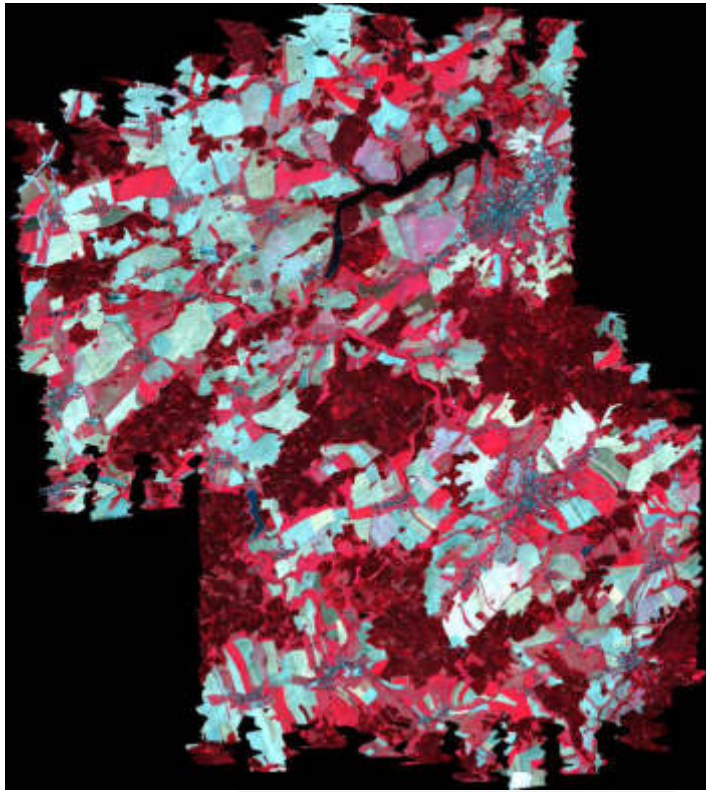
HELMHOLTZ
Centre for Environmental Research

UFZ‘s remote sensing based land-cover/use mapping activities



UFZ sensor, CIR image, Zeulenroda, Summer 2012

Leipzig, iDiv, 15.01.2020
sMon workshop

Daniel Doktor	Group leader, Prinicipal Investigator, daniel.doktor@ufz.de
Sebastian Preidl	Methods for data compositing and classification, sebastian.preidl@ufz.de
Maximilian Lange	Processing, phenology + intensity derivation, maximilian.lange@ufz.de
Andreas Schmidt	Co-registration of satellite time series, andreasdd.schmidt@ufz.de

Available spatial information

Status quo:

- land-cover maps of spatially and thematically low resolution
- Sentinel-2 offers new possibilities towards a plot based classification down to species level

Agriculture (1961-1999)

Increase of 106% of overall food crop yield per unit area

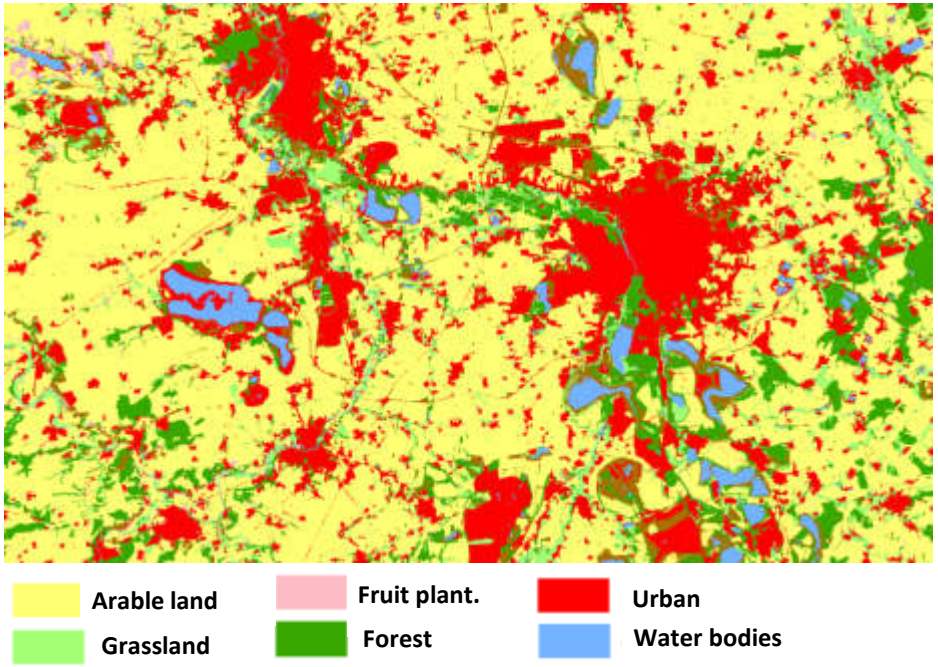
12% increase in cropland

10% rise in permanent pasture

97% rise in irrigated land

638%, 203%, and 854% increase, in the use of fertilizers, pesticides, herbicides

Source: ATKIS 2015, Federal Agency for Cartography and Geodesy, Area Leipzig-Halle



Foley et al. (2005) Nature
Green (2005) Science
Haberl et al. (2007) PNAS

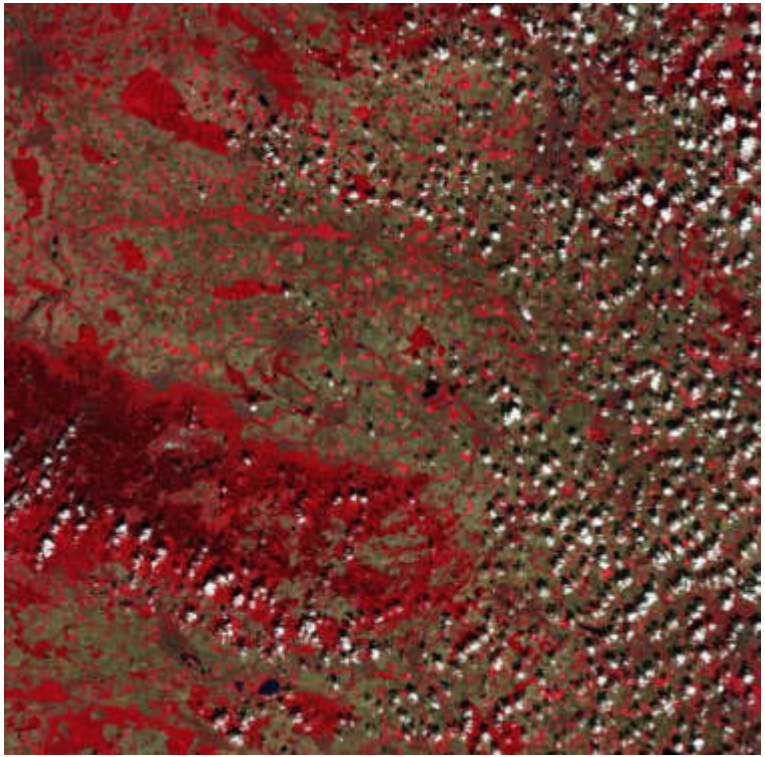
(Spectral) data base

- Sentinel-2 satellite data
- Spatial resolution: 10/20 m
- Spectral resolution: 13 bands (9 bands at 20 m)

