A novel approach for mapping material stocks of buildings and infrastructure from remote-sensing data

University of Natural Resources and Life Sciences, Vienna
Department of Economics and Social Sciences
Institute of Social Ecology

Dominik Wiedenhofer, Doris Virág, Christoph Plutzar, Helmut Haberl (SEC, BOKU)
David Frantz, Franz Schug, Sebastian van der Linden, Patrick Hostert (EO-Lab, HU-Berlin)

Fresh of the press, 18.February 2021: Haberl*, Wiedenhofer*, et al. (2021) „High-Resolution Maps of Material Stocks in Buildings and Infrastructures in Austria and Germany“. *Environmental Science & Technology.* https://doi.org/10.1021/acs.est.0c05642.

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Understanding the Role of Material Stock Patterns for the Transformation to a Sustainable Society: The Stock-Flow-Service Nexus

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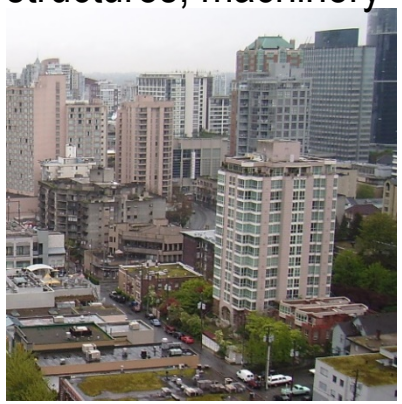
Stocks Buildings, infra-structures, machinery



Sustainability Transformations require a re-configuration of the stock-flow-service nexuses to achieve higher wellbeing for all, at much lower levels of resource use and emissions

Flows Energy, materials, Waste, emissions

Services Contributions to social well-being

Haberl, Wiedenhofer, *et al* 2017. *Sustainability,* DOI:10.3390/su9071049
Kalt, Wiedenhofer, *et al.* 2019, *Energy Research & Social Science.* DOI:10.1016/j.erss.2019.02.026
Haberl, Wiedenhofer, *et al.* 2019, *Nature Sustainability*. DOI: 10.1038/s41893-019-0225-2

Fotos: Helmut Haberl

Mapping material stocks

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- Spatial patterns of material stocks are a key factor for the material & energy flows required to provide services
- Spatial patterns of stocks key for issues such as urbanization, spatial planning, secondary resource management and urban mining, etc
- Mapping material stock distribution requires an encompassing knowledge of built environments: infrastructures, buildings, building types, building area and height.
- Highly detailed cadastral data and official 3D-city models are an ideal source. However, data is not available everywhere, acquisition can be difficult and expensive.
- Night-Time Lights are widely used to map various socio-economic issues as well as material stocks. However, they are usually spatially quite aggregated

