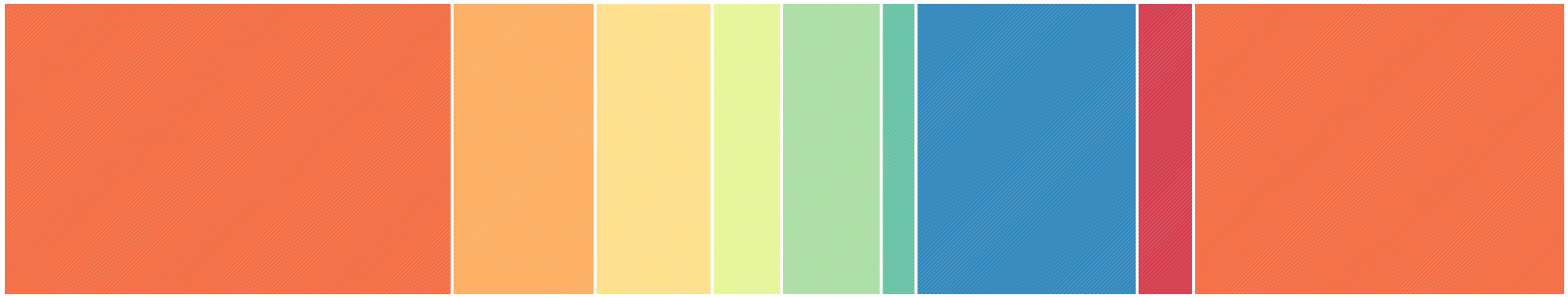
Coupling of phenological information and synthetically generated time-series for crop types as indicator for vegetation coverage information

Markus Möller[1], **Michael Förster**[2], Henning Gerstmann[1], Feng Gao[3] & Detlef Thürkow[1]



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[2] Technical University Berlin, Geoinformation and Environmental Planning Lab, Germany
[3] US Department of Agriculture, Hydrology and Remote Sensing Laboratory, USA

Outline

Outline

Soil erosion, phenology and vegetation coverage

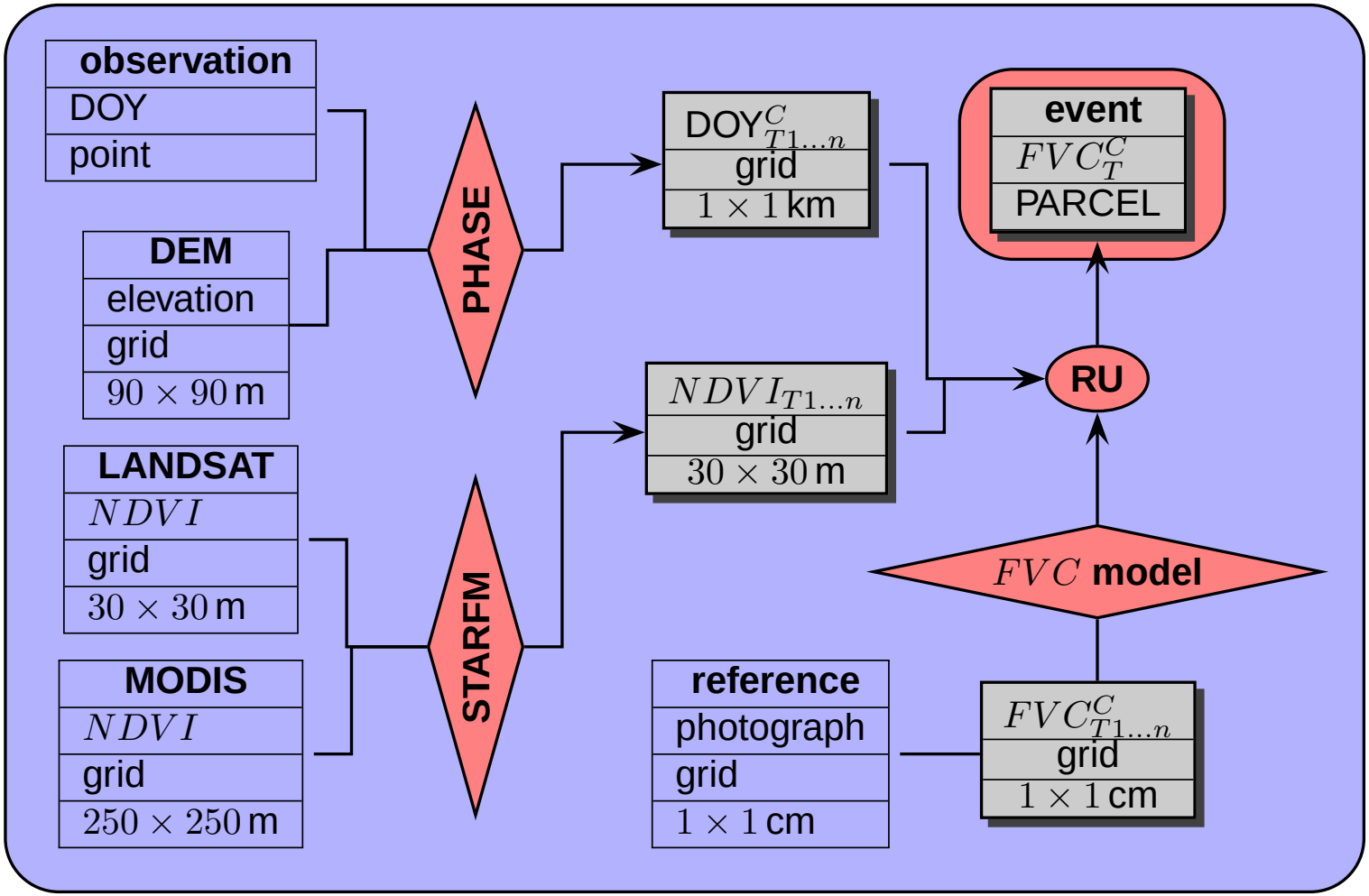
- Soil erosion is an event-based process which is mainly controlled by the simultaneous occurrence of heavy rain events and low soil coverage.
- Extensive phenological information can be used as an indicator for time frames of high erodibility.

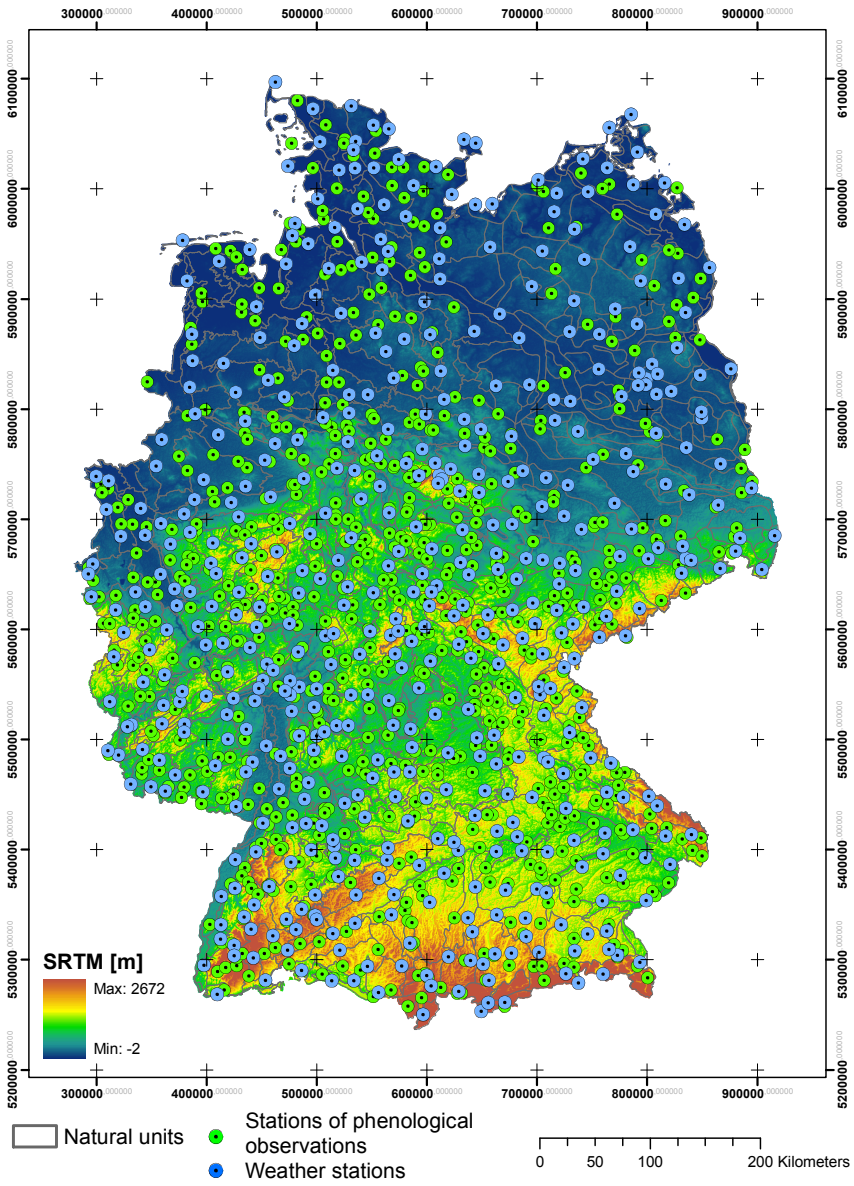
Coupling of crop phenology and *NDVI* profiles

- Automatic interpolation of phenological phases
- Generating of *NDVI* profiles derived from time-series of high temporal resolution
- Development of a phase-specific fractional vegetation coverage model

Outline

Workflow


observation
DOY
point
DEM
elevation
grid
90 × 90 m
LANDSAT
NDVI
grid
30 × 30 m
MODIS
NDVI
grid
250 × 250 m
PHASE
STARFM
DOY$^{C}_{T1...n}$
grid
1 × 1 km
NDVI$_{T1...n}$
grid
30 × 30 m
reference
photograph
grid
1 × 1 cm
event
FVC$^{C}_{T}$
PARCEL
RU
FVC model
FVC$^{C}_{T1...n}$
grid
1 × 1 cm



Point data sets

- Phenological observation network of the German Weather Service (DWD)
  - phenological observations sampled by $\approx$ 1200 volunteers
  - positional accuracy: $2 - 5$ km
- DWD meteorological observation network
  - $\approx$ 500 stations
  - daily mean temperatures

Spatial data

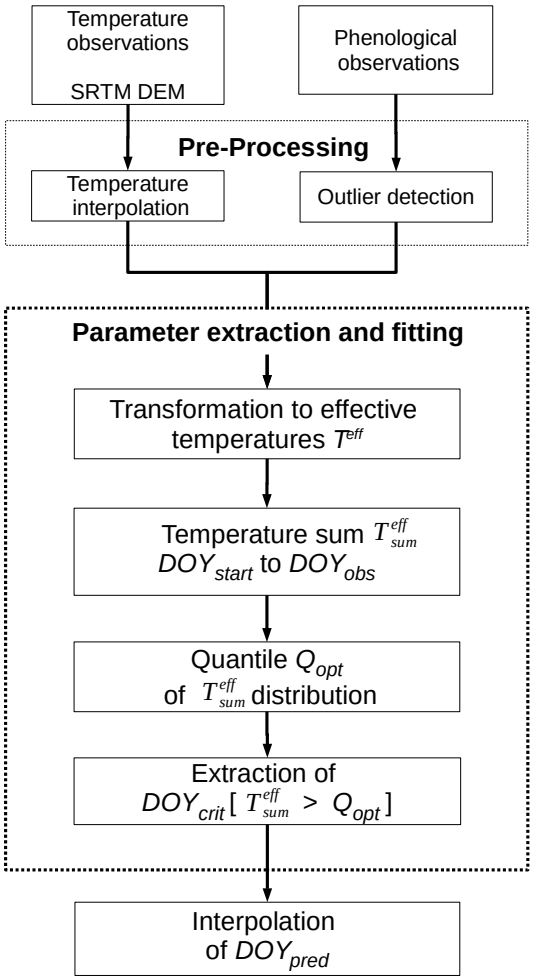
- SRTM DEM 90×90 m resampled to 1×1 km

Reported phenological phases for eight typical field crops in Germany

crop	scientific name	ID	reported phases
Winter wheat	*Triticum aestivum L.*	202	10, 12, 15, 18,19, 21, 24
Winter rye	*Secale cereale L.*	203	10, 12, 15, 5, 6, 18, 21, 24
Winter barley	*Hordeum vulgare L.*	204	10, 12, 15, 18, 21, 24
Oilseed rape	*Brassica napus L.*	205	10, 12, 14, 67, 17, 5, 22, 24
Oat	*Avena sativa L.*	208	10, 12, 15, 66, 19, 21, 24
Maize	*Zea mays L.*	215	10, 12, 67, 5, 65, 19, 20, 21, 24
Potato	*Solanum tuberosum L.*	234	10, 12, 5, 24
Sugar beet	*Beta vulgaris* subsp. *vulgaris*	253	10, 12, 13, 24

5 – Beginning of flowering | 6 – full flowering | 10 - Beginning of sowing | 12 - emergence | 13 - closed stand | 15, 67 - beginning of shooting/stem elongation | 17 - beginning of bud formation | 18 - beginning of heading | 19 - beginning of milk ripening | 20 - beginning of early dough ripening | 21 - beginning of yellow ripening | 22 - beginning of full ripening | 24 - harvest | 65 - beginning of tassel emergence

Model structure



Growing Degree Day approach

$$GDD = 0.5 \times (T_{max} - T_{min}) - T_B$$

Model core

$$T^{eff}_{sum}[j] \geqq Q_{opt} \left[\sum_{i=DOY_{start}}^{DOY_{obs}} \left((\overline{T}_{i,j} - T_B) \times \frac{DL_i}{24} \right) \right]$$

Gerstmann, H., Möller, M., Doktor, D. & Gläßer, C. (20??). PHASE: A geostatistical model for the Kriging-based spatial prediction of crop phenology using public phenological and climatological observations. *Computers and Electronics in Agriculture*, submitted.

