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MAT_STOCKS Kick-off: WELCOME!

12.4.2018

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MAT_STOCKS im Überblick
Road-Map für Agenda

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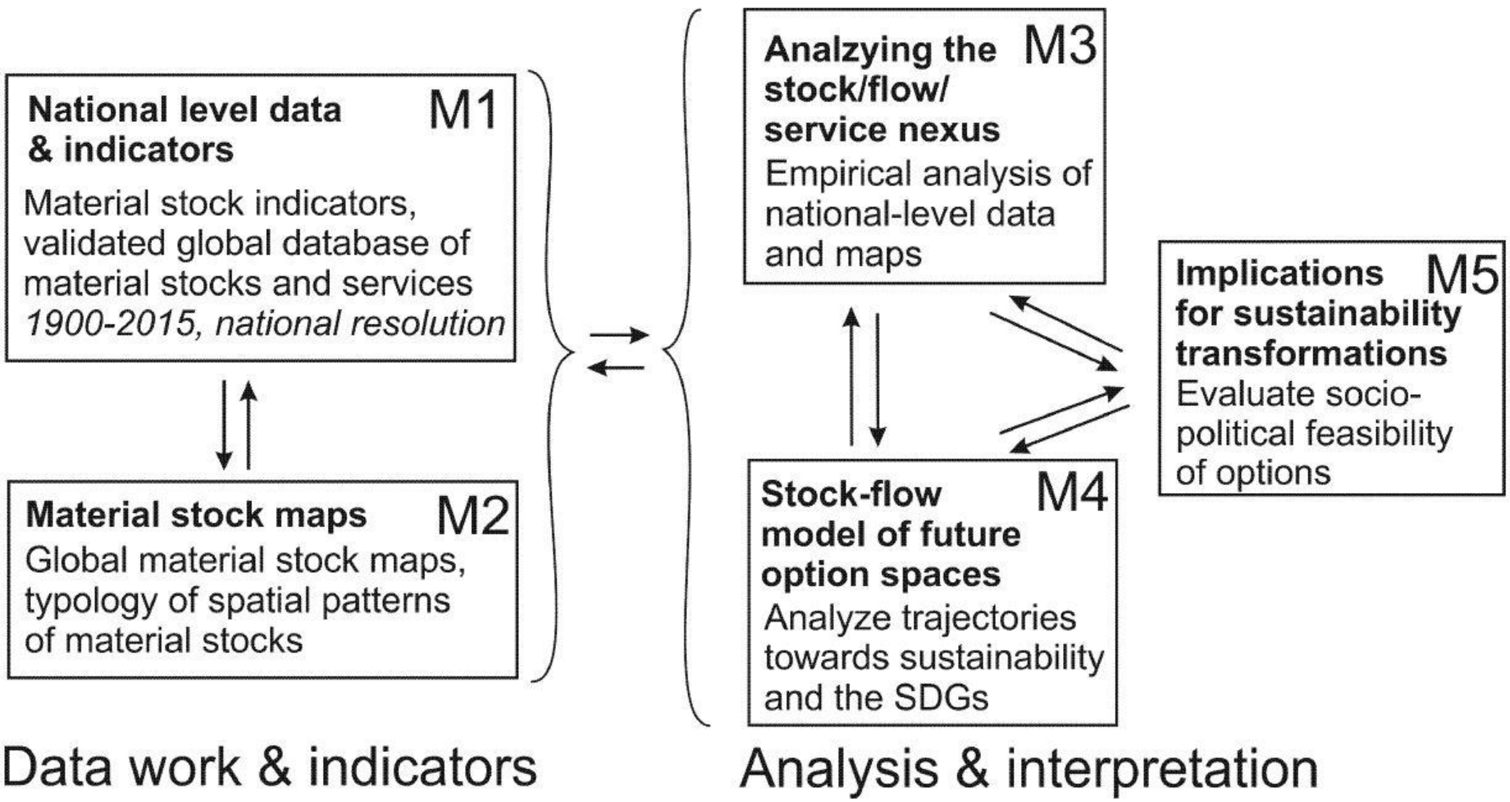
Vormittag

Nachmittag



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Beyond the state of the art (selection from proposal)

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- **Robust global national-level database** with systematic quantification of uncertainties
- **Path dependencies** (e.g. future maintenance requirements)
- **Stock-flow-service nexus –** beyond eco-efficiency & IPAT
- **Global maps of material stocks - beyond nighttime lights**
- Test hypotheses related to **urbanization, urban form, scaling laws**
- **Global model of stocks, flows and services,** GHG emission module
- Option spaces for **low-carbon futures** and **SDGs**
- Evaluating the **effectiveness of strategies in meeting key targets**
- **Identifying innovative leverage points** for sustainability transformations.

