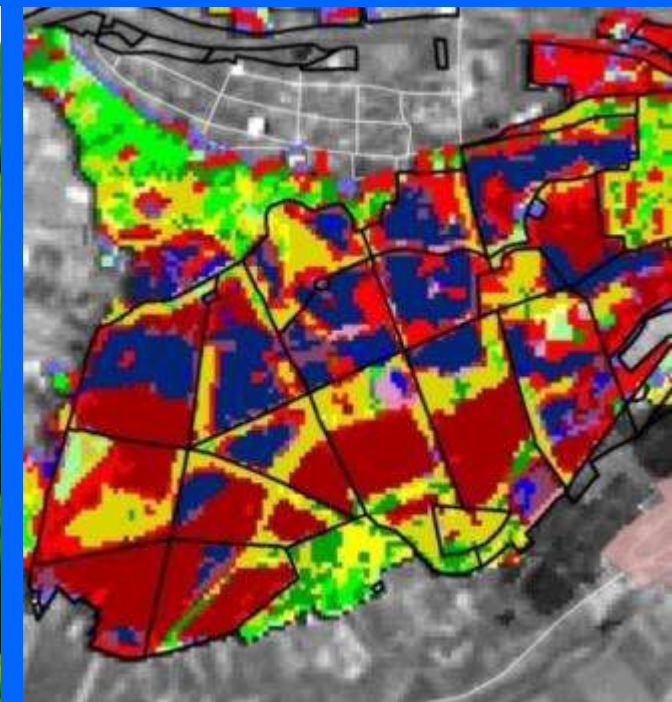




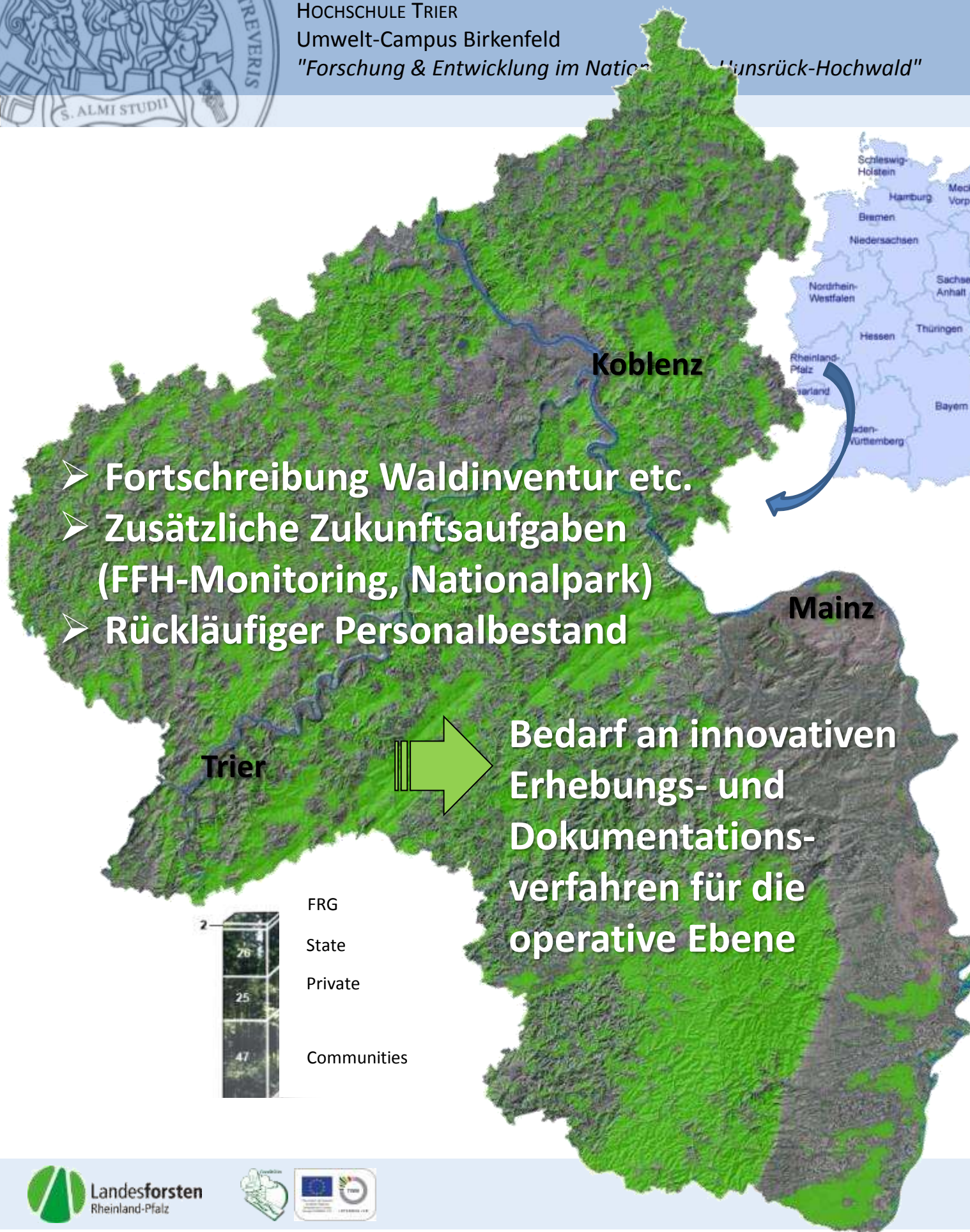
Joachim Hill

Johannes Stoffels, Henning Buddenbaum, Sebastian Mader, Pyare Pueschel,
Sandra Dotzler, David Frantz, Thomas Sachtler, Sascha Nink

Umweltfernerkundung im Nationalpark Hunsrück: zum Monitoring von Baumartenverteilung, Waldstruktur und ökophysiologischen Größen

**Environmental Remote Sensing
and Geoinformatics**

Faculty of Geography and
Environmental Sciences
Trier University - D-54286 TRIER
<http://www.feut.de>



- Fortschreibung Waldinventur etc.
- Zusätzliche Zukunftsaufgaben (FFH-Monitoring, Nationalpark)
- Rückläufiger Personalbestand

Bedarf an innovativen Erhebungs- und Dokumentationsverfahren für die operative Ebene

Rheinland-Pfalz

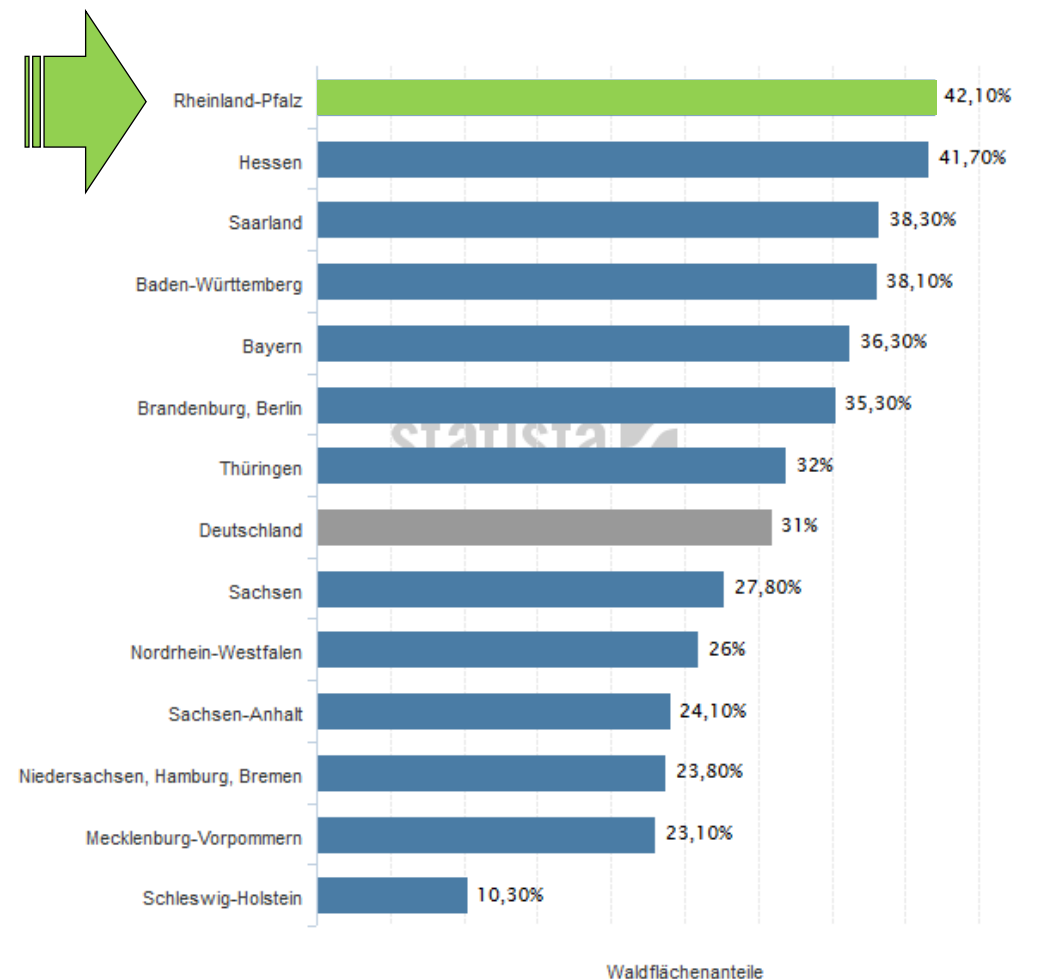
(19,854 km², Bevölkerung 4 Millionen)

42 % der Landesfläche Forst (834.000 ha)

50,000 Beschäftigte

8.500 Private Dienstleister

Jährliche Wertschöpfung ca. 6.5 Mio. Euro



1 Deutschland; 2001 bis 2003

Quelle: BMELV (Bundeswaldinventur)

© Statista 2013

2004

Baumartenkartierung

Holzvorräte

Klimawandel

Waldwachstum

Methoden

Multispektrale
Fernerkundung

OSTEIFEL

F-Auftrag

2006

2008

Laserscanning

RegioWood

Rheinland-
Pfalz

Forstamts-
ebene

Haardt
(Edelkastanie)

ForestClim

2010

Hyperspektrale
Fernerkundung

Trocknis
2003
RLP

Laserscanning

EnMAP

- Waldwachstum
- Ökophysiologie

Ökosystem-
Prozesse

forum-
stat

Small Area
Estimation

2012

Forstamts-
ebene

Sentinel-2 Inventur

Verfügbarkeit
Hyperspektralsensor
Uni Trier

EnMAP-II

Ökosystem-
Prozesse

forum-
stat-II

2015

- Klassifikation
- Holzvorrat
- Prozesskette Sentinel-2/-3

Nationalpark

- Small Area Estimation
- Assimilation
- Klassifikatoren



EnMAP Instrument - Bench Clean Room (KT)

EnMAP
Hyperspectral Imager

September 2011



Remote Sensing Section

GFZ
German Research Centre for Geosciences

EnMAP core science team – development of a spaceborne hyperspectral remote sensing system

Environmental Mapping and Analysis Program



[Home](#) [Mission](#) [Mission elements](#) [Applications](#) [Glossary](#) [Links](#) [Contact](#)

Core Science Team

It is the objective of the EnMAP Core Science Team (ECST) to support the communication with the wider science community of EnMAP and to ensure scientific state of the art data exploitation. In this context the ECST shall be dedicated to the strategic planning and management of scientific algorithm and application development outside the ground processing.

Agriculture

Prof. Dr. Wolfram Mauser (Member)
Ludwig-Maximilian-University München
w.mauser[at]iggf.geo.uni-muenchen.de

Coastal and Inland Waters

Dr. Roland Doerffer (Member)
GKSS Research Centre
roland.doerffer[at]gkss.de

Ecosystems and gradual transitions

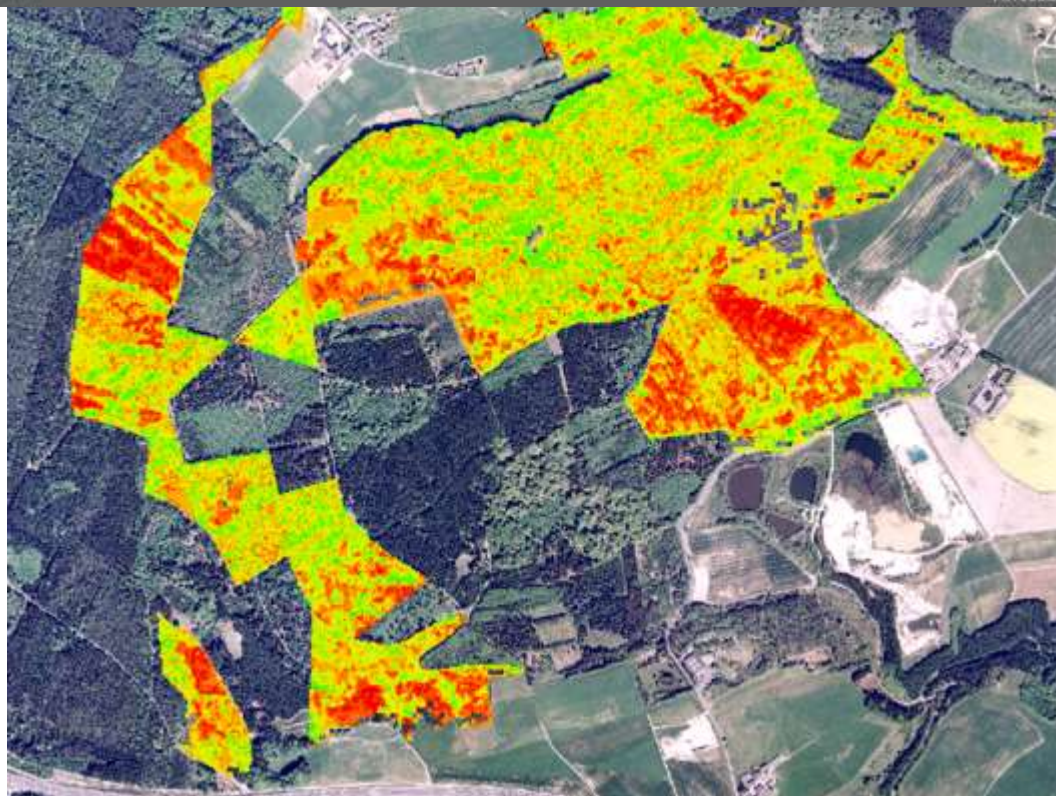
Prof. Dr. Patrick Hostert (Member)
Humboldt-University Berlin
patrick.hostert[at]geo.hu-berlin.de

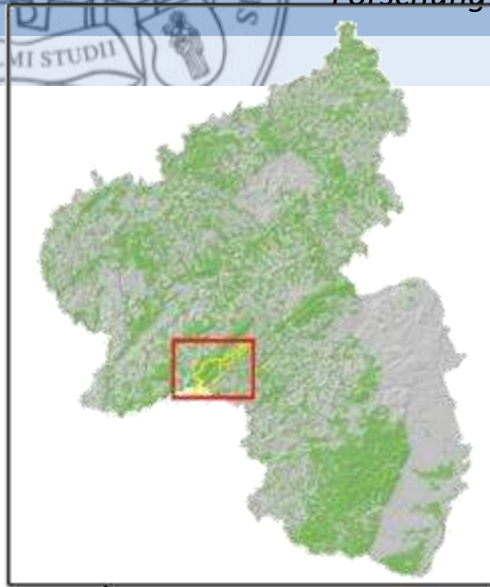
Forest and Vegetation

Prof. Dr. Joachim Hill (Member)
University of Trier
hill[at]uni-trier.de

Geology and Soil Science

Prof. Dr. Hermann Kaufmann (Principle Investigator and Chair)
GFZ German Research Centre for Geosciences
charly[at]gfg-potsdam.de





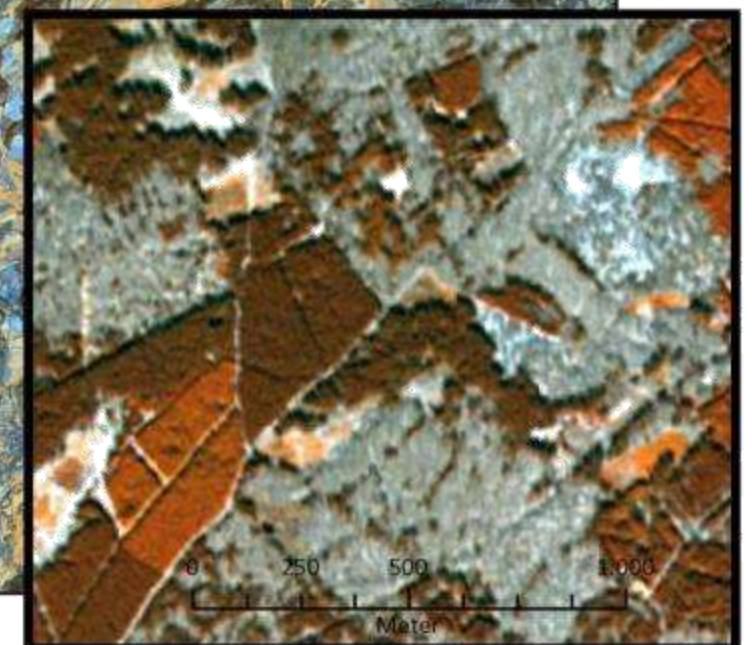
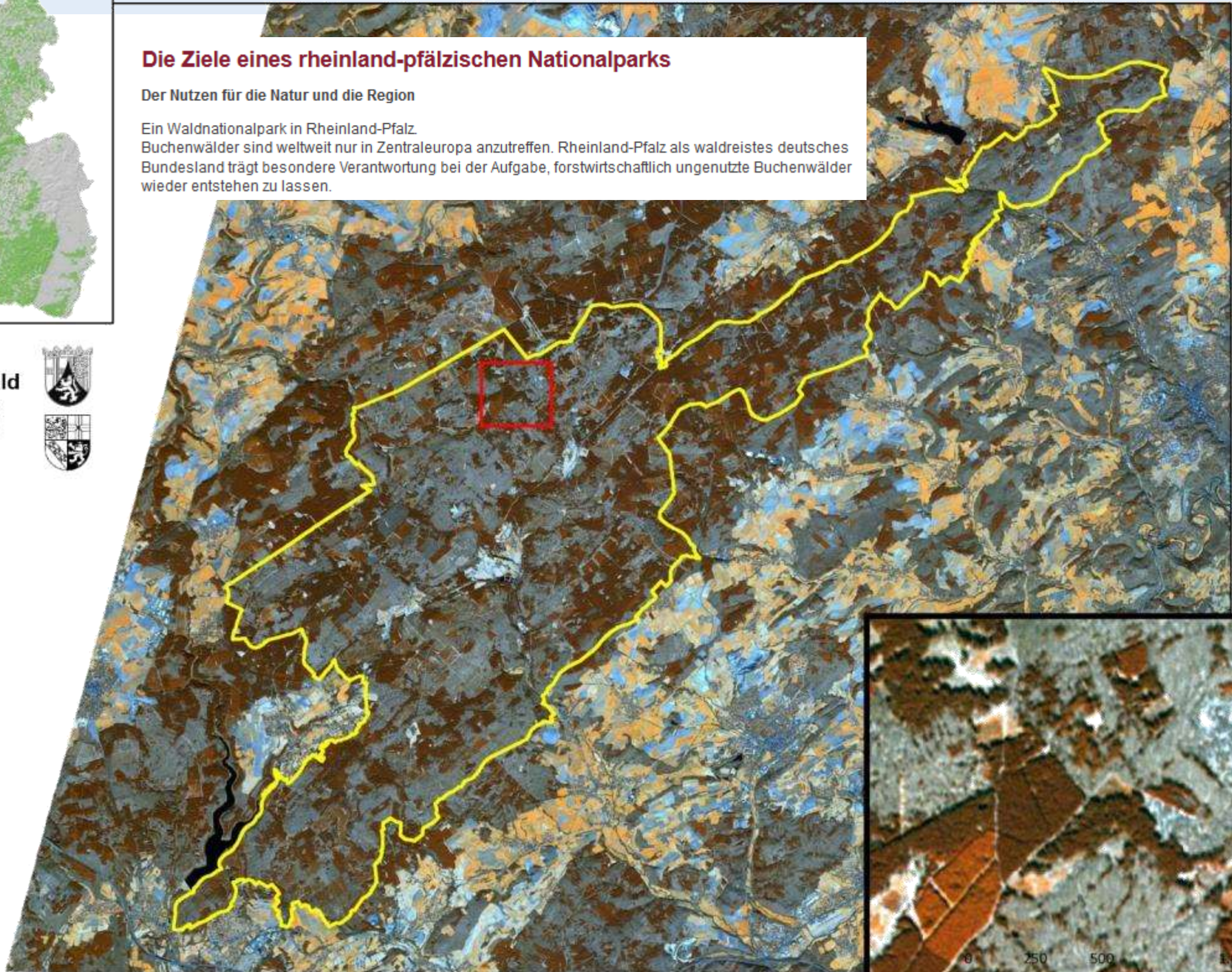
**Nationalpark
Hunsrück-Hochwald
in Rheinland-Pfalz
und dem Saarland**

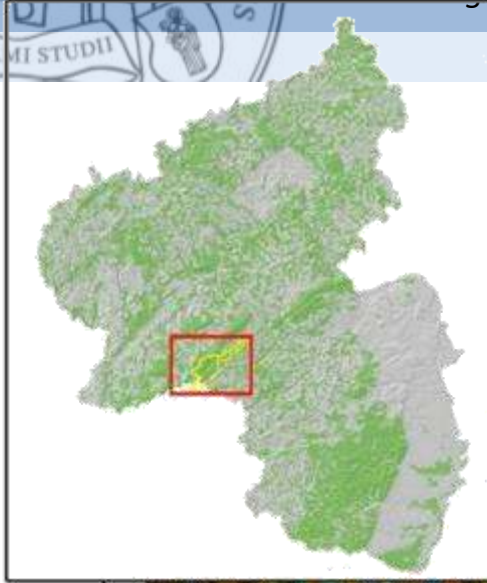


Die Ziele eines rheinland-pfälzischen Nationalparks

Der Nutzen für die Natur und die Region

Ein Waldnationalpark in Rheinland-Pfalz.
Buchenwälder sind weltweit nur in Zentraleuropa anzutreffen. Rheinland-Pfalz als walddreistes deutsches Bundesland trägt besondere Verantwortung bei der Aufgabe, forstwirtschaftlich ungenutzte Buchenwälder wieder entstehen zu lassen.





Nationalpark
Hunsrück-Hochwald
in Rheinland-Pfalz
und dem Saarland



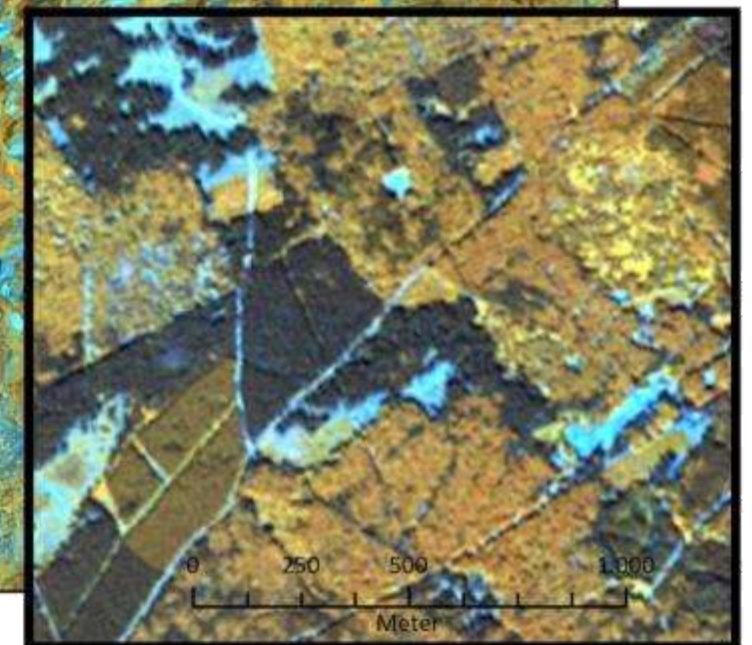
Die Ziele eines rheinland-pfälzischen Nationalparks

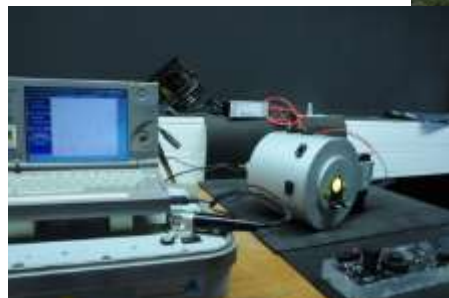
Der Nutzen für die Natur und die Region

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Buchenwälder sind weltweit nur in Zentraleuropa anzutreffen. Rheinland-Pfalz als walдреistes deutsches Bundesland trägt besondere Verantwortung bei der Aufgabe, forstwirtschaftlich ungenutzte Buchenwälder wieder entstehen zu lassen.

- *Veränderung der Baumartenverteilung*
- *Regionaler Klimawandel/Standortsensitivität*
- *Waldstrukturen (Lebensraumtypen, Natura2000)*
- *Renaturierung, Biodiversität*
- *Kalamitäten (Borkenkäfer)*



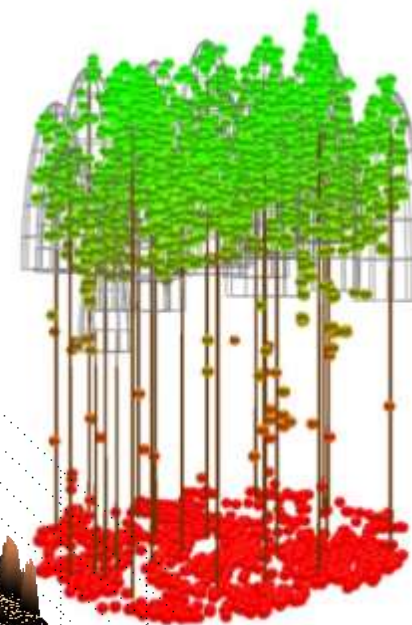
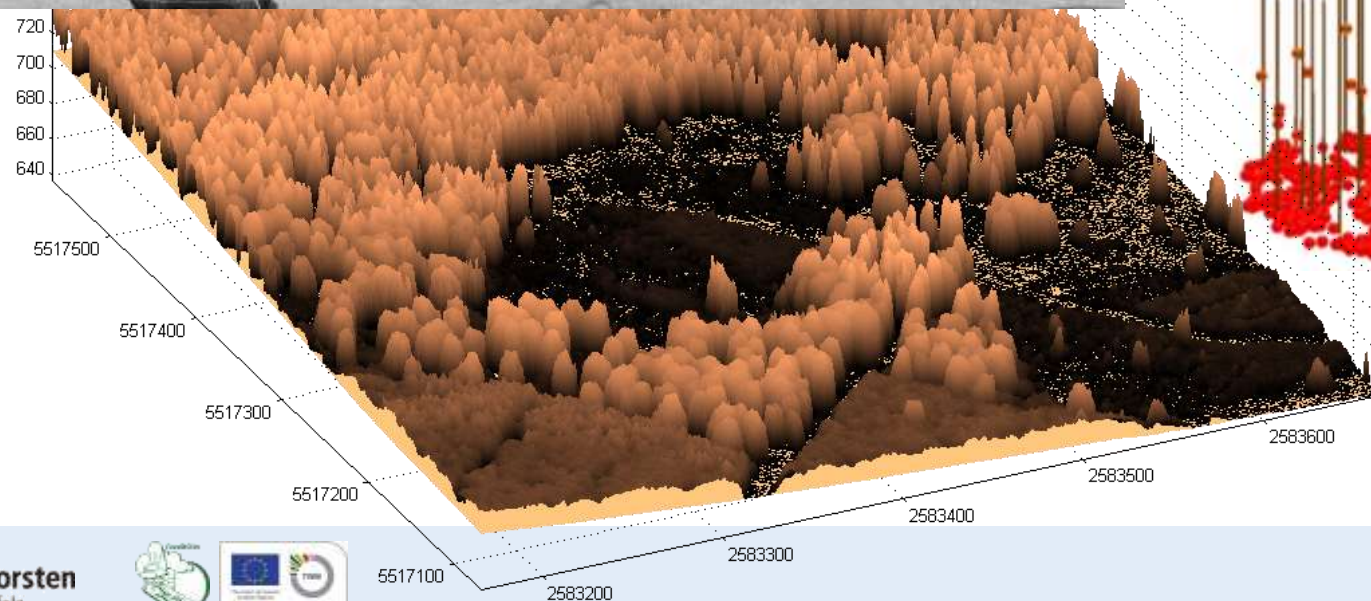


Terrestrisches Laserscanning

03.04.2014



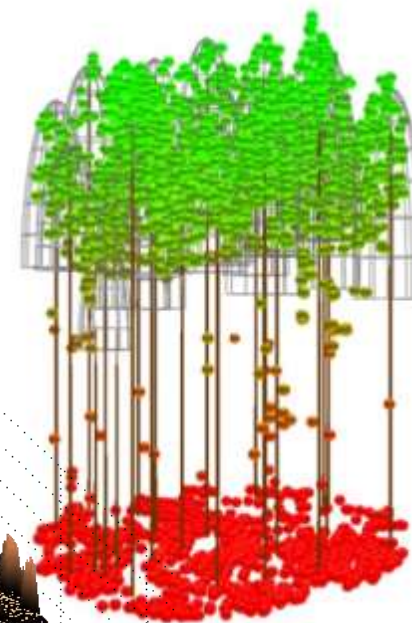
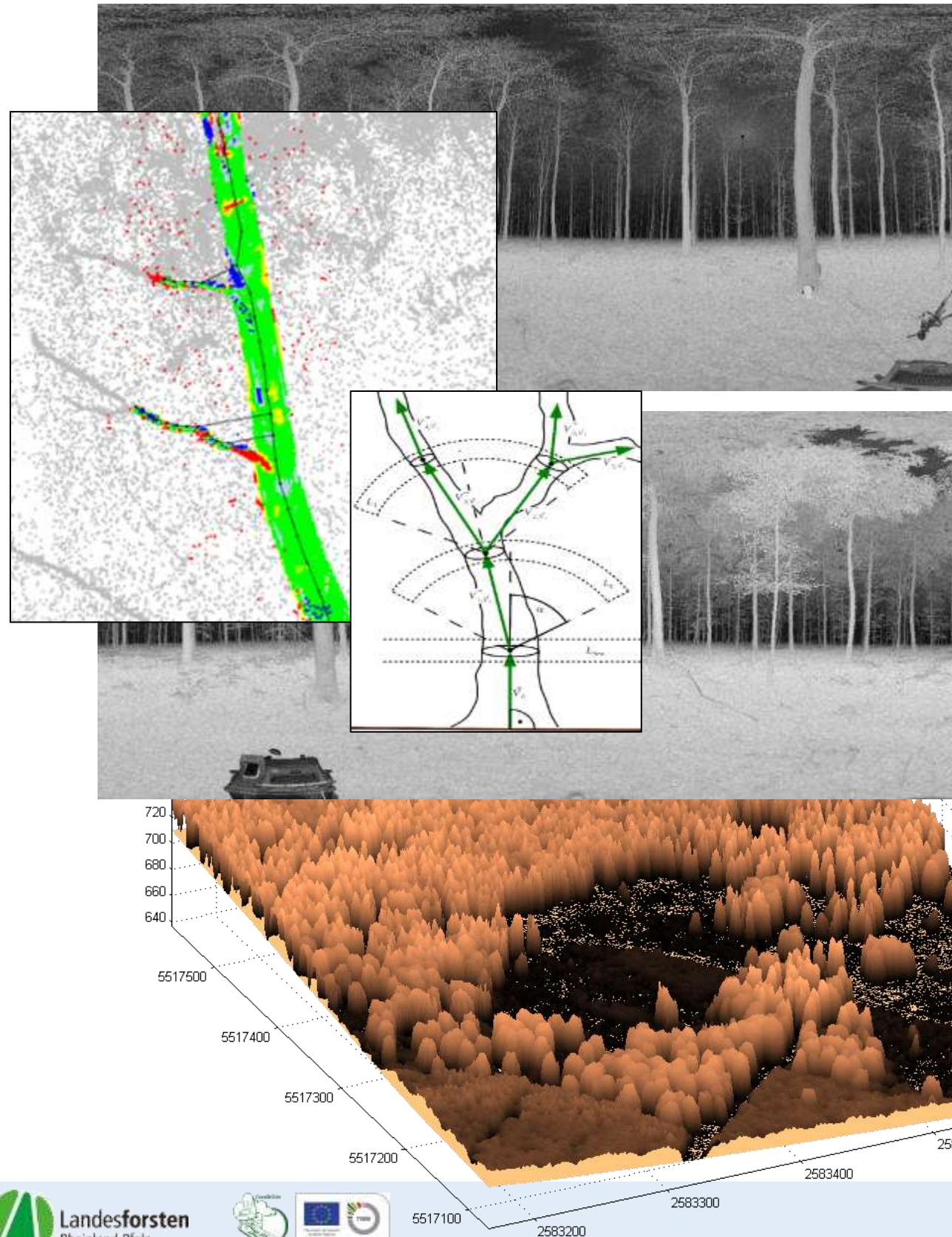
11.06.2014