- Global repetition rate: 5 days, Germany 2-3 days
- Vegetation Monitoring, Phenology
- Masking of clouds
- Big Data

- **Sentinel-2 archive is kept up-to-date at UFZ**

- **Data processing at UFZ or prospective in Jülich**



Sentinel 2 a CIR image, 30th of August 2016

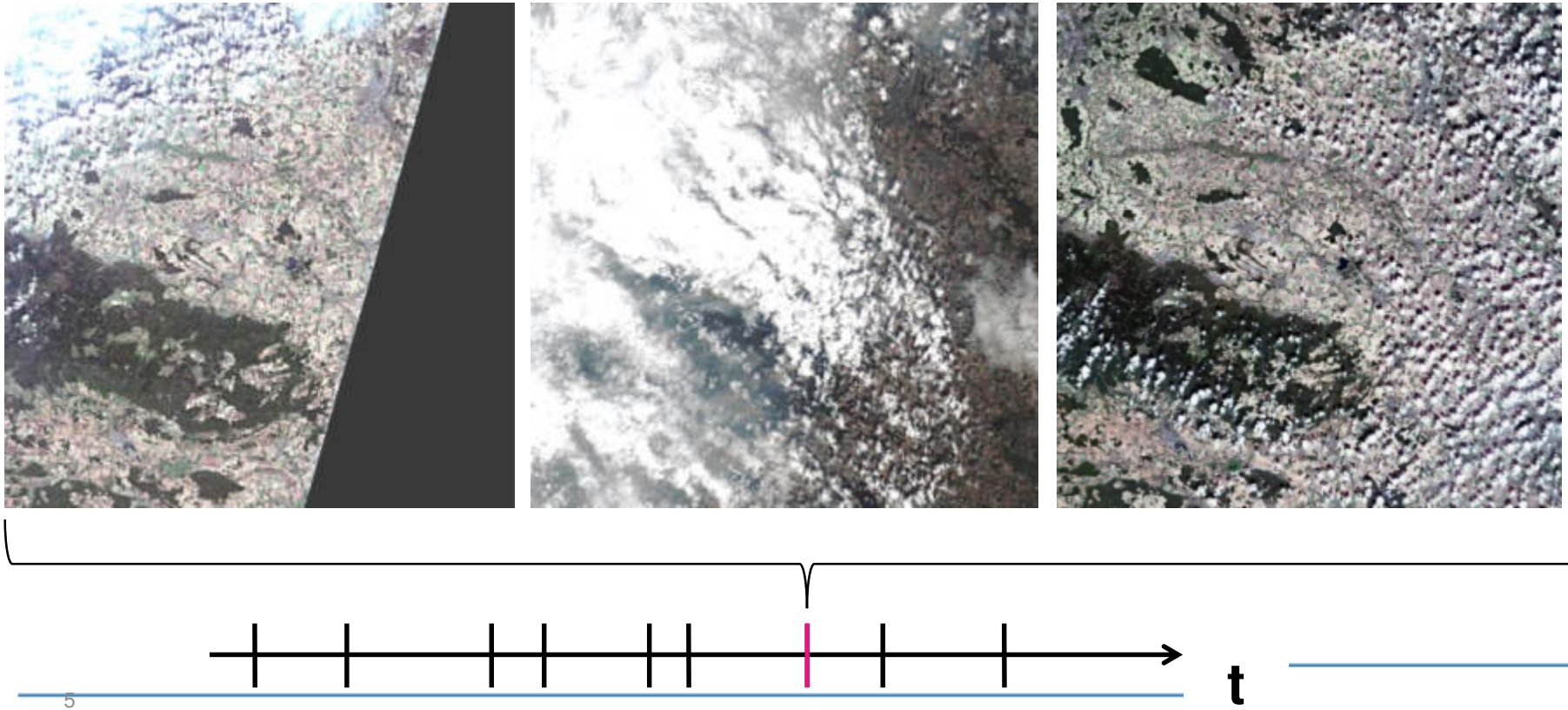
Adaptable pixel-based compositing and classification

- Automised and purely data-driven approach to best capture crop phenology
- Satellite data is composited at flexible time intervals based on cloud-cover and training data
- Derivation of model uncertainties

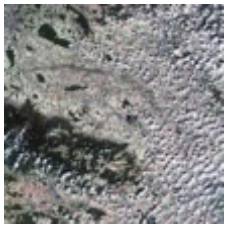
- Germany divided into 6 bio-geographical regions similar in plant phenology for regionalised classification
- InVeKoS data for training & validation

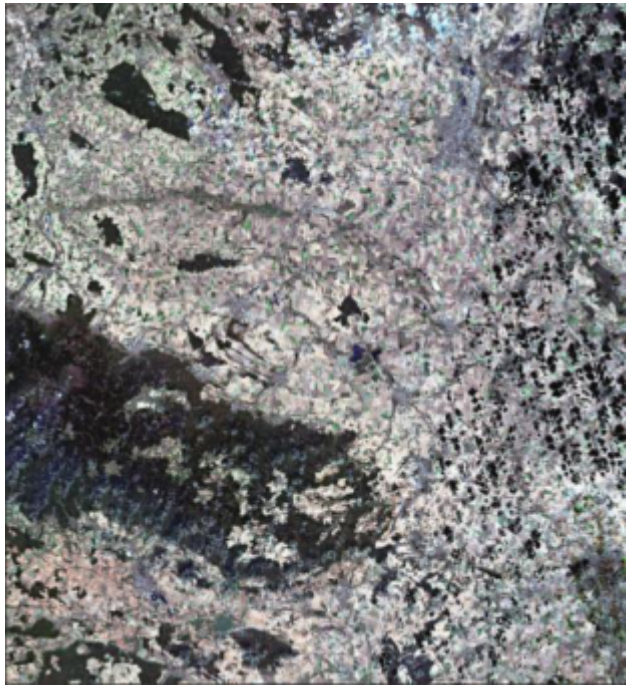
Preidl, S., Lange, M., Doktor, D. (2019). Introducing APiC for regionalised land-cover mapping on the national scale using Sentinel-2A imagery. REMOTE SENSING OF ENVIRONMENT (accepted)

