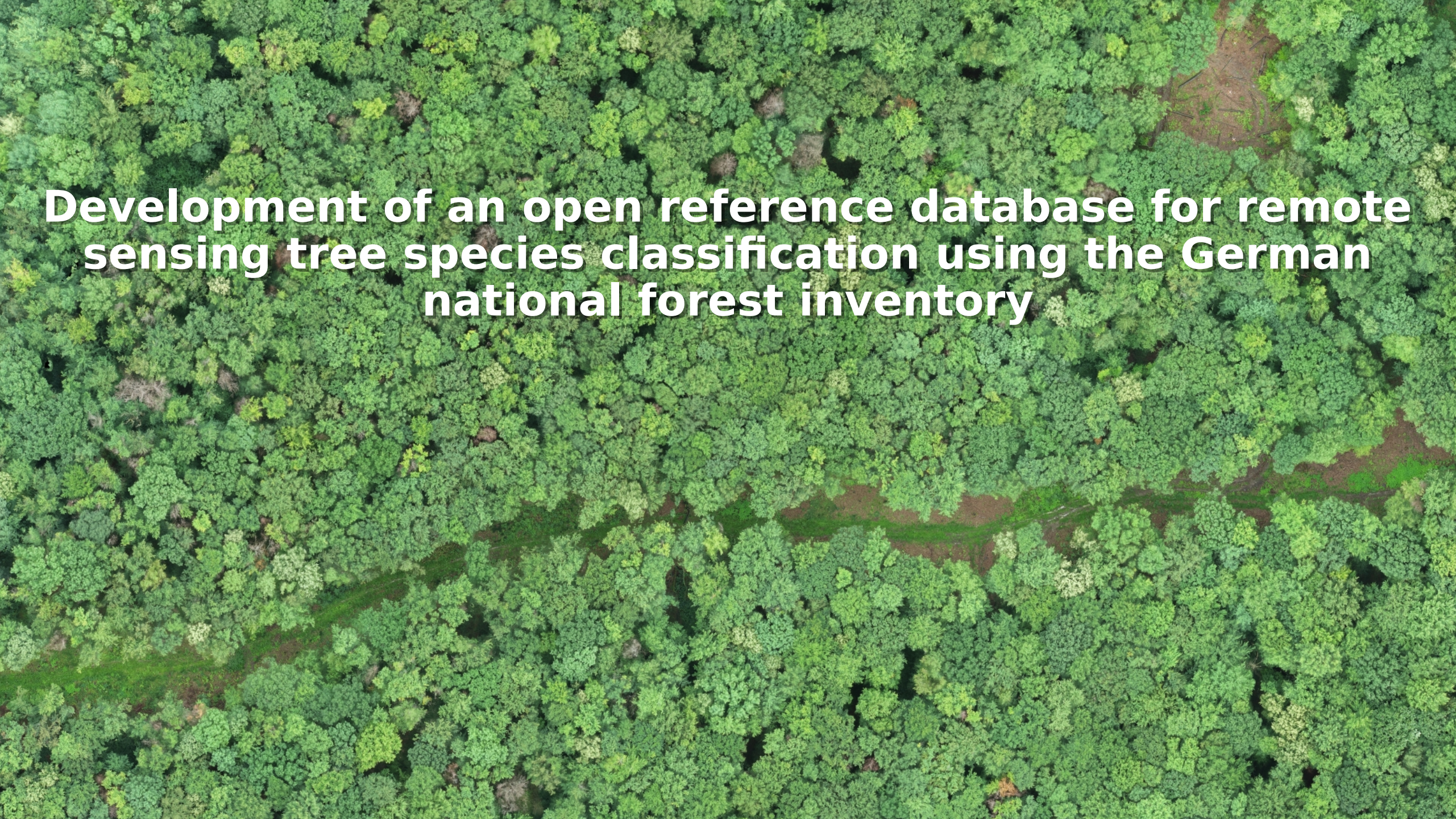

Development of an open reference database for remote sensing tree species classification using the German national forest inventory

KLIma angepasste BAumartenwahl

Bundesministerium für Verkehr und digitale Infrastruktur

Duration: 1.10.2020-30.09.2023
Financing: BMVI

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THÜNEN

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

KlimBA: Project Goals

How can data from the National Forest Inventory (NFI) be utilized to develop remote sensing based products for forest monitoring and planing?

→ Development of a public reference database for tree species classifications

→ Development of a national tree species map

→ Compilation of tree species suitability maps using ecological information and model future site conditions

→ Assessing the resilience of forest stands by comparison of the observed tree species to the modeled suitability maps

Highly relevant for:

- Forest Managers
- NGO‘s
- Conservation and planning agencies
- Politics
- …

Provided by:

- @ stand level from forest management inventories
- @ enterprise level from sample-based inventories
- @ national level from the national forest inventory (NFI)
- Information is updated every decade

Forests in Germany face manifold challenges:

- Climate change alters growth conditions
- Nitrogen depositions alter the side conditions
- Society demands a wide range of ecosystem services

Forest management:

- Promoting tree species that can adopt to altered growth conditions
- increase the structural complexity of forest stands by an accelerated forest transition towards structural rich uneven age forest structures

Brocken, Harz 2021

New dynamic forest monitoring an planning tools are needed!

Remote Sensing could significantly contribute to the enhancement of forest monitoring systems

Remote sensing:

- Provides area wide information with a high temporal frequency
- The Copernicus program provides standardized products from S1 & S2 which have a spatial resolution suitable for large area and management / stand-level monitoring
- Many projects develop approaches to provide tree species maps from Copernicus data

Reference data:

- All projects require reference data to train and validated their classification systems
- Obtaining such reference data can be laborious and expansive
- Reference data could be sourced from forest inventories BUT such information is usually not publicly available

Objectives & Research Questions

Objective:
Development of a public reference data base for tree species classification using Copernicus data

Research Questions:

