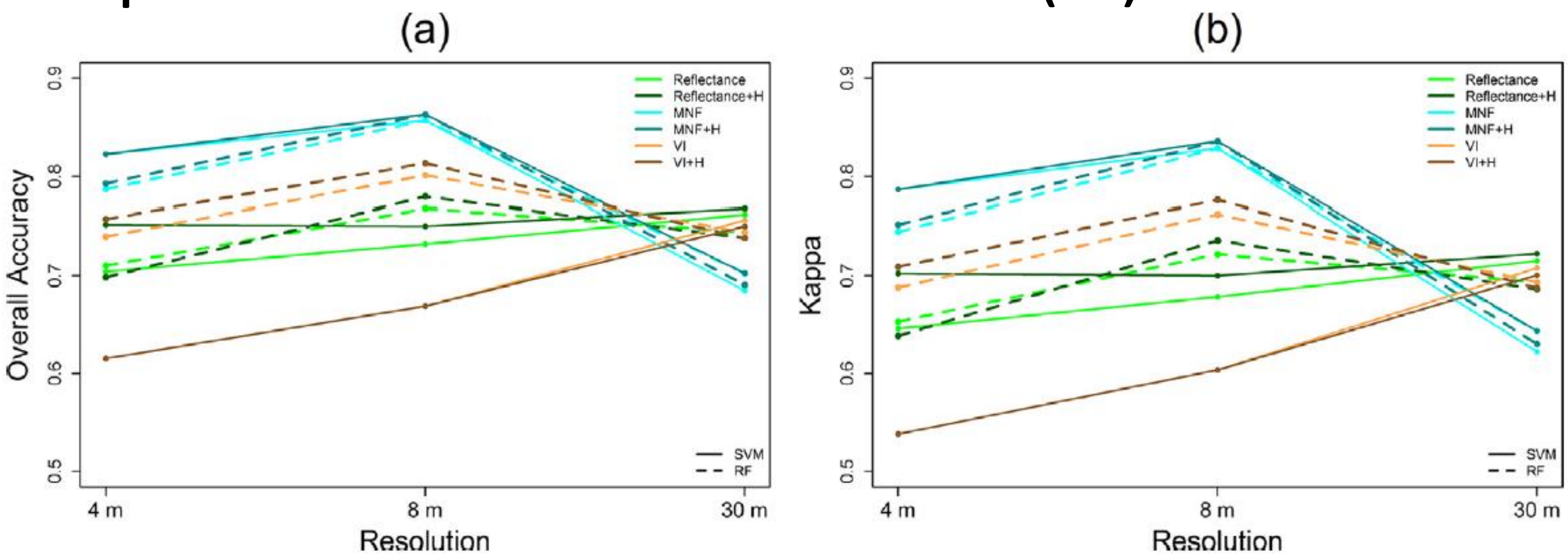
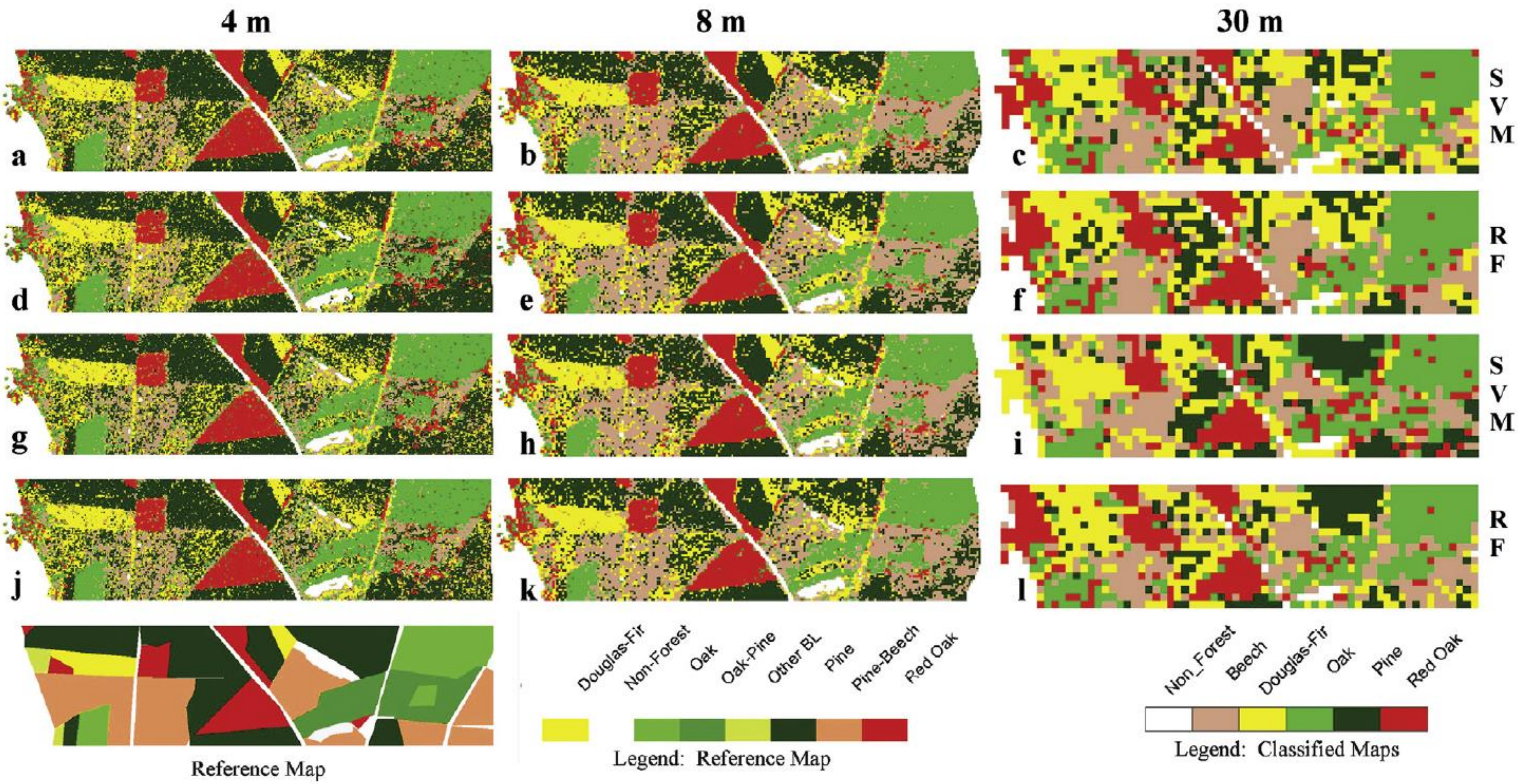