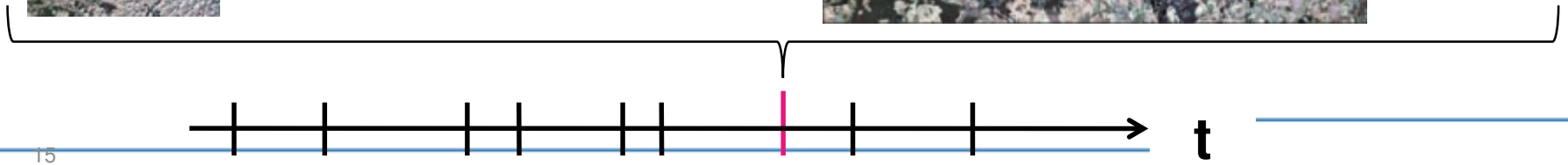
Land-use classification – cloud cover



Land-use classification – pixel-based compositing

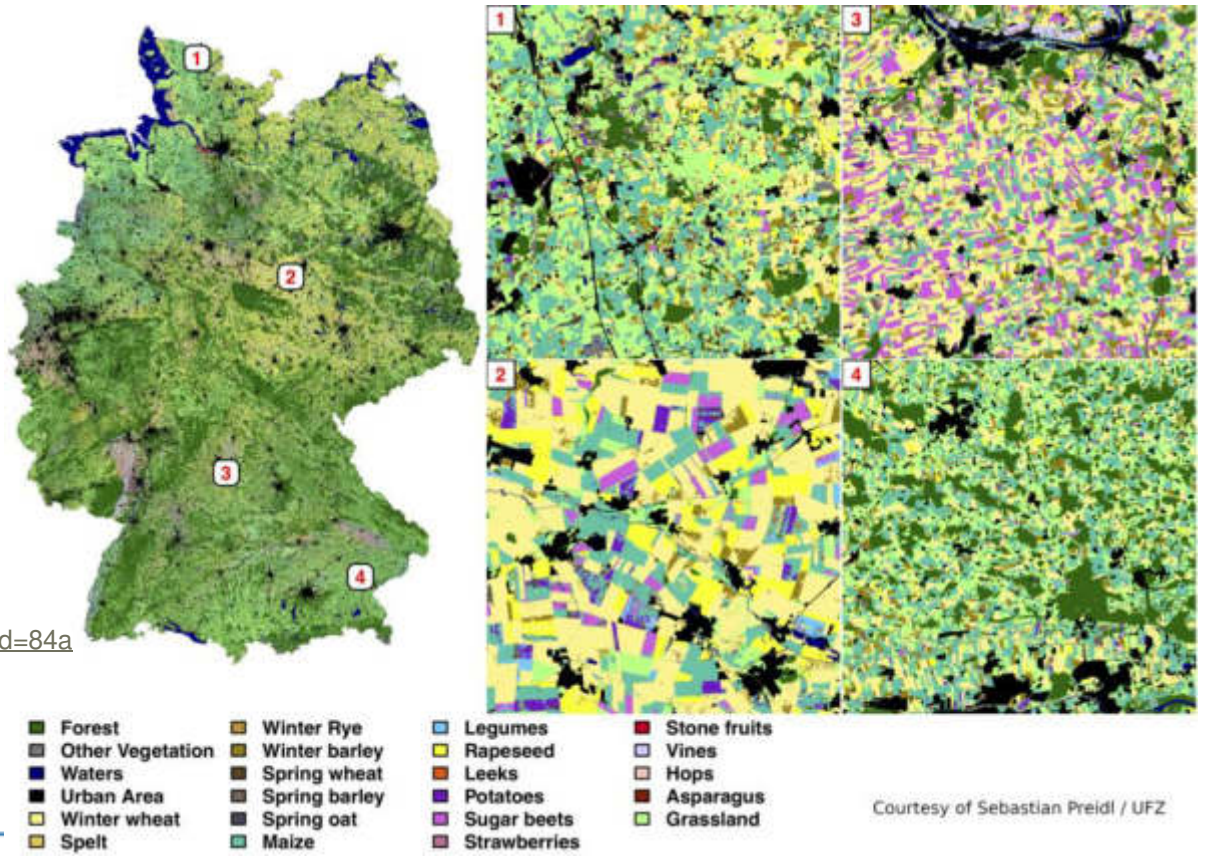






Classified crop types and grassland

- 19 crop types incl. grassland could be classified
- Field parcels clearly identifiable
- Difference in plot size and cultivated crop between regions



http://ufz.maps.arcgis.com/apps/Styler/index.html?appid=84a36f4e815e4aa88f38a6d0f8382590

Preidl, S., Lange, M., Doktor, D. (2019). Introducing APiC for regionalised land-cover mapping on the national scale using Sentinel-2A imagery. REMOTE SENSING OF ENVIRONMENT (accepted)

Classification accuracy

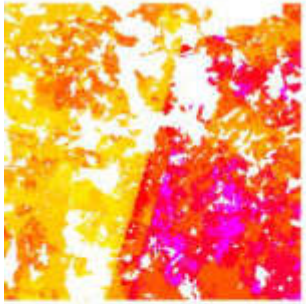
- Overall accuracy of 87 %
- Main crop types (winter wheat, maize and raps) over 90 %
- Small classes & small field sizes less well classified