Möller, M., Möller, S., Doktor, D., Gläßer, C. (2011): Automatic interpolation of phenological phases in Germany. In *MultiTemp2011, 6th International Workshop on the Analysis of Multi-temporal Remote Sensing Images* (pp. 37–40). Trento/Italy.

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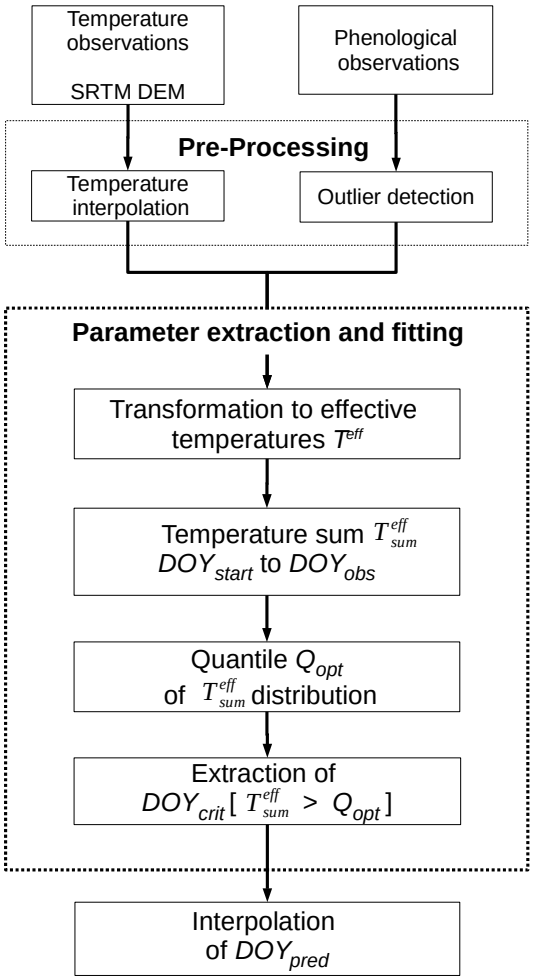
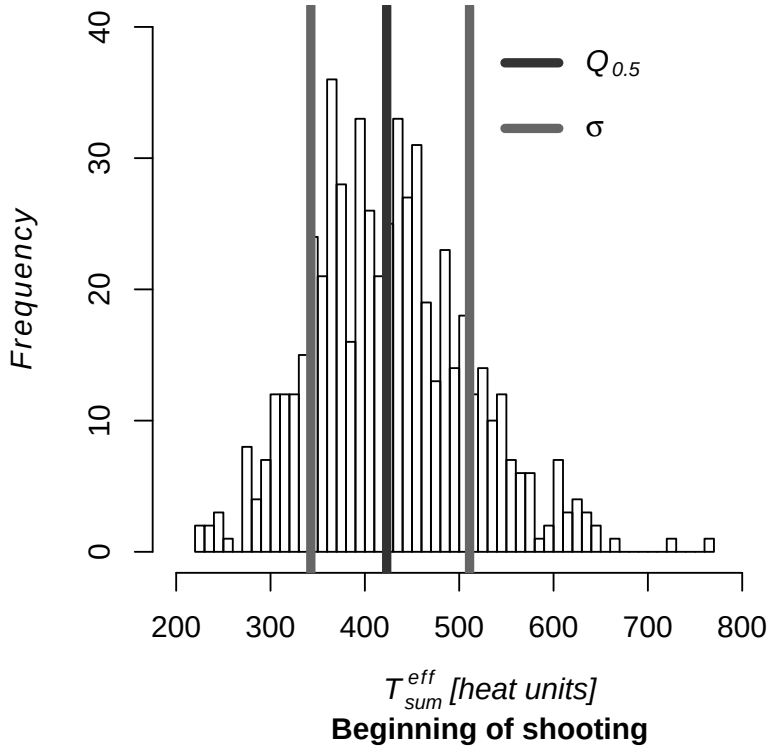
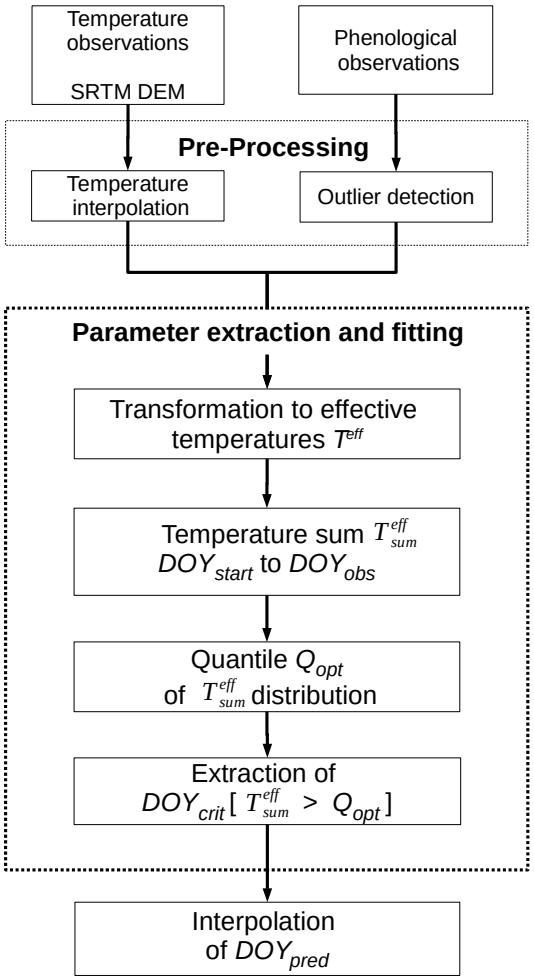


Statistical filtering



Distribution of T^{eff}_{sum} calculated for all phenological stations from sowing to the observation date for *shooting* of *Winter Wheat* in 2011

Model structure



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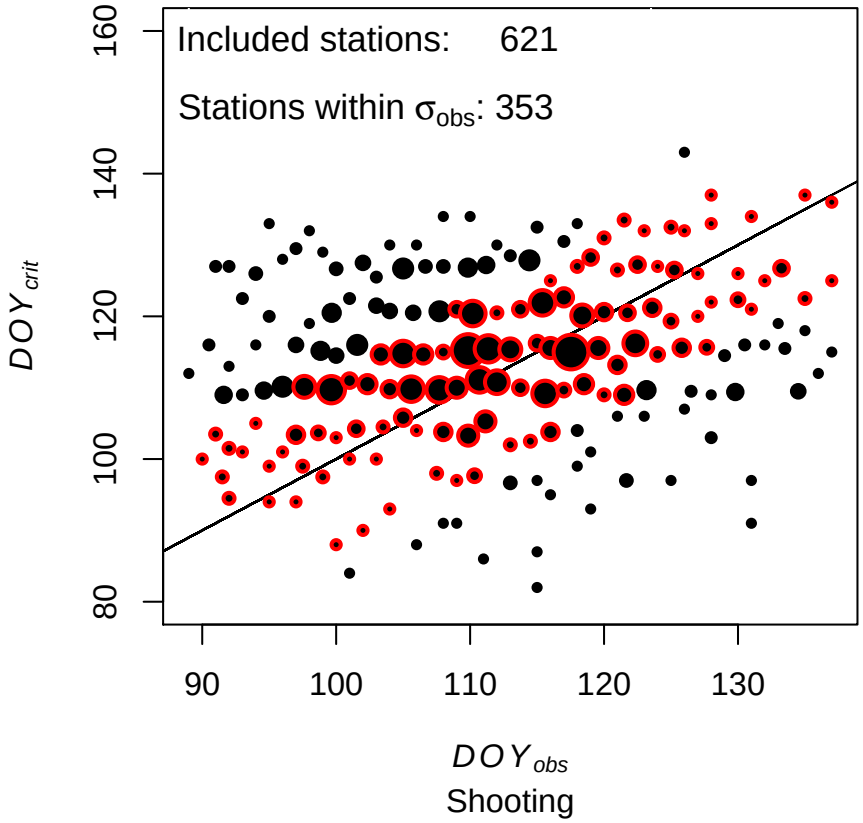
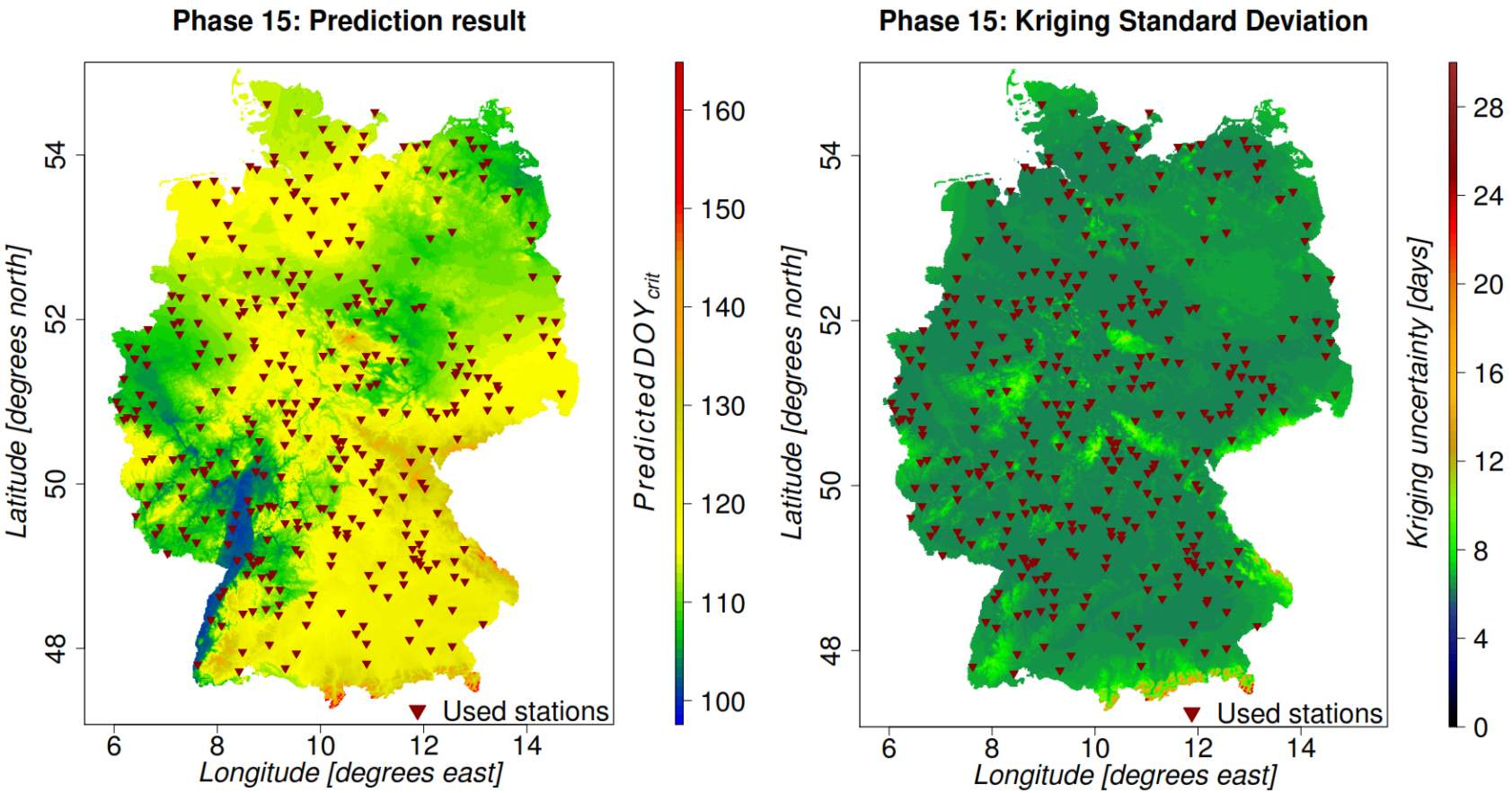


Density plot of DOY_{crit} and DOY_{obs} for *shooting* of *Winter Wheat* in 2011