Terrestrisches Laserscanning

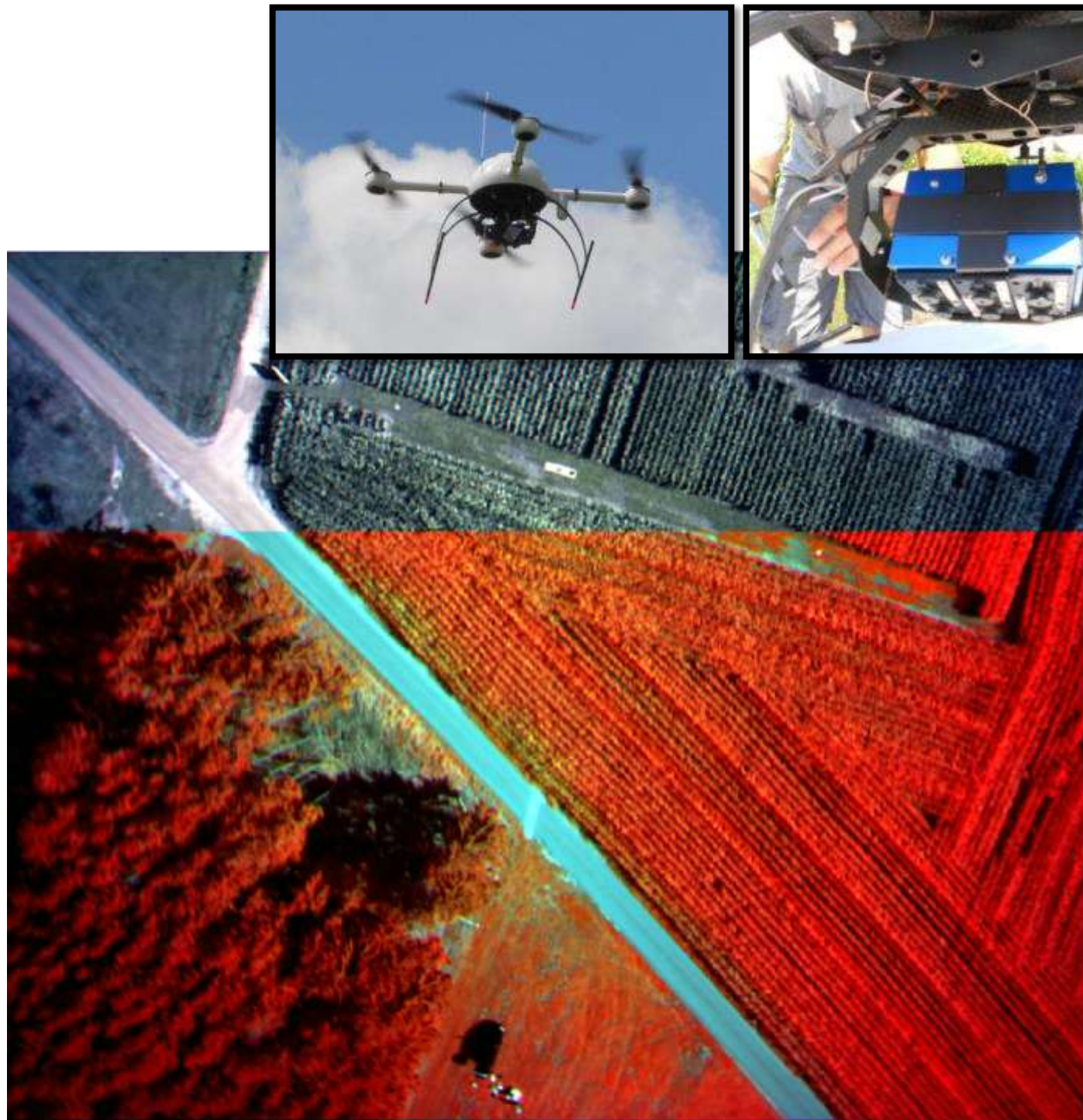
03.04.2014

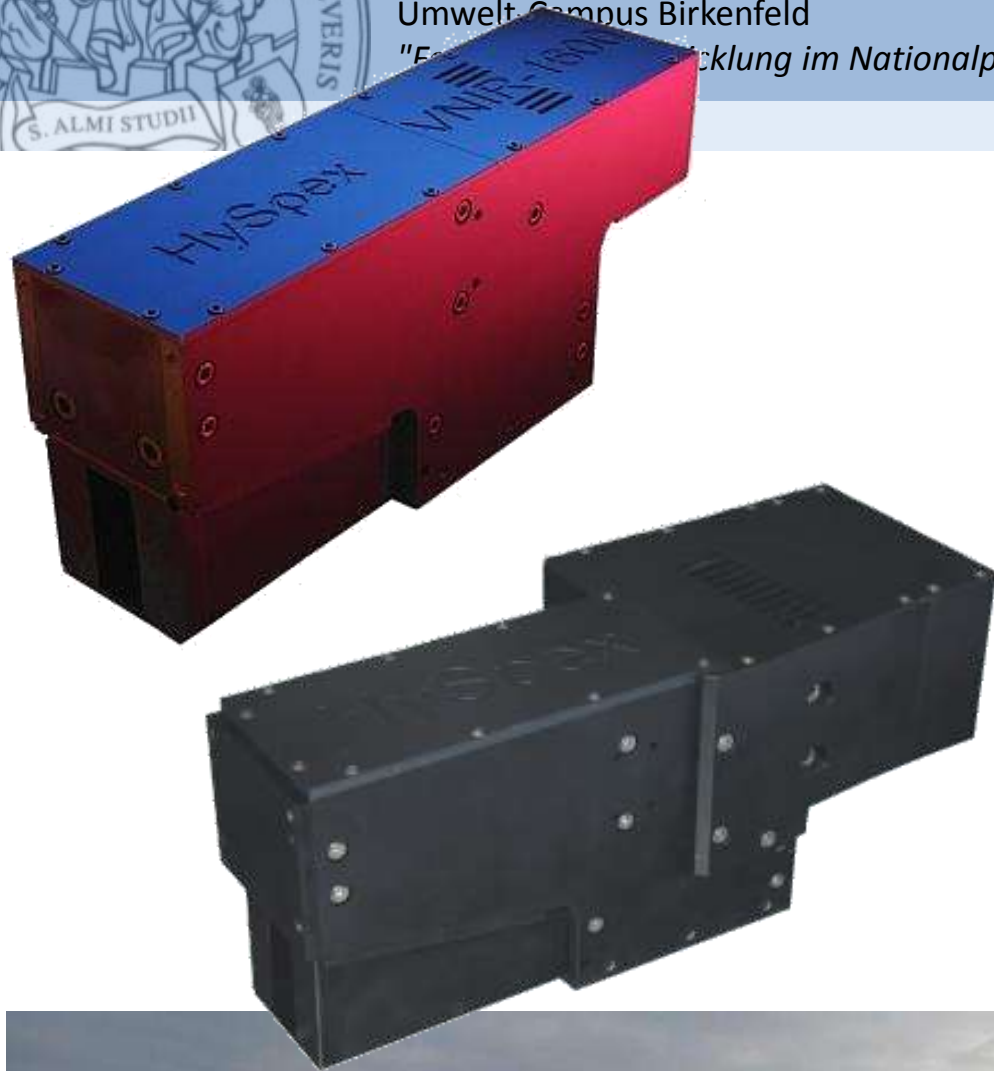
11.06.2014





Drohnen (UAVs)





HySpex VNIR-1600 und SWIR-320m-e

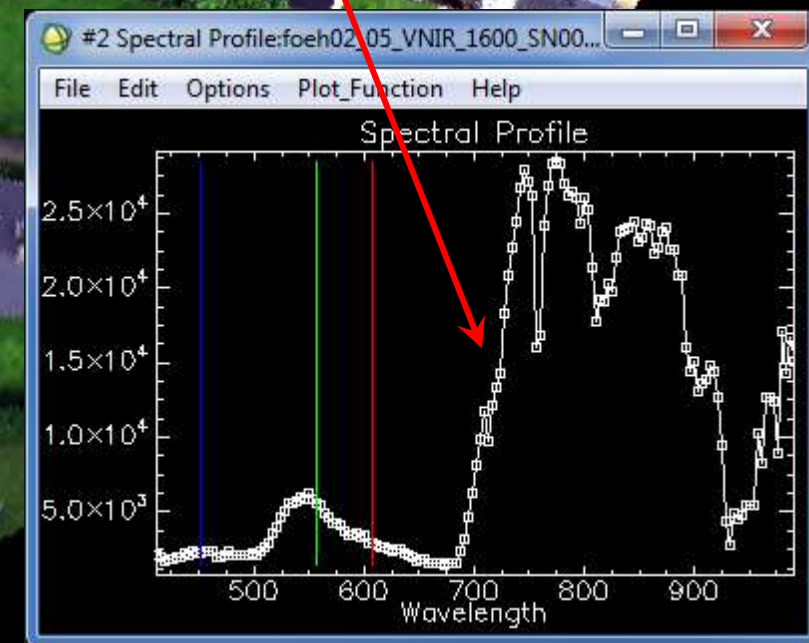
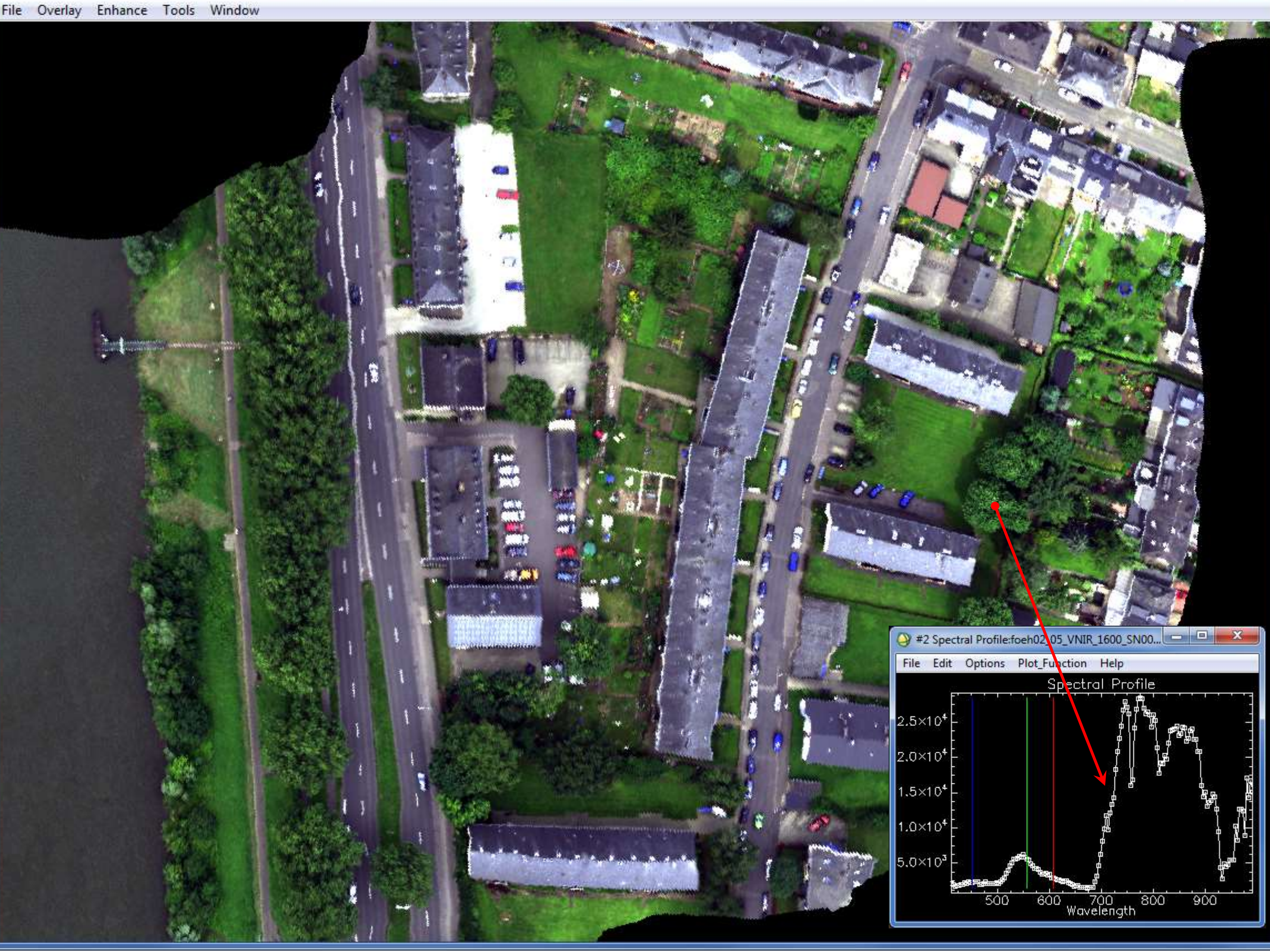
	VNIR	SWIR
Detector	SSi CCD 1600 x 1200 px	HgCdTe 320 x 256 px.
Spectral range	0.4–1.0 μm	1.0–2.5 μm
Spatial pixels	1600	320
FOV across track	17°	13.5°
Pixel FOV across/ along track	0.18 mrad/ 0.36 mrad	0.75 mrad
Spectral sampling	3.7 nm	6.0 nm
Number of bands	160	256
Digitization	12 bit	14 bit
Max frame rate	135 fps	100 fps
Sensor head weight	4.6 kg	7.5 kg

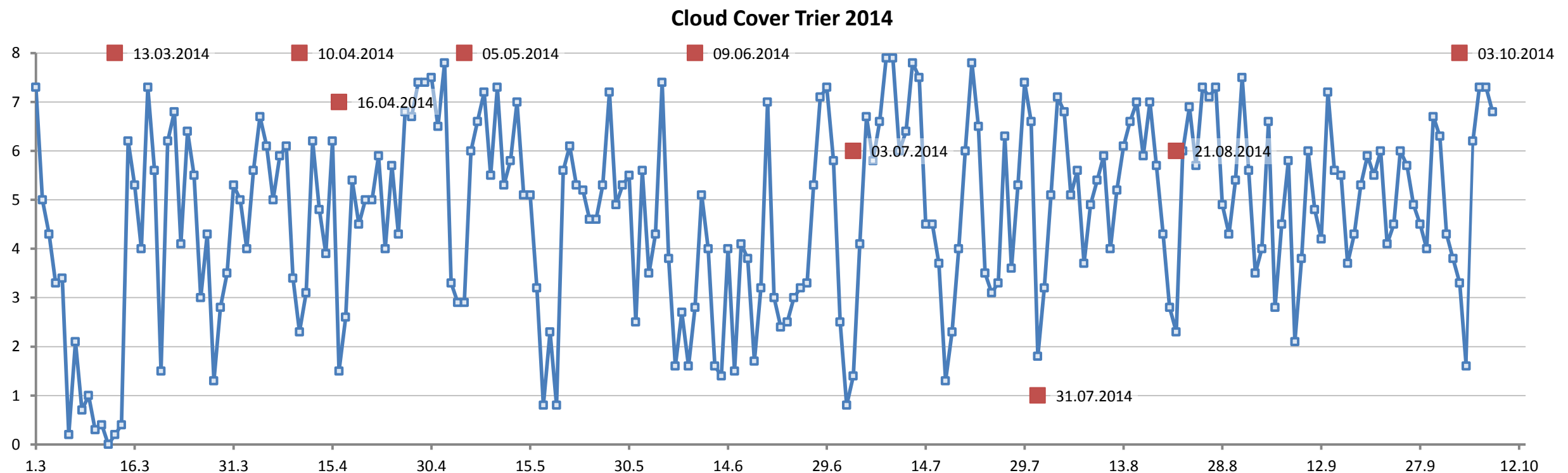
www.hyspex.no



IMU/GPS

Parametrische Geo-Referenzierung
Dank mit einer überschaubaren Anzahl
von Passpunkten



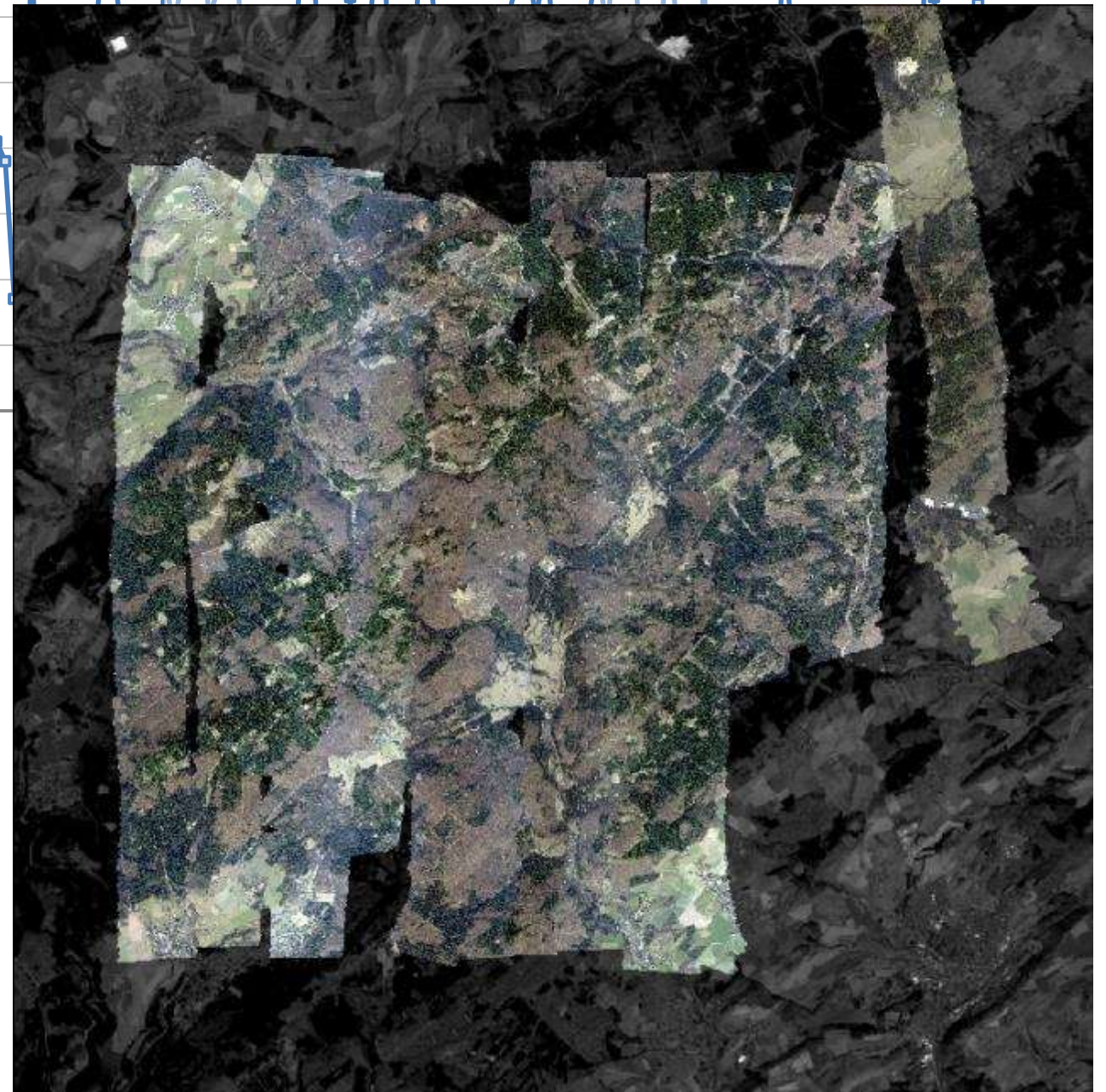
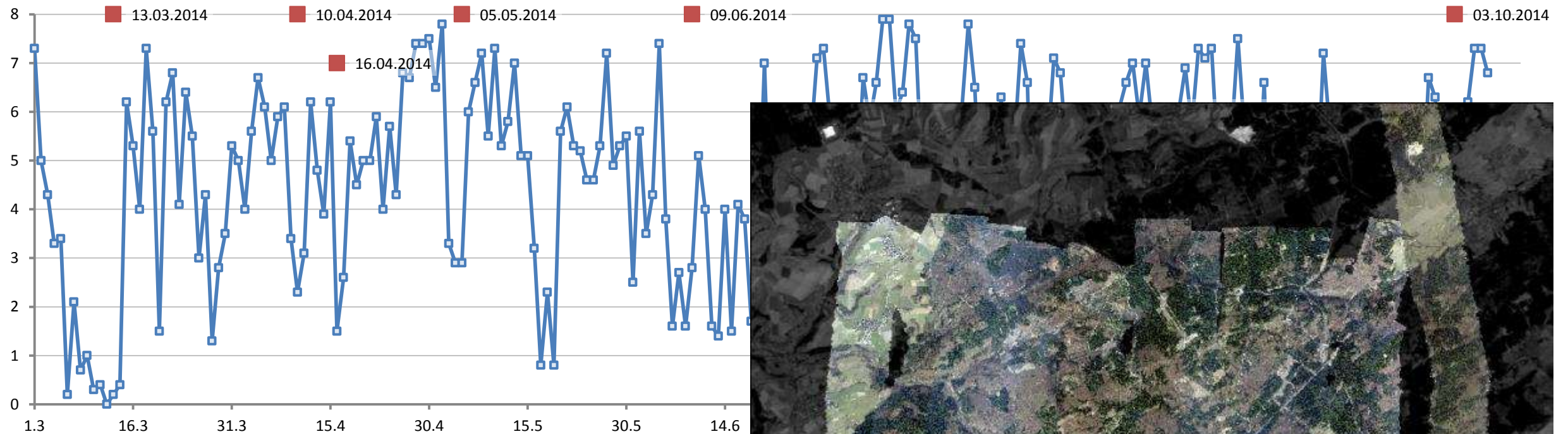


Date	Target Area
13 Mar	National Park
10 Apr	National Park
16 Apr	Merzalben
16 Apr	National Park (DLR)
05 May	National Park

Date	Target Area
09 Jun	National Park, Belgium
03 Jul	Donnersberg, NP (GPS Fail)
31 Jul	Trier (NP too cloudy)
21 Aug	Donnersberg (NP too cloudy)
03 Oct	National Park (5/20 strips)



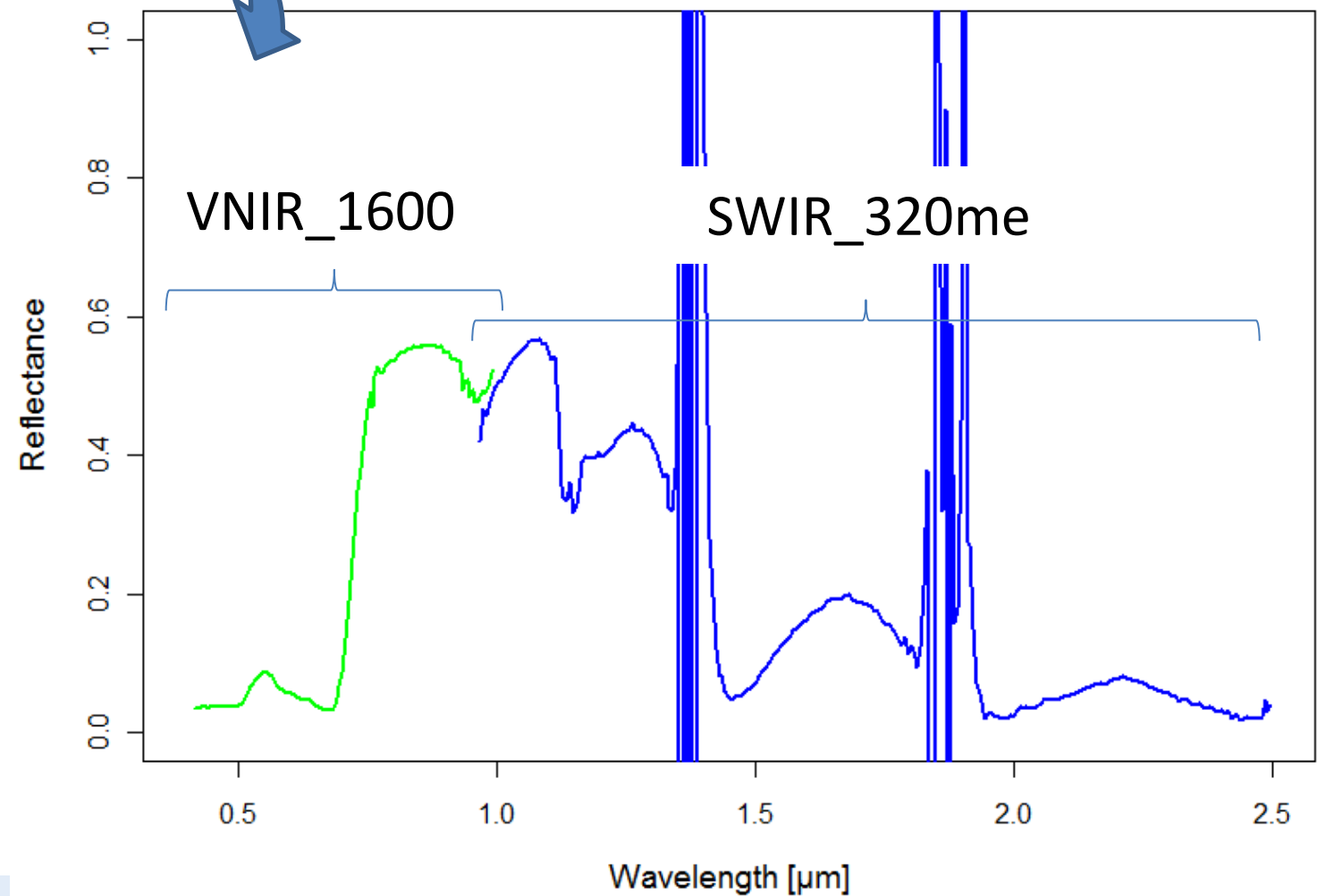
Cloud Cover Trier 2014



Date	Target Area
13 Mar	National Park
10 Apr	National Park
16 Apr	Merzalben
16 Apr	National Park (DLR)
05 May	National Park



Korrektur von Atmosphäreneffekten (AtCPro 6.1)





- Erfassung der Hauptbaumarten
- Ökophysiologische Parameter und Klimasensitivität
- Waldstruktur, Holzvorräte/Biomasse
- Datenintegration (ALS & Hyperpectral Imaging)
- Ausblick



Rheinland-Pfalz

(19,854 km², Bevölkerung 4 Millionen)

Erfassung der Hauptbaumarten

- Wichtigste Baumarten: Fichte, Buche, Eiche, Douglasie, Kiefer
- 16 forstliche Wuchsgebiete mit teils sehr unterschiedlichen wuchsklimatischen Bedingungen

- Erstellung satellitenbasierter Karten zur ökologischen Hauptbaumart (Eiche, Buche, Fichte, Kiefer, Douglasie in den Entwicklungsphasen Qualifizierung, Dimensionierung und Reife).
- Nutzung bereits bestehender und zu aktualisierender Forsteinrichtungsdaten als Referenzinformation
- Integration in künftige, operative Einrichtungsverfahren

Waldökologisches Forstinformationssystem (WöFIS)

Verknüpfung von Geometrie- und Sachdaten zu

Baumarten, Standorteigenschaften, Waldentwicklungszielen, Besitzverhältnissen, Infrastruktur, Ökologischem Wert, ...



Maske : Waldort

1 Maske

Eingabedaten

Betrieb

FA-Nr. Forstamt Stichtag

41 TRIER (FA) 1999

WBA 1

Betrieb 21100 130 STADT Trier (3)

FU 13 TRIER-WEISSHAUS

Waldort

Distrikt Abt. Waldort Waldort-Name Fläche [ha]

215 c0 4.5

Bodennutzungsart Holzboden Nachhaltigkeitsklasse Hochwald

Ökol. Hauptbaumart Dou

Leitbaumart Buche

Mischungsform Nadel-Misch

Verjüngungsflächen [ha]

Natur VJ künstl. VJ Voranbau Blößenfläche [ha]

0.0 0.0 0.0 0.0

Baumarten

Anzahl 12

Bef. einh.	Baumart	Alter	Fläche [ha]	Phase	Holzproduktziel	Intensität	BHD	bef	Ekl	BG	EW	Ans/ha	Vorrat	Zuw.	Schälsch.	Splittersch.	sonst. Stammsch.	zugel.	Äst. Ist	Äst. Soll
1	Dou	28	1.3	Dim	Wert	vollBw	mi		1	1	2	100	499	27.6						5
1	Fi	59	0.5	Rei	Mas no	vollBw	st		1	1	1	40	215	7.0			leicht			0
1	Fi	45	0.5	Dim	Mas no	vollBw	mi		1	1	2	80	170	8.1						0
1	Dou	45	0.2	Dim	Wert	vollBw	st		1	1	2	80	99	3.8						5
1	Dou	64	0.1	Dim	Mas no	vollBw	st		2	1	1	50	43	1.1			leicht			0
1	Dou	67	0.2	Dim	Wert	vollBw	st		1	1	1	70	111	2.6			leicht			5
1	Eka	102	0.4	Rei	Mas ge	vollBw	mi		2	1	1	40	136	3.1						0

Waldfunktionen und Umweltvorsorgeplanungsflächen

Waldfunktion	WF-Fläche [ha]	UVPI Gesamt [ha]	UVPI Künstl. Vj [ha]	UVPI Voranbau [ha]
Erholungswald	0.0	0.0	0.0	0.0
sonstige wertvolle Biotope/ sonstige Biotope	0.0	0.0	0.0	0.0

weitere Baumarten

Baumart	Alter M	Phase	Lage
eLä	102	Rei	Nordv

Status: unverändert Bearbeitungs-Modus: Ändern

Stichtag

Kombination von Geodaten und relationaler Datenbank

Große Variabilität der naturräumlichen und wuchs- klimatischen Standort- bedingungen

Länge der forstlichen Vegetationszeit

146 Tage → 159 Tage ← 173 Tage

Mittlere Temperatur

13,6°C → 14,6°C ← 15,7°C

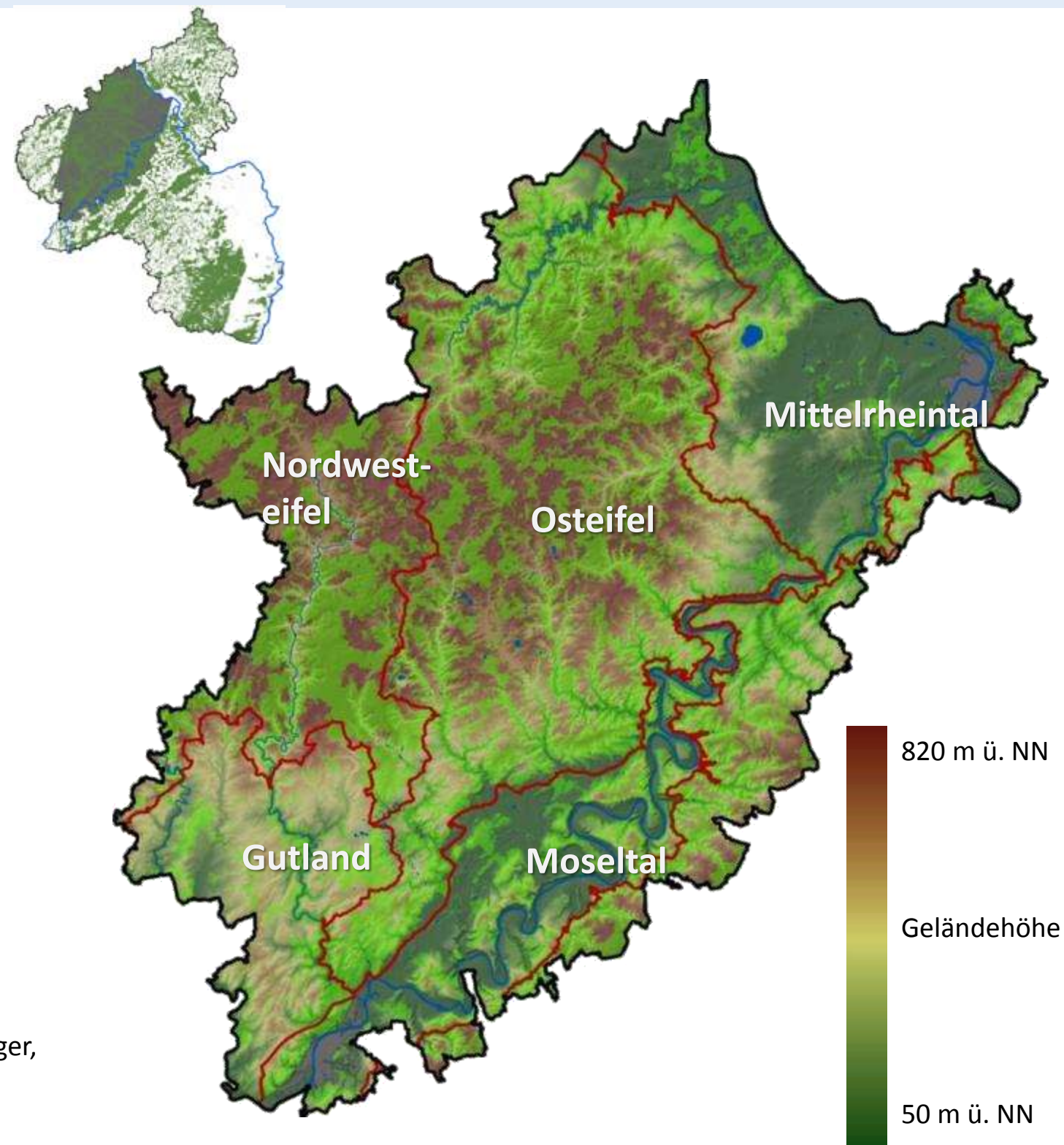
Mittlerer Niederschlag

23 mm → 343 mm ← 366 mm

Mittlere Geländehöhe (m ü. NN)

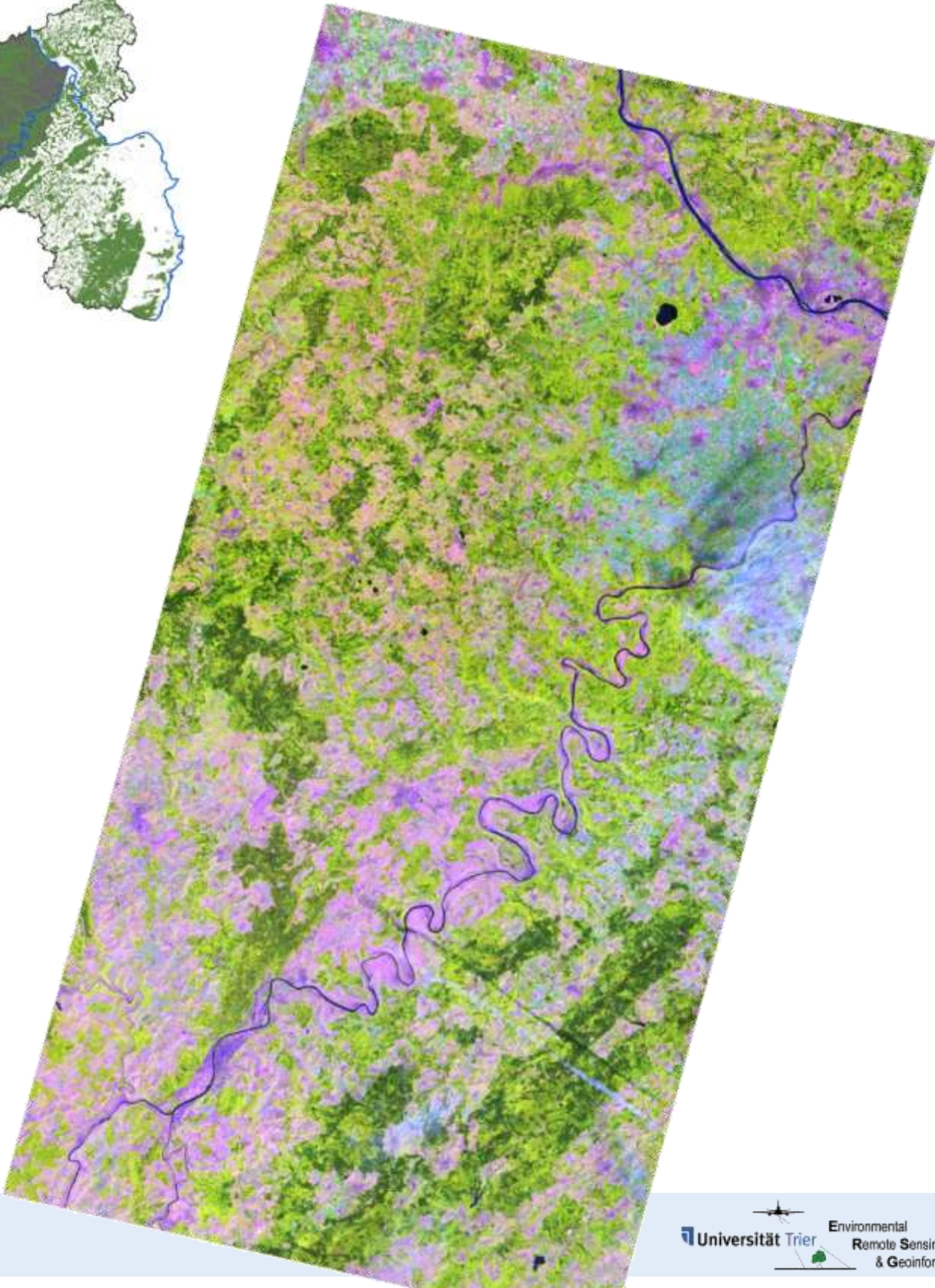
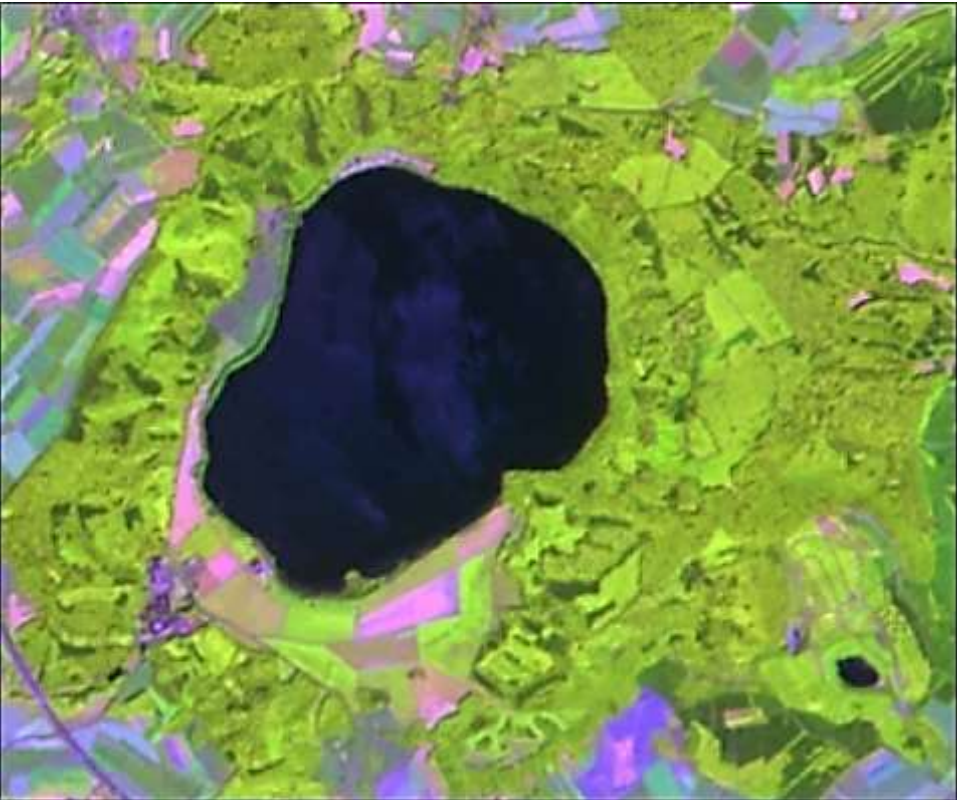
182 → 334 ← 482