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MODULE 1

Objectives Module 1: National level data and indicators

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- (Build on ongoing efforts in the FWF project MISO)
- Develop consistent and systematic **indicators for the stock/flow/service nexus**
- Establish a **globally consistent national-level long term database on material stocks and services**
- **Validate results** and perform a **systematic error propagation analysis and quantification of uncertainty**
- Global analyses will yield results at different levels
- **~12 case studies** : USA, Japan, the United Kingdom, Russia (respectively the USSR or the Former Soviet Union), Austria, China, India and South Africa. ~4 additional case studies will be identified early on in the project

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Investigating the socioeconomic metabolism: economy-wide material flow accounting (ew-MFA)

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~ 50 categories

Krausmann, et al. (2017). Material Flow Accounting: Measuring Global Material Use for Sustainable Development. *Annual Review of Environment and Resources*. doi:10.1146/annurev-environ-102016-060726.

Schandl et al. (2017). Global Material Flows and Resource Productivity: Forty Years of Evidence. *Journal of Industrial Ecology*. doi:10.1111/jiec.12626

Extending ew-MFA – a more comprehensive perspective on SEM: applying accounting principles & using a dynamic stock/flow model

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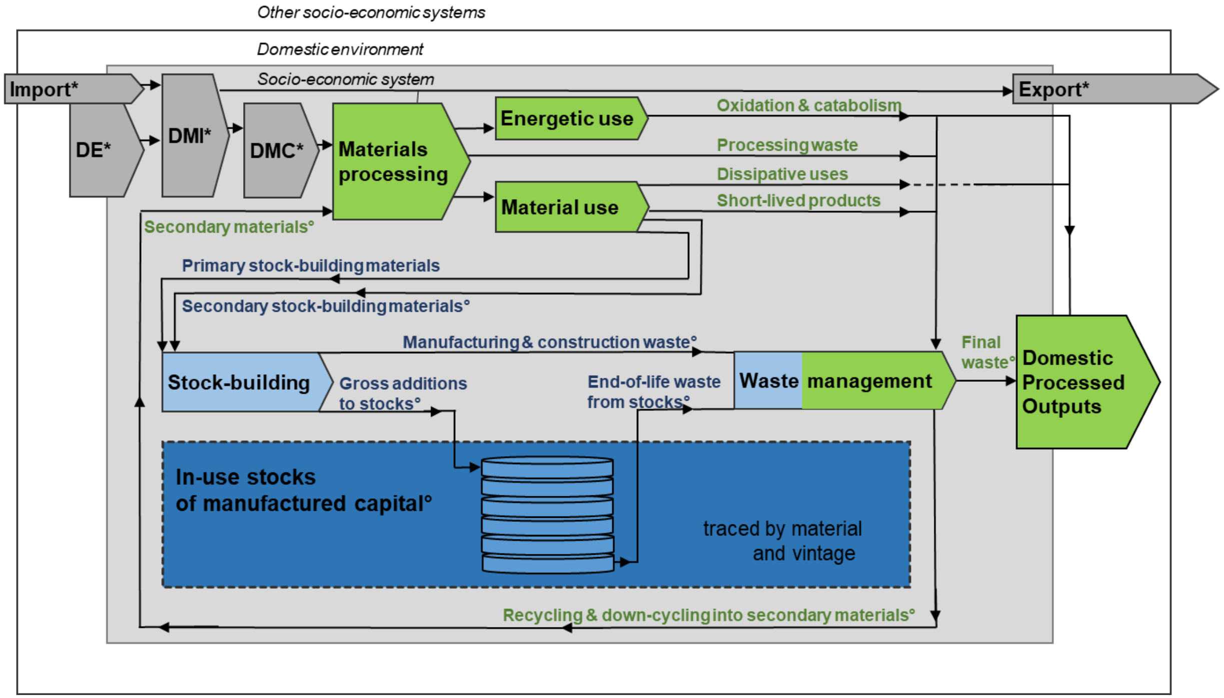