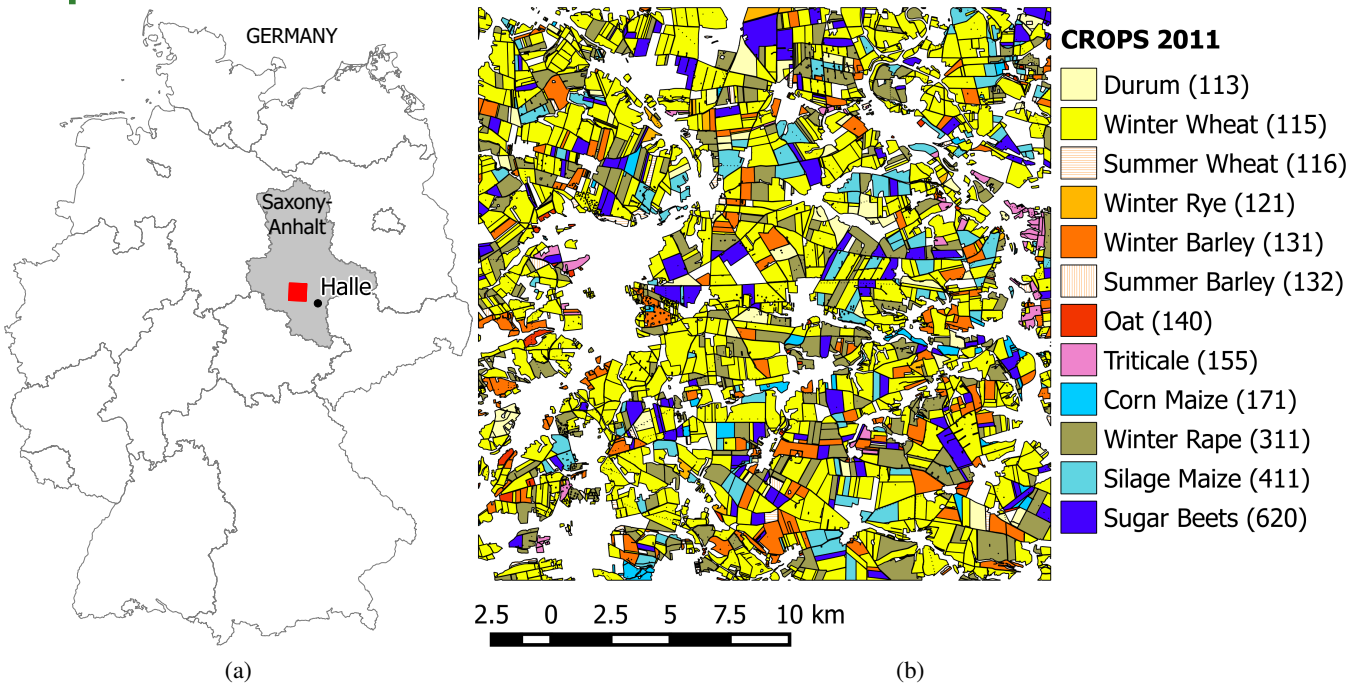
Shooting of *Winter Wheat* in 2011

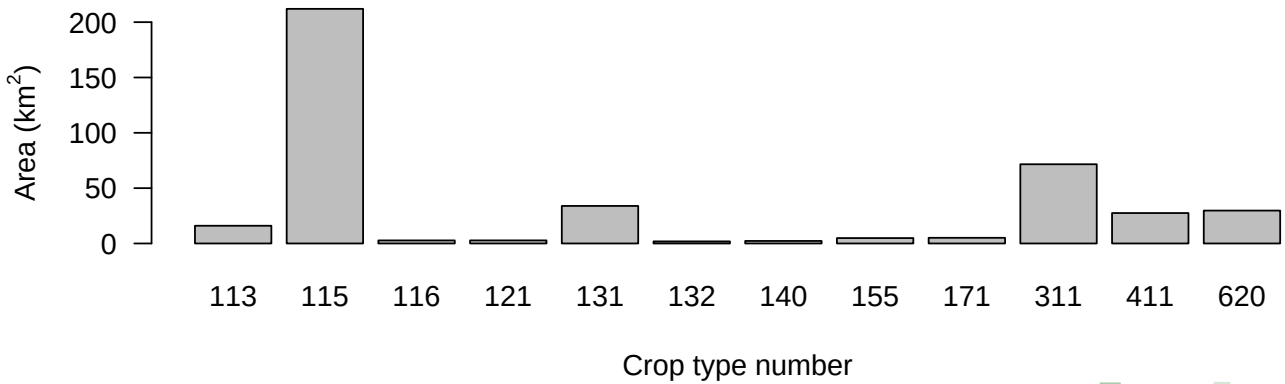


Accuracy metrics

Plant	**Phase**	T_B	Q_{opt}	$nmax$	$RMSE_{mod}$	R^2_{mod}	$RMSE_{raw}$	R^2_{raw}
Winter wheat	emergence	0	0.35	50	12.66	0.91	10.90	0.18
	shooting	0	0.55	25	6.11	0.59	10.46	0.03
	heading	8	0.50	40	2.75	0.69	5.51	0.24
	milk ripening	6	0.45	50	3.33	0.58	9.25	0.03
	yellow ripening	0	0.45	13	3.88	0.72	7.29	0.13

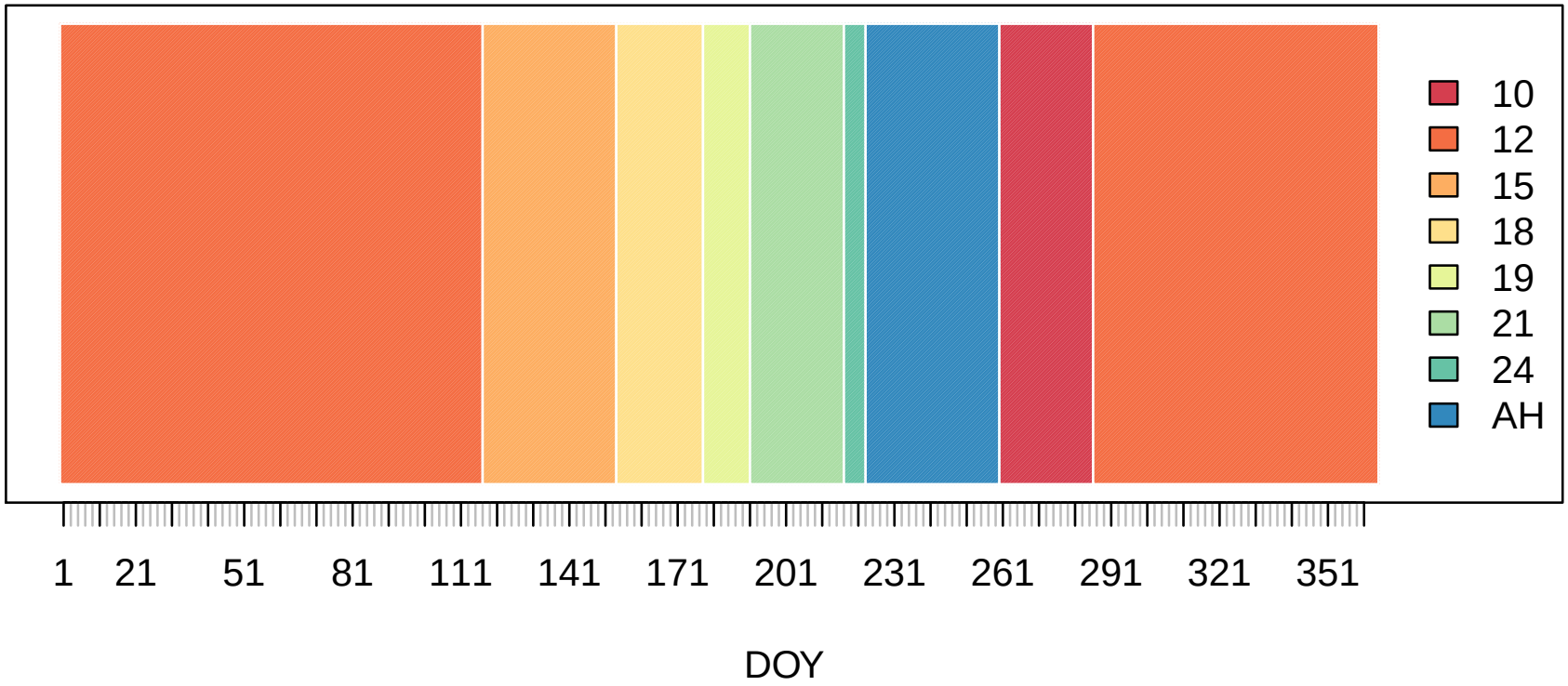
Temporal phase windows: *Winter Wheat* 2011





Temporal phase windows: *Winter Wheat*

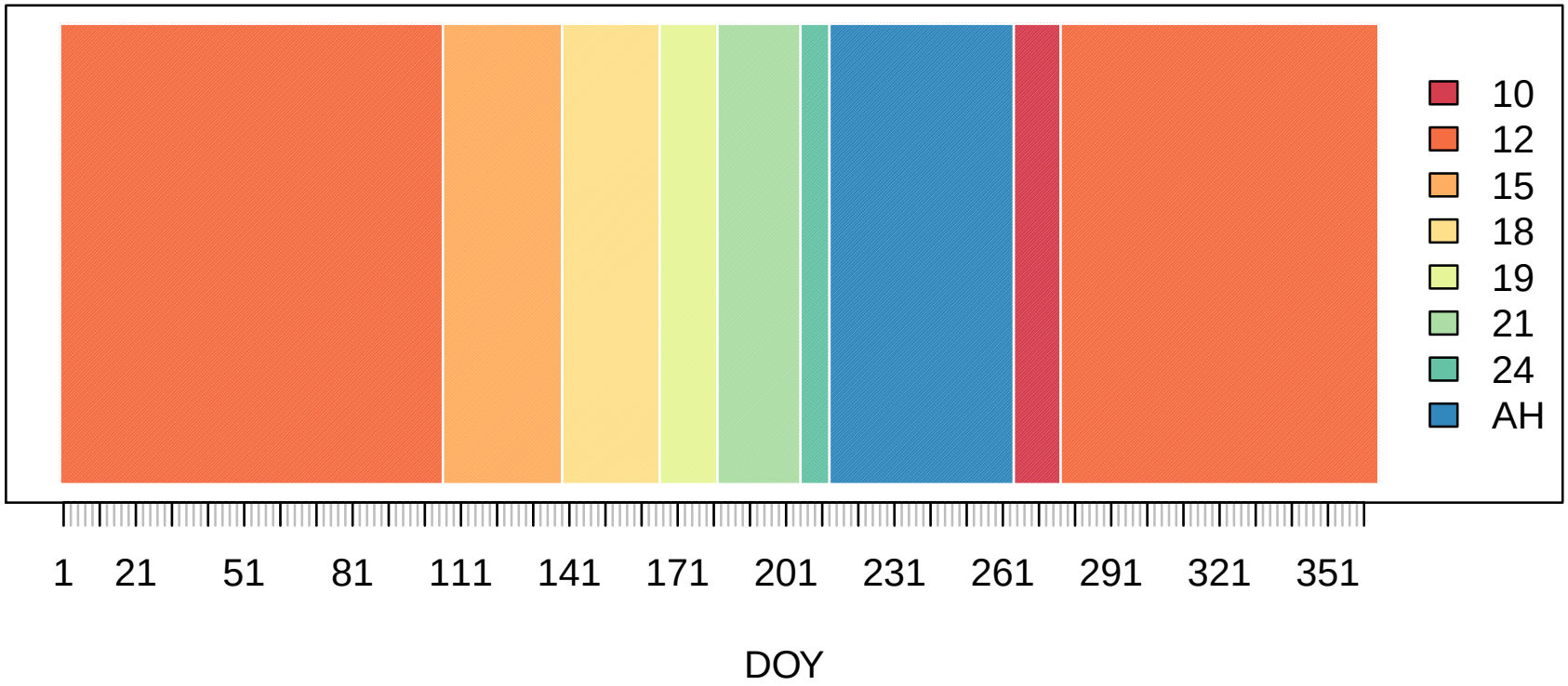
2010



10 – sowing | 12 – emergence | 15 – shooting | 18 – heading | 19 – milk ripening | 21 – yellow ripening | 24 – harvest

Temporal phase windows: *Winter Wheat*

2011



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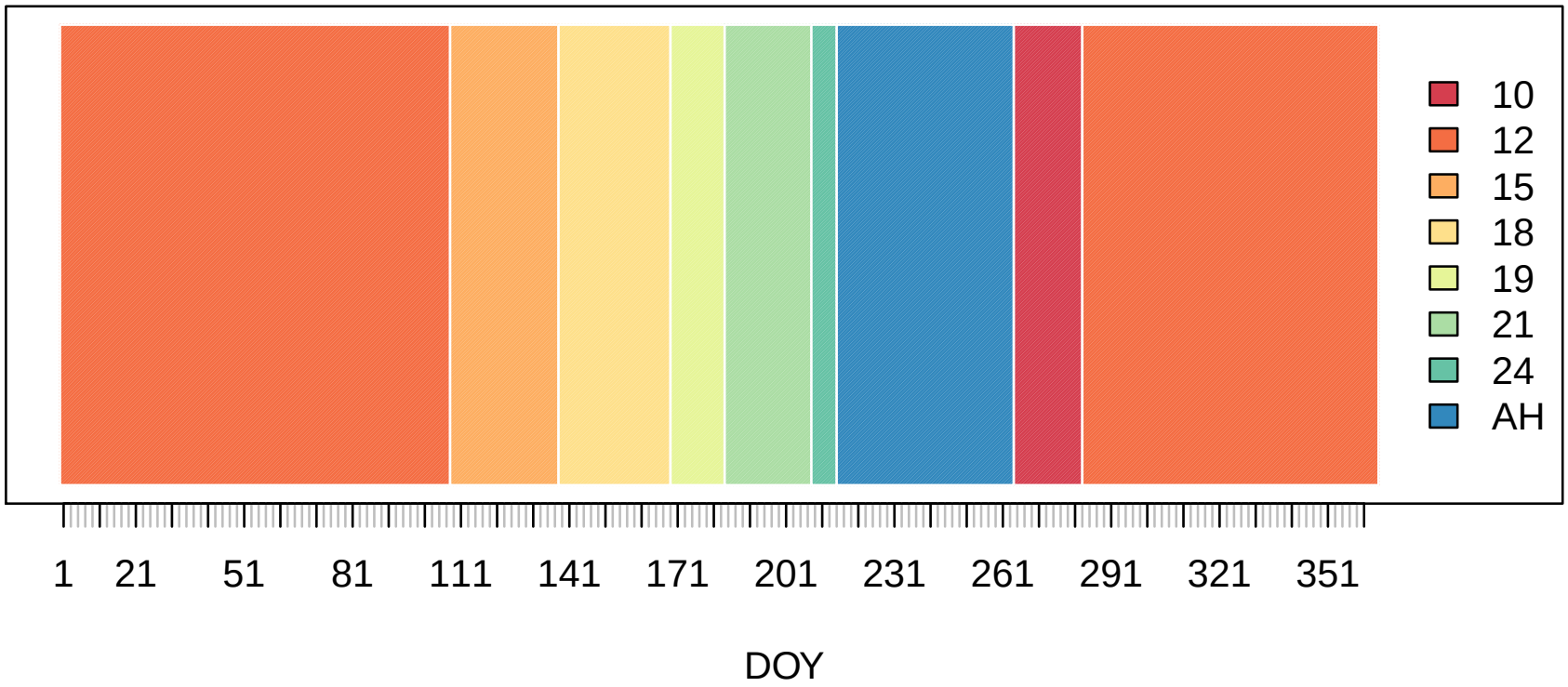
Temporal phase windows: *Winter Wheat*

