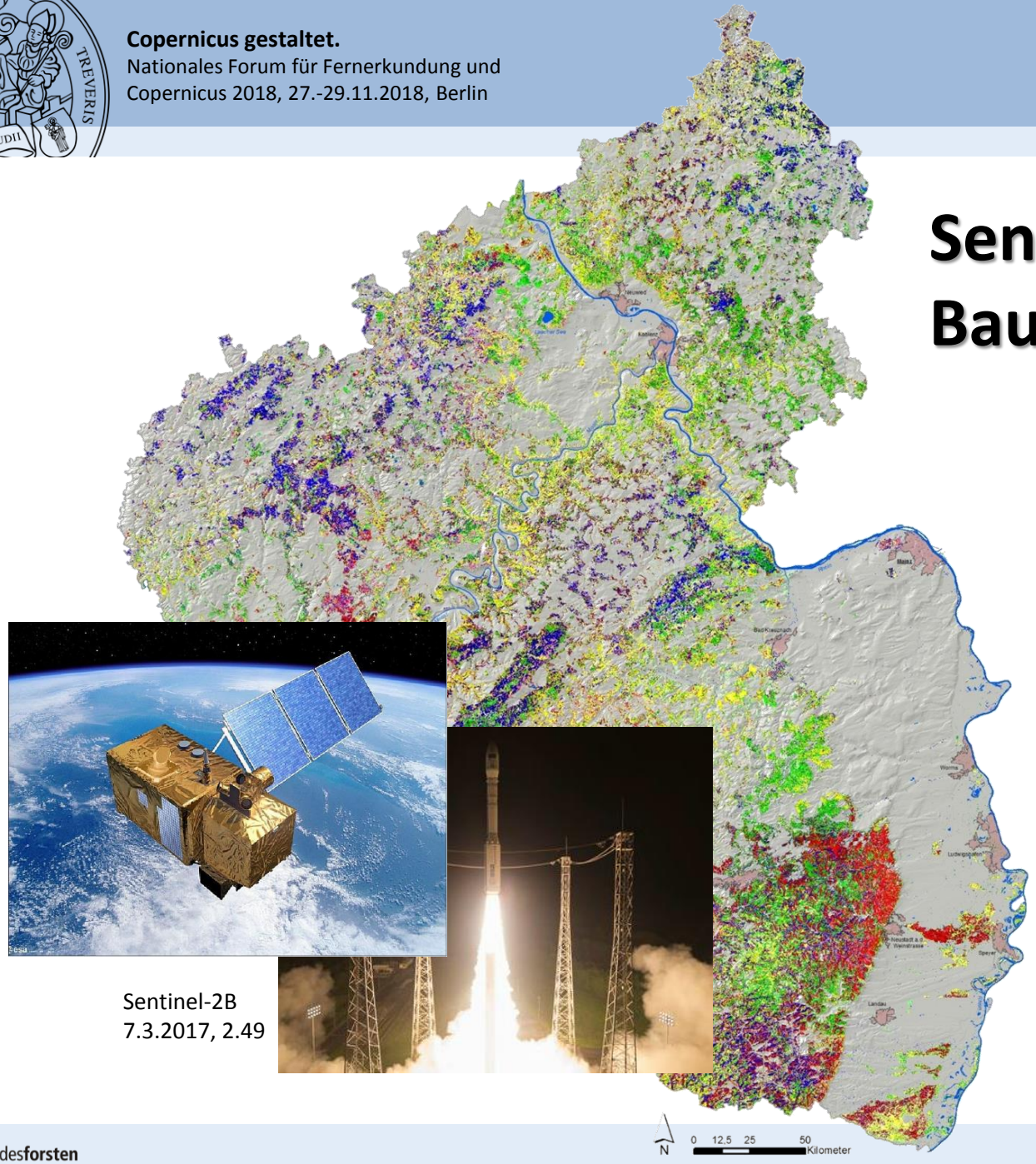







Sentinel-2B
7.3.2017, 2.49

# Sentinel4GRIPS: Copernicus als Baustein der Forstverwaltung

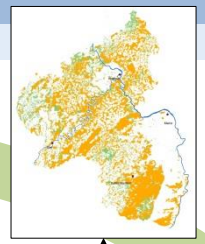
Joachim Hill[1], Sebastian Mader[1], David Frantz[3], Johannes Stoffels[1], Joachim Langshausen[2], Jürgen Dietz[2], Christoph Averdung[4], Jens Göpfert[5]

1) Universität Trier, Umweltfernerkundung und Geoinformatik
2) Landesforsten Rheinland-Pfalz, Zentralstelle der Forstverwaltung
3) Humboldt-Universität zu Berlin, Geomatik,
4) CPA Geo-Information, Grantham-Allee 2-8, D-53757 Sankt Augustin
5) Landesamt für Vermessung und Geobasisinformation Rheinland-Pfalz

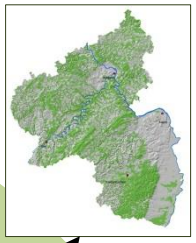
**Environmental Remote Sensing and GeoInformatics**

Faculty of Environmental & Regional Sciences
Trier University
D-54286 TRIER, Germany
hillj@uni-trier.de - http://www.feut.de

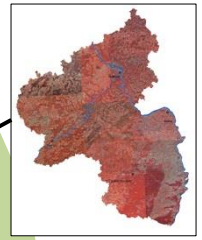
# Großrauminventur- und Planungssystem (GRIPS)



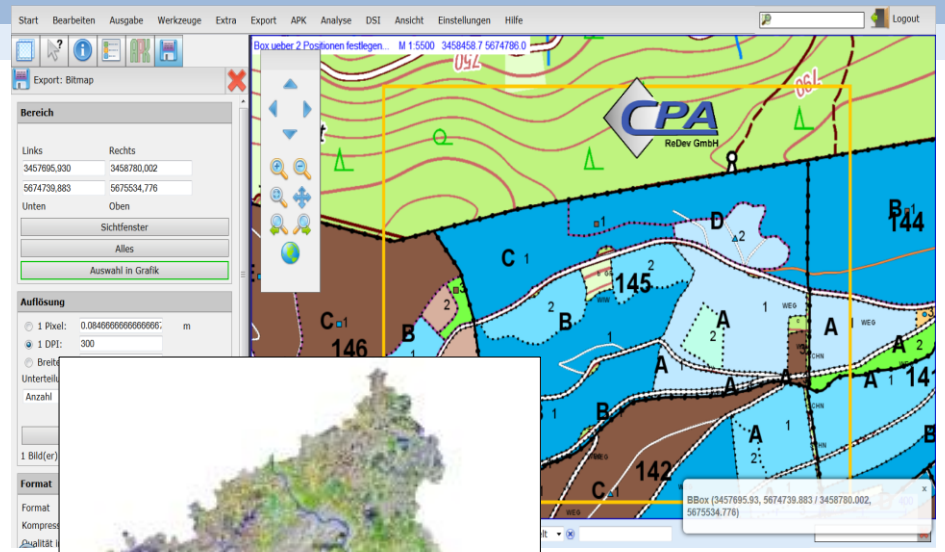
Forsteinrichtungsdaten



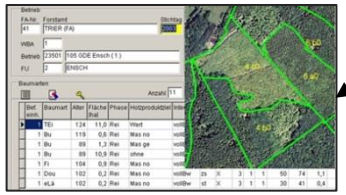
Betriebsdaten



Luftbilder



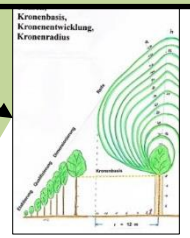
Mobile Endgeräte
Forsteinrichtung vor Ort



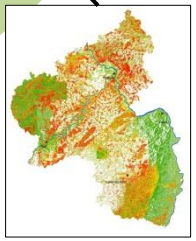
Desktop
Planung und Analyse

**Objekt-orientiertes Forst-informations-system**

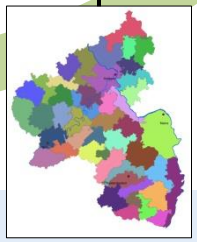
**Operative Integration von Erdbeobachtungsdaten**



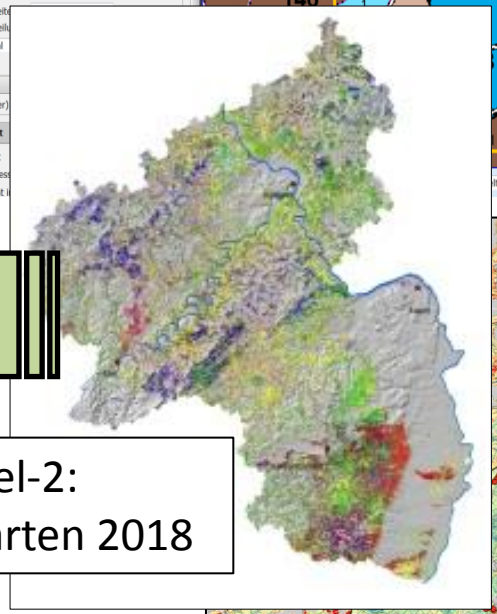
Fortschreibung /Modelle



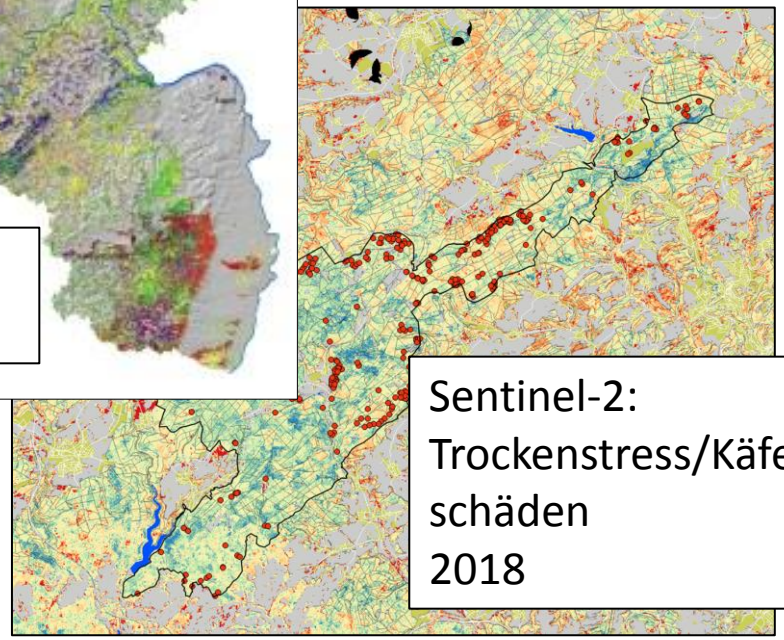
LiDAR



Administrative Daten



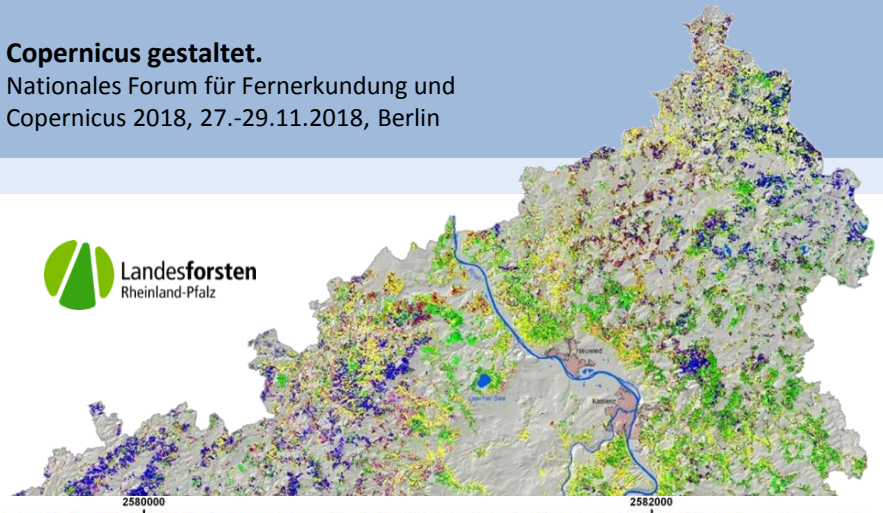
Sentinel-2: Baumarten 2018



Sentinel-2: Trockenstress/Käfer-schäden 2018

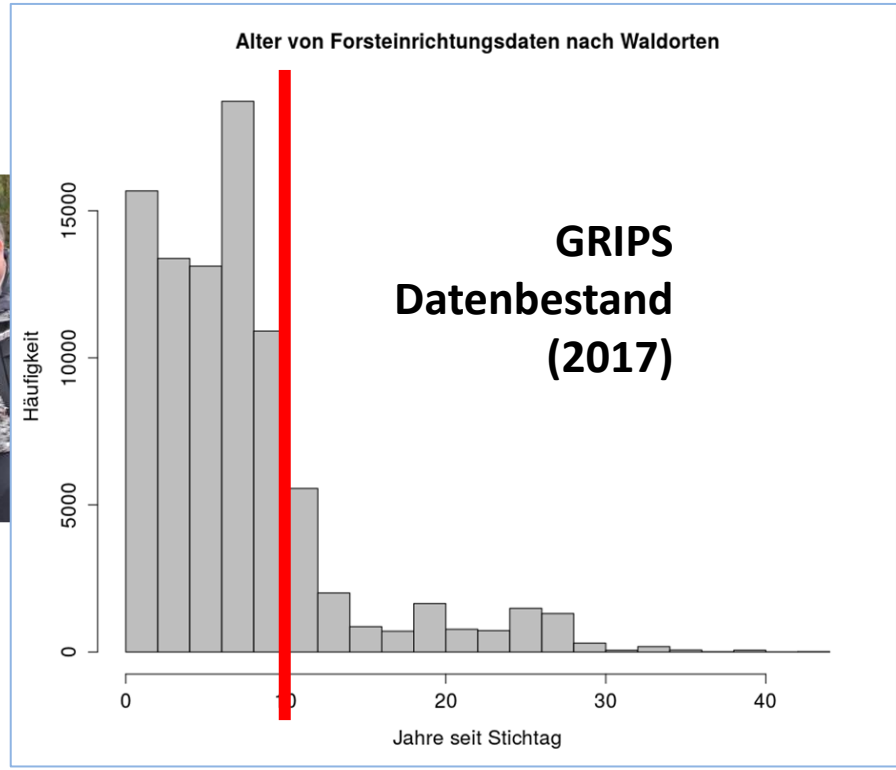
# Wall-to-Wall
# VHR Satellite Map of Tree Species

