Space-borne green roof monitoring for supporting climate resilient settlement planning

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Umwelt Bundesamt

Setting the scene

German climate change adaptation strategy (DAS)

- Climate change monitoring at national level
  - Indicator-based framework
  - Anchored in climate adaptation act (since 2024)
  - Regular reporting

Purpose of DAS-Monitoring

- Providing broad overview on climate change impacts and adaptation at national level
- Informing general public and policy makers

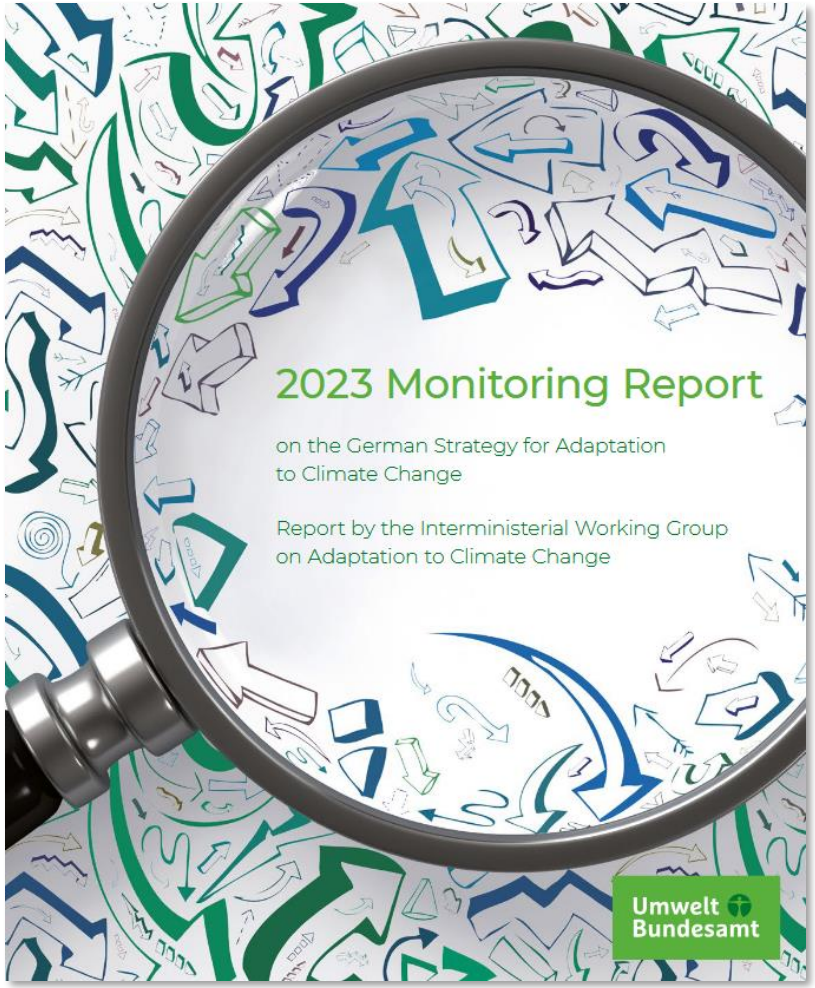


Fig.: Cover of 2023 DAS-Monitoring Report, UBA 2023

Importance of green roofs

Why focusing on green roofs?

- Pressing topic of urban heat islands
- ‘Sponge city’ concept:
  - Blue-green infrastructure to improve urban climate change resilience
- Key intervention: greening rooftops
  - Has been shown to reduce surface and air temperature
  - Multi-functional urban ecosystems