2012



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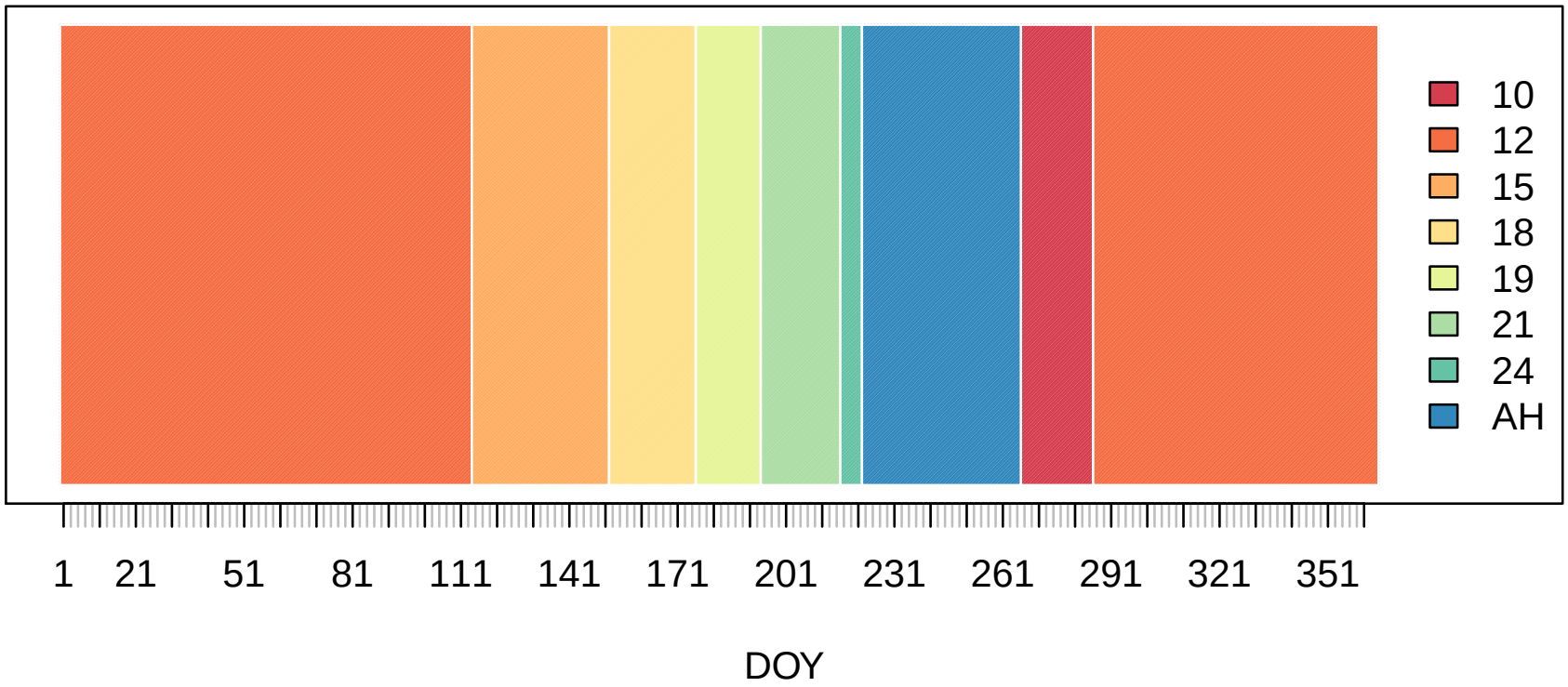
Temporal phase windows: *Winter Wheat*

2013



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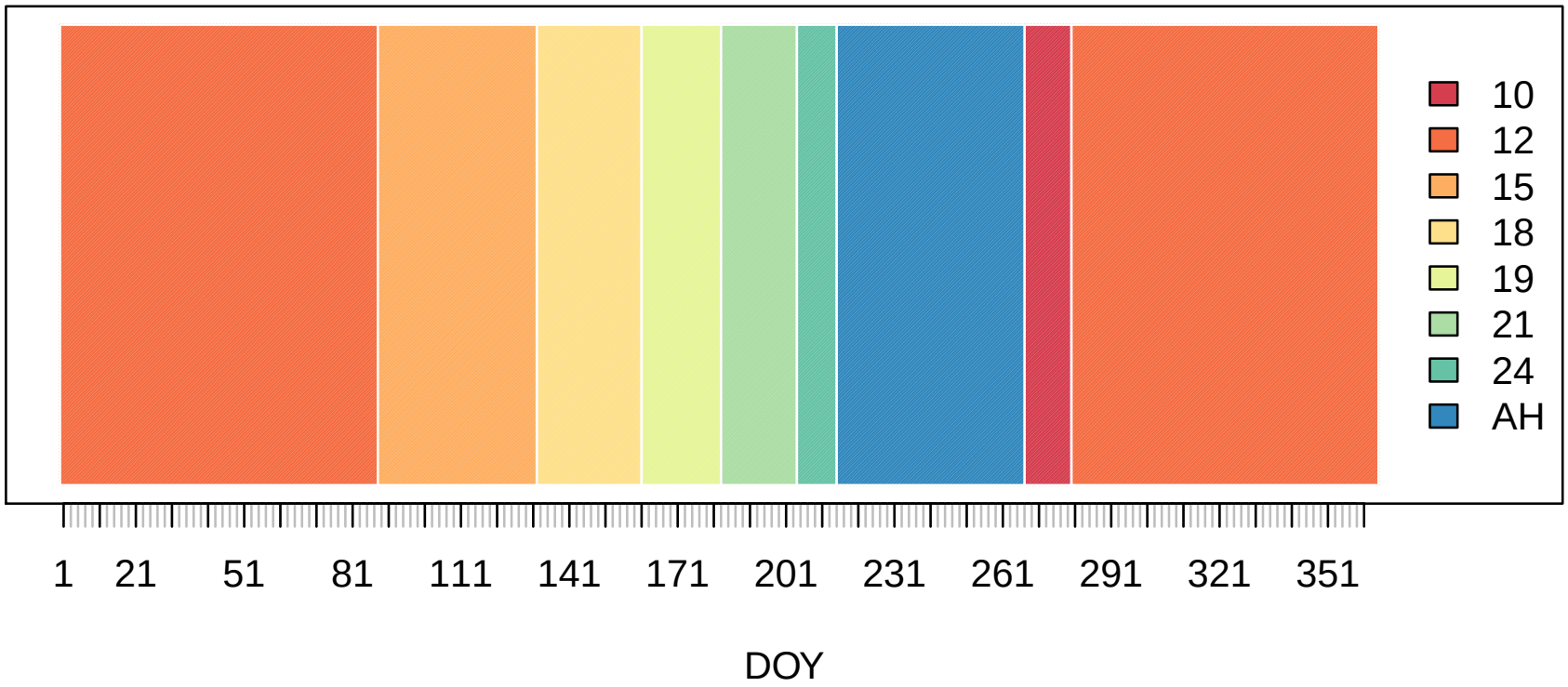
Temporal phase windows: *Winter Wheat*

2014



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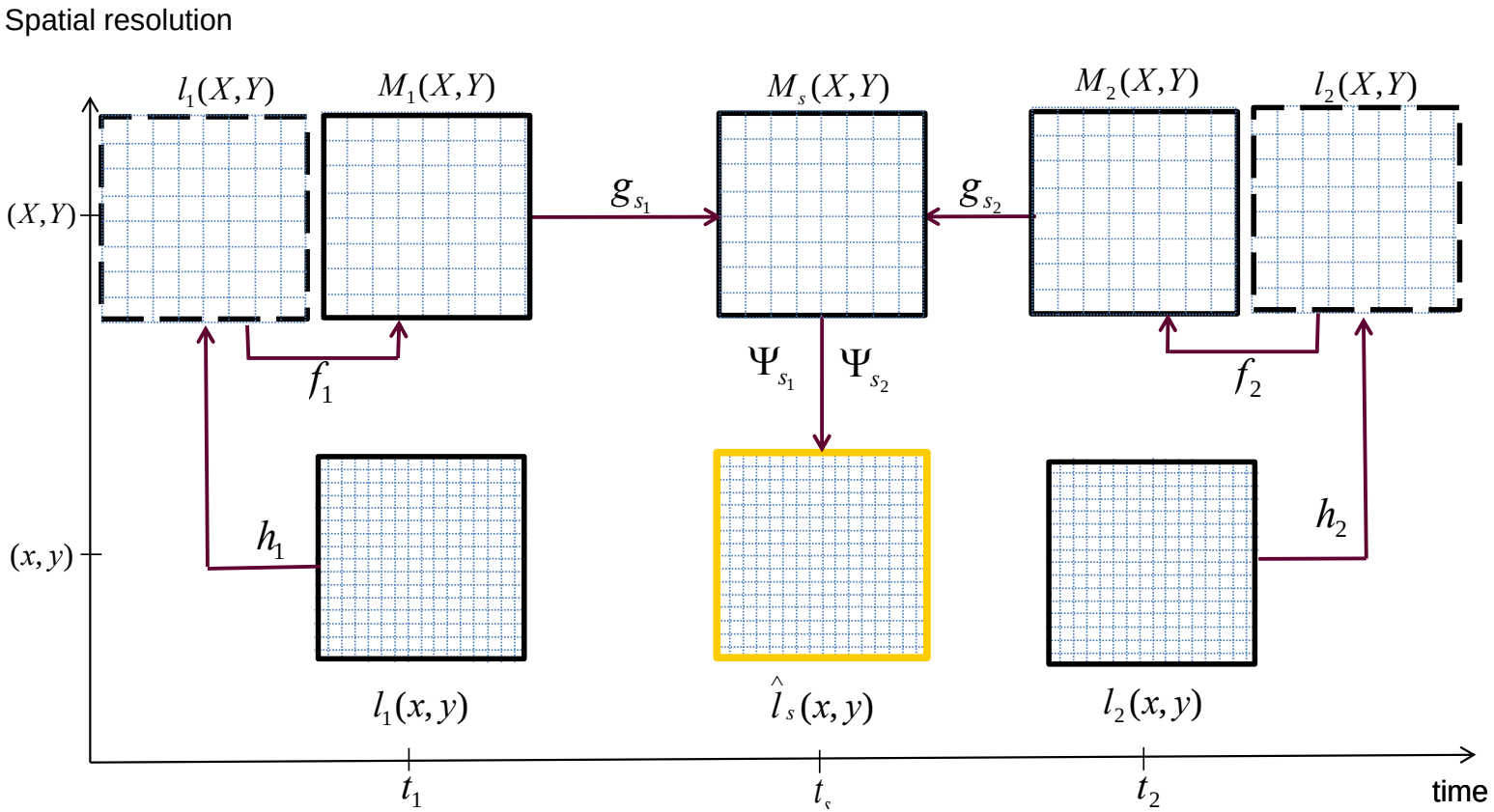
Spatial and Temporal Adaptive Reflectance Fusion Model



Gao, F., Masek, J., Schwaller, M., Hall, F., 2006. On the blending of the Landsat and MODIS surface reflectance: Predicting daily Landsat surface reflectance. IEEE Transactions on Geoscience and Remote Sensing 44, 2207–2218.