Landesforsten Rheinland-Pfalz

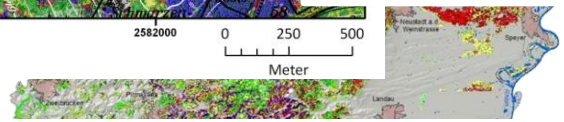


**Effizienzsteigerung durch eine landesweite, aktuelle Baumartenkartierung:**

**Optimierte Planung der Vor-Ort-Begehung bei der Forsteinrichtung**




**GRIPS Datenbestand (2017)**




Satellitenbilddaten:

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

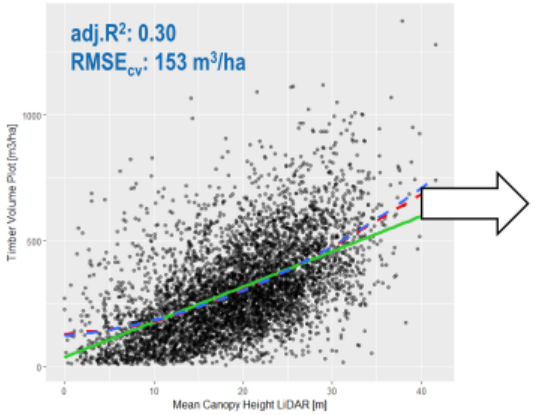
WÖFIS (Landesforsten RLP), ATKIS (LvermGeo RLP)

Stoffels, J.; Hill, J.; Sachtleber, T.; Mader, S.; Buddenbaum, H.; Stern, O.; Langshausen, J.; Dietz, J.; Ontrup, G. Satellite-based derivation of high-resolution forest information layers for operational forest management. *Forests* 2015, 6, 1982–2013

ETH zürich

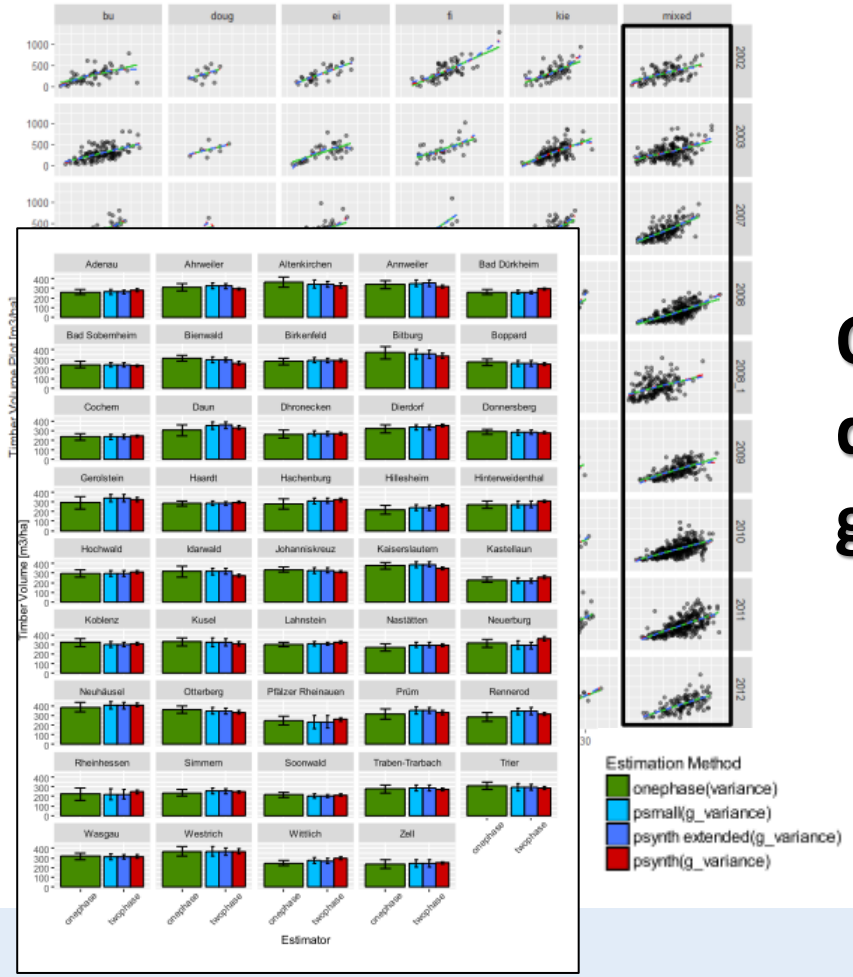
**Modellierung**

## OLS Regression Model (Plot Level)




| *Model* | |
|---|---|
| *MCH, LiDAR-Jahr* | adj.R²: 0.42<br>RMSE$_{cv}$: 140.3 m³/ha |
| *MCH, LiDAR-Jahr, Baumarten* | adj.R²: 0.45<br>RMSE$_{cv}$: 137.9 m³/ha |
| *MCH, LiDAR-Jahr, Baumarten, Wuchgebiete* | adj.R²: 0.45<br>RMSE$_{cv}$: 137.6 m³/ha |

Vorrat = f(MCH, LiDAR-Befliegungsjahre , Baumarten)



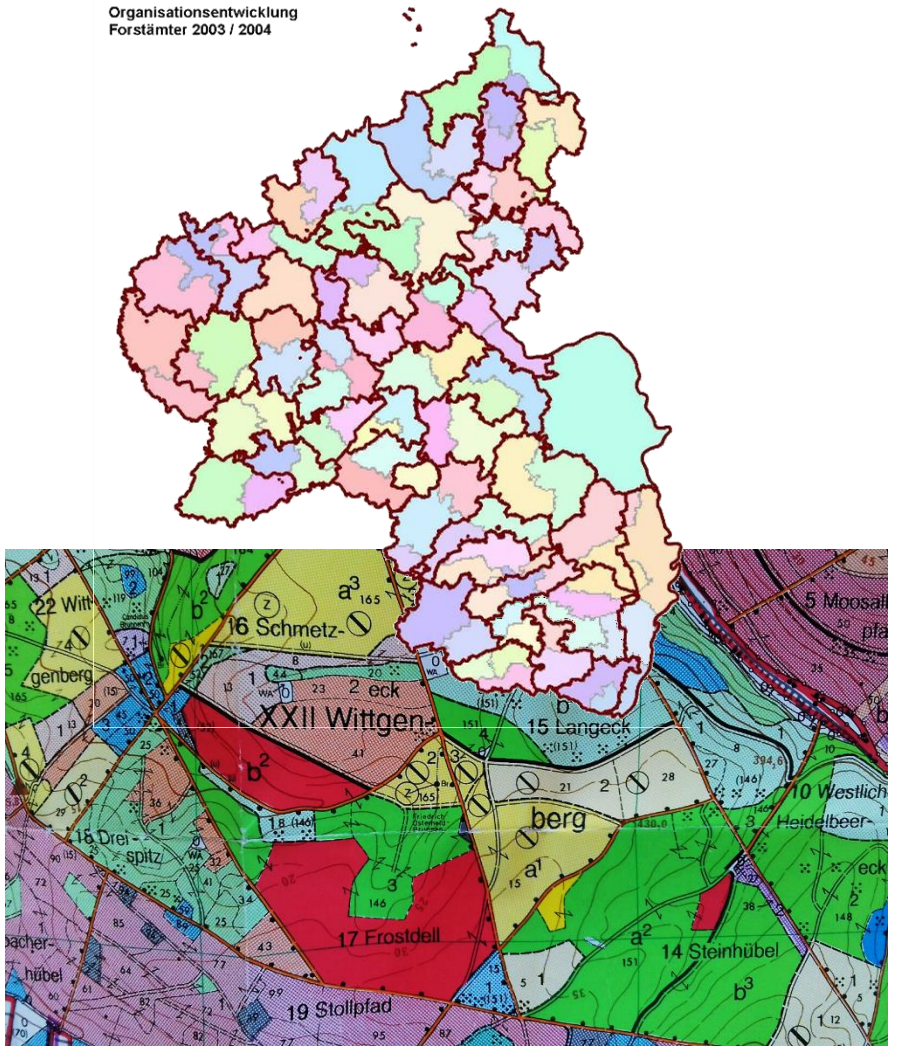

Skalierung der Ergebnisse der Bundes-und **Landeswaldinventur** zur Nutzung auf Forstamts- bzw. Revierebene durch geeignete Kleingebietsschätzer (small area estimates):

# Optimierung von Inventuren durch Nutzung der satelliten-gestützten Baumartenerfassung

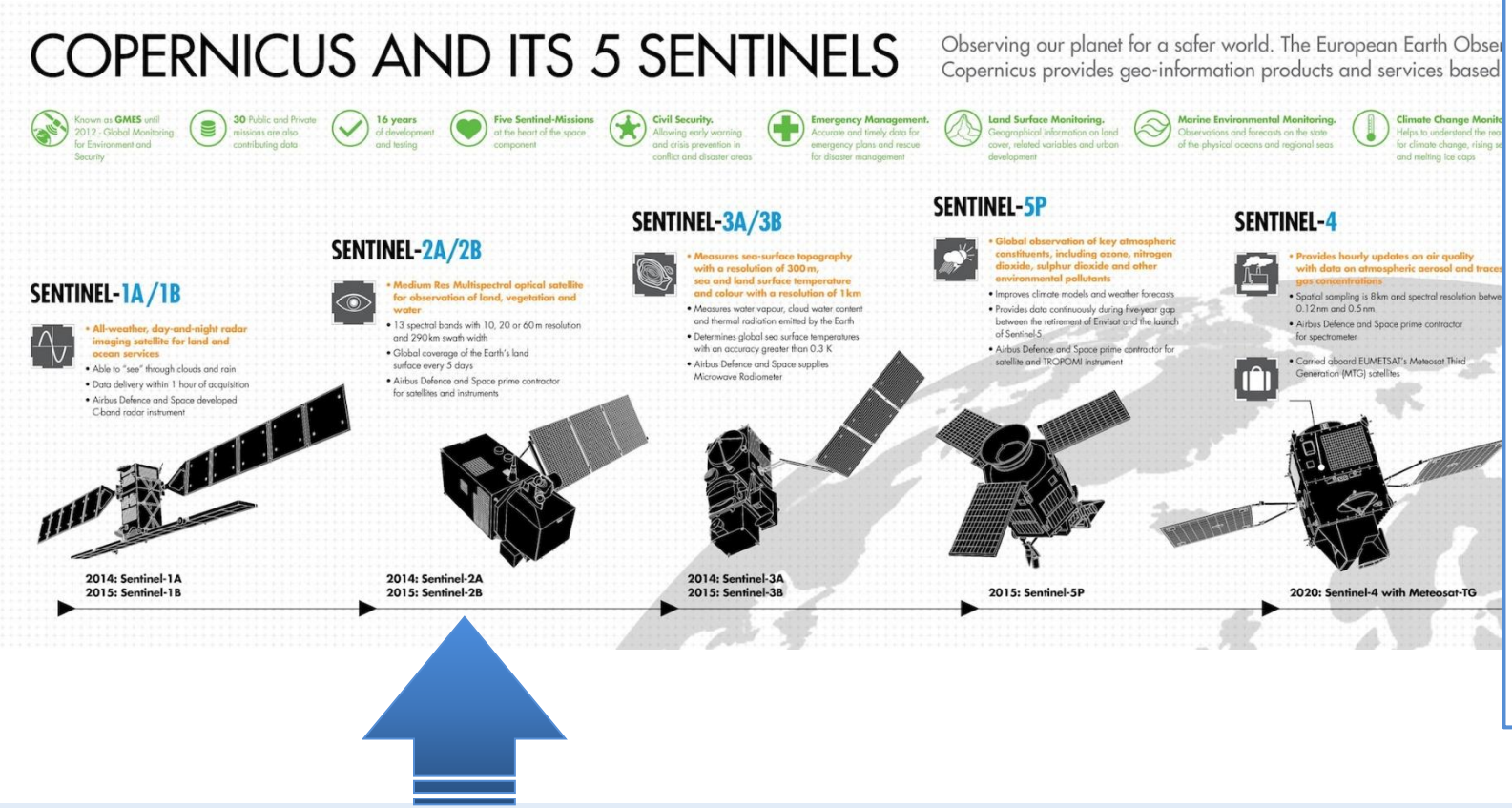
Hill, A., Buddenbaum, H., Mandallaz, D., 2018, Combining canopy height and tree species map information für large-scale timber volume estimations under strong heterogeinity of auxiliary data and variable sample plot sizes, *European Journal of Forest Research*, 1-17.

