Christian-Albrechts-Universität zu Kiel

Modeling a mountainous forest catchment with SWAT+

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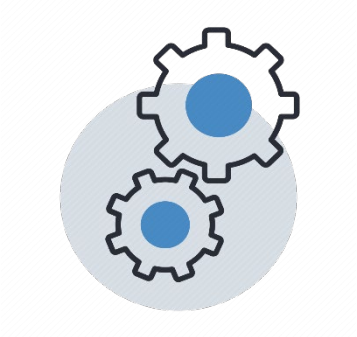
Motivation

- Preserve ecosystem services provided by forests
- Improve representation of forest growth and transpiration in SWAT+

Background and methods

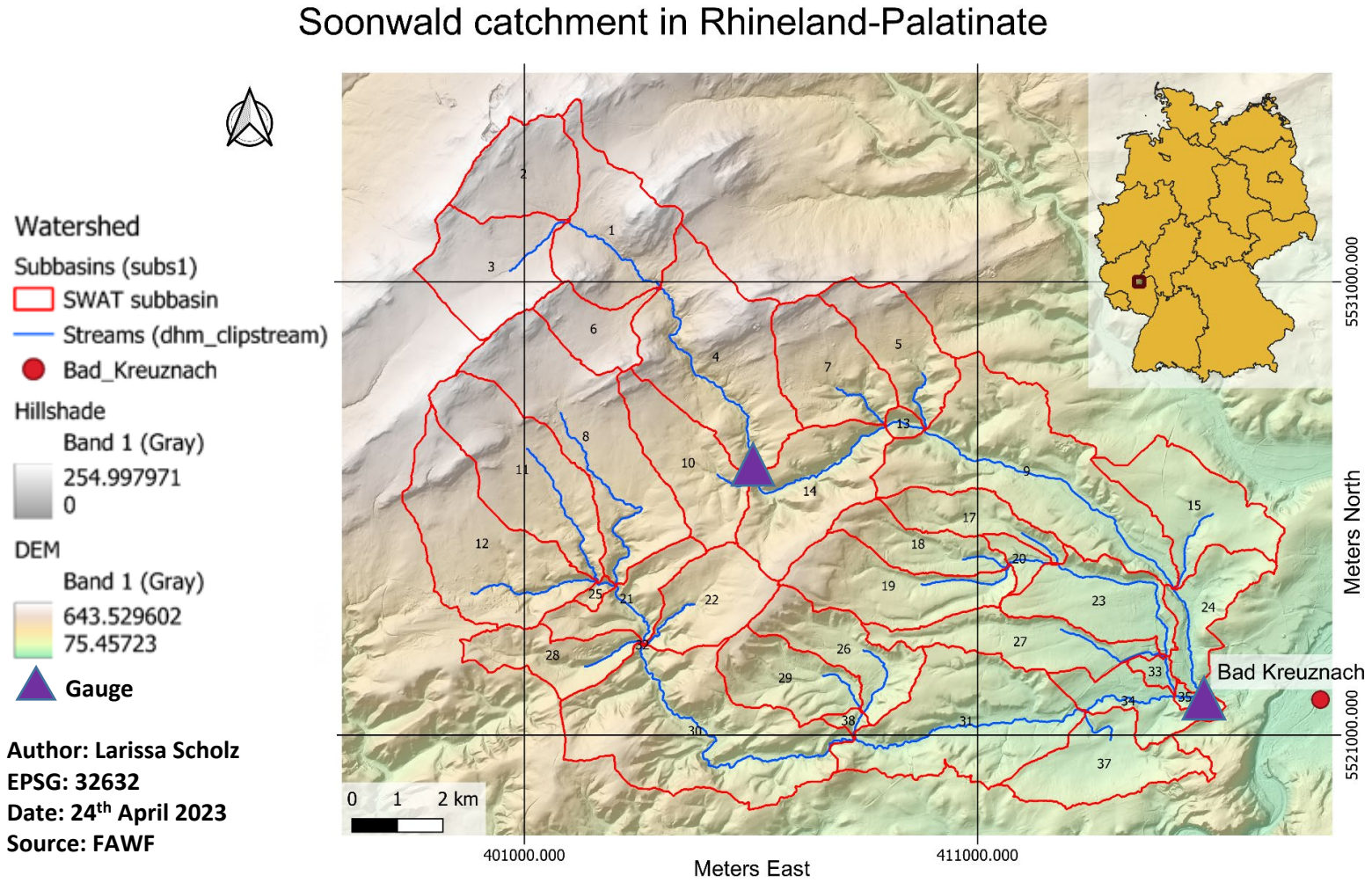


Study area

- Area: ~ 182 km²
- Elevation: 75-643 m.a.s.l.
- 2 gauges
- Main land uses:

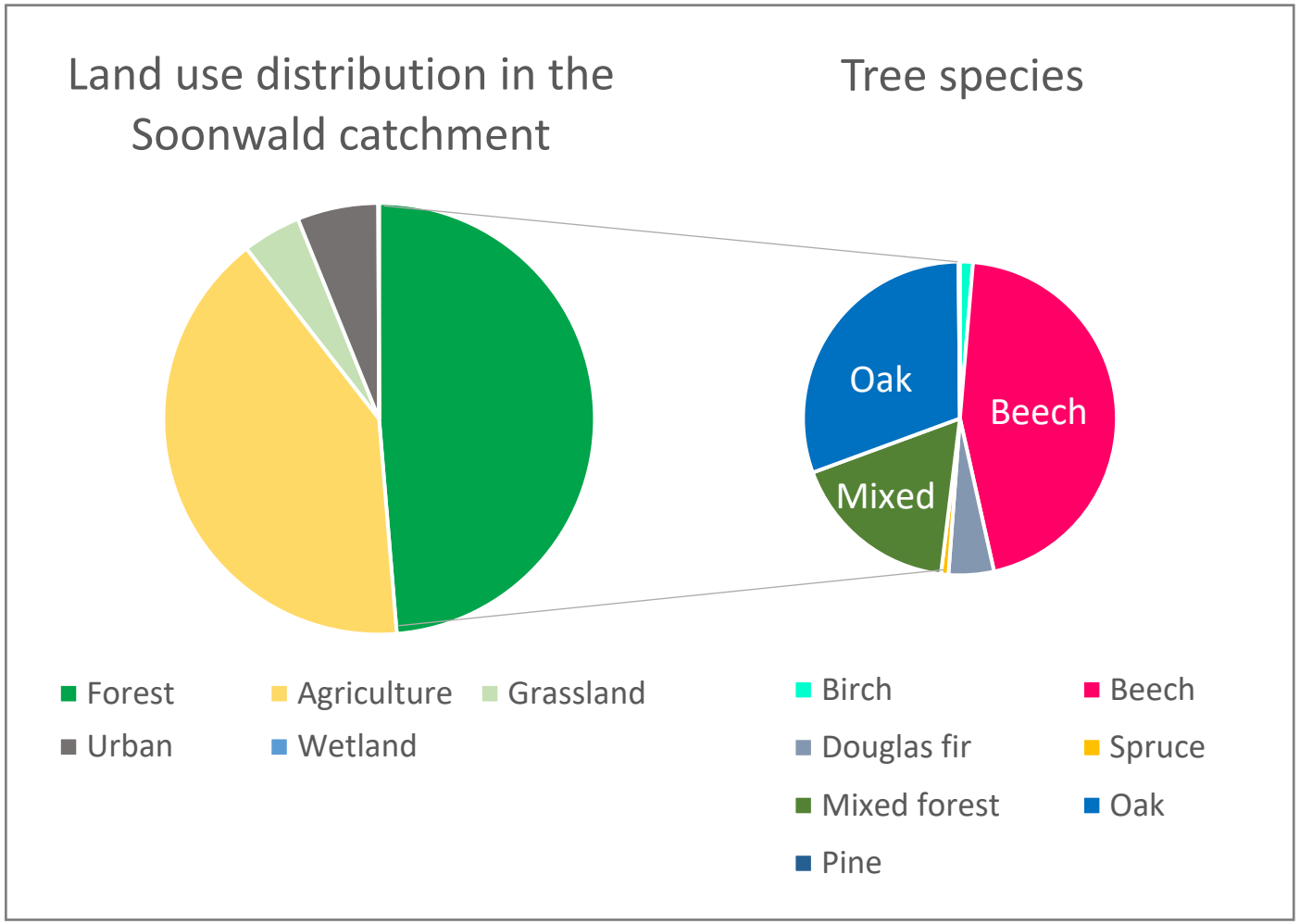
  Forest: ~ 50%

  Agriculture: ~ 40%



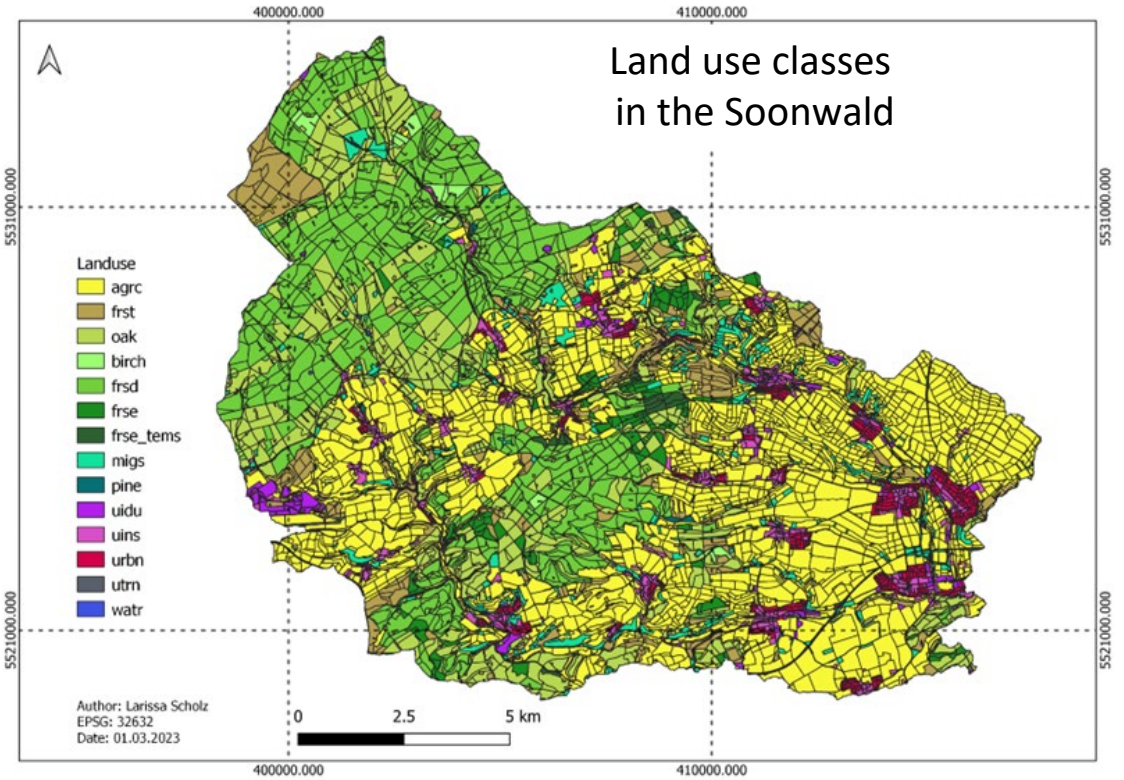
Model setup

- Private soil, land use, elevation data [1,2]
- Open-source weather data, spatially interpolated using INTERMET [3,4]



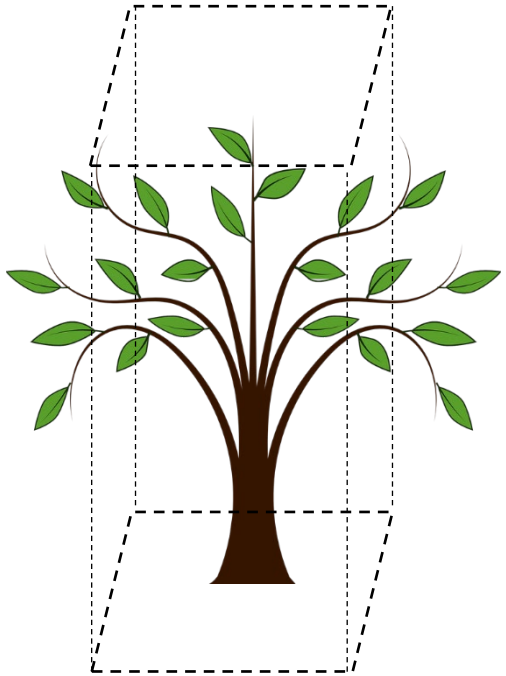
Model calibration

- Multi-gauge calibration of nested catchment:
  - ➢ large differences in land use, geology and soil characteristics between upper and lower part of catchment
- Latin hypercube sampling with 1000 parameter sets
- Choice of best model run based on MAE and KGE
- Calibration period: 2009-2013
- Validation period: 2014-2018



Leaf area index (LAI)

- Total leaf area per unit ground area [m^2/m^2]
- Measure of canopy density and biomass
- Indicator of forest growth and transpiration



Adaptation of LAI in SWAT+

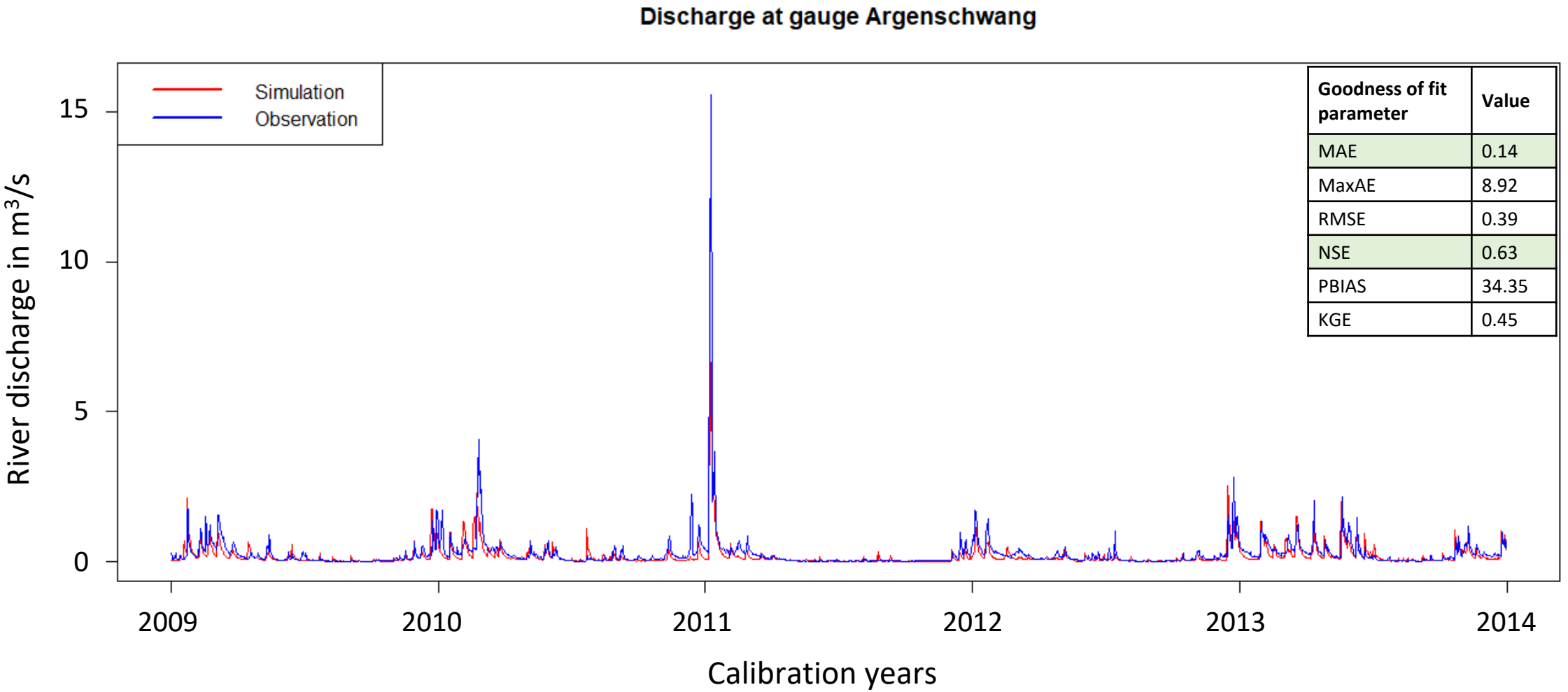
Default plant database	Modified plant database
• Differentiation of LAI for a few different tree species • Does not represent actual tree phenology	• Definition/adaptation of plant parameters for main tree species in the study area: →Minimum and maximum LAI (lai_max1, lai_max2) →Adaptation of LAI development curve (hu_lai_decl, dlai_rate) • Based on phenological monitoring data (direct harvesting)

Evaluation of modeled LAI with Sentinel-3-derived LAI

- Satellite product with highest spatial and temporal resolution
- available in 10-day intervals
- 300x300 m pixel size
- Derives LAI from OLCI (Ocean and Land Colour Instrument)
- Employs temporal compositing to fill data gaps
- Detects landscape-LAI, not tree-species-specific-LAI