Fig. 6. Behavior of (a) OA and (b) kappa against the spatial resolution for all predictor layers and classifiers.

Ghosh, A., Fassnacht, F. E. et al. (2014). A framework for mapping tree species combining hyperspectral and LiDAR data: Role of selected classifiers and sensor across three spatial scales. *Int. J. of Appl. Earth Obs. and Geoinf.*, *26*, 49–63.



Tree species maps obtained with MNF (and MNF + H) as predictor layer.

Ghosh, A., Fassnacht, F. E. et al. (2014). A framework for mapping tree species combining hyperspectral and LiDAR data: Role of selected classifiers and sensor across three spatial scales. *Int. J. of Appl. Earth Obs. and Geoinf.*, *26*, 49–63.

Spectral Resolution

What is the optimal pixel size for classifying tree species?

Case studies suggest:

Either possibly small pixels (< 0.5 m)

Or: pixels close to the size of an individual crown

BUT: So far the spatial unit was a pixel!

Spectral Resolution

Was is the optimal spatial unit to obtain species information?

Three obvious approaches:

(I) Pixel
(II) Single-tree objects
(III) Stands or other operational unit

Was is the optimal spatial unit to obtain species information?

Results from the literature are mixed:

Ørka et al. 2013: Single-tree approach better than area-based approach (combined hyperspectral / ALS datasets).

Clark et al. 2005: Leaf Scale is better than crown level, crown level is better than pixel-level (hyperspectral data – crown level = averaging all pixels of a crown).

Clark et al. 2012: Pixel spectra are better than crown-mean spectra, pixel-majority voting is better than pixel spectra (hyperspectral data).

Hans Ole Ørka, Michele Dalponte, Terje Gobakken, Erik Næsset & Liviu Theodor Ene (2013) Characterizing forest species composition using multiple remote sensing data sources and inventory approaches, *Scandinavian Journal of Forest Research*, **2013**, 28:7, 677-688.

