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Mapping land-use intensity of grasslands in Germany with machine learning and Sentinel-2 time series

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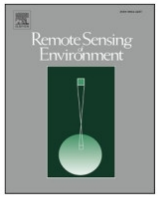
D.1 - Fernerkundung im Naturschutz

Background
Related Publication

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse



Mapping land-use intensity of grasslands in Germany with machine learning and Sentinel-2 time series

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Background

Importance of estimating grassland management and land-use intensity

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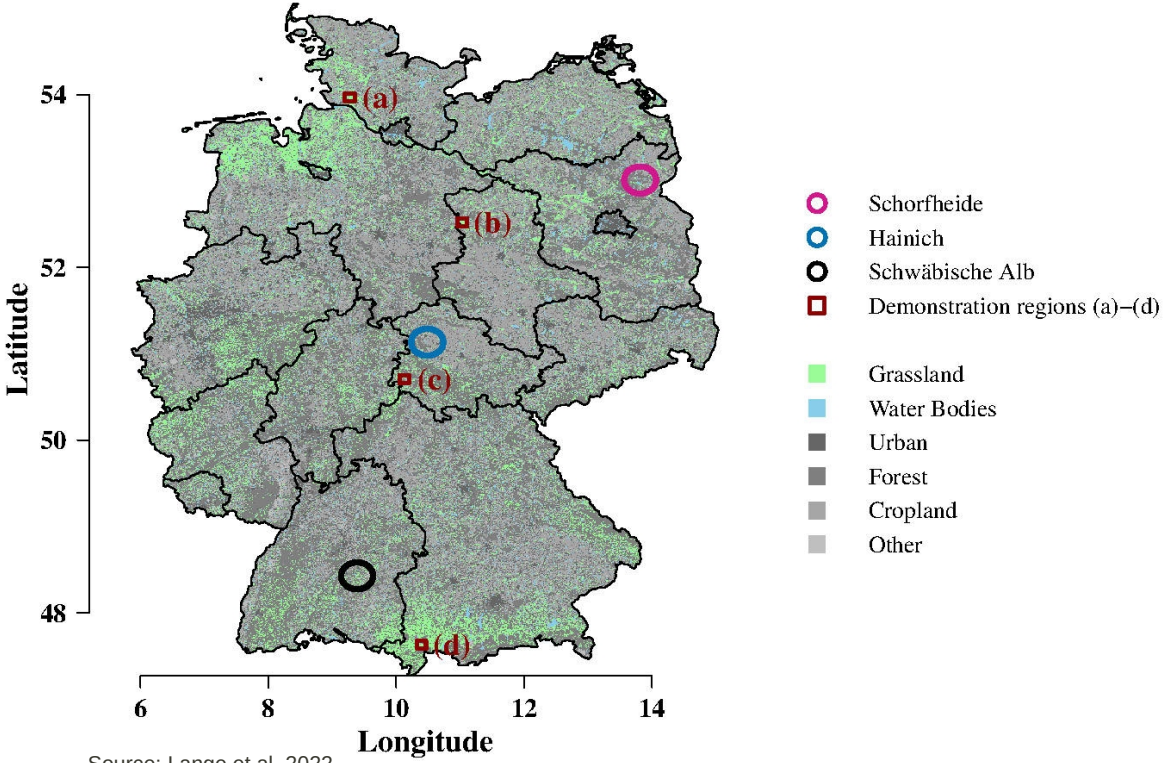
Data
Study Area

- Grasslands in Germany
- Three calibration/validation areas (DFG Biodiversity Exploratories) Data from **2017** & **2018**
- Four regions for feasibility demonstration



Source: Lange et al. 2022

Data
Land-management information from DFG Biodiversity Exploratories

- **Livestock**
  - Livestock units (based on species and age) per grazing period per plot
- **Mowing** frequency
  - 0-5 dates per year
- **Fertilisation**
  - Amount and type
  - Dates
  - Excl. dung deposition from livestock

Source: Westdeutsche Zeitung 2018, www.wz.de; BauernZeitung.at 2016 von agrarfoto.com

Data
Satellite observations: Copernicus Sentinel-2

- **Multispectral satellite data**
- 20 m x 20 m spatial resolution
- 3-5 days temporal resolution
- 9 spectral bands in
  VIS, VNIR and SWIR

- 2017 and 2018
- Germany-wide
- 146.4 million grassland pixels
  (according to **ATKIS DLM**; Bundesamt für Kartographie und Geodäsie, 2015)

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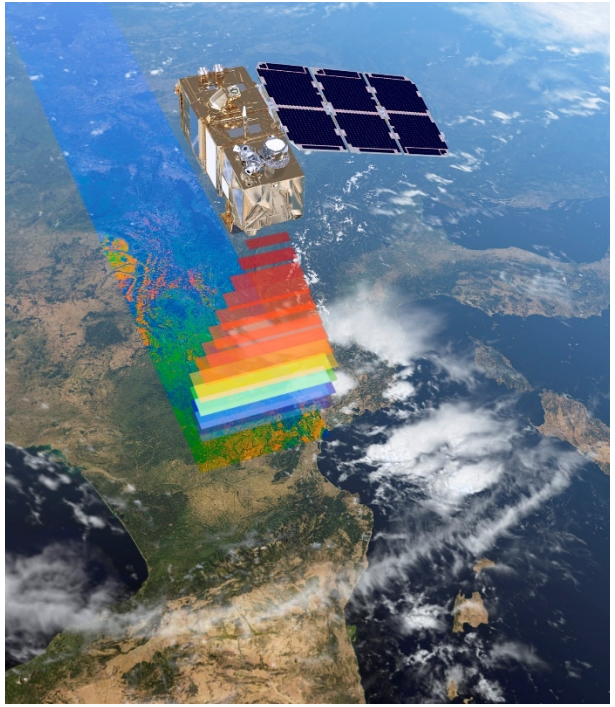