# Zielvorgaben zu einer landesweiten Erfassung von Hauptbaumarten und Entwicklungsphasen mit Sentinel-2-Daten

- Nutzung landesweit verfügbarer, amtlicher Bestandsinformationen (FE) als Referenzdaten,
- Keine Erhebung zusätzlicher und spezifischer terrestrischer Referenzinformationen,
- Kosteneffiziente Datennutzung (Sentinel, Landesvermessung, BWI/LWI, …),
- Weitgehend automatisierte Bearbeitung, möglichst geringe Anteile interaktiver Steuerung,
- Möglichst schnelle Integration aktueller Informationen aus Erdbeobachtung in die amtlichen Bestandsdaten (FE),
- Landesweite Abdeckung



Copernicus
Europe's eyes on Earth




## Die Sentinel-2-Mission

- 13 Spektralkanäle: **konsistente Zeitreihen** der Variabilität der Erdoberfläche, Minimierung von **Artefakten durch Atmosphäreneinflüsse**.
- Polarer Orbit in ca. 800 km Höhe: beide Systeme (Sentinel-2A & -2B) garantieren eine **Wiederholrate von 2-3 Tagen bei wolken-freien Bedingungen in mittleren Breiten**.
- Mit der kurzen Wiederholrate können erstmals auch schnelle Veränderungen beobachtet werden, beispielsweise **Vegetation während der Wachstumsphase**.
- Rechnerisch kann eine räumliche Auflösung von 10 m erzielt werden
- Weitere VHR-Systeme (SPOT, RapidEye, …) bieten eine zusätzliche **Absicherung bei kurzfristigen Ereignissen** …

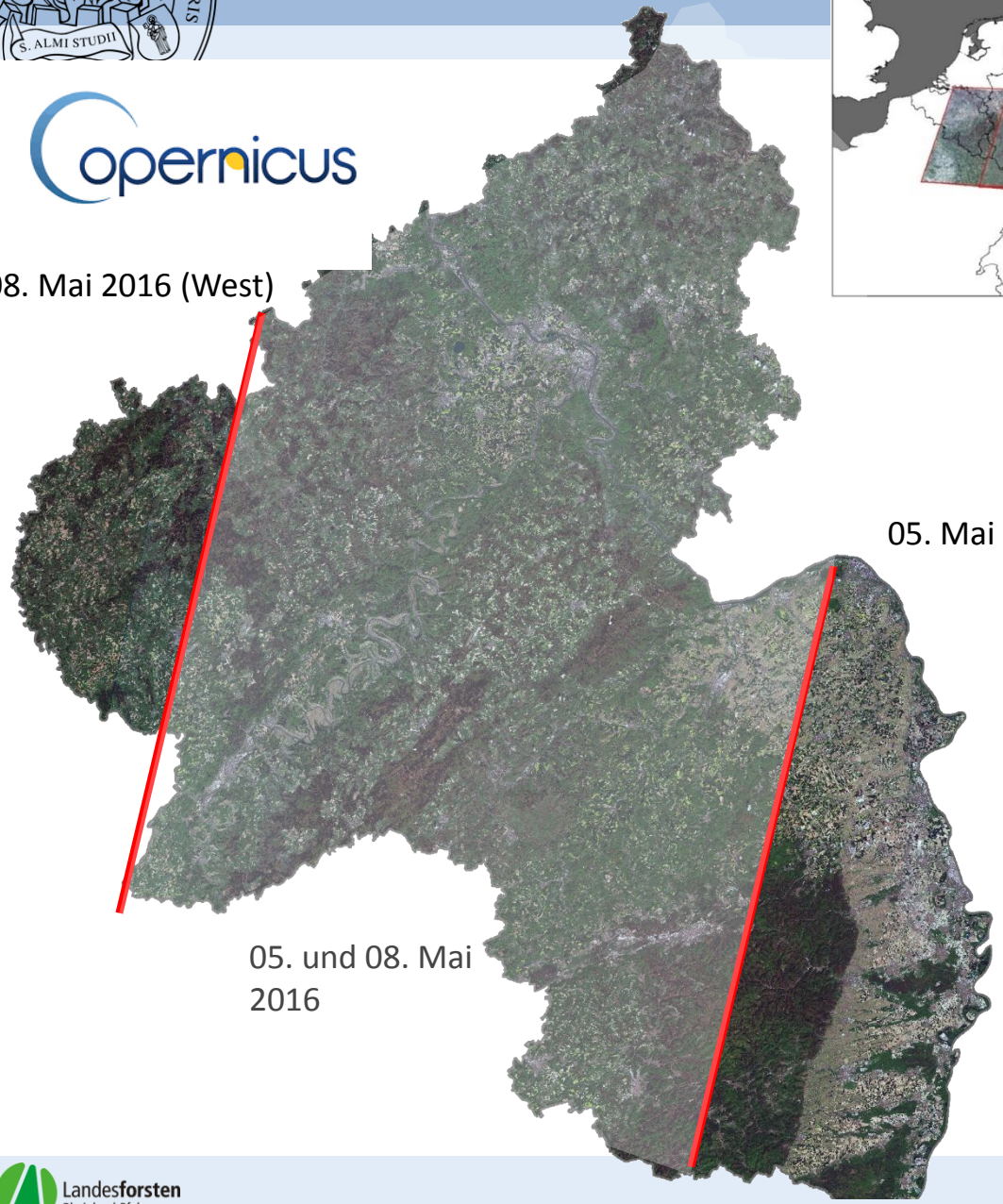
esa Sentinel Online

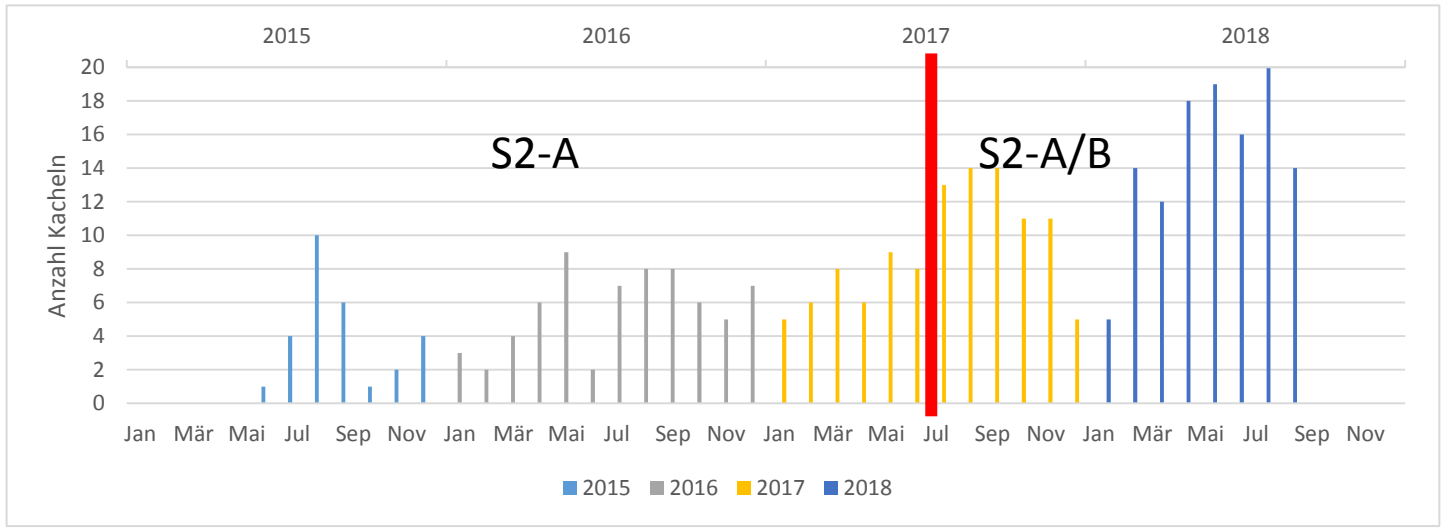
The Sentinel-2 mission is performed by 2 identical satellites (S2A, launched in June 2015, and S2B, launched in March 2017) each carrying the Multi-Spectral Instrument (MSI). Thanks to a wide imaging swath of 295 km, the two satellites ensure a revisit time of 5 days over a large part of global emerged lands and coastal waters, **producing some 4 Terabytes of data every day**.

08. Mai 2016 (West)

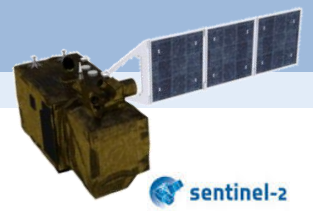
05. Mai 2016 (Ost)

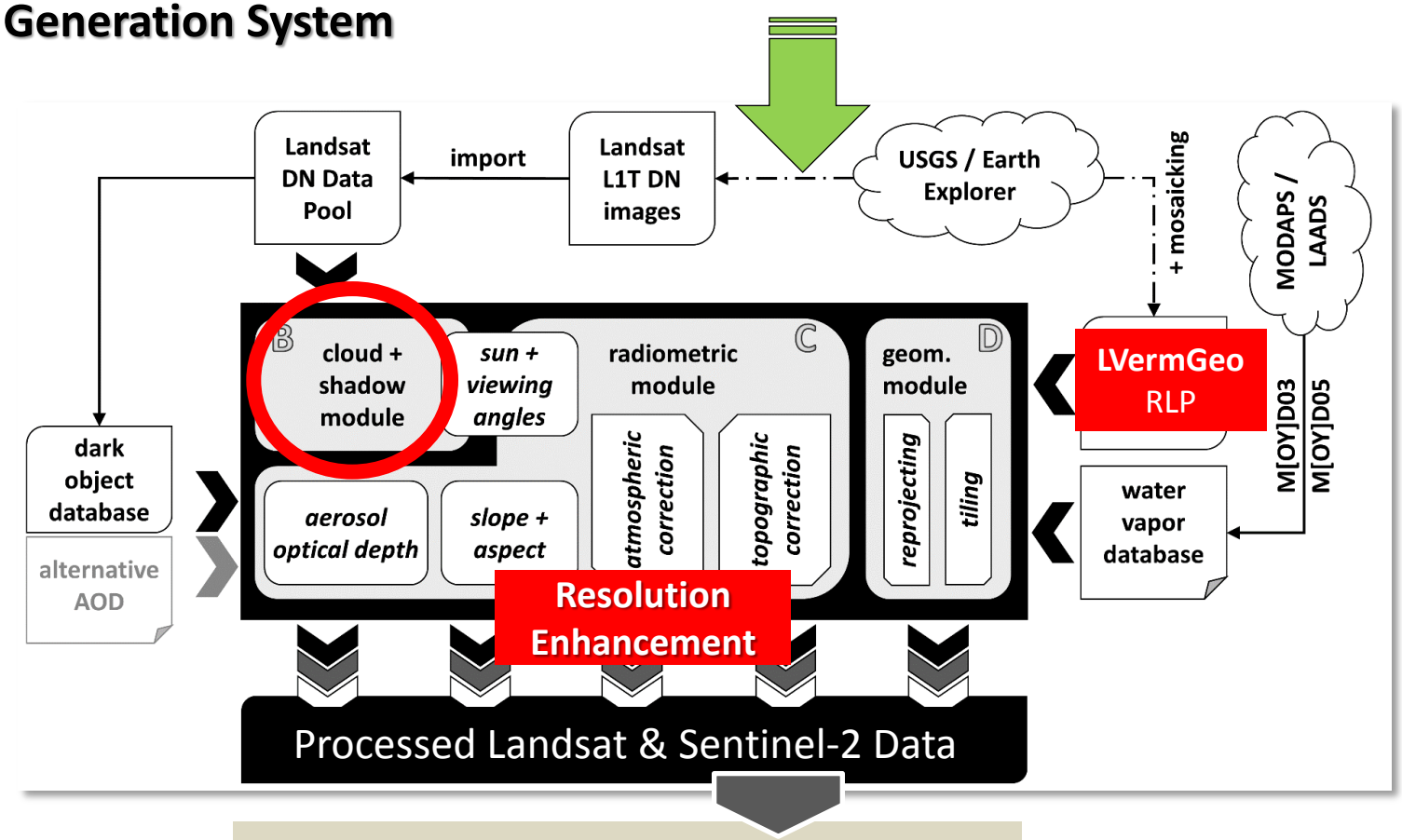
05. und 08. Mai 2016

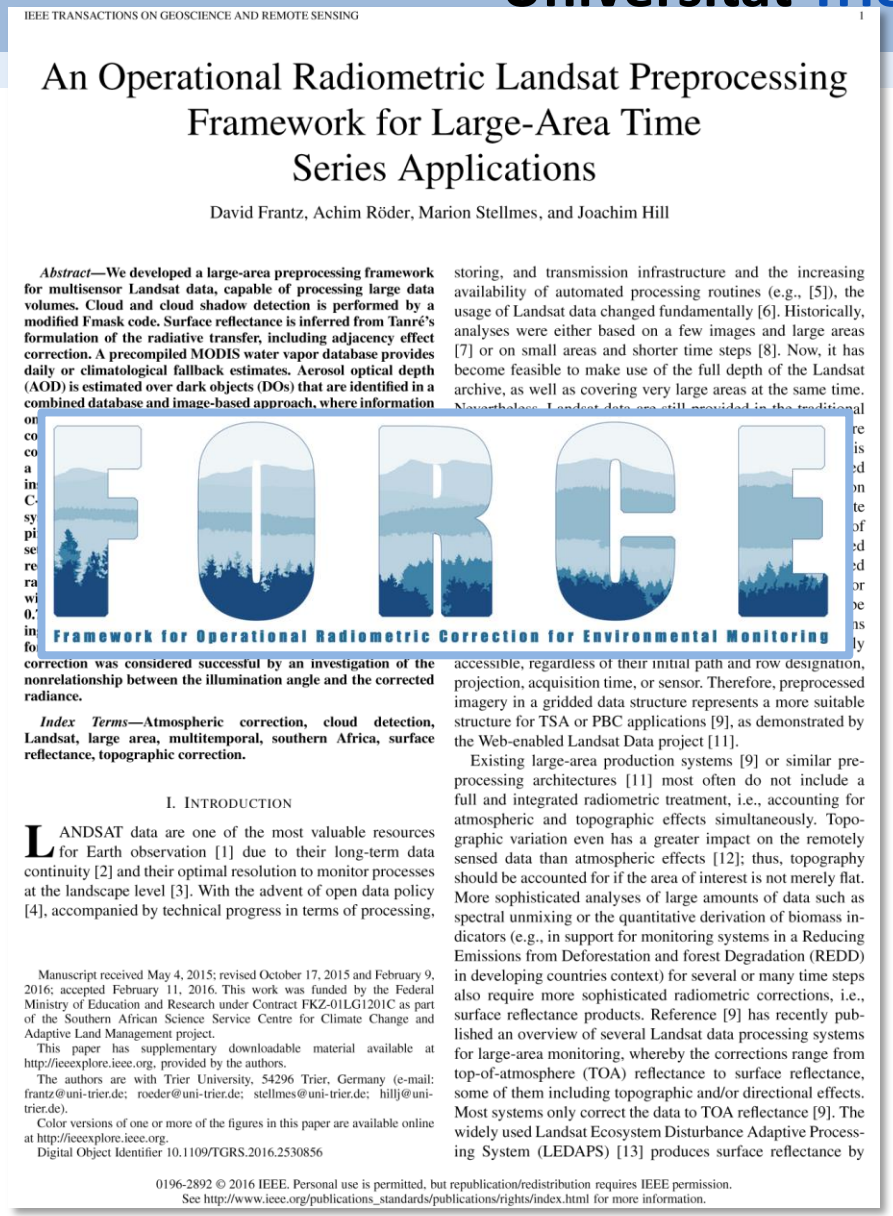




# Autonomous Level 2 Product Generation System



IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING 1

## An Operational Radiometric Landsat Preprocessing Framework for Large-Area Time Series Applications

David Frantz, Achim Röder, Marion Stellmes, and Joachim Hill

***Abstract*—We developed a large-area preprocessing framework for multisensor Landsat data, capable of processing large data volumes. Cloud and cloud shadow detection is performed by a modified Fmask code. Surface reflectance is inferred from Tanré's formulation of the radiative transfer, including adjacency effect correction. A precompiled MODIS water vapor database provides daily or climatological fallback estimates. Aerosol optical depth (AOD) is estimated over dark objects (DOs) that are identified in a combined database and image-based approach, where information on co... correction was considered successful by an investigation of the nonrelationship between the illumination angle and the corrected radiance.**