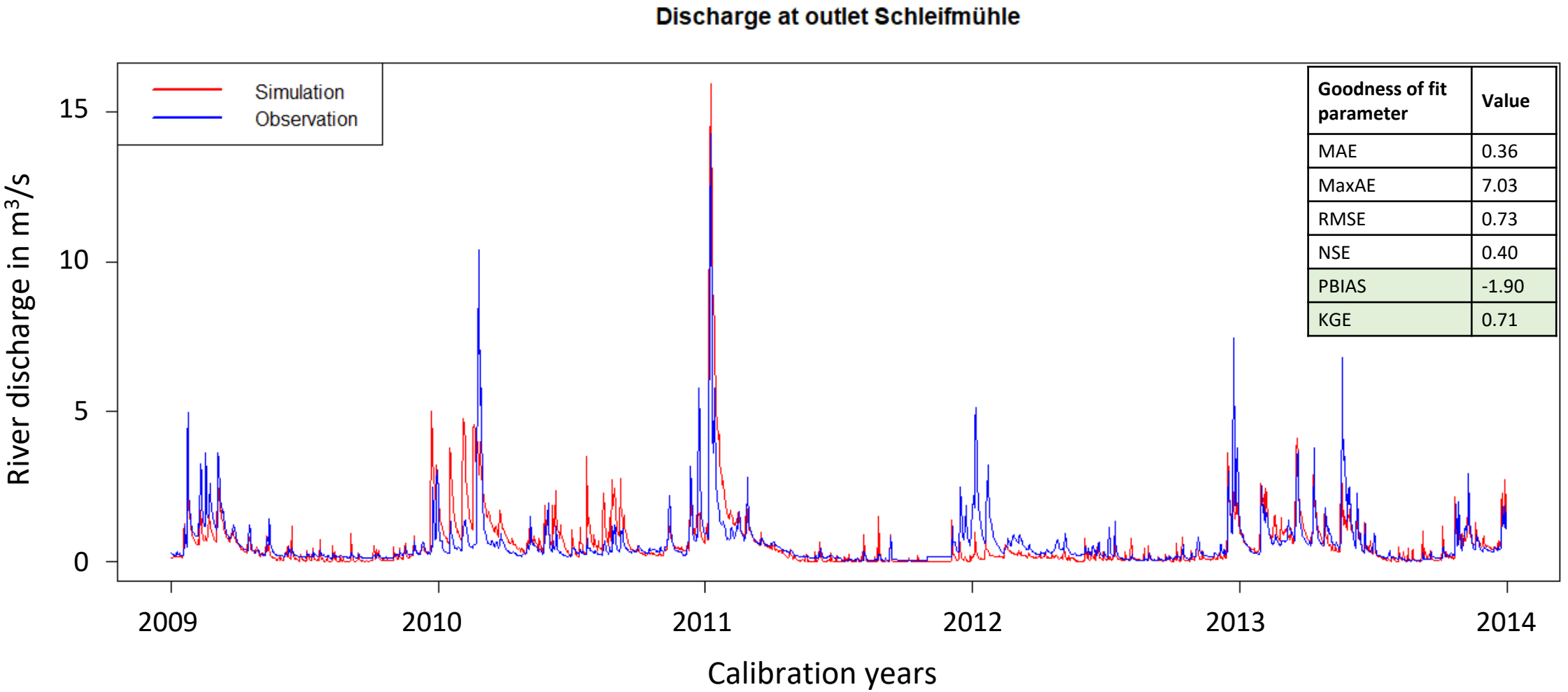
Results

Preliminary calibration gauge 1 (upstream)



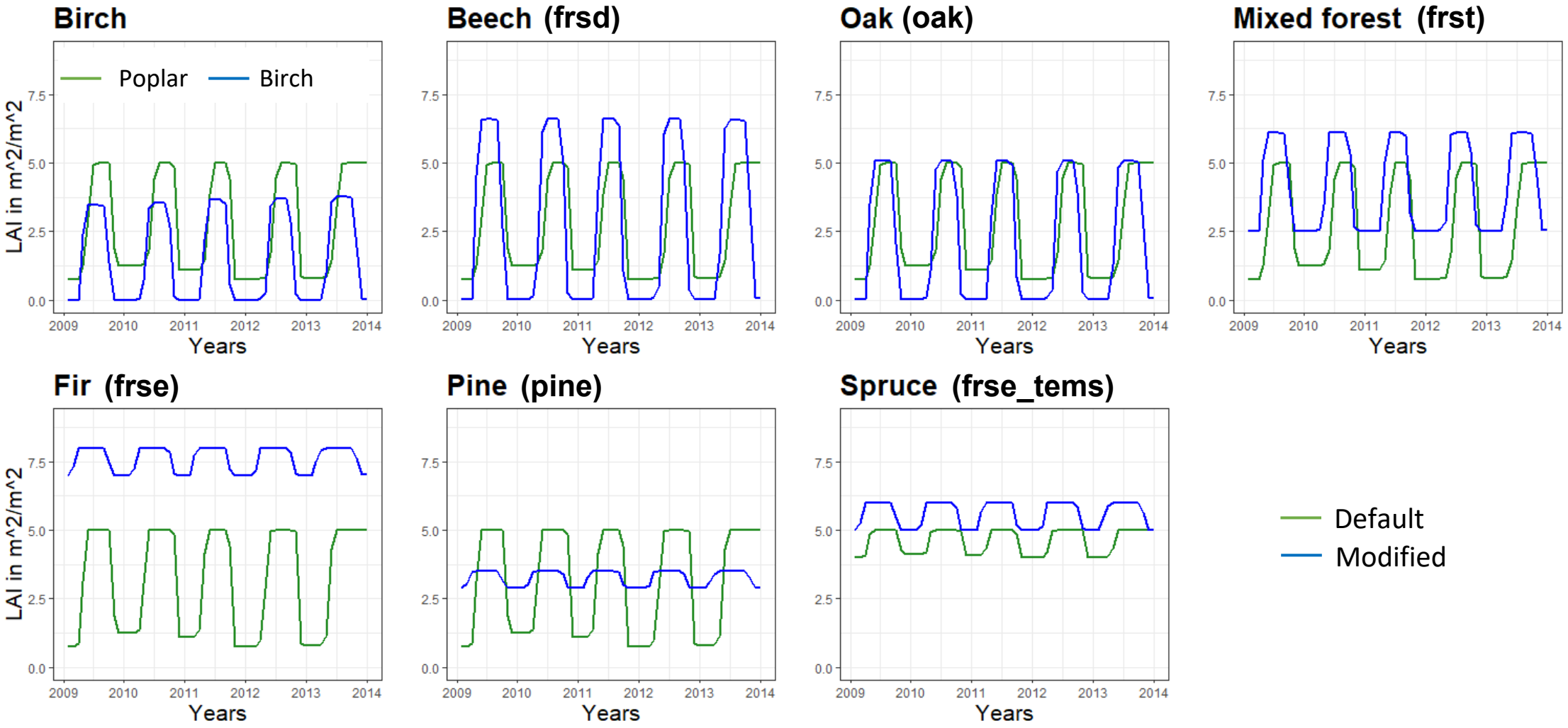
Goodness of fit parameter	Value
MAE	0.14
MaxAE	8.92
RMSE	0.39
NSE	0.63
PBIAS	34.35
KGE	0.45

Preliminary calibration gauge 2 (downstream)