Wiedenhofer, D., Fishman, T., Haas, W., Haas, W., Krausmann, F., (2019). Integrating material stock dynamics into economy-wide material flow accounting: concepts, modelling, and global application for 1900-2050. 10.1016/j.ecolecon.2018.09.010

Half of global resource consumption is used to expand and maintain in-use stocks of manufactured capital

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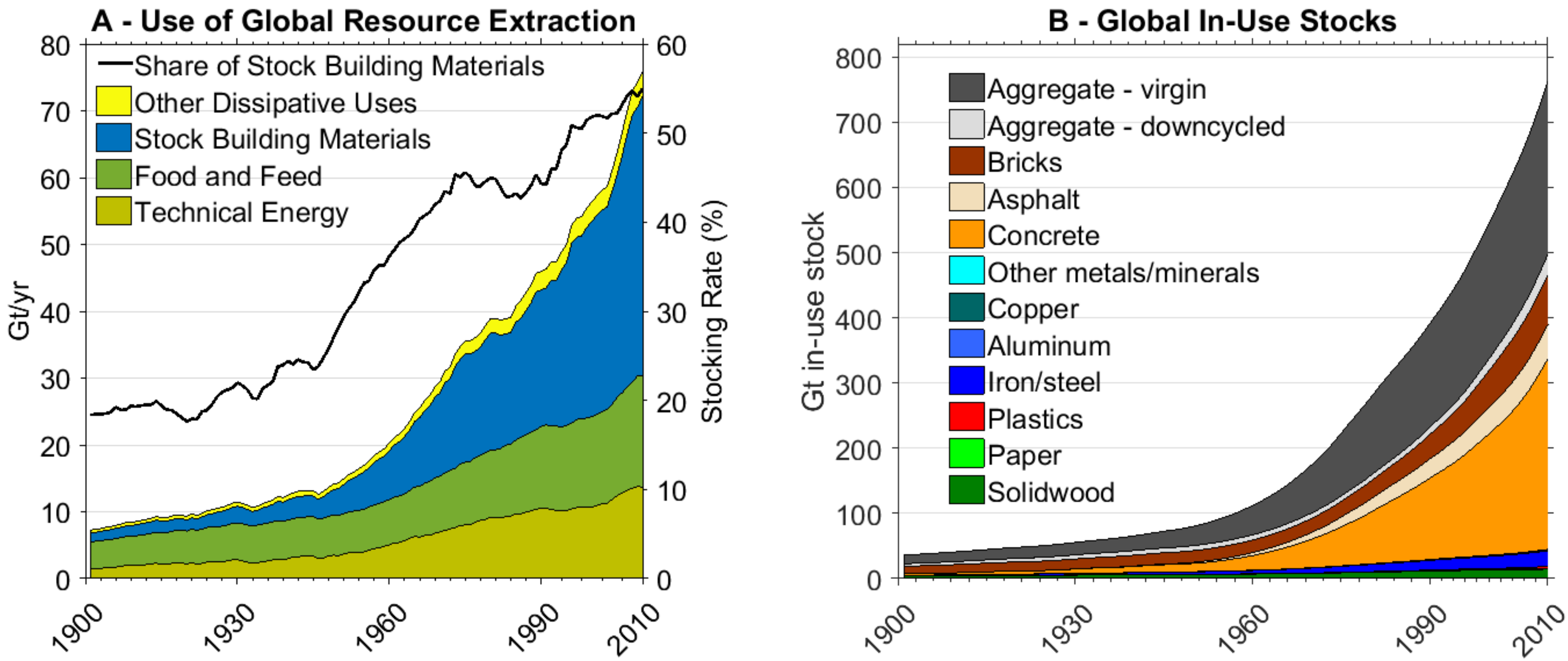

Krausmann F., Wiedenhofer D., Lauk C., Haas W., Tanikawa H., Fishman T., Miatto, A., Schandl H., and Haberl, H. (2017). Global Socioeconomic Material Stocks Rise 23-Fold over the 20th Century and Require Half of Annual Resource Use." *Proceedings of the National Academy of Sciences*.