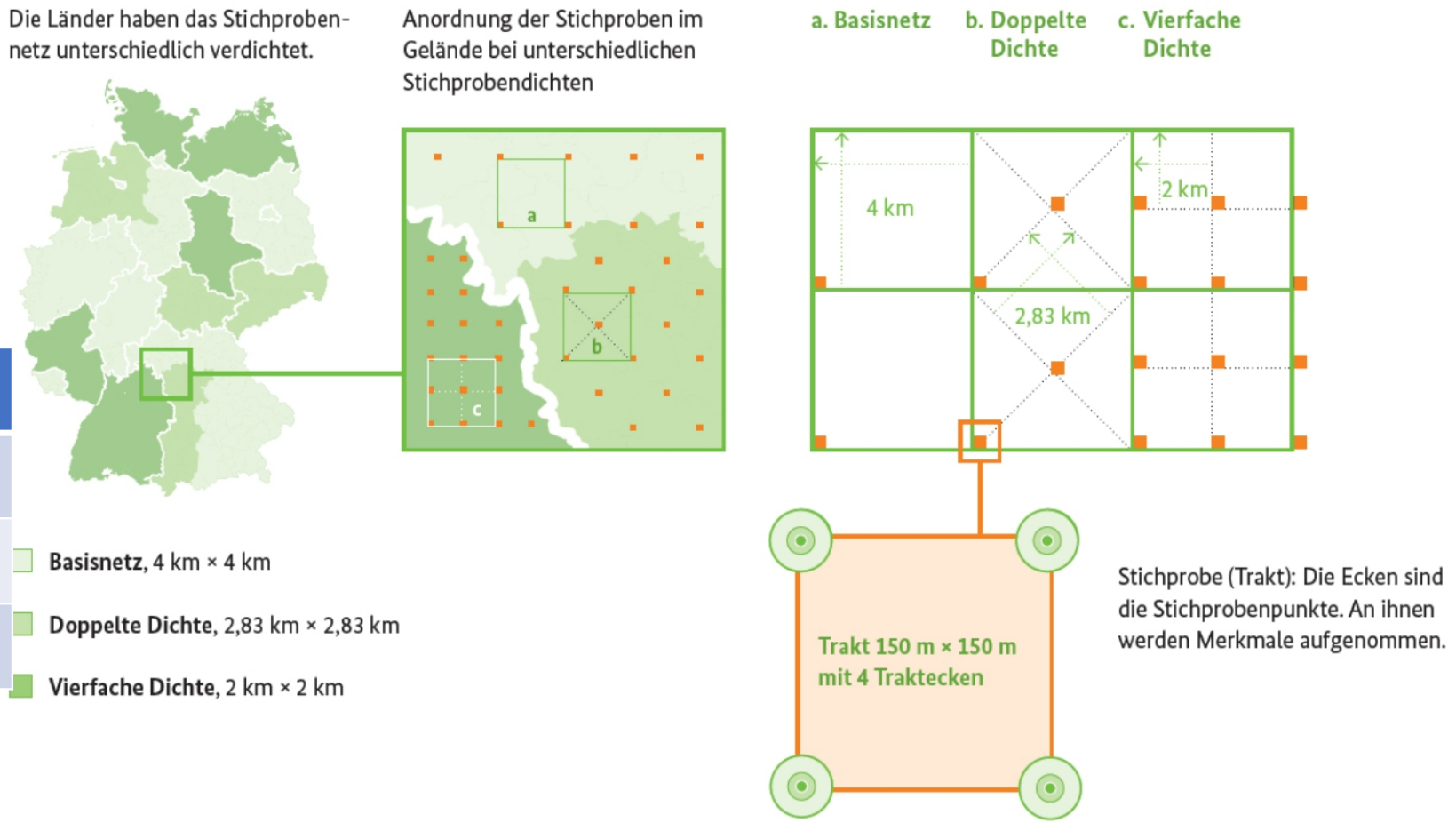
- How to compile reference data for remote sensing based classifications from the NFI inventory design?
- How to design, structure and publish the reference database to make it suitable for the RS community?

Data

Bundeswaldinventur /NFI

Sample-Design:

Year	Clusters	Points
2012	25382	68201
2017	5768	15740
2021	*ca. 29000*	*ca. 81000*



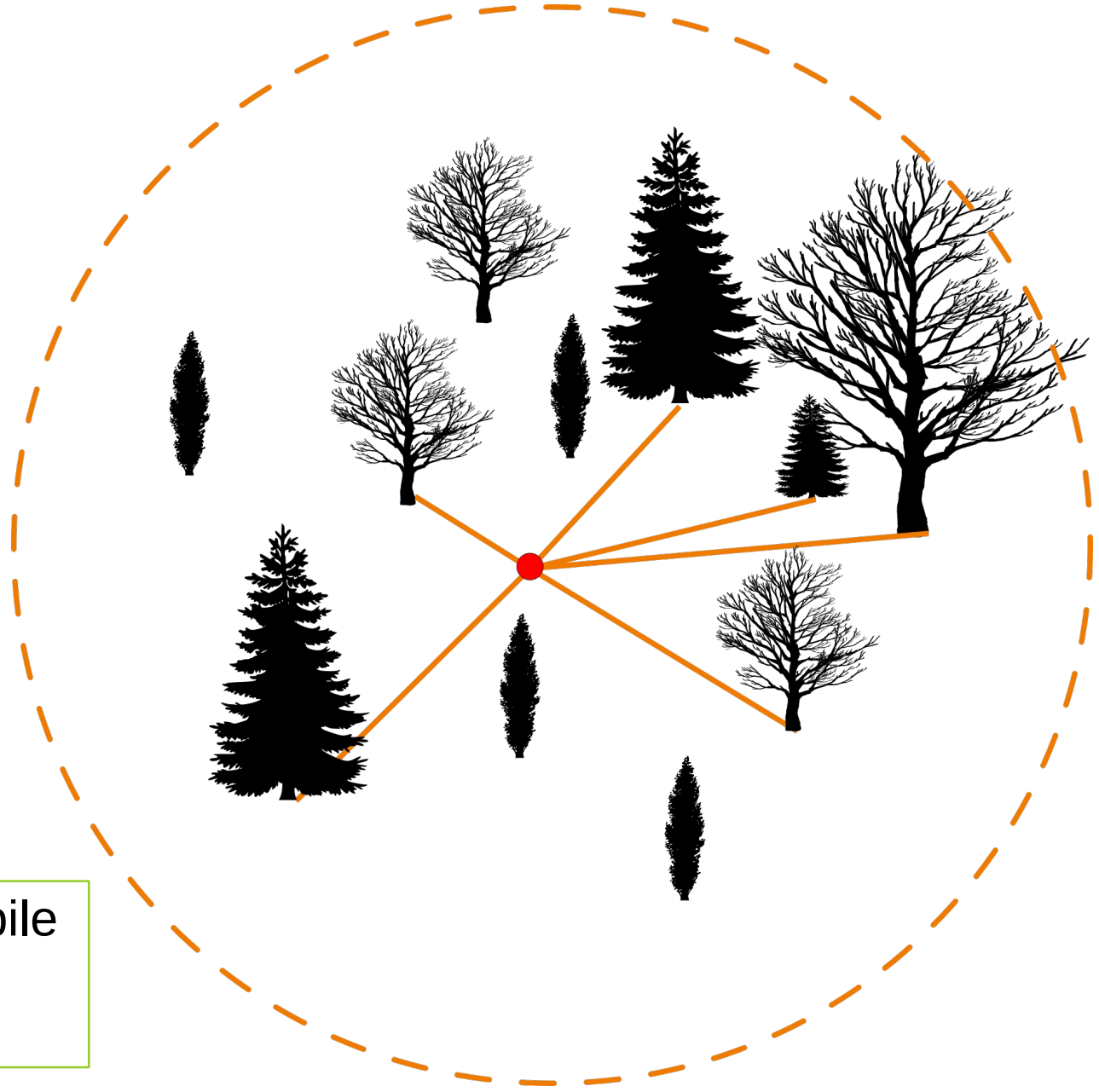
Source: https://www.bundeswaldinventur.de/

Plot-Design:

- Angle count sampling with *k=4*

Challenges:

- Angle count sampling does not select all trees in a fixed area
- Positional error of the sample point coordinates is unknown and potentially high
- Only ‘visible’ trees can be monitored from space



The plot-design is by no means optimal to compile a reference database for remote sensing classification!