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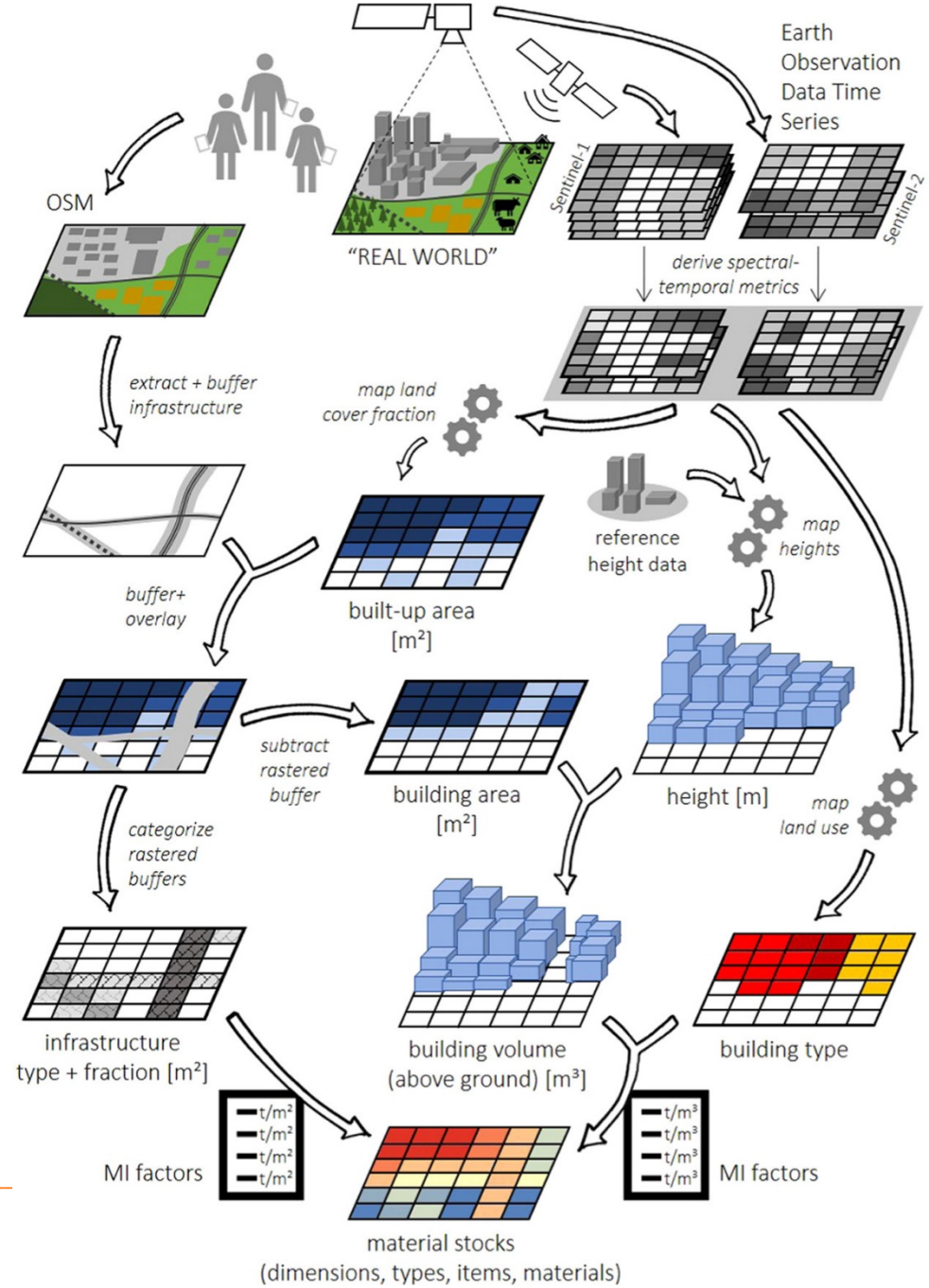
Workflow of our novel method for mapping material stocks, using ..

- Earth Observation Data from newest generation satelites
- Crowd-sourced data from OpenStreet Maps
- Material intensities by stock types



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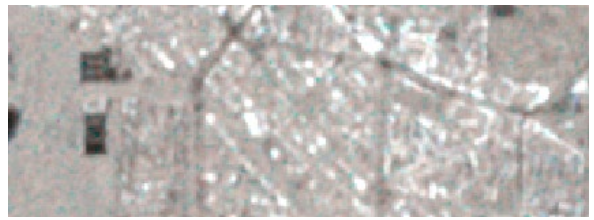
Data

We use freely available Copernicus Sentinel-2 optical, Sentinel-1 radar and OpenStreetMap data to map material stocks.

	Sentinel-2	Sentinel-1	OpenStreetMap
			
Data availability	free of charge	free of charge	free of charge
Data type	Optical, satellite	SAR, satellite	Vector, crowd-sourced
Information	…about surface materials	…about surface roughness	…about specific land use features
Temporal resolution	1 image every 5 - 10 days since 2017	1 Image every 1-3 days since ~ 2014	Single date (unclear)
Spatial resolution	10m / 20m	10m	-
Spectral resolution	10 (13) spectral bands	VV + VH polarization (2 bands)	-

Identifying types of stocks and developing appropriate material intensities

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Identifying built-up area and stock types