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Development of the global socio-economic metabolism: Stock-building and in-use stocks from 1900-2015

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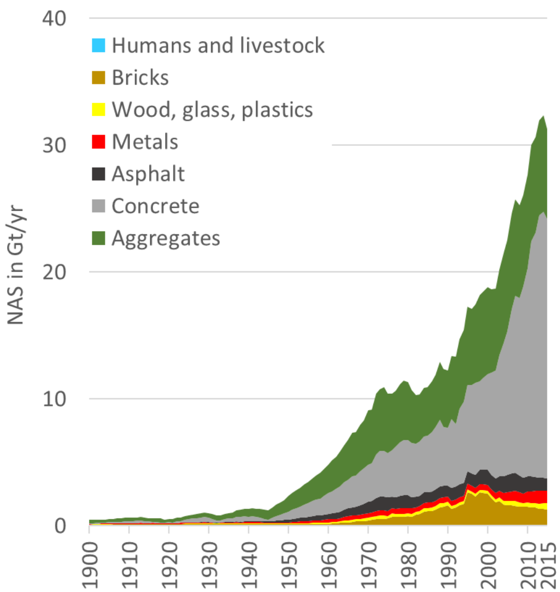
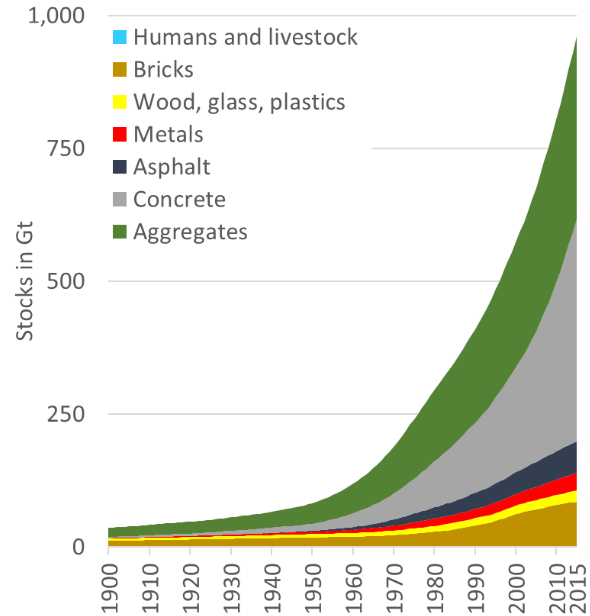
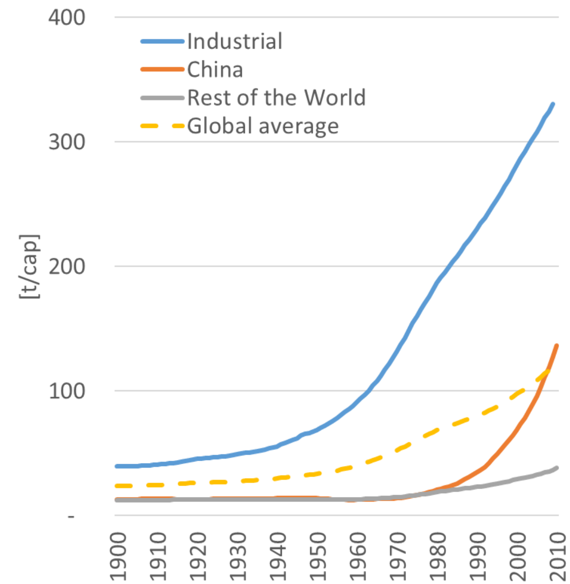
Yearly net additions to stock



In-use stocks of artefacts



Stocks per capita



Krausmann, Fridolin, Christian Lauk, Willi Haas, and Dominik Wiedenhofer. 'From Resource Extraction to Outflows of Wastes and Emissions: The Socioeconomic Metabolism of the Global Economy, 1900–2015'. *Global Environmental Change* 52 (September 2018): 131–40. https://doi.org/10.1016/j.gloenvcha.2018.07.003.

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An integrated & cumulative perspective on material and energy flows and the stock-building from 1900-2015