Remote sensing data

Sentinel-2

- Pre-Processing with FORCE v3.6
- National data cube 2017-2020
- Uni Göttingen

Sentinel-1

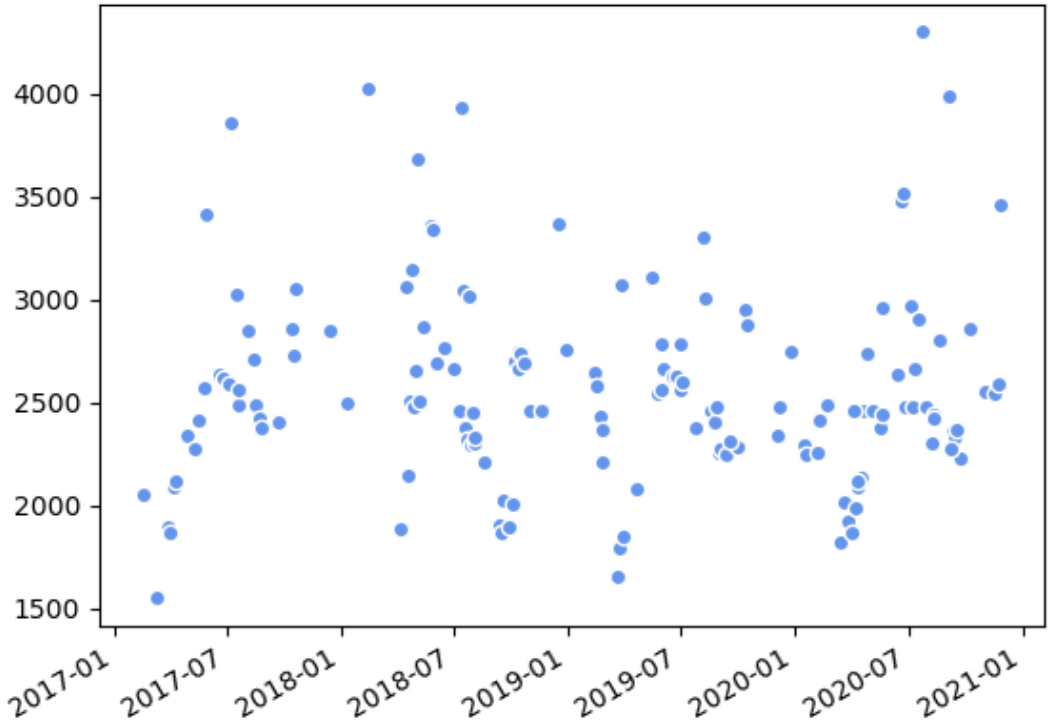
- Pre-Processing SNAP
- National data cube 2017-2020
- CODE-DE

Digitale Ortho-Images (DOP)

- 20cm spatial resolution
- National coverage of Federal Agency of Cartography and Geodesie (BKG)

Challenges-Remote Sensing

- National coverage of S2 images for 2017-2020 has 12 Terra Byte
- L2a data still is noisy
- Policy, support & future of the CODE-DE platform is unclear
- Quality and acquisition season of the DOP images from the BKG is variable



S2-L2a NIR, time series from a spruce stand

Methods

Approach

A two stage approach which utilizes he single tree information is used:

Stage 1: Tree species maps are created in the plot surroundings using high resolution aerial images

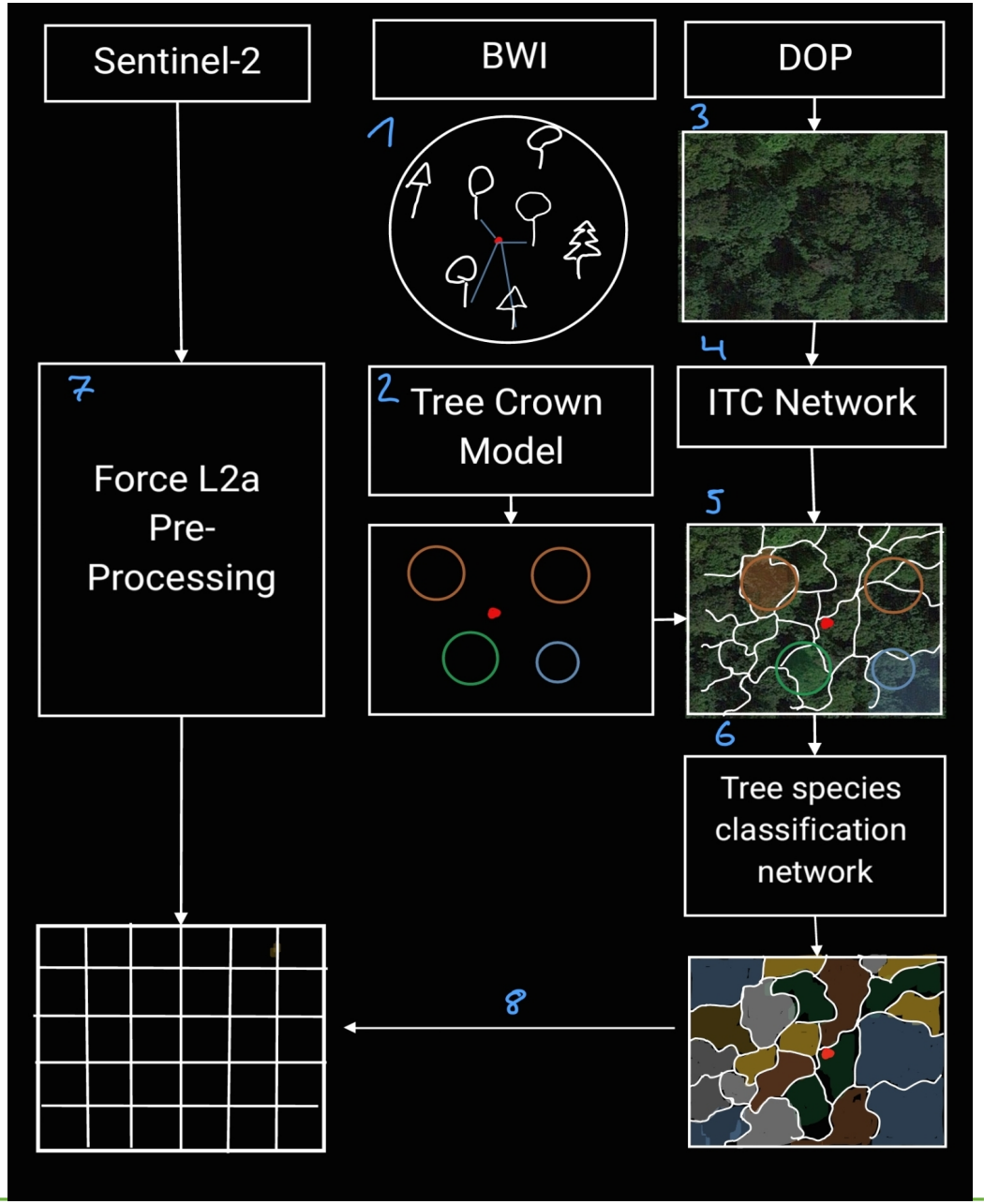
Stage 2: The plot surrounding maps are used to create the S2 reference data