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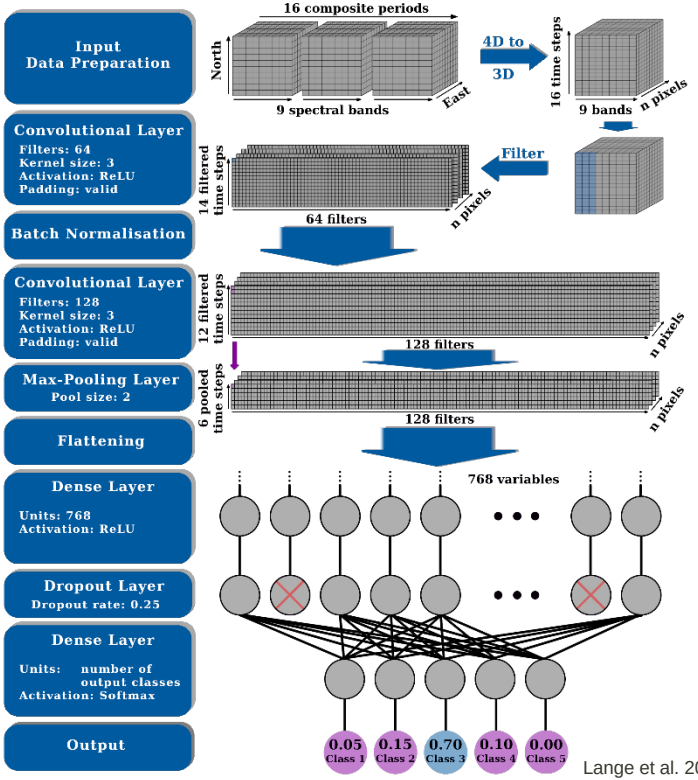
Methods

Convolutional Neural Networks (CNN) + Land-use intensity index

- Predictors: S-2 composite time series
- Targets: **Grazing** intensity, **Mowing** number, **Fertilisation**
- LUI index proposed by *Blüthgen et. al, 2012**
- G, M and F from machine learning predictions in Biodiversity Exploratories

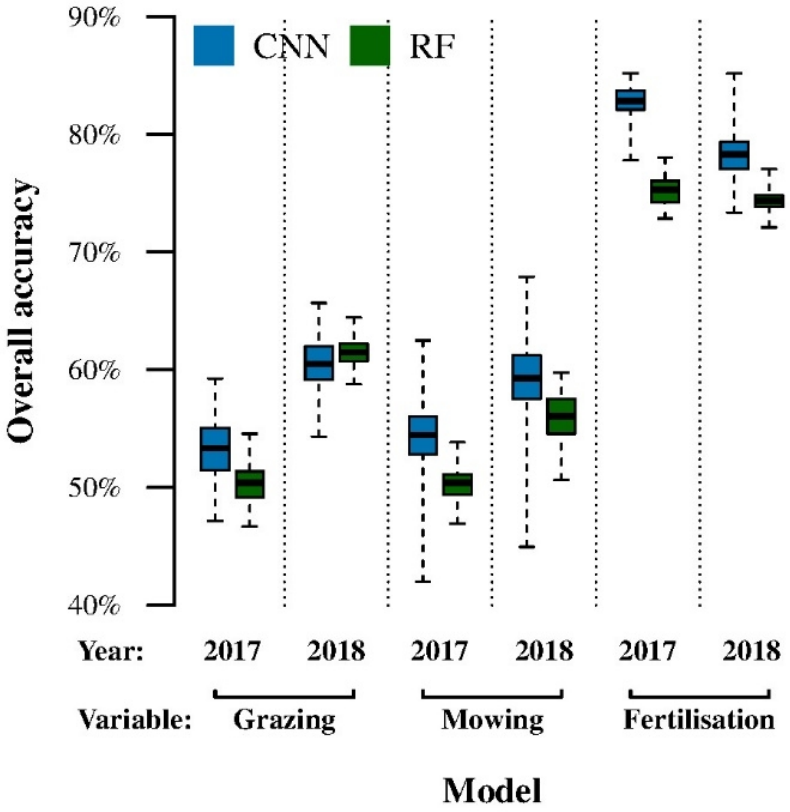
$$LUI_{region} = \frac{G}{\overline{G}_{region}} + \frac{M}{\overline{M}_{region}} + \frac{F}{\overline{F}_{region}}$$



Lange et al. 2022

* Blüthgen, N., Dormann, et. al (2012). A quantitative index of land-use intensity in grasslands: Integrating mowing, grazing and fertilization. *Basic and Applied Ecology* 13, 207–2020. doi:**10.1016/j.baae.2012.04.001**.