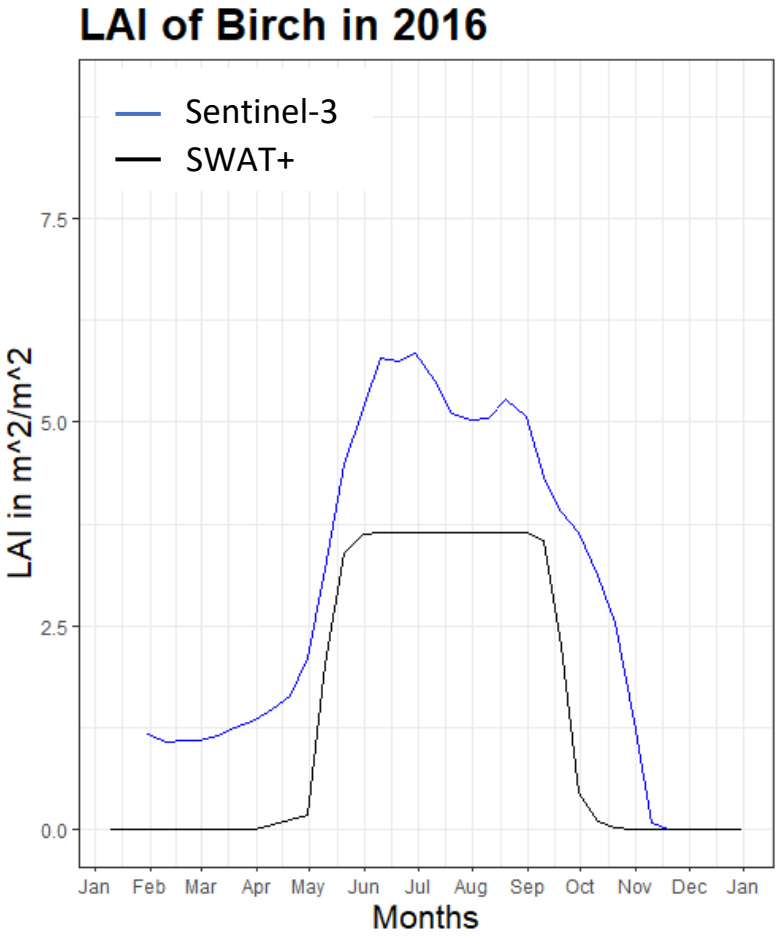


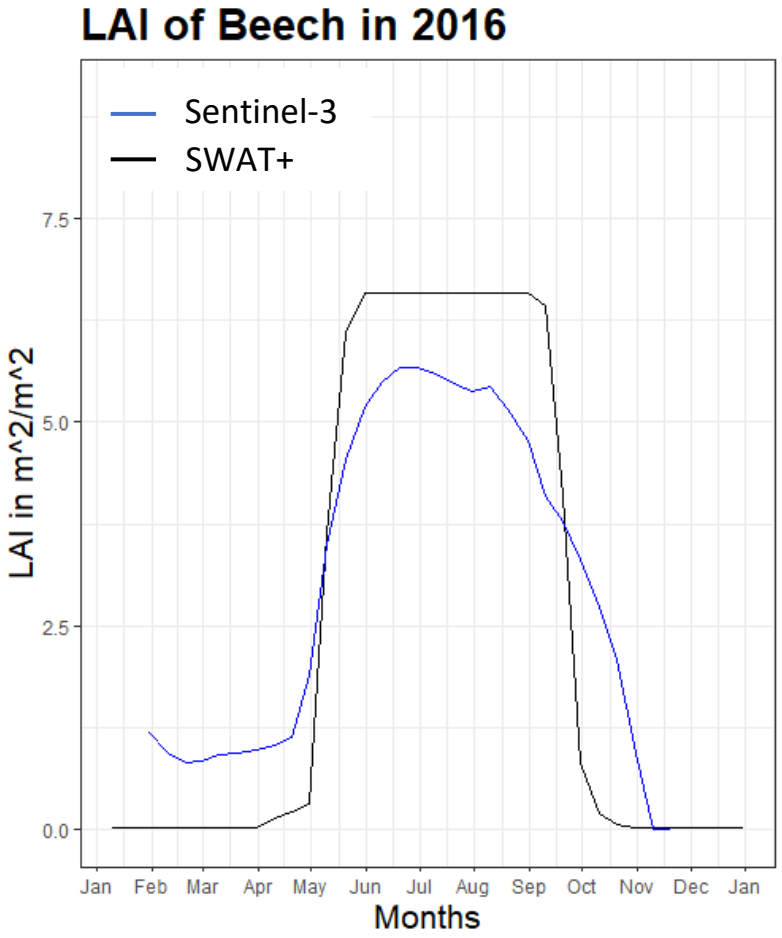
Goodness of fit parameter	Value
MAE	0.36
MaxAE	7.03
RMSE	0.73
NSE	0.40
PBIAS	-1.90
KGE	0.71

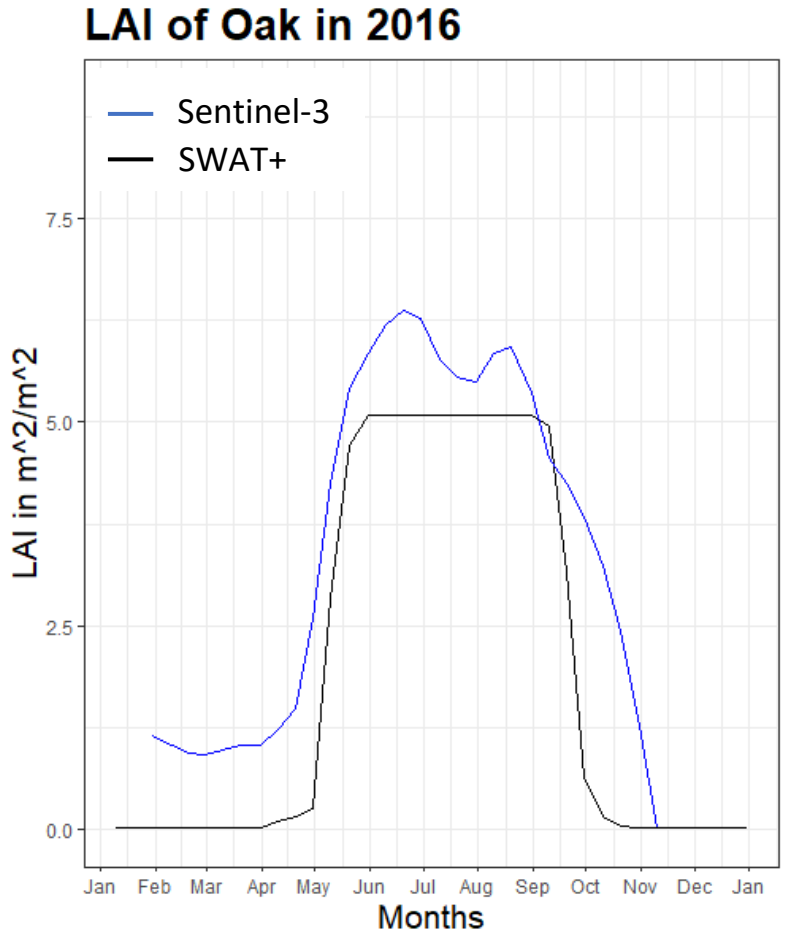
Default vs. modified LAI from 2009 to 2013