- Subpixel shares of built-up area identified via machine-learning based regression approach (Okujeni et al. 2017; Frantz 2019; Schug et al. 2020), trained and validated by manually labelled reference data for 160 sites (~36,000 samples)

- Support vector regression model used to estimate building heights from combined Earth Observation data, trained on several highly accurate open-source 3D building models available in Germany (Frantz et al. 2021)

- Classification of building types based on morphological metrics from Earth Observation satellite data used for a random forest classifier; 1604 training samples were manually collected (Frantz 2019; Schug et al. in review)

Developing appropriate and representative material intensities: tons per m3 and per m2

- 5 building types, 21 infrastructure types, 13 materials
- Developed with national experts and from the literature

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A novel high resolution map of material stocks in Germany & Austria

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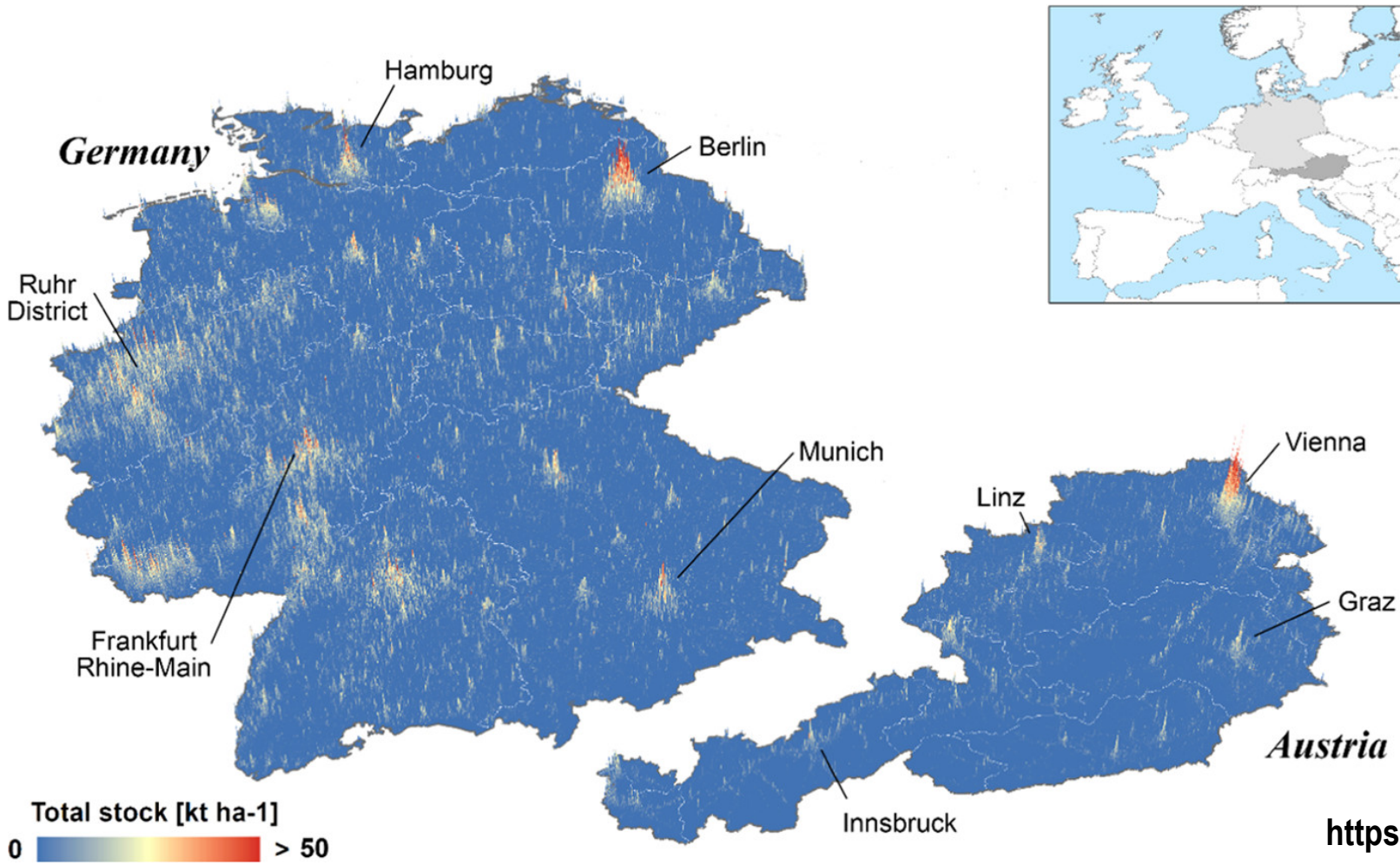
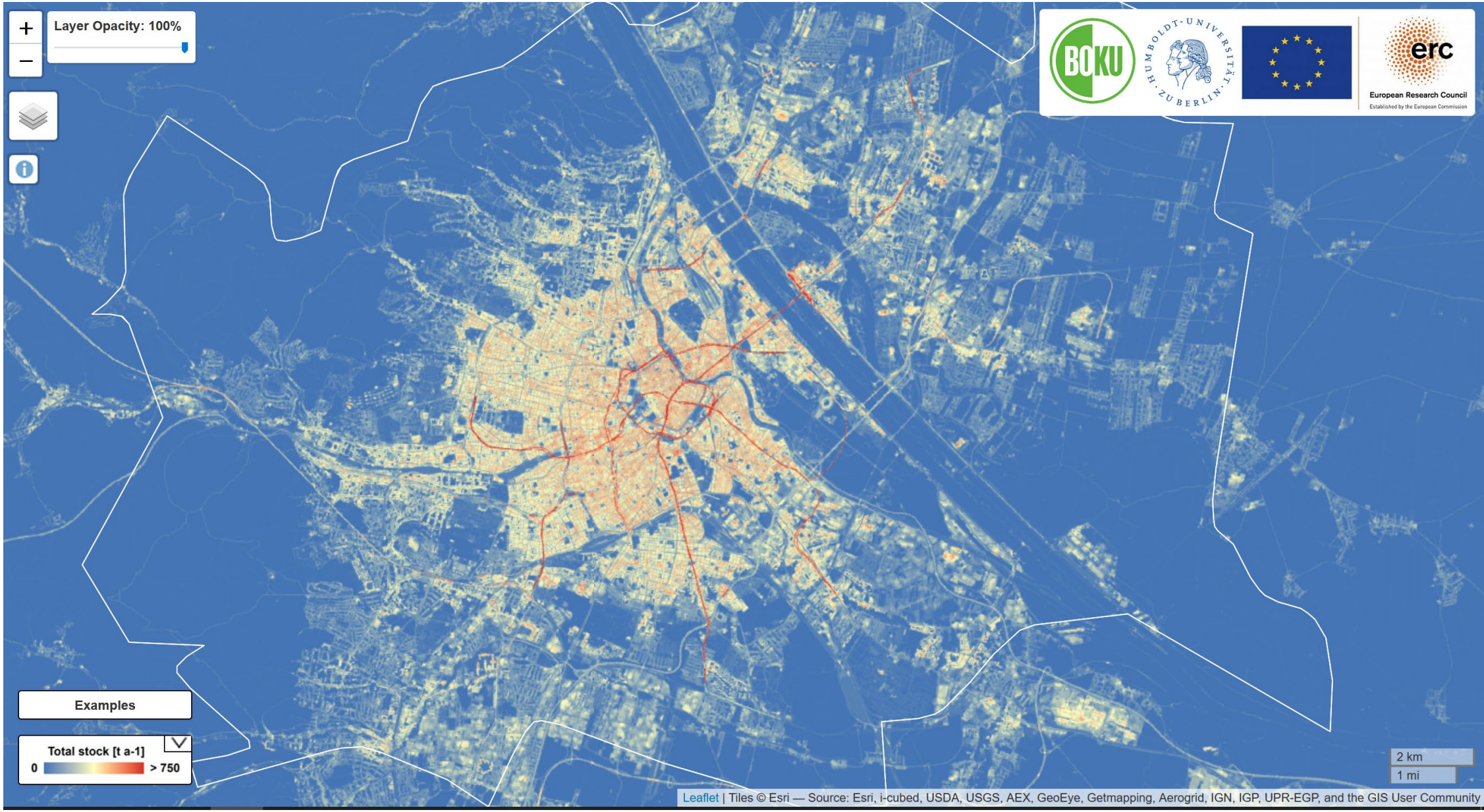