Methods
Validation & Substantiation



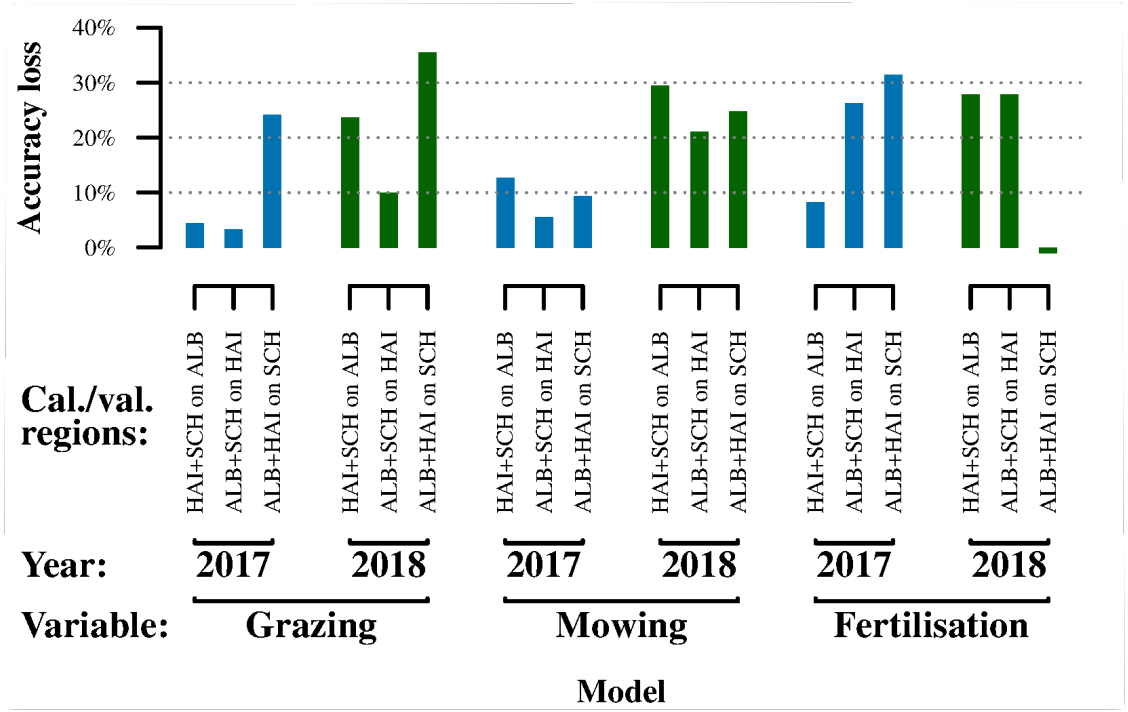
Lange et al. 2022

OA translate into R^2 ground vs satellite around 0.7

Some years and regions (Schorfheide) with lower accuracy

Methods
Validation & Substantiation

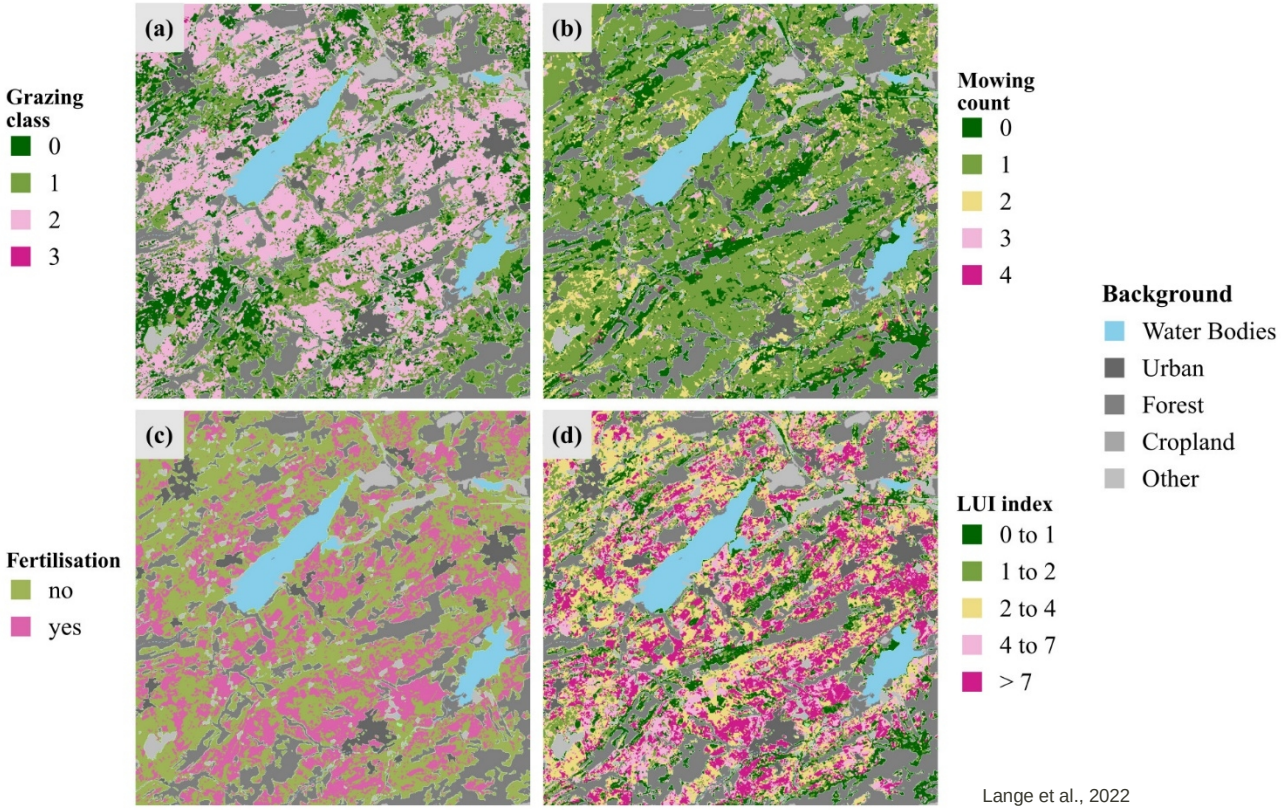
- 3-fold cross-validation
  - Models are sensitive to training data
  - More calibration/validation areas needed to improve model robustness!
- Delineation of the model‘s **area of applicability** (AOA) *



Lange et al. 2022

* Meyer, H., Pebesma, E., 2021. Predicting into unknown space? Estimating the area of applicability of spatial prediction models. *Methods in Ecology and Evolution*. doi:**10.1111/2041-210X.13650**.

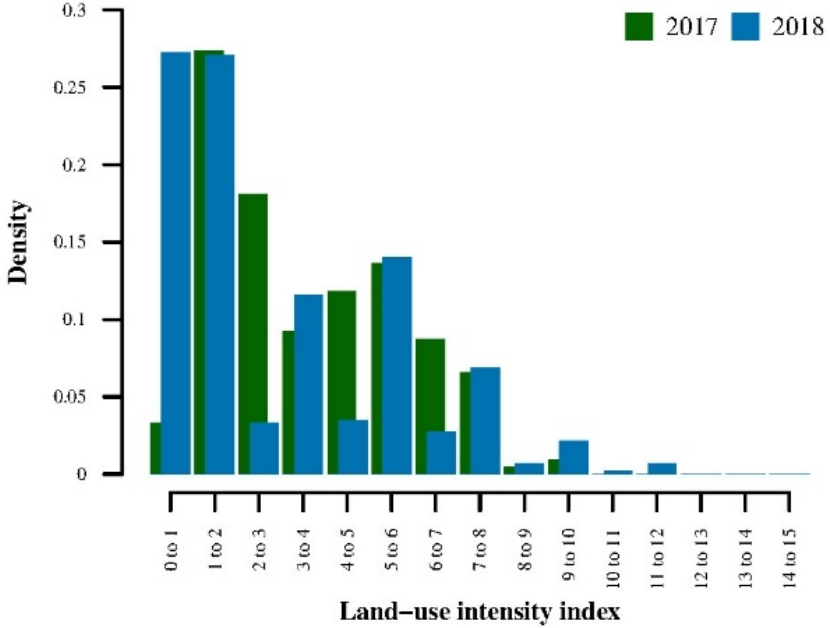
Results
Land management & Land-use intensity maps