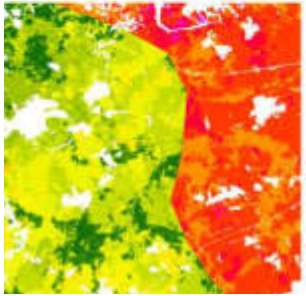
	Alpine Foreland		SW-Uplands		W-Uplands		E-Uplands		NE-Lowlands		NW-Lowlands	
Land-Use Classes	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA
Winter wheat	92.95	89.68	91.35	88.55	89.84	86.69	90.90	89.99	89.73	79.80	88.69	84.11
Spelt			26.63	77.83	22.40	30.49	16.81	70.87	33.05	71.59	28.63	38.25
Winter Rye			43.74	73.37	17.71	45.66	14.76	72.45	64.16	78.23	38.09	78.33
Winter barley	74.62	84.73	77.04	80.99	72.07	87.03	79.52	81.42	63.99	90.78	74.98	79.63
Spring wheat					18.37	23.73	14.90	75.01	40.29	32.87	12.51	28.54
Spring barley	56.96	87.15	82.88	82.66	59.20	62.75	84.42	75.00	49.81	55.17	51.29	61.16
Spring oat			50.04	64.91	45.19	33.45	39.50	57.36	31.22	40.60	33.27	26.69
Maize	90.54	91.02	87.23	90.58	89.65	94.33	93.87	95.85	94.45	92.08	95.53	94.48
Legumes			71.18	75.82	59.87	62.83	67.36	81.55	73.41	69.27	56.69	45.58
Rapeseed	74.57	86.85	91.64	93.07	92.61	93.22	95.65	96.27	94.24	98.48	91.04	96.47
Leeks			64.55	60.46					76.21	25.21	50.57	43.18
Potatoes	93.57	95.35	74.82	79.18	72.67	56.37	67.82	66.86	53.16	71.56	78.53	84.71
Sugar beets	93.19	96.29	93.06	91.20	91.57	89.28	87.43	91.60	85.14	88.53	83.42	94.31
Strawberries			55.60	48.29	75.57	21.90			56.27	13.90	56.88	36.88
Stone fruits	52.30	83.01	29.21	74.97	44.11	35.01	31.95	87.30	34.16	82.56	63.20	64.30
Vines			94.73	91.89	81.51	62.34						
Hop	78.12	93.31										
Asparagus			63.20	64.23					46.04	43.67	38.73	44.01
Grassland	96.46	90.25	92.38	86.72	97.05	94.93	97.71	91.47	96.66	88.72	97.13	90.44
Overall Accuracy	**90.38**		**87.4**		**89.52**		**89.78**		**85.94**		**87.76**	
Kappa Coefficient	**0.877**		**0.853**		**0.854**		**0.871**		**0.83**		**0.846**	

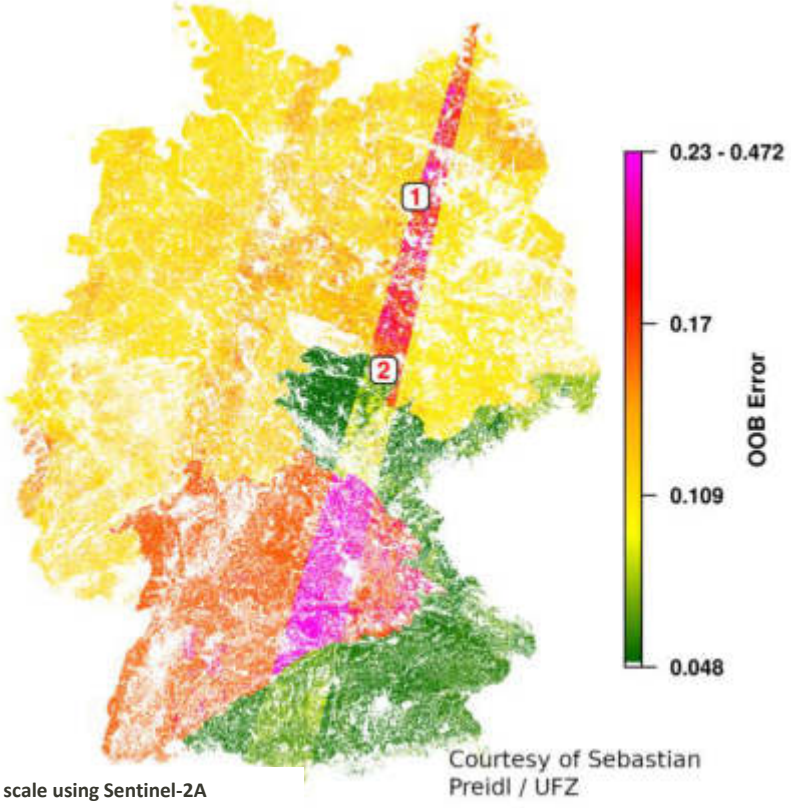
Preidl, S., Lange, M., Doktor, D. (2019). Introducing APiC for regionalised land-cover mapping on the national scale using Sentinel-2A imagery. REMOTE SENSING OF ENVIRONMENT (accepted)

Classification performance

- Pixel-wise prediction error which can be associated with classification
- Clear regional differences based on satellite data and InVeKoS data availability
- Even single clouds in satellite time series are exhibited as increased prediction error



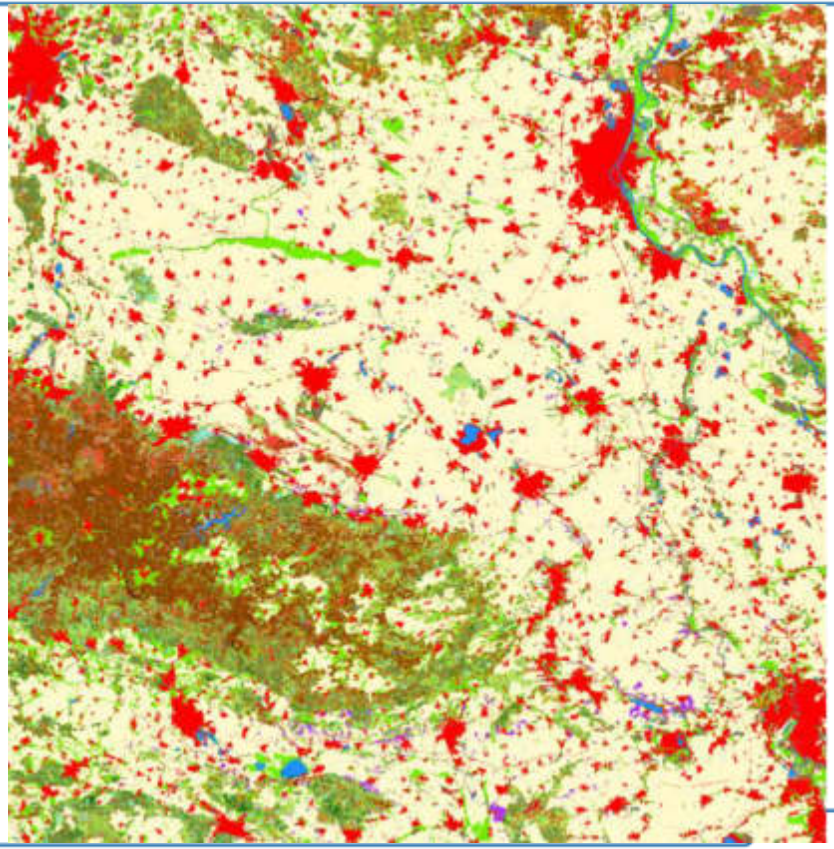




Preidl, S., Lange, M., Doktor, D. (2019). Introducing APiC for regionalised land-cover mapping on the national scale using Sentinel-2A imagery. REMOTE SENSING OF ENVIRONMENT (accepted)