Tab. 1 Number of plots with >90% basal area of one species

Species	Points
Spruce	10695
Pine	12693
Beech	5066
Oak	2154

Stage 1

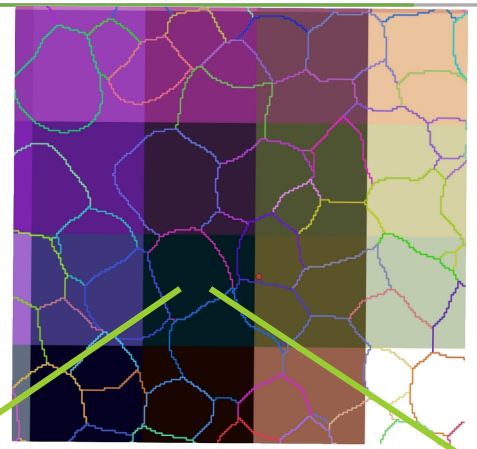
1) Calculate single tree positions from the plot coordinates, angle and distance measurements of trees
2) Model tree crown radius for each tree using species specific stand-space models
3) Cut out 300x300m extent around each sample-point from the digital orthophoto (DOP)
4) Apply U-Net based deep learning approach for individual tree crown (ITC) detection (Freudenberg et al., submitted)
5) Intersect tree crown models with ITC-segments and apply heuristic assignments to identify matches with high probability of being correctly assign
6) Train U-Net based species classification network to classify the tree species all segments in the 300x300 extent (Nölke et al., 2020)
7) Process Sentinel-2 images to L2 product using FORCE
8) Intersect the classified ITC-Segments with the Sentinel-2 pixels



Stage 2

1)For each S2-Pixel within the 300x300m extent we derive a vector with the species proportion (*p*)

2)For each S2-pixel we derive the full time series stack of reflectance values



Theoretical size of the reference data:

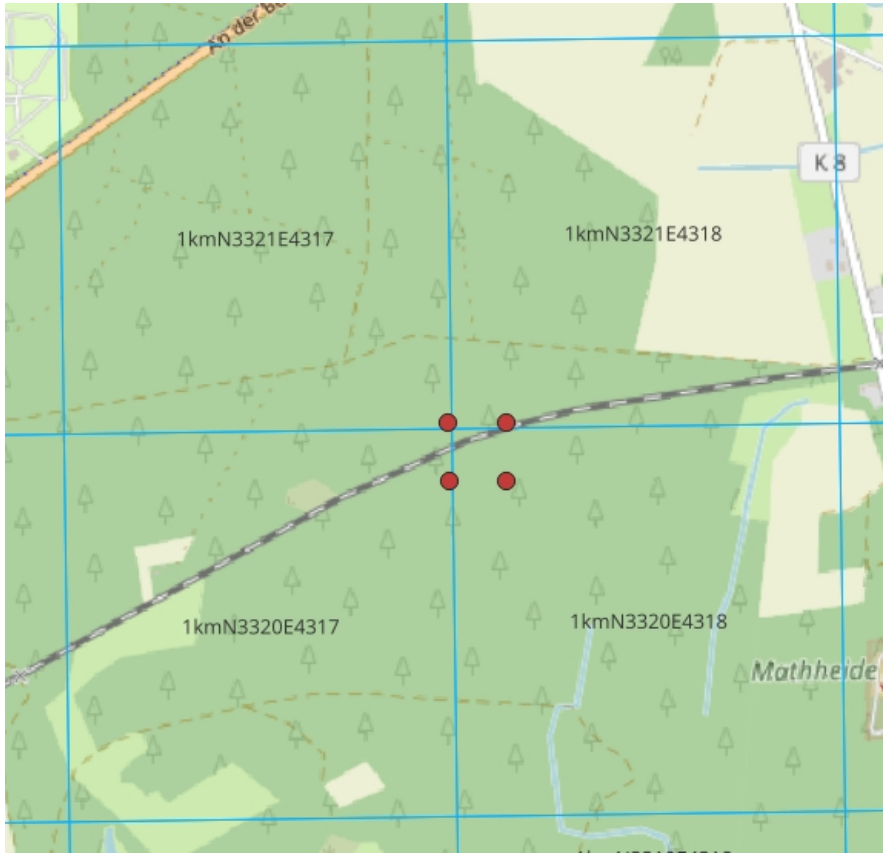
81’000 plots x 900 pixel = 72’900’000

Time	***Band 1***	***Band 2***	***Band 3***
04052017	0.8	0.8	0.8
04052018	0.2	0.2	0.2
09052018	0.5	0.5	0.5
15052018	0.7	0.7	0.7
24052018	0.7	0.7	0.7
…	…	…	…