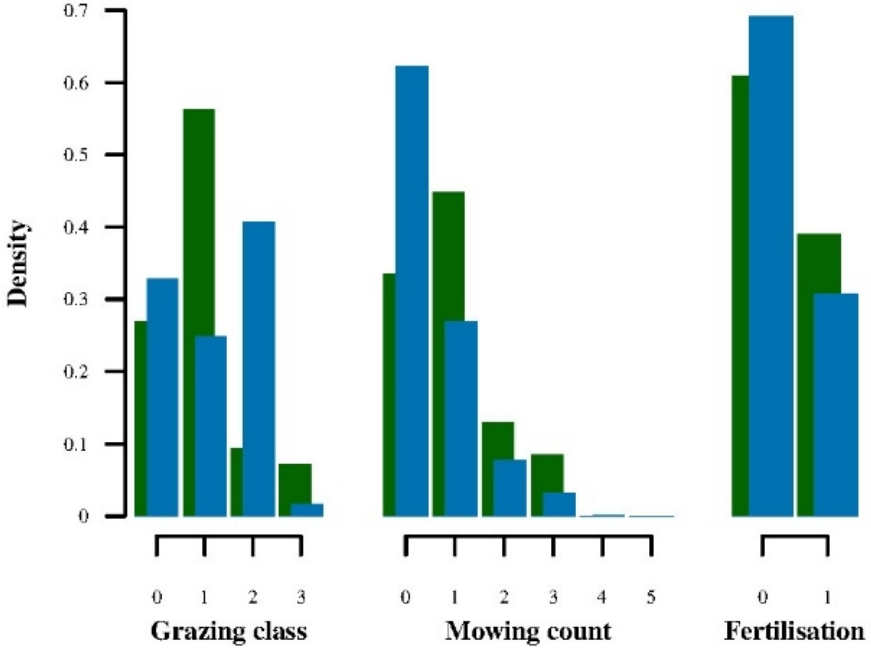


Lange et al., 2022

- **Oberallgäu 2018**
- Intensive grazing
- Low to moderate number of mowing events (potential underestimation)
- Divers fertilisation patterns
- Moderate to high LUI

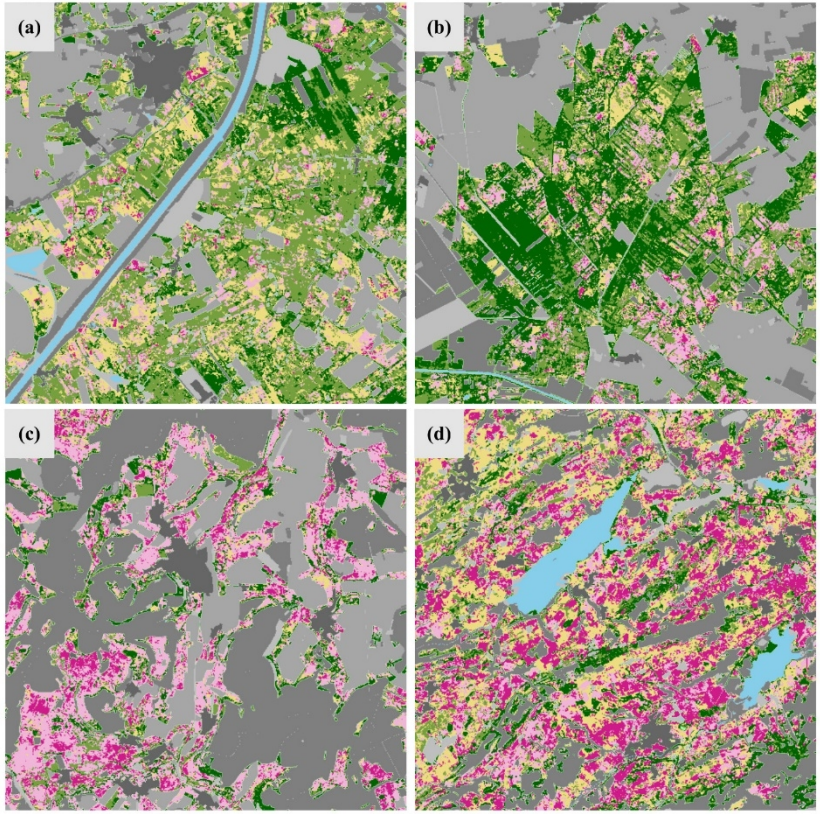
Results
Germany-wide land-management histograms