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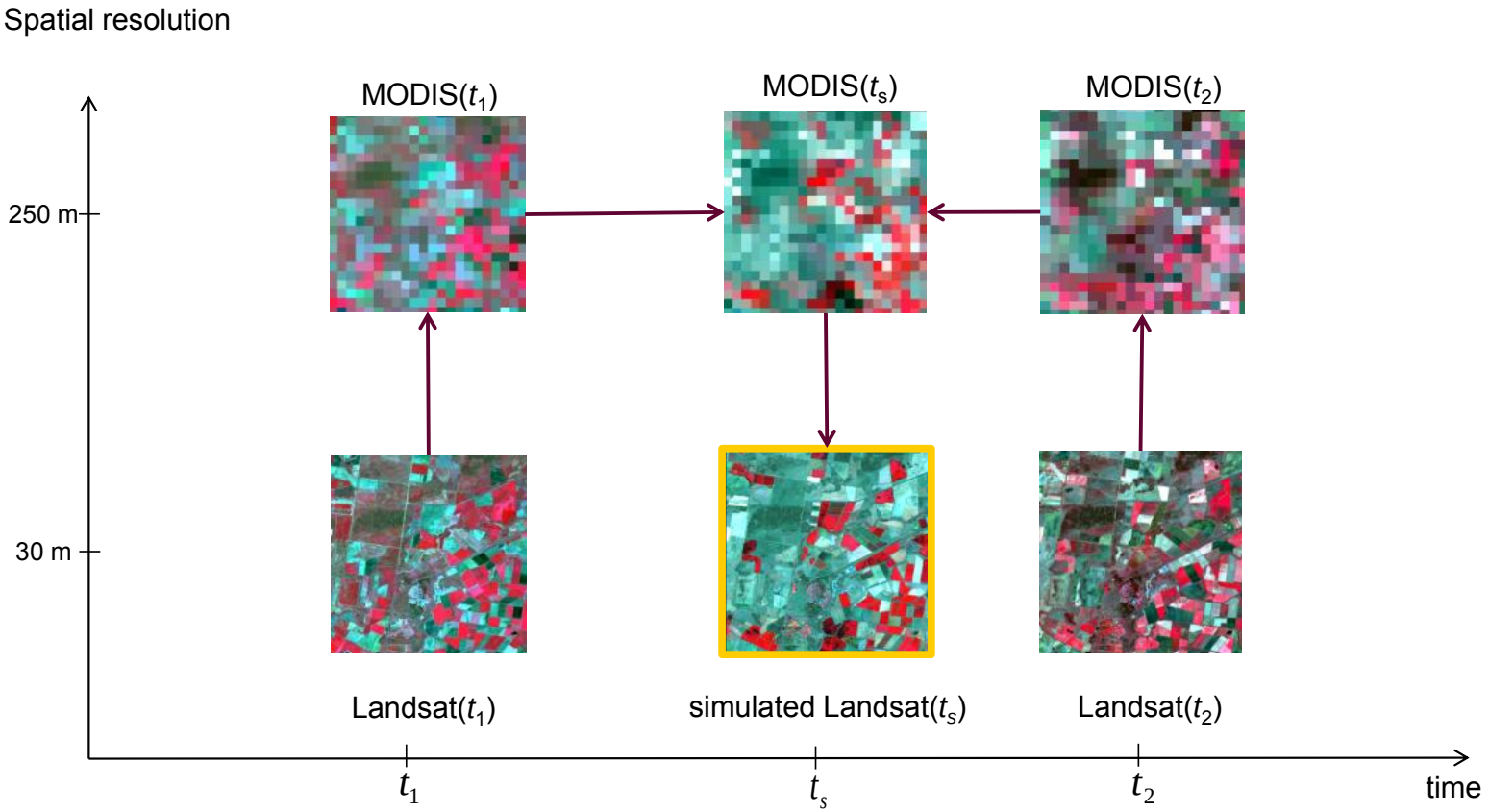

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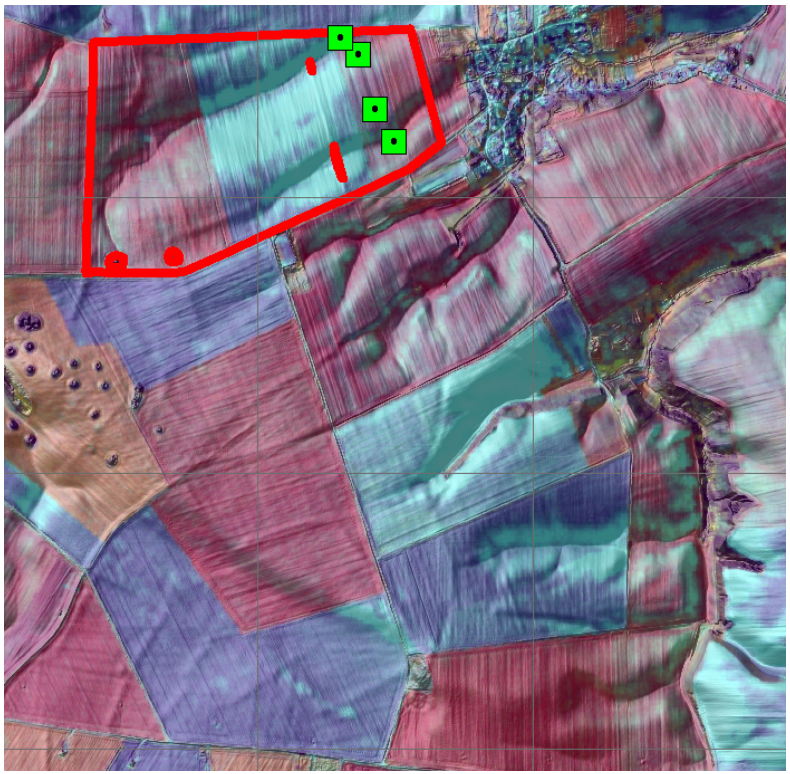
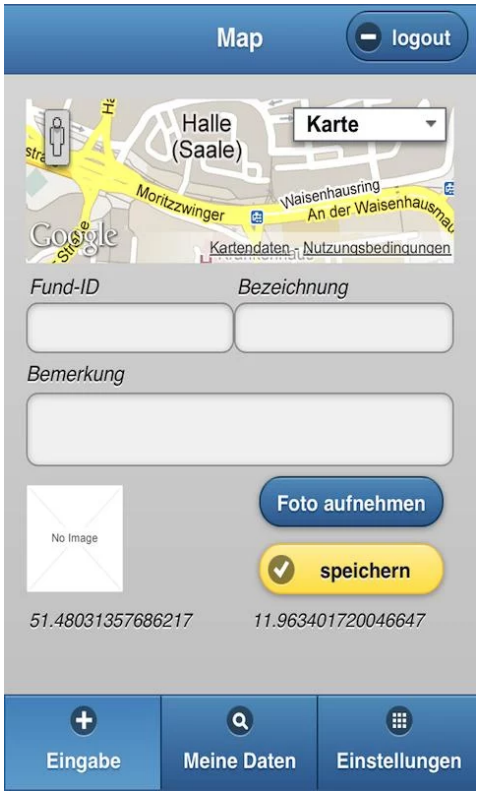
Photo spots