***Index Terms*—Atmospheric correction, cloud detection, Landsat, large area, multitemporal, southern Africa, surface reflectance, topographic correction.**

### I. Introduction

LANDSAT data are one of the most valuable resources for Earth observation [1] due to their long-term data continuity [2] and their optimal resolution to monitor processes at the landscape level [3]. With the advent of open data policy [4], accompanied by technical progress in terms of processing, storing, and transmission infrastructure and the increasing availability of automated processing routines (e.g., [5]), the usage of Landsat data changed fundamentally [6]. Historically, analyses were either based on a few images and large areas [7] or on small areas and shorter time steps [8]. Now, it has become feasible to make use of the full depth of the Landsat archive, as well as covering very large areas at the same time. Nevertheless, Landsat data are still provided in the traditional ... accessible, regardless of their initial path and row designation, projection, acquisition time, or sensor. Therefore, preprocessed imagery in a gridded data structure represents a more suitable structure for TSA or PBC applications [9], as demonstrated by the Web-enabled Landsat Data project [11].

Existing large-area production systems [9] or similar preprocessing architectures [11] most often do not include a full and integrated radiometric treatment, i.e., accounting for atmospheric and topographic effects simultaneously. Topographic variation even has a greater impact on the remotely sensed data than atmospheric effects [12]; thus, topography should be accounted for if the area of interest is not merely flat. More sophisticated analyses of large amounts of data such as spectral unmixing or the quantitative derivation of biomass indicators (e.g., in support for monitoring systems in a Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries context) for several or many time steps also require more sophisticated radiometric corrections, i.e., surface reflectance products. Reference [9] has recently published an overview of several Landsat data processing systems for large-area monitoring, whereby the corrections range from top-of-atmosphere (TOA) reflectance to surface reflectance, some of them including topographic and/or directional effects. Most systems only correct the data to TOA reflectance [9]. The widely used Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) [13] produces surface reflectance by

Manuscript received May 4, 2015; revised October 17, 2015 and February 9, 2016; accepted February 11, 2016. This work was funded by the Federal Ministry of Education and Research under Contract FKZ-01LG1201C as part of the Southern African Science Service Centre for Climate Change and Adaptive Land Management project.

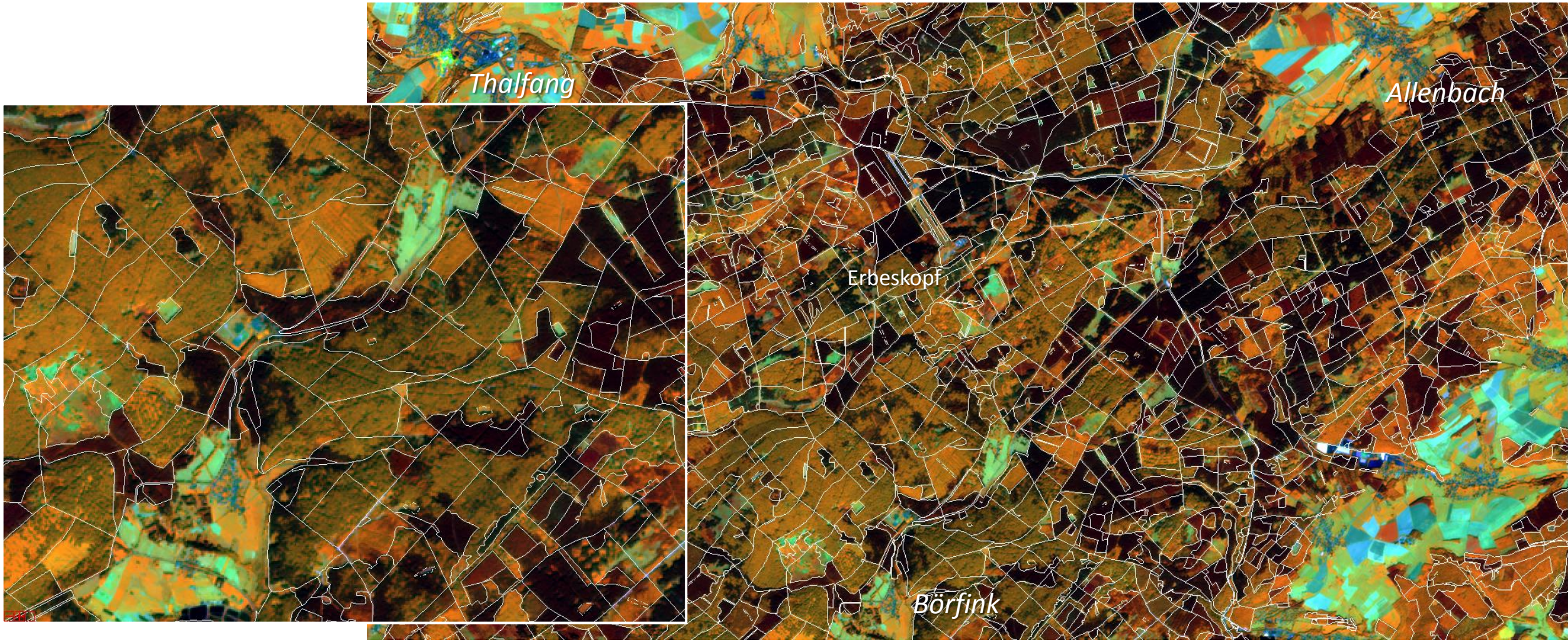
This paper has supplementary downloadable material available at http://ieeexplore.ieee.org, provided by the authors.

The authors are with Trier University, 54296 Trier, Germany (e-mail: frantz@uni-trier.de; roeder@uni-trier.de; stellmes@uni-trier.de; hillj@uni-trier.de).

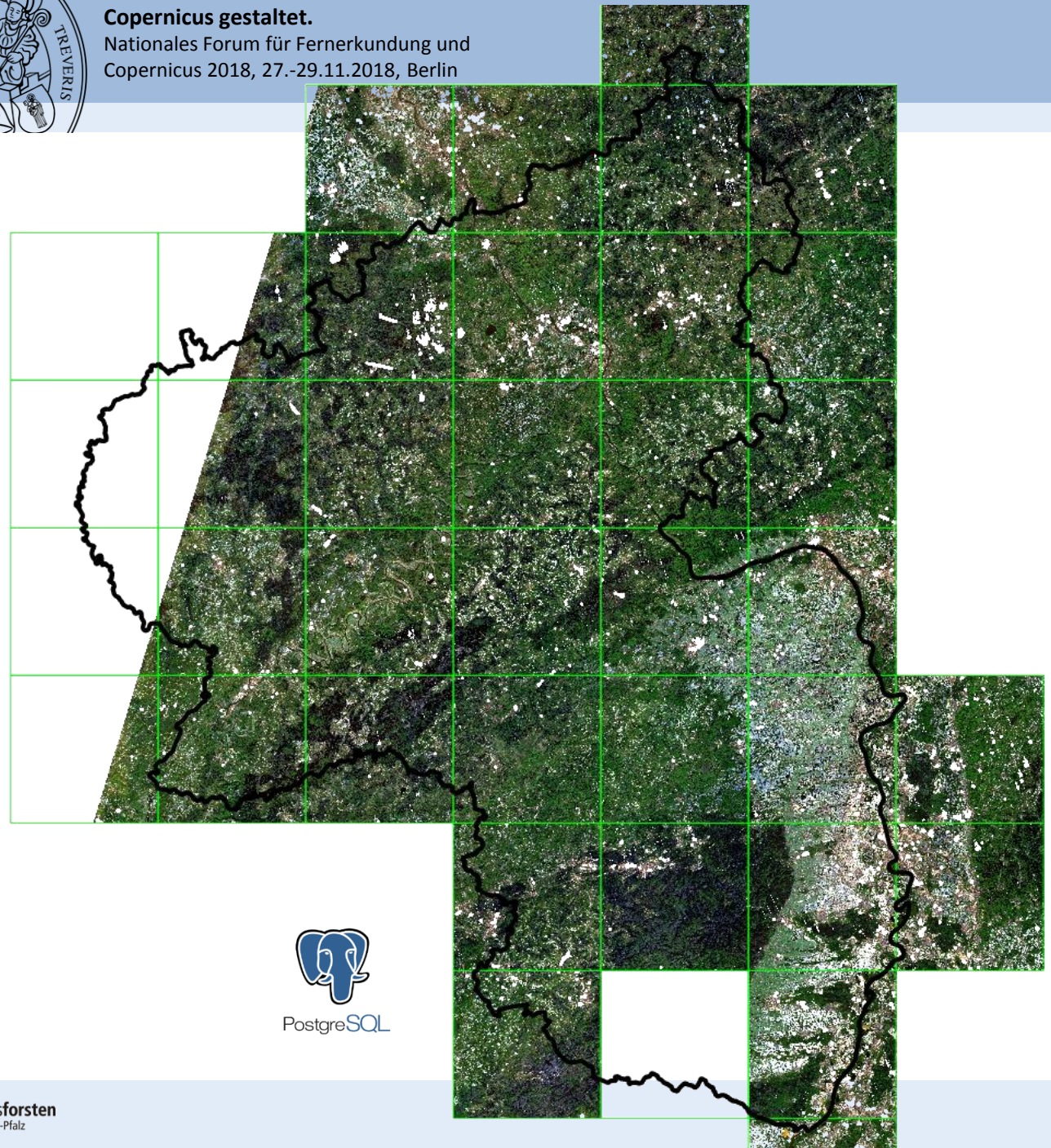
Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TGRS.2016.2530856

0196-2892 © 2016 IEEE. Personal use is permitted, but republication/redistribution requires IEEE permission.
See http://www.ieee.org/publications_standards/publications/rights/index.html for more information.




Pre-Processed Sentinel-2A, 23.8.2016, RGB= 842-1610-665 nm, GRIPS-Waldeinteilung



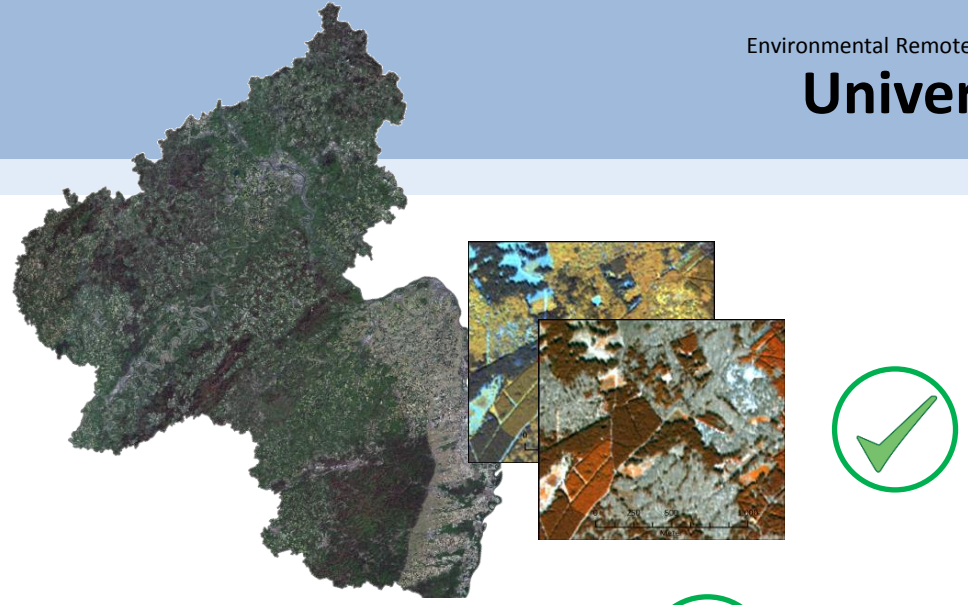
PostgreSQL

# Mosaik aus multi-temporalen Sentinel-2 A/B Bilddaten

**20.4.2018**
**10.5.2017**
**19.6.2017**
**23.8. 2016/2017**

- automatische Generierung per SQL-Code aus der Gesamtdatenbank
- insgesamt für RLP verfügbare Kacheln im Datenarchiv (Okt 2018): 4140 = 745 GB
- zur Abdeckung der Landesfläche RLP benötigte 30x30 km² Kacheln : 38
- Datenmenge je Abdeckung: 6.84 Gbyte
- Datenmenge 4 Termine: 27.36 Gbyte

# Prozessierungsschritte



**Level 0**

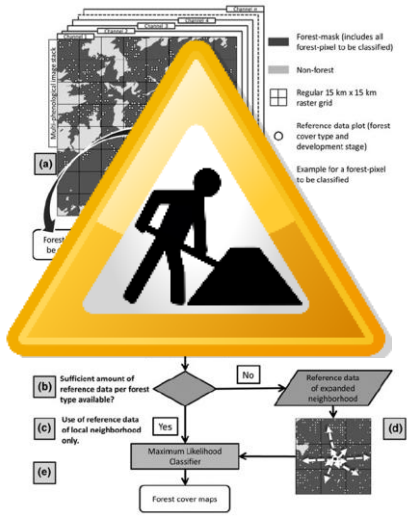
**Multi-Saisonale Satellitendaten**
(April/Mai & Juli/August) [3-Jahres-Zeitfenster]