Lange et al., 2022

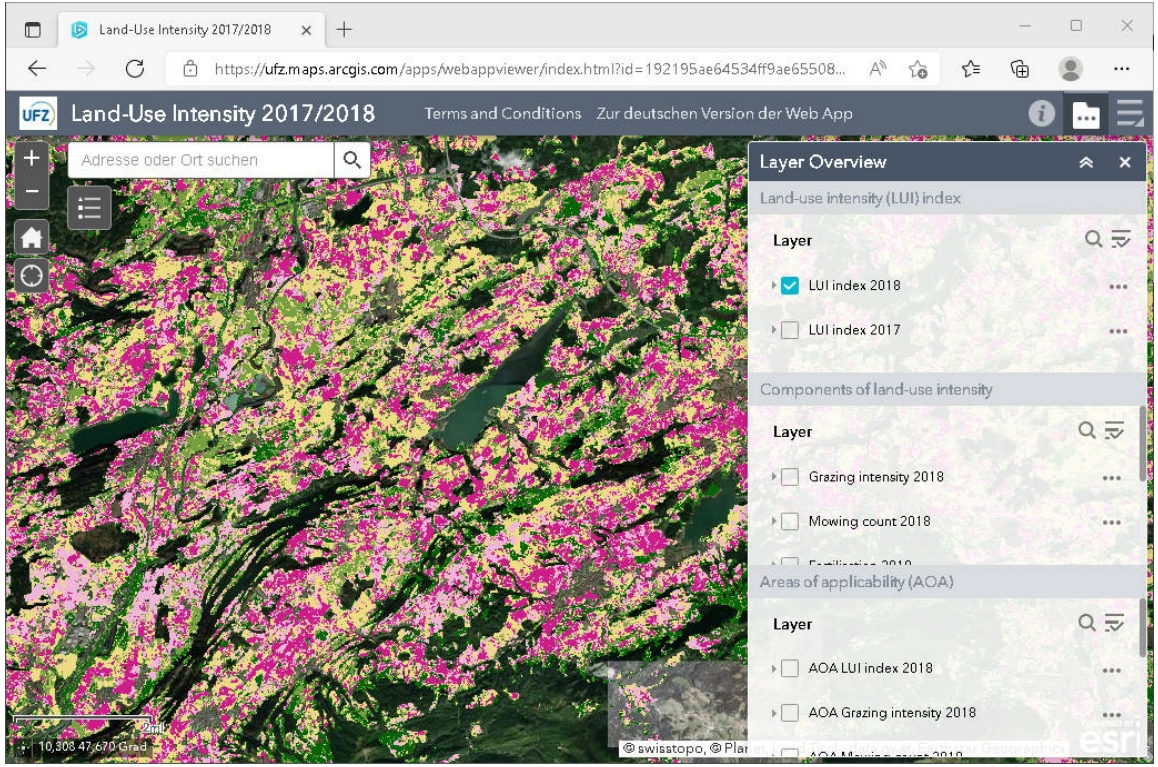
Results
Land-use intensity maps



Lange et al., 2022

- **(a) Dithmarschen, (b) Ohre-Drömling, (c) Rhön & (d) Oberallgäu, 2018**
- Varying intensity
- Patterns seem to represent fields / parcels with respective management
- Extensive: (b) Ohre-Drömling
- Moderate: (c) Dithmarschen (intensively grazed, less mowing & fertilisation)
- Intensive: (c) and (d)

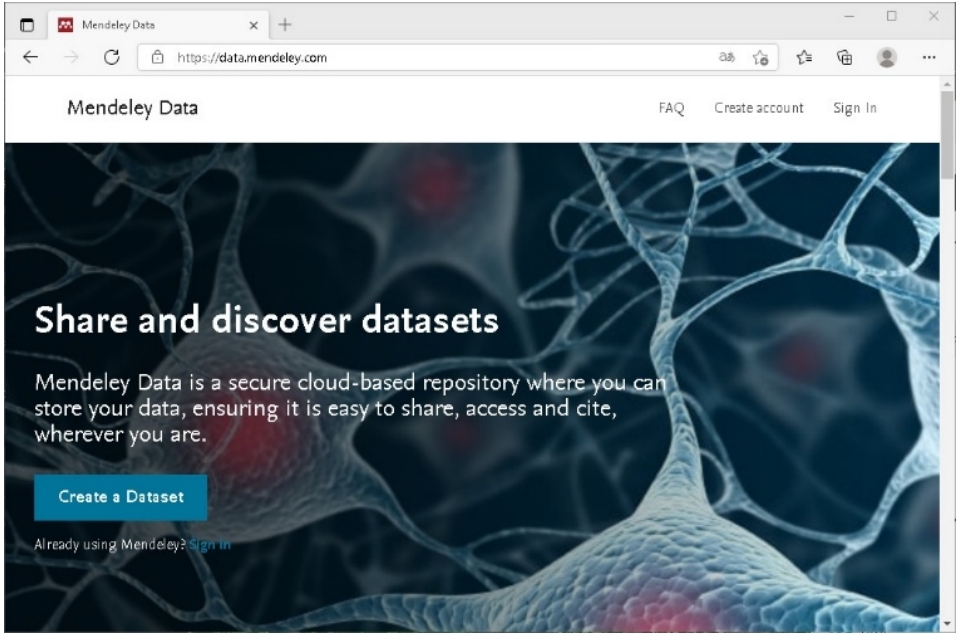
Web-Service
https://www.ufz.de/land-use-intensity



- **Web-Service including all Germany-wide products from 2017 and 2018**
- Grazing intensity
- Mowing frequency
- Fertilisation
- Land-use intensity
- Area of applicability

Data product publication
Mendeley Data

Publication of datasets in Mendeley Data:
https://doi.org/10.17632/m9rrv26dvf.1



Discussion
Questions & Answers

Web-Service: https://www.ufz.de/land-use-intensity
Data publication: https://doi.org/10.17632/m9rrv26dvf.1
Publication: https://doi.org/10.1016/j.rse.2022.112888

- Datasets
  - Land management data
  - Sentinel-2 time series
- Data preparation
  - Sampling
  - Compositing
- Machine Learning & Validation
- Mapping
- Area of Applicability

Thank you!

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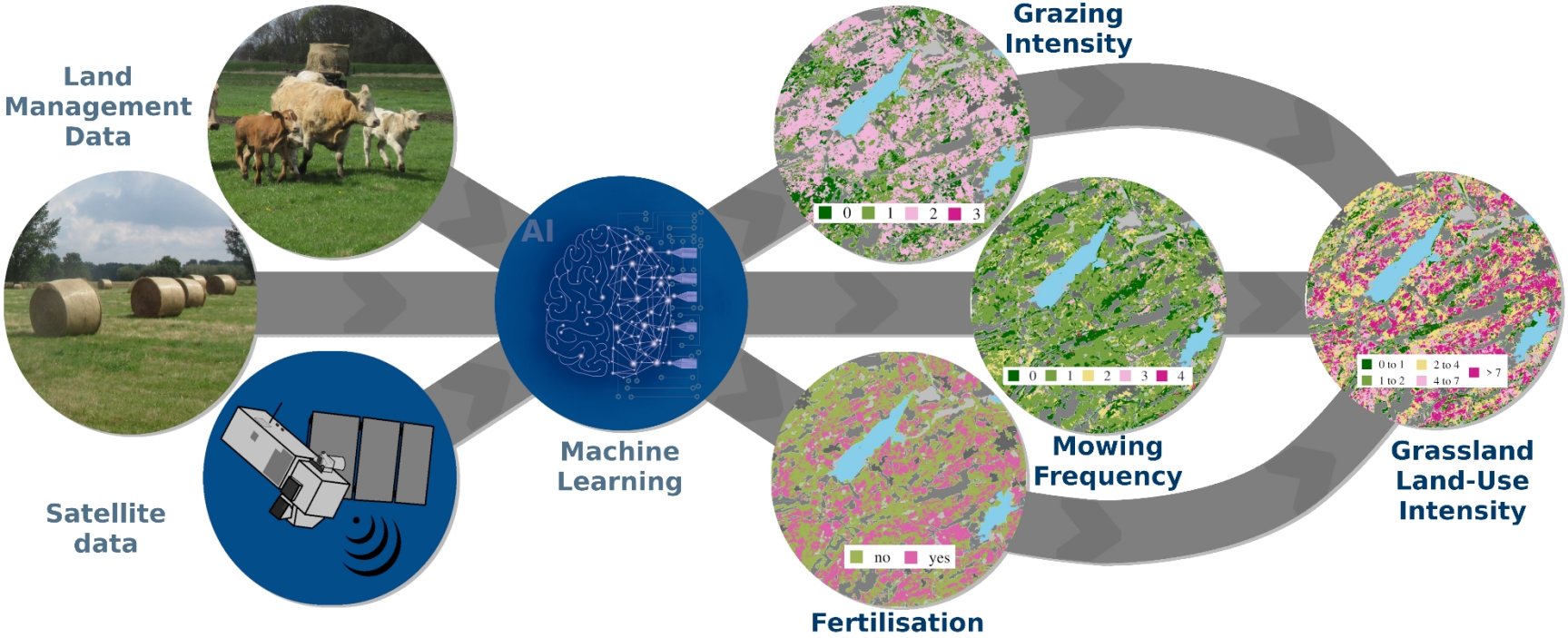
Supplementary Slides
Summary