Fig.: Climate resilient sponge city, UBA 2023

Response indicator: green roof area

Aim

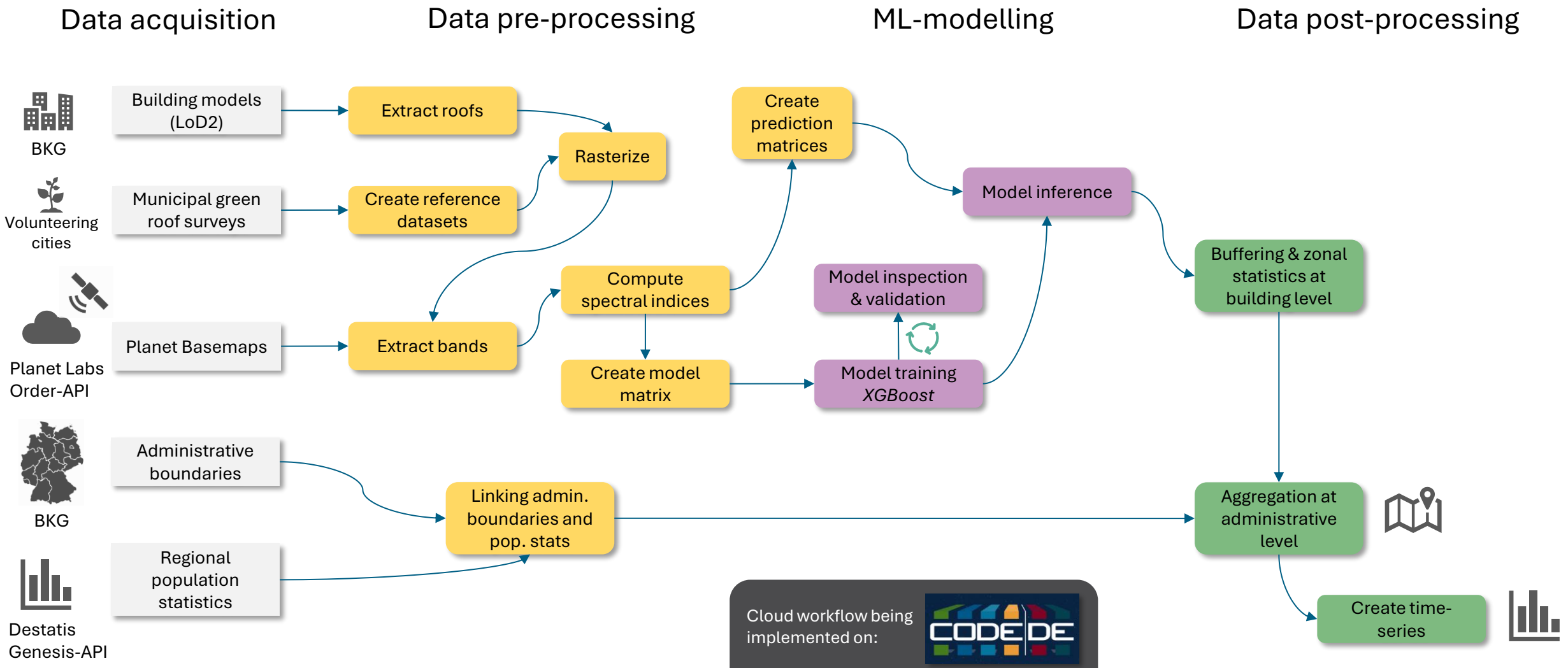
- Ability to answer questions, such as:
  - How much greened roof area is out there?
  - How is it changing over time?

- Objective: further develop & operationalize EO-based indicator to monitor green roof area at national level
  - Precursor project: DASIF
  - Approach: automated EO & ML-based green roof detection

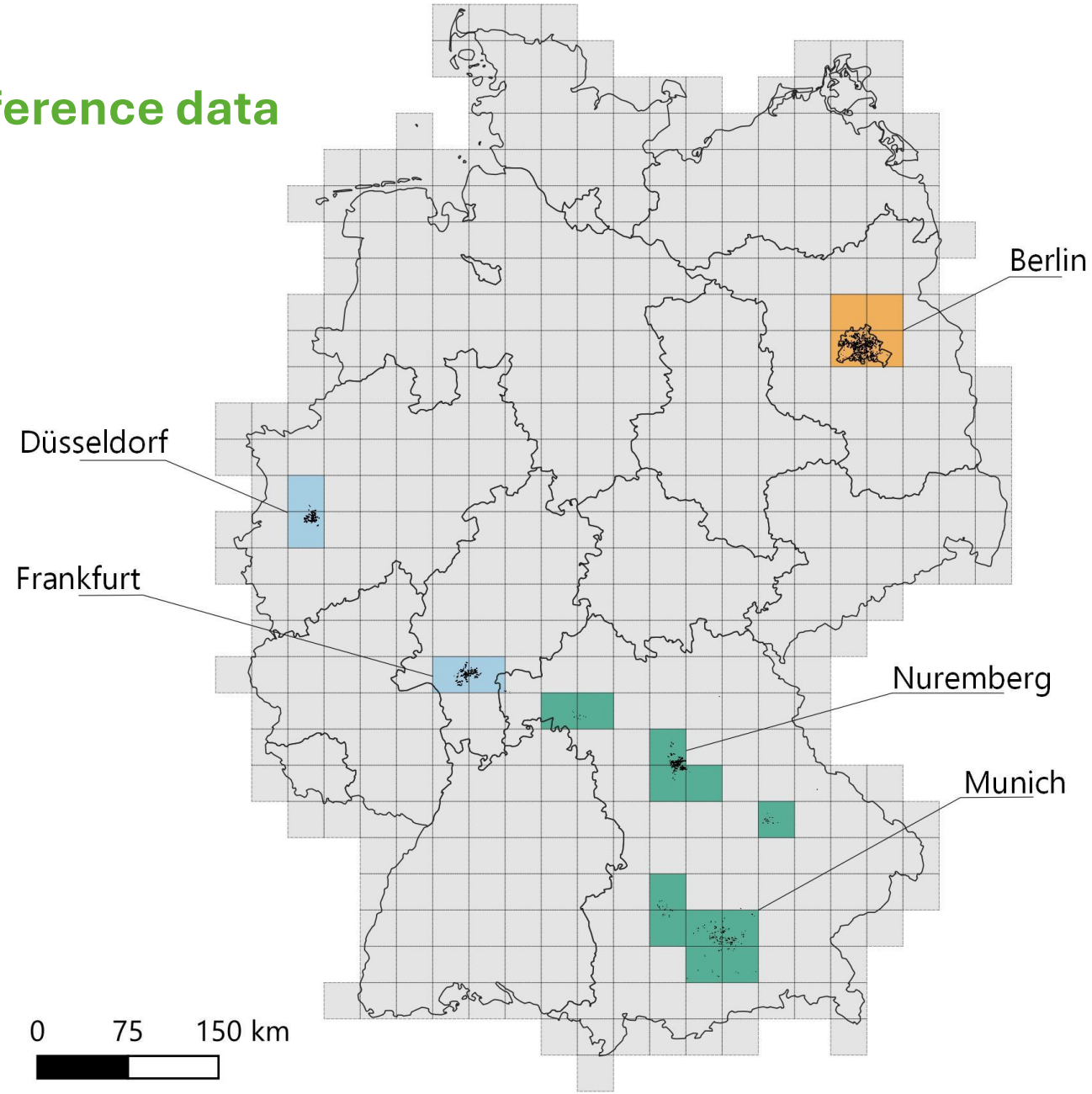
***Today**: presenting ongoing work, focusing on concept and data*