Coming-up: Tree species classification

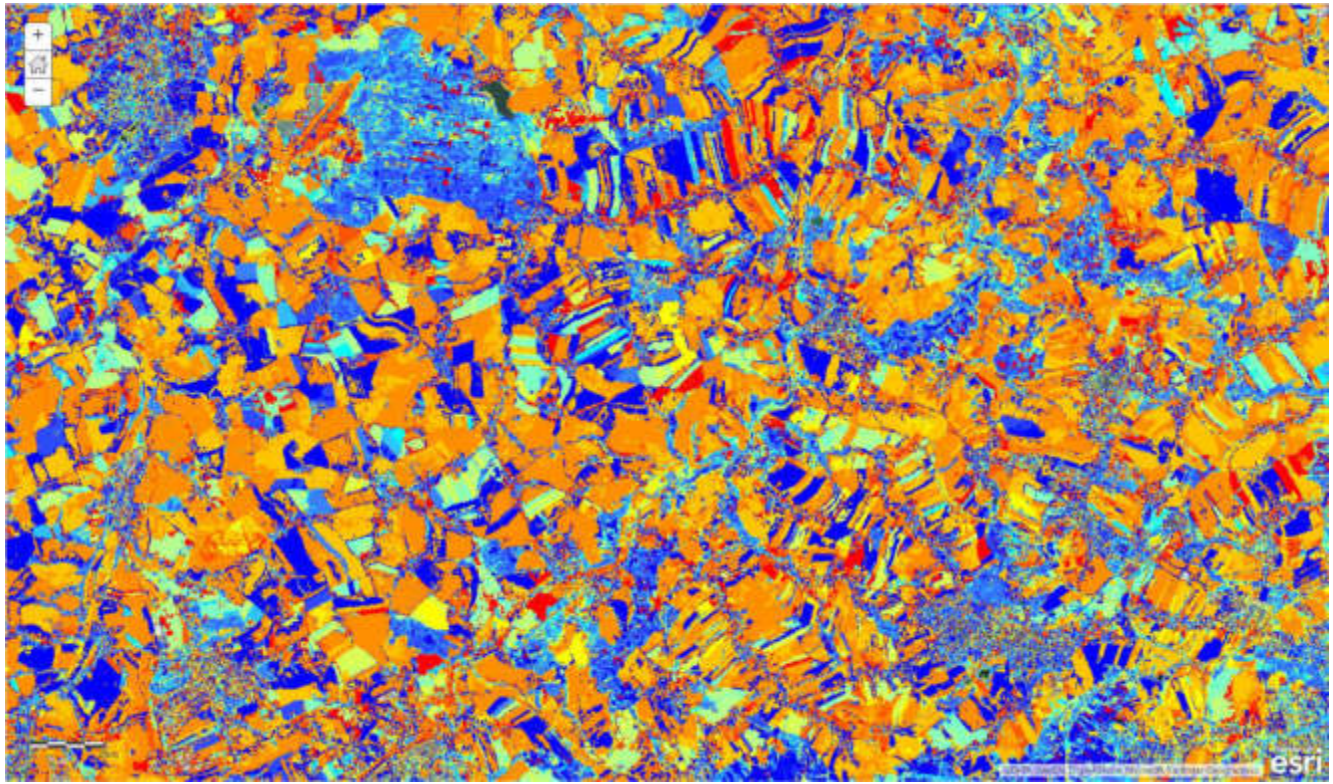
- The methodology presented can be translated to classify tree species: BfN-project “Wakanaka”
- (https://forschung-sachsen-anhalt.de/project/wakanaka-ermittlung-naturschutzbezogener-20953)
- Local forest inventories are used for training / validation
- Robust differentiation of 4 deciduous and 4 conifer tree species



Kyffhäuser, Harz mountains and Elm (South to North)