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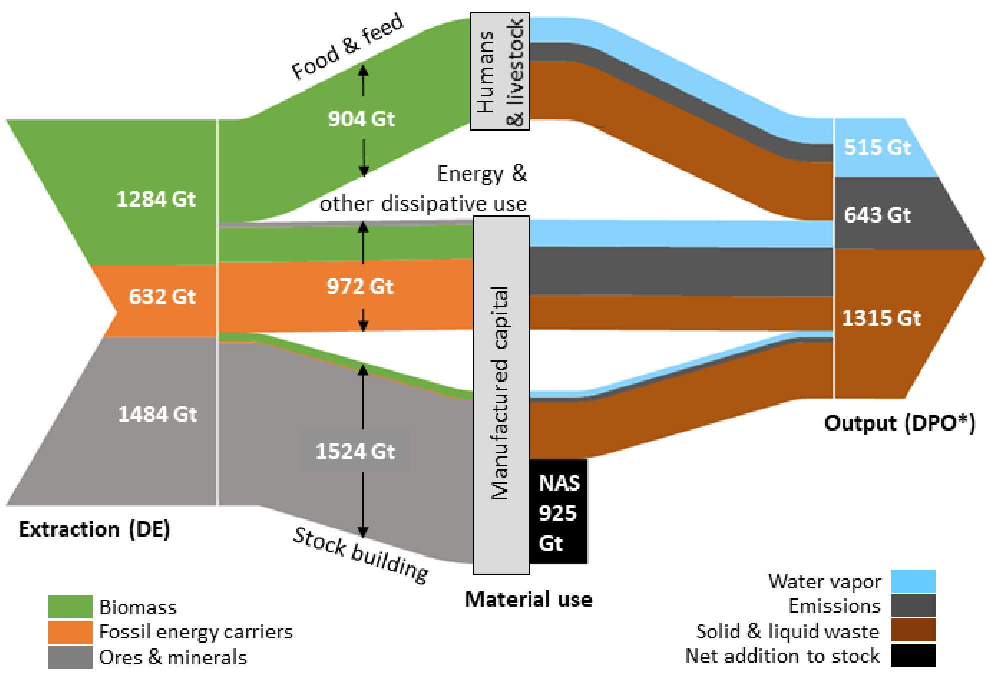

$$\sum_{t}^{1900-2015} DE, Energetic\ use, Material\ use, NAS, DPO$$

- Krausmann, Fridolin, Christian Lauk, Willi Haas, and Dominik Wiedenhofer. 'From Resource Extraction to Outflows of Wastes and Emissions: The Socioeconomic Metabolism of the Global Economy, 1900–2015'. *Global Environmental Change* 52 (September 2018): 131–40. https://doi.org/10.1016/j.gloenvcha.2018.07.003.

AG1: MISO 2.0 for MatStocks – adapting the modeling approach → towards 3.0 ?

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From global & world-regional to national-level databases

- **Requires intensive datawork:** data for the period 1960/70-2015 from databases from national and international organizations (FAO, UN, IEA, USGS, BGS) and industry organizations (CEMBUREAU, World Steel, Aluminum association, Plastics Europe). Improvement of data from available global MFA database (1950-2010).
- Systematic uncertainty assessments

Extending the MISO model from 1.0 to 2.0 → towards a higher resolution of "stock types":

- Linking stock functioning to provided services (e.g. from „concrete" to concrete in different in-uses, e.g. buildings, infrastructure).
- Based on production statistics, further differentiation already possible: stock-building material inflow data can be split into 5 to 8 functional differentiations, "which kind of stocks are built":

Roads	**Buildings & Construction**
Infrastructure & Supply Networks	**Machinery & Transport Euipment**
Consumer Goods & Short lived Products	

National long-term country-case studies (e.g., USA, China, UK): PhD-Project

From MISO 2.0 to 3.0 – further differentiations?

AG2: Reviewing and Conceptualizing the Stock/Flow/Services Nexus

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AG2 reviews various discourses to inform theoretical work on the concept of „services“ within MatStocks and the SFS Nexus → close interaction with AG1 MISO 2.0

Macro level: societal „welfare“ and alternative measures to GDP

Meso-level: focuses on more specific services and their biophysical basis

Guiding questions for reviewing the specific discourses → to be refined 20.4.

- How are “services” conceptualized?
- How are biophysical stocks & flows conceptualized?
- How are their interactions conceptualized?
- How are each of the elements delimited from each other and from other, not included, elements? (e.g. what exactly is the respective flow allocated to the specific services, where is the boundary to other flows and stocks and/or services?)