https://ows.geo.hu-berlin.de/webviewer/stocks/

Haberl*, Wiedenhofer*, et al. (2021) „High-Resolution Maps of Material Stocks in Buildings and Infrastructures in Austria and Germany“. *Environmental Science & Technology.* https://doi.org/10.1021/acs.est.0c05642.



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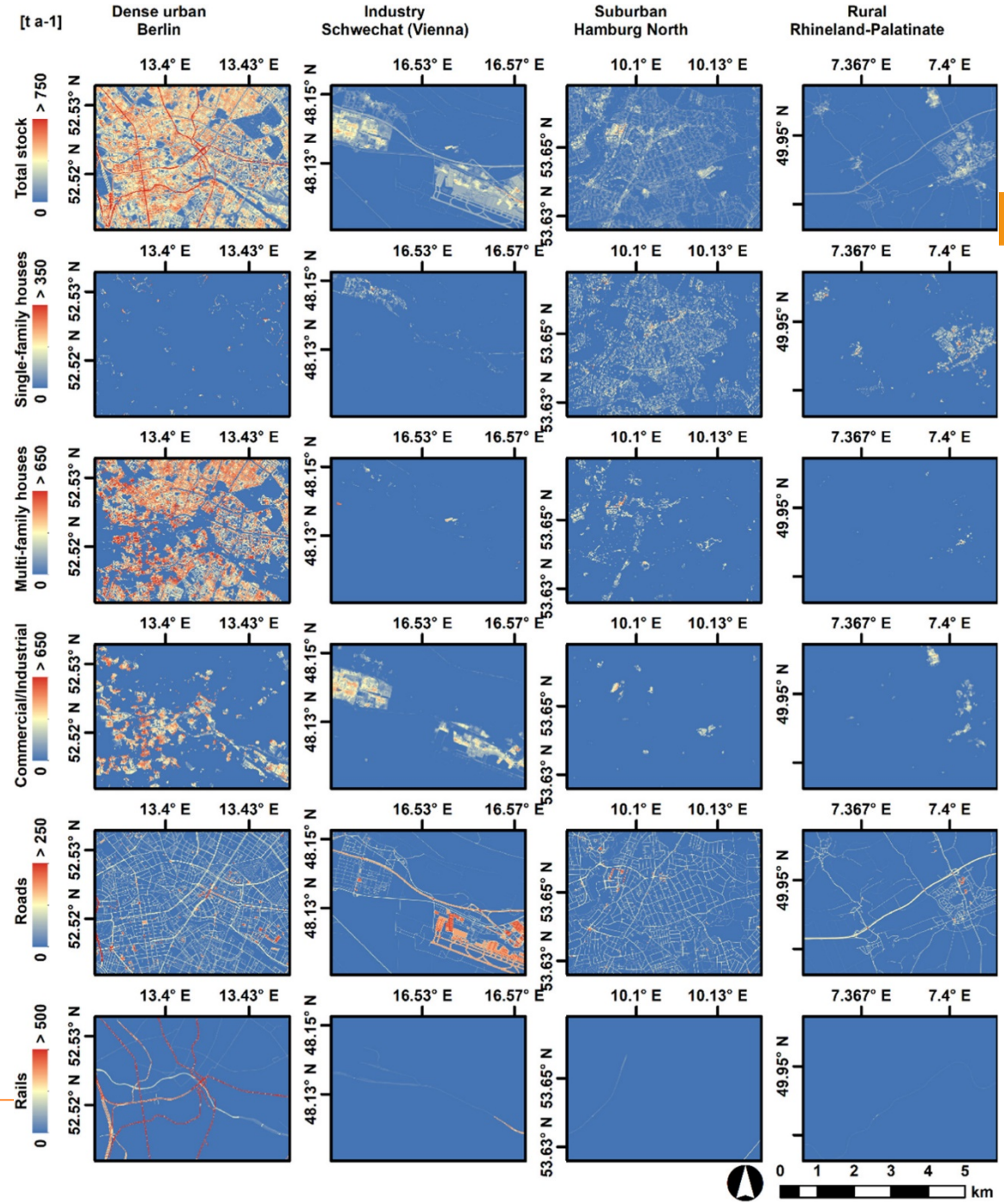
Topical resolution of stock maps