Ripeness / Senescence, Sachsen, Chemnitz

Year 2018



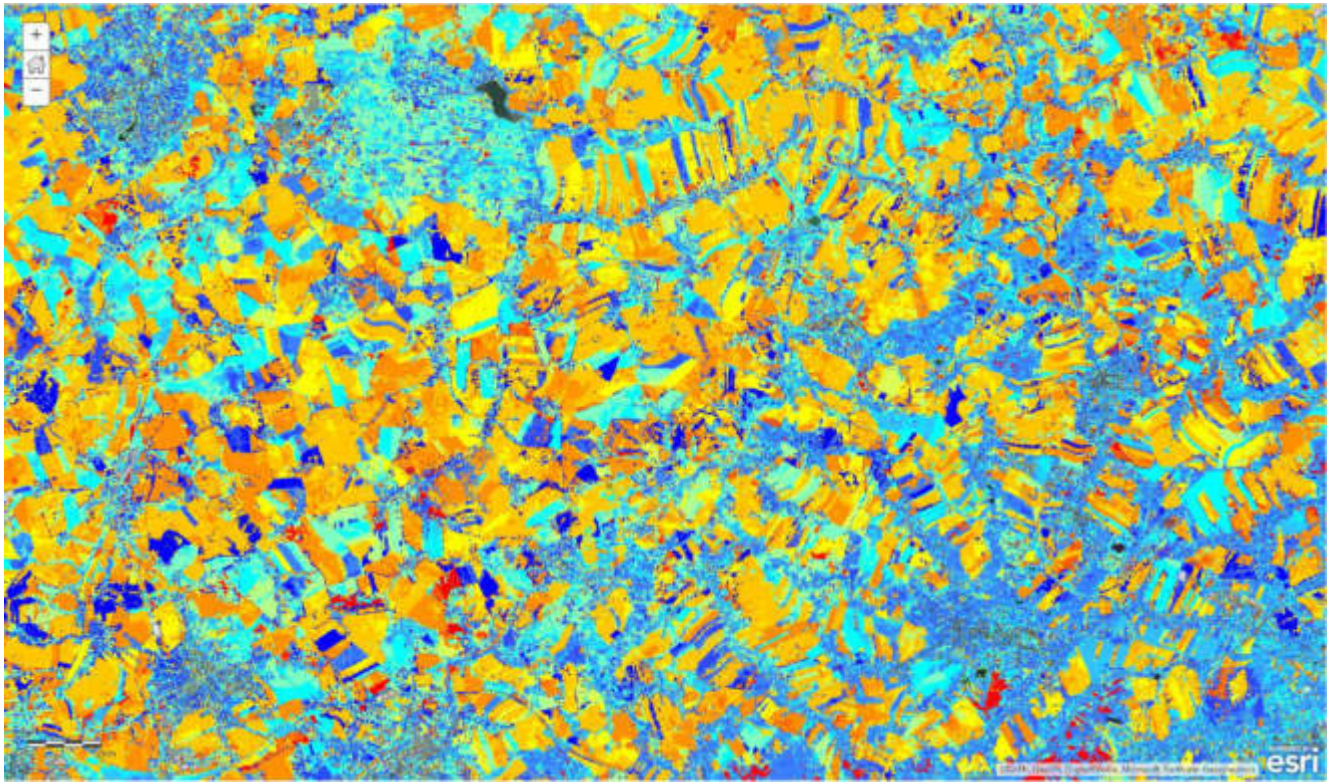
Day of Year

- 18 - 140
- 140.0000001 - 156
- 156.0000001 - 172
- 172.0000001 - 188
- 188.0000001 - 204
- 204.0000001 - 220
- 220.0000001 - 236
- 236.0000001 - 252
- 252.0000001 - 268
- 268.0000001 - 284
- 284.0000001 - 300
- 300.0000001 - 330
- 330.0000001 - 366

Many crops already ripe/senescent in June due to warm temperatures / drought

Ripeness / Senescence, Sachsen, Chemnitz

Year 2017



Day of Year

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- 220.0000001 - 236
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- 252.0000001 - 268
- 268.0000001 - 284
- 284.0000001 - 300
- 300.0000001 - 330
- 330.0000001 - 366

Later ripeness/senescence in 2017 due to average weather patterns

Matching satellite products and ground observations

RMSE (Days)	Year	Green-Up		Heading		Senescence	
Winter wheat	2013, 2015	20.37	(6)	10.48	(17)	13.59	(17)
Winter barley	2013, 2015	6.17	(2)	6.84	(4)	9.53	(4)
Oilseed rape	2013, 2015	5.10	(2)			9.06	(5)
Sugar beet	2013, 2015	14.17	(4)				

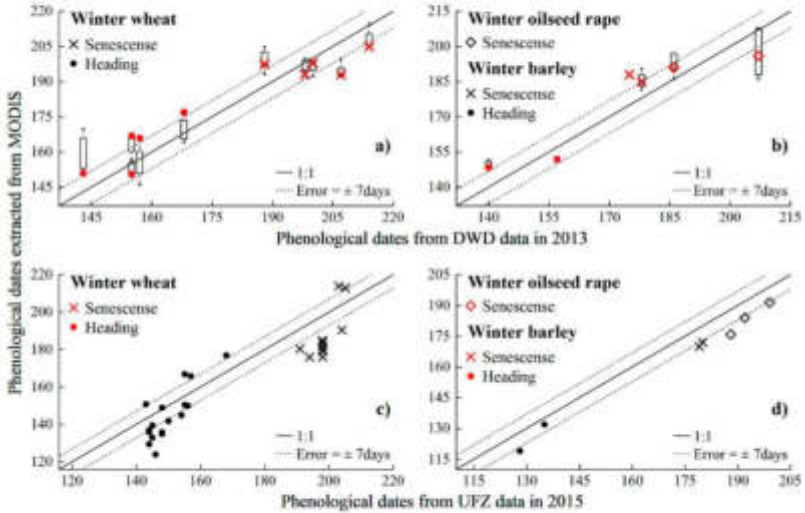

Figure 6. Validated satellite-derived phenological dates for different crops in: (**a**,**b**) 2013 versus DWD data; (**c**,**d**) 2015 versus UFZ data. Red-coloured symbols indicate fields which were closest to DWD stations. Each box represents phenostages of all fields which were within 3 km around one DWD station.

remote sensing

MDPI

Article

Optimising Phenological Metrics Extraction for Different Crop Types in Germany Using the Moderate Resolution Imaging Spectrometer (MODIS)

Xingmei Xu [1,*], Christopher Conrad [2] and Daniel Doktor [1]

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[2] Department of Remote Sensing, Institute of Geography and Geology, University of Würzburg, 97074 Würzburg, Germany; christopher.conrad@uni-wuerzburg.de
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Academic Editors: Jose Moreno and Prasad S. Thenkabail
Received: 2 January 2017; Accepted: 6 March 2017; Published: 9 March 2017

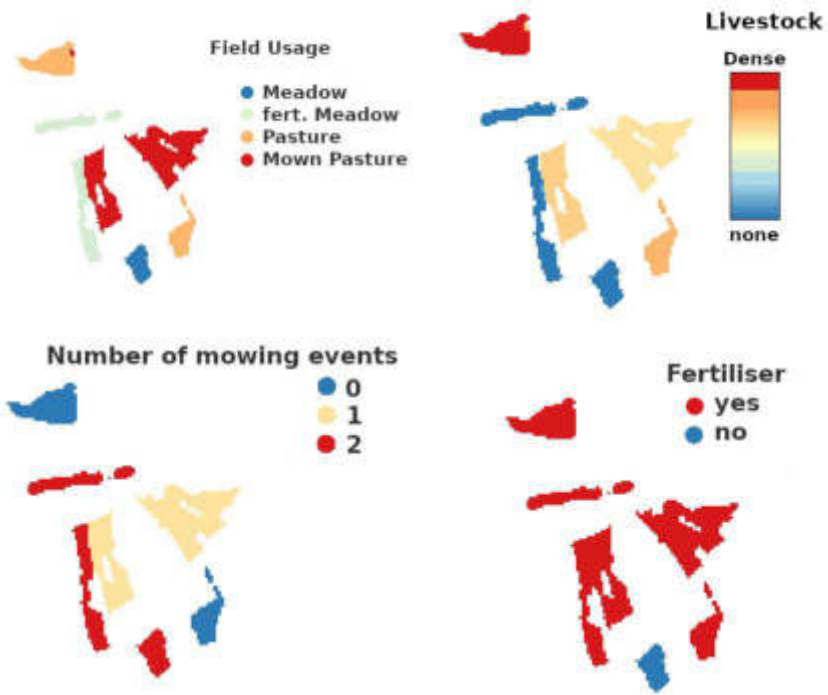
Good match between satellite derived phenology and ground obsverations despite sparse ground network and high intra-field variability

Land-use intensity of grasslands

Intensity measures

- Mowing frequency
- Livestock density
- Fertiliser amount

Data
Overview



- 7 pastures/meadows in central Germany
- Data includes:
  - Mowing dates
  - Fertilisation type, amount and dates
  - Livestock number

Methodology
Land-use intensity metrics (from EVI evolution)

Mowing

- Number of rapid decrease events
- First decrease event related to number of mowing events?