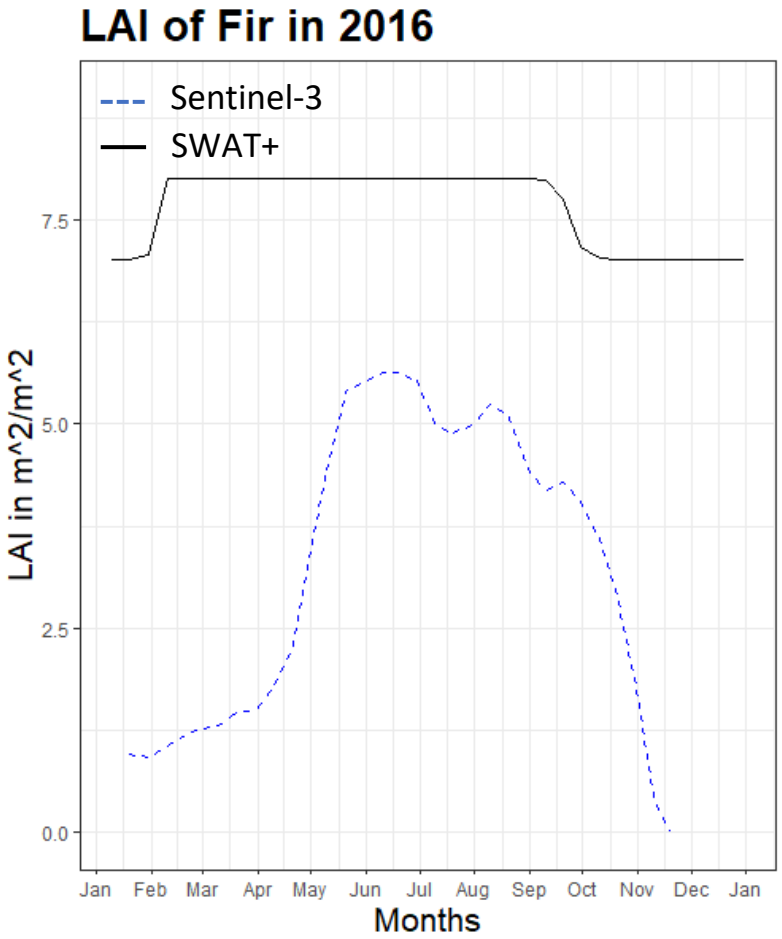
Comparison SWAT+ vs. Sentinel-3 LAI

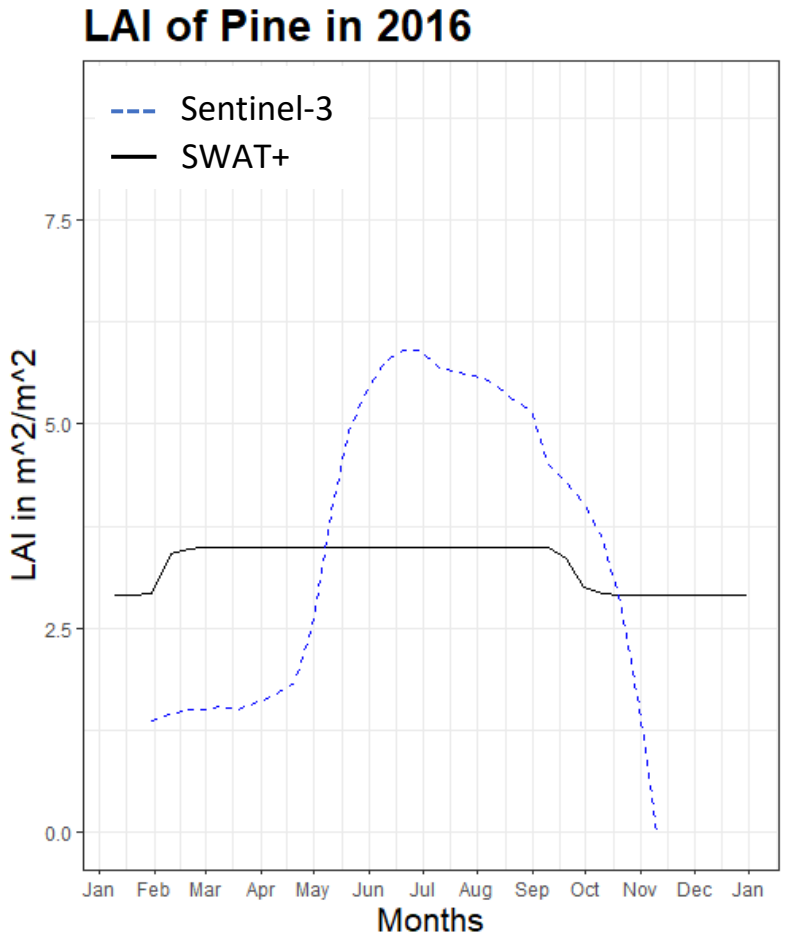


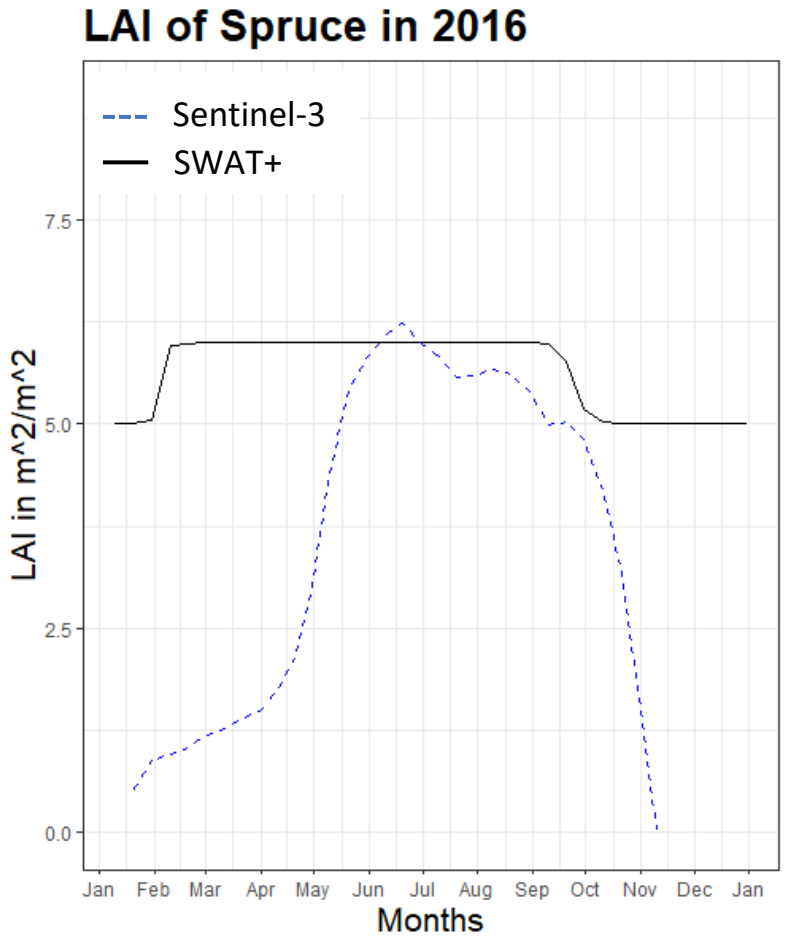




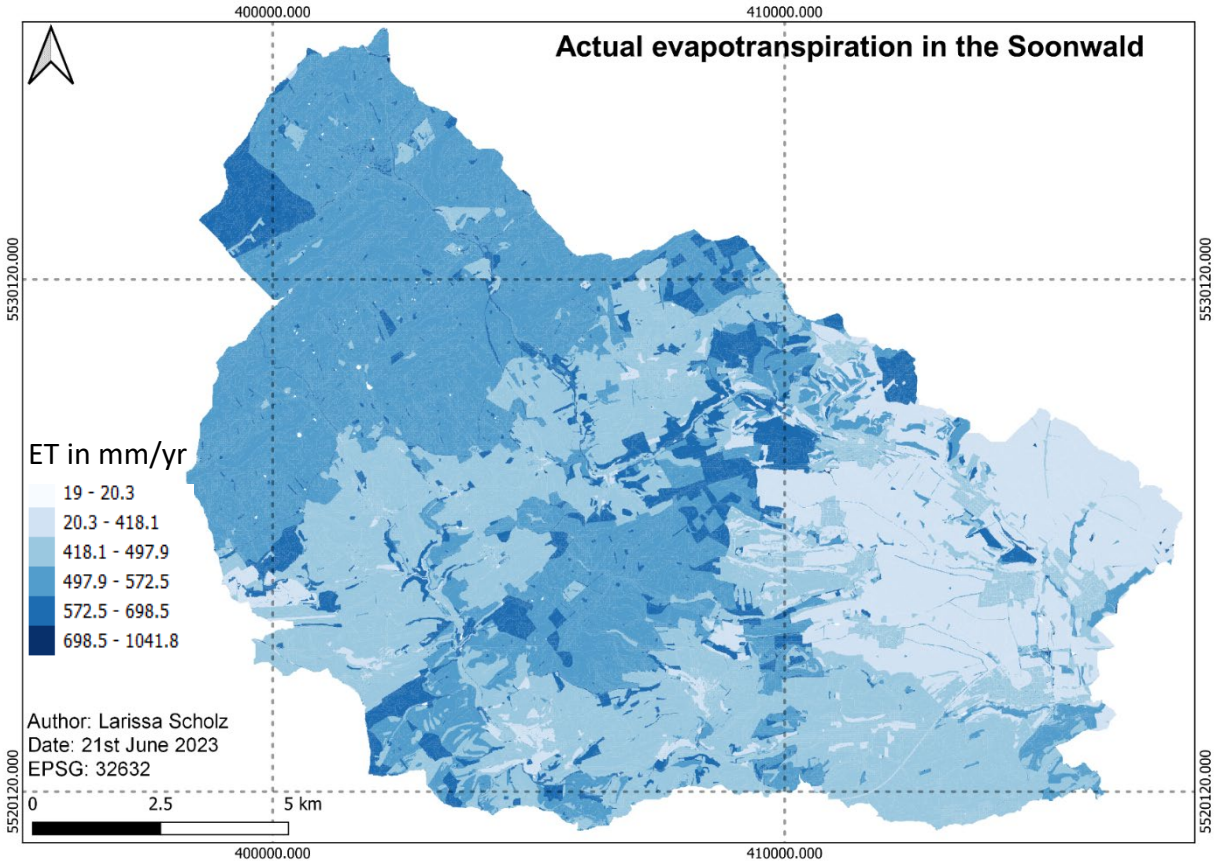
Comparison SWAT+ vs. Sentinel-3 LAI

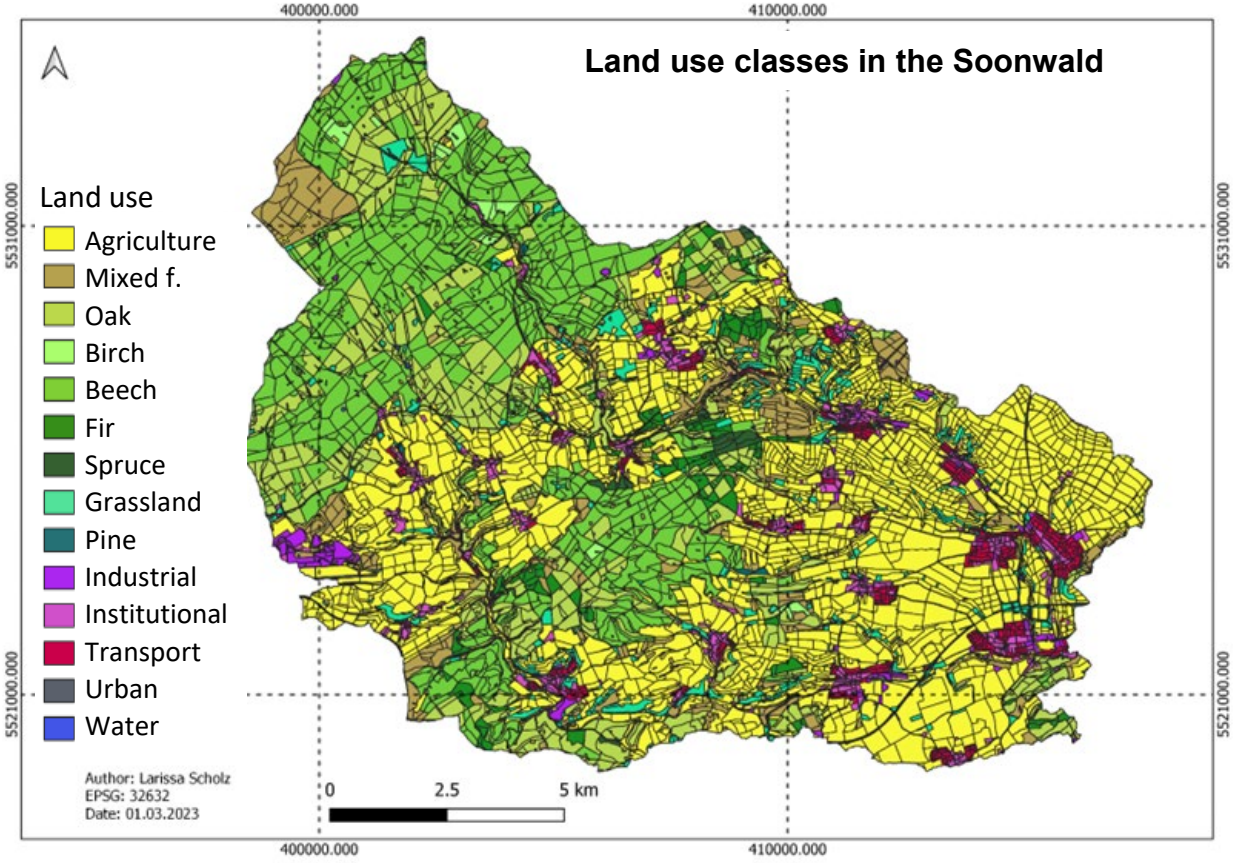






Preliminary spatial evapotranspiration





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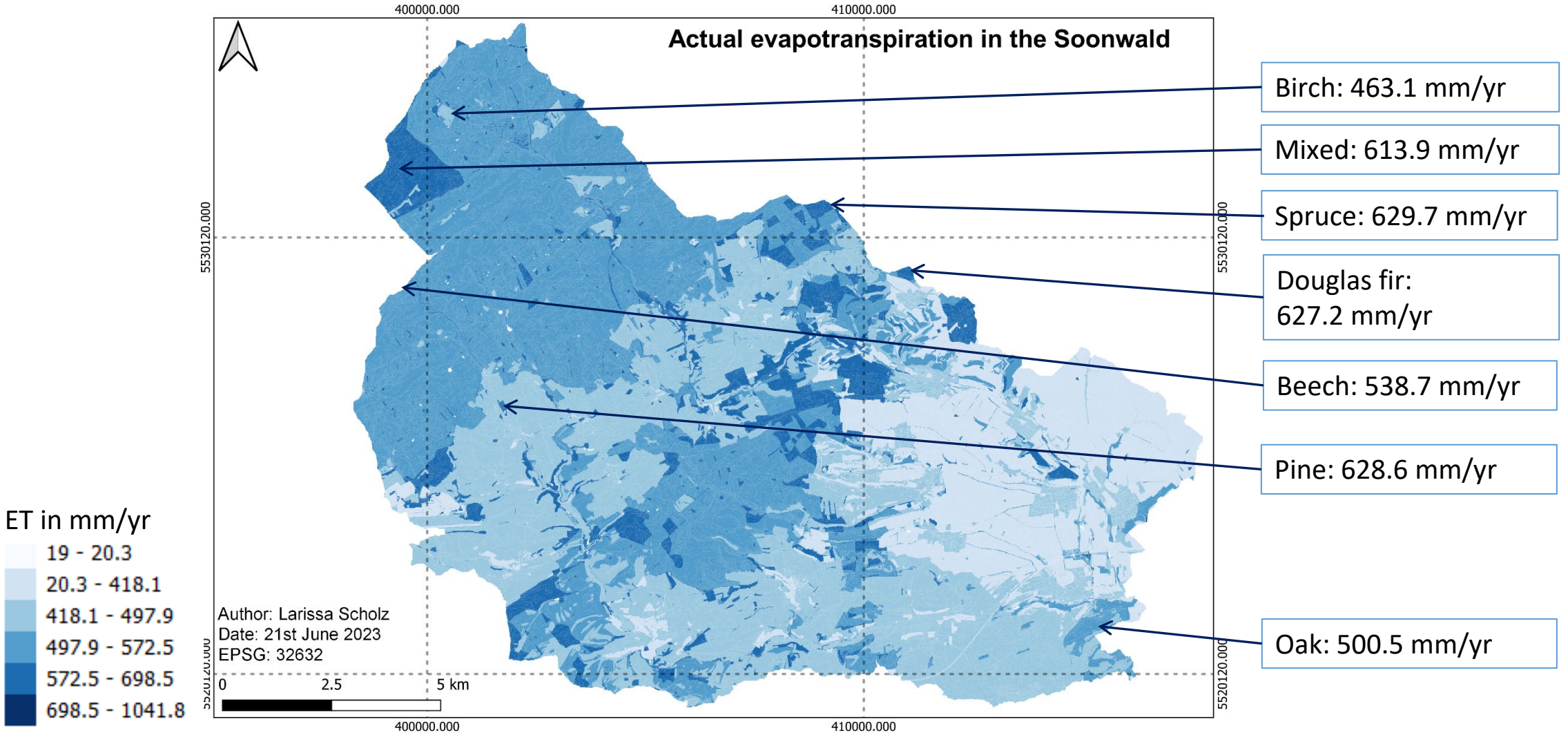

Discussion

LAI adaptation in SWAT - what worked well

- Representation of dormancy/growth period of forests 
- Absolute values of LAI agree with empirical data 
- Deciduous tree species also well represented by Sentinel data 

LAI adaptation in SWAT - what could be improved

- Shape of LAI curve – less edgy