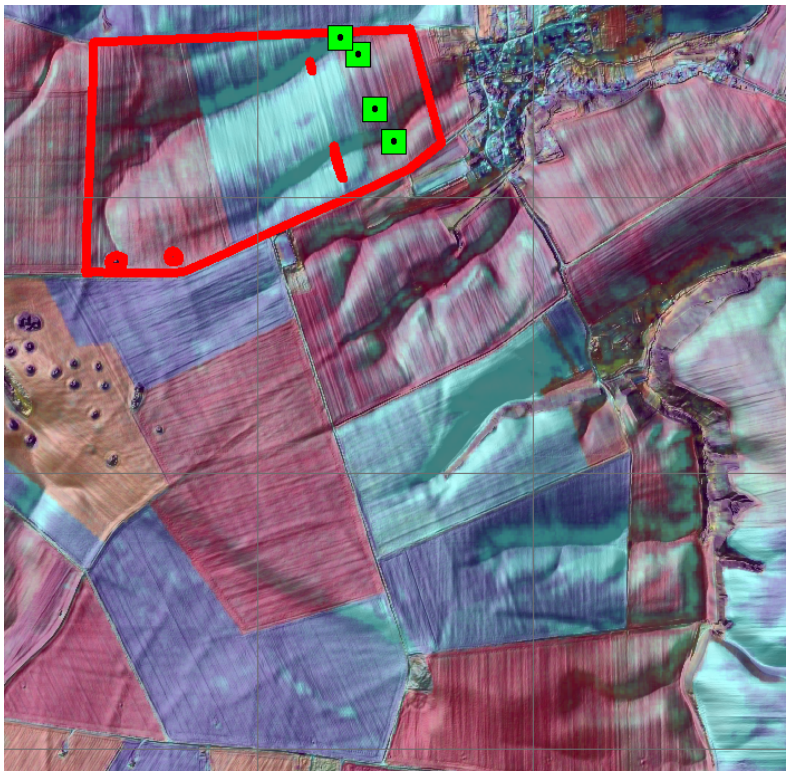


Mapping App



http://www.umgeodat.de/?q=node/8

Photo spots



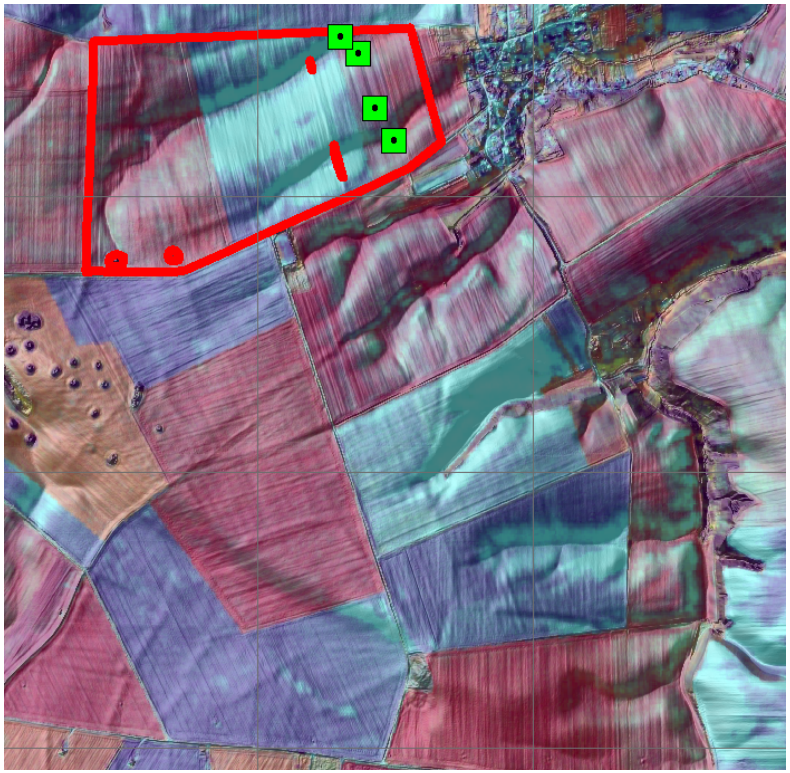
Spot 1

Spot 2

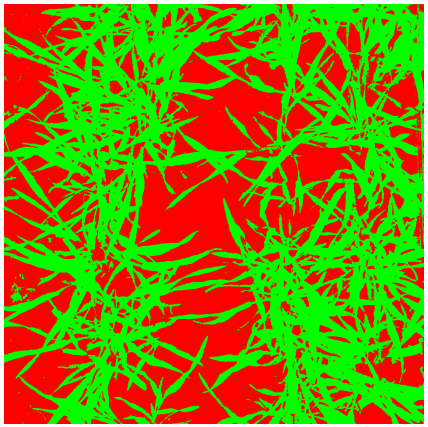
Spot 4

Spot 5

Winter Wheat 2014

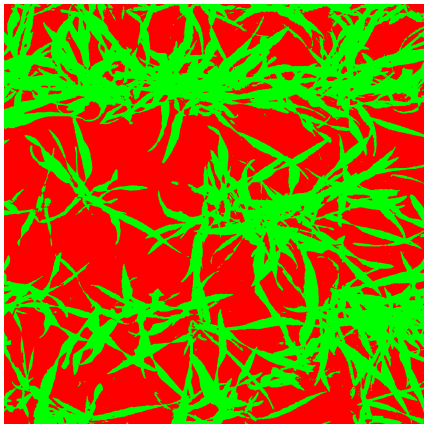


Spot 1

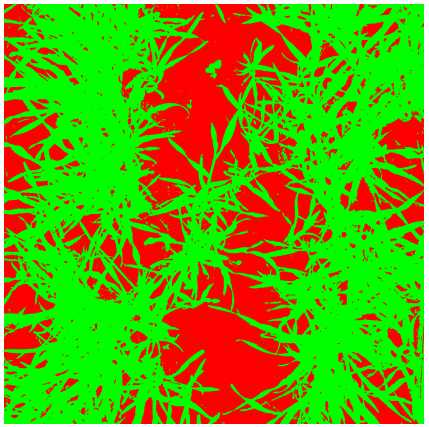


Spot 2

Spot 4

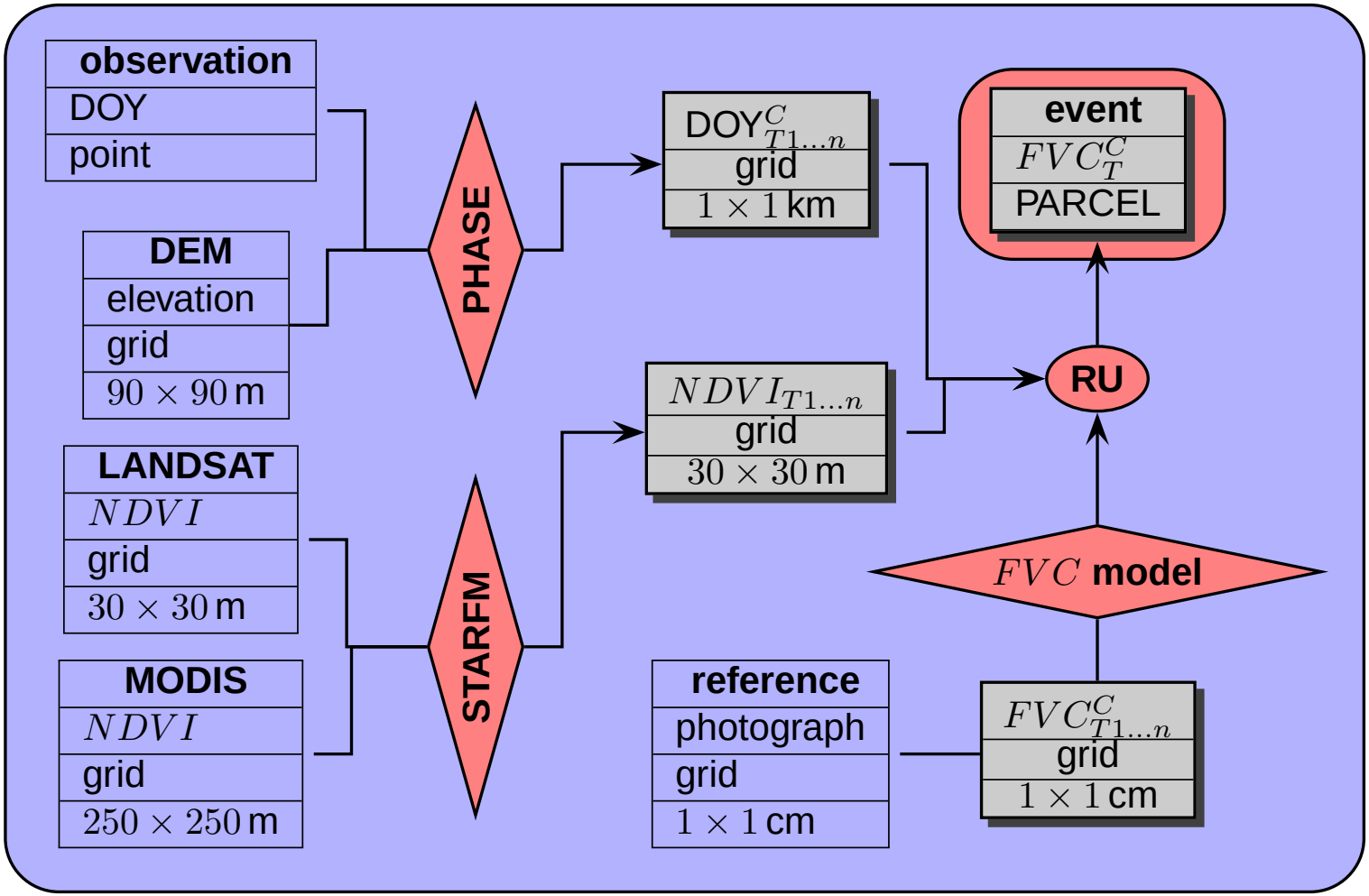


Spot 5



Outline

Workflow


observation
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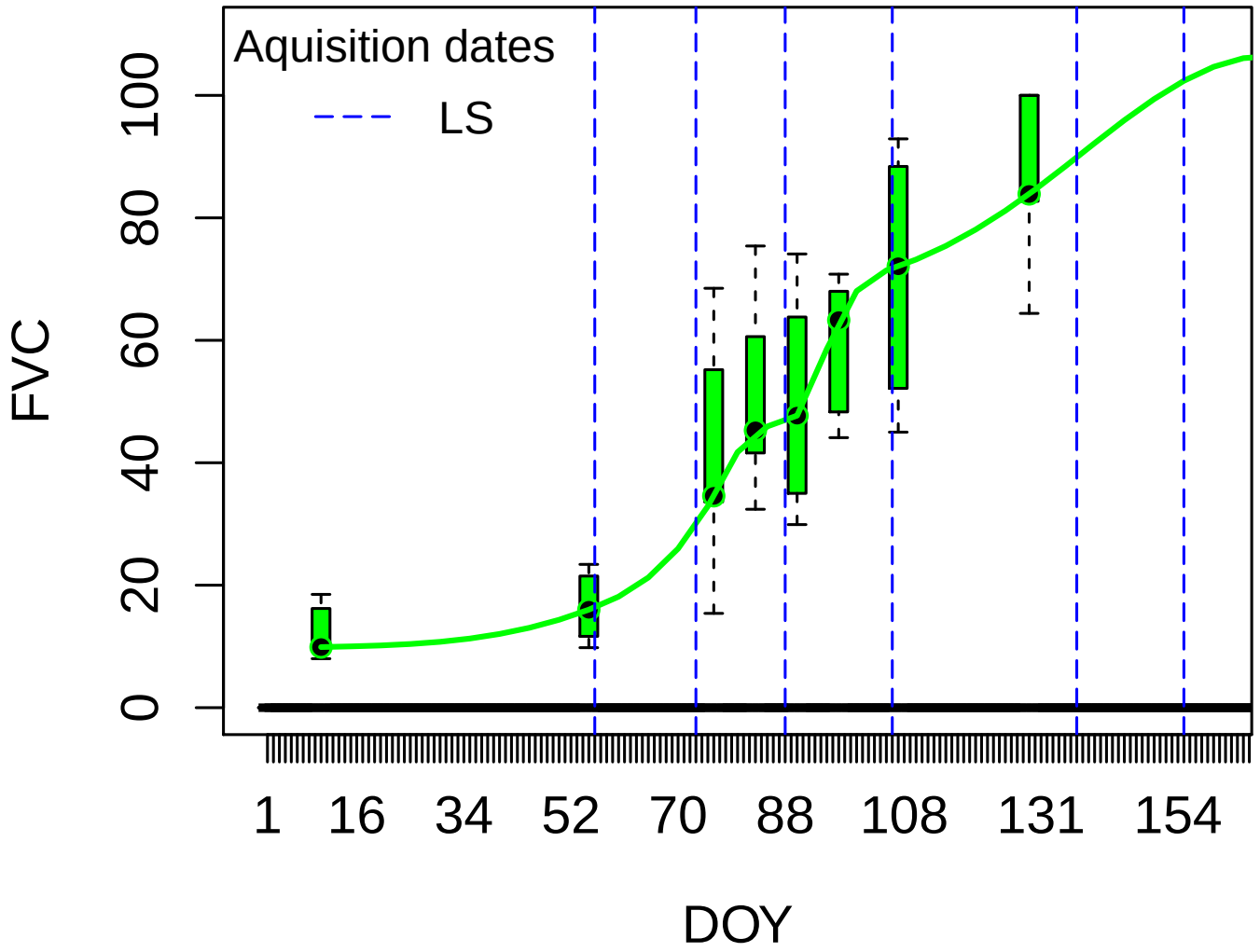
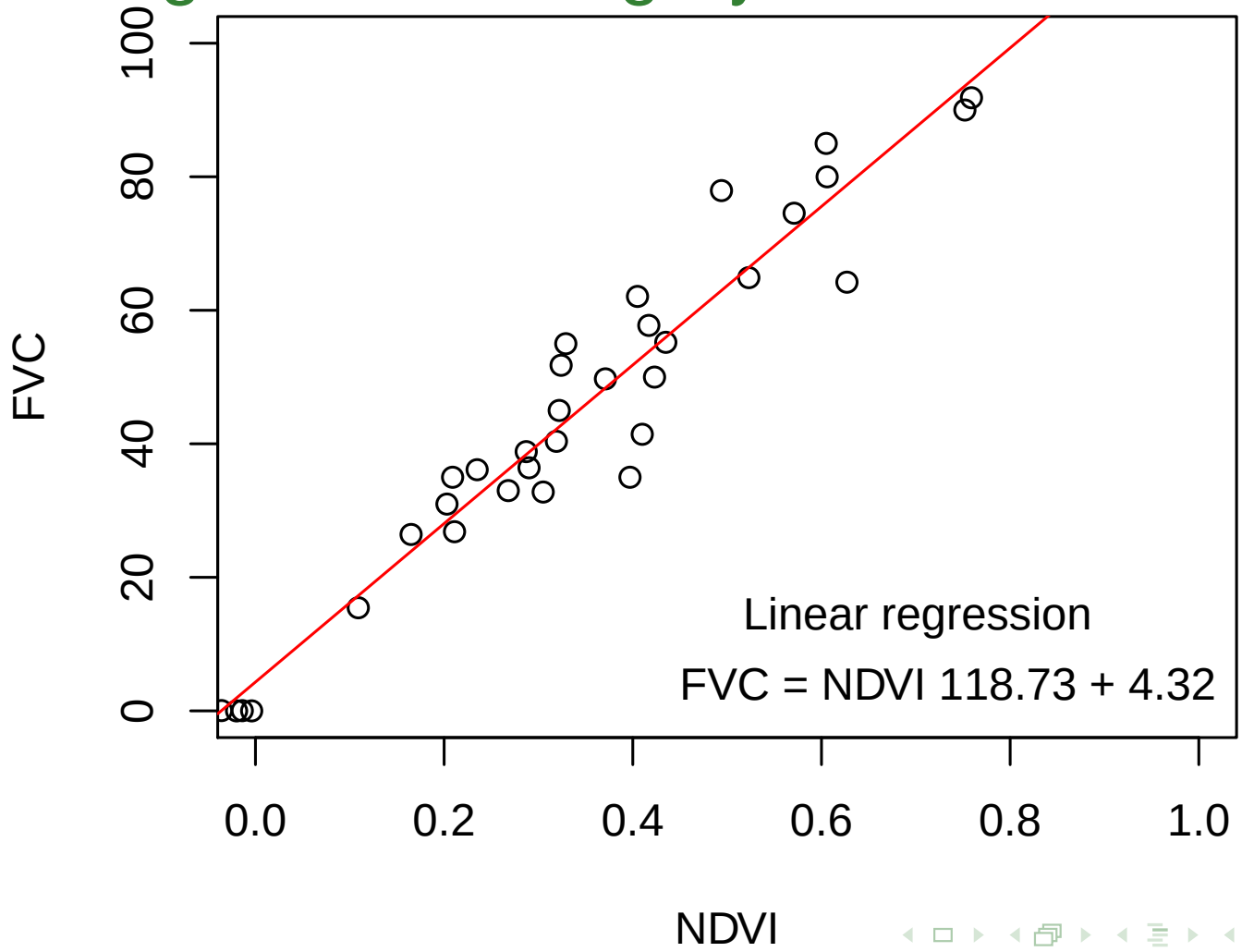
reference
photograph
grid
1 × 1 cm
event
FVC$^{C}_{T}$
PARCEL
RU
FVC model
FVC$^{C}_{T1...n}$
grid
1 × 1 cm