Lange et al. 2022: Graphical Abstract

Data
Land-management data classification

- **Grazing intensity**
  - Livestock units per area per day
  - Four classes

G	G_I
0	0
1	$0 < G_I \leqq 0.33$
2	$0.33 < G_I \leqq 0.88$
3	$G_I > 0.88$

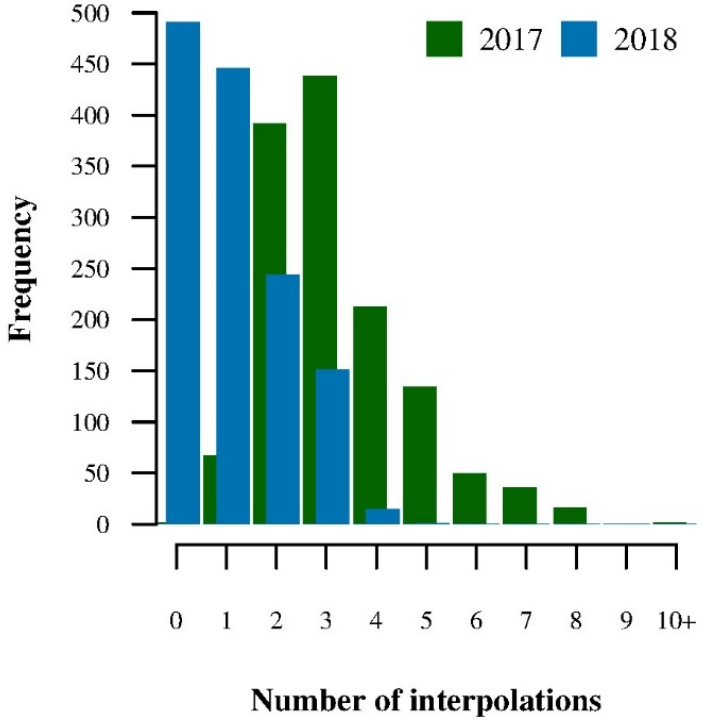
- **Mowing** number per year
  - Six classes (0-5x mowing)
- **Fertilisation: yes / no**
  - Two classes

Source: Westdeutsche Zeitung 2018, www.wz.de; BauernZeitung.at 2016 von agrarfoto.com

Data
Satellite data preprocessing

- Time series harmonisation
- 16 composite periods
- Interpolation of missing values

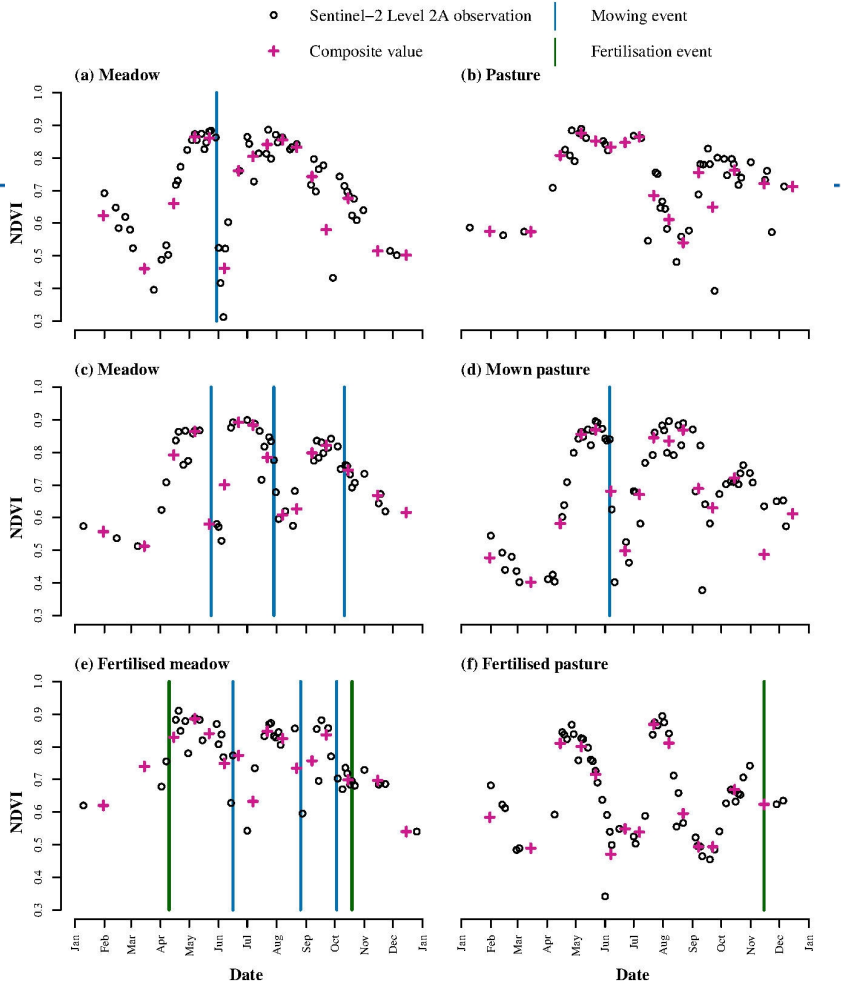
Period	Name	Satellite scenes
1	Jan/Feb	all of January and February
2	Mar	all of March
3	Apr	all of April
4,6,8,10,12	$Month_1$	first half of months May to September, respectively
5,7,9,11,13	$Month_2$	second half of months May to September, respectively
14	Oct	all of October
15	Nov	all of November
16	Dec	all of December