**Level 1**

**Level 2**

**Automatischer Download & Datenaufbereitung**
Geo-Projektion, Kachelung, Integrierte Atmosphären- und Illuminationskorrektur, Resolution Merge, Temporales Compositing…

**Klassifikations-algorithmen**

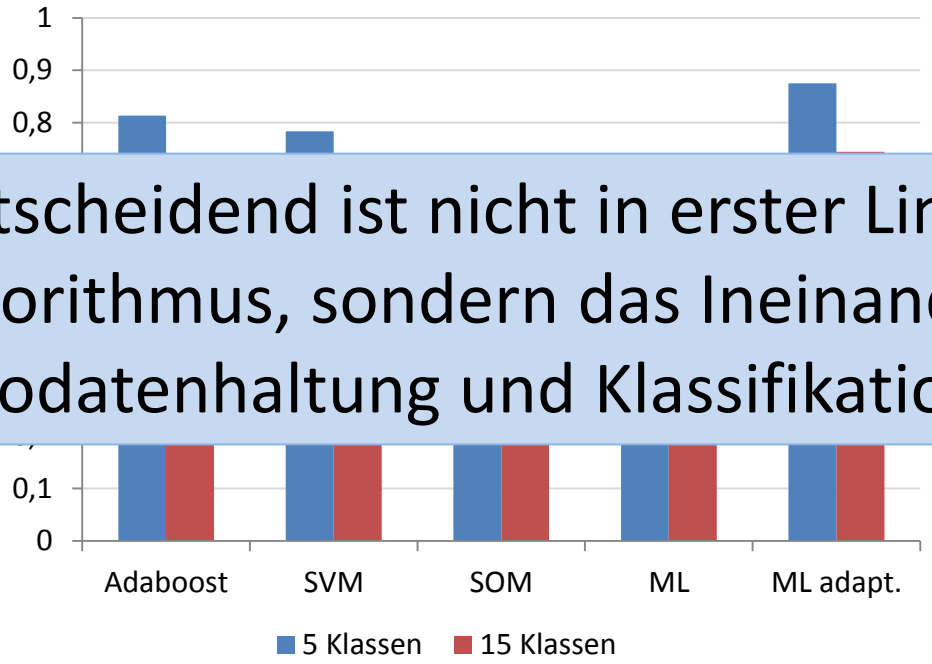



**Level 4**

**Thematisches Produkt**
Qualitätskontrolle

FORCE
Framework for Operational Radiometric Correction for Environmental Monitoring

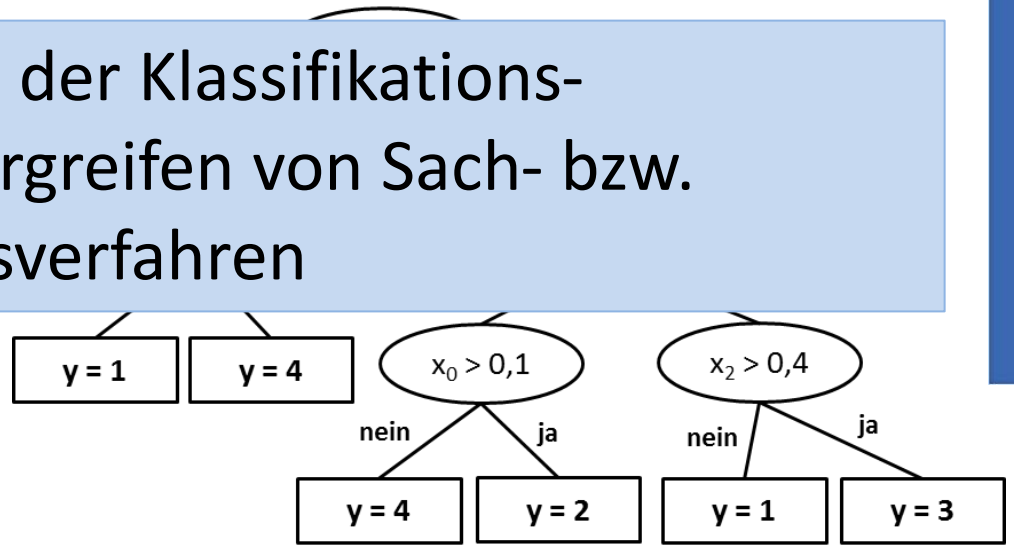
**Stoffels, J., Mader, S., Hill, J., Werner, W. & Ontrup, G.** (2012). Satellite-based stand-wise forest cover type mapping using a spatially adaptive classification approach. *Eur J Forest Res*, 131 (4): 1071-1089.




Entscheidend ist nicht in erster Linie der Klassifikations-algorithmus, sondern das Ineinandergreifen von Sach- bzw. Geodatenhaltung und Klassifikationsverfahren

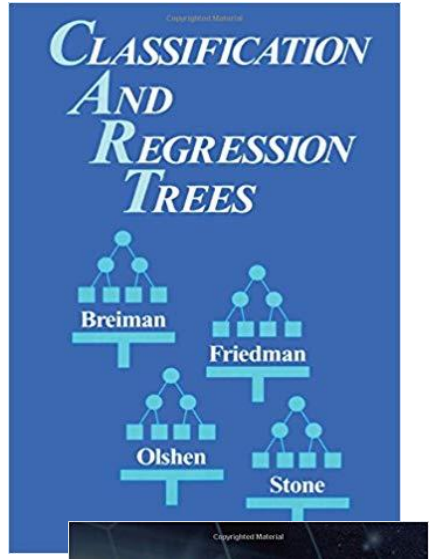
**Adaptive Boosting** – Ensemble Method
**Support Vector Machines** – Linear Discriminant
**Self Organising Maps** – Neural Networks
**Maximum Likelihood** – Density Estimation
**Adaptive Maximum Likelihood** – Local adaptation