Fertilisation

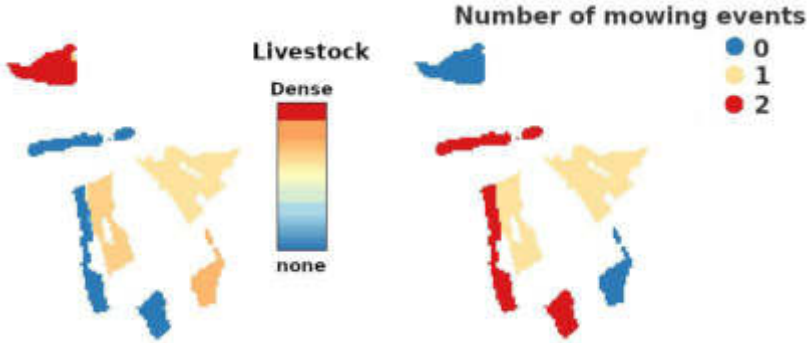
- Number of rapid increase events
- Statistical values: mean, trend

Livestock
(Grazing and droppings)

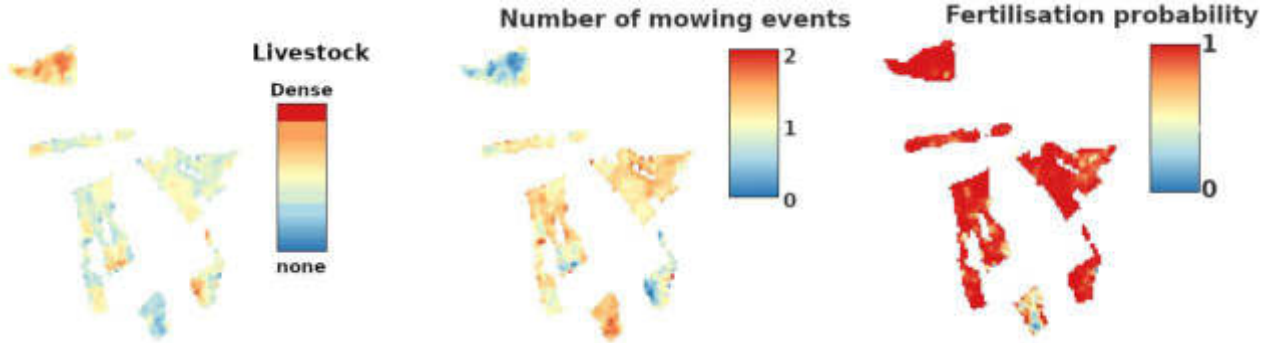
- Statistical values: variance, mean, trend
- Number of decrease/increase events
- Sum of index increase or decrease

First results
(GLM) Modelling of land-use intensity

Data



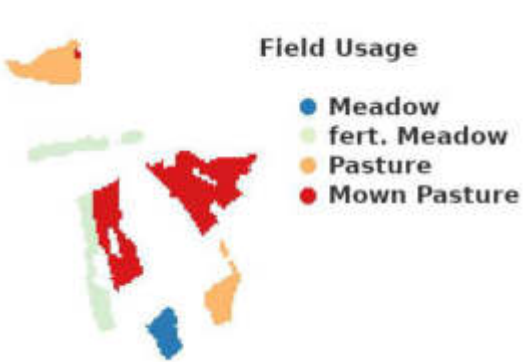
Model

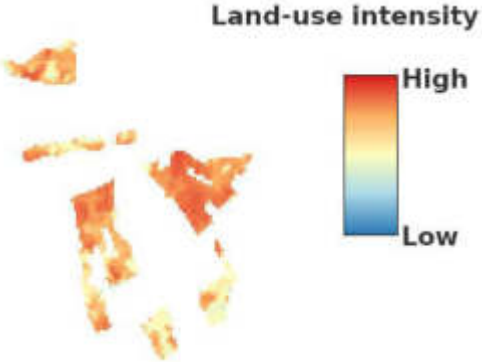


Metrics

- [x] Date of first decrease event
- [x] Number of decrease events
- [x] Variance (NDVI)
- [x] Sum of index increase
- [x] Index mean (EVI)
- [x] Index intra-year trend (EVI)
- [ ] ...

First results
Modelling of land-use intensity





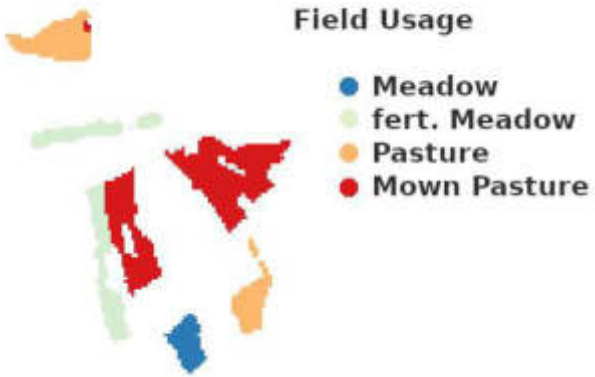
Non-linear interactions (between mowing frequency and livestock density) hamper prediction.

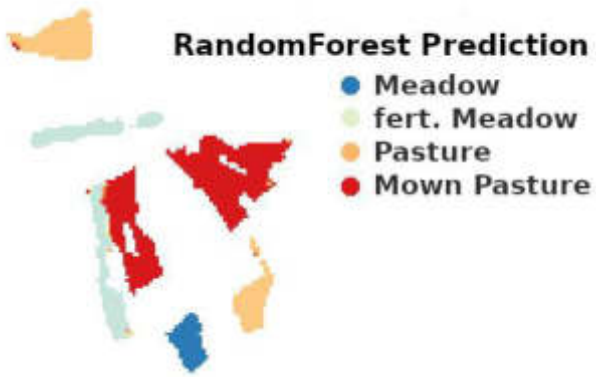
Image Source: Google Earth (2019/04)

Methodology
Supervised classification

- Training / Validation
  20% / 80%

Supervised machine learning methods facilitate almost perfect prediction.