Species	***p***
Beech	0.8
Oak	0.2
Spruce	0
Pine	0
Larch	0
…	
Total	1

Design & Access to the reference database

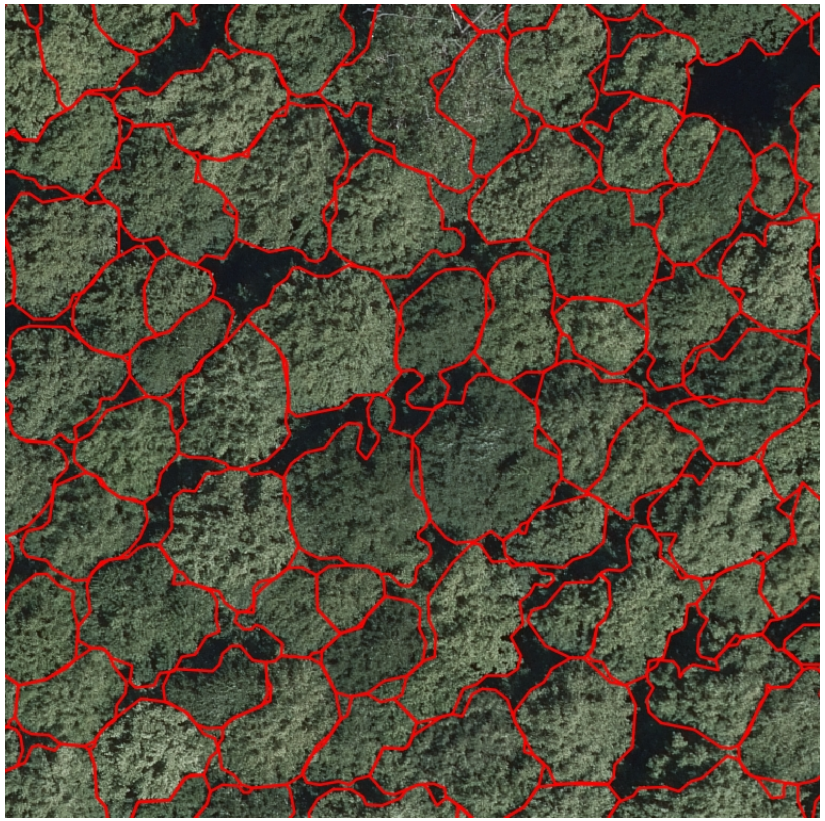
- All of the reference pixel values, the image metadata and their species proportions will be extracted into a SLQ database
- Providing the species proportions enables users to select their own thresholds for creating labeled data
- As the exact plot coordinates must not be disclosed but we will include the INSPIRE grid ID (1km)
- All data will be stored in a centralized database on a virtual server operated by CODE-DE
- Data will be accessible via our website

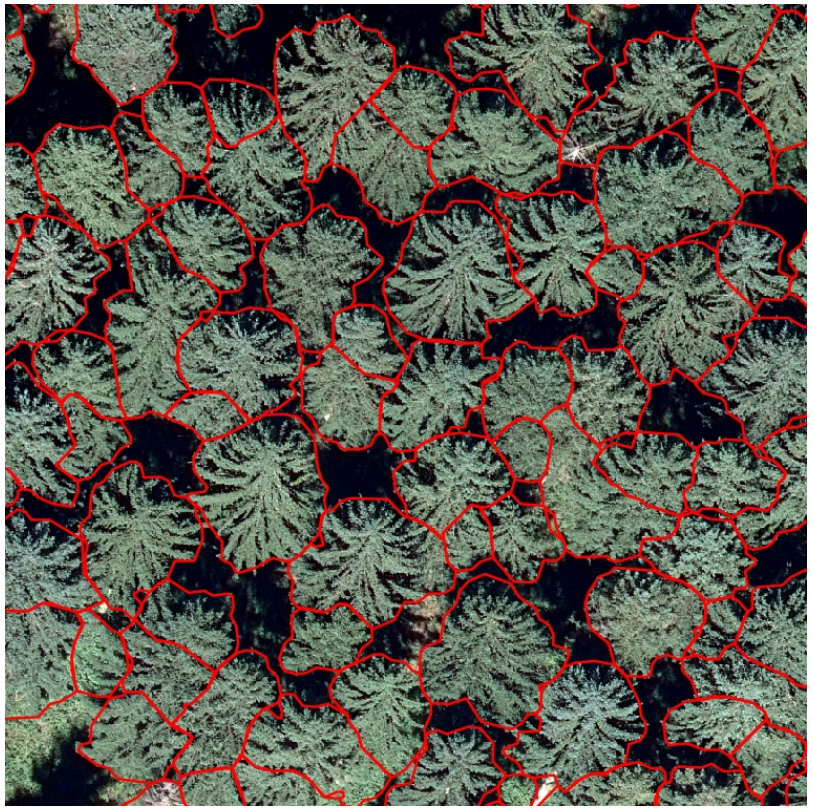


First Results

Tree crown delineation

Freudenberg et al. (submitted):





U-Net tree crown segmentation on aerial images with 5cm spatial resolution

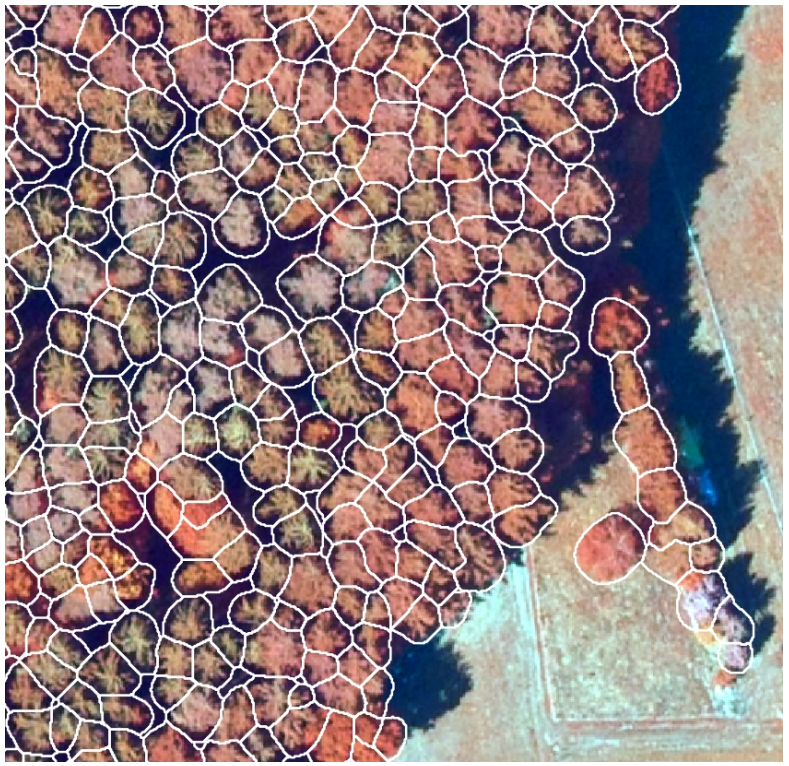
10-fold cross-validation:

- Overall accuracy: 52%
- Precision: 70.9 %
- Recall: 66.2%

Tree crown delineation

We adapted the existing U-Net to the DOP images of the BKG with a small training dataset of *n*=100 plots