Quelle: SGD Süd, Außenstelle Forsteinrichtung, 2003; Gauer & Aldinger, 2005



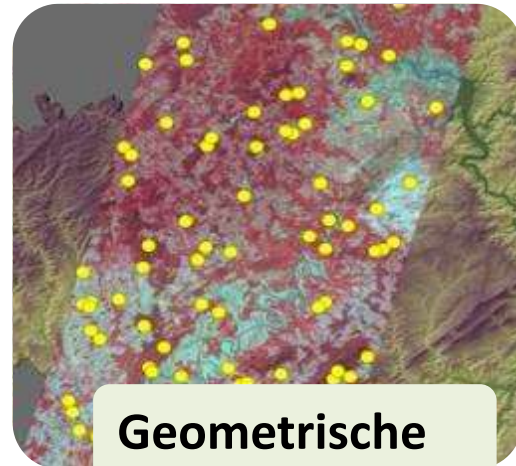


Sensor	Aufnahme- charakteristik	verfügbare Aufnahmen
ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)	3 unabhängige optomechanische Systeme mit insgesamt 15 Kanälen Auflösung: VIS: 15x15 m SWIR: 30x30 m TIR: 90x90 m	26.06.2001 06.04.2005





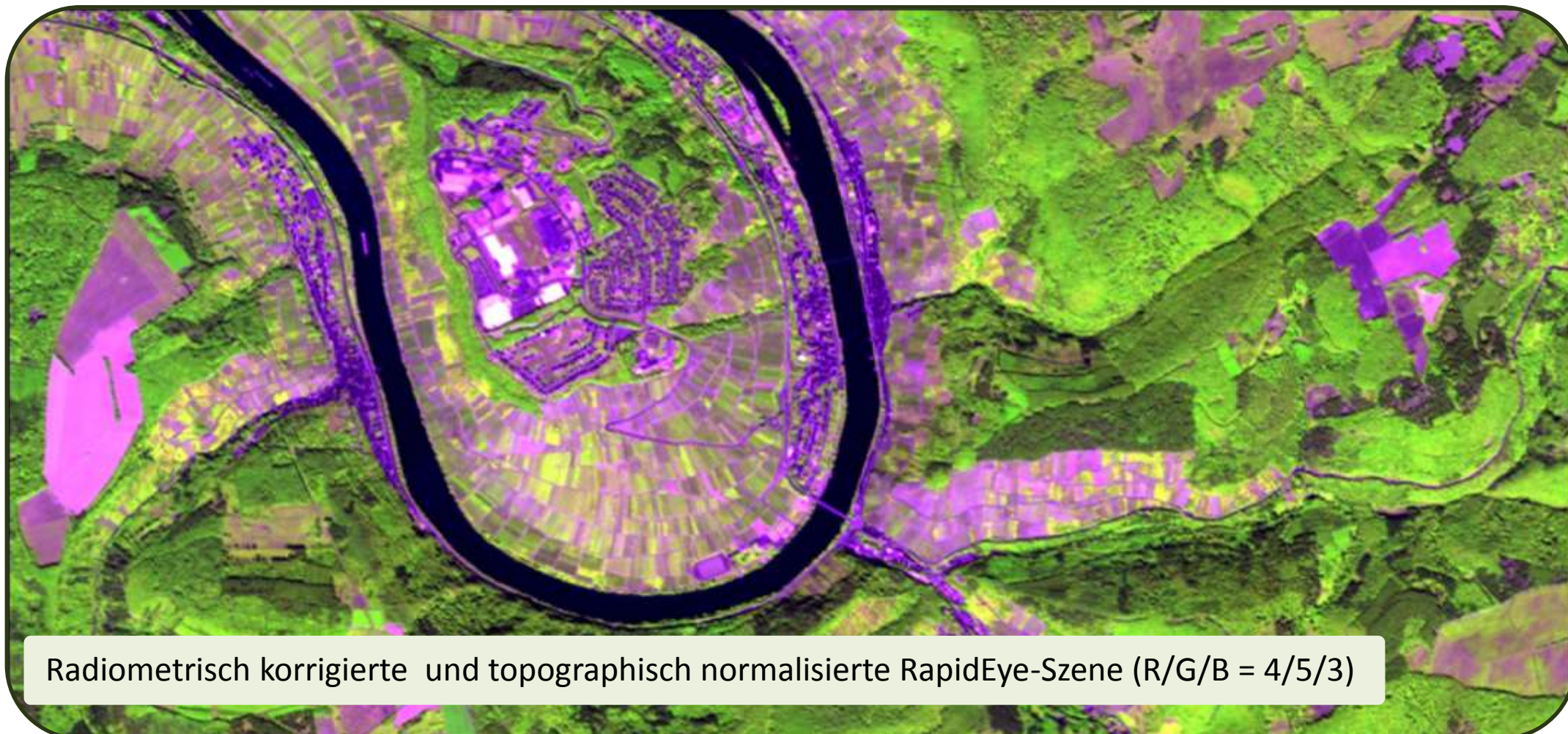
Bildfusion
(ASTER, SPOT)



**Geometrische
Korrektur**



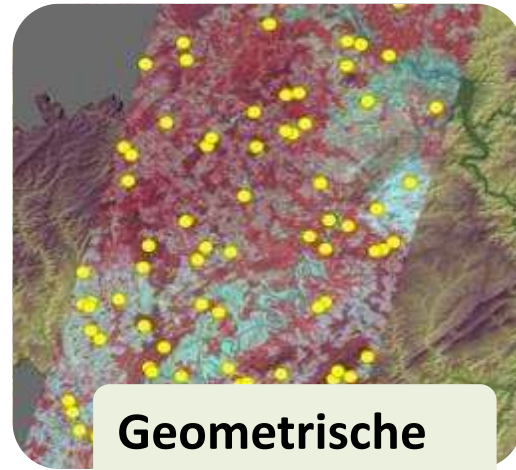
**Radiometrische
Korrektur**



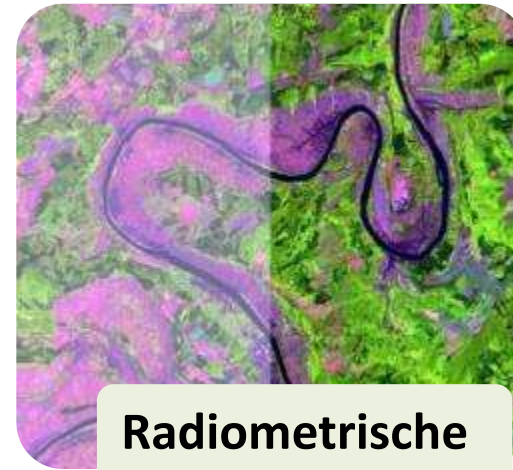
Radiometrisch korrigierte und topographisch normalisierte RapidEye-Szene (R/G/B = 4/5/3)



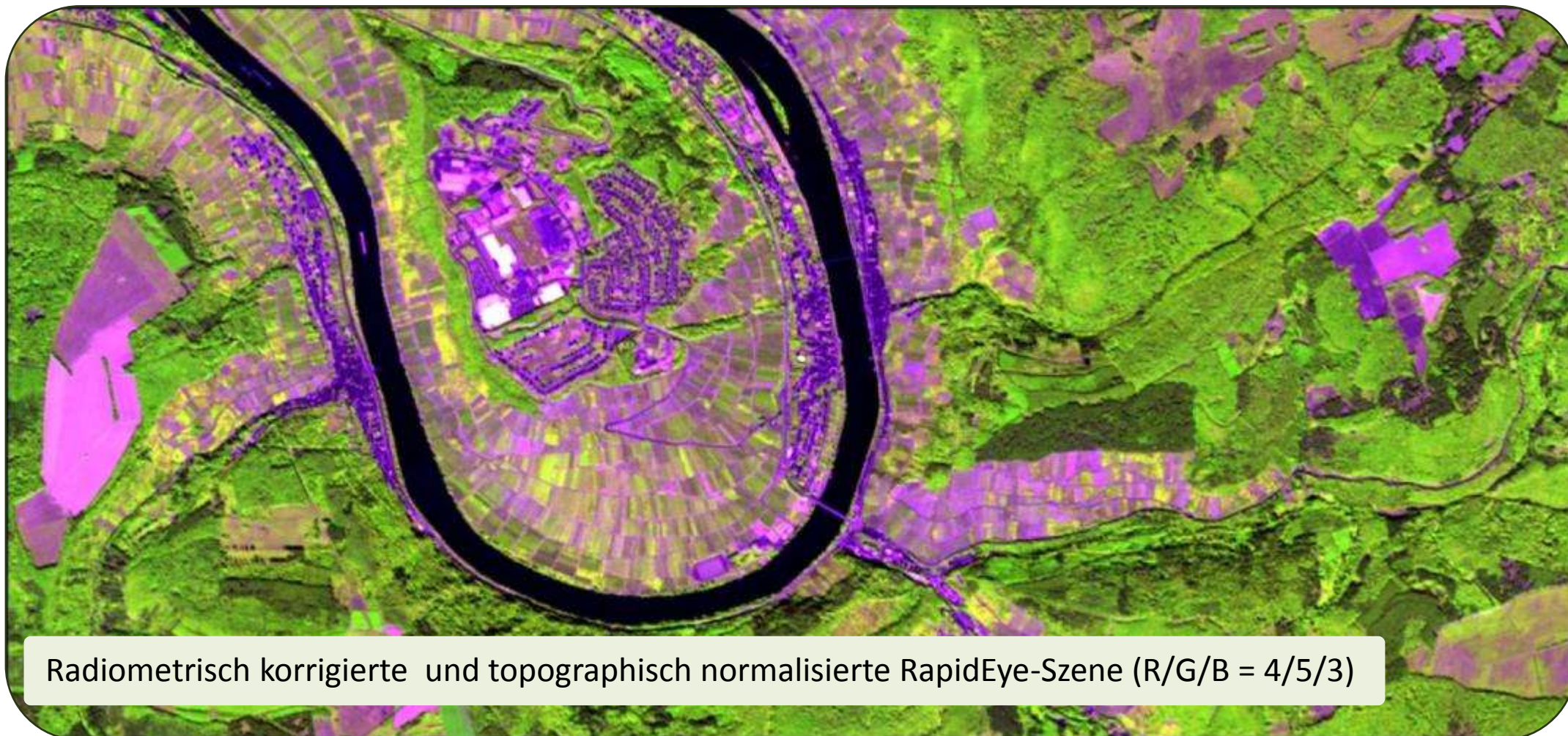
Bildfusion
(ASTER, SPOT)



**Geometrische
Korrektur**



**Radiometrische
Korrektur**

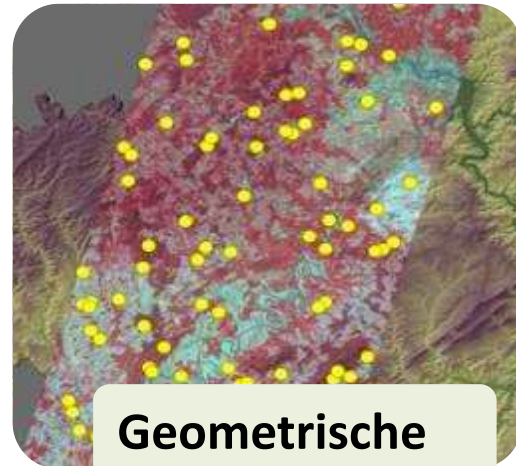


Radiometrisch korrigierte und topographisch normalisierte RapidEye-Szene (R/G/B = 4/5/3)

Hill & Sturm, 1991
Hill, 1993
Hill, Mehl &
Radeloff, 1995
Hill & Mehl, 2003



Bildfusion
(ASTER, SPOT)



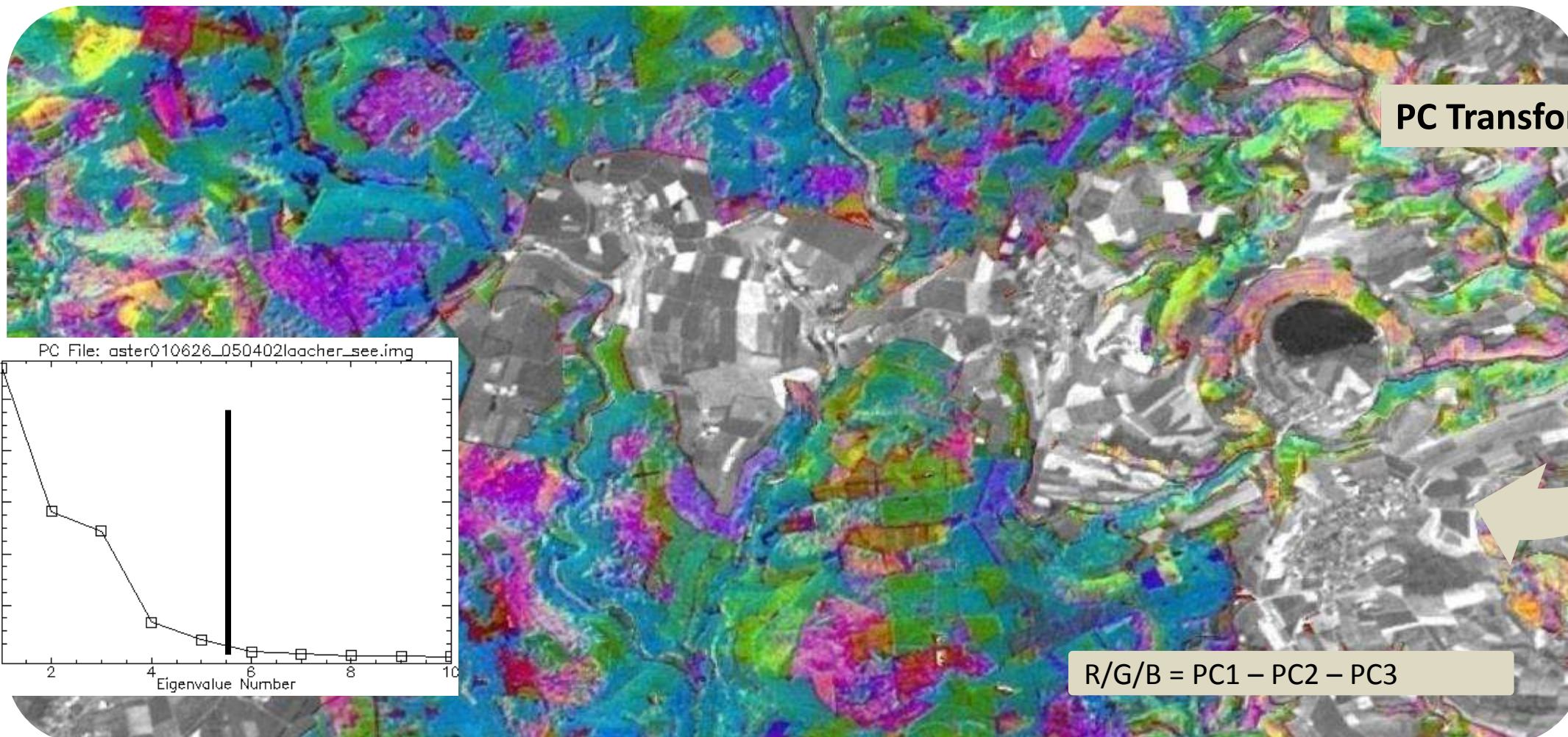
Geometrische Korrektur



Radiometrische Korrektur

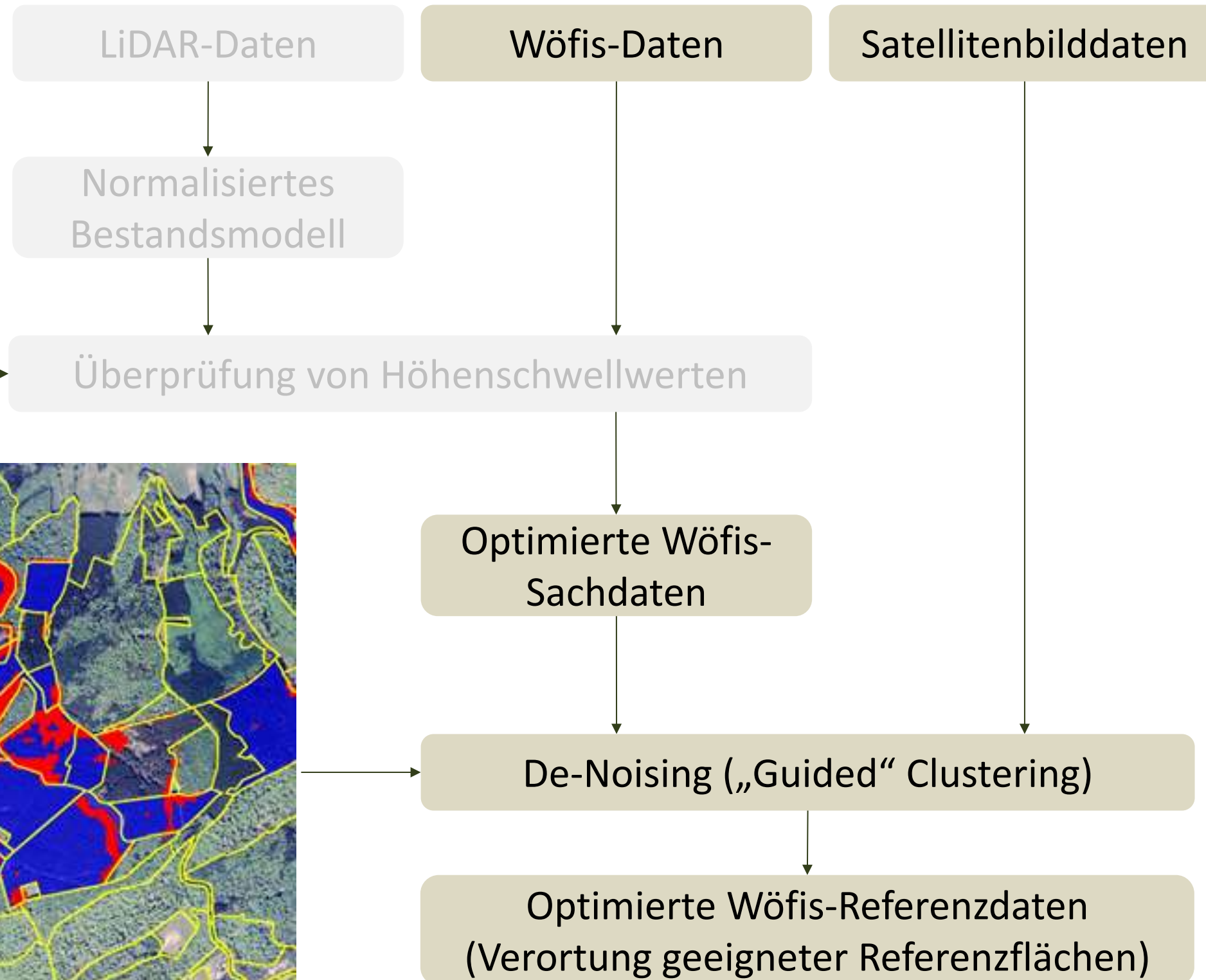


Maskierung Waldflächen

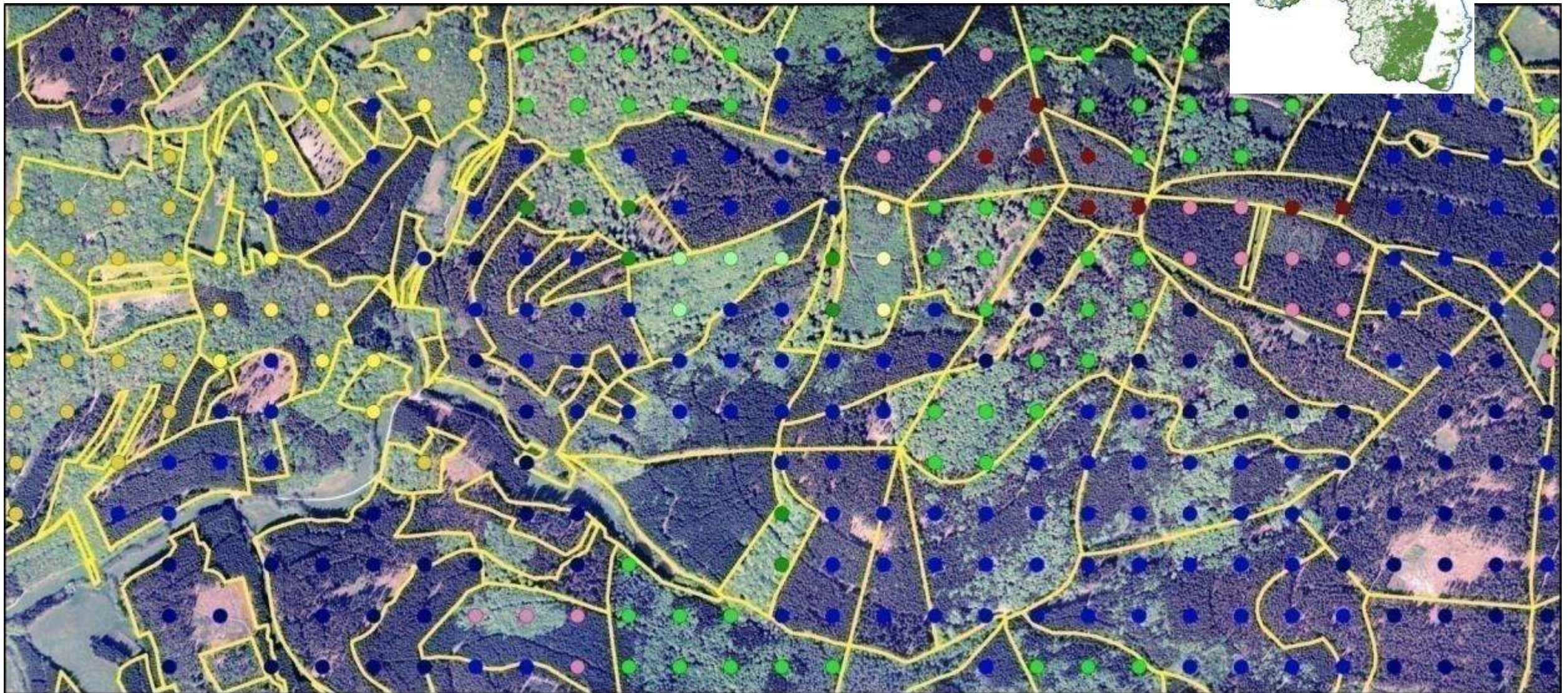


Aufbereitung der Referenzdaten

Entwicklungsphasen →



- Regelmäßiges Punktraster (100 m x 100m)
- Vermeidung von Waldrändern, Waldortgrenzen und Wegen
- Ableitung der Spektralinformation aus den Satellitenbilddaten



Wall-to-Wall Mapping of Important Tree Species

Process Flow

Multi-Temporal Satellite Data
(April & July/August) [5-Year Window]



Geometric Ortho-Rectification
Atmospheric & Topographic Correction
Resolution Merge (optional)



Distributed Class References from Official Forest
Database

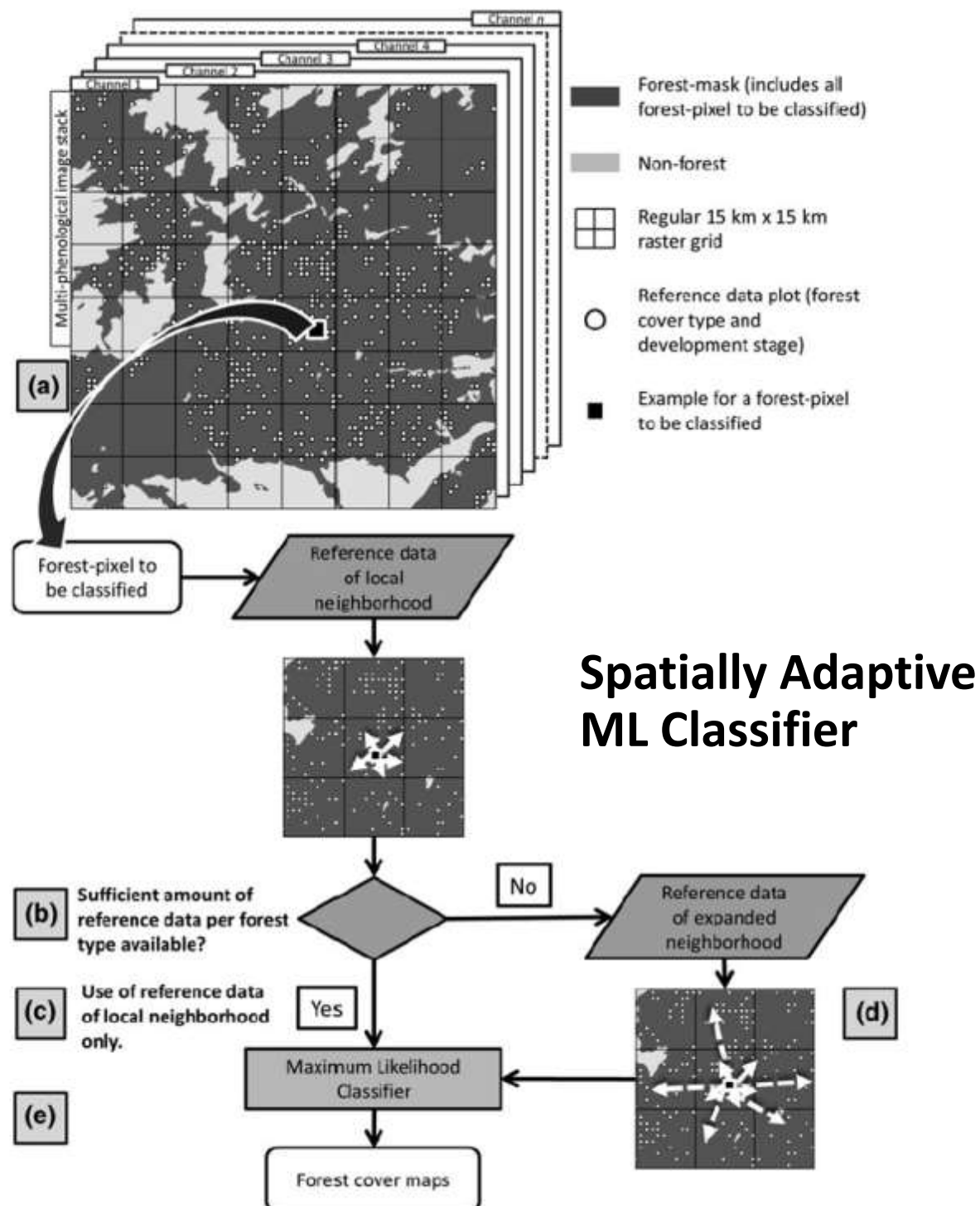
Reference Data Quality Check



Spatially Adaptive Classification



Quality Assessment

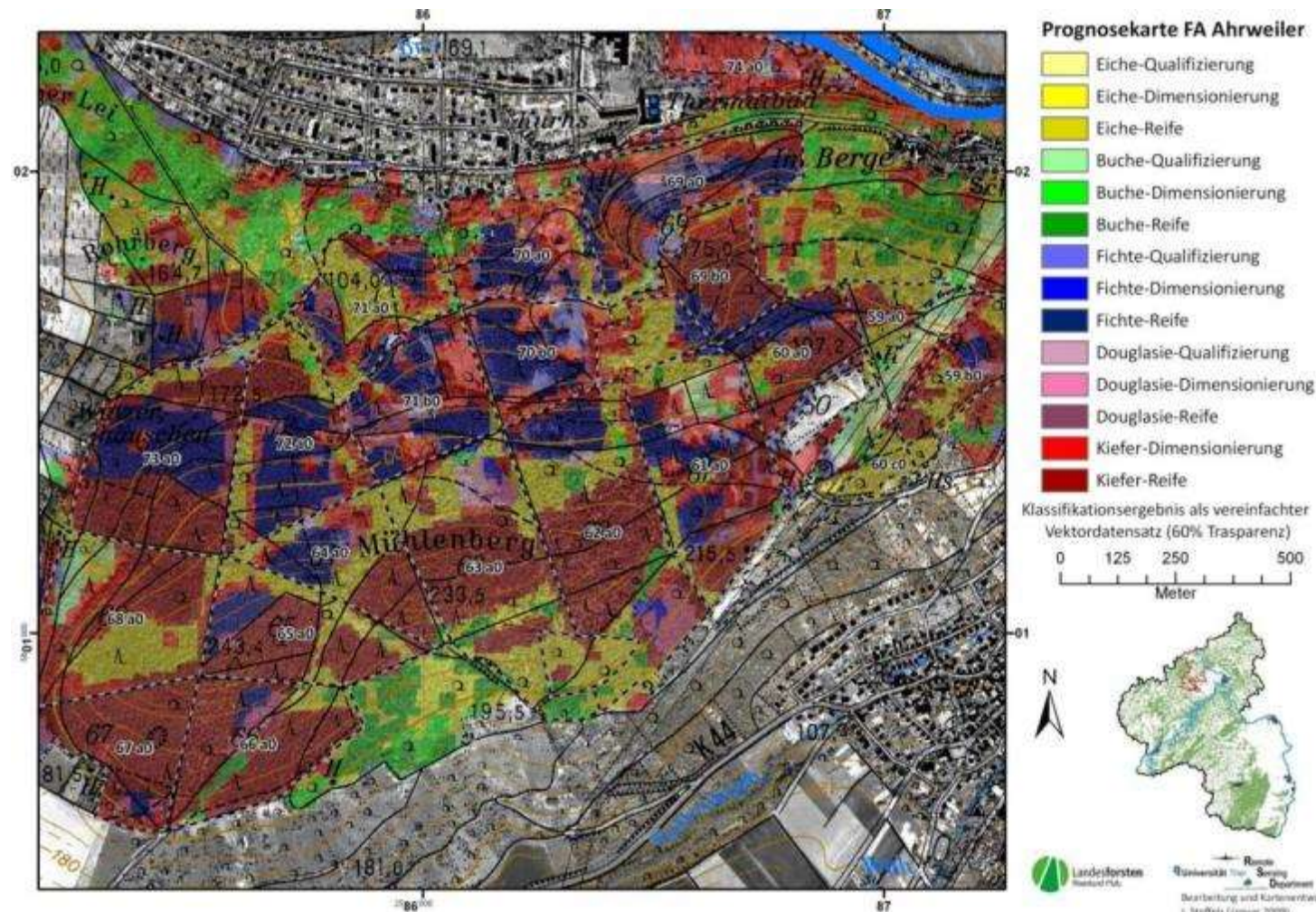


Stoffels, J., Mader, S., Hill, J., Werner, W. & Ontrup, G. (2012). Satellite-based stand-wise forest cover type mapping using a spatially adaptive classification approach. *European Journal of Forest Research*, 131 (4): 1071-1089.