Supervised classification
“Extrapolation“

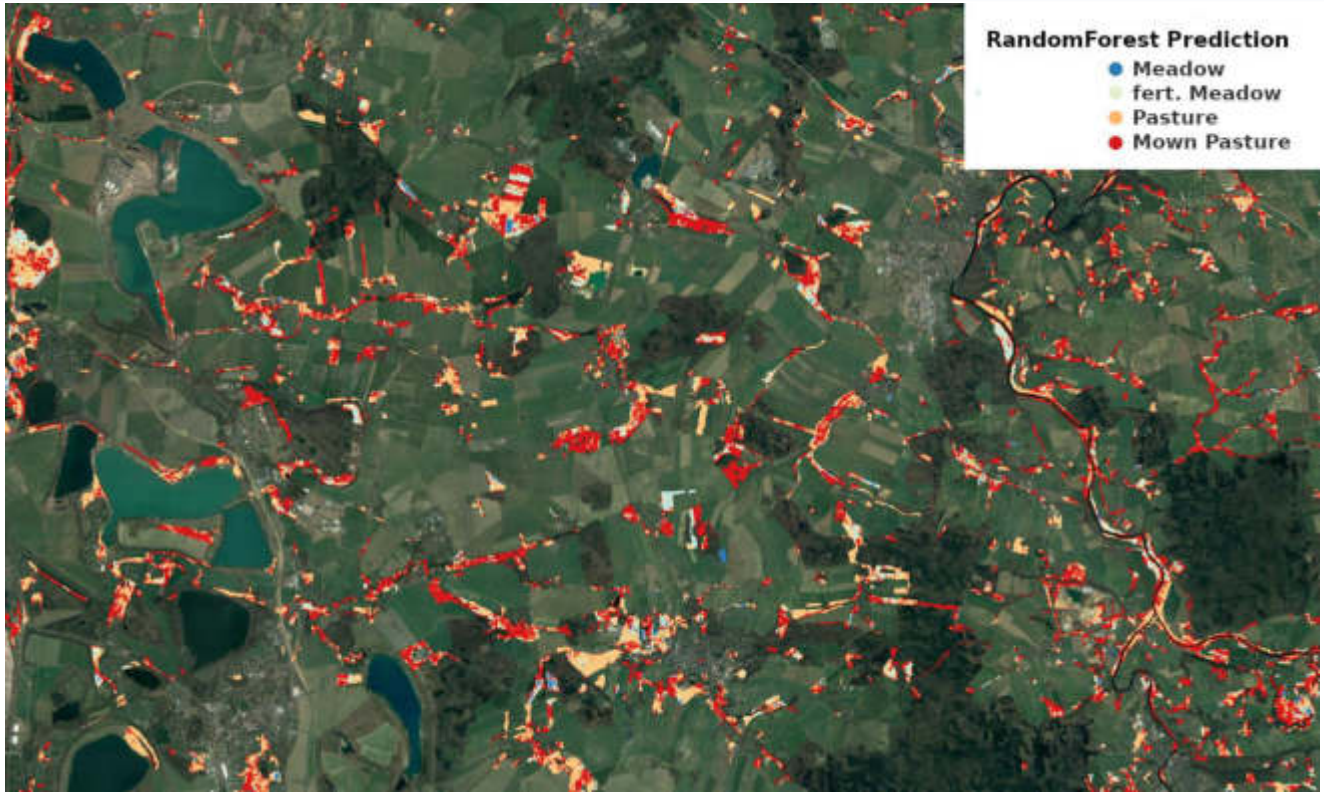
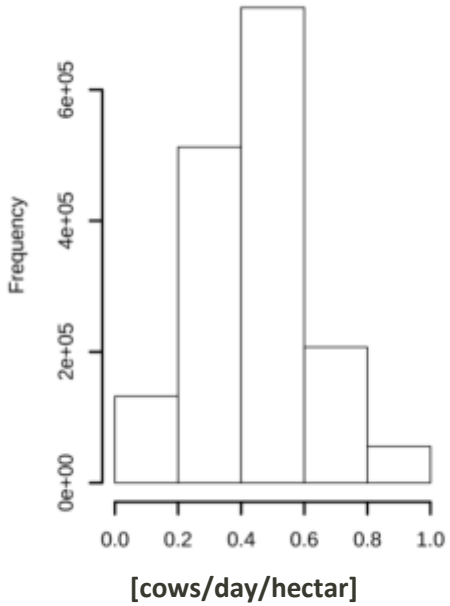


Image Source: Google Earth (2019/04)

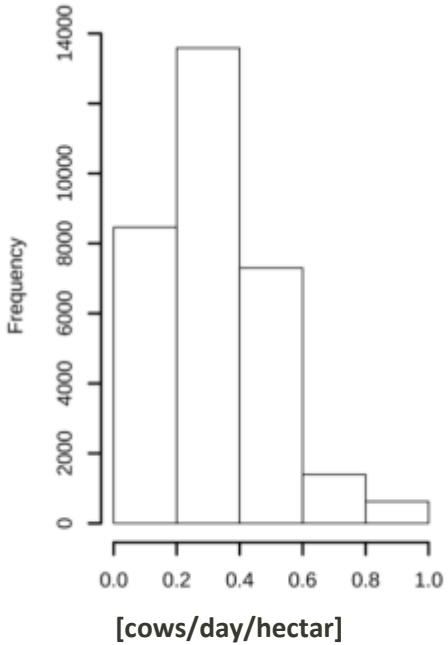
Extrapolation possible, but too few validation data yet available for robust evaluation of method.

Extrapolation: Method comparison
Livestock density comparison

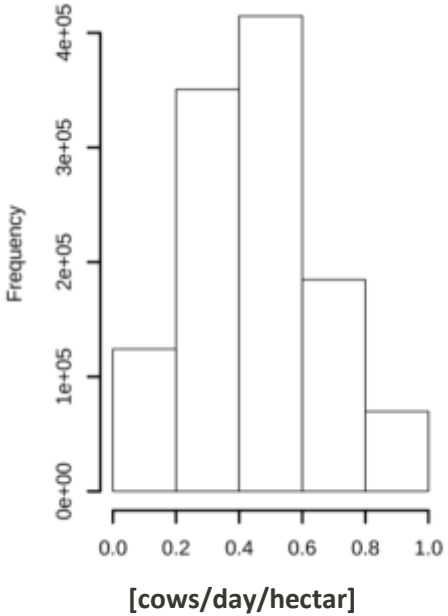
Allgäu



Leipzig



Nordfriesland



Extrapolation: Method comparison
Grassland at Wadden sea

Image Source: Google Earth (2019/08)

Metric: Number of NDVI decreases

Modelled livestock density

Land-use intensity classification