U-Net tree crown segmentation on aerial images with 20cm spatial resolution



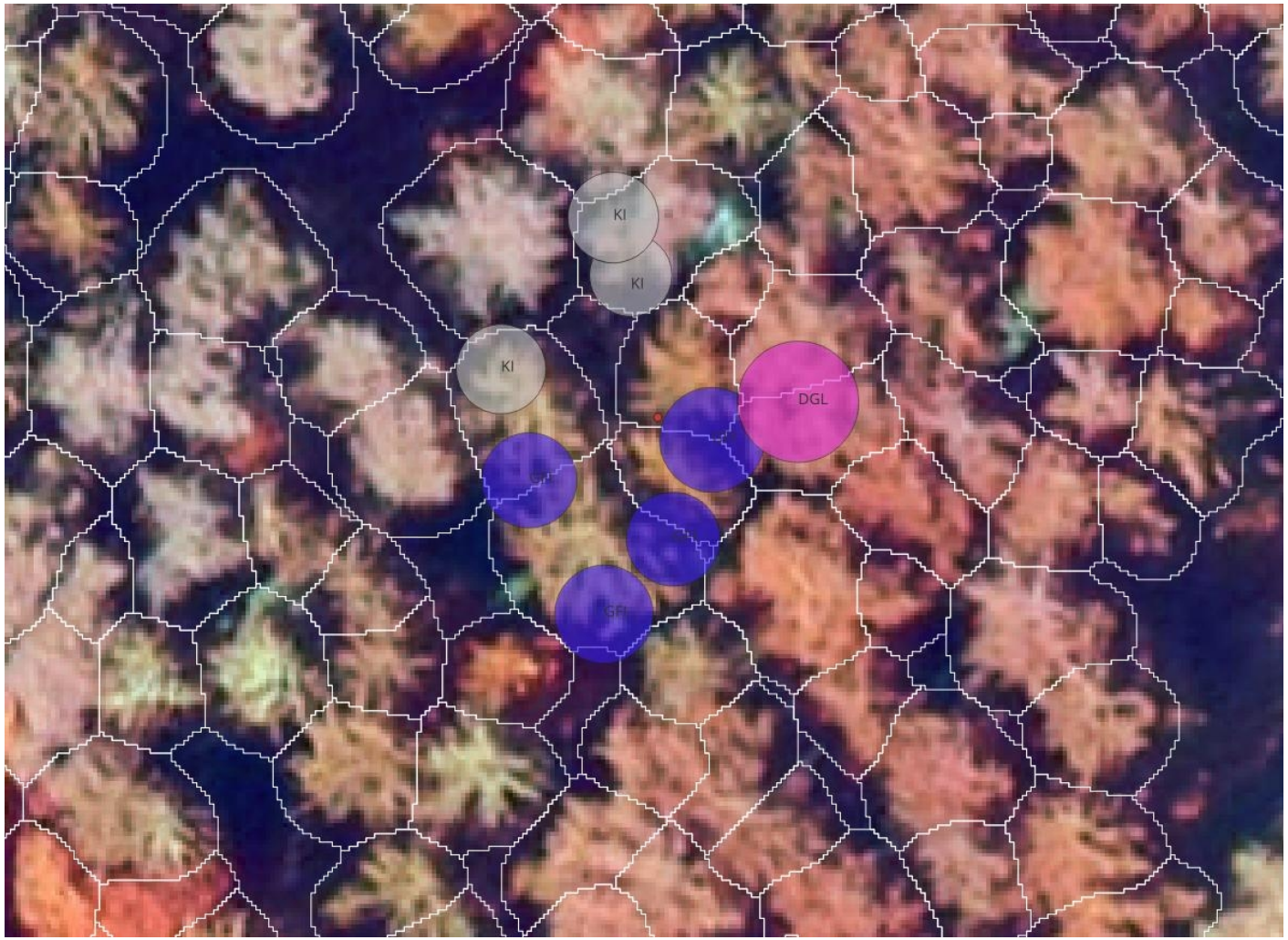
BWI Plot 63299

BWI Plot 1277

First observations:

- Segmentation can be transferred to DOP20
- Image quality is quite variable
- Crown cover mask are quite exact
- Coniferous trees are better segmented than deciduous trees
- Processing time ~1sek / Plot