Lange et al. 2022

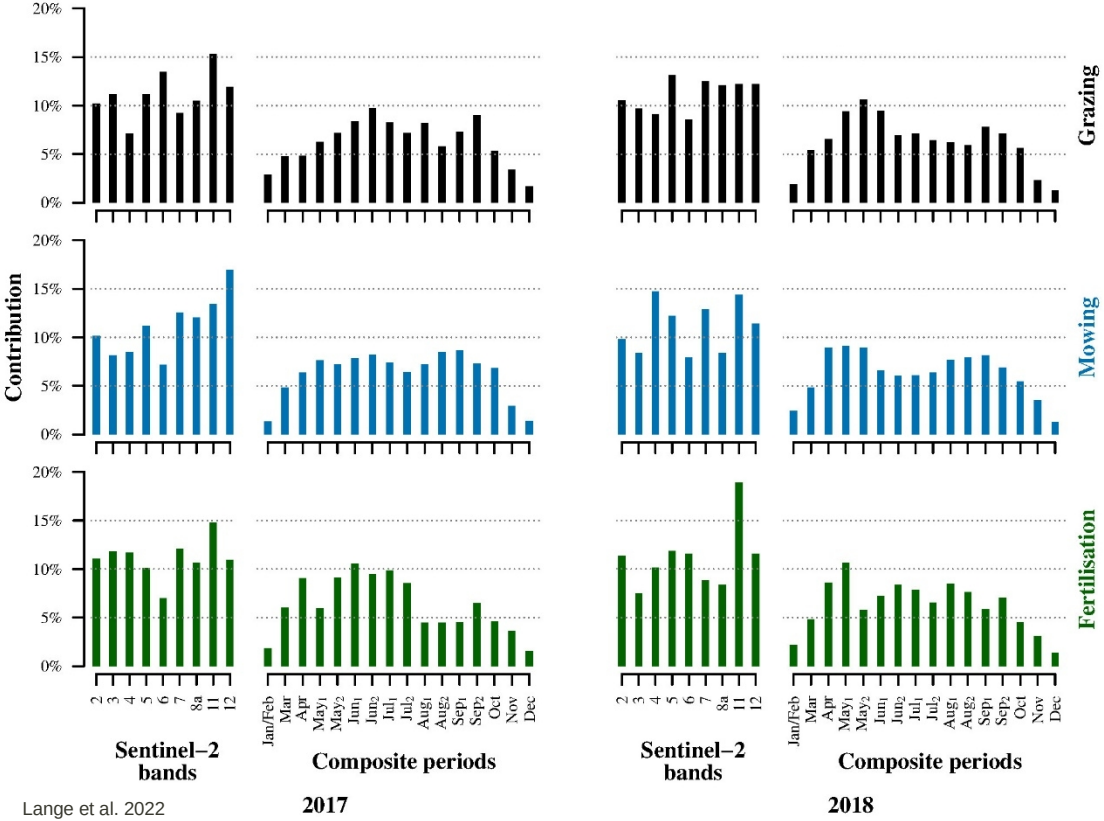
Supplementary Slides
VI time series vs land management

- **NDVI (Normalised Difference Vegetation Index)**
  - **represents vegetation „greenness“**
- **Land management has distinctive effects on vegetation, e.g.:**
  - **Mowing: rapid VI decrease**
  - **Fertilisation: rapid VI increase**
  - **Grazing: high variability**
- **Note: Pastures are grazed, meadows not.**



Lange et al. 2022

Supplementary Slides
Feature importances of CNN models

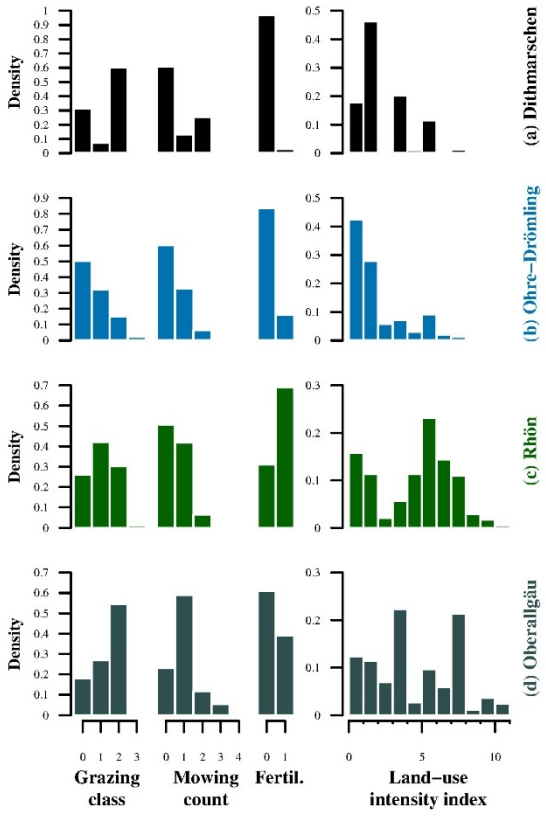


Lange et al. 2022

- Shapley Additive Explanations (SHAP) proposed by *Lundberg and Lee, 2017**
- High importance of **SWIR** and **VNIR** bands
- High importance of **spring** and **fall** satellite imagery
- Differences between 2017 and 2018
- Differences between target variables

* Lundberg, S.M., Lee, S., 2017. A Unified Approach to Interpreting Model Predictions, in: Guyon, I., Luxburg, U.V., Bengio, S., Wallach, H., Fergus, R., Vishwanathan, S., Garnett, R. (Eds.), *Advances in Neural Information Processing Systems* 30. Curran Associates, Inc. volume 30, pp. 4765–4774. URL:http://papers.nips.cc/paper/7062-a-unified-approach-to-interpreting-model-predictions.pdf