Clark, M.L.; Roberts, D.A.; Clark, D.B. Hyperspectral discrimination of tropical rainforest tree species at leaf to crown scales. *Remote Sens. Environ.* **2005**, *96*, 375–398.

Clark, M.L., Roberts, D.A. Species-Level Differences in Hyperspectral Metrics among Tropical Rainforest Trees as Determined by a Tree-Based Classifier, *Remote Sensing*, **2012**, 4, 1820-1855

Was is the optimal spatial unit to obtain species information?

Advantages of object-based approaches (single tree and stand-level) in case accurate objects can be obtained:

- Meaningful units (practitioners work with it)

- Combination of LiDAR and Hyperspectral becomes more powerful:
  - normalization of spectra (sunlit parts of the crowns)
  - Majority voting approaches
  - single-tree based geometric information (crown-base height, canopy transects, crown volume, …)
  - Density information from LiDAR + spectral information from satellites

Spectral Resolution

Was is the optimal spatial unit to obtain species information?

Challenges of object-based approaches (single tree and stand-level):

- The quality of the results largely depends on the delineation success

- Classifications on stand-level-objects have to consider that differing forest densities may lead to very distinct reflectance signals for the identical species composition

Some other points…

Some other points…

Do we need more definitions?

Tree species classification/discrimination
(HAS to be on single-tree level?)

Tree species mapping
(Quite a notable number of paper didn’t present maps!)

Forest composition classification
(HAS to be object-based? What do we actually need? Mixture information? Dominant species?)

Forest composition mapping
(What to put in the map?)

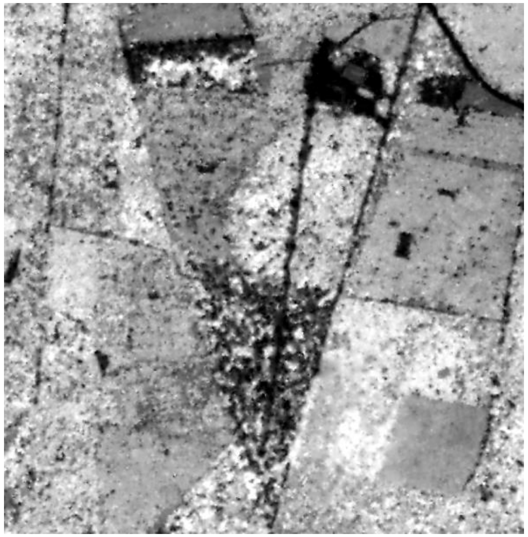
One LiDAR flight is enough…

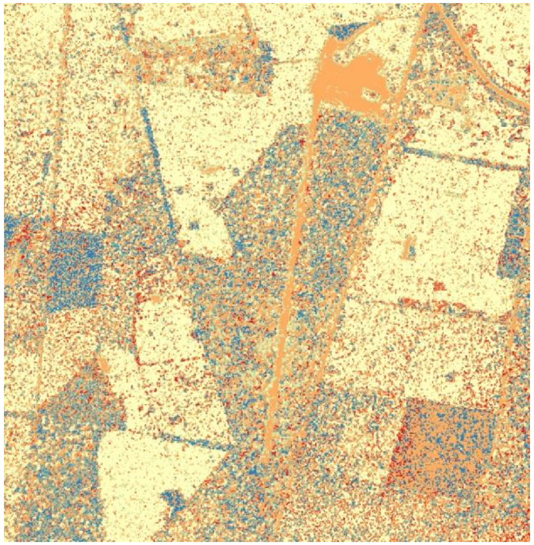
Do we need regular LiDAR/ Hyperspectral flights?
New options with VHR satellite data

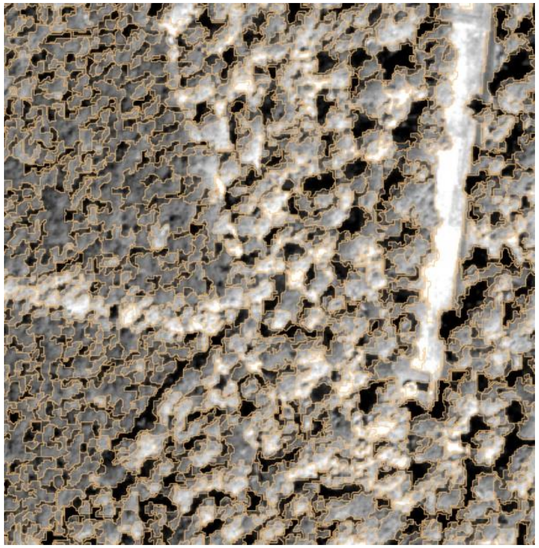
<u>Height (photogrammetry)</u>
=> Proxy for DBH

<u>Tree species</u>
⇒ Species specific Biomass allometry

<u>Forest density</u>
=> Proxy for number of stems / single tree delin.