Fig.: Green rooftops © Heiner / stock.adobe.com

Cloud workflow



Reference data



- Reference data generated by capitalizing on municipal green roof mapping campaigns

Tab.: *Overview of reference data*

Year	Non-green roof area (ha)	Green roof area (ha)
2021	484	61
2022	165	24
2023	320	57
Total	**969**	**142**

Roof data

Level of Detail 2 (LoD2) building model data

- Extraction of roof geometries, building & roofs types, and heights
- In total 89 k .xml files, approx. 55 M buildings for Germany

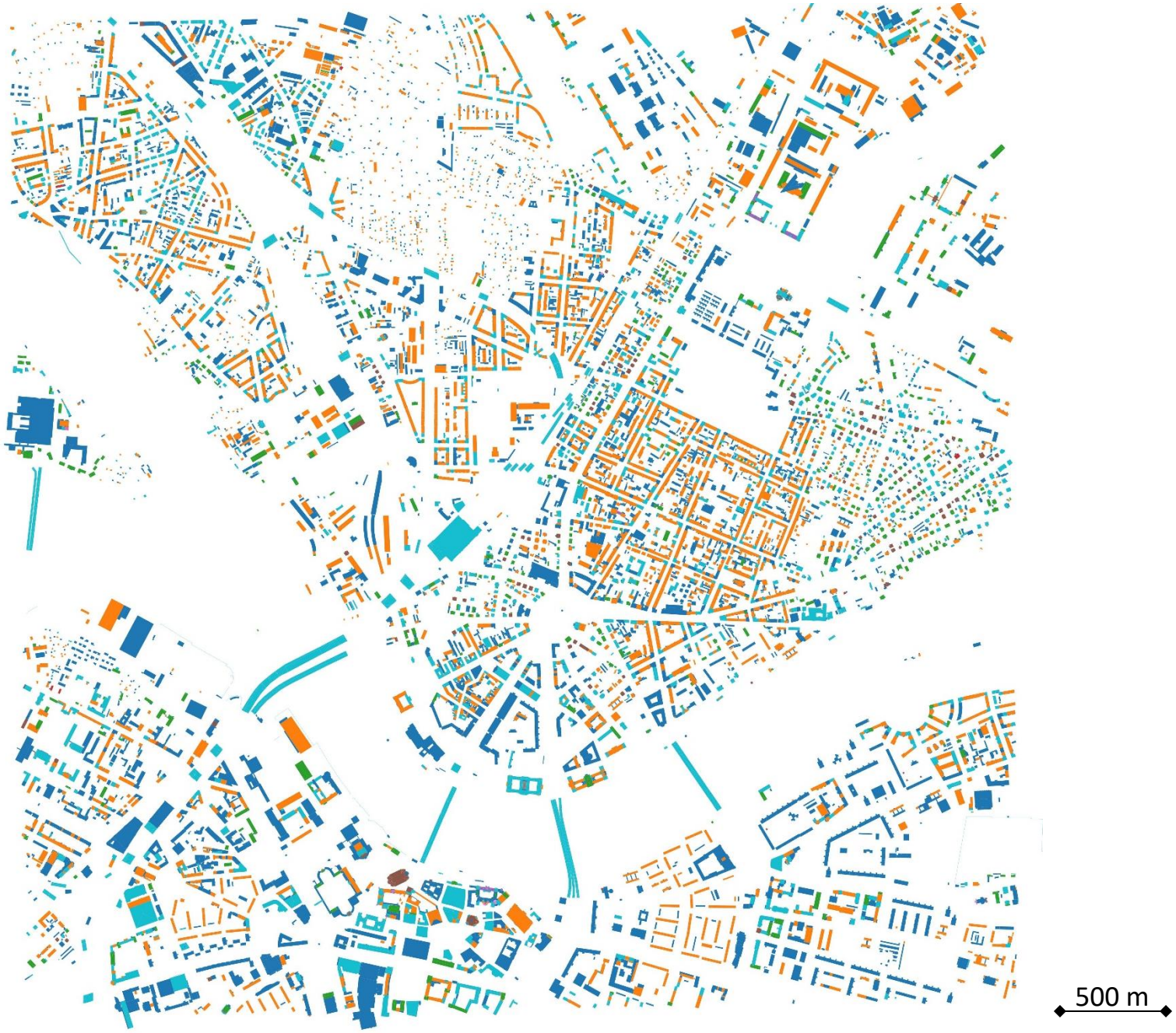


Fig.: LoD2 illustration for Dresden

Satellite imagery

Multispectral Planet Basemaps

- Cloud-free, monthly mosaics with spatial resolution of 4.77 m (at equator)
  → Analysis-ready data