Erzielte Genauigkeit (Pilotstudie, Stoffels et al. 2012)

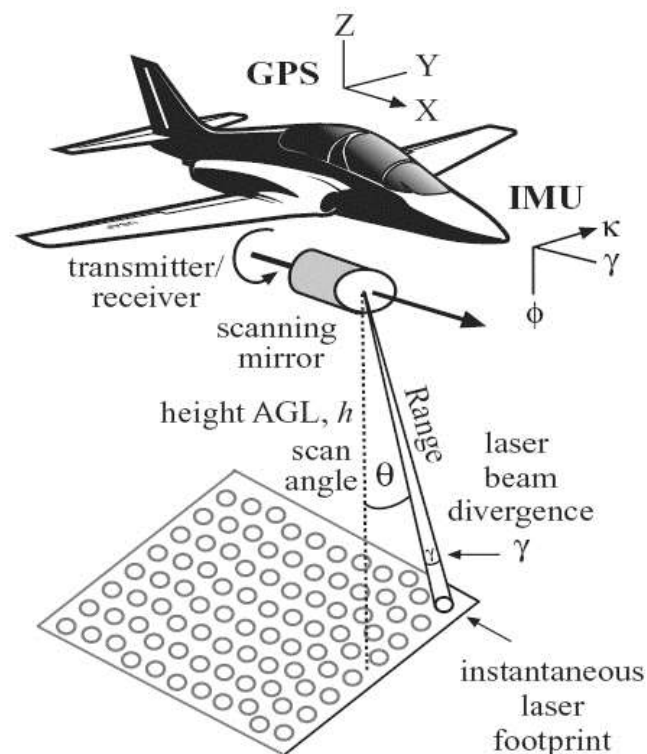
- ❖ 87,5% 5 Hauptbaumarten
- ❖ 74,4 % 5 Hauptbaumarten & 2-3 Entwicklungsphasen (= 13 Klassen)

	Species & Development Stages		Species	
	Producers Accuracy	Users Accuracy	Producers Accuracy	Users Accuracy
Oak (Qua)	75.00%	40.78%		
Oak (Dim)	53.95%	75.23%	85.84%	85.11%
Oak (Mat)	71.72%	72.22%		
Beech (Qua)	77.03%	82.61%		
Beech (Dim)	66.13%	72.57%	85.43%	86.17%
Beech (Mat)	81.58%	75.15%		
Spruce (Qua)	69.41%	86.76%		
Spruce (Dim)	67.60%	85.21%	88.25%	92.46%
Spruce (Mat)	95.42%	77.66%		
Douglas Fir (Qua)	89.19%	70.21%	94.54%	79.72%
Douglas Fir (Dim)	80.73%	71.54%		
Pine (Dim)	81.48%	51.16%	85.81%	95.49%
Pine (Mat)	71.90%	96.67%		



Stoffels, J., Mader, S., Hill, J., Werner, W. & Ontrup, G. (2012). Satellite-based stand-wise forest cover type mapping using a spatially adaptive classification approach. European Journal of Forest Research, 131 (4): 1071-1089

LIDAR Data Collection



Erschließung zusätzlicher Datenebenen

Airborne Laser-Scanning:
Normalized Crown Models



5m Raster Size



1 m Raster Size

Derzeitige Abdeckung RLP
(September 2013) = 100%

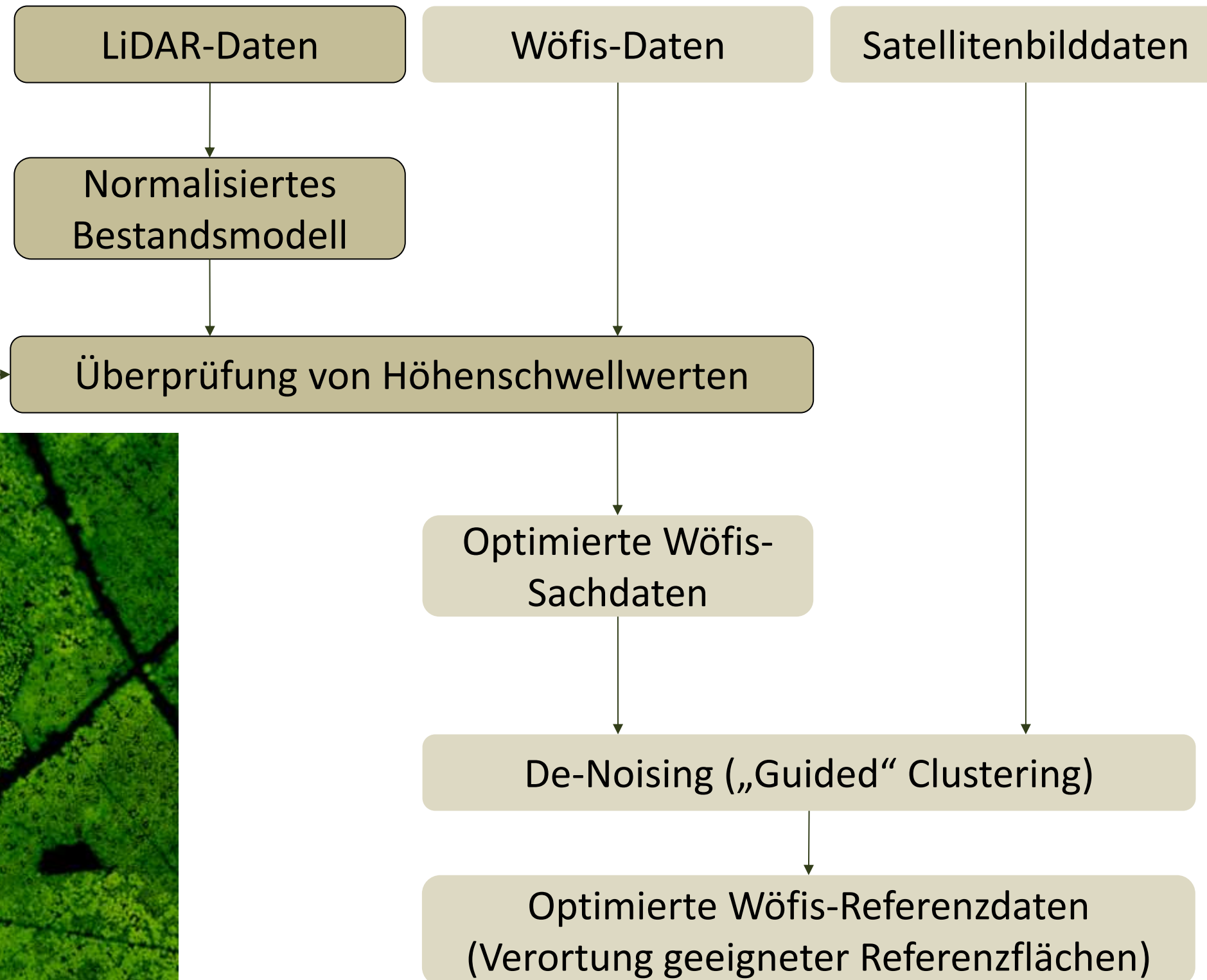
H. Buddenbaum, S. Seeling & J. Hill (2013): Fusion of full waveform LiDAR and imaging spectroscopy remote sensing data for the characterization of forest stands. *International Journal of Remote Sensing*, 34 (13): 4511-4524.



Aufbereitung der Referenzdaten

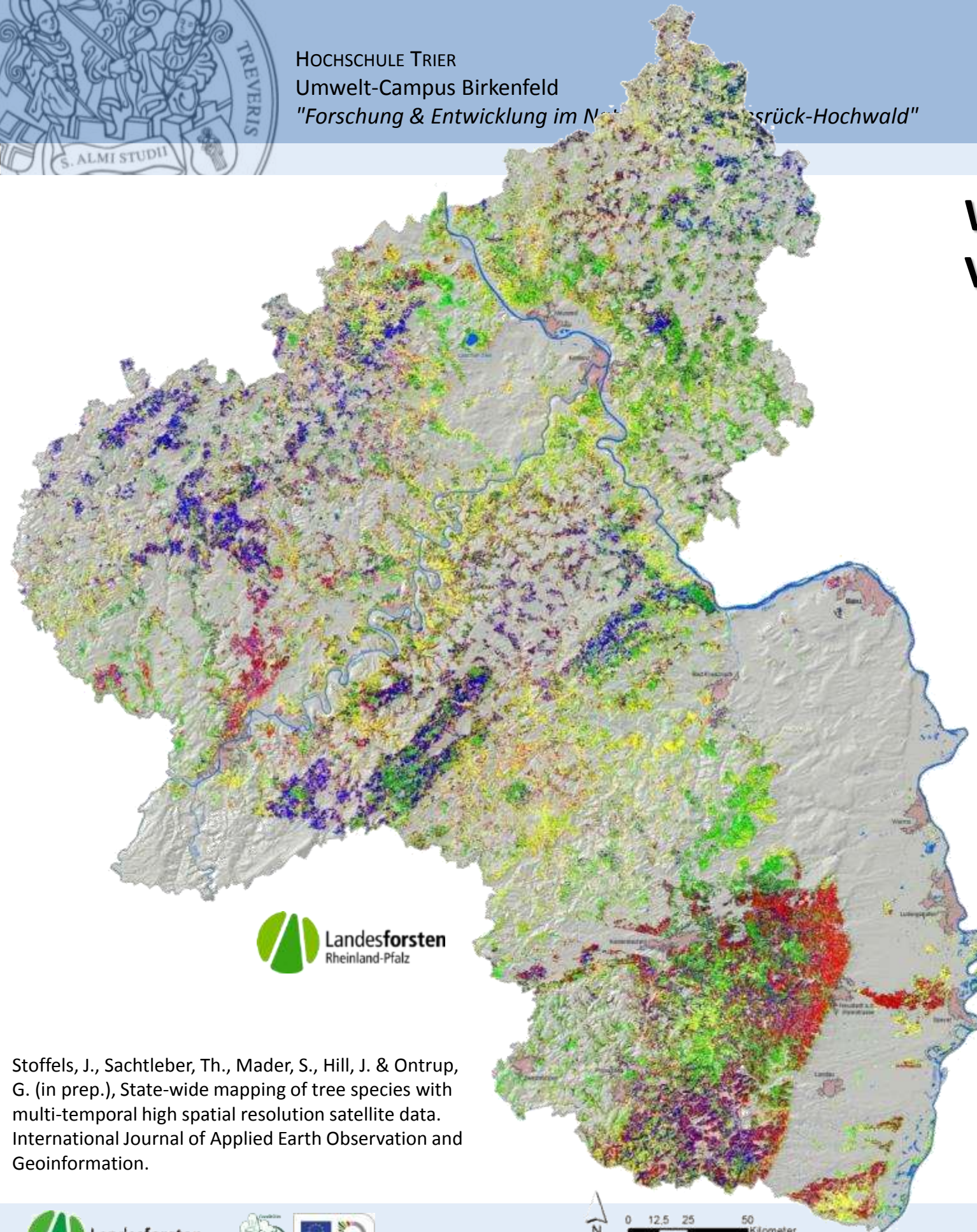
+ Laser-Scanning

Entwicklungsphasen





Wall-to-Wall VHR Satellite Map of Tree Species



Oak		Qualification
		Dimensioning
		Maturity
Beech		Qualification
		Dimensioning
		Maturity
Spruce		Qualification
		Dimensioning
		Maturity
Douglas Fir		Qualification
		Dimensioning
		Maturity
Pine		Qualification
		Dimensioning
		Maturity

	Water Surfaces
	State Area

Projection: Transverse Mercator, Spheroid: Bessel, Datum: Potsdam
Scale: 1:1.000.000

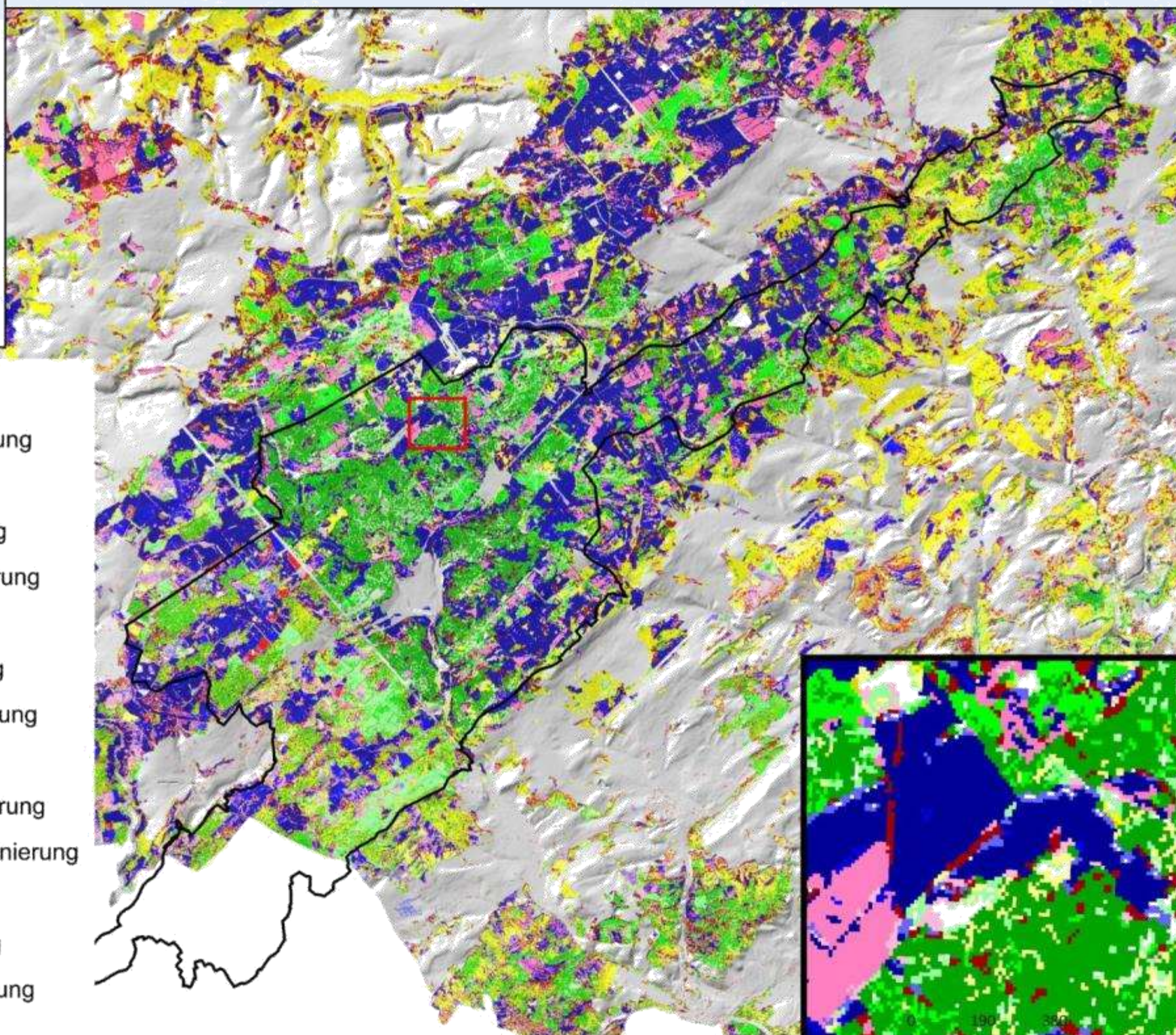
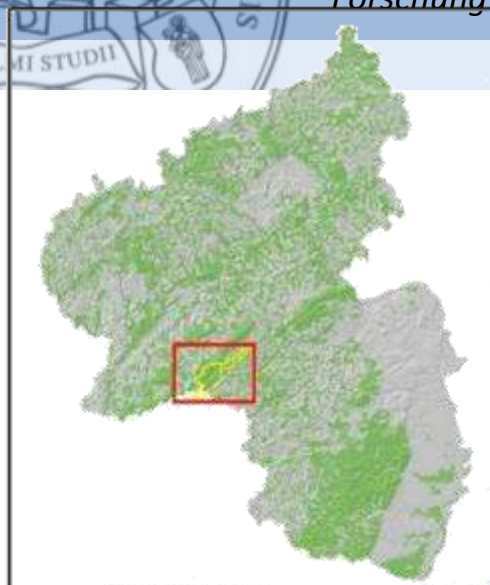
Satellite Data:

32 SPOT4/SPOT5-Scenes (2005 -2011)
3 RapidEye-Scenes (2010 und 2011)

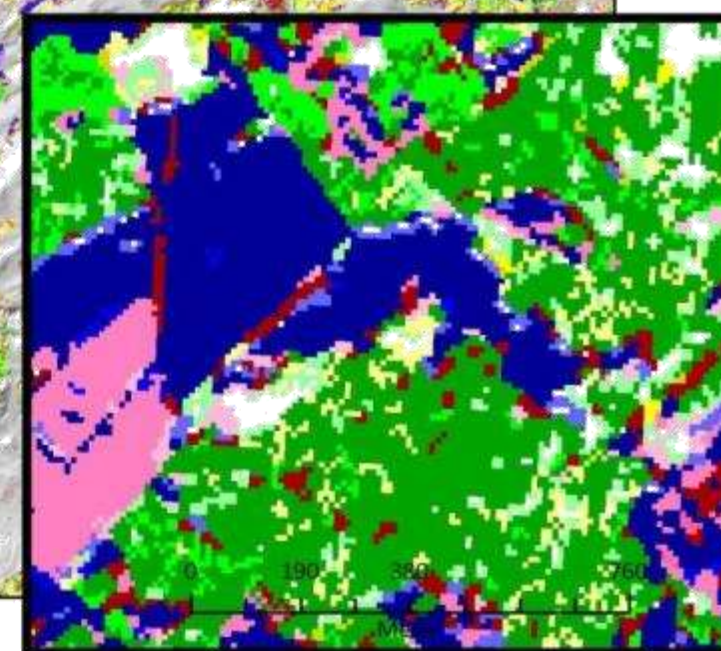
WÖFIS (Landesforsten RLP)
ATKIS (LvermGeo RLP)

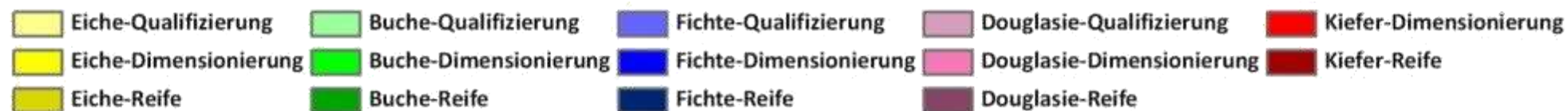
T. Sachtleber, J. Stoffels, J. Hill, S. Mader (2013)
Environmental Remote Sensing & Geoinformatics
Trier University

Stoffels, J., Sachtleber, Th., Mader, S., Hill, J. & Ontrup, G. (in prep.), State-wide mapping of tree species with multi-temporal high spatial resolution satellite data. International Journal of Applied Earth Observation and Geoinformation.



-  Eiche-Qualifizierung
-  Eiche-Dimensionierung
-  Eiche-Reife
-  Buche-Qualifizierung
-  Buche-Dimensionierung
-  Buche-Reife
-  Fichte-Qualifizierung
-  Fichte-Dimensionierung
-  Fichte-Reife
-  Douglasie-Qualifizierung
-  Douglasie-Dimensionierung
-  Douglasie-Reife
-  Kiefer-Qualifizierung
-  Kiefer-Dimensionierung
-  Kiefer-Reife





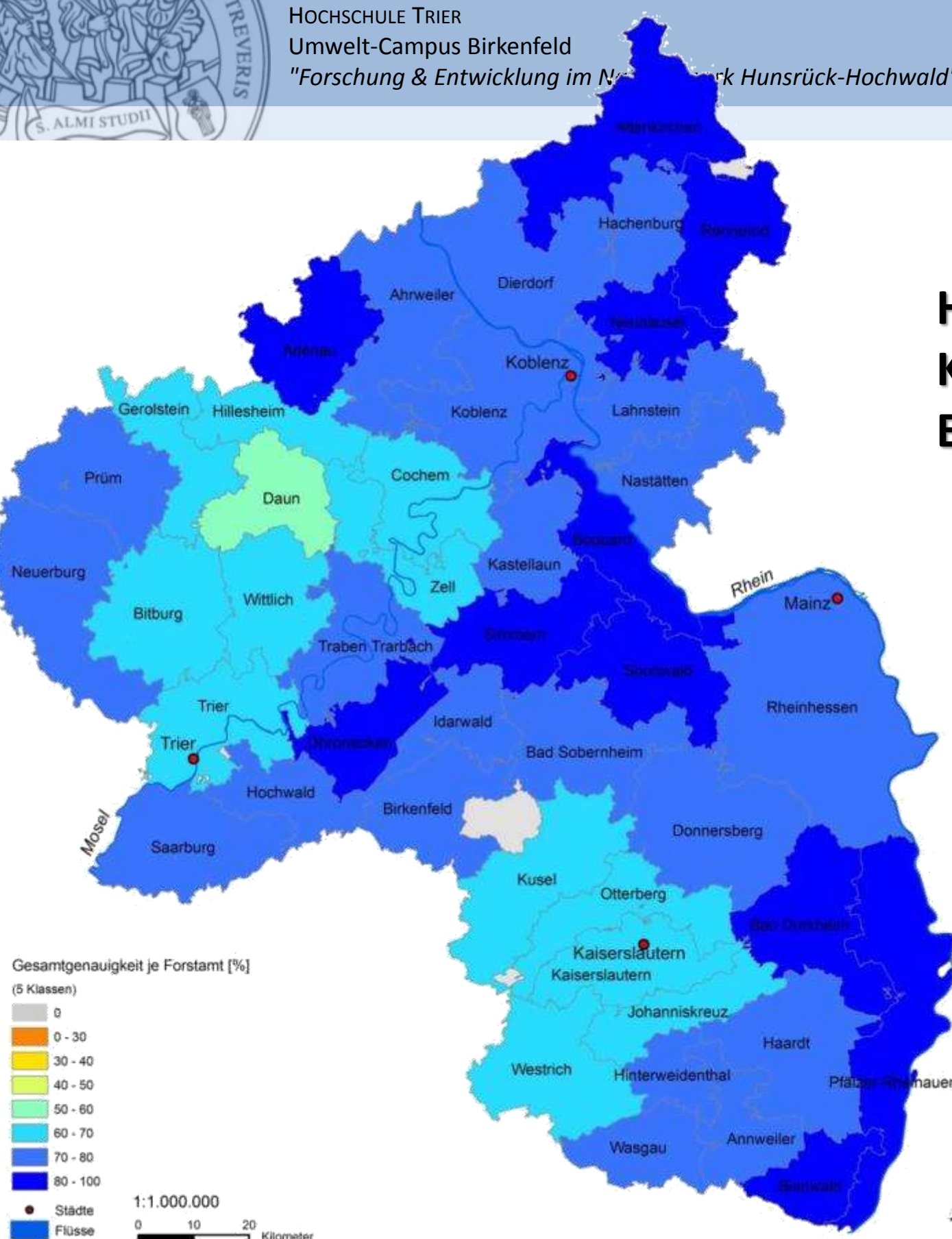
**Digitale und
analoge
Prognosekarten,
Statistiken und
„Verdachts-
flächen“**

(RapidEye, 6 m)

Höchst unterschiedliche Klassifikationsgenauigkeiten auf der Ebene einzelner Forstämter

Mögliche Ursachen:

- Unterschiedliche Komplexität der Baumartenzusammensetzung
- Unangemessene Generalisierung (5 Hauptbaumarten)
- Datenlage
-

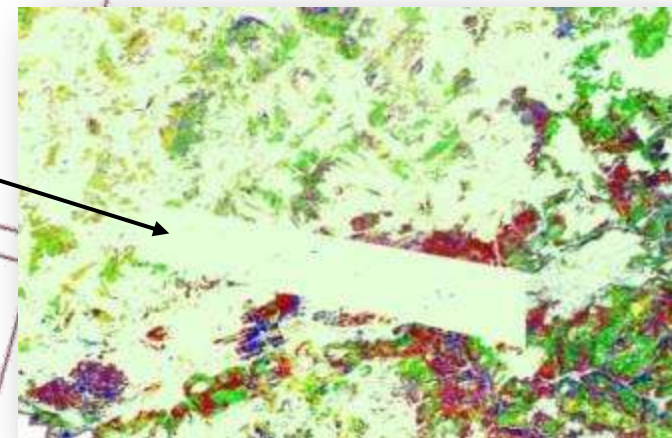
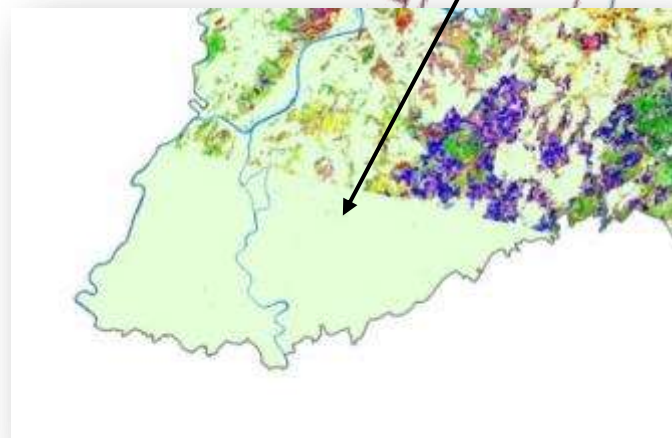


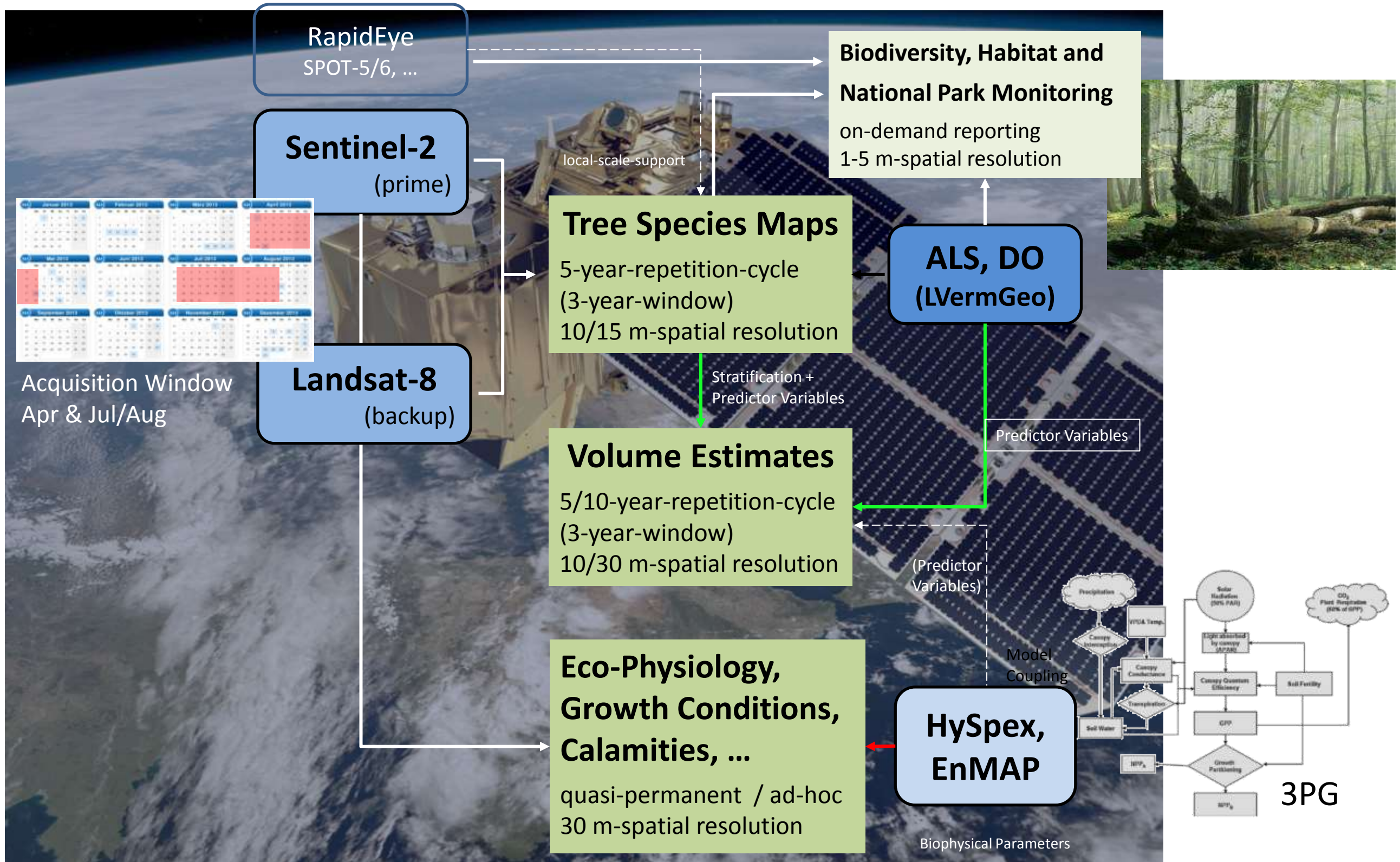
32 SPOT4/SPOT5-Scenes (2005 -2011)
3 RapidEye-Scenes (2010 und 2011)

 Spring  Summer

Problems

- ❖ Inefficient Data Acquisition (SPOT)
- ❖ Extended Acquisition Period (6 Years !)
- ❖ Processing Overkill (too small subsets)
- ❖ Remaining Data Gaps

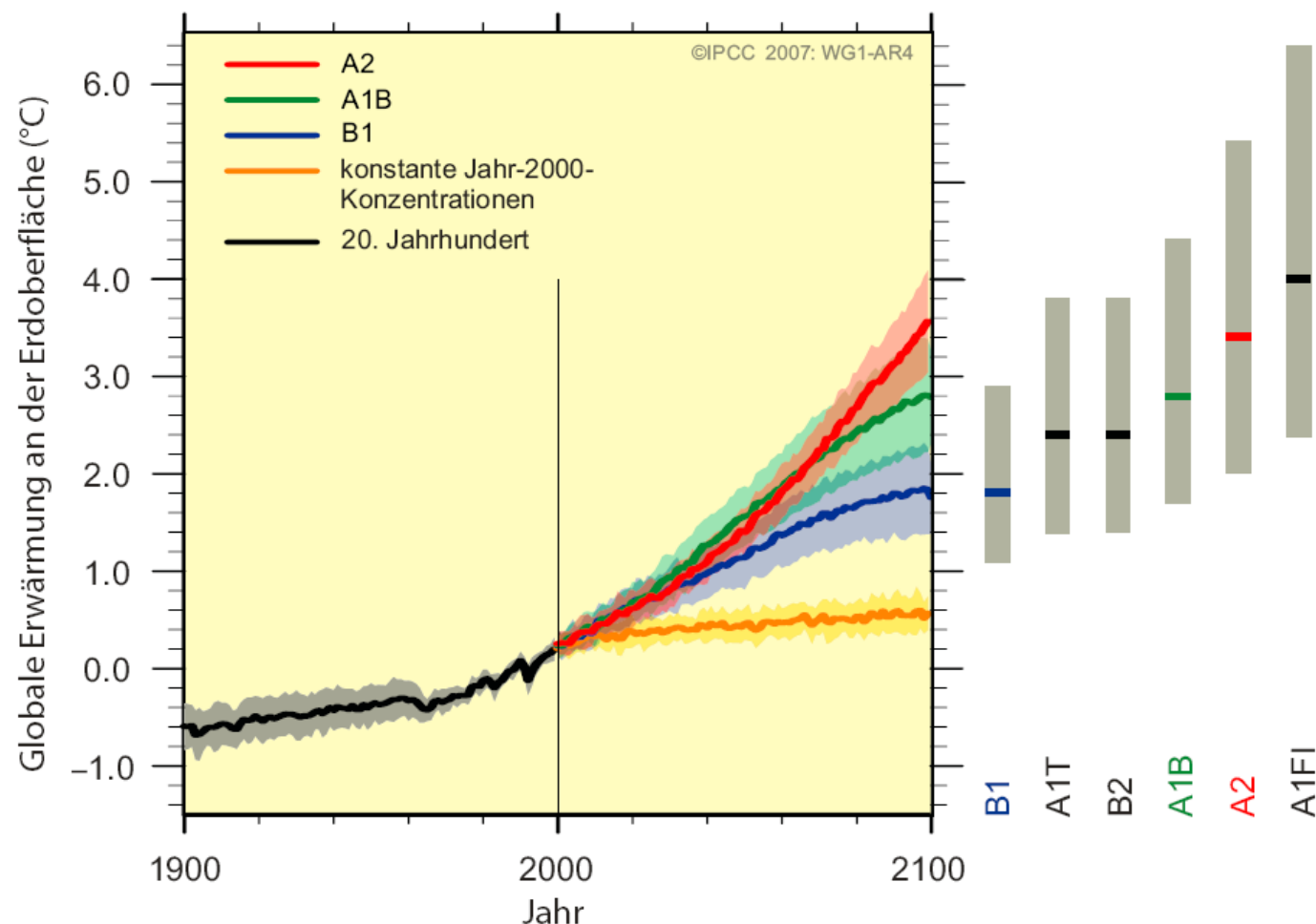




Forest Resources in the Rhineland-Palatinate (RLP) Federal State

➤ Development of Adaptation and Management Strategies against the Background of Regional Climate Change (ForestClim)

MULTIMODELL-MITTEL UND GESCHÄTZTE BANDBREITEN FÜR DIE ERWÄRMUNG AN DER ERDOBERFLÄCHE



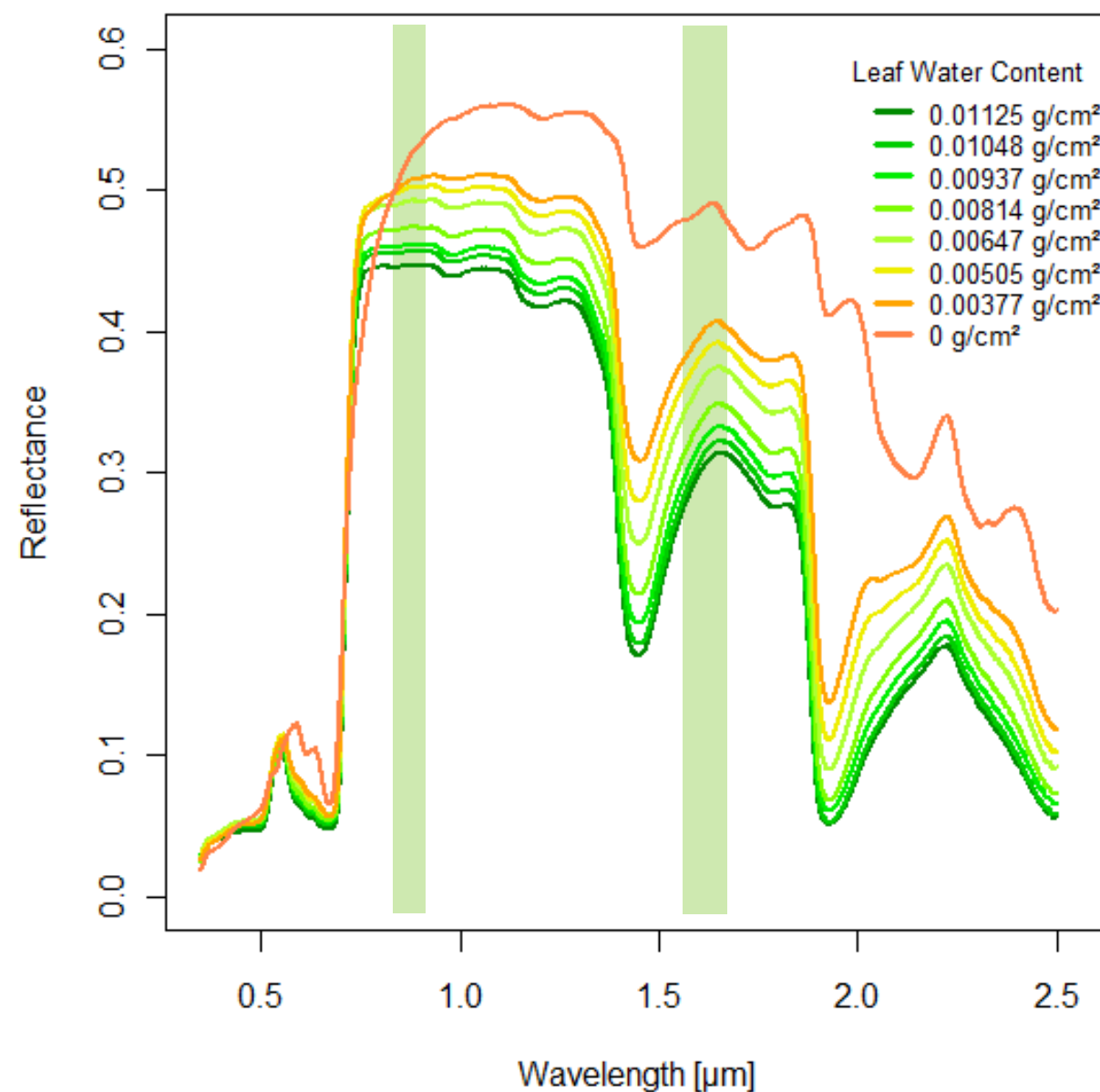
IPCC 2007
<http://www.de-ipcc.de/download/IPCC2007-FullDocument.pdf>

Will Beech Continue to be the Economically Most Important Tree Species?