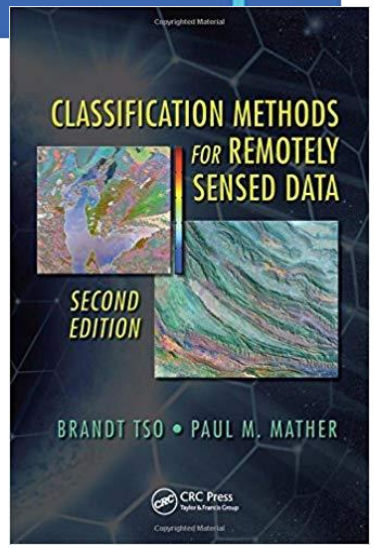
CART



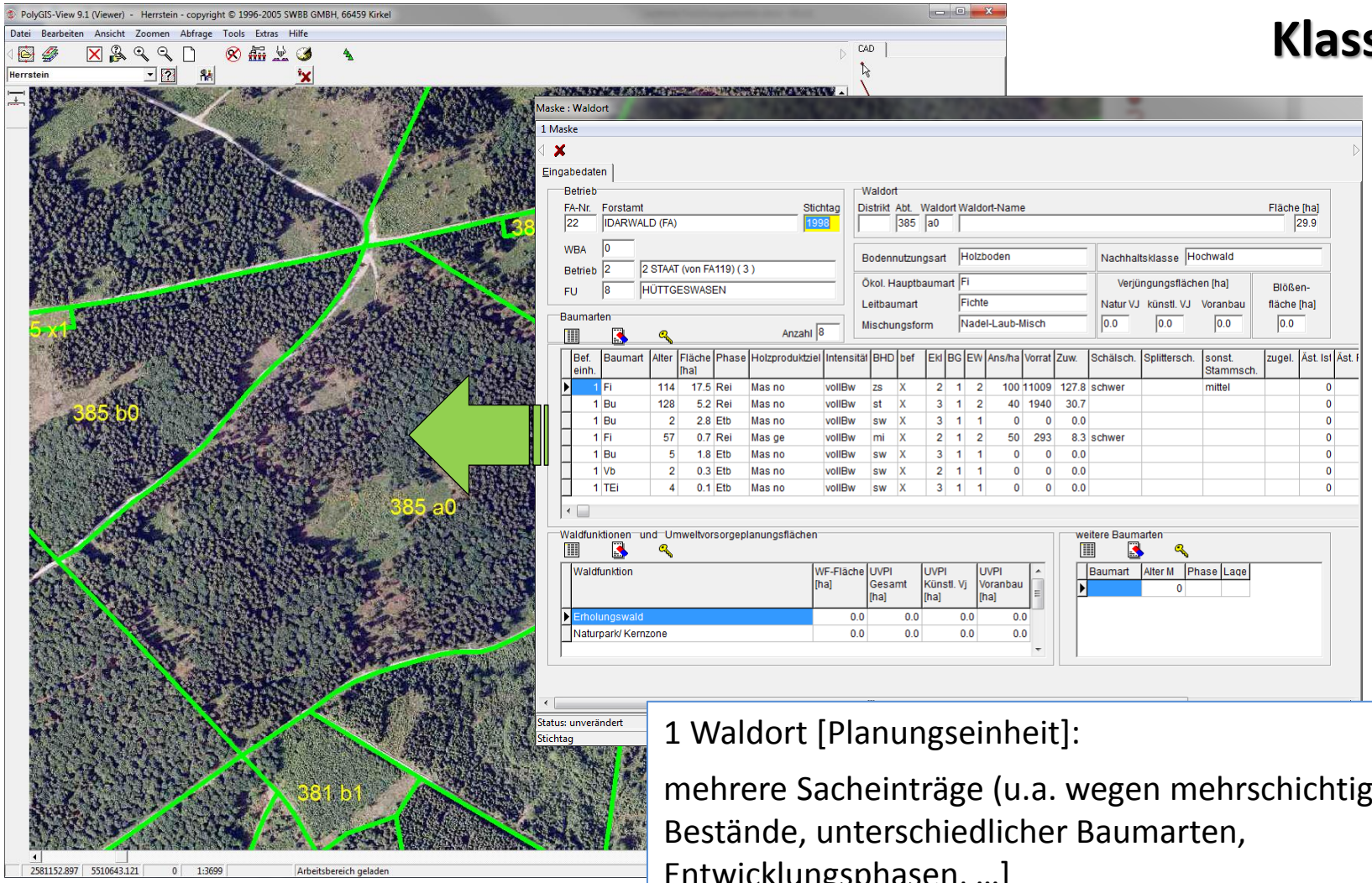

- Binärbaum
- 1 Schwellwert je Knoten
- Gini Impurity

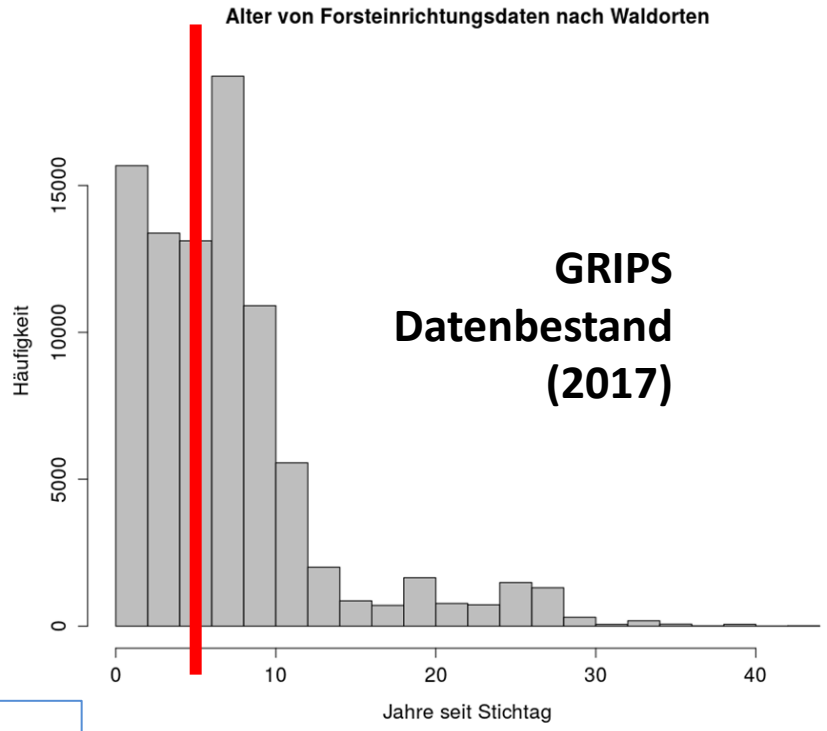
**Random Forest** – Ensemble Method



# Klassifikatortraining aus GRIPS …



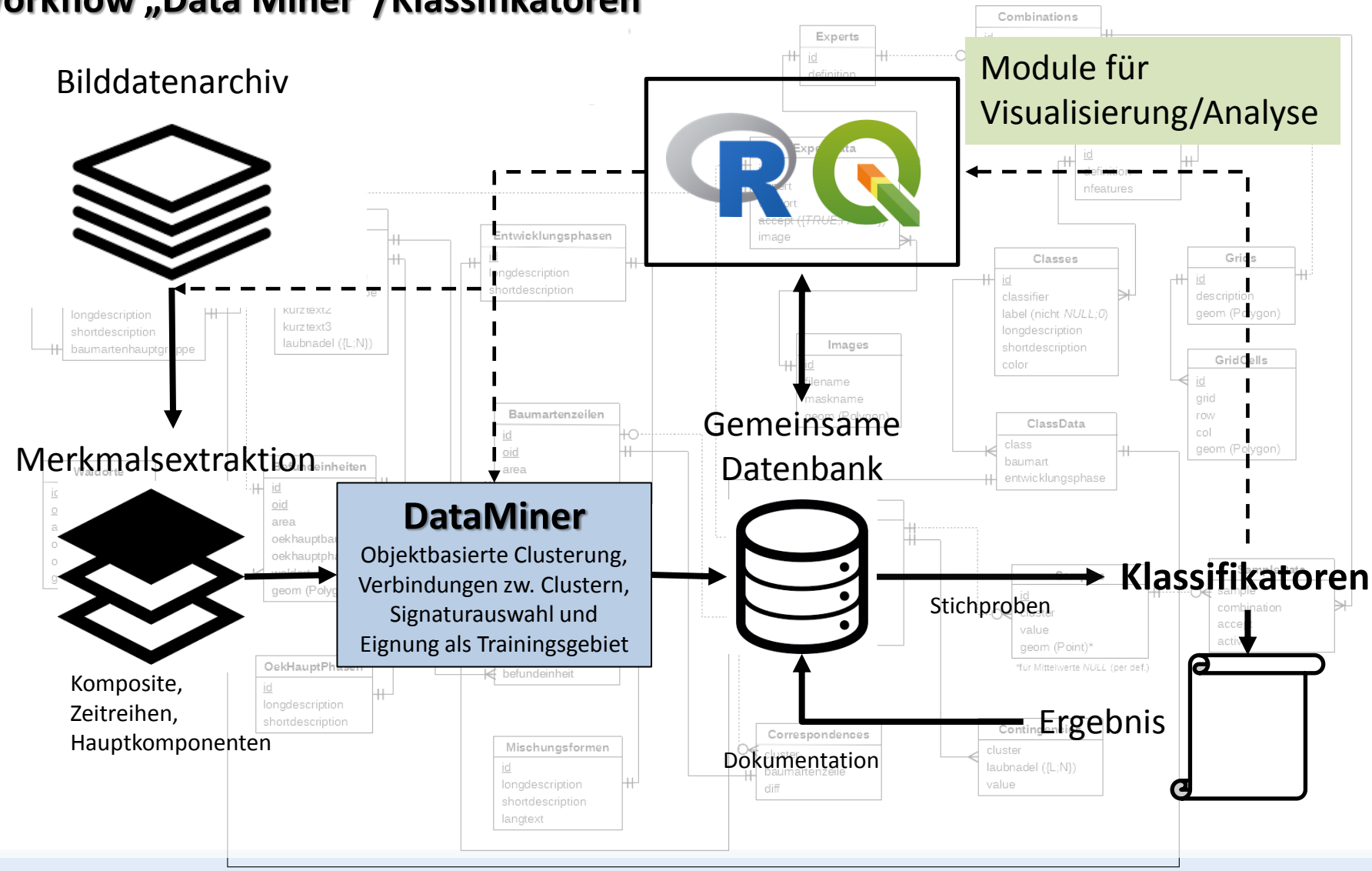




**GRIPS Datenbestand (2017)**

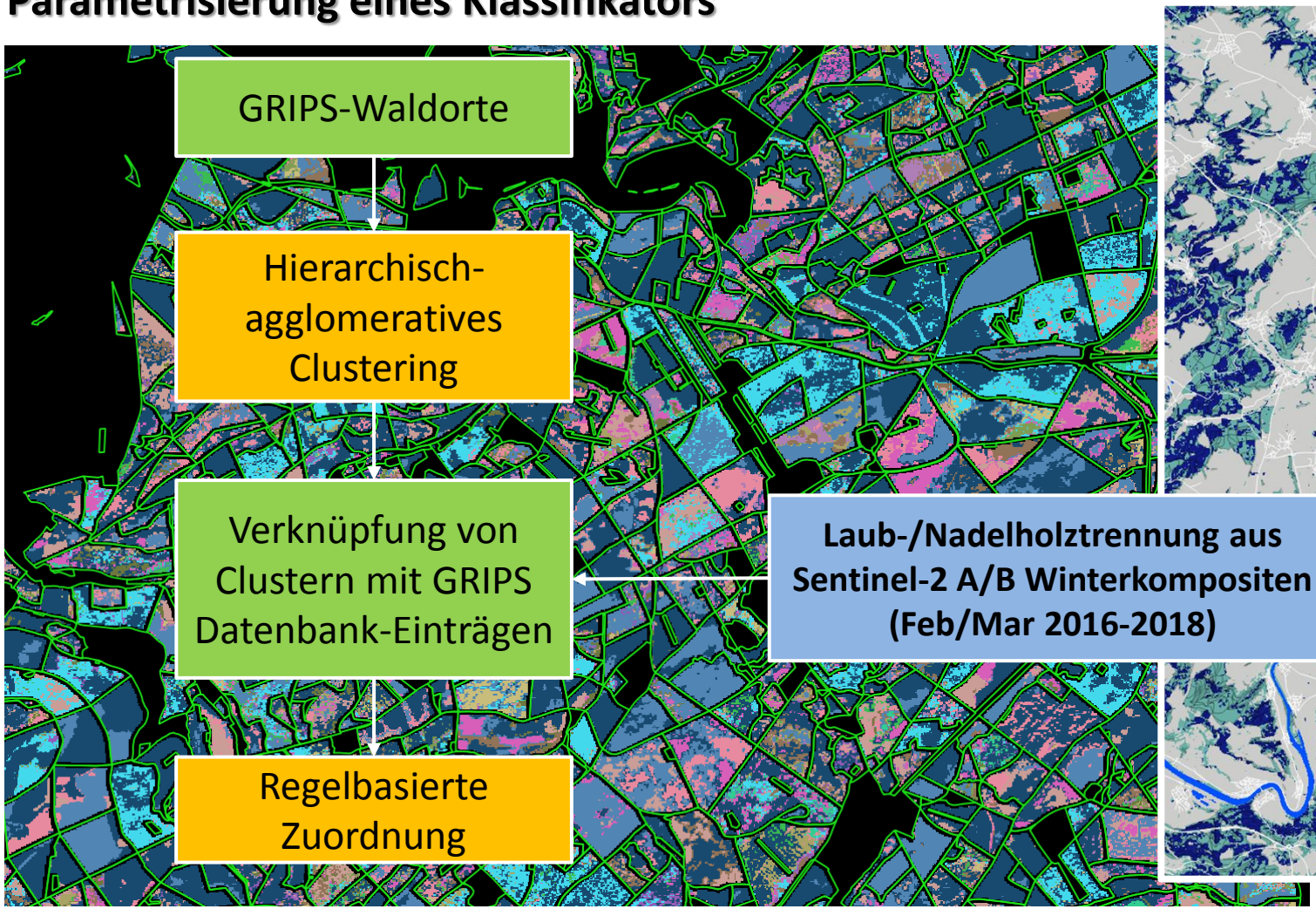
1 Waldort [Planungseinheit]:

mehrere Sacheinträge (u.a. wegen mehrschichtiger Bestände, unterschiedlicher Baumarten, Entwicklungsphasen, …]

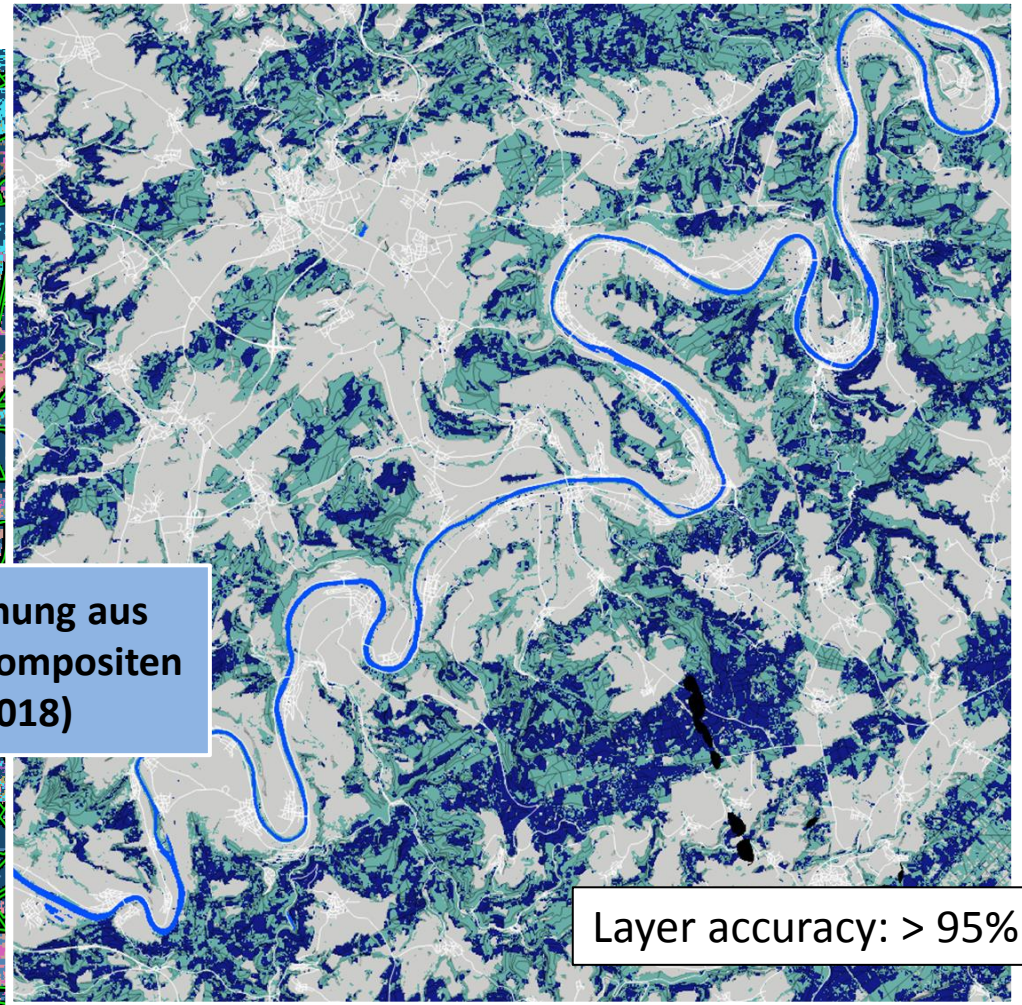
# Workflow „Data Miner“/Klassifikatoren



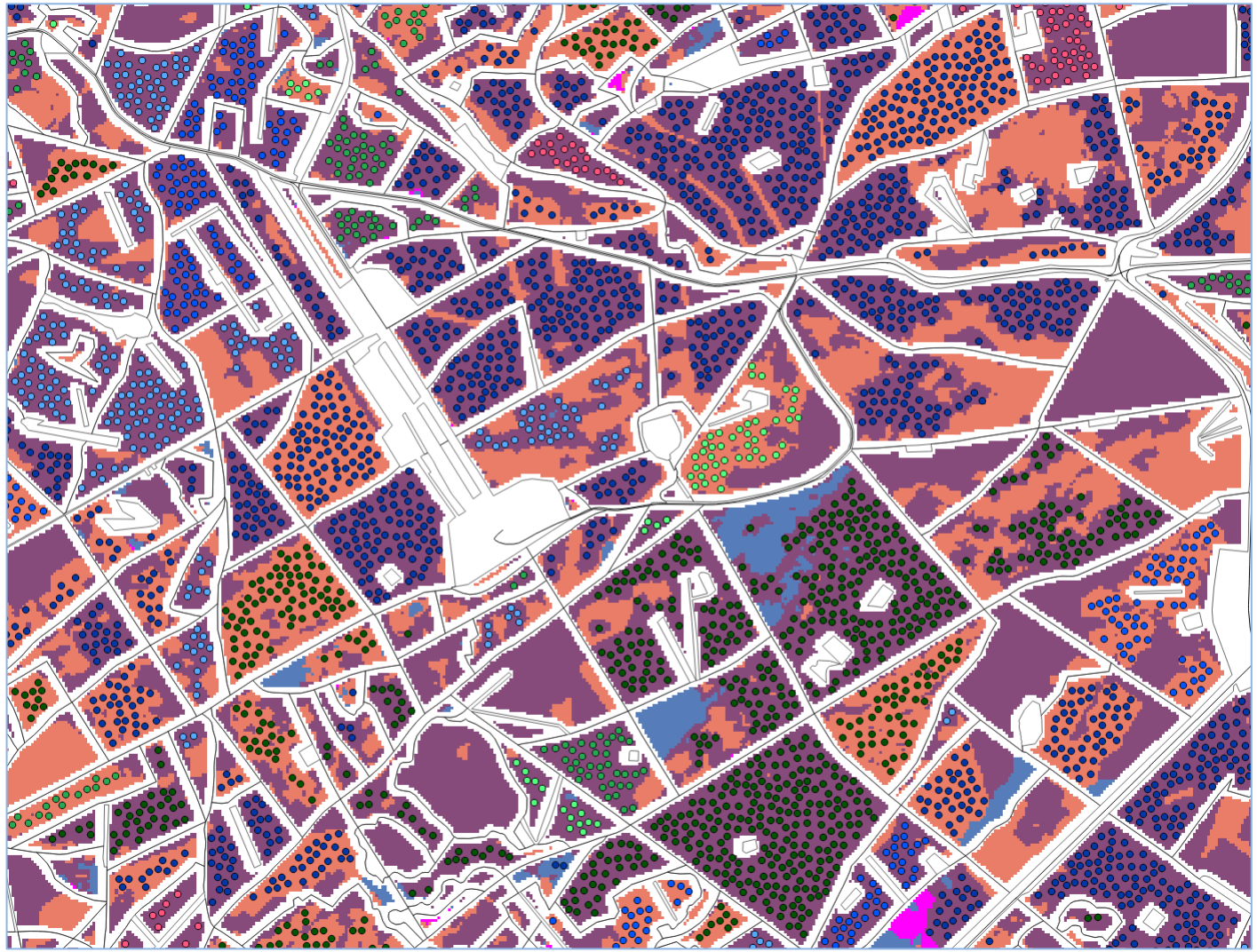
# Automatische Auswahl von validen GRIPS-Datenbankeinträgen zur optimalen Parametrisierung eines Klassifikators