Linking tree positions and tree crown segments

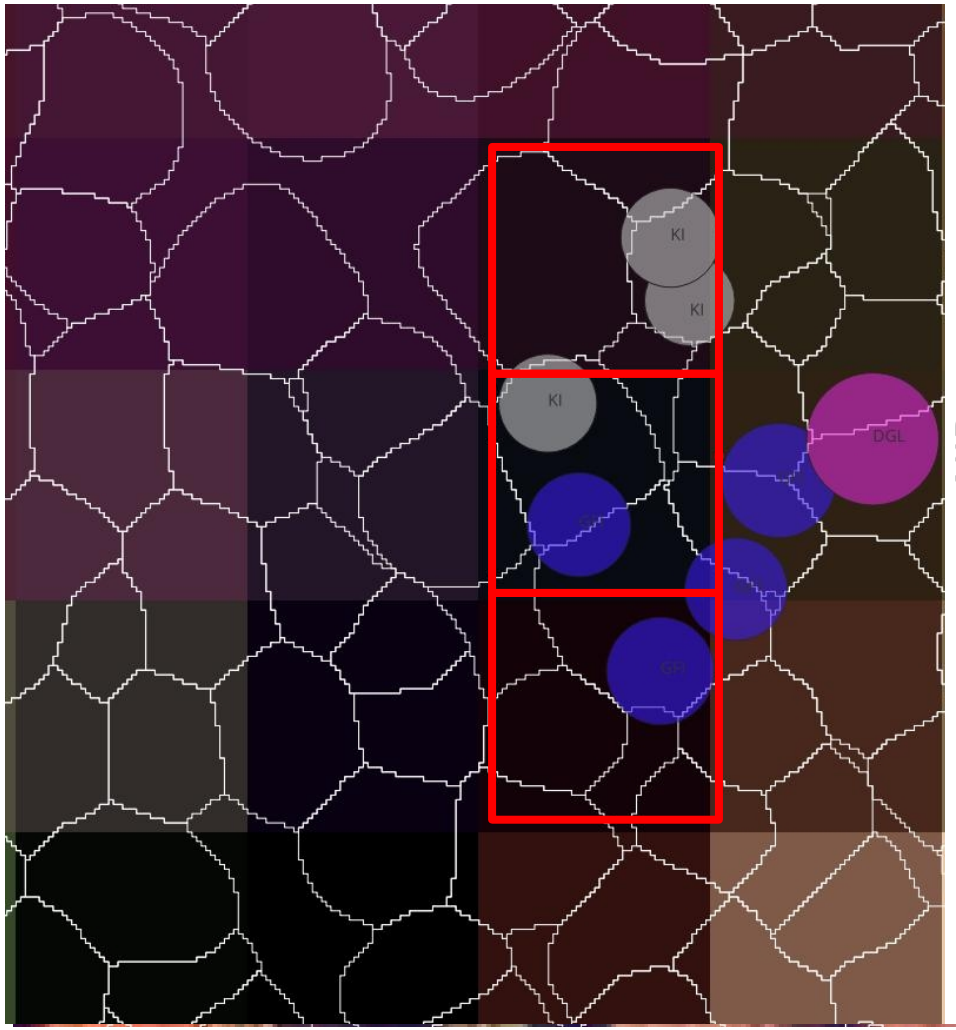


BWI Plot 63299

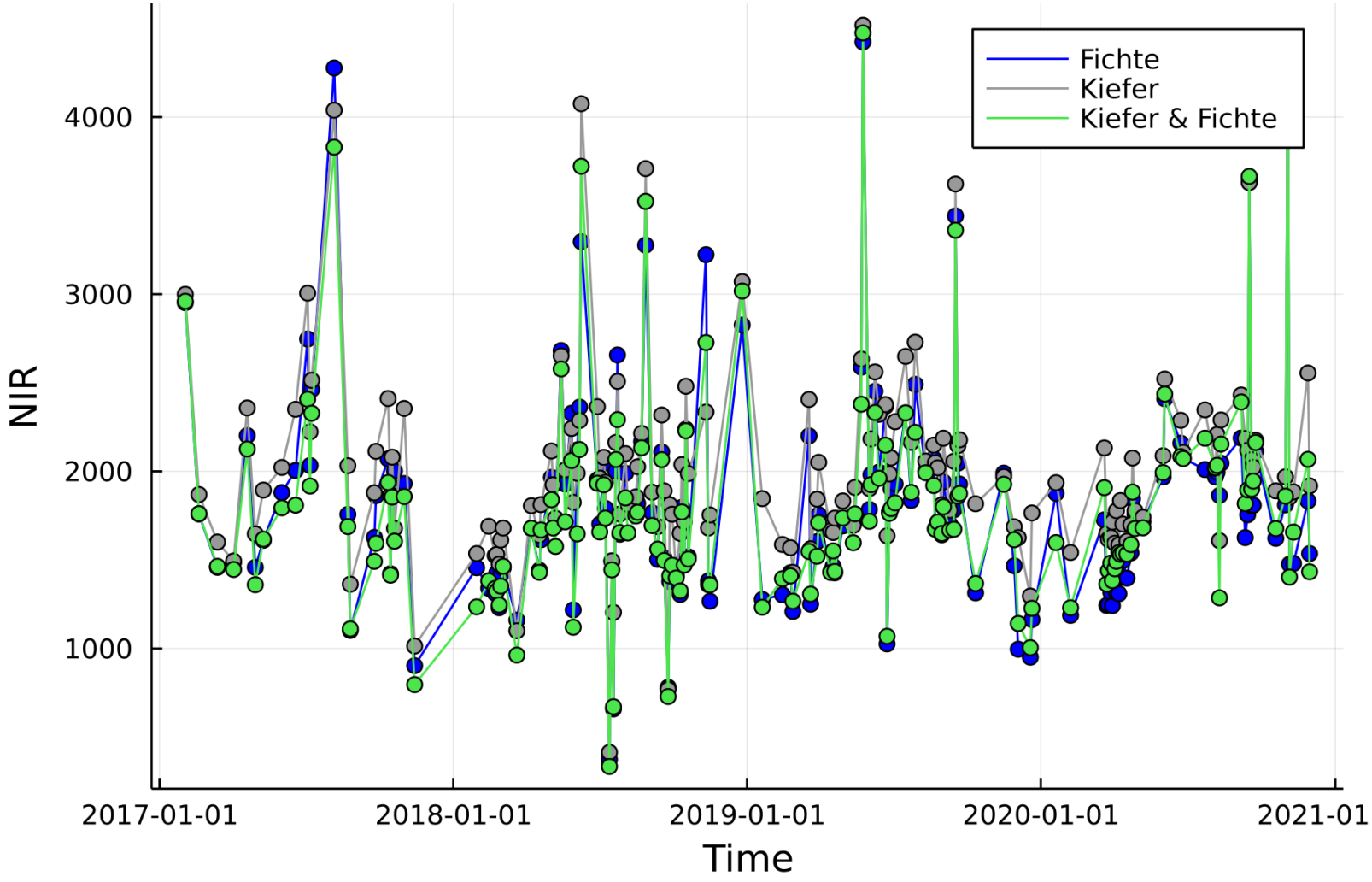
First observations:

- A an automatic intersection with position only will not be successful
- The relative positions of the trees is quite precise
- A pattern matching approach to automatically shift the plot positions would be helpful
- Using a heuristic approach the quality of the assignment need to be quantified