Mapping results: *Winter Wheat* in spring 2014

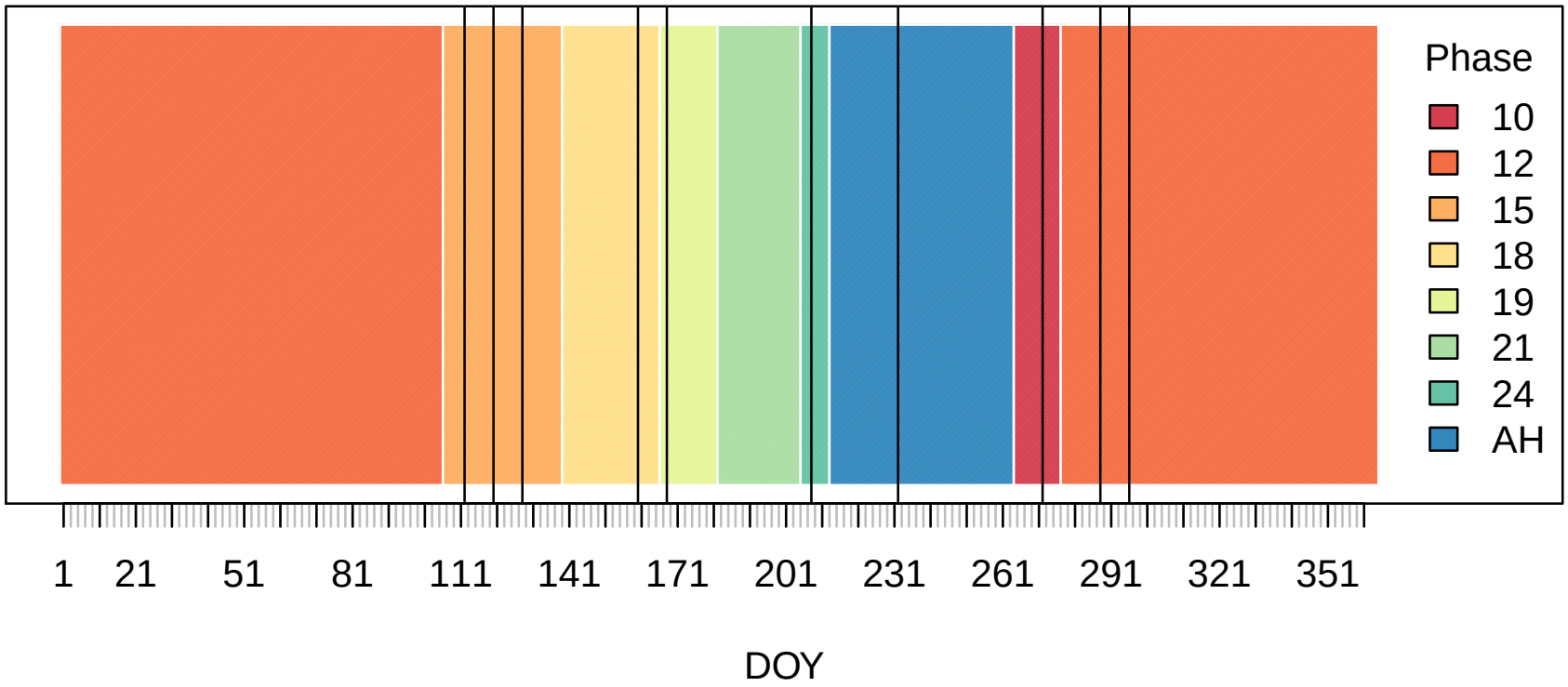


FVC model based on samples of 2013/2014 and corresponding Landsat imagery



Winter Wheat 2011

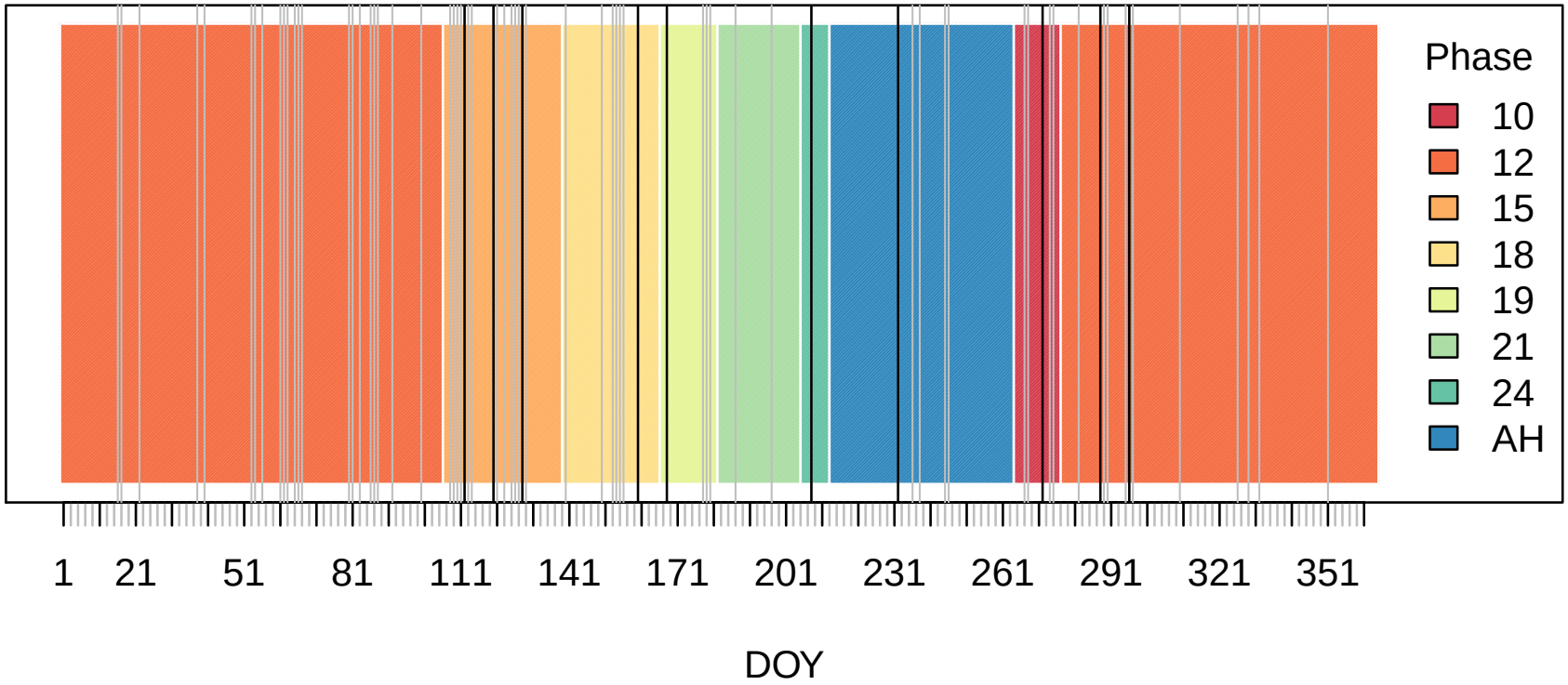
available Landsat 7 imagery



10 – sowing | 12 – emergence | 15 – shooting | 18 – heading | 19 – milk ripening | 21 – yellow ripening | 24 – harvest

Winter Wheat 2011

simulated Landsat 7 imagery (cloud cover $< 70\,\%$)



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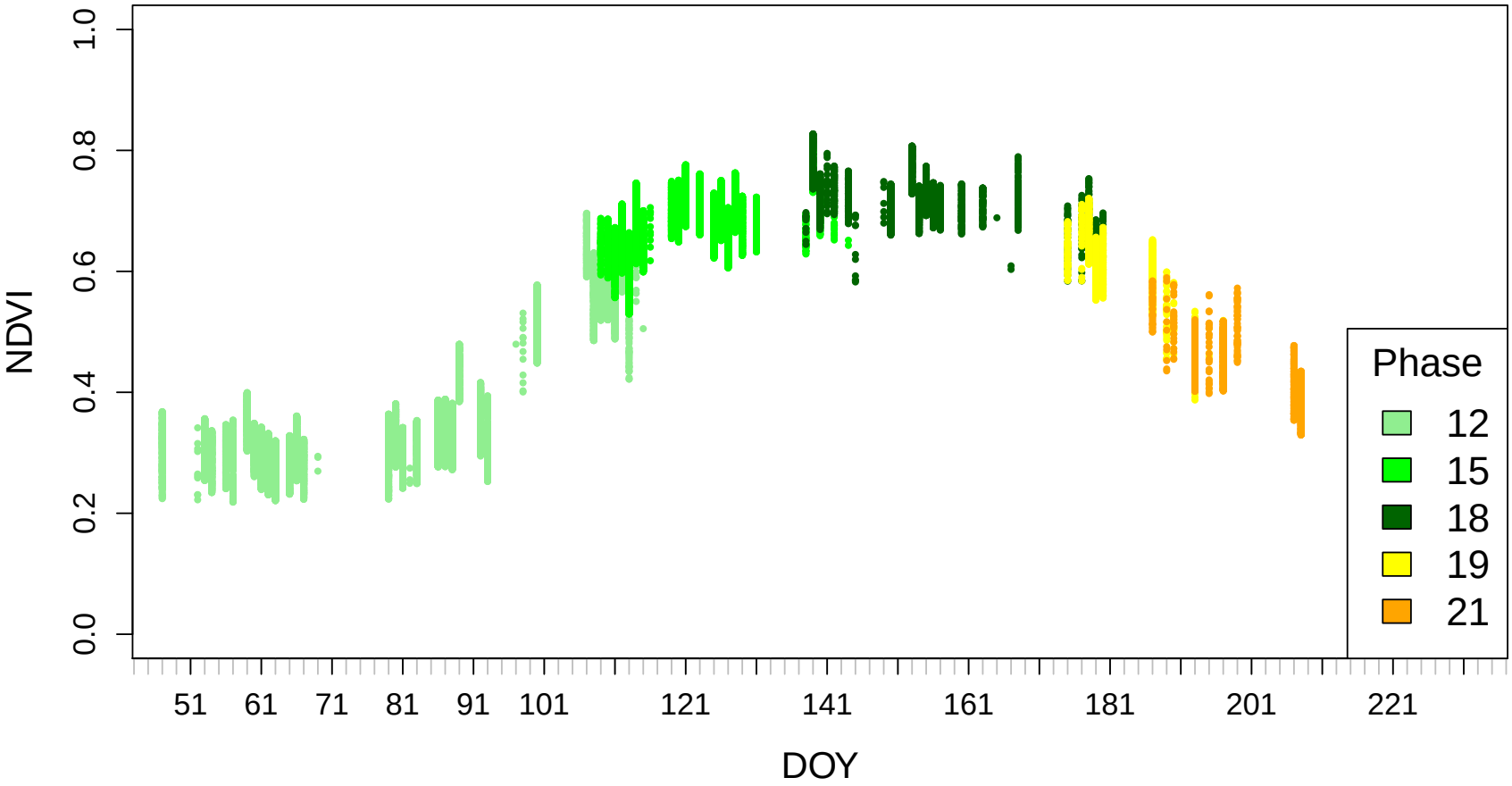
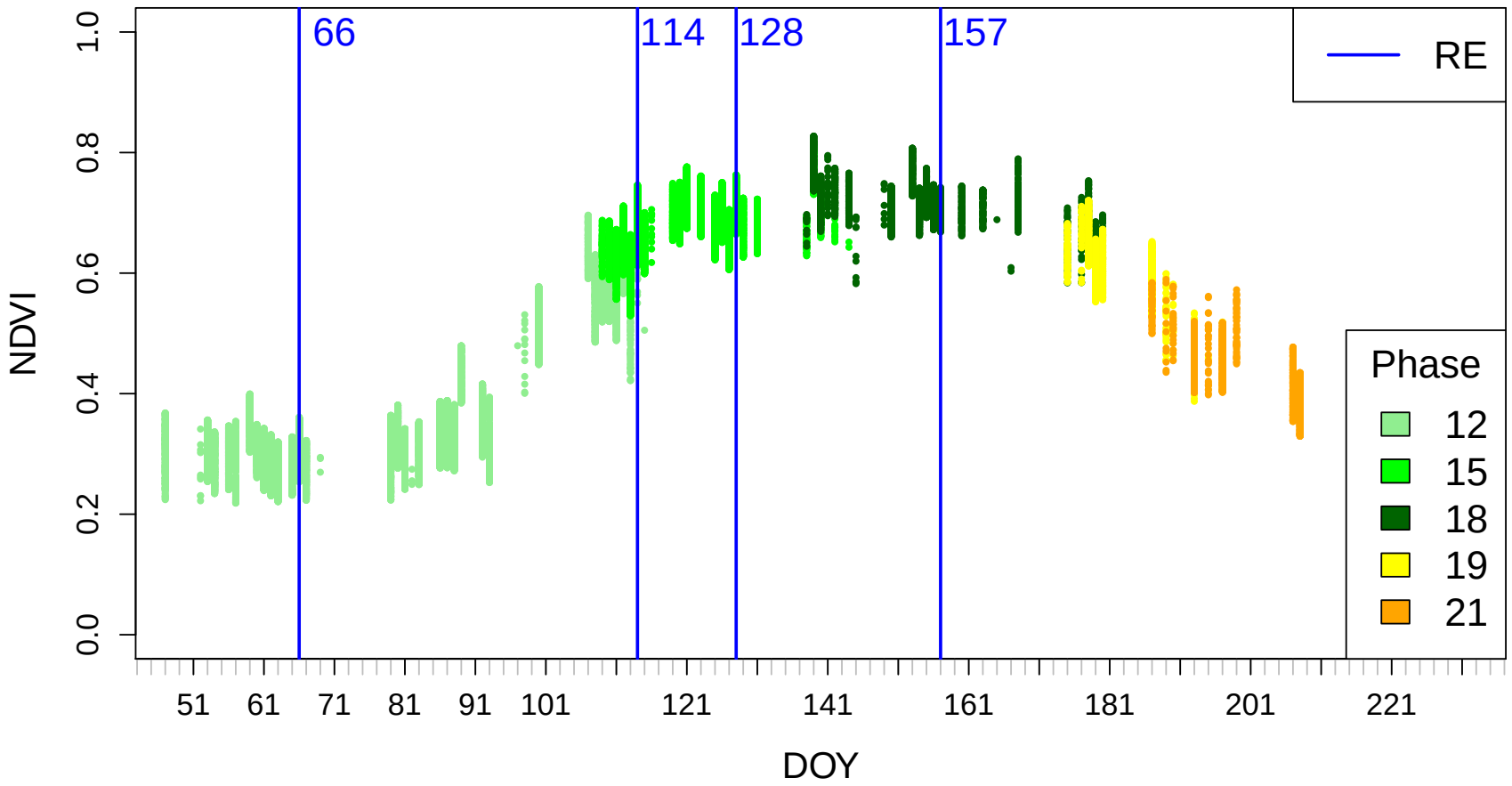
25 % and 75 % *NDVI* quantiles