Tab.: *Covariates used for binary classification*

Grouping	Covariates
Spectral bands	RGB, yellow, red edge, NIR
Spectral indices (vegetation)	EVI, MSAVI2, MTVI2, NDVI
Spectral indices (impervious surfaces)	CBCI, NISI, PISI

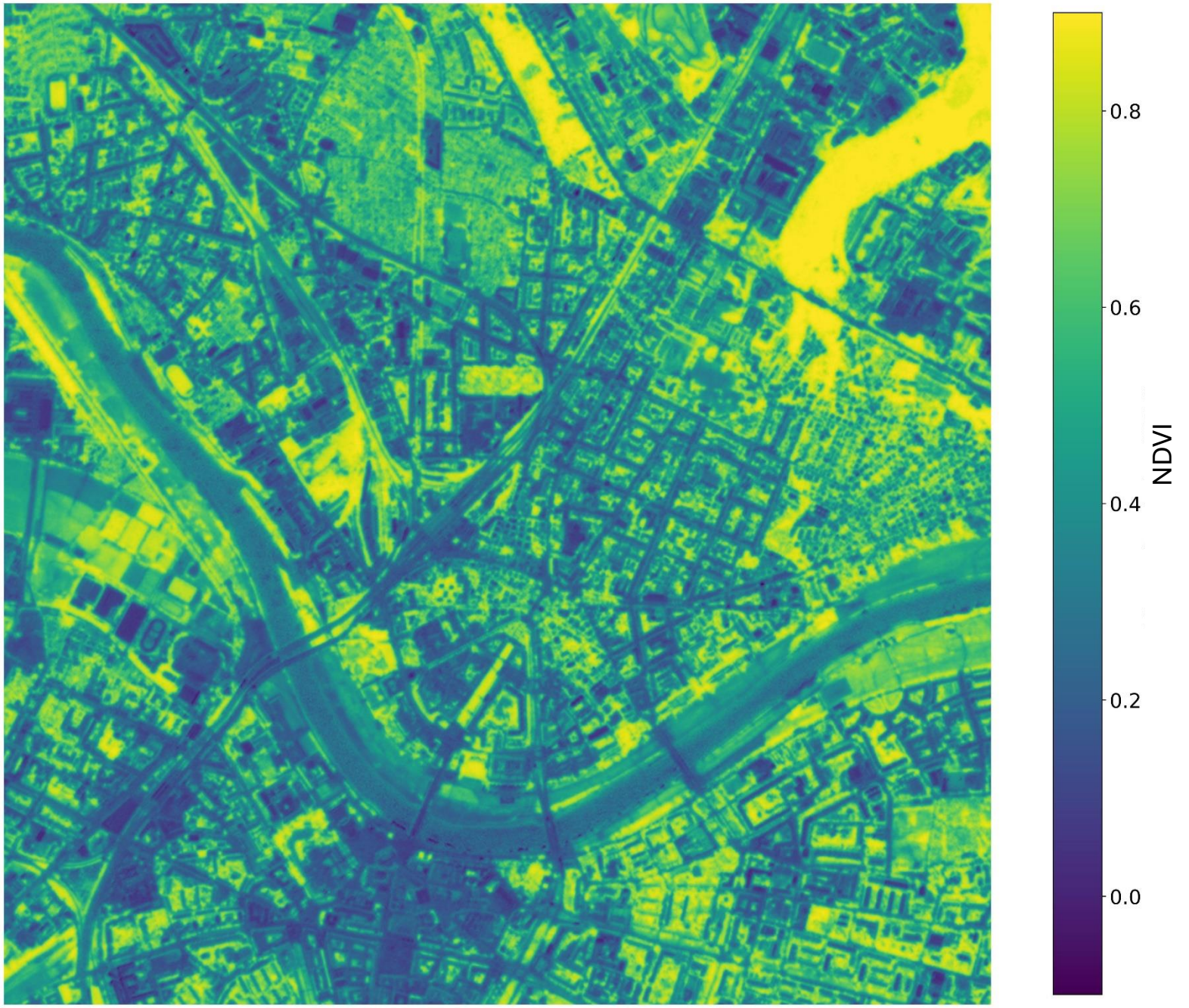


Fig.: NDVI illustration for Dresden

Validation

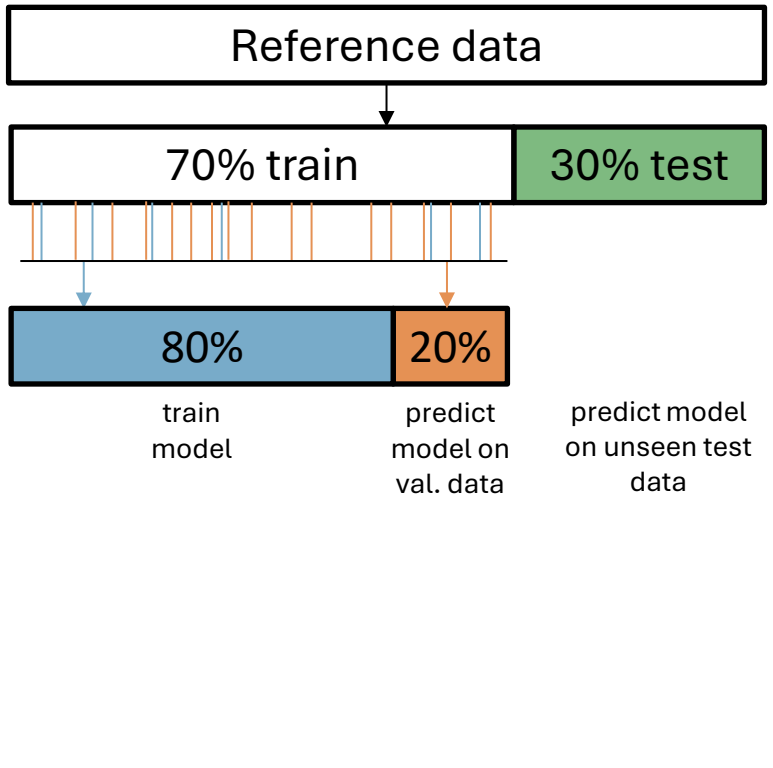