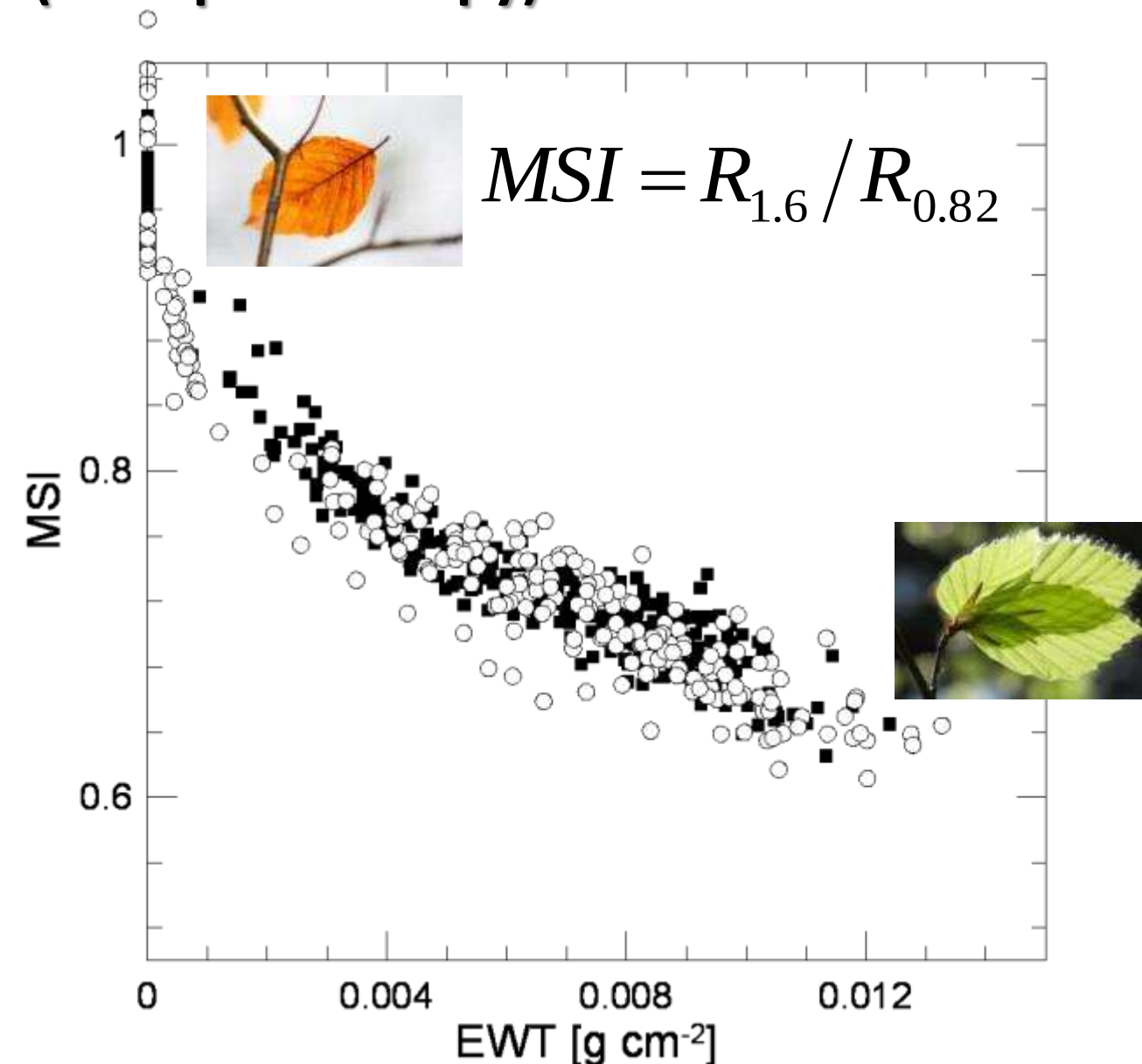
Will the Expected Climate Change Impact be of Equal Importance across Ecoregions?



Spectral Response to Leaf Water Content (Lab Spectroscopy)



Beech (*Fagus sylvatica*): Leaf Water Content [g/cm²]
[Series 1, 7 time steps, average of 25 leaves]



Hunt, E.R., & Rock, B.N. (1989). Detection of changes in leaf water content using near and middle-infrared reflectances, *Remote Sensing of Environment*, 30, 43-54.

HySpex Hyperspectral Imaging

Freilandexperimente am Gewächshaus



Kontrollgruppe

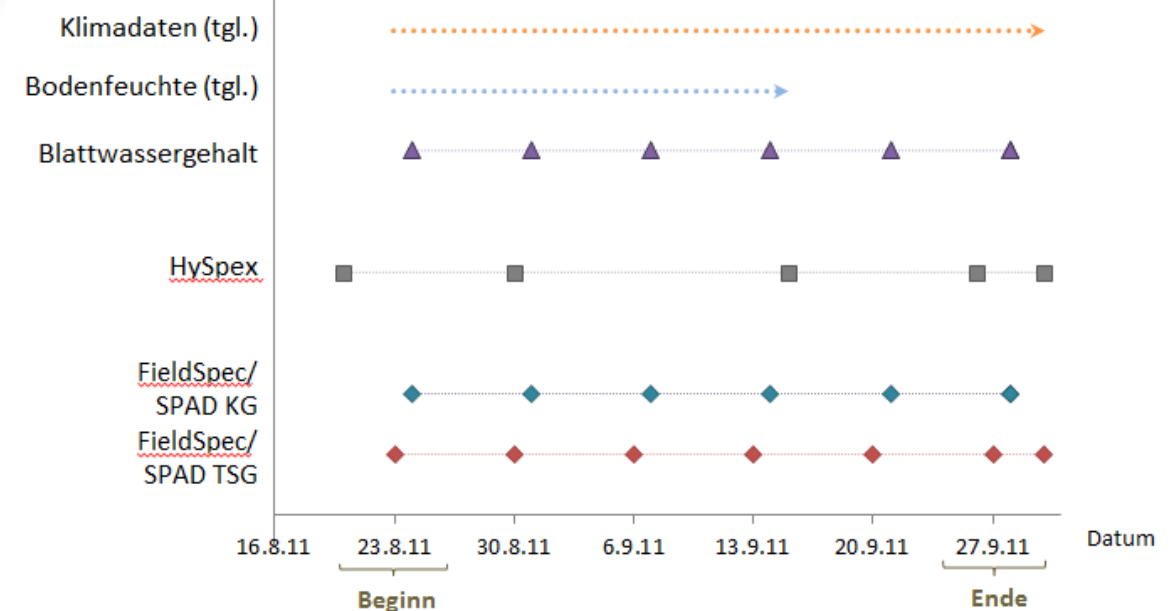


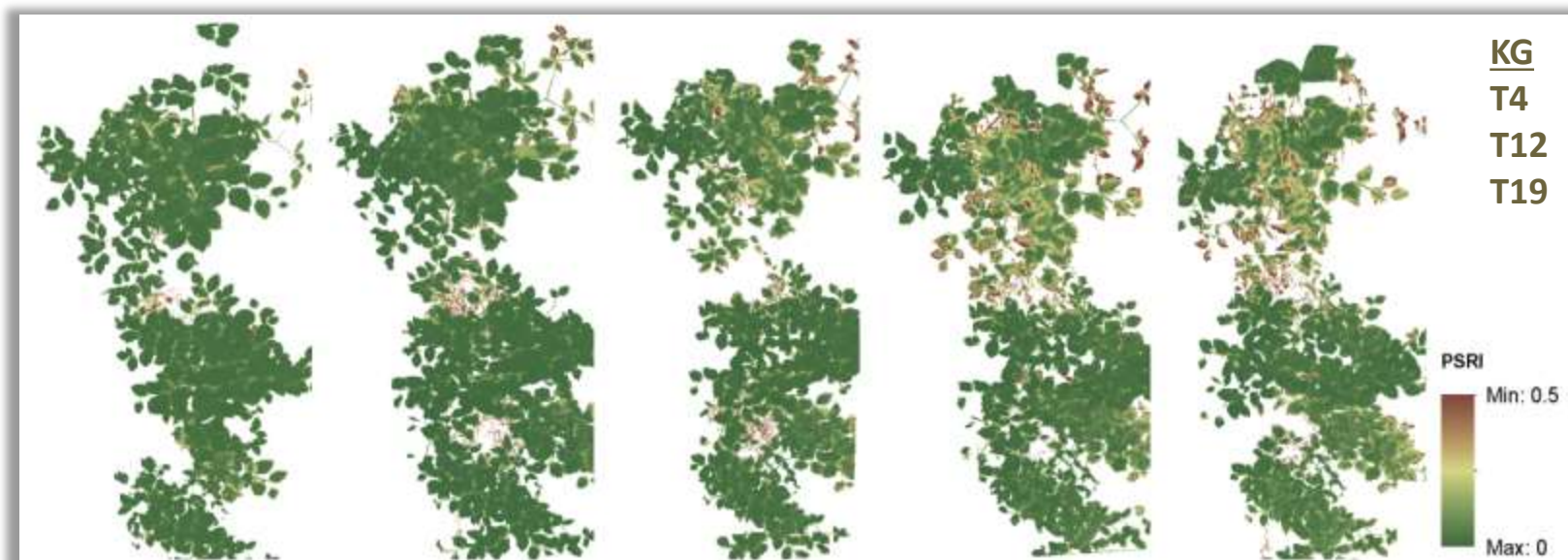
9 Töpfe
22 Bäume

Trockenstressgruppe



8 Töpfe
24 Bäume





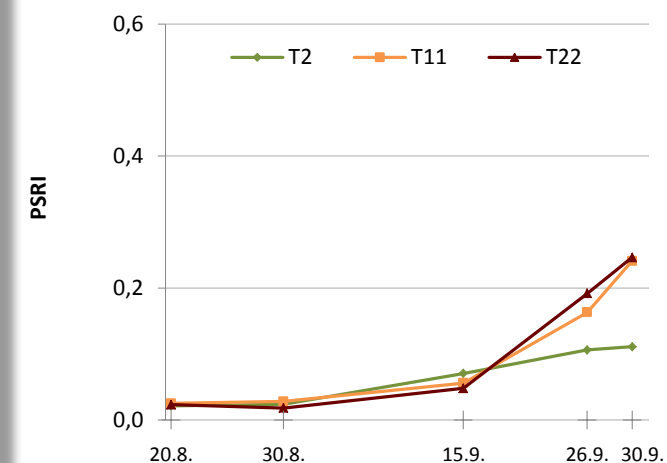
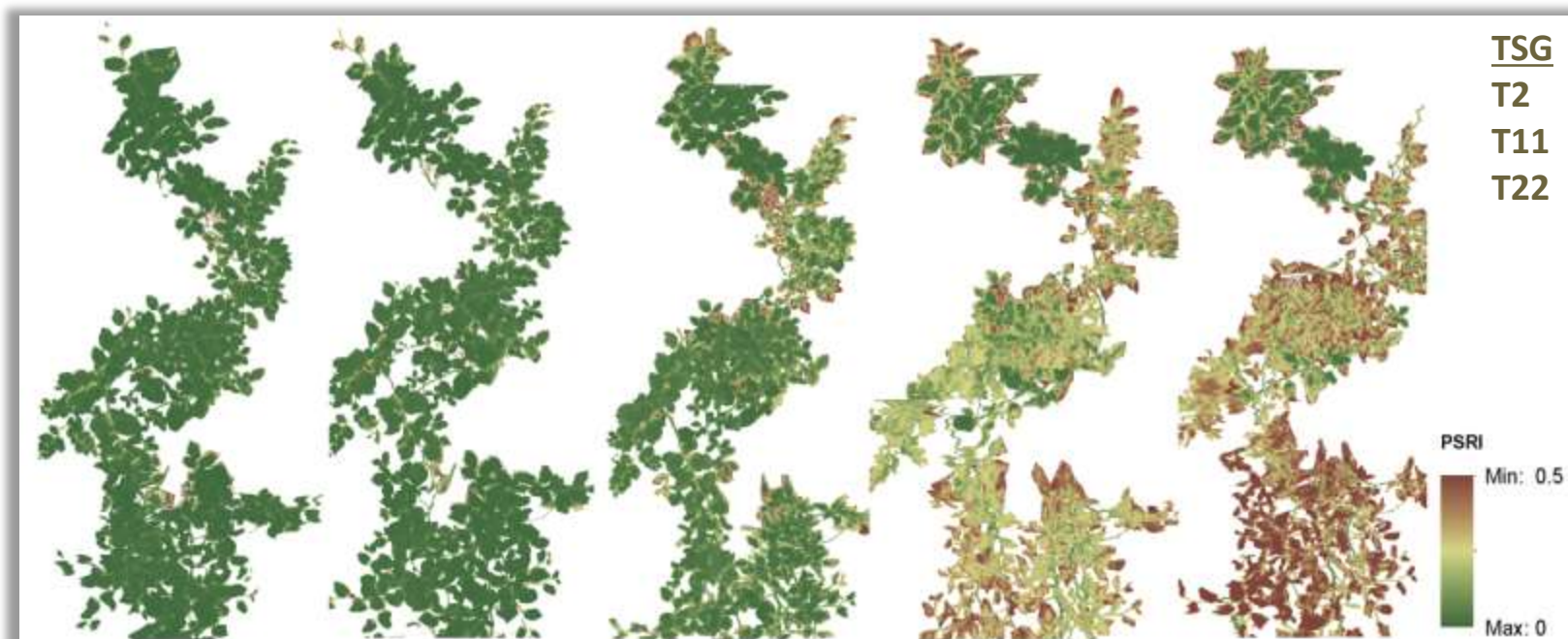
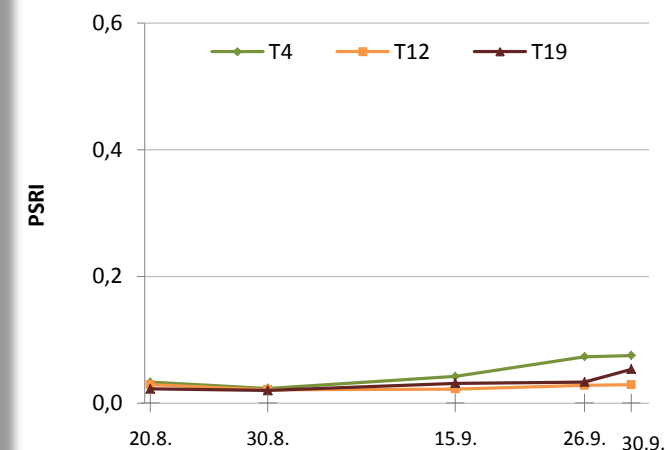
20.8.11

30.8.11

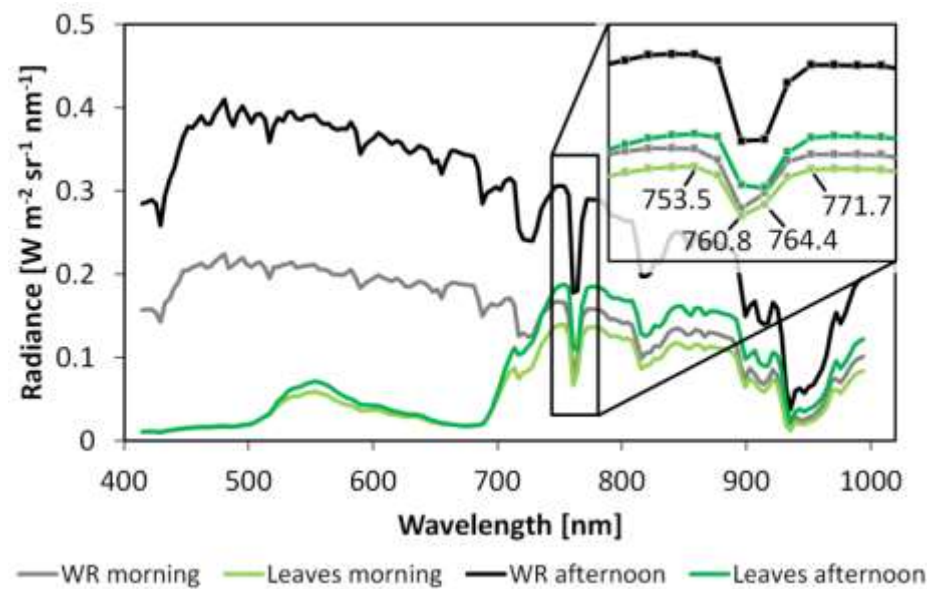
15.9.11

26.9.11

30.9.11

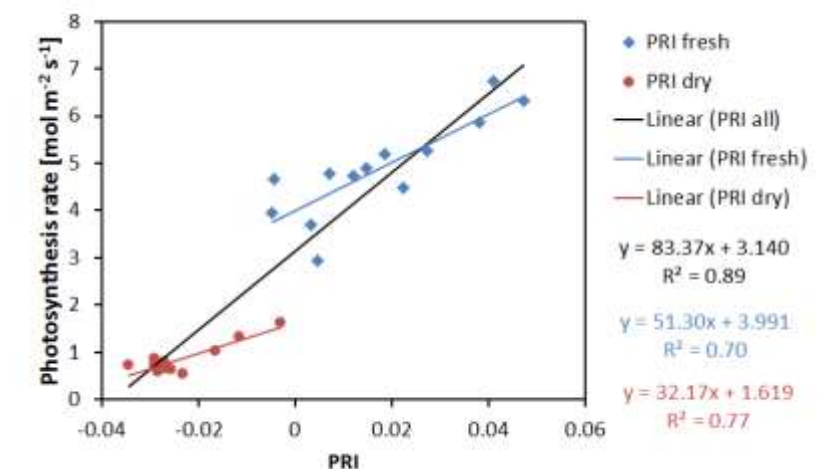
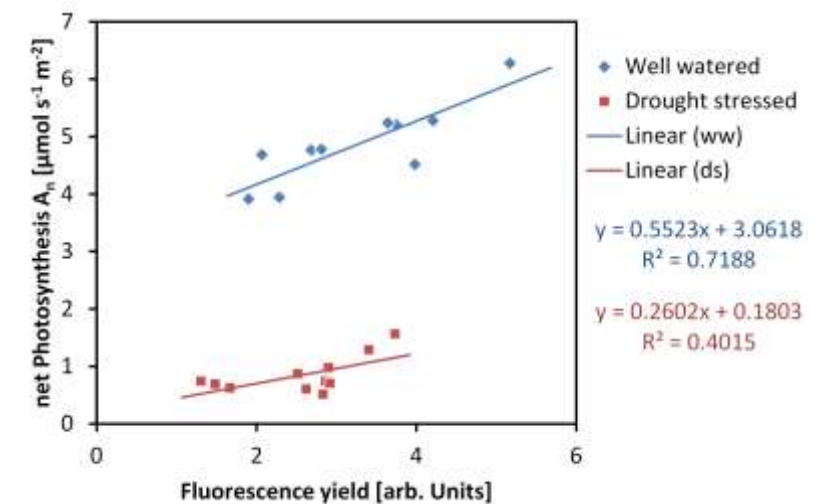
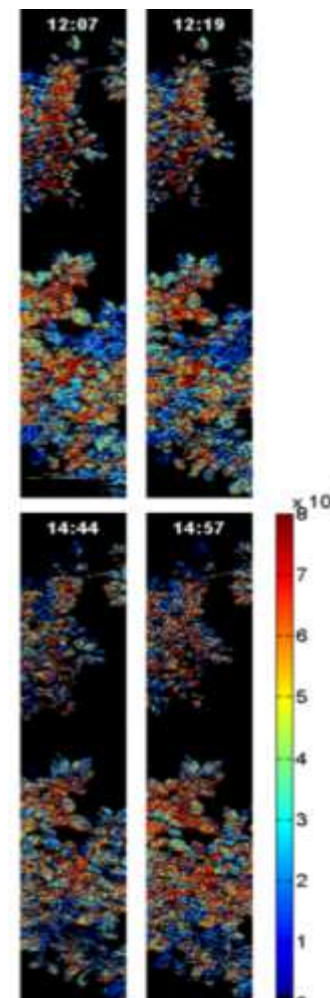
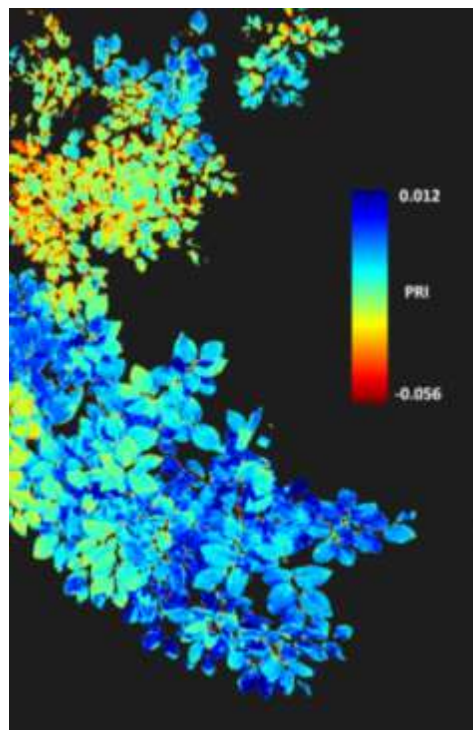


Spektralindizes - Plant Senescence Reflectance Index ($PSRI = (R_{680} - R_{500}) / (R_{750})$)



$$F_S = \frac{L_1 - \frac{E_1}{E_2} L_2}{1 - \frac{E_1}{E_2}}$$

$$F_{\text{Syield}} = \frac{F_S}{\text{APAR}}$$

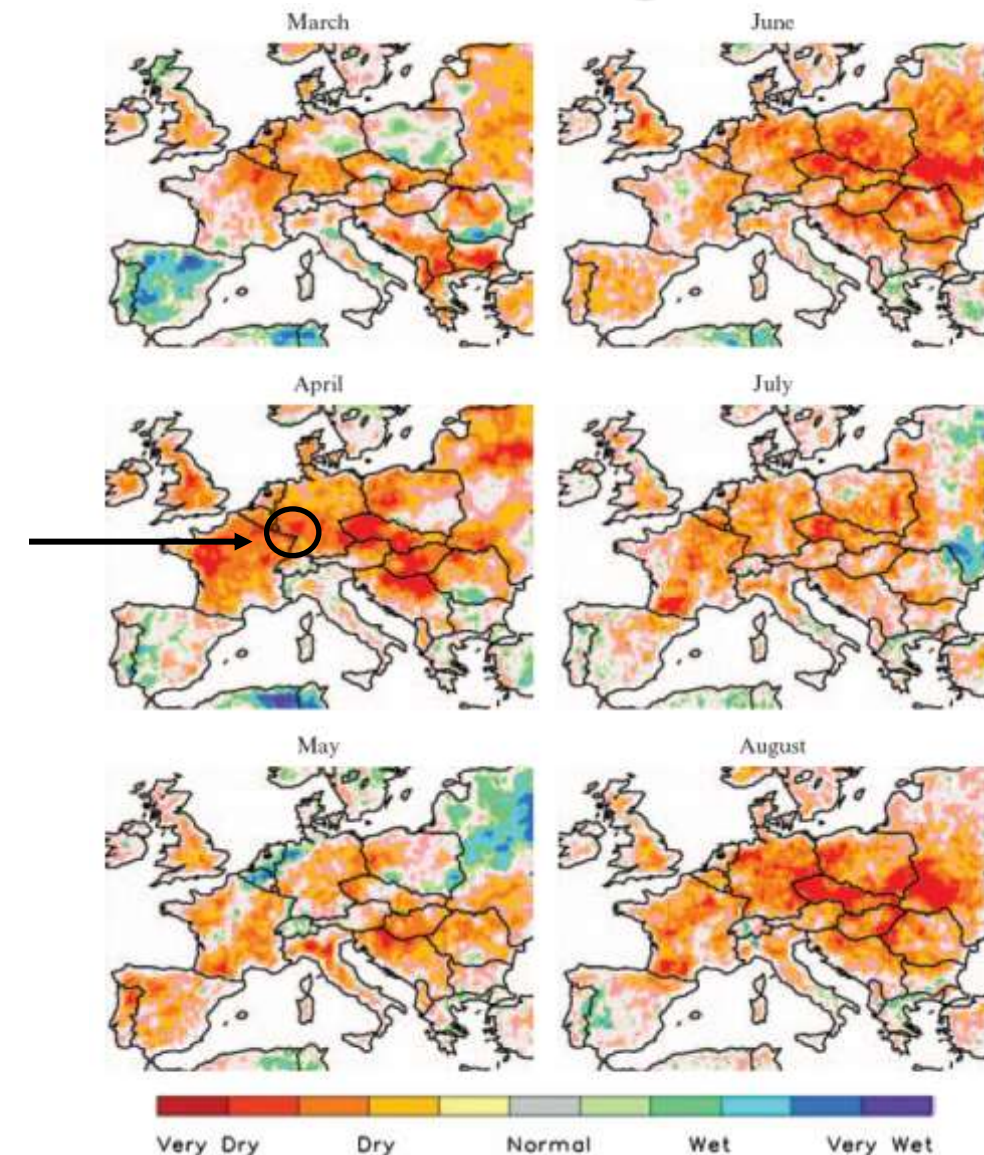


- H. Buddenbaum et al. (2014): IUFRO World Congress, Salt Lake City / ForestSat, Riva di Garda.

Summer 2003: An Opportunity for Studying the Impact of Extreme Drought Stress on Tree Species in Temperate Forests

- ... if the climate change simulations under future emissions scenarios prove to be realistic, the hot, dry summer of 2003 gives us an idea of things to come (Fink et al., 2004).
- The 2003 heat wave, by mimicking quite closely the possible course of summers in the latter part of the 21st century, can thus be used within certain limits as an analog to what may occur with more regularity in the future (Beniston, 2004).

Imsbach, 19 Sep 2003
© FAWF Trippstadt



Experimental Wetness Indicator derived from the SSM/I sensor (see <http://lwf.ncdc.noaa.gov/>), showing monthly anomalies for 2003 with respect to the base period 1988–2002 [from Gobron et al., 2005].

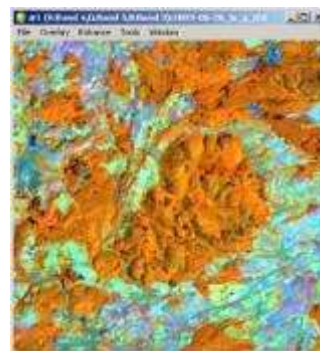
J. Hill, M. Stellmes, J. Stoffels, W. Werner, H. Buddenbaum, D. Frantz, & J. Langshausen, 2014, An Idea of Things to Come: Using Satellite Observations for Assessing Site-Specific Sensitivities of European Beech to Excessive Drought Conditions, IUFRO Salt Lake City

Landsat Data Availability „Donnersberg“ 2003

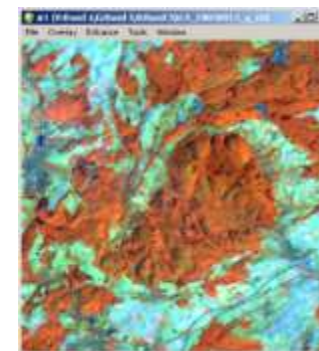
path 195 – row 26



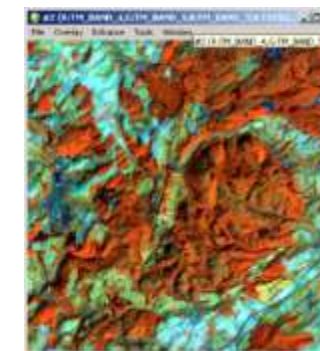
20030415



20030626



20030813



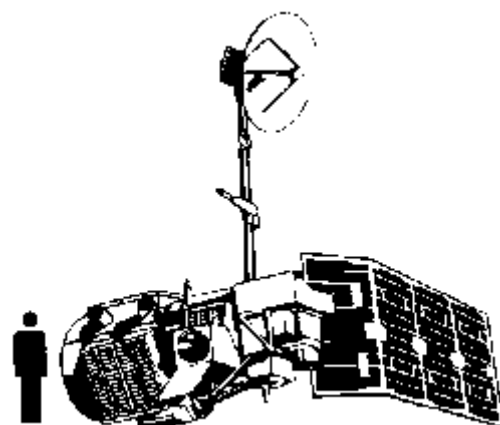
20030914



20031016



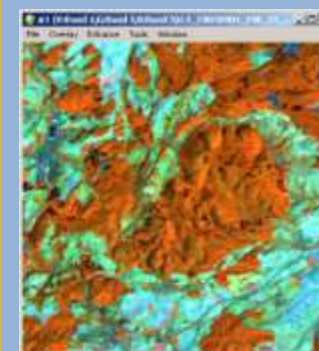
path 196 – row 25



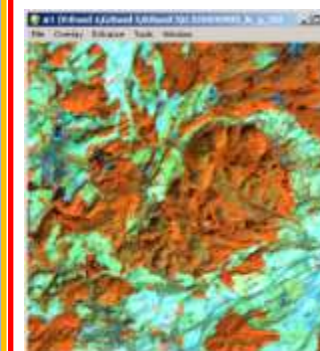
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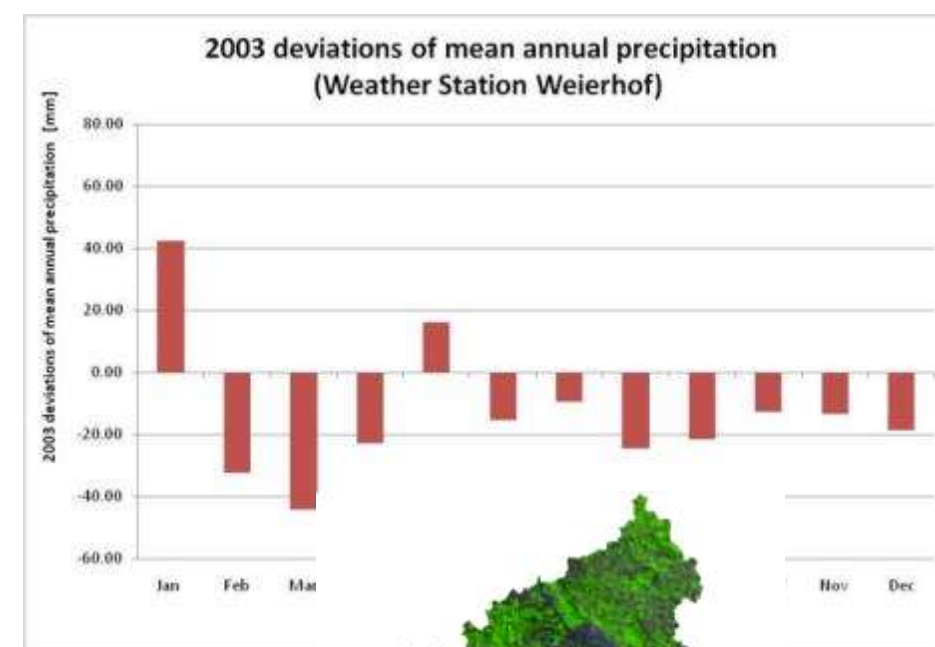
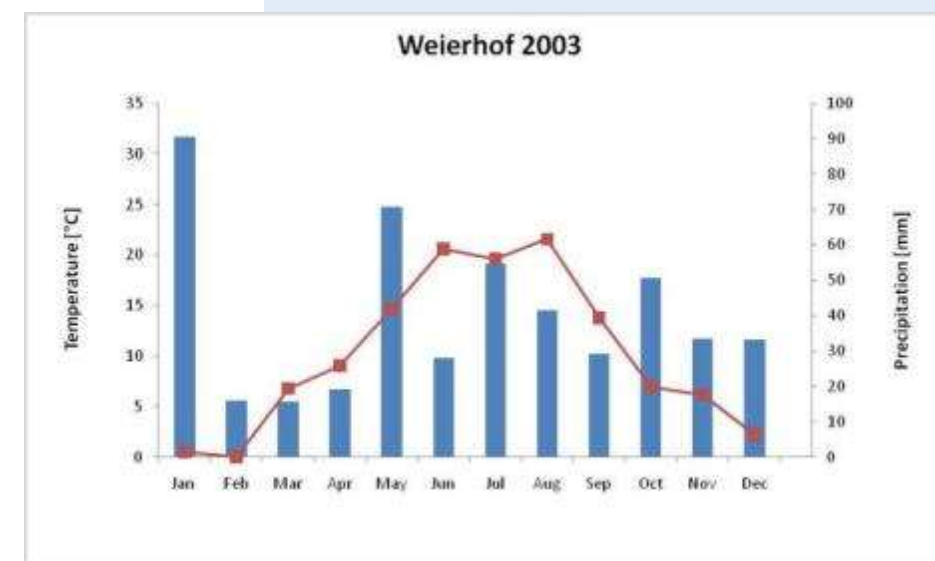
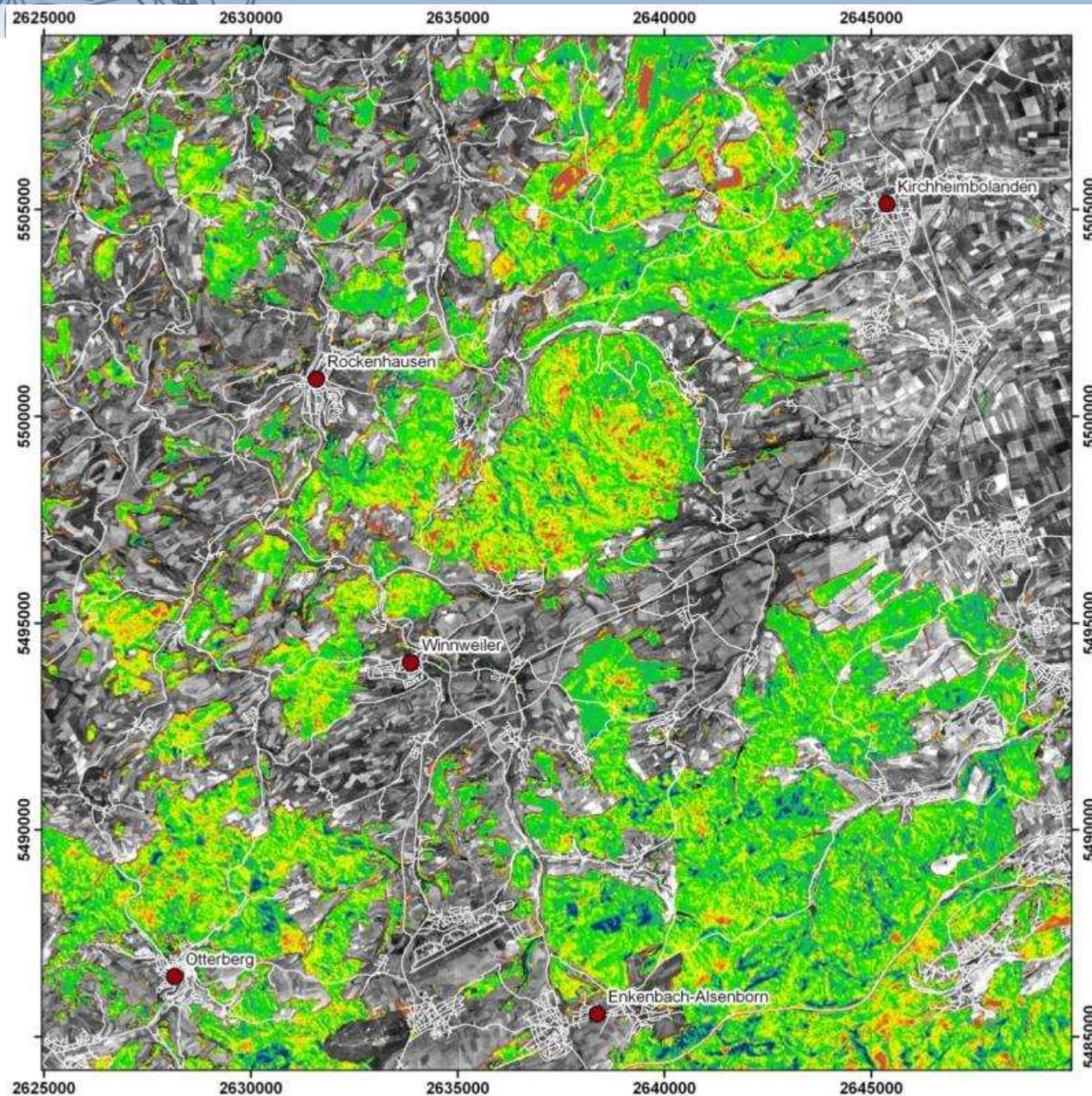