Results
Regional land-management histograms

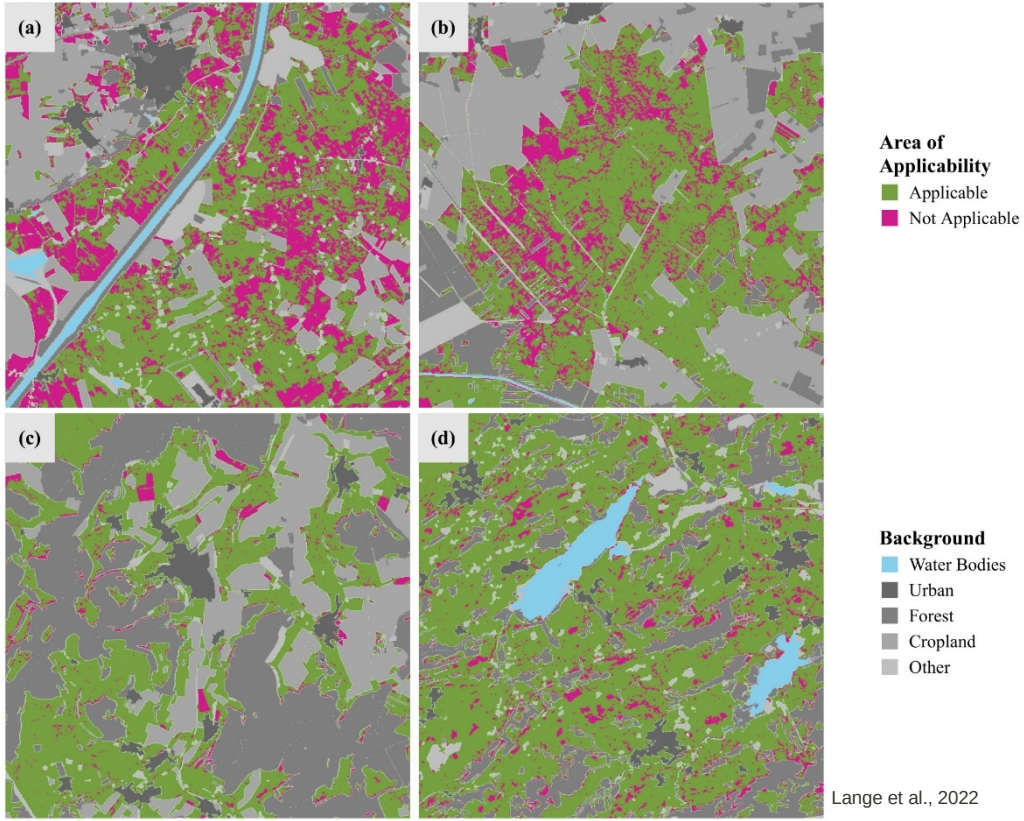


Lange et al., 2022

- **(a) Dithmarschen, (b) Ohre-Drömling, (c) Rhön & (d) Oberallgäu, 2018**

- Varying usage patterns
- (a) intensive grazing, extensive mowing & fertilisation
- (b) extensive use
- (c) high share of fertilised plots, moderate to high grazing, moderate mowing
- (d) intensive grazing, low to moderate mowing frequency, moderate share of fertilisation

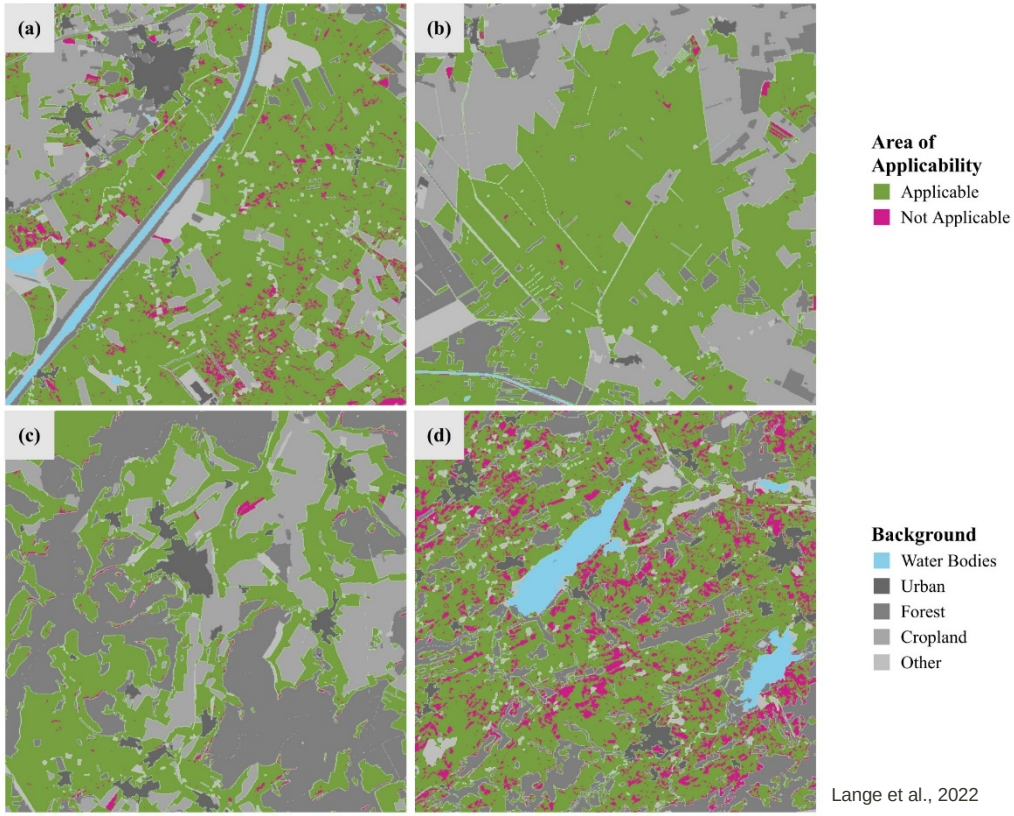
Supplementary Slides
Area of applicability 2017



Lange et al., 2022

- **(a) Dithmarschen, (b) Ohre-Drömling, (c) Rhön & (d) Oberallgäu, 2017**
- High number of pixels outside AOA (29%)
- Potentially related to Sentinel-2 data availability

Supplementary Slides
Area of applicability 2018



Lange et al., 2022

- **(a) Dithmarschen, (b) Ohre-Drömling, (c) Rhön & (d) Oberallgäu, 2018**
- 7% of all pixels outside AOA
- Pixels outside AOA clustered, potentially related to fields/parcels with respective management
- Northwestern Germany and Alpine Foothills exhibit most pixels outside AOA
- More training data needed, especially from this regions!