- Need to improve representation of mixed forests – almost no pure stands left in the Soonwald
- Incorporate understory vegetation
- More validation data for different species in different environments

Summary and outlook

Summary

- Successful adaptation of SWAT+ plant database
- LAI validation with Sentinel-3 data is only applicable for large tree stands
- Modified LAI curves agree with empirical literature data

Outlook

- Employ this model to improve representation of water stress and its effects on tree transpiration

References

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Questions?
Thank you for listening!

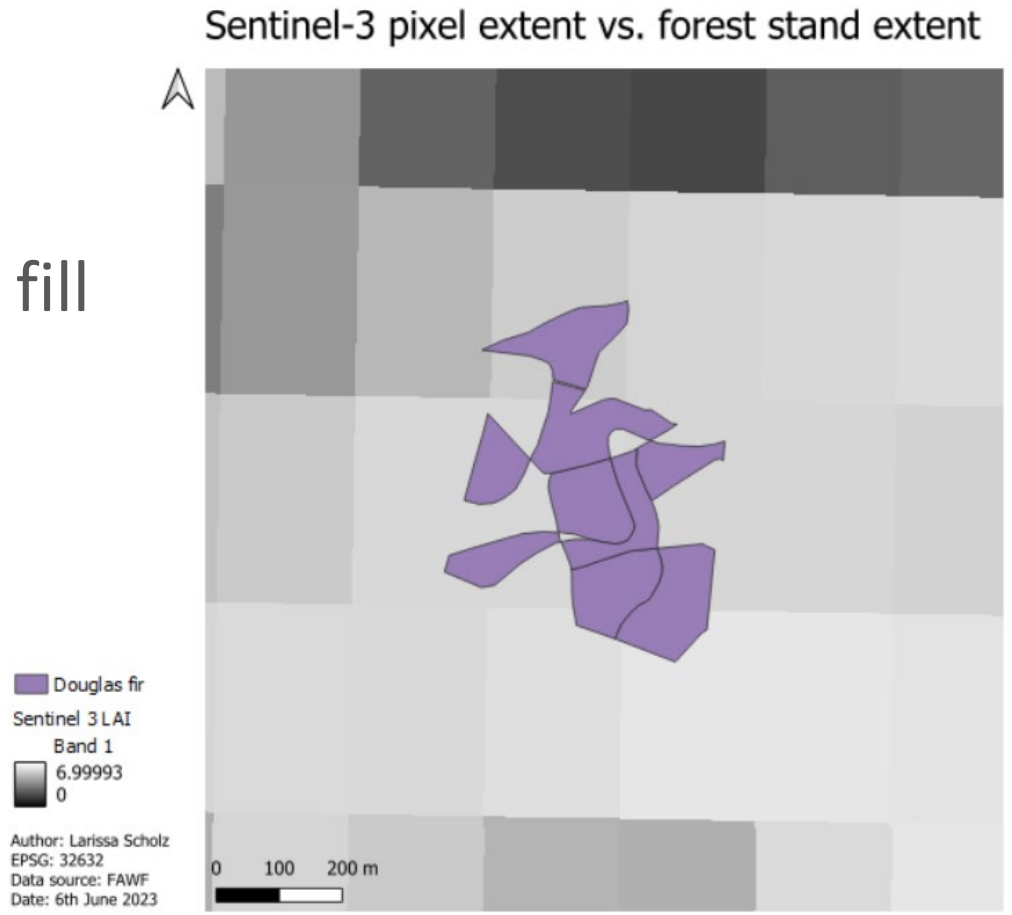
Gauge Argenschwang
Foto: Larissa Scholz
07.03.2023