20030804

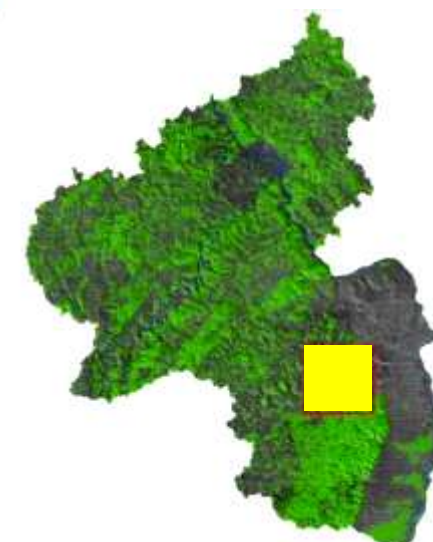
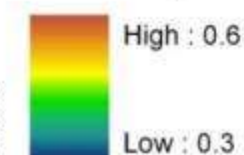


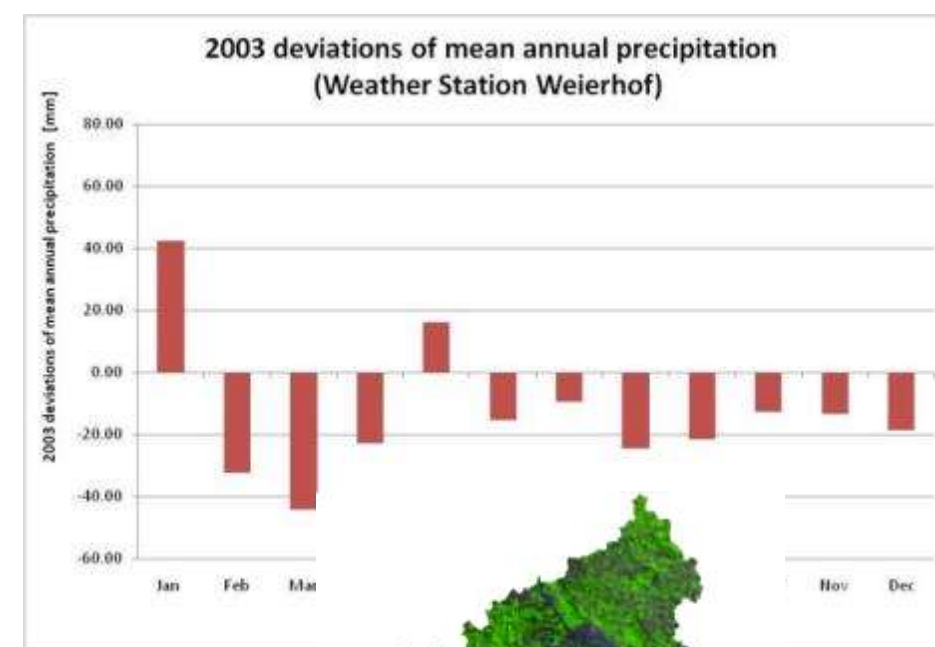
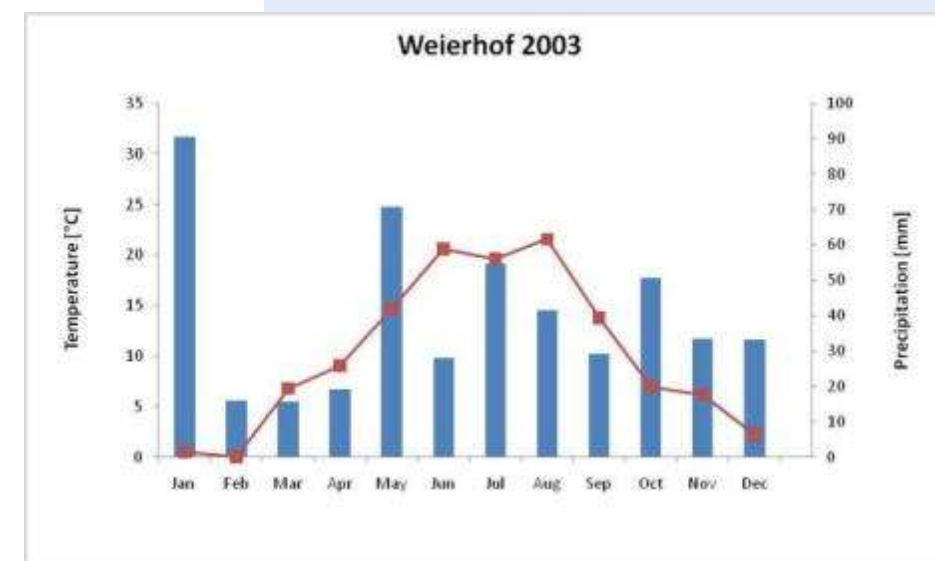
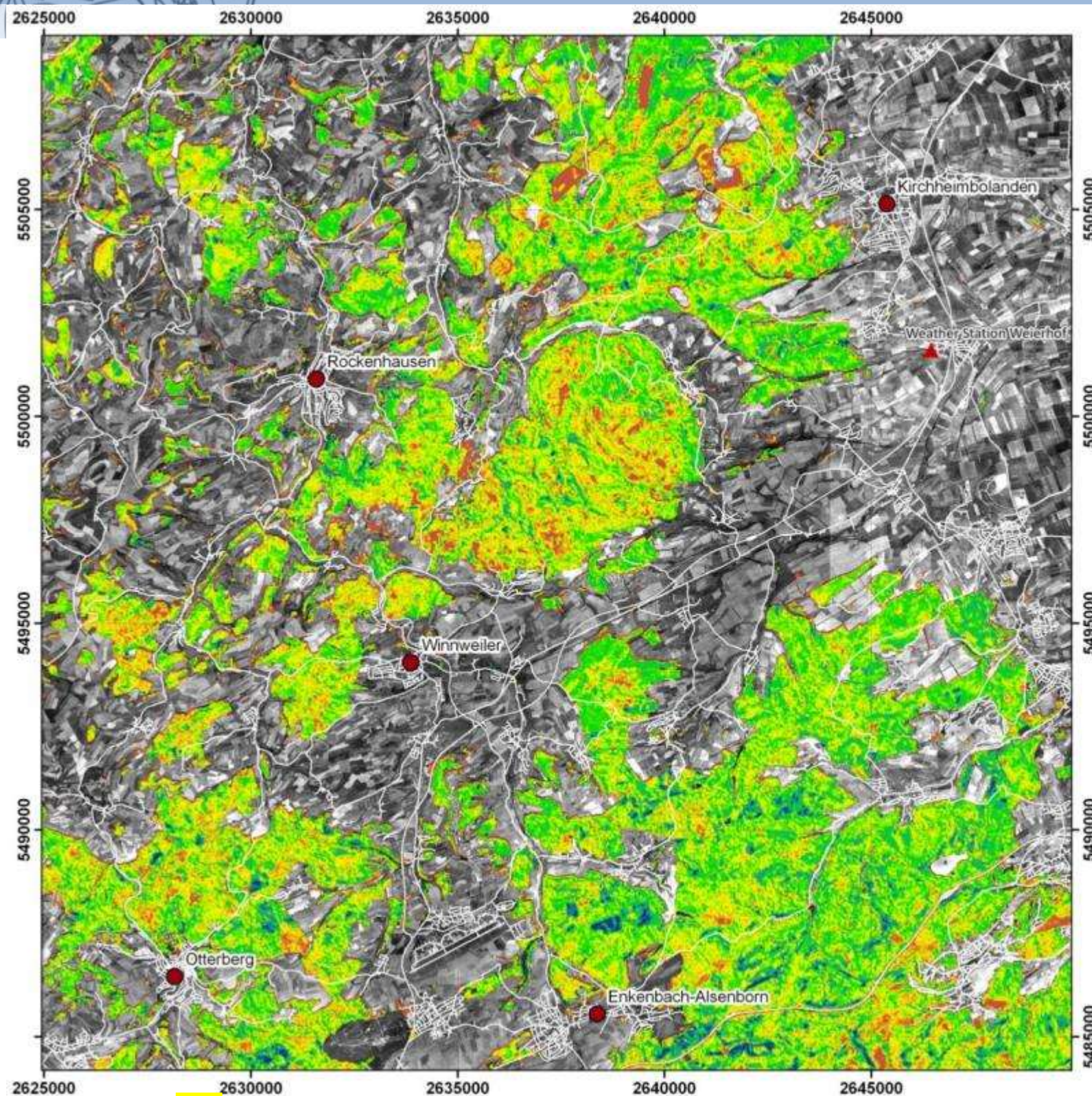
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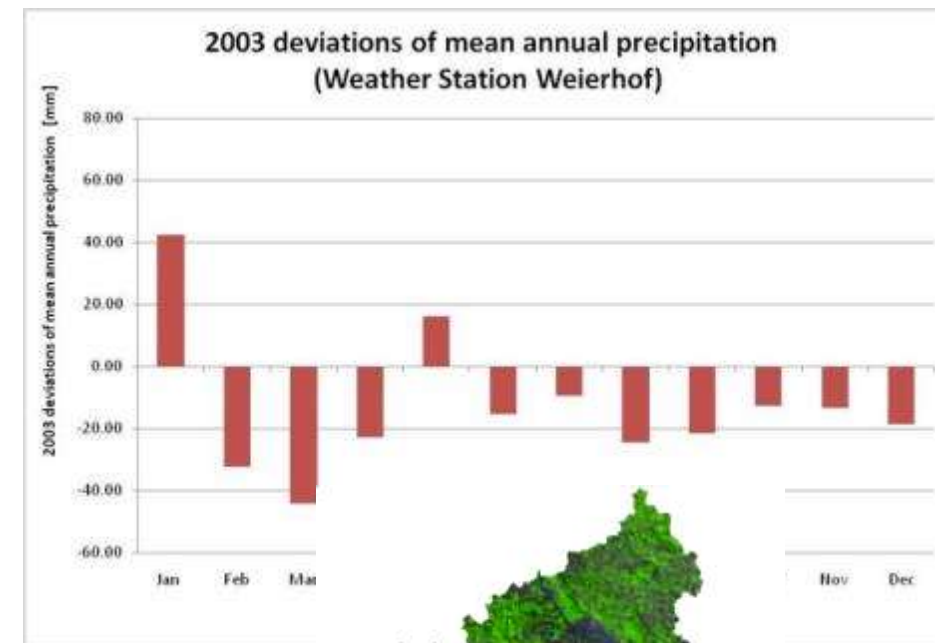
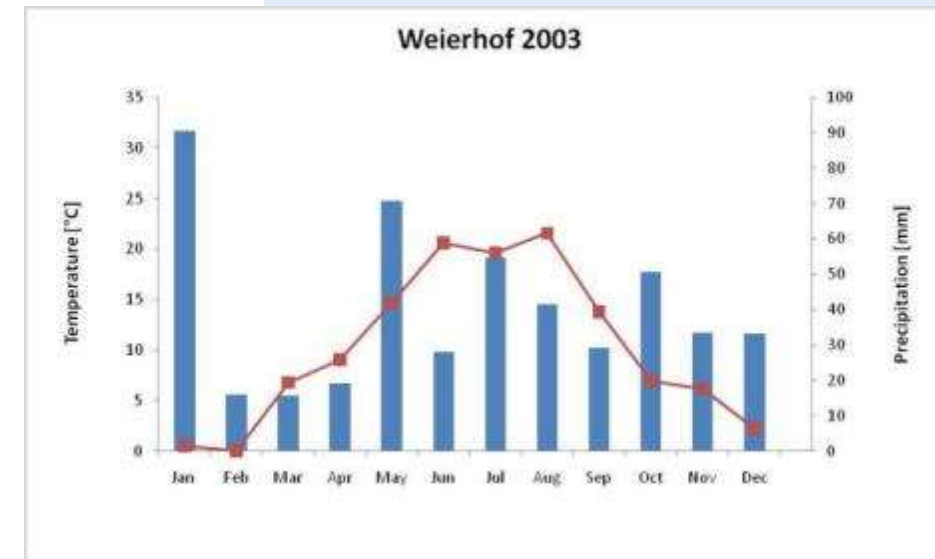
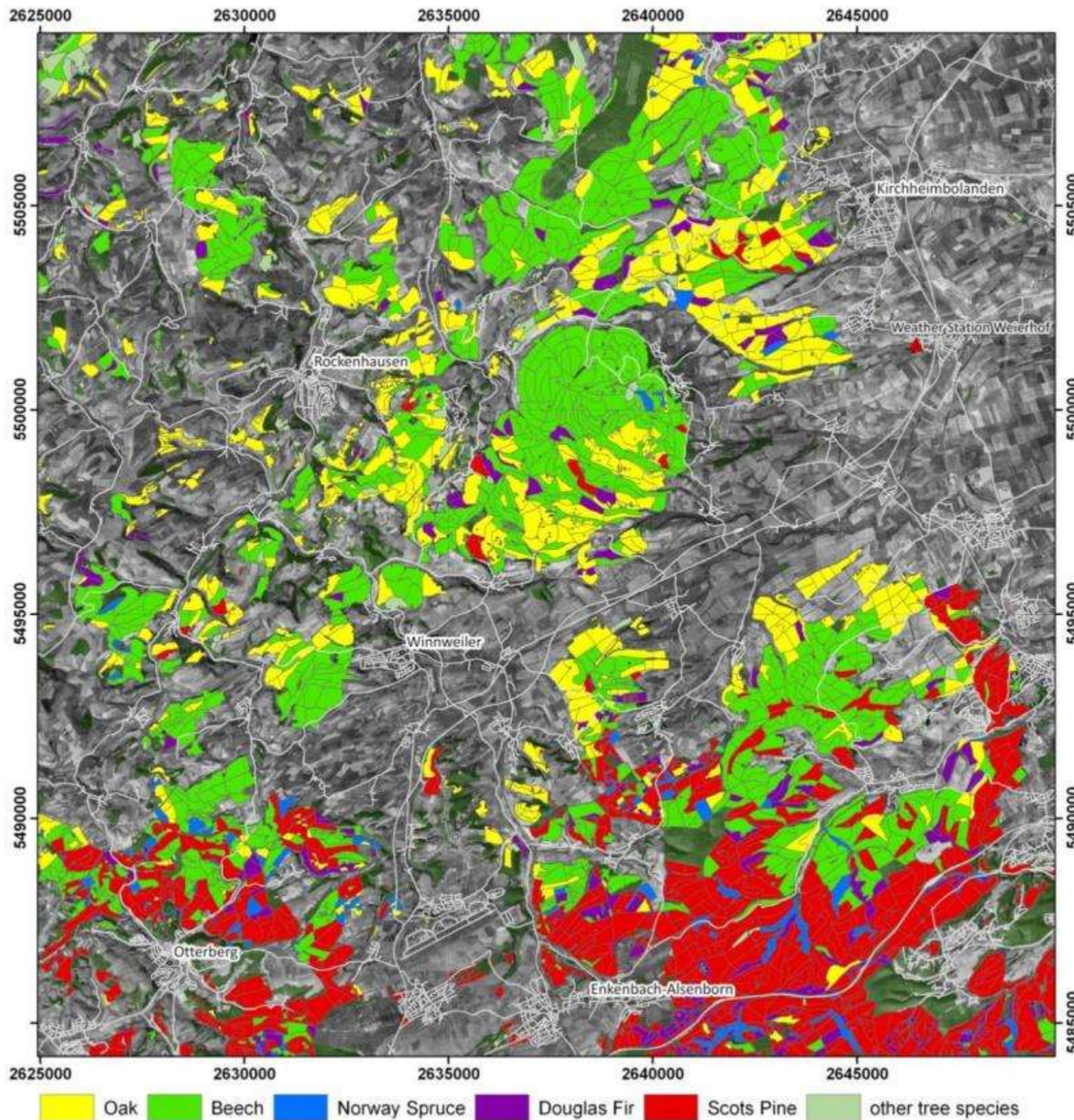




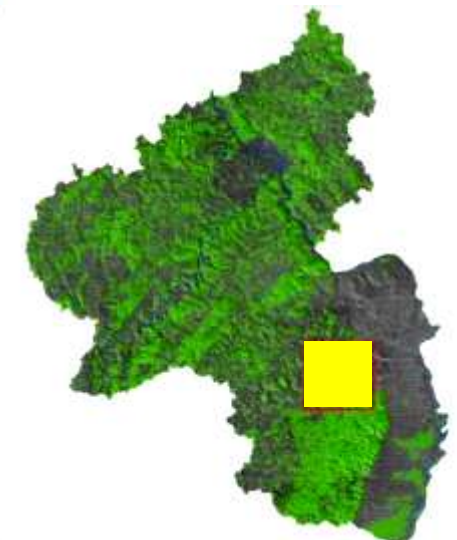
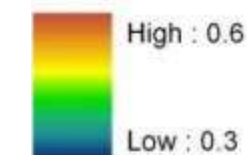
MSI July

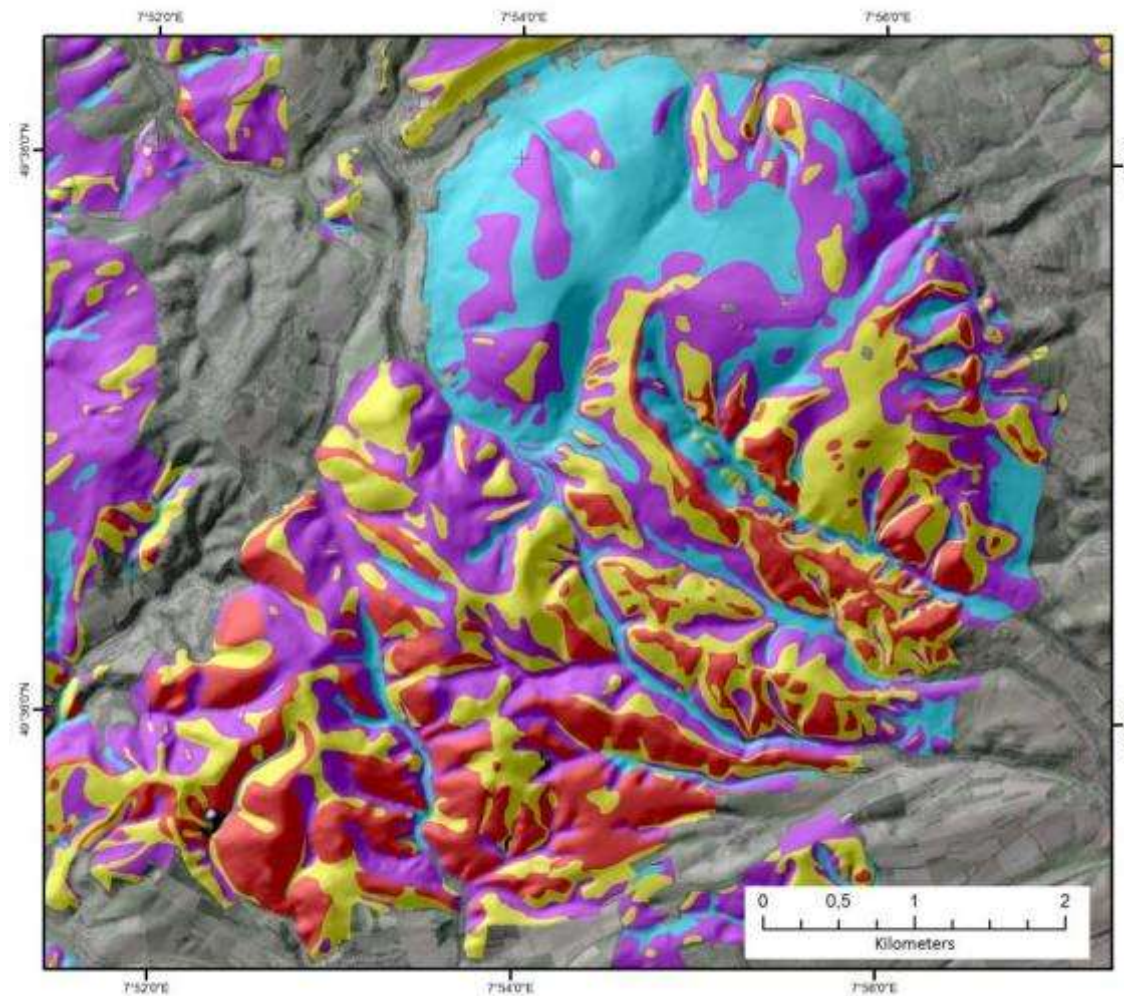






SI September

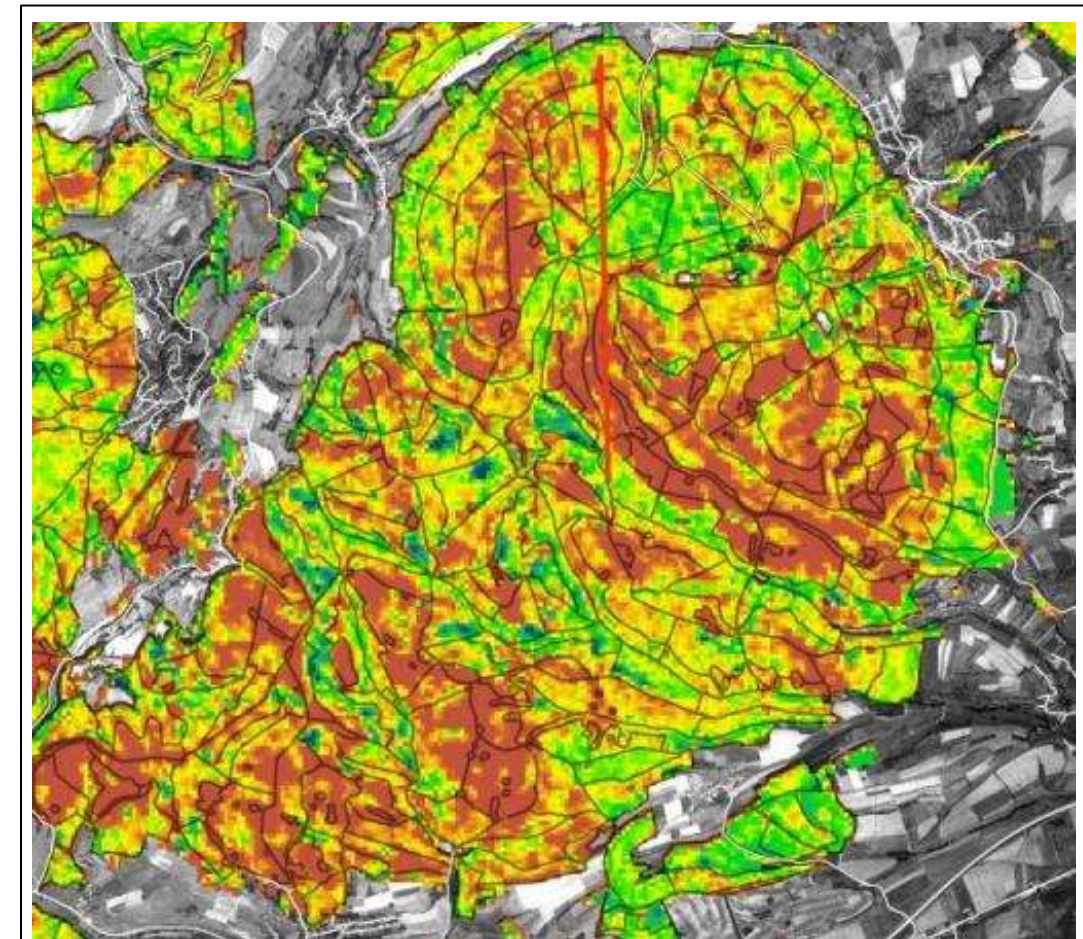




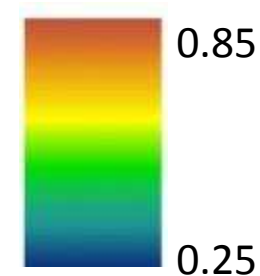
Soil moisture regime

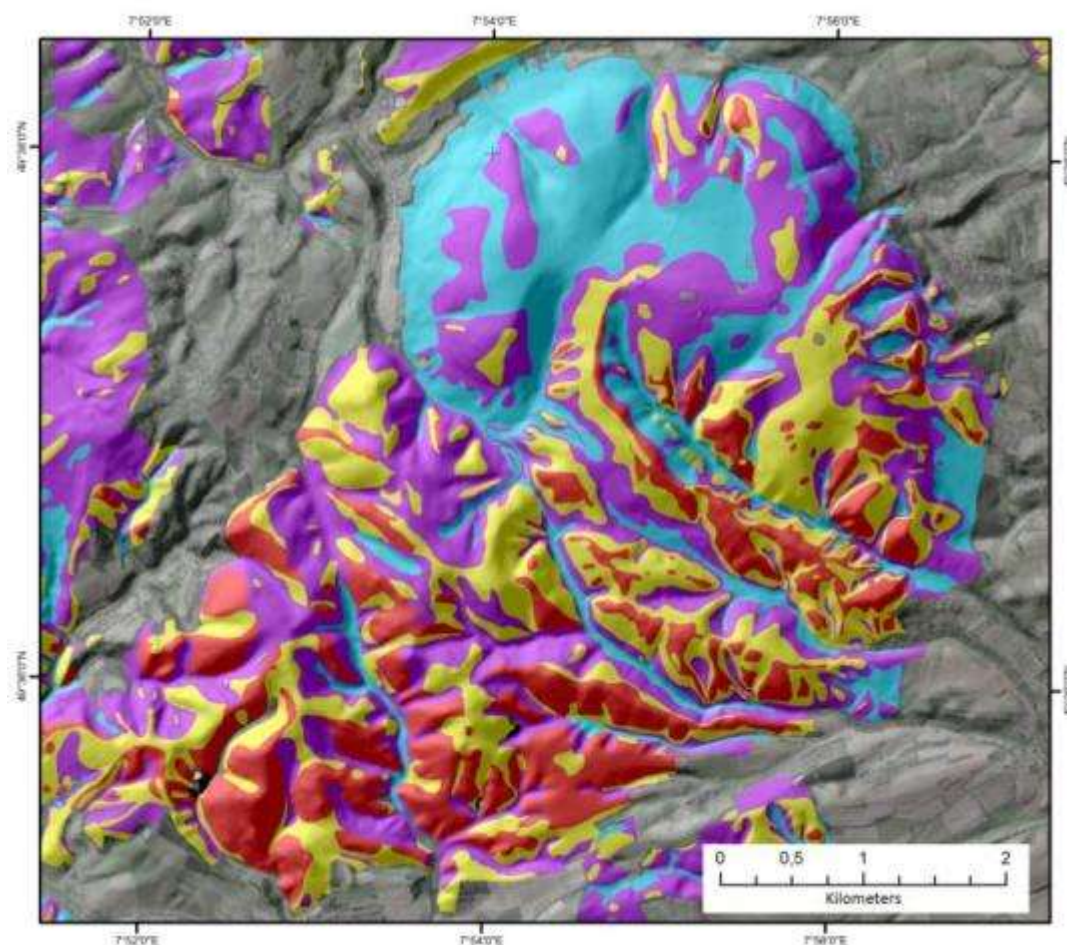


Source:
State Forest Service Rhineland-Palatinate
Ecological Site Classification



MSI 14 Sep 2003 (Landsat-5 TM)





Soil moisture regime



Source:
State Forest Service Rhineland-Palatinate
Ecological Site Classification

Very Dry Site Conditions

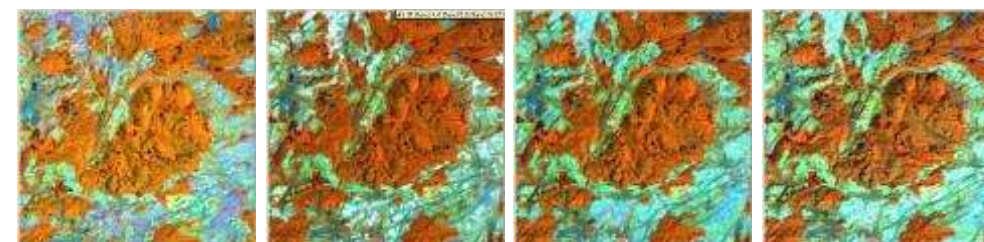
(2810 Observations)

Moisture Stress Index

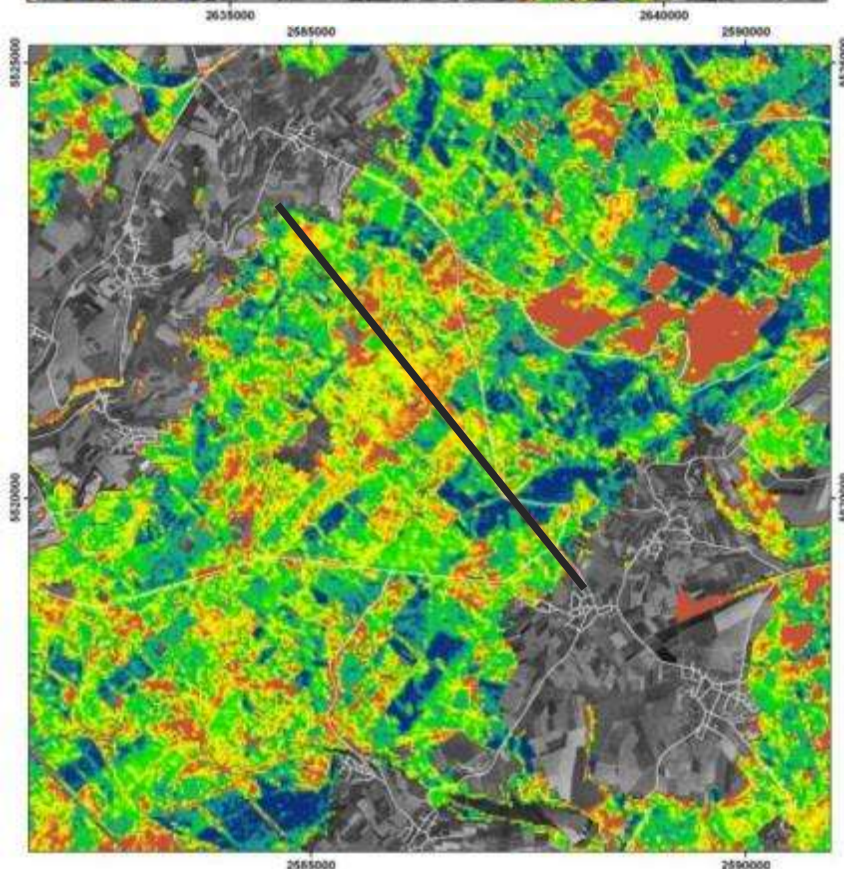
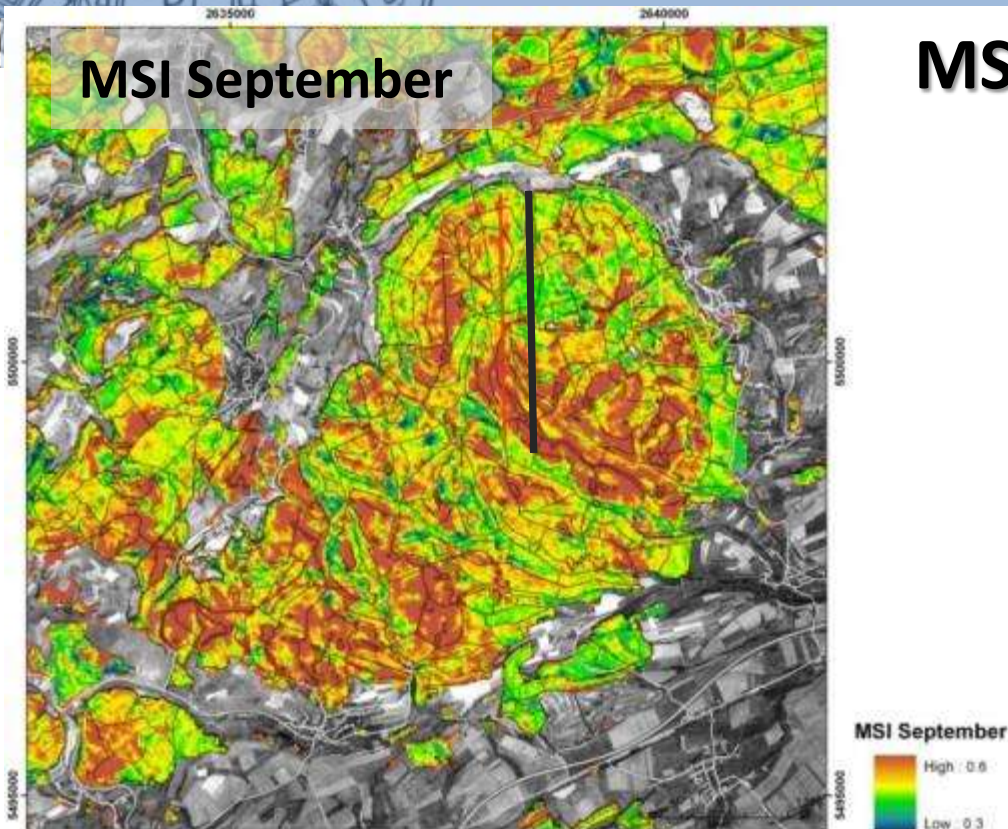