Preliminary results from cross-validation

- Based on multi-annual reference data (2021 – 2023)

Cross-validation strategy

Stratified random split
strata: year + label class

Stratified k-fold (splits: n = 5)



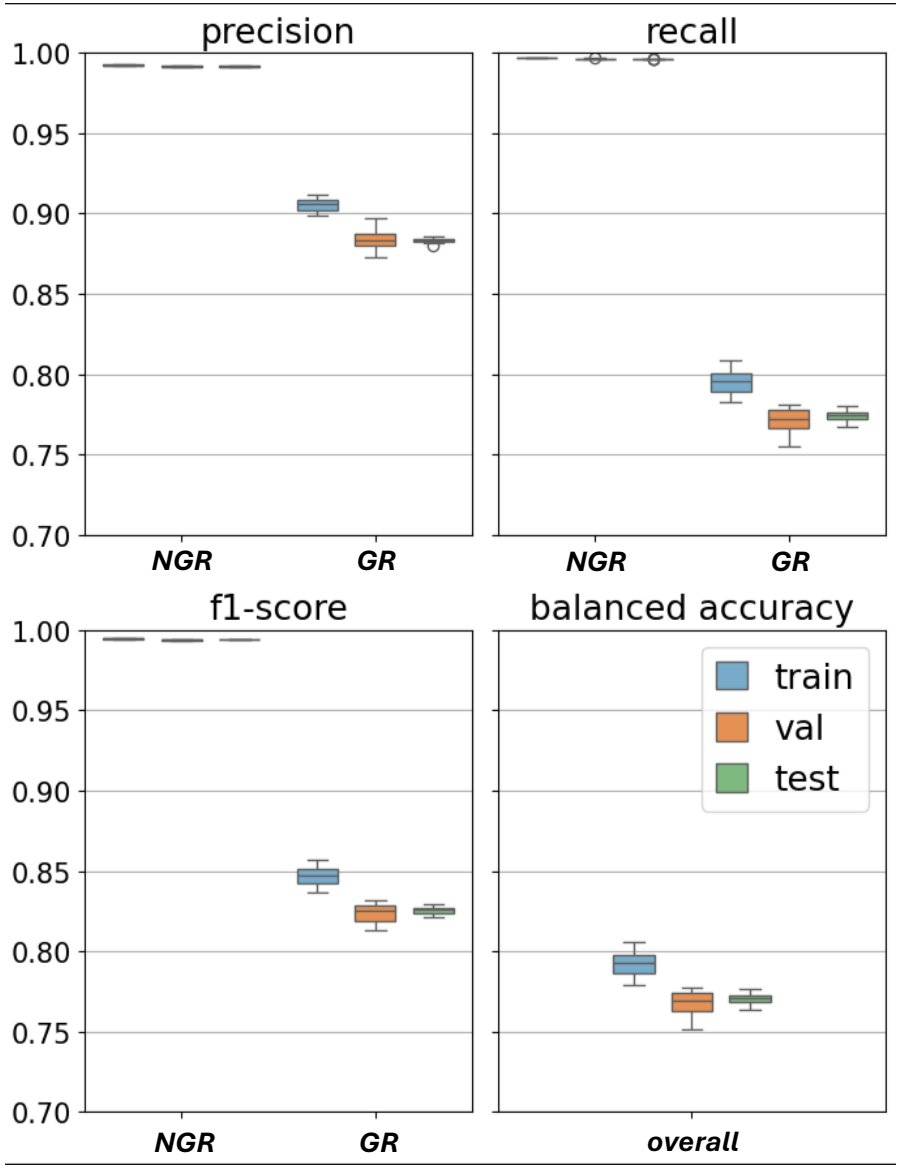


Fig.: Cross-validation overview. NGR = non green roof class; GR = green roof class