**Laub-/Nadelholztrennung aus Sentinel-2 A/B Winterkompositen (Feb/Mar 2016-2018)**



Layer accuracy: > 95%



# Erbeskopf-Region, RLP

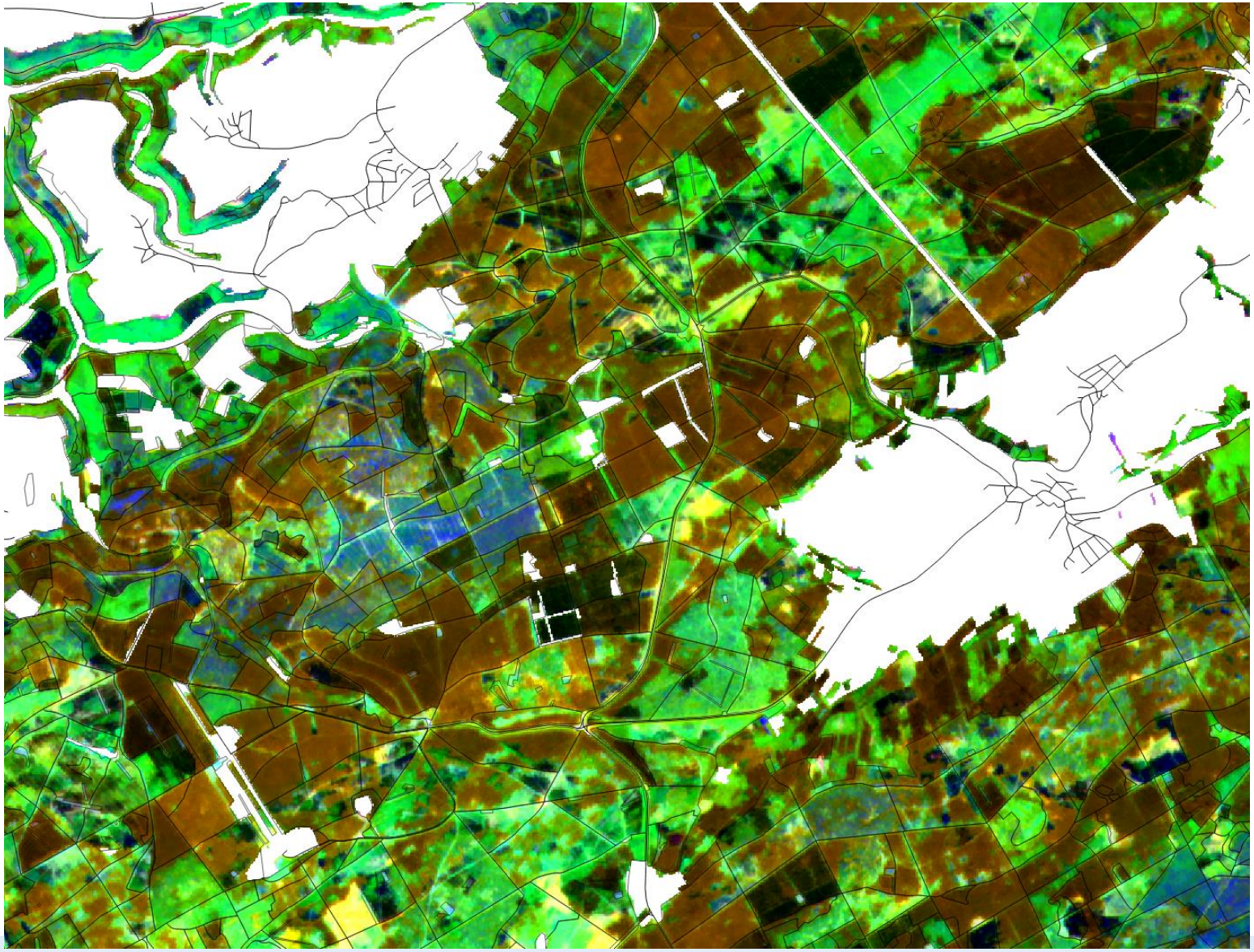
## Ergebnis „Data Miner“

Waldortspezifische Cluster-Analyse zur Charakterisierung räumlicher Inhomogenität

überlagert mit:

Automatisch erzeugte Sampling-Positionen für Hauptbaumarten und Entwicklungsphasen

PostgreSQL

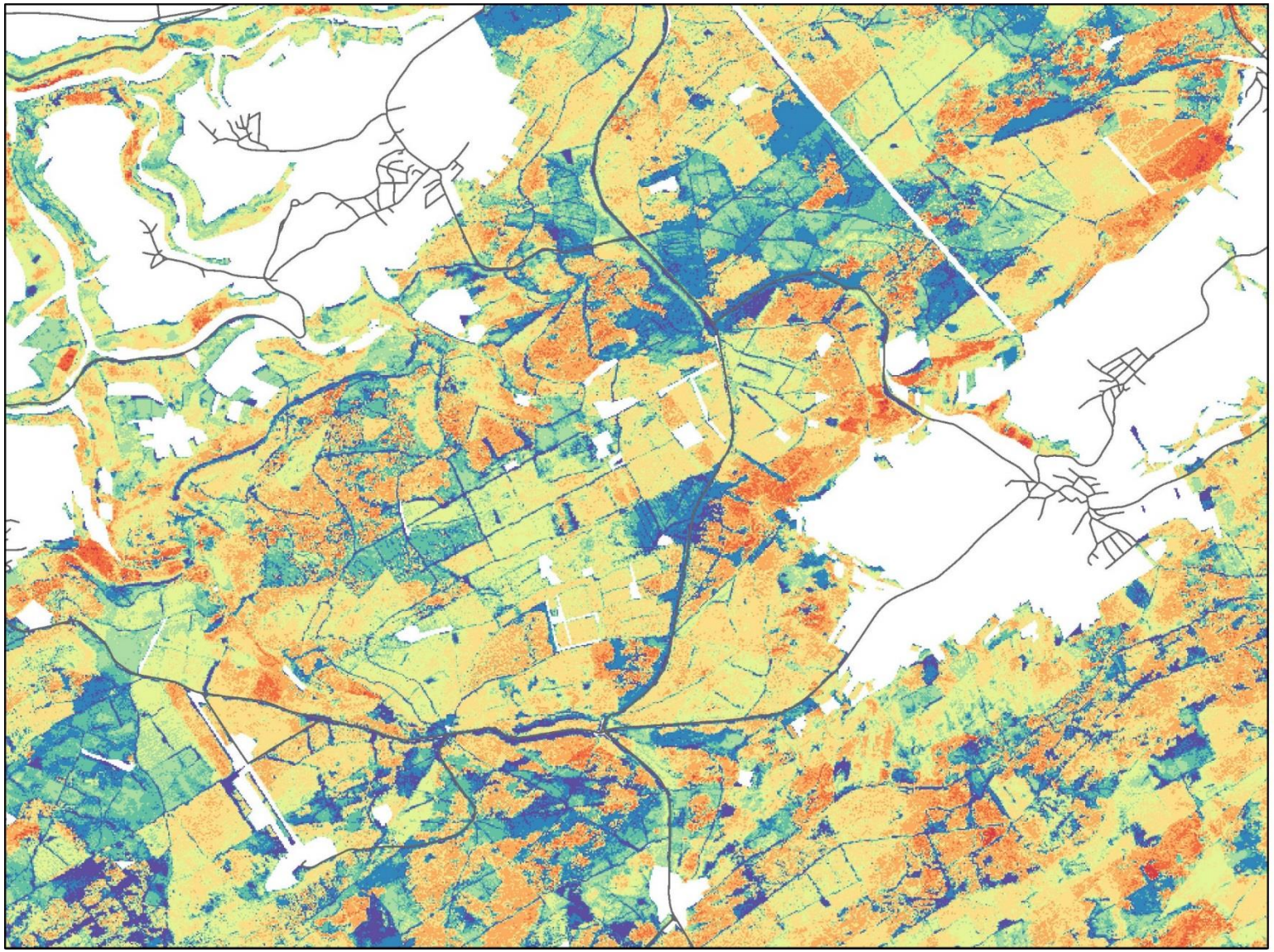


# Erbeskopf-Region, RLP

**GridClass Random Forest**

Aus insgesamt 4 saisonalen Sentinel-2-Datensätzen abgeleitete Klassifikation der Hauptbaumarten und Entwicklungsphasen

6 Hauptkomponenten



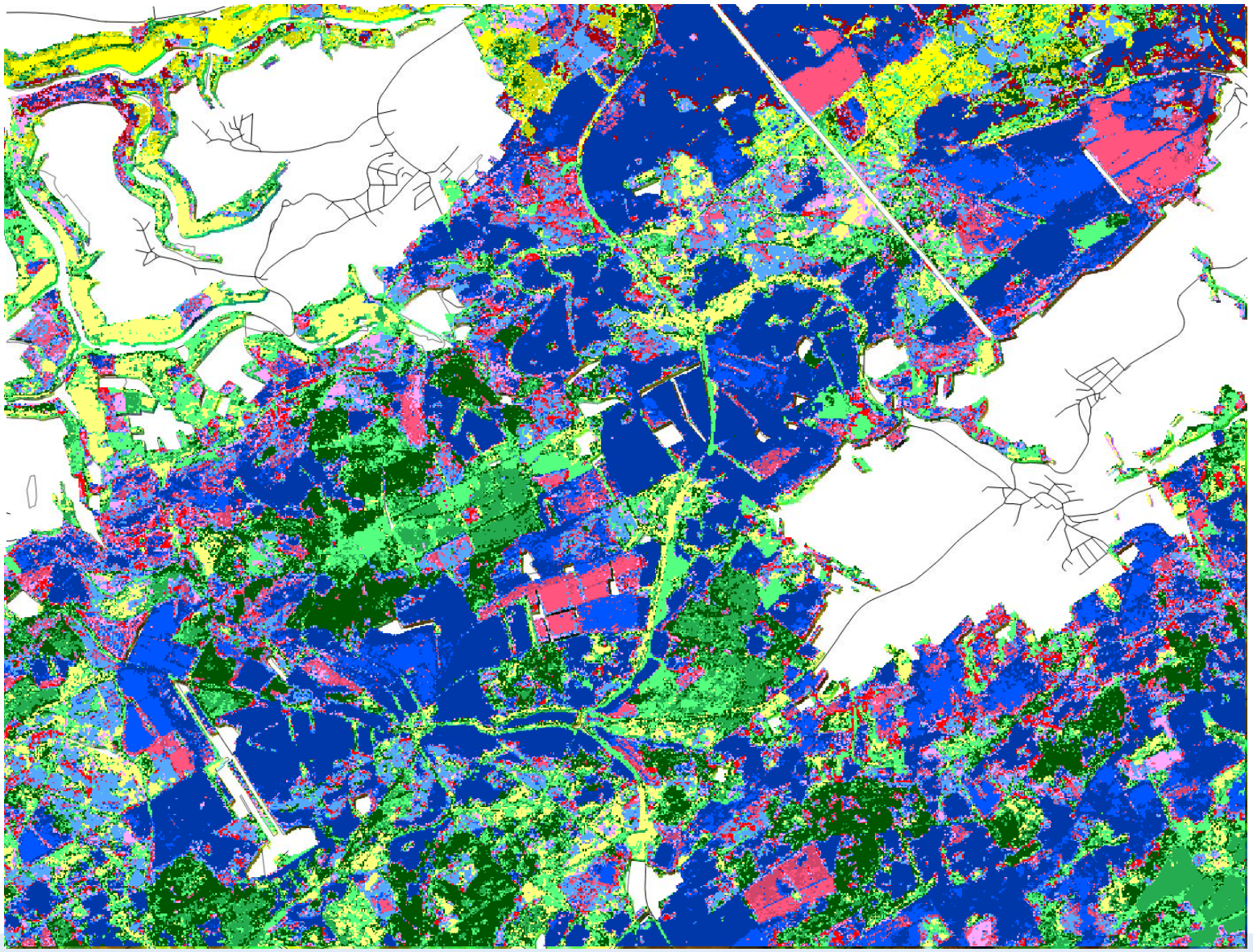
# Erbeskopf-Region, RLP

**BDOM (photogrammetrisch erzeugtes Oberflächenmodell) 2015/16**

Hoher Aktualitätsgrad (2015/16)
2016/17 bereits verfügbar

Objekthöhe
- > 50 m
- ≤ 50 m
- ≤ 35 m
- ≤ 30 m
- ≤ 25 m
- ≤ 20 m
- ≤ 15 m
- ≤ 10 m
- ≤ 5 m
- ≤ 1 m