- 5 building types
- 21 infrastructure types
- 13 materials



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Novel high-resolution versus usual spatial aggregations

from 10m to 100m to 1km

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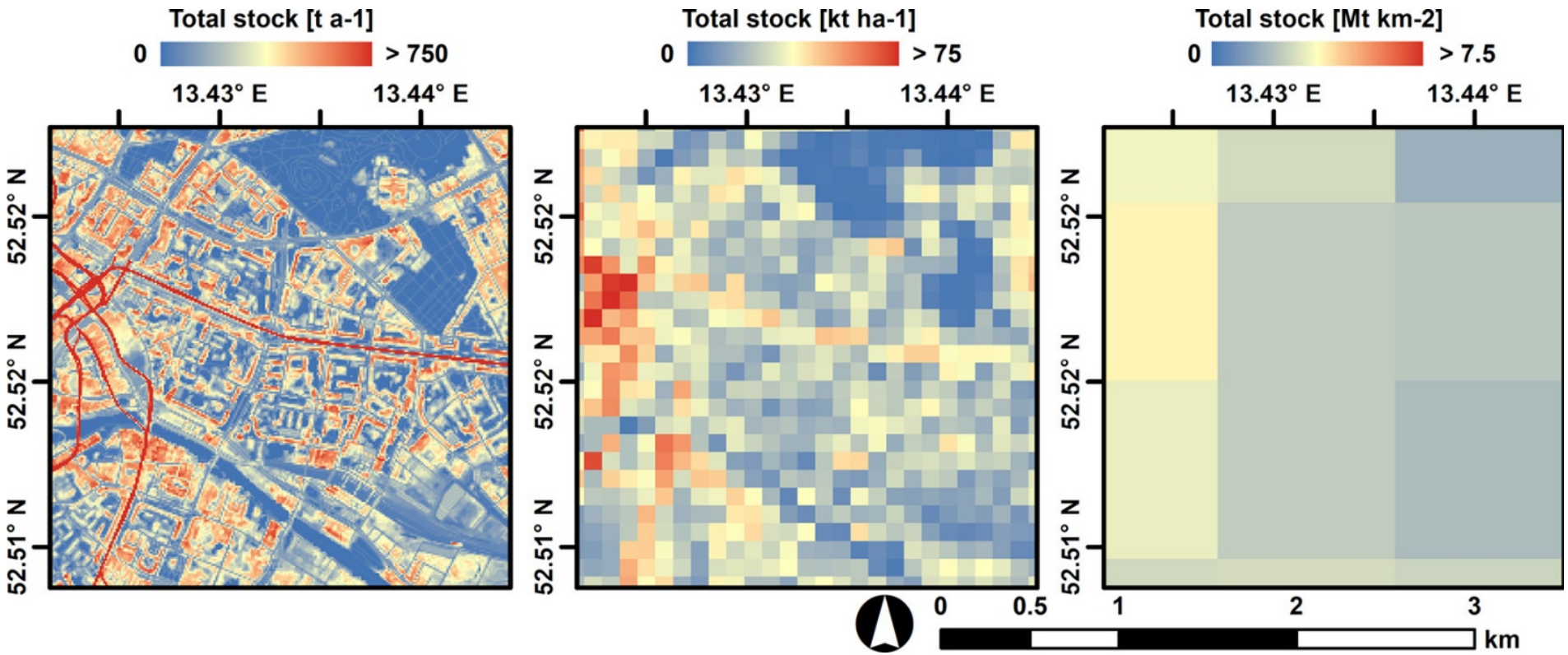