Aggregation of green roof statistics

pixel level inference

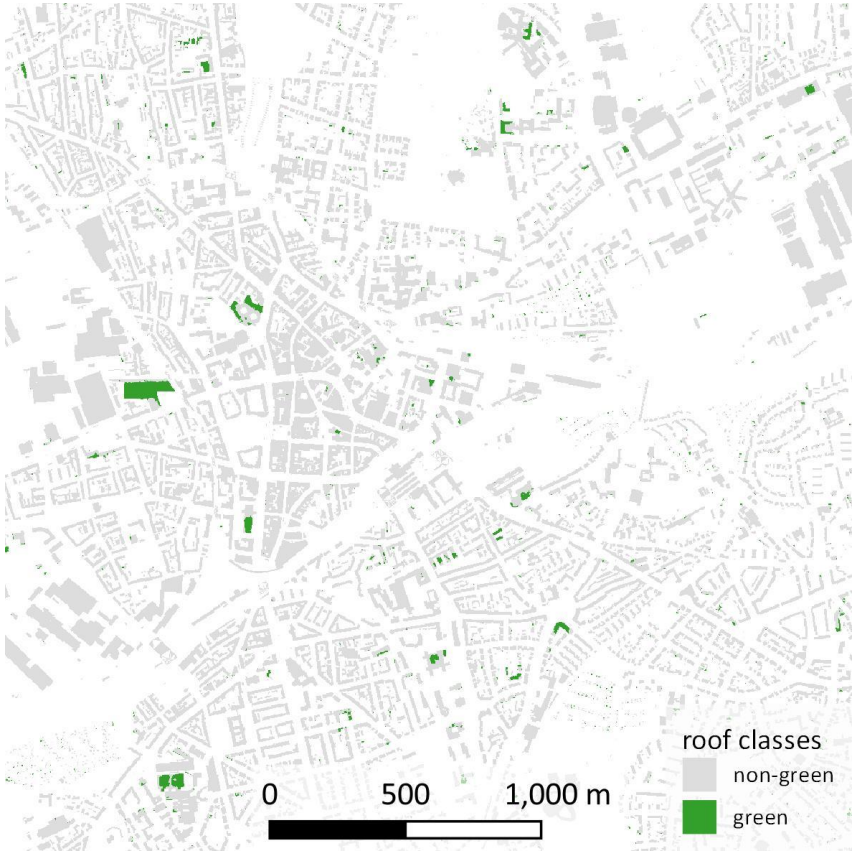


Fig.: Example illustrations for 2021

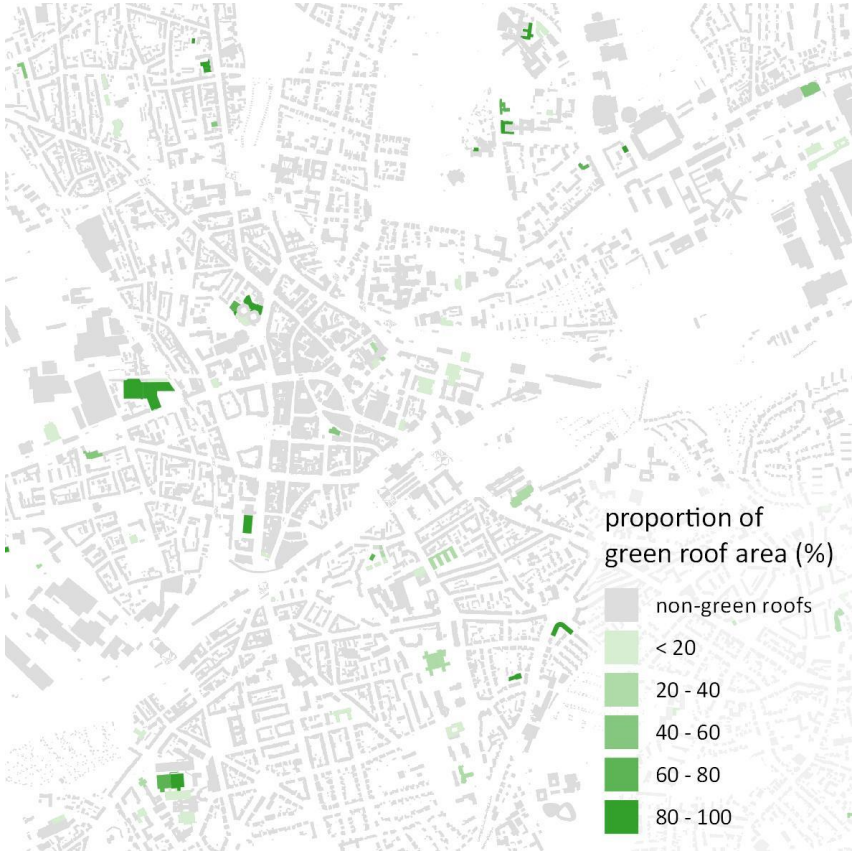
Aggregation of green roof statistics