26 Jun 2003 19 Jul 2003 04 Aug 2003 09 Sep 2003

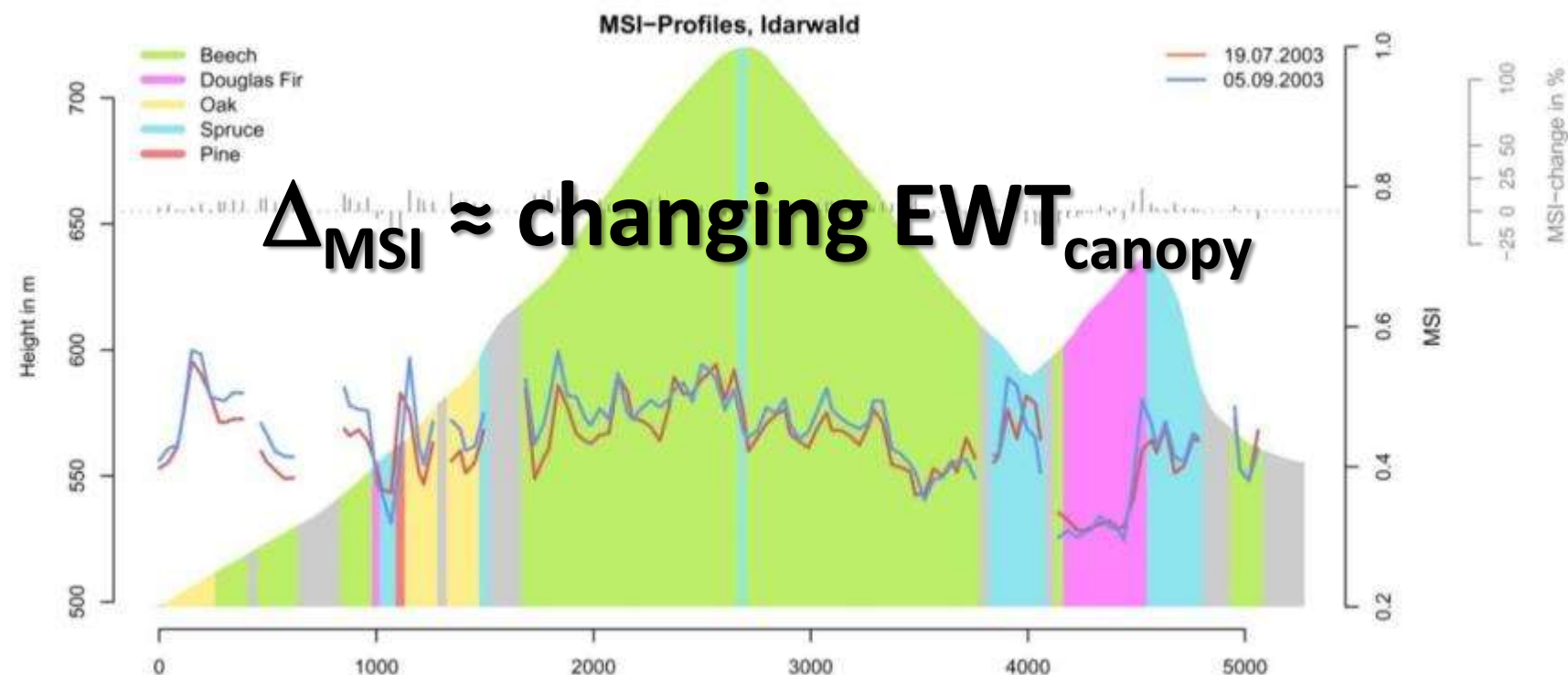
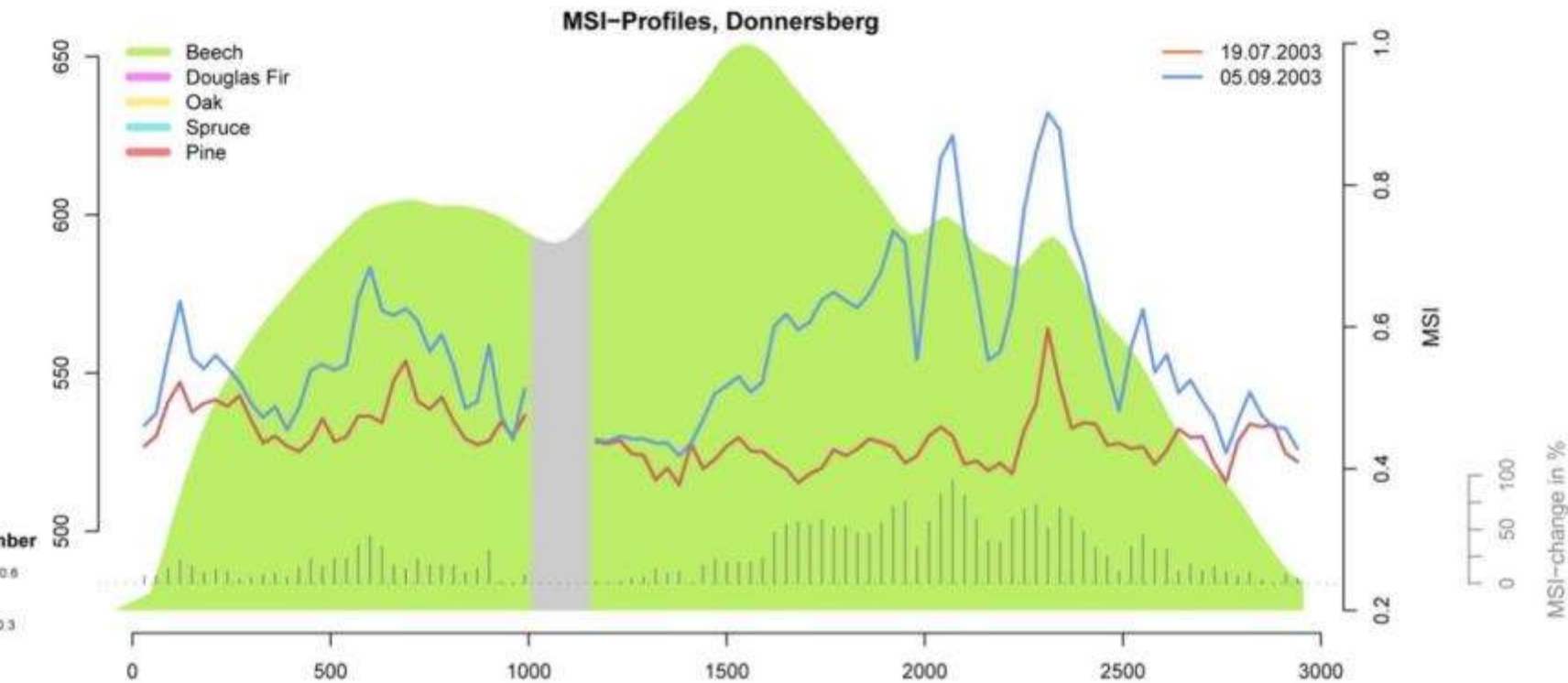
Landsat Acquisition Dates



MSI September



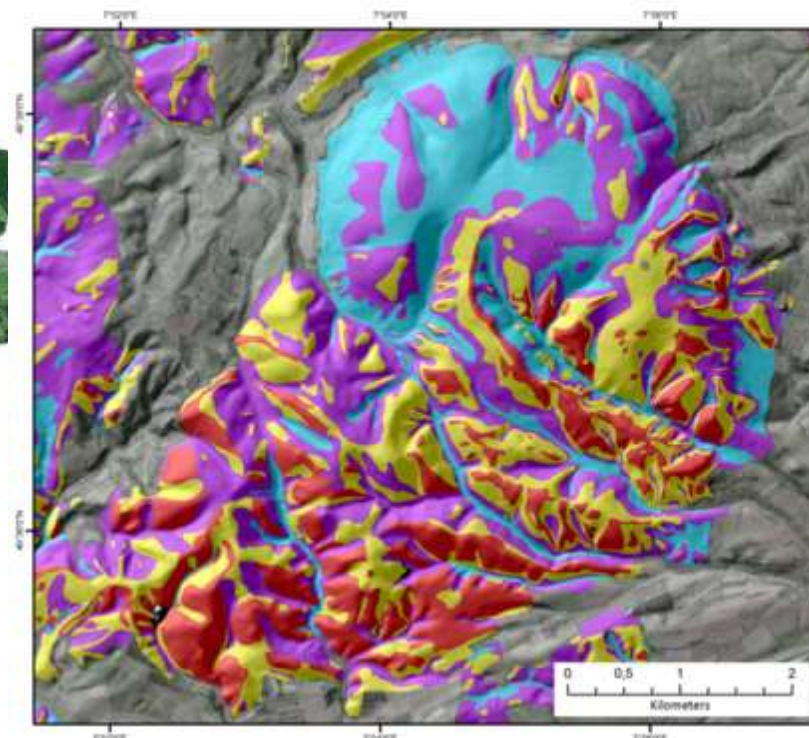
MSI-Profiles July vs. September 2003



$$\Delta_{\text{MSI}} \approx \text{changing EWT}_{\text{canopy}}$$



Donnersberg: Mosaic July 2014
(fast geo-correction of 11 HySpex flight lines)



Soil moisture regime



Source:
State Forest Service Rhineland-Palatinate
Ecological Site Classification



INTERNATIONAL SYMPOSIUM ON REMOTE SENSING OF ENVIRONMENT

POTENTIAL OF ENMAP FOR EARLY DETECTION OF DROUGHT STRESS IN A CENTRAL EUROPEAN FOREST

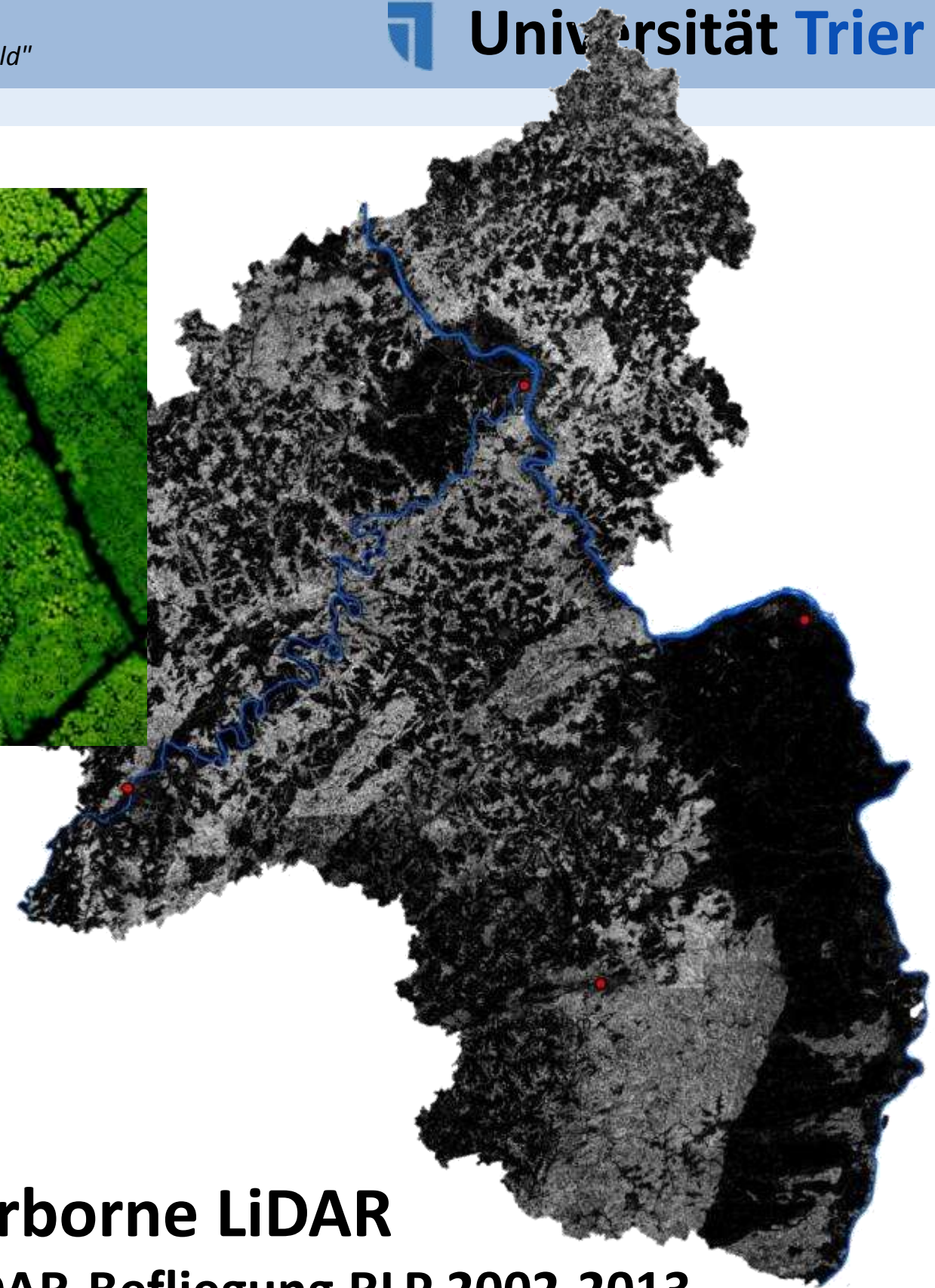
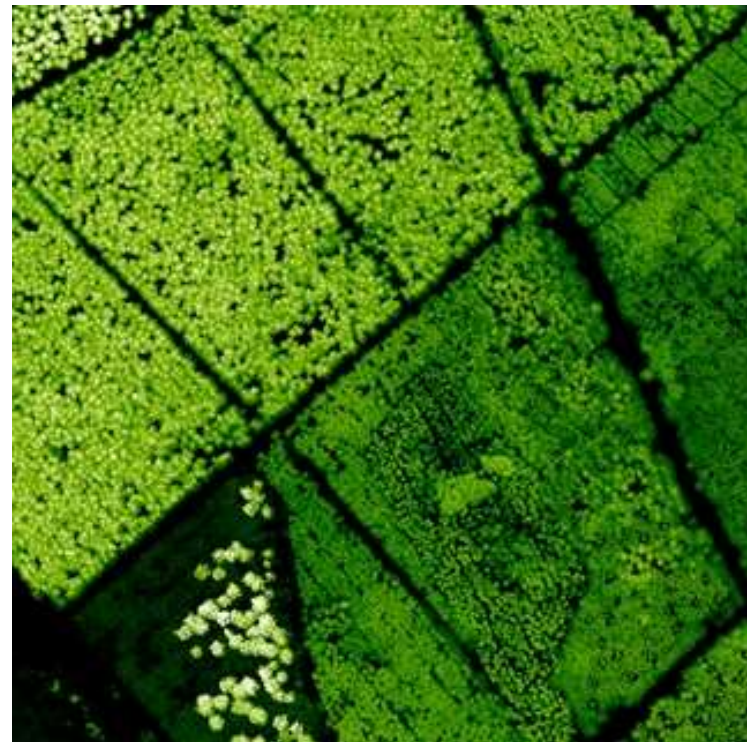
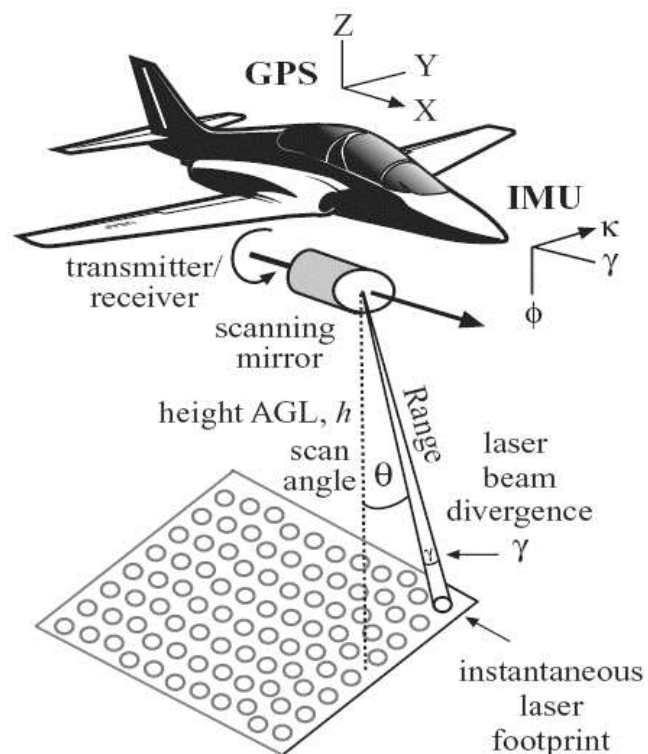
S. Dotzler^{a,*}, H. Buddenbaum^a, J. Hill^a, J. Stoffels^a

^a University of Trier, Environmental Remote Sensing and Geoinformatics, 54286 Trier, Germany – dotzler@uni-trier.de

THEME: Forests, Biodiversity and Terrestrial Ecosystems, Special Session: EnMAP.

KEY WORDS: Max. 6 keywords of your choice here: Hyperspectral, European Beech, water stress, site conditions

LIDAR Data Collection



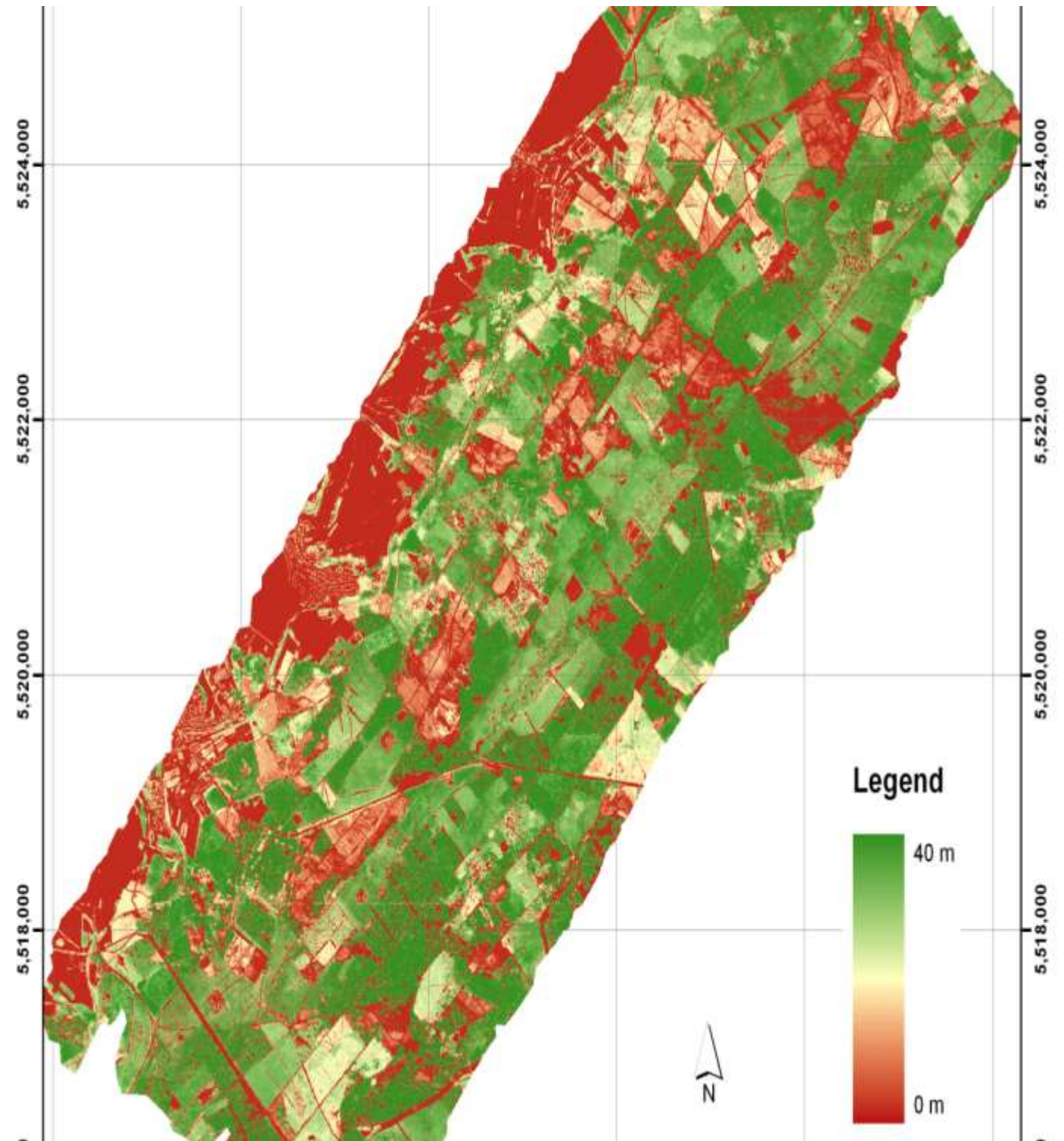
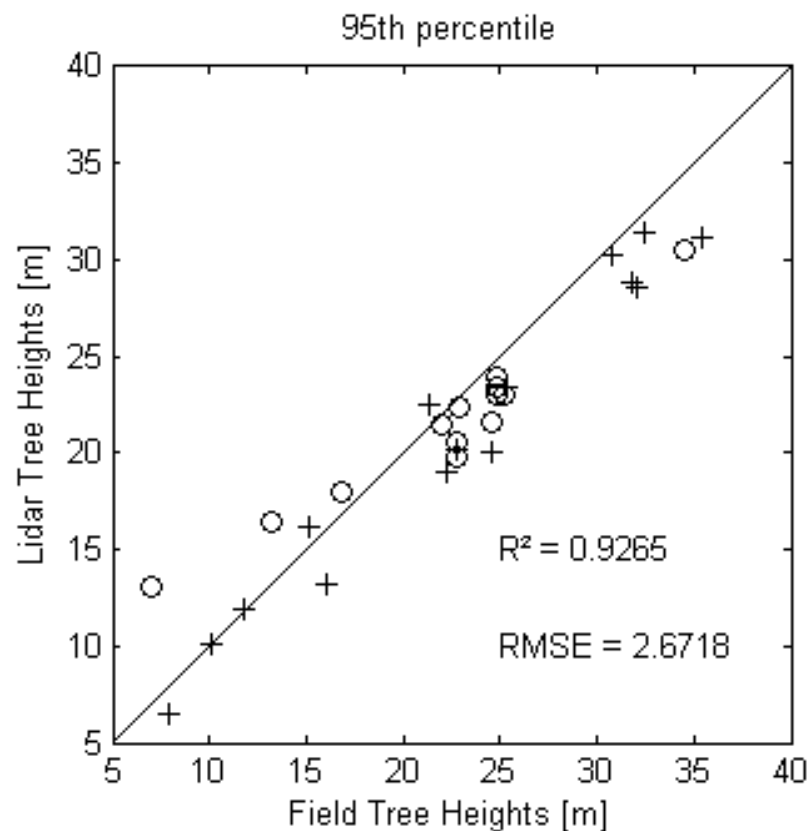
- Vollständige Abdeckung der Landesfläche
- Nutzung des normalisierten Kronenmodells
- Unterschiedliche Sensoren und Punktdichten

Airborne LiDAR

LiDAR-Befliegung RLP 2002-2013

Baumhöhen im Untersuchungsgebiet Idarwald/Morbach

Gelände- und Lidarschätzung
der Baumhöhen



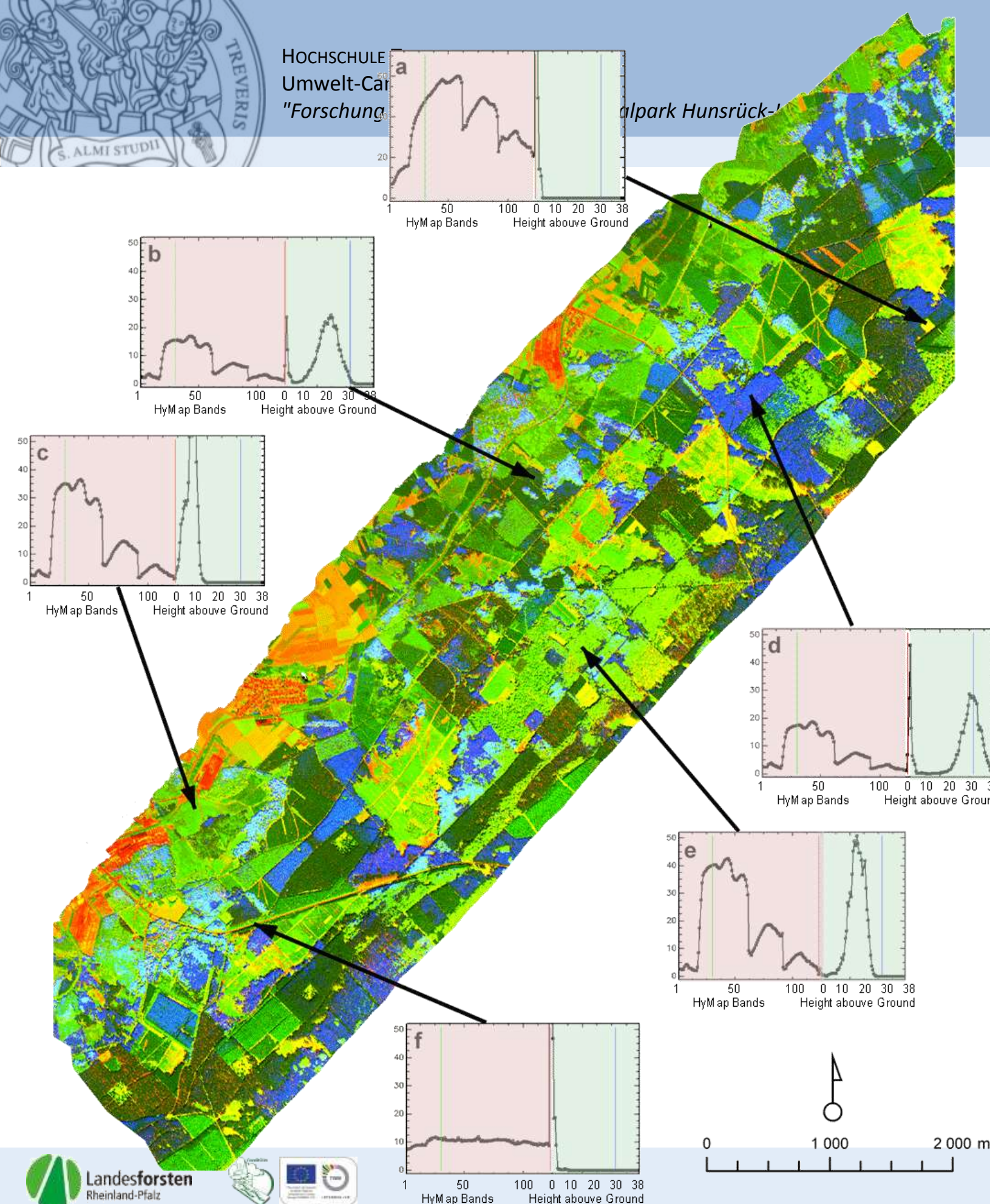
Idarwald ALS & Hyperspectral Imaging

122 Hymap bands combined with 76 fullwave LiDAR bands.

Combined spectra show reflectance properties and stand structure.

Forest stands with nearly identical reflectance spectra can be discriminated thanks to Lidar spectrum (b-d and c-e), while in non-forested areas Lidar spectrum is featureless (a-f).

H. Buddenbaum, S. Seeling & J. Hill (2013): Fusion of full waveform LiDAR and imaging spectroscopy remote sensing data for the characterization of forest stands. *International Journal of Remote Sensing*, 34 (13): 4511-4524.



Fractional Cover can be estimated using

- ✓ Full waveforms
- ✓ First/Intermediate/Last/Ground pulses
- ✓ First/Ground pulse

⇒ Different FC-models
(e.g. Hopkins & Chasmer, 2009)

$$FC_{\text{Lidar(BL)}} = 1 - \left(\frac{\left(\frac{\sum I_{\text{GroundSingle}}}{\sum I_{\text{Total}}} \right) + \sqrt{\frac{\sum I_{\text{GroundLast}}}{\sum I_{\text{Total}}}}}{\left(\frac{\sum I_{\text{First}} + \sum I_{\text{Single}}}{\sum I_{\text{Total}}} \right) + \sqrt{\frac{\sum I_{\text{Intermediate}} + \sum I_{\text{Last}}}{\sum I_{\text{Total}}}}} \right)$$

⇒ From fractional cover to LAI

$$LAI = \frac{-1}{b \cdot G(\theta = 0^\circ) \cdot \Omega} \cdot \frac{\ln(a_0 - FC)}{a_0}$$

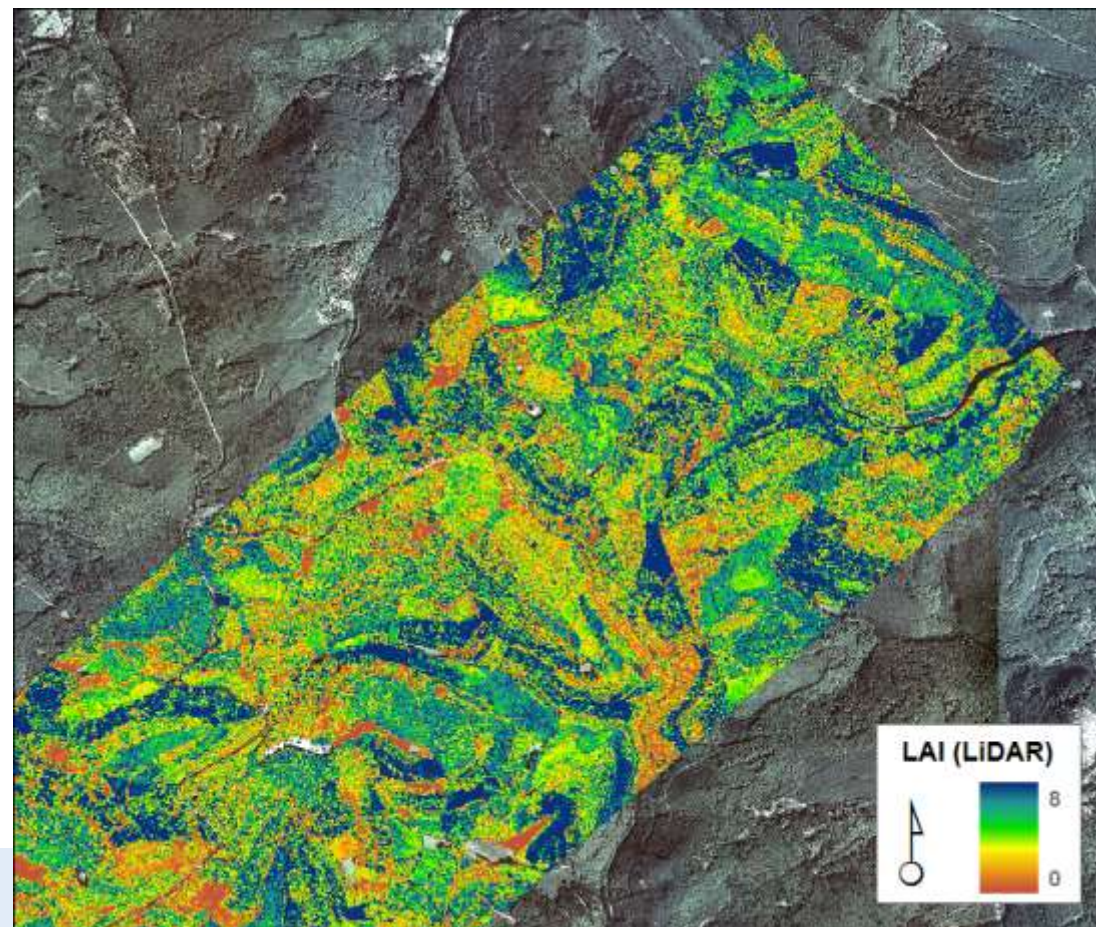
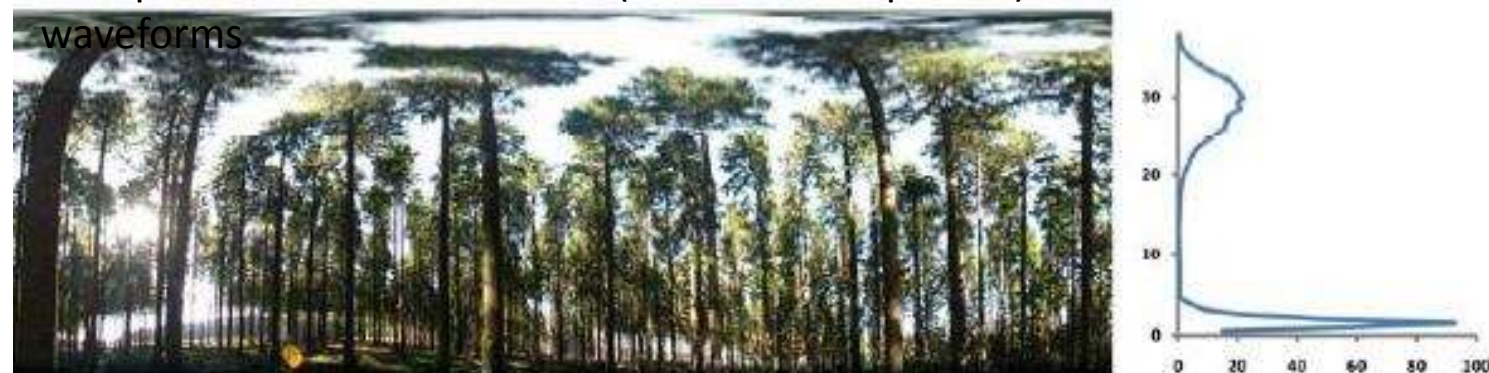
Verger et al. (2009):