LAI validation with literature

Validation source	Data Source	Pro's	Con's
Empirical data		Site specific	Narrow applicability
Sentinel-3	Copernicus project [5]	Hard data	Landscape LAI only, no tree species specification possible, weaknesses in methodology
Hemispherical photography	GREVE 2010 [6]	Conducted and validated in comparable regional conditions	Weaknesses in methodology
Literature		Peer reviewed	Different site conditions
	ČERNÝ et al. 2018 [7]	Comparison of different methods	Conducted in different area (Sweden) Beech trees only
	WAGNER et al. 2011 [8]	Minimum and maximum LAI values for different tree species	Soft data from other model, no time series
	RAUTIAINEN et al. 201 [9]	Differentiation between coniferous and deciduous tree species	Conducted in different area (Finland)

Differences in LAI curves SWAT+ vs. Sentinel-3

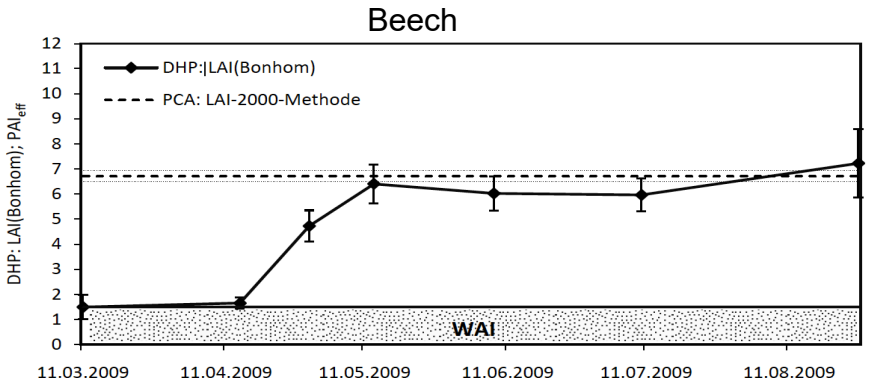
- Representation of coniferous trees not successful
- coniferous tree stands are too small to fill an entire Sentinel-3 pixel
- satellite picks up large areas of other vegetation as well
- tree stands are not pure, almost all are mixed to some degree

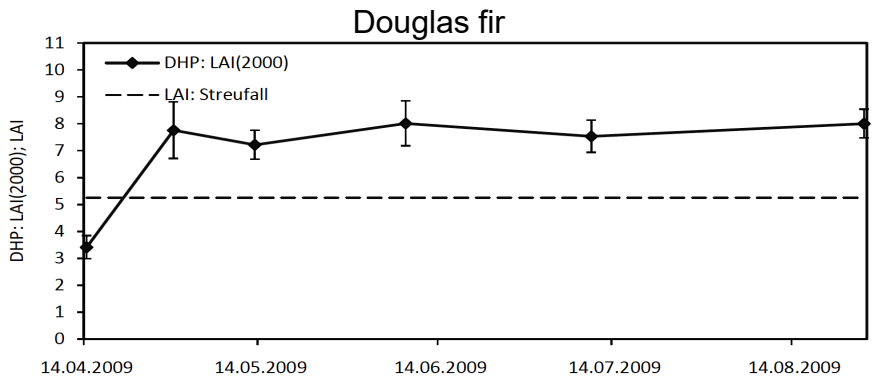


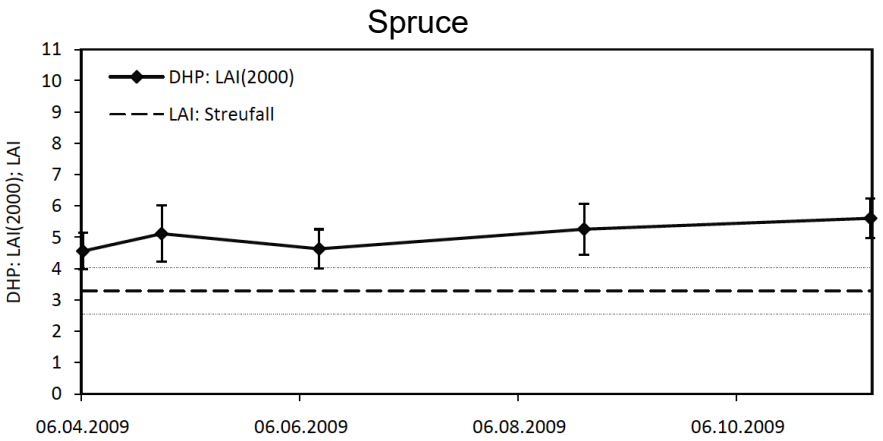
LAI adpatation

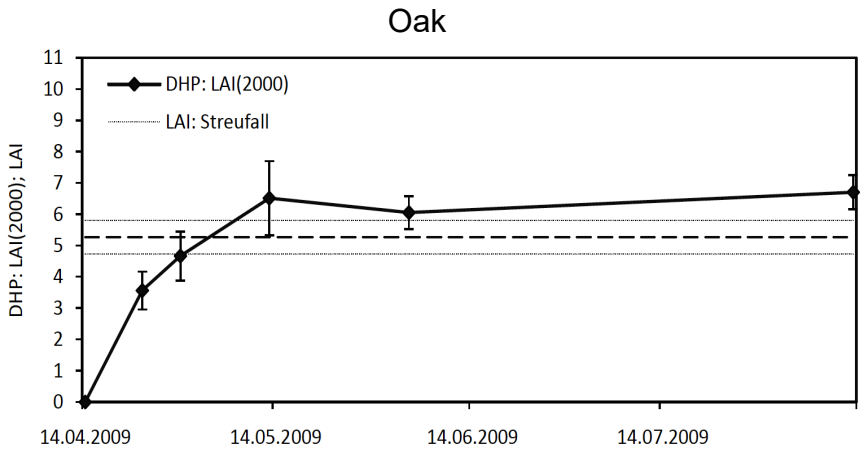
- In the SWAT plant database there is no **differentiation between tree species**. Tree species do, however, differ in LAI. The values used in the model setup were derived from measurements of the FAWF monitoring program using **direct harvesting** methods. Standardization and cross-validation between methodologies with other studies has been carried out (Greve 2010)
- The LAI modification contained both, absolute values on minimum and maximum LAI for each tree species, as well as the adaption of the LAI development curve (`lai_max1´, `lai_max2´, `hu_lai_decl´, `dlai_rate), which requires detailed phenological information provided by the **FAWF monitoring program** for the study area.