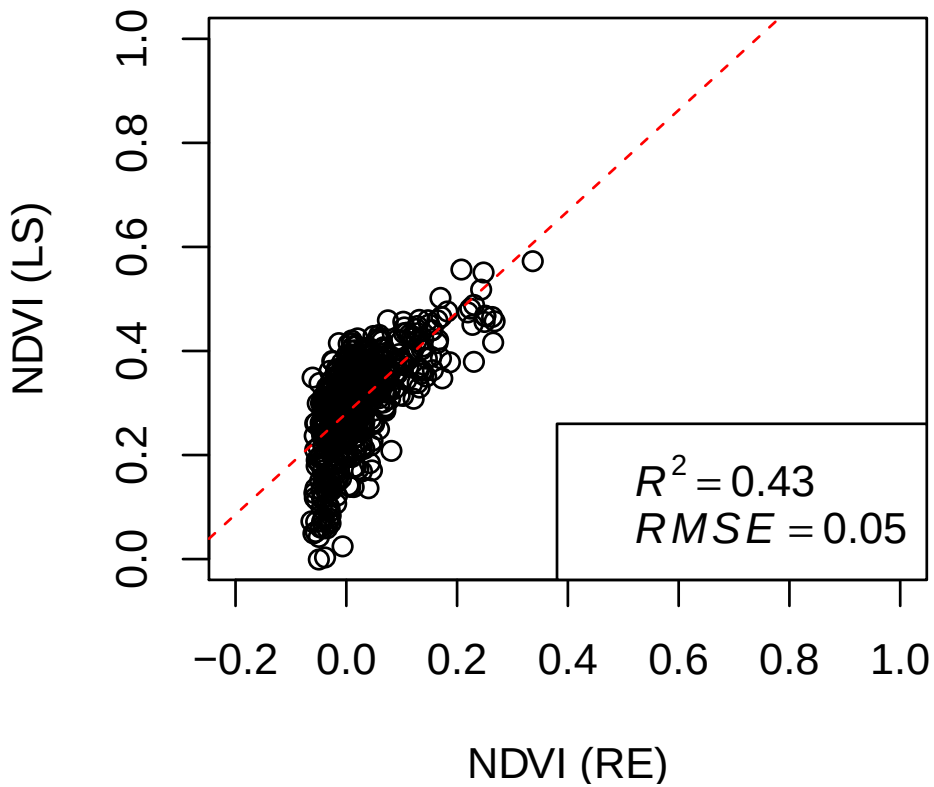


Validation: available RapidEye imagery

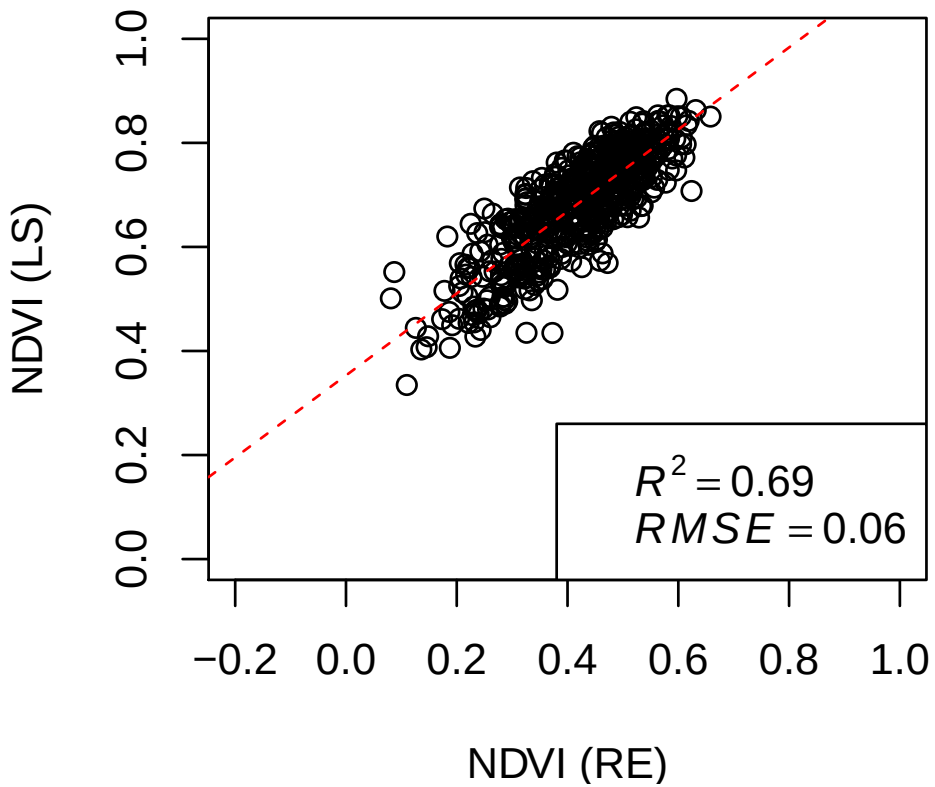


Validation: scatterplots

DOY 66 – PHASE 12

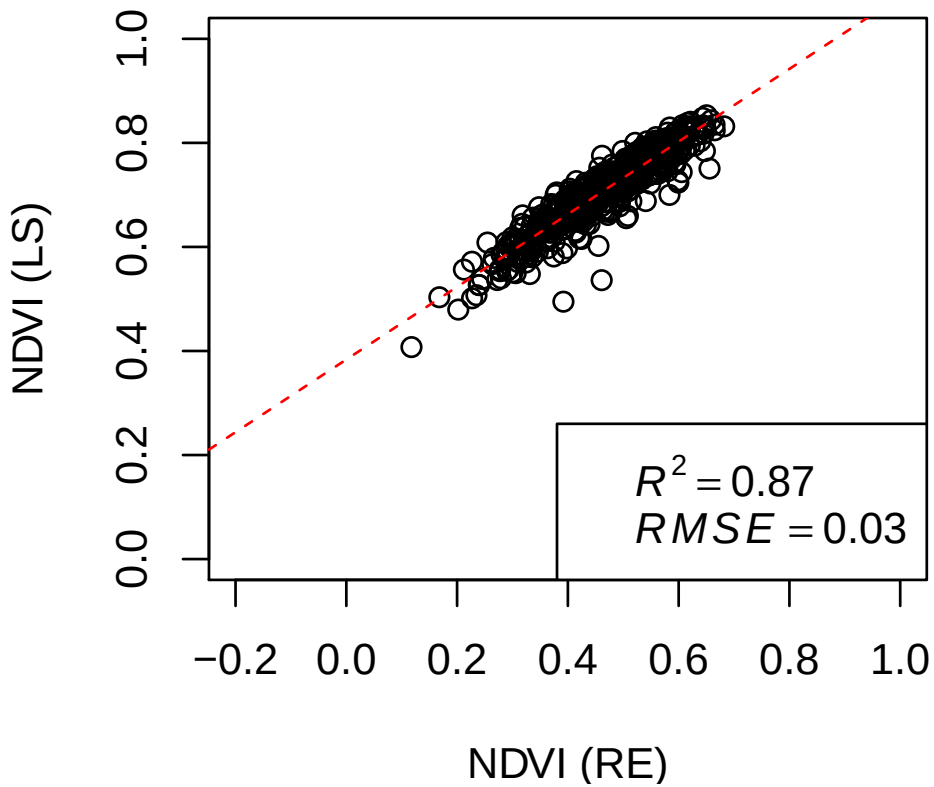


DOY 114 – PHASE 15

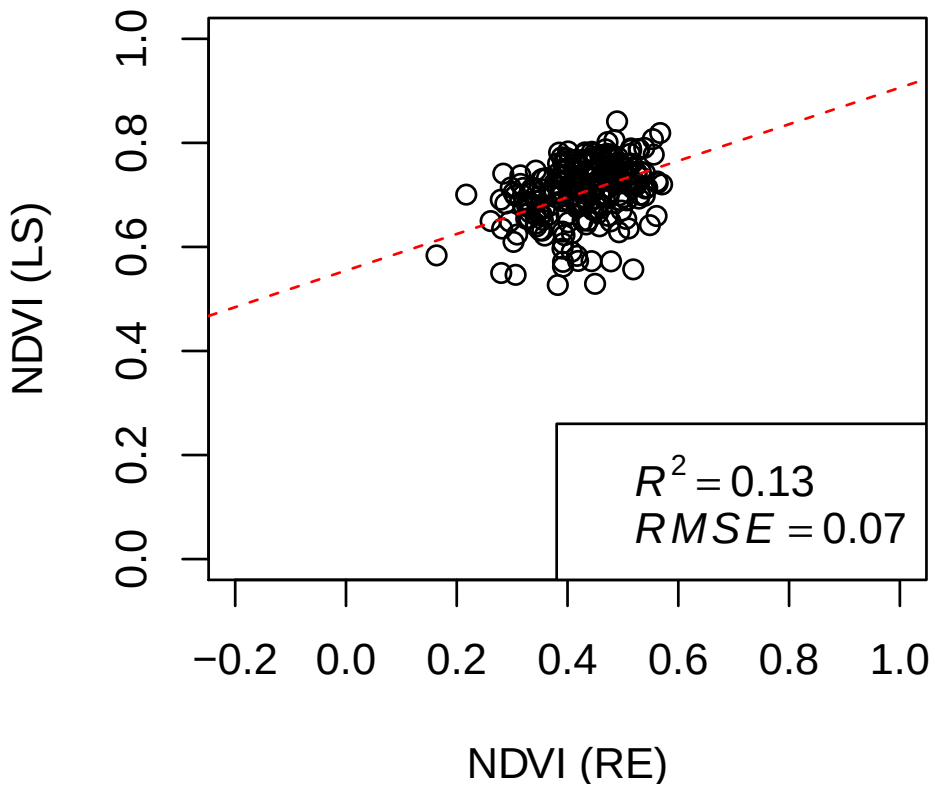


Validation: scatterplots

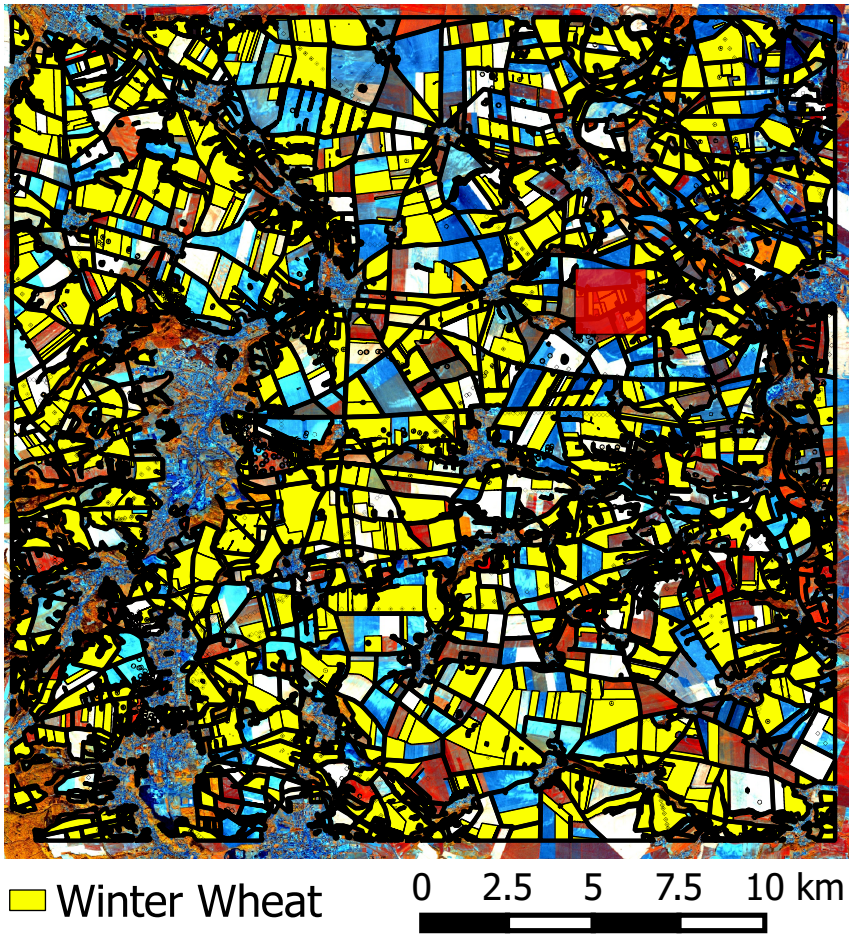
DOY 128 – PHASE 15

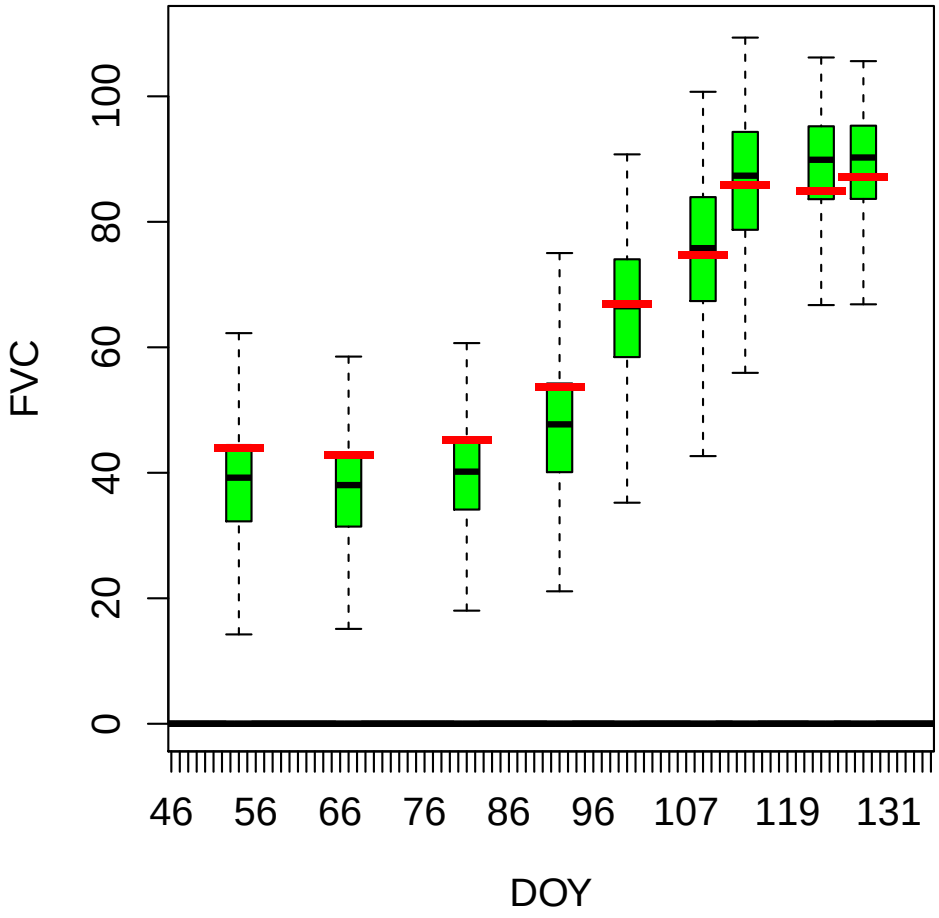


DOY 156 – PHASE 18



FVC prediction for phase 12 and 15 in 2011





Outline

Conclusion

- Vegetation indices show a high correlation to fractional vegetation cover during **green** phenological phases.
- We have shown how such relevant time periods can be identified by coupling phenological phases and simulated *NDVI* time series over a specific vegetation period.

Outlook

- effective sampling
- application for crop residue coverages
- implementation in a WebGIS environment

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Thank you for your attention!

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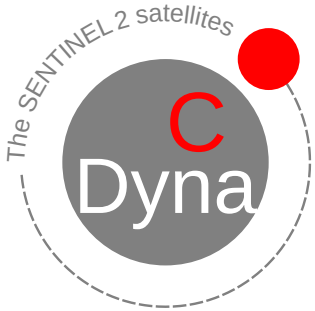

Temporal and spatial C-factor derivation by using Sentinel 2 imagery for the localization of soil erosion events by water
http://paradigmaps.geo.uni-halle.de/dynac

Phenological structuring of high temporal Sentinel-2 satellite imagery to improve land cover classification
http://paradigmaps.geo.uni-halle.de/phenos