building level

Fig.: Example illustrations for 2021

Aggregation of green roof statistics

building level → lower administrative level



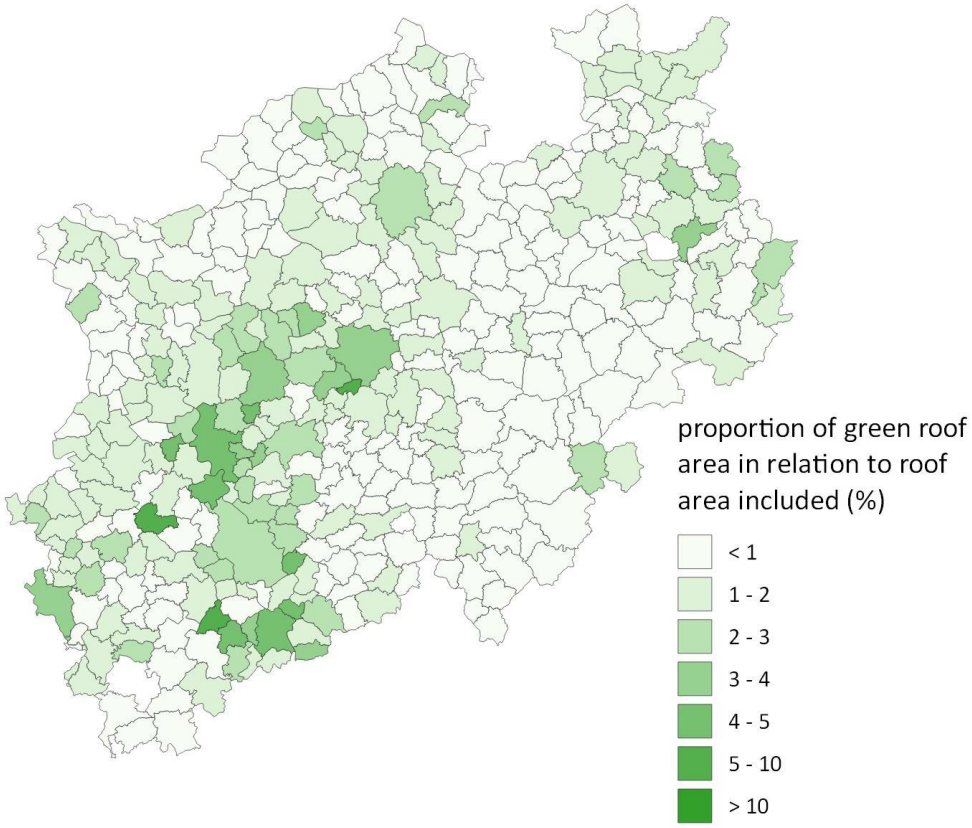
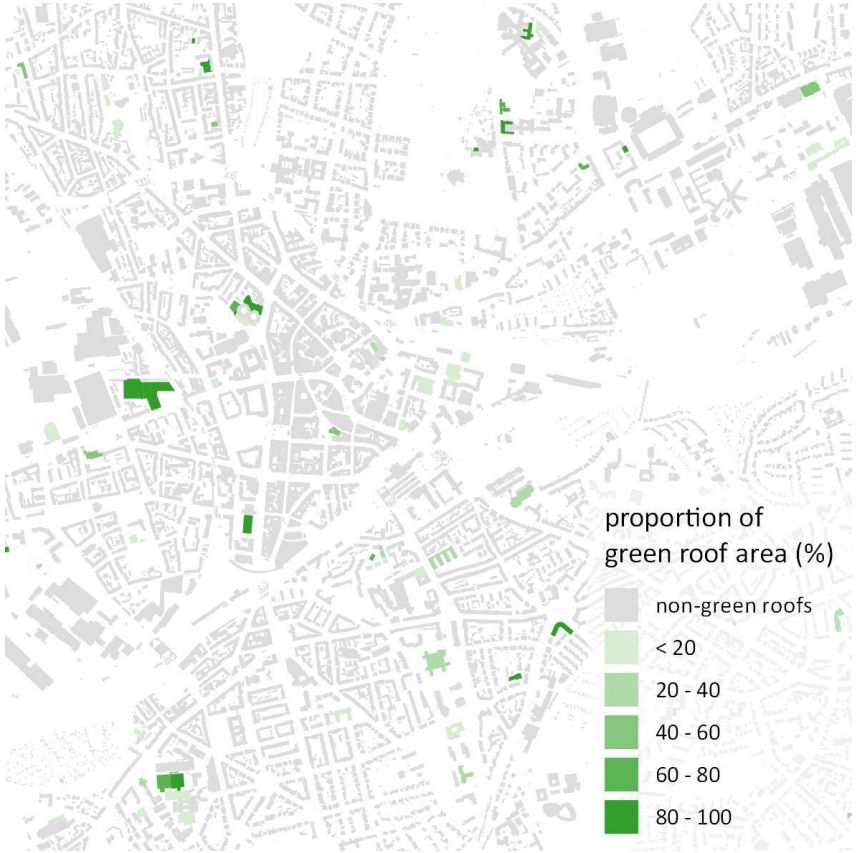