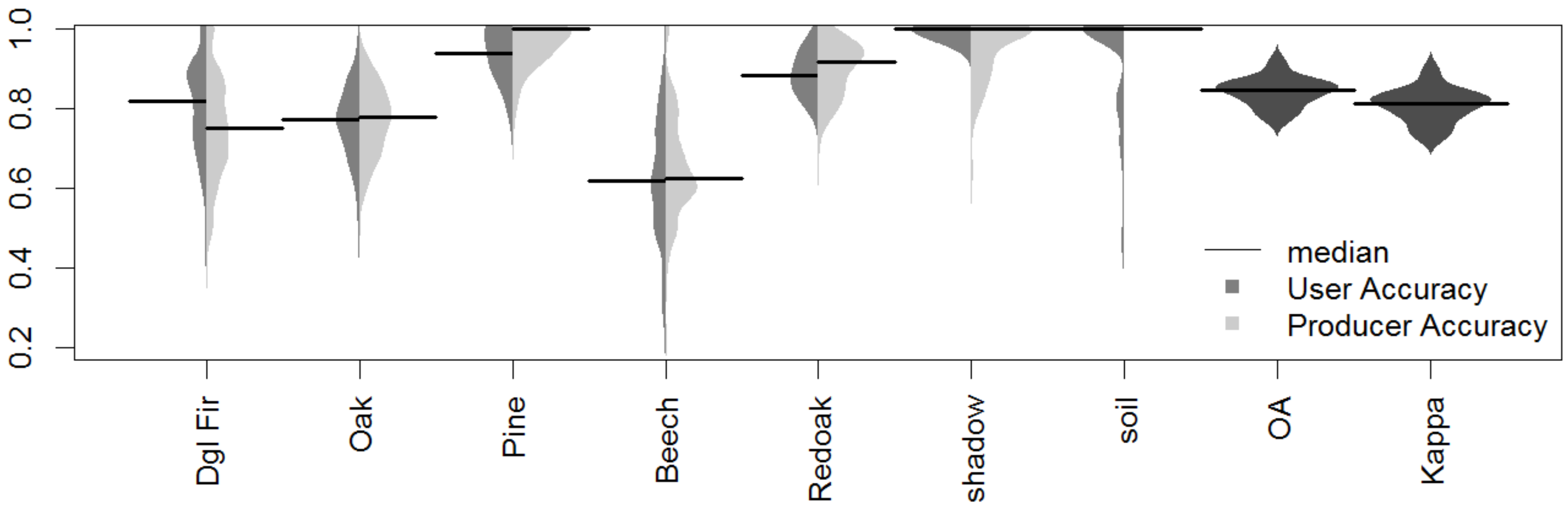




Some other points…

One LiDAR flight is enough…

Do we need LiDAR/ Hyperspectral flights?



Tree Species classification results with WV-2 data (SVM)

Conclusions

Conclusions

Fassnacht, F. E., Latifi, H., Sterenczak, K., Modzelewska, A., Lefsky, M., Waser, L. T., Straub, C., Ghosh, A. (2016): Reviewof studies on tree species classification from remotely sensed data. Remote Sensing of Environment 186, pp. 64–87.

Conclusions

Complete coverage of the VIS-SWIR region is desirable

Operational perspective: Processing speed could be optimized by reducing the number of bands (still not fully clear how).

Questions related to scale have rarely been adressed

Optimal scale still unclear; single-tree-level seems promising, BUT: delineation quality, processing speed, …

References

(first three graphs)

Fassnacht, F. E., Latifi, H., Sterenczak, K., Modzelewska, A., Lefsky, M., Waser, L. T., Straub, C., Ghosh, A. (2016): Reviewof studies on tree species classification from remotely sensed data. Remote Sensing of Environment 186, pp. 64–87.