Hemispheric photos from comparable sites









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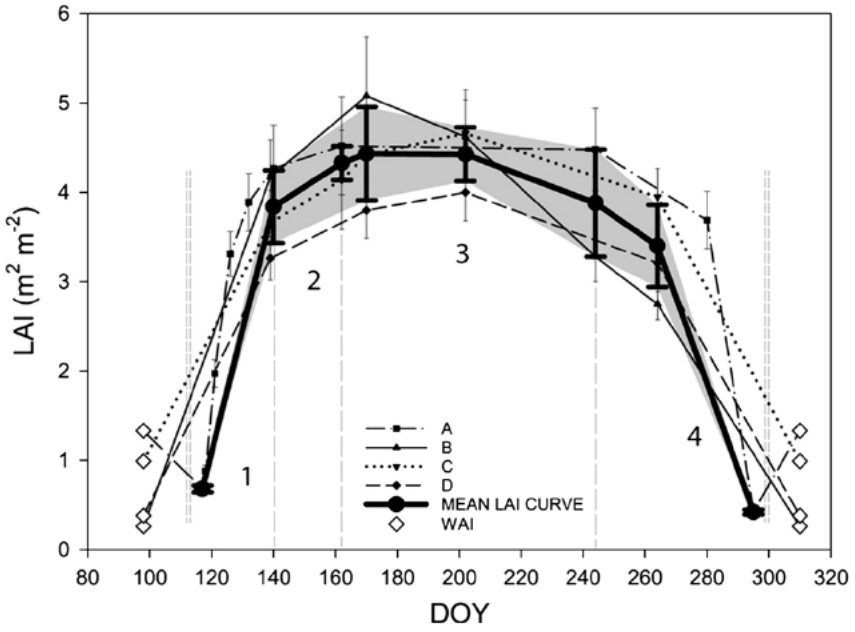
LAI validation literature



CERNY et al. 2018:
Beech site in Sweden
Methods:

LAI validation literature

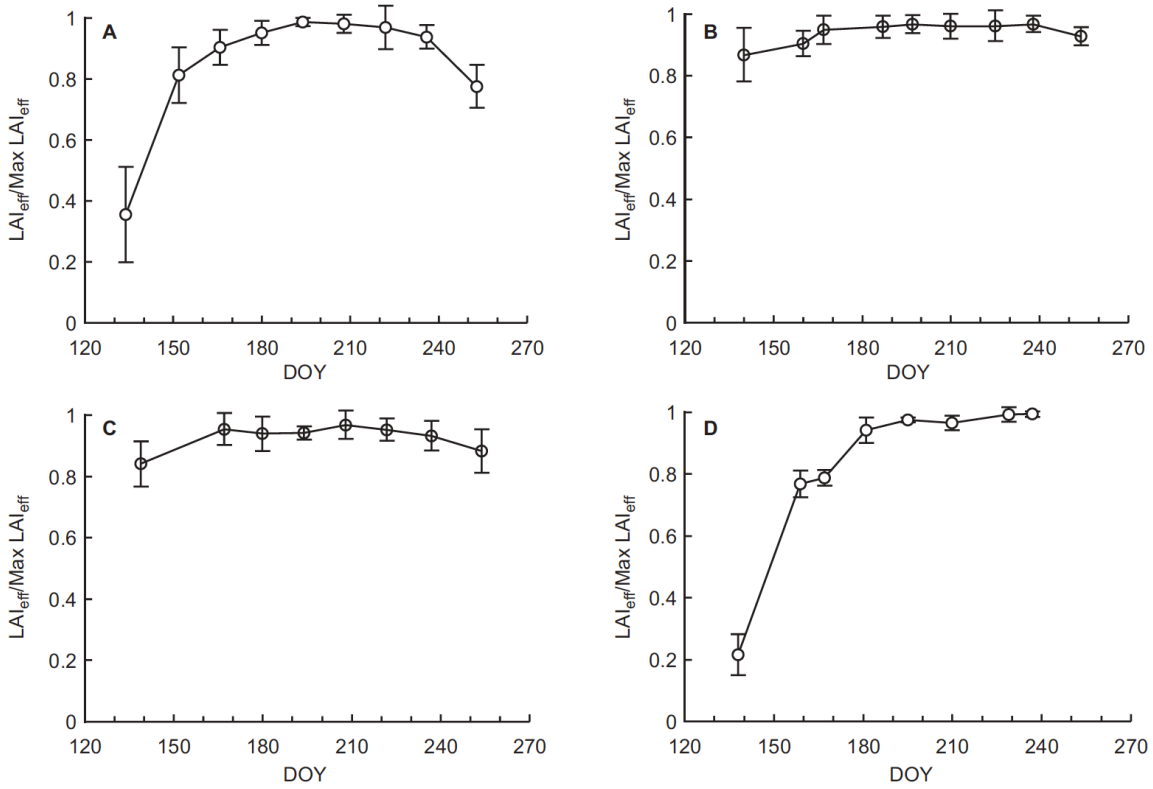
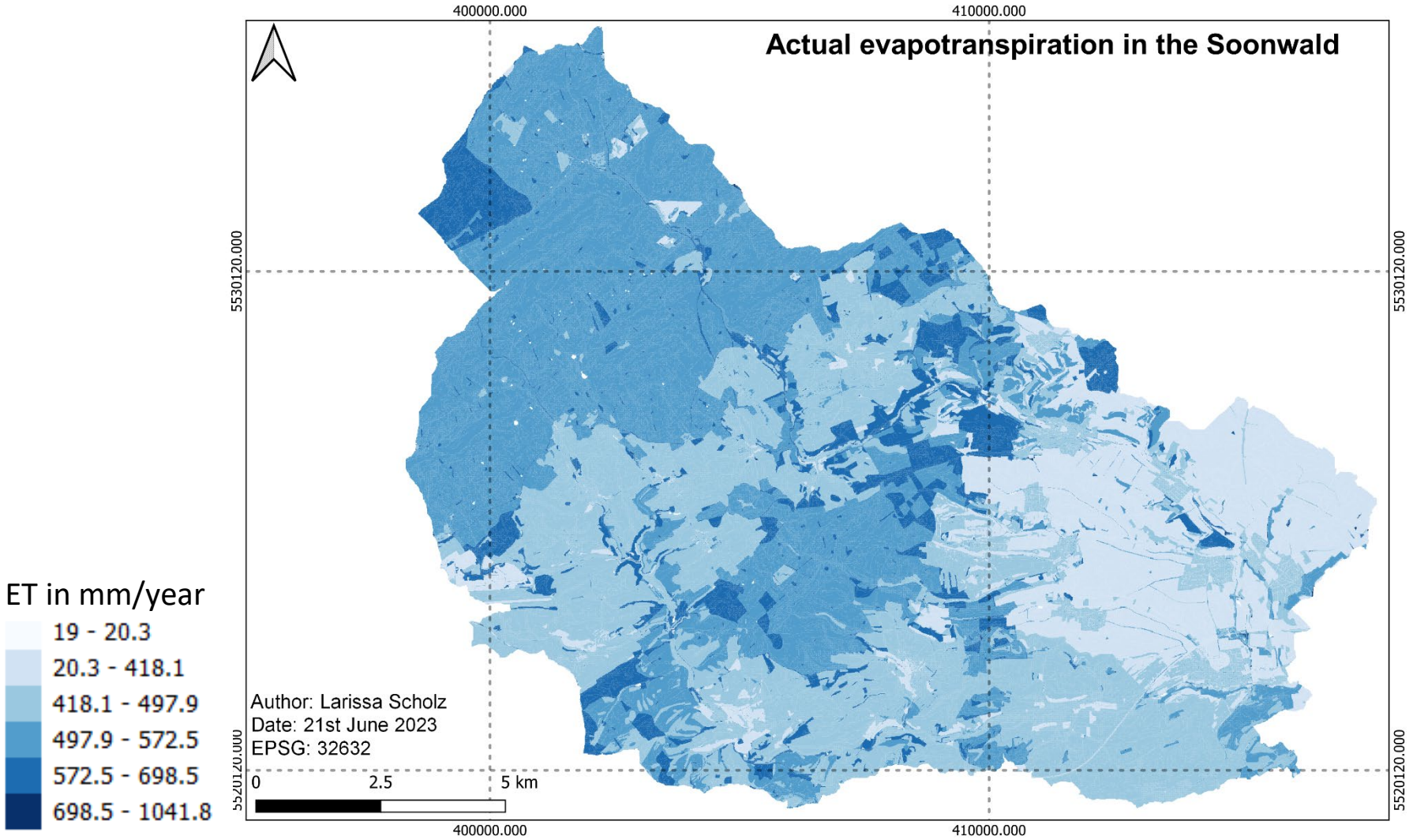


Fig. 3. The relative LAI_{eff} (i.e. LAI_{eff} at a given DOY divided by the seasonal maximum LAI_{eff}) obtained from *in situ* measurements. (**A**) deciduous stands, (**B**) coniferous stands, (**C**) mixed coniferous-deciduous stands, and (**D**) seedling stands. The error bars show standard deviations. Note that relative LAI_{eff} does not reach one in **A**–**C** because the curves show mean values for all stands. i.e. the maximal LAI_{eff} values were not reached on the same date in all the stands.

Preliminary spatial evapotranspiration

Tree species	ET in mm/year
Birch	646.9
Pine	618.8
Spruce	617.3
Douglas fir	609.3
Mixed forest	601.9
Beech	529.1
Oak	522.3



Preliminary spatial evapotranspiration (Mittelwerte)