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Next steps – mapping more countries and refining the method

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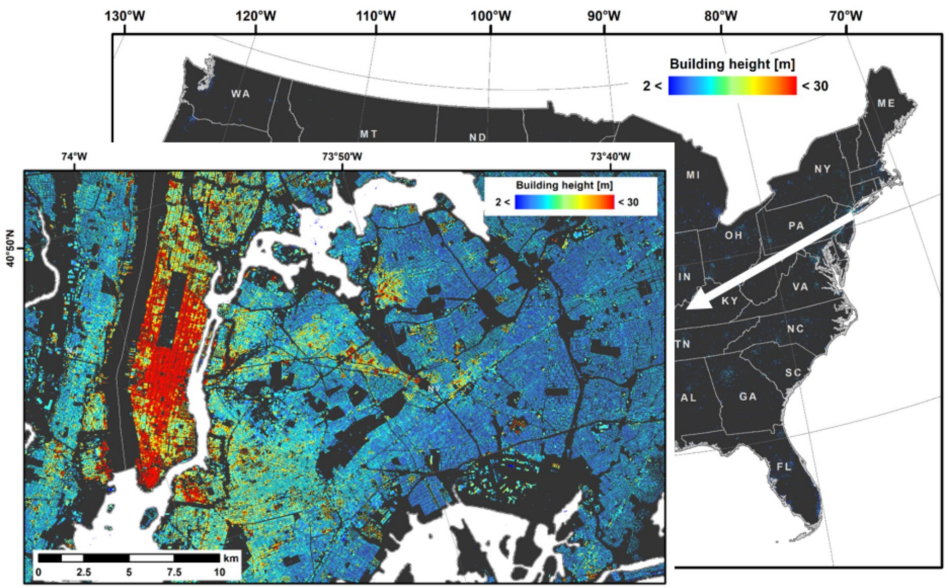
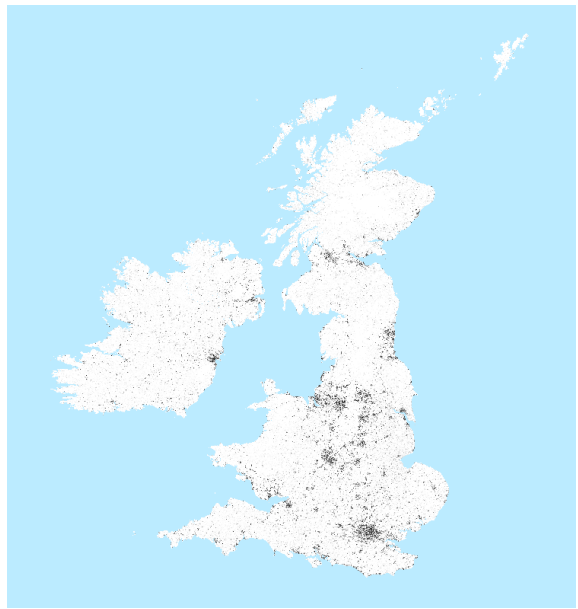
- In progress: mapping USA, UK & Uganda
- Each country has specific challenges, enabling further refining the method





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Conclusions

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- Intensive but rewarding interdisciplinary collaboration required to bridge Remote Sensing and Industrial Ecology
- Novel high-resolution mapping method yields comprehensive maps for material stocks of buildings and infrastructures, including infos on dimensions, types, items, materials
- Over-estimations possible, however other methods also have their limitations
- Method can be applied on very large scales, using freely available Earth Observation and crowd-sourced data (OSM)
- Required training data and necessary detailed information for material intensities is a limitation
- Application to other countries will help refine this novel method

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Dr. Dominik Wiedenhofer - *Dominik.wiedenhofer(at)boku.ac.at*

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Project and more results:

Matstocks.boku.ac.at

https://ows.geo.hu-berlin.de/webviewer/stocks/

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