LVermGeo RLP



# Erbeskopf-Region, RLP

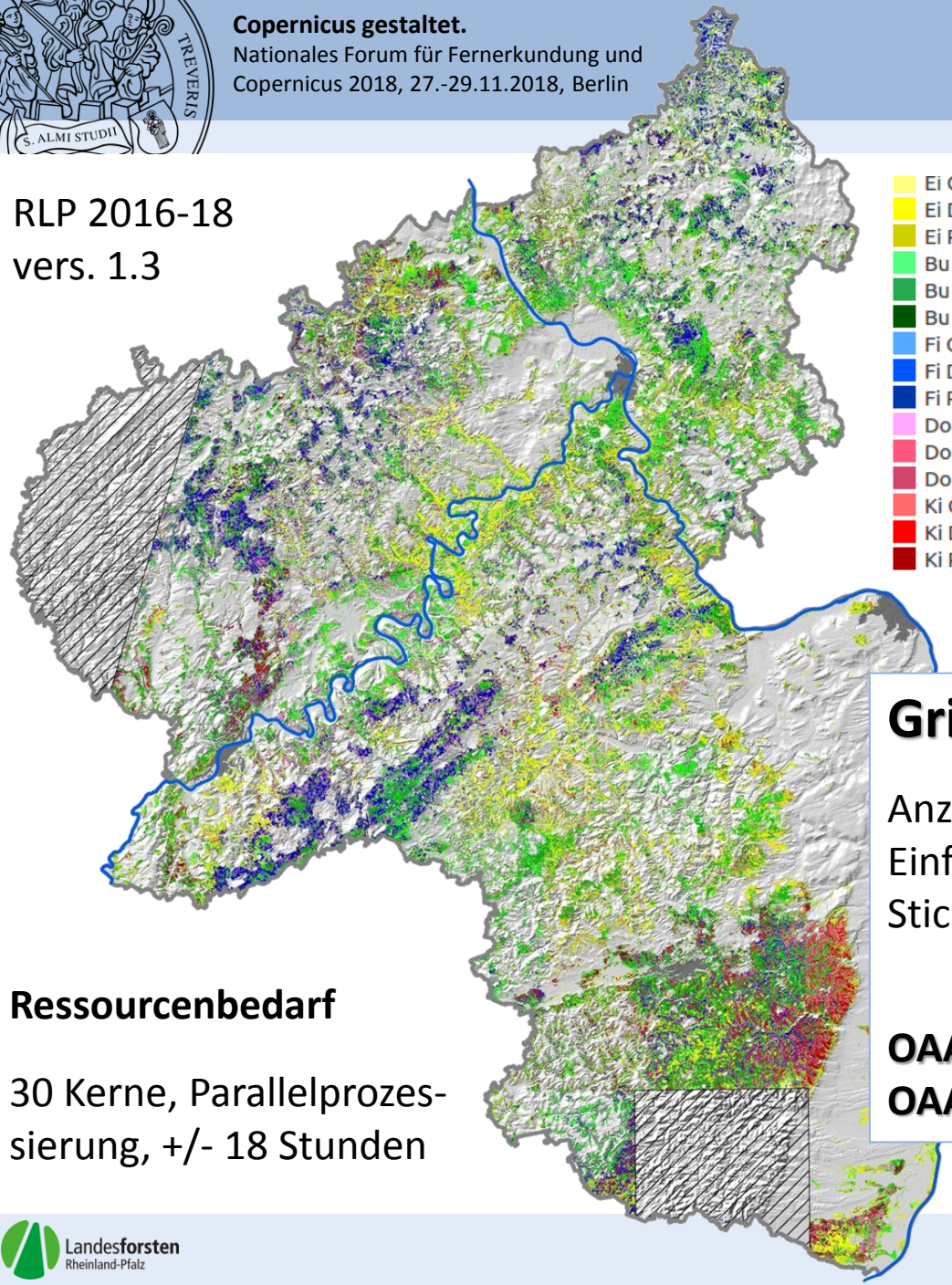
## GridClass Random Forest

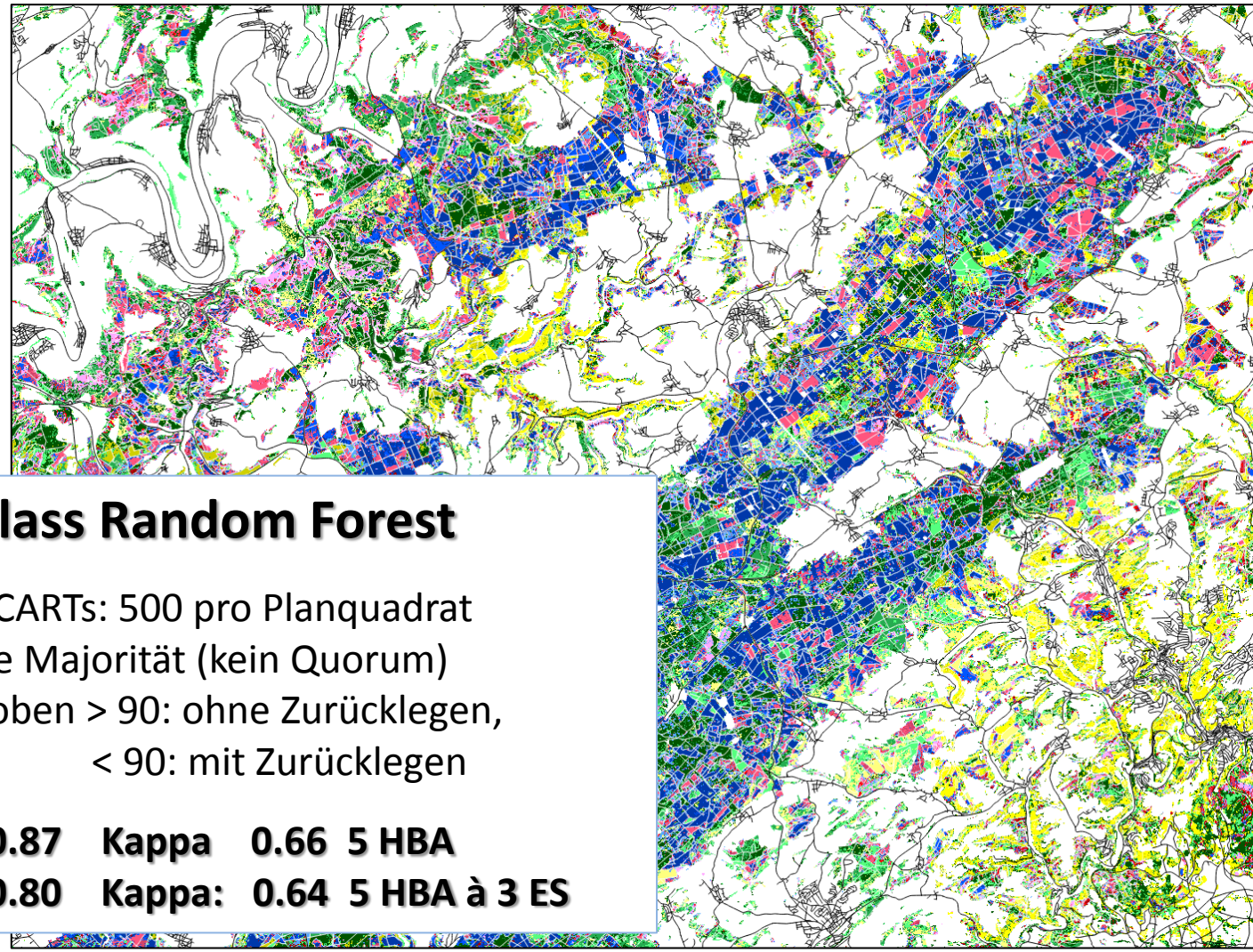
Aus insgesamt 4 saisonalen Sentinel-2-Datensätzen abgeleitete Klassifikation der Hauptbaumarten und Entwicklungsphasen

- Ei Qua
- Ei Dim
- Ei Rei
- Bu Qua
- Bu Dim
- Bu Rei
- Fi Qua
- Fi Dim
- Fi Rei
- Dou Qua
- Dou Dim
- Dou Rei
- Ki Qua
- Ki Dim
- Ki Rei

PostgreSQL

RLP 2016-18
vers. 1.3



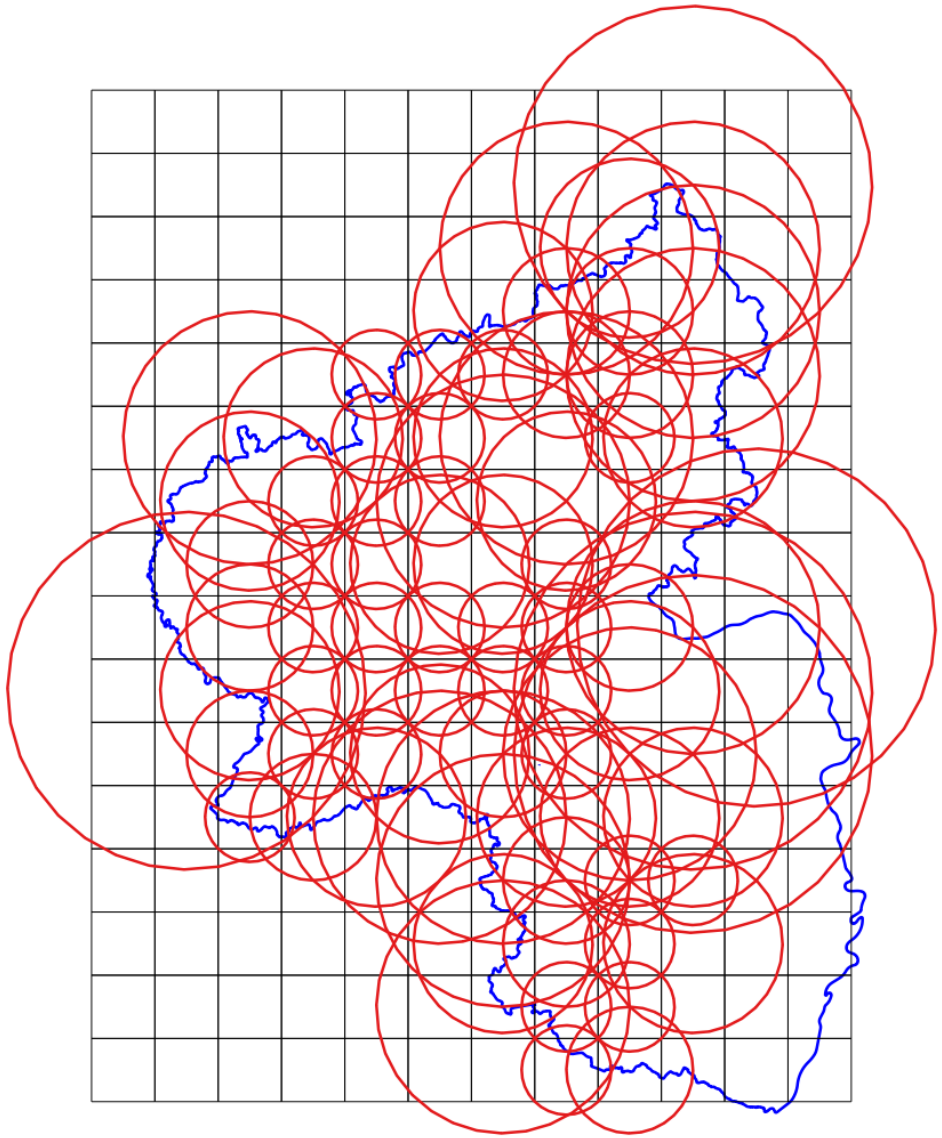
## GridClass Random Forest

Anzahl CARTs: 500 pro Planquadrat
Einfache Majorität (kein Quorum)
Stichproben > 90: ohne Zurücklegen,
< 90: mit Zurücklegen

**OAA 0.87 Kappa 0.66 5 HBA**
**OAA 0.80 Kappa: 0.64 5 HBA à 3 ES**

**Ressourcenbedarf**

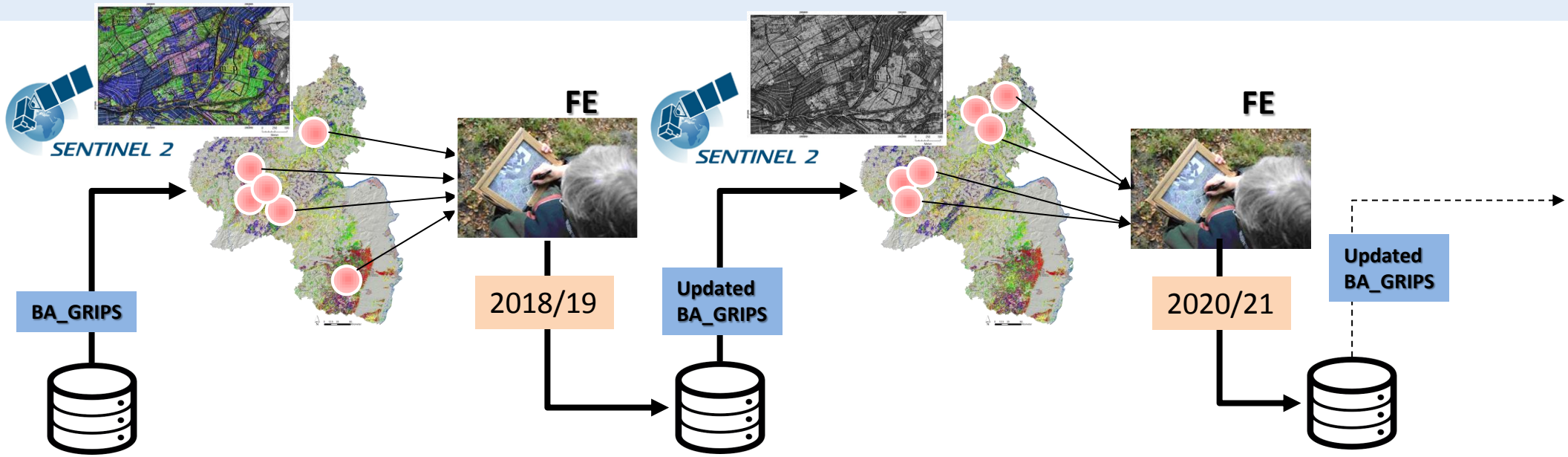
30 Kerne, Parallelprozes-
sierung, +/- 18 Stunden



# Landesweite BA-Klassifikation RLP GridClass-Random Forest

Random Forest, 500 Trees, Simple Majority

| | Hersteller-genauigkeit | Nutzer-genauigkeit |
|---|---|---|
| Eiche | 0.856 | 0.785 |
| Buche | 0.883 | 0.834 |
| Fichte | 0.815 | 0.768 |
| Douglasie | 0.825 | 0.530 |
| Kiefer | 0.803 | 0.676 |




## *Résumé*

- Sentinel-2 wird weiterhin Daten in bisher nicht gekanntem Umfang bereitstellen
- Wir verfügen über leistungsstarke Klassifikationsalgorithmen
- Entscheidende Voraussetzung zur Sentinel-Datennutzung: **Integration der Fernerkundungsdaten in effiziente Datenhaltungs- und Dokumentationssysteme** (z.B. GRIPS)
- Dabei ist die **Aktualität der amtlichen Datenbestände** entscheidend: jeder neu eingerichtete Waldort mit explizitem Geometriebezug verbessert die Qualität der Ergebnisse
- Damit wächst die Differenzierbarkeit (zusätzliche Baumarten, z.B. Edelkastanie)

# Vielen Dank für Ihre Aufmerksamkeit.

FKZ 50EW1605, gefördert durch

Bundesministerium für Verkehr und digitale Infrastruktur

DLR Deutsches Zentrum für Luft- und Raumfahrt