Extracting S2 time series data

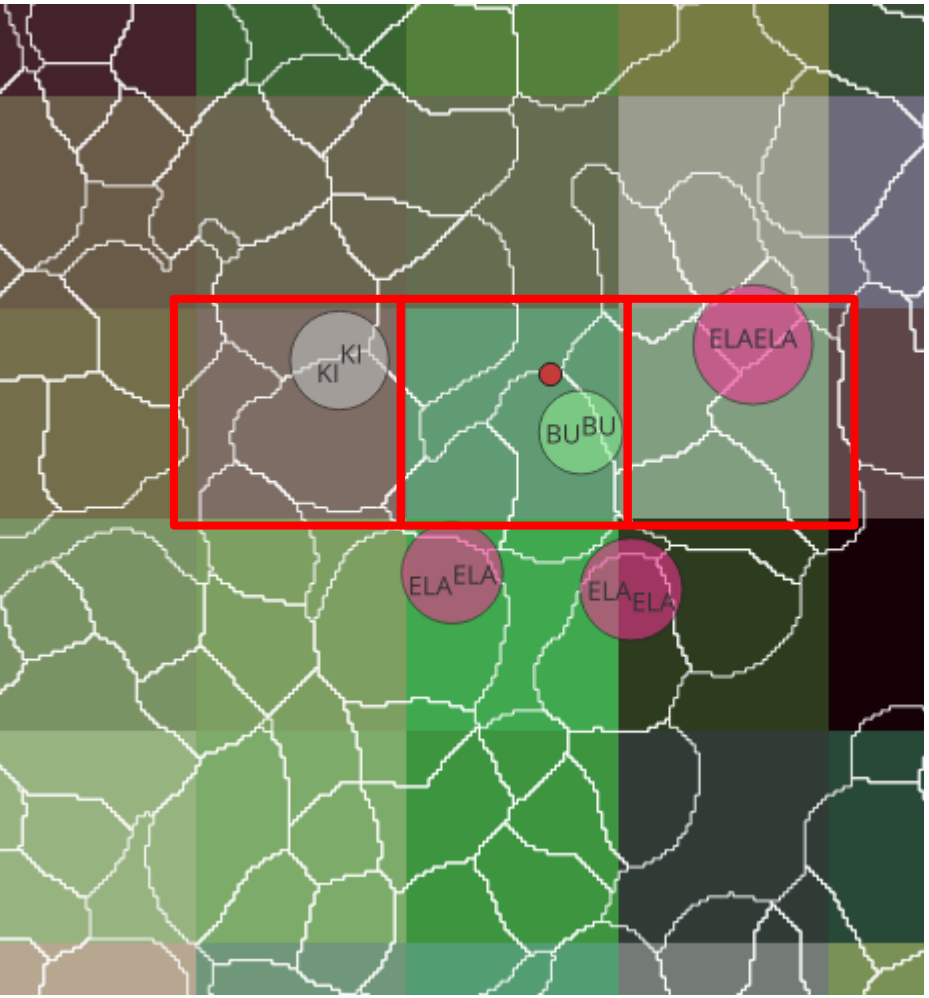


BWI Plot 63299

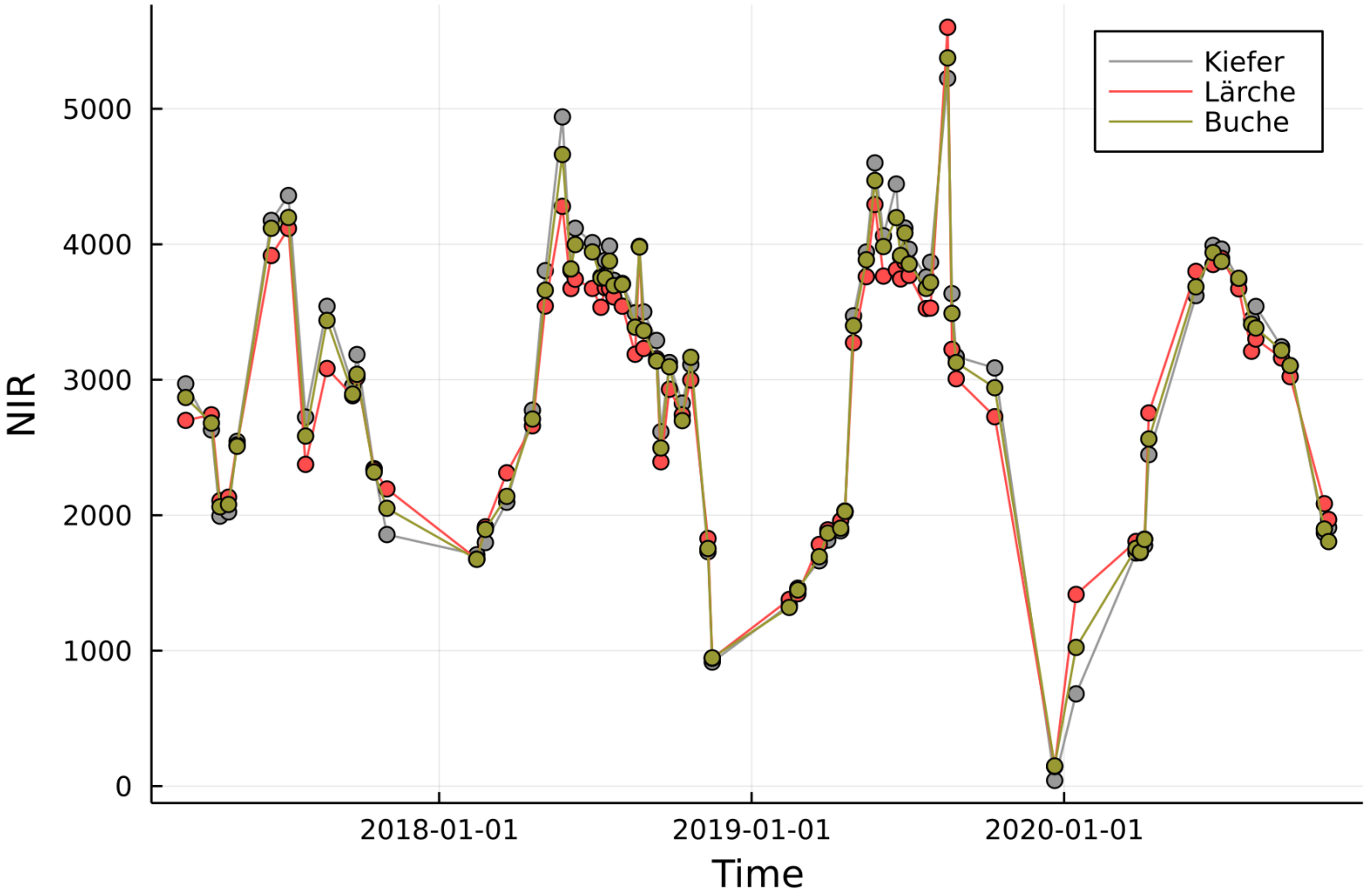


FORCE L2 time series

Extracting S2 time series data



BWI Plot 60693



FORCE L2 time series

Discussion

- The German NFI program provides the largest available dataset with tree species information
- The NFI sampling-design is well suited to generate a national reference data set as it is based on a probability sampling design covering entire Germany
- The plot design is not optimal for remote sensing based applications
- The presented two stage approach can solve some of the problems from the sampling design by sourcing information on the single tree level in the first stage
- Even though, the quality of the DOP data is variable, the first results from U-net based segmentation are promising
- The S2-L2 time series are still quite noisy > L3 time series interpolation ???

Outlook

- Improve the accuracy of the plot positions by updating the coordinates with the GNSS information collected in 2021
- Update data cube with S2 2021
- Train and implement the tree species classification at the single tree level for the 300x300m extent
- Evaluate noise filtering & interpolation techniques for the S2 time series

User workshop in Göttingen (~September,2022):

- Meet potential users of the reference data set
- Continue the discussions on the design of the reference dataset
- Identify and connect projects that are interested to use the reference data
- Identify projects that can contribute data to the reference dataset


www.treespecies.de

References:

Freudenberg, M. Magdon, P. & Nölke, N. (submitted): Individual Tree Crown Delineation in High Resolution Remote Sensing Images based on U-Net

Nölke, N., Freudenberg, M., Kleinn, C., Fuchs, H., & Magdon, P. (2020). Baumartenerkennung mithilfe von künstlicher Intelligenz (KI). AFZ - Der Wald, 15, 40–42.