Fig.: Example illustrations for 2021

Aggregation of green roof statistics

building level → lower administrative level → national level



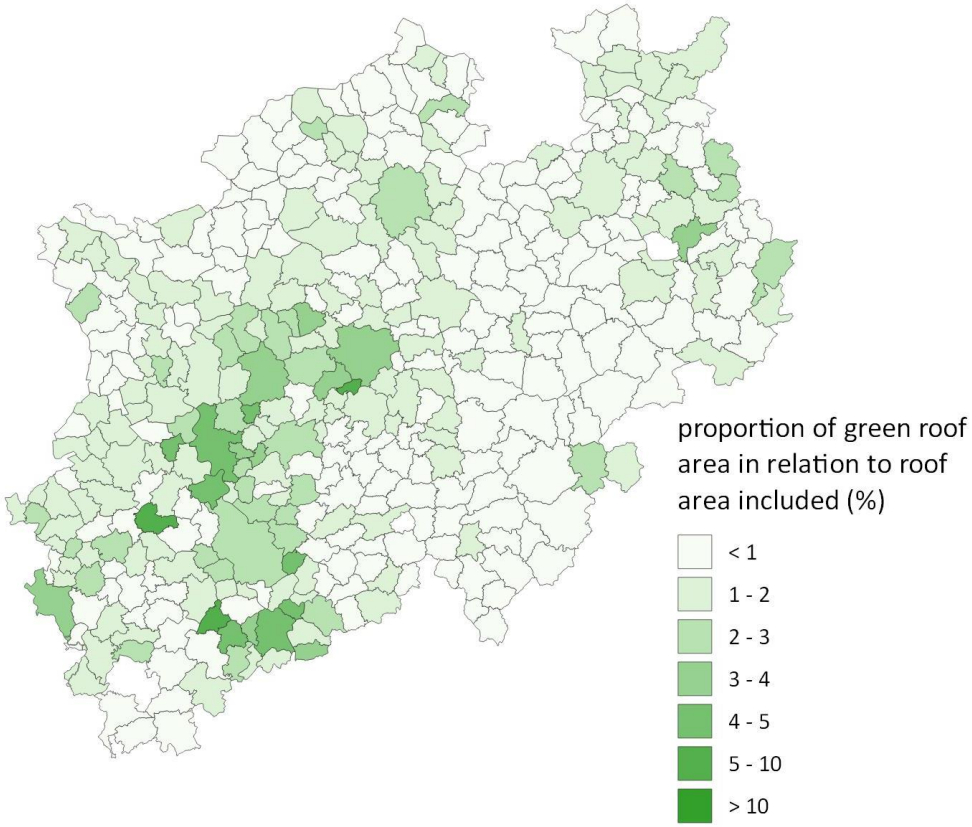


Fig.: Example illustrations for 2021

Challenges

- Basemaps' geometric accuracy of up to 10 m (RMSE)
  → Impact on roof edges and smaller buildings

- Adjacent vegetation partially covering roofs
  → Blocking the view

- Potential mitigation measures:
  - Internal roof shape buffering
  - Minimum building size
  - Integration of high resolution data from upcoming German Digital Twin (DigiZ-DE)
    → Crown segments and height

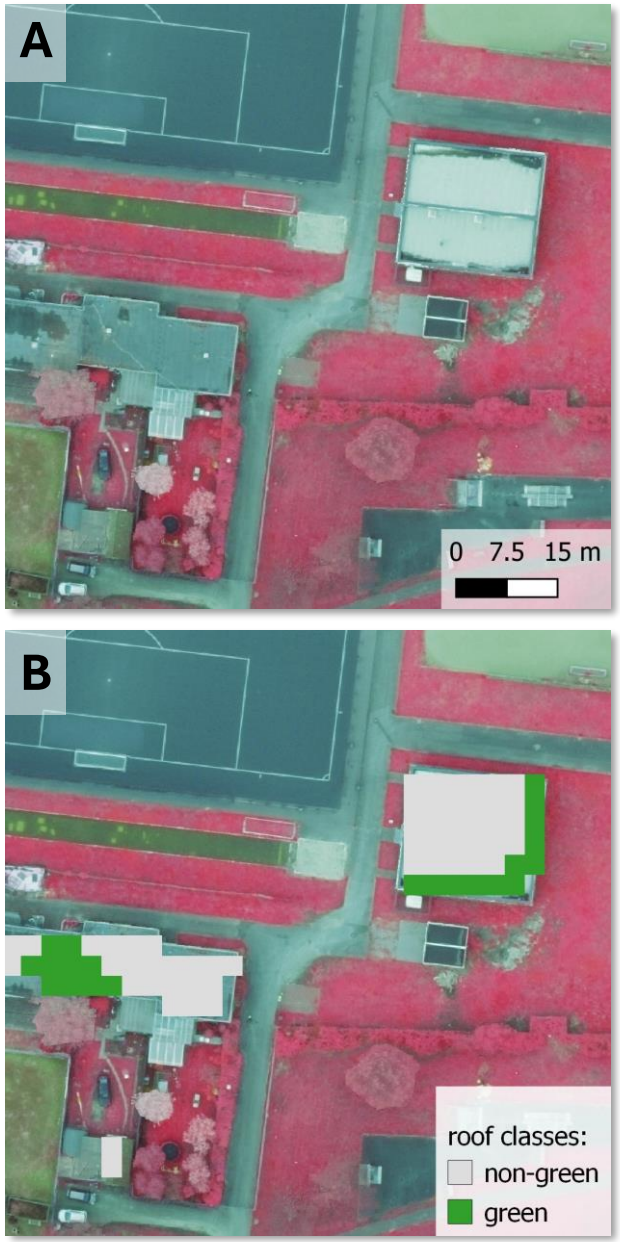


Fig.: A) false colour aerial image of non-green rooftops; B) overlaid class prediction

Take home

- Work in progress but preliminary validation results look promising
- Challenges remain: testing various mitigation measures
- Analysis-ready data, high resolution satellite imagery may enable systematic monitoring of adaptation measures aiming at increasing climate change resilience of urban areas
- Planned output (beyond reporting in 2027): aggregated data on green roof area (proportion and per cap.) at administrative level (e.g. NUTS 3) → Open data

Thanks so much for your attention!

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