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MODULE 2 – MAPPING STOCK PATTERNS

Module 2
Mapping Material Stocks with Remote Sensing

Patrick Hostert
Sebastian van der Linden
Franz Schug

Module overview

Goals and methods

- *Establish wall-to-wall maps of the spatial* ***material stock distribution based on remote sensing data***
- *Create a* ***typology of spatial patterns*** *of material stocks*

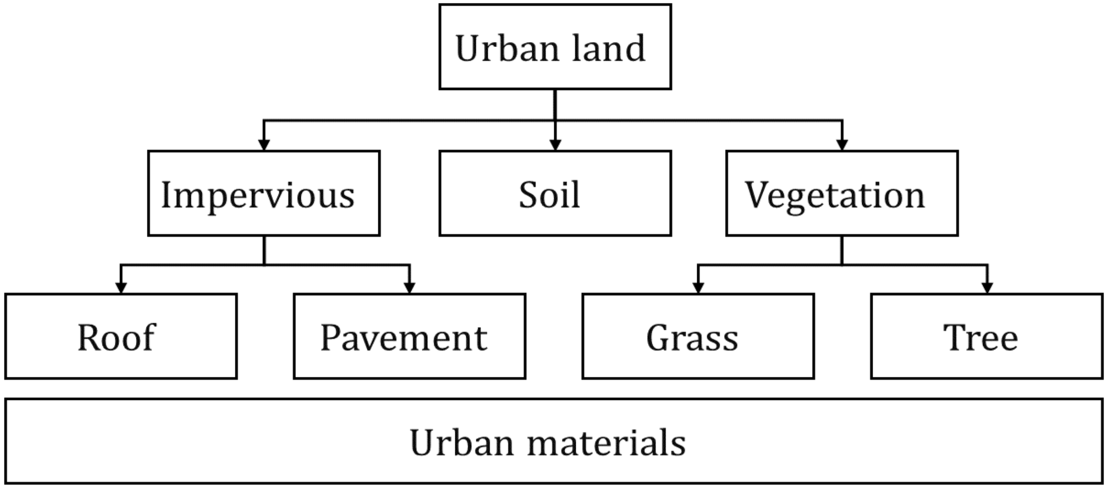
The following approach will be pursued

- ***Human-made infrastructures and the degree of imperviousness*** *will be mapped from optical S2 data and S1 SAR data or extracted from existing data sets.*
- *For the layers created, a* ***data mining approach*** *will be run on spectral-temporal metrics from optical and SAR data.*
- ***Functional types mapping*** *will be performed based on training data from available national databases. Spatial patterns of material stocks will be developed using* ***Self-Organizing Maps****.*

State-of-the-art remote sensing in urban mapping

Optical RS - Urban surface classification

- Classifiers can **separate surface classes** based on spectral information. Methods and possible outcome are highly dependent on the kind of data.



Simple exemplary classification scheme

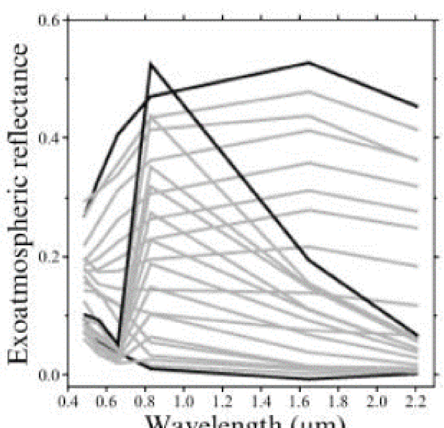
State-of-the-art remote sensing in urban mapping

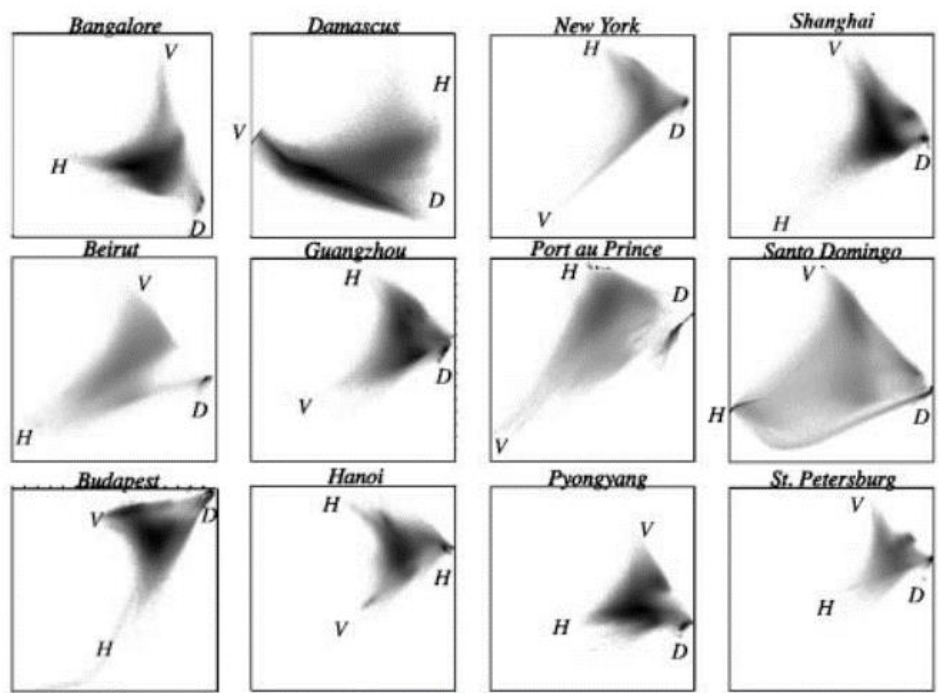
Optical RS - The urban spectral mixing space