$b = 0.945$, $G = 0.5$, $a_0 = 1.05$

$\Omega = 1$ for deciduous, 0.6 for coniferous stands



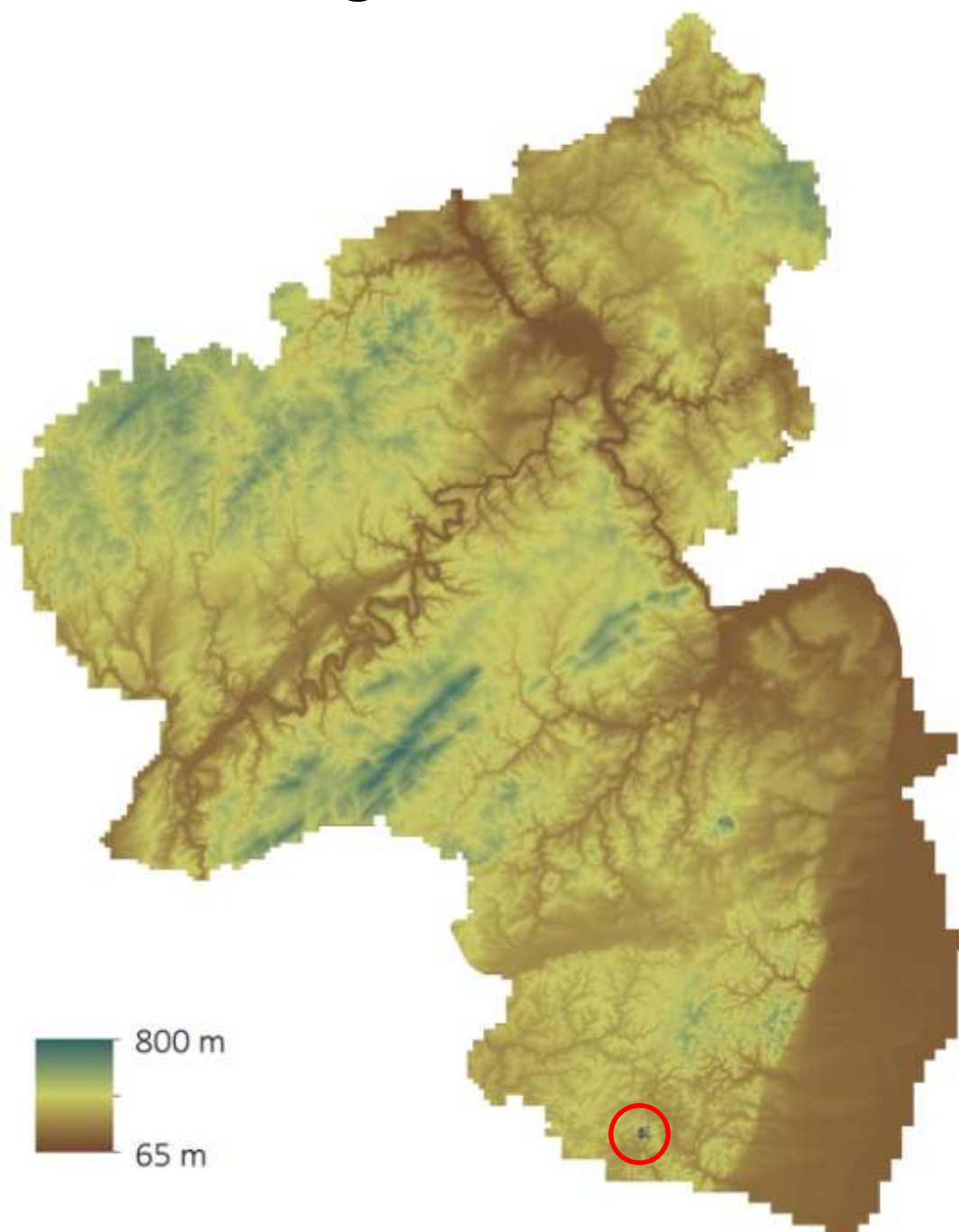
Canopies of different structure (unrolled hemiphotos) and associated waveforms



LAI map for Northern Merzalben region, derived from airborne LiDAR

Laserscanning-Testdatensatz 2014

Baumhöhen (1m Auflösung)

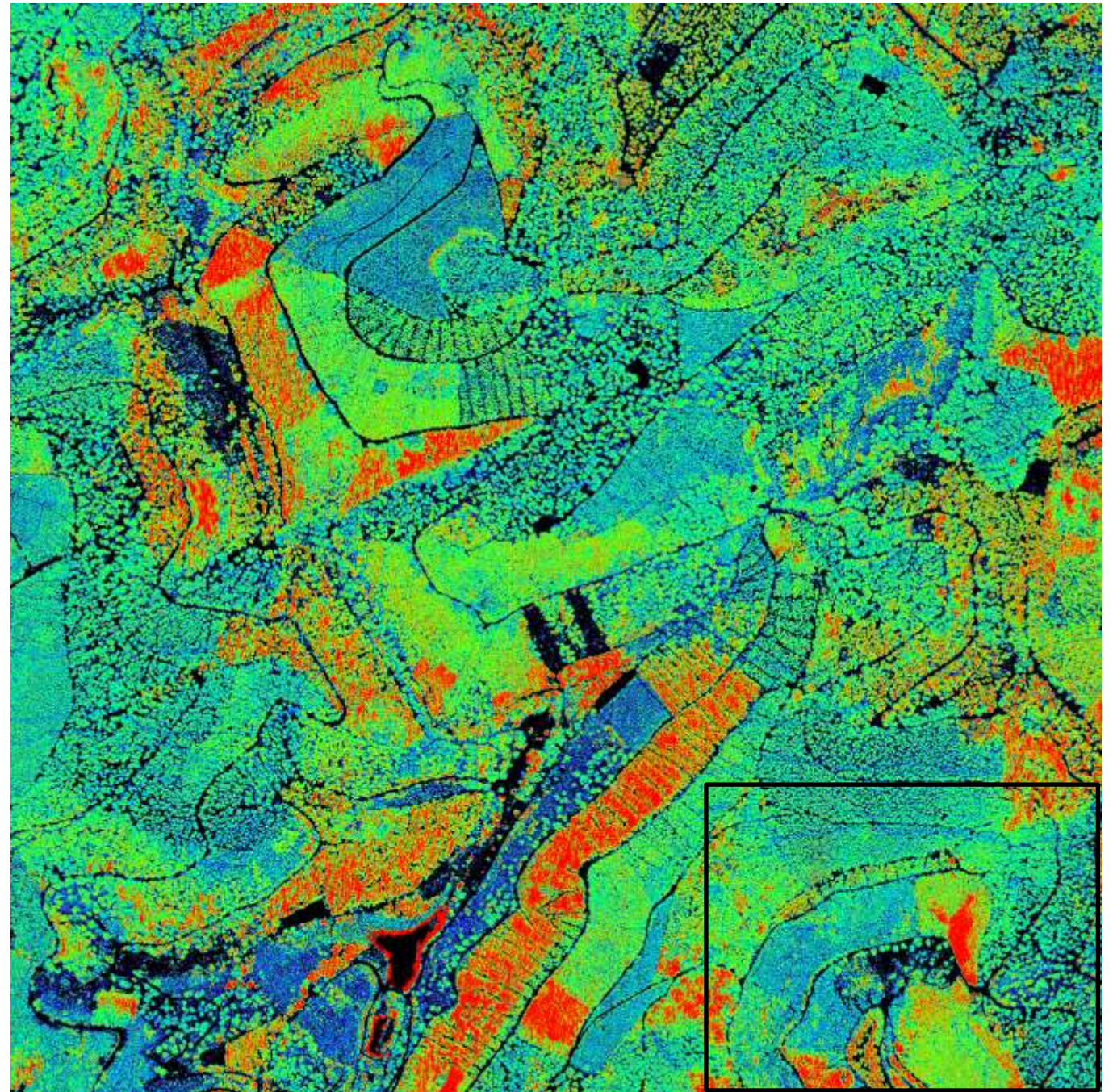
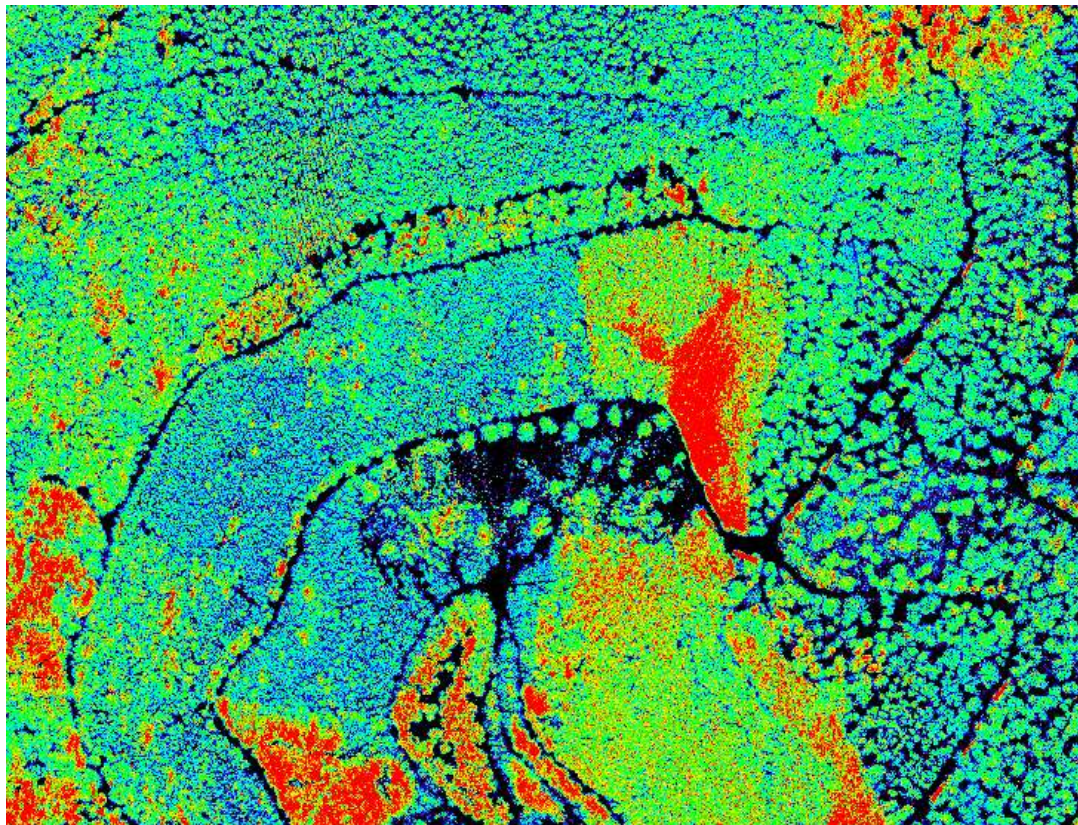


Buddenbaum, Henning (2010) Charakterisierung von Forstbeständen mit Hilfe von Laserscanning und Reflexionsmodellierung. Dissertation

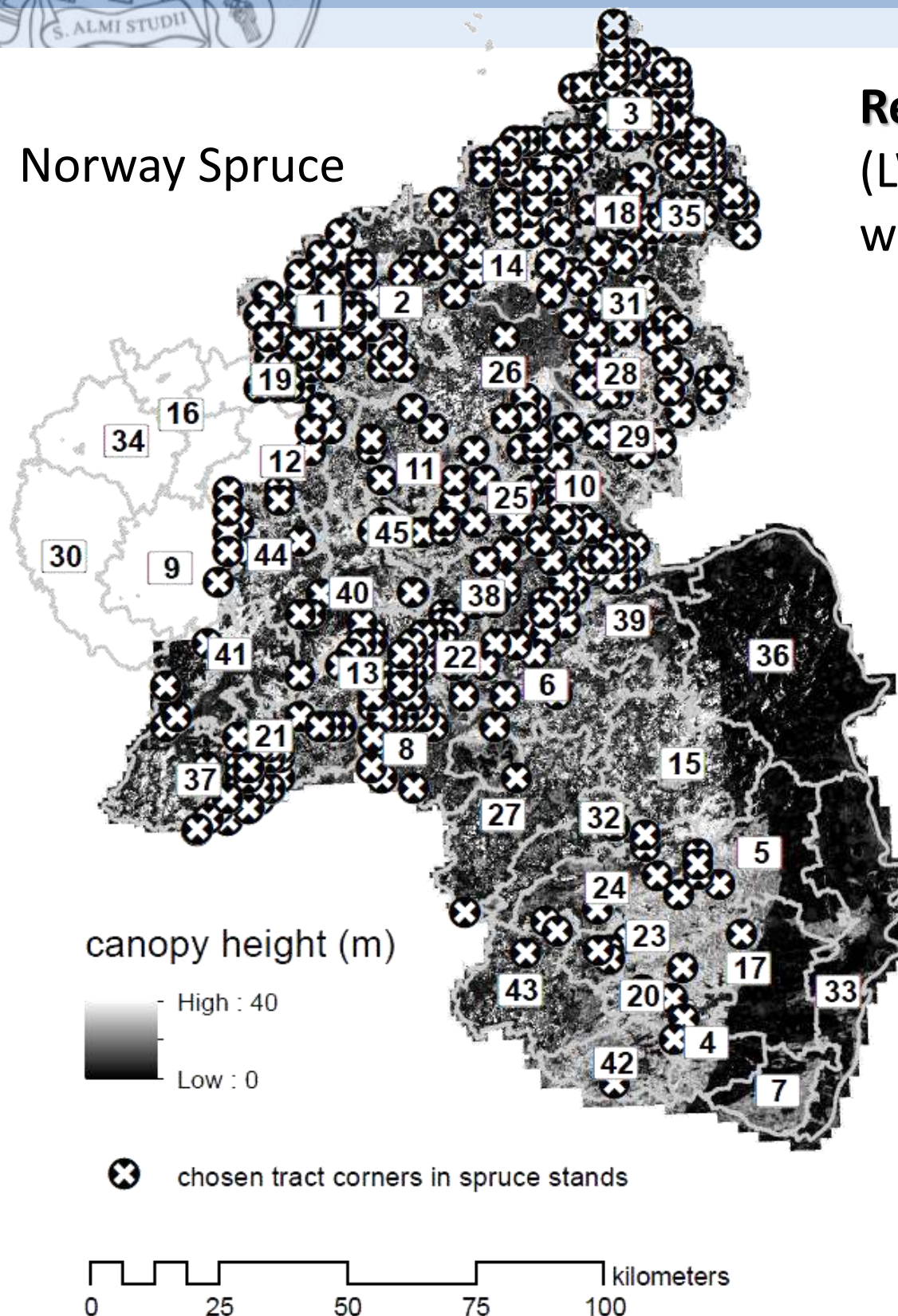
<http://ubt.opus.hbz-nrw.de/volltexte/2011/615/>

Proportional Tree Cover

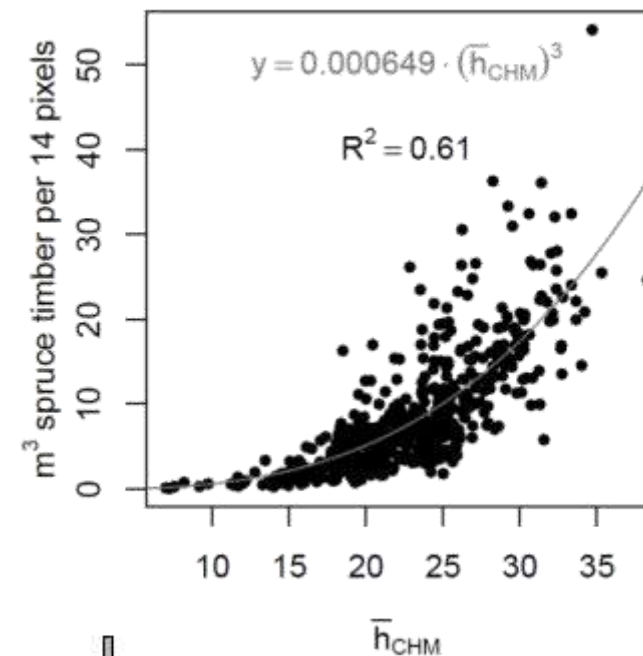
- Durch die hohe Punktdichte konnte der Bedeckungsgrad in 1m Auflösung berechnet werden



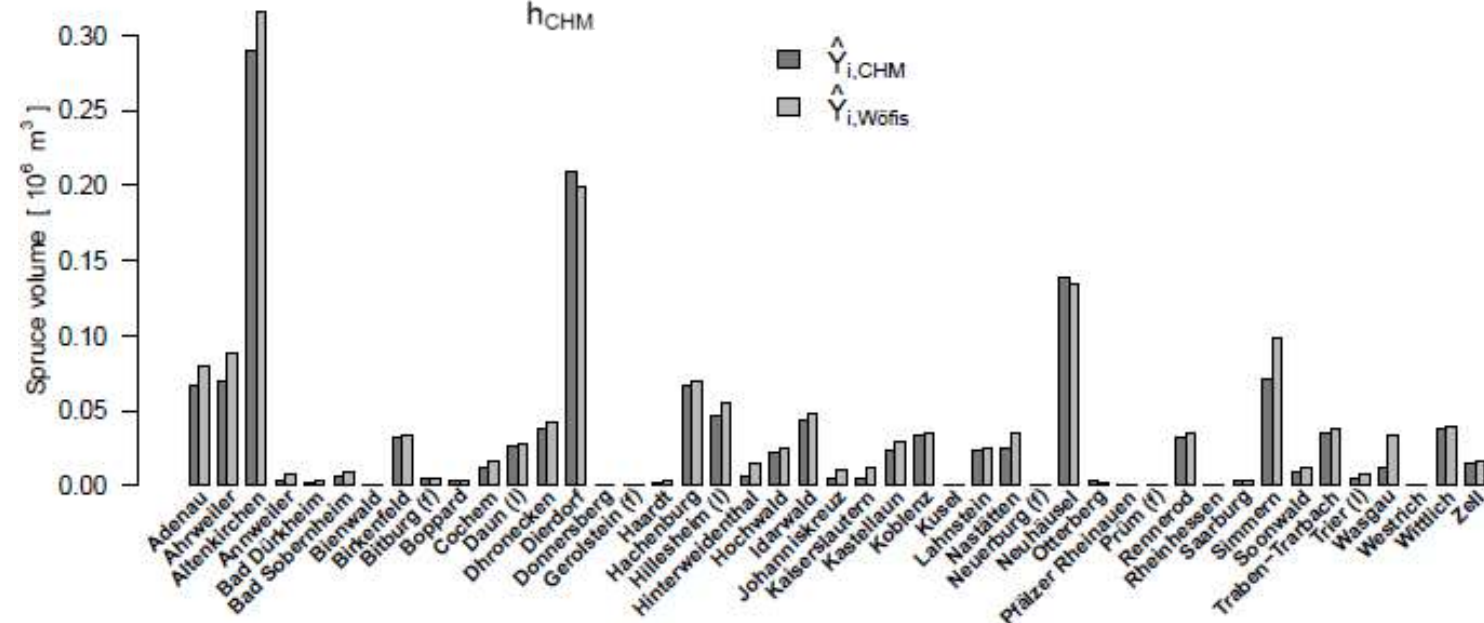
Norway Spruce



Regression Estimators [combining terrestrial survey (LWI) & ALS-CHM data] yield timber volume estimates with comparable accuracy to conventional inventories ...

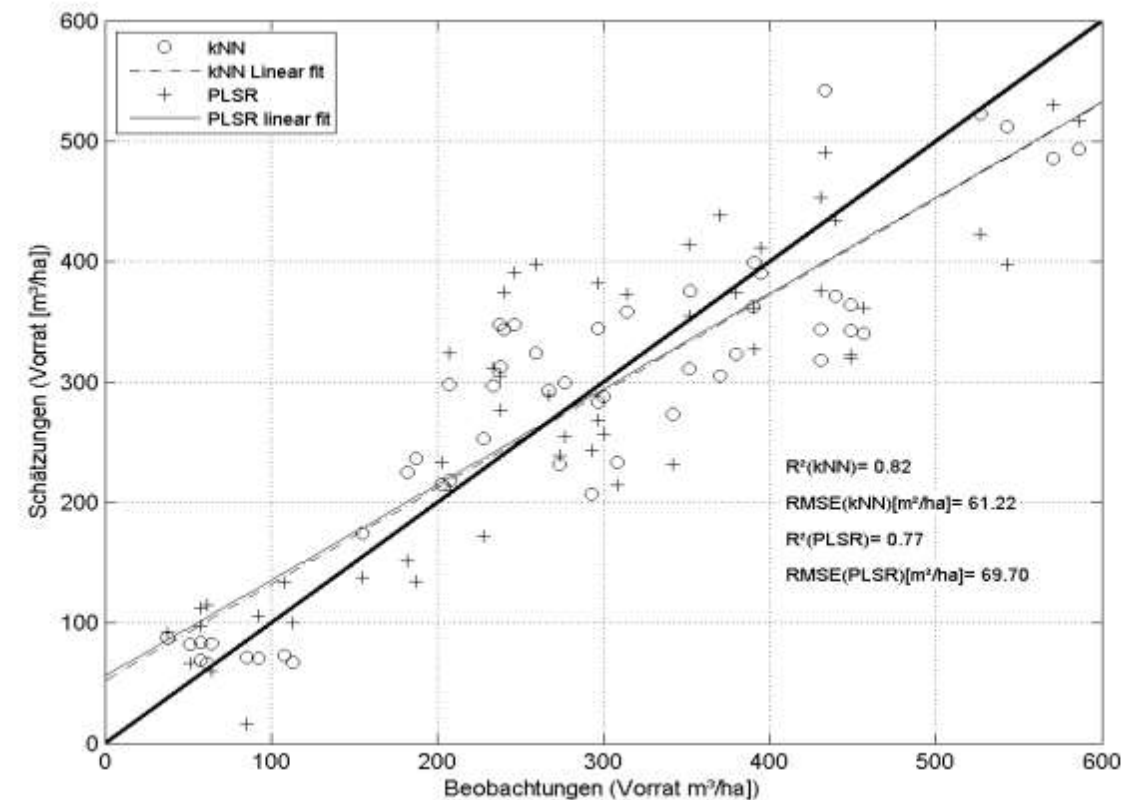
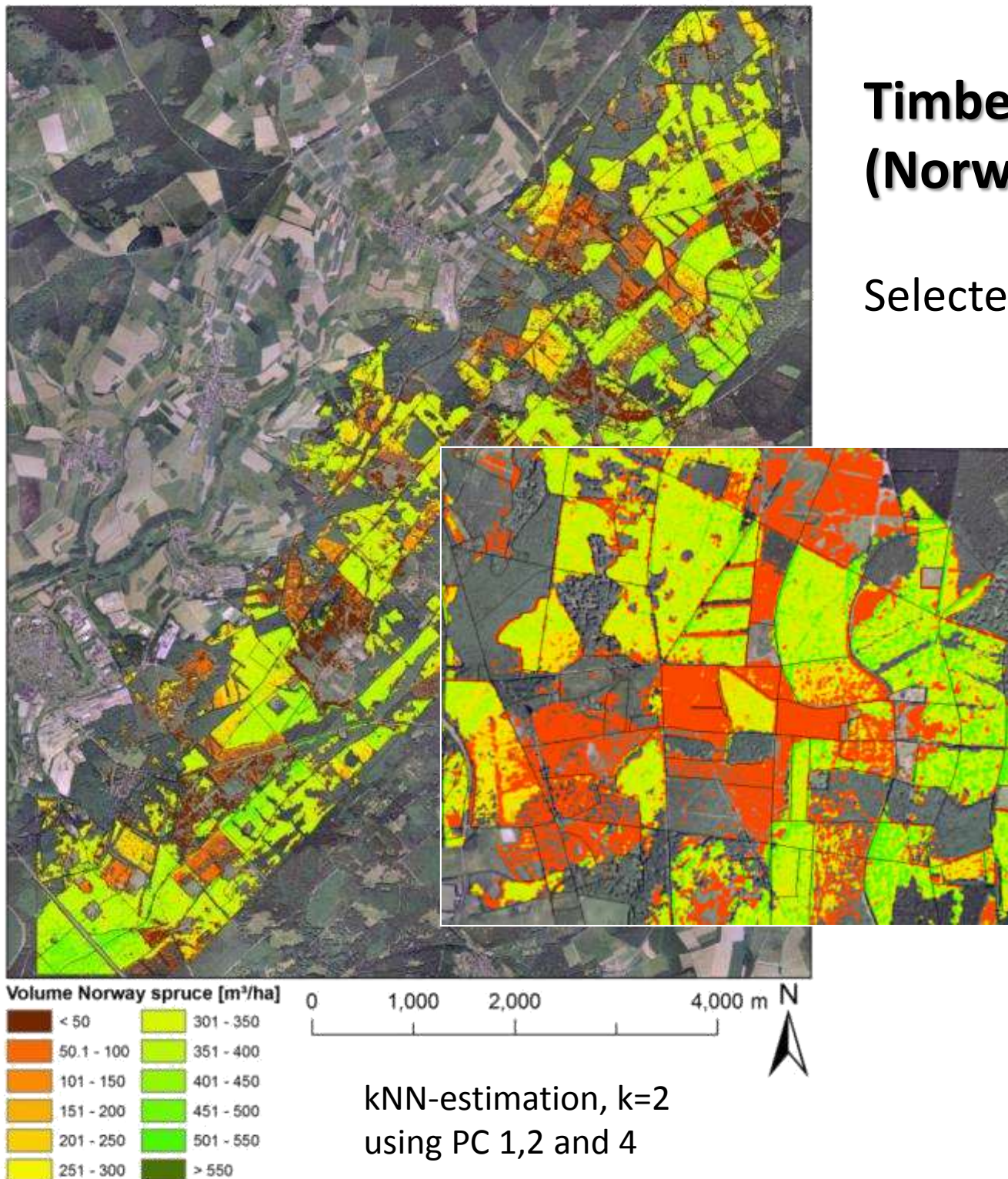


Generalized Regression Estimator



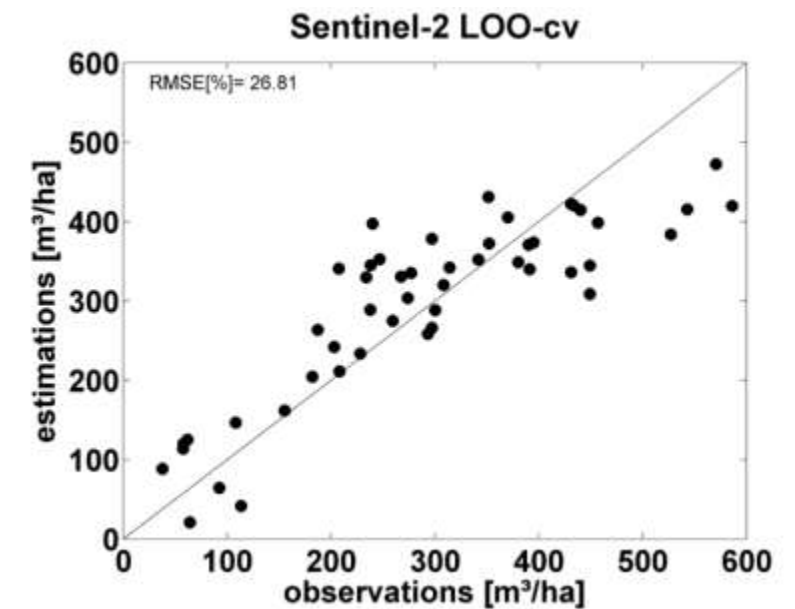
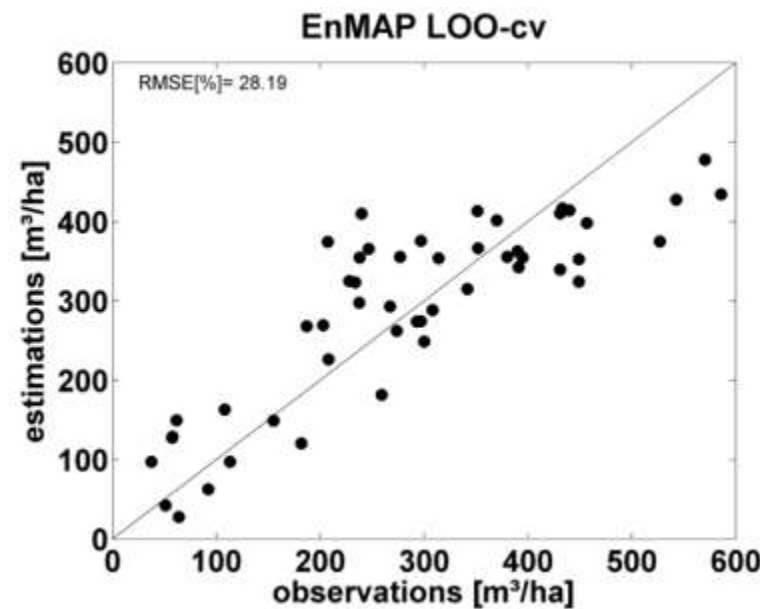
Timber Volume Distribution Map (Norway Spruce)

Selected Principal Components & PLSR / k-NN

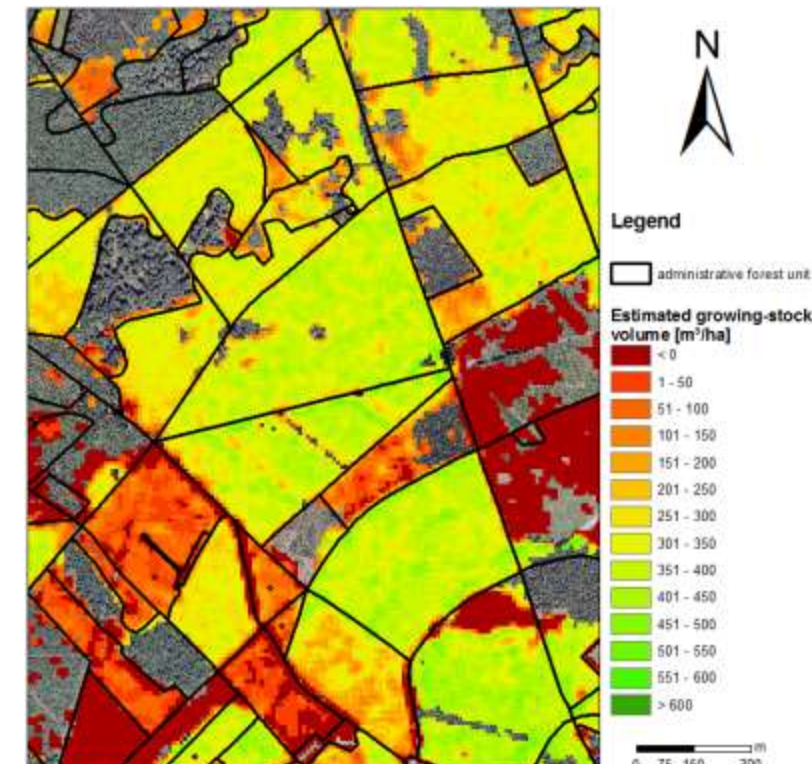
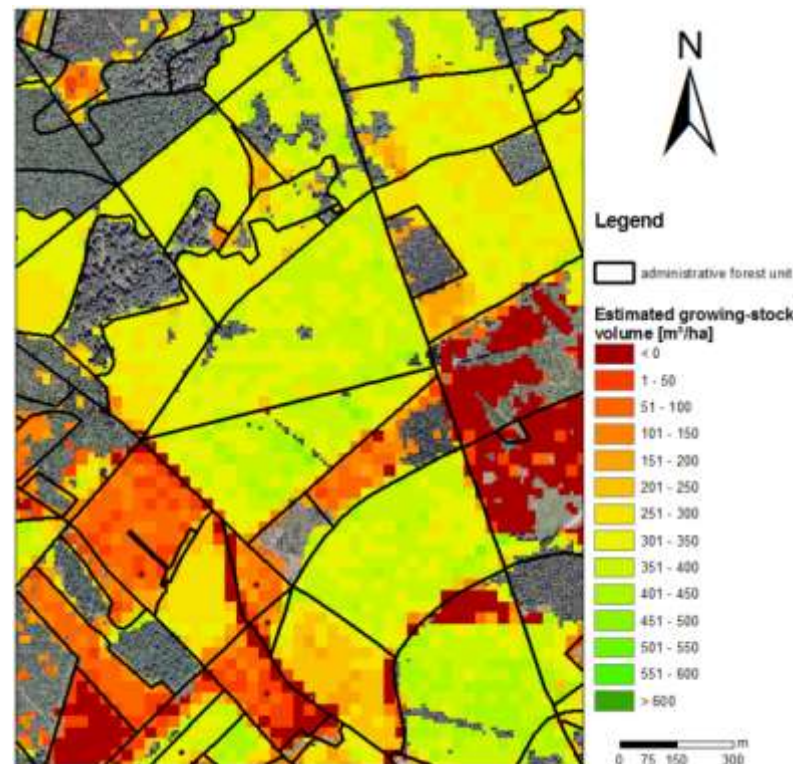
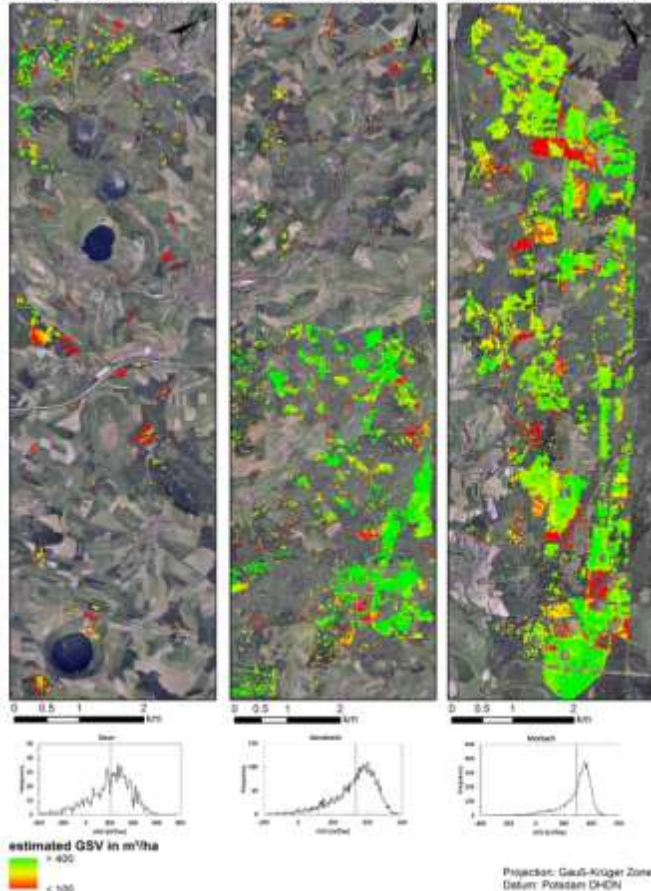


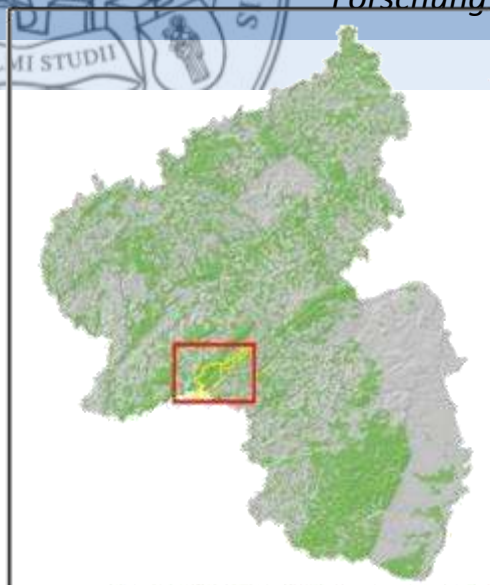
Comparison between simulated EnMAP and Sentinel-2 data

- Estimations based on PLS regression and kNN
- Results of EnMAP and Sentinel-2 were very similar for Norway spruce



Map of GSV estimation with PLSR and simulated EnMAP data





Nationalpark Hunsrück/Hochwald

Borkenkäfer-Kalamitäten





Merzalben (Pfalz) EnMAP Forestry Core Site