- Information from multi-spectral imagery can be used to statistically derive multi-dimensional surface **feature spaces** based on physical reflectance properties.

V: Vegetation
H: High Albedo
D: Dark Surface

Different surface reflectance spectra

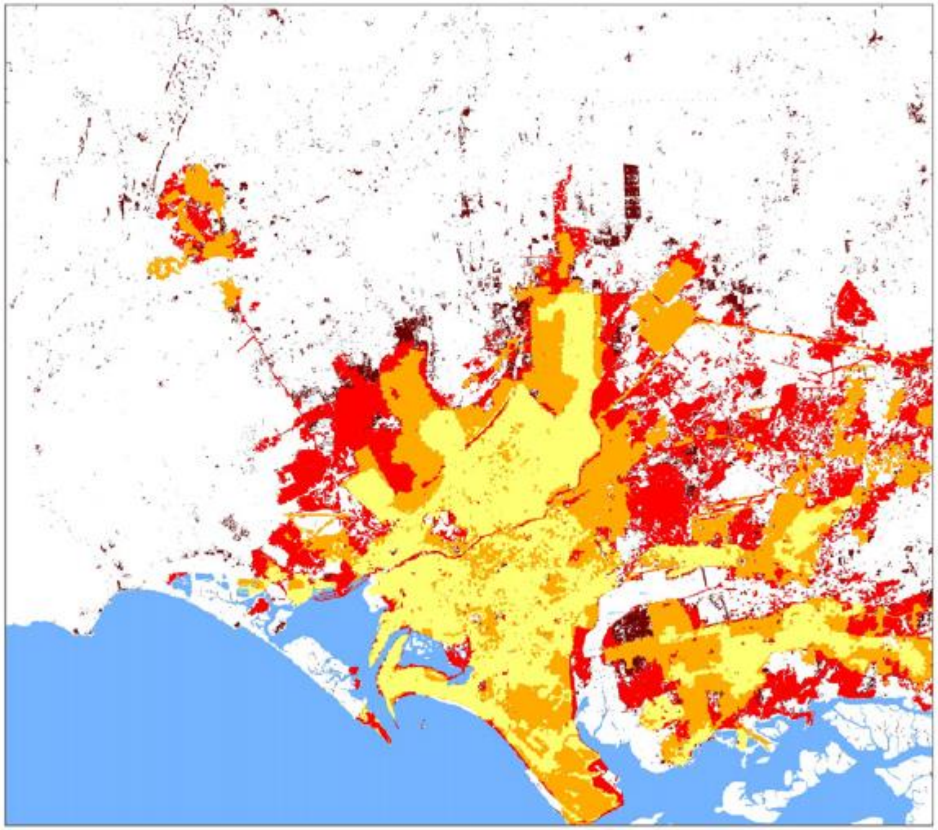




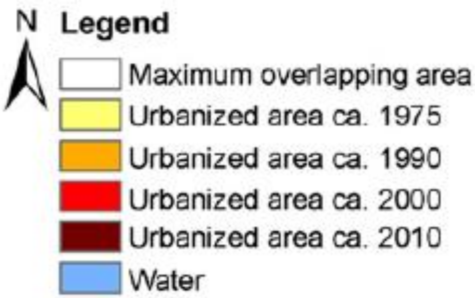
Small 2005

State-of-the-art remote sensing in urban mapping

Optical RS and SAR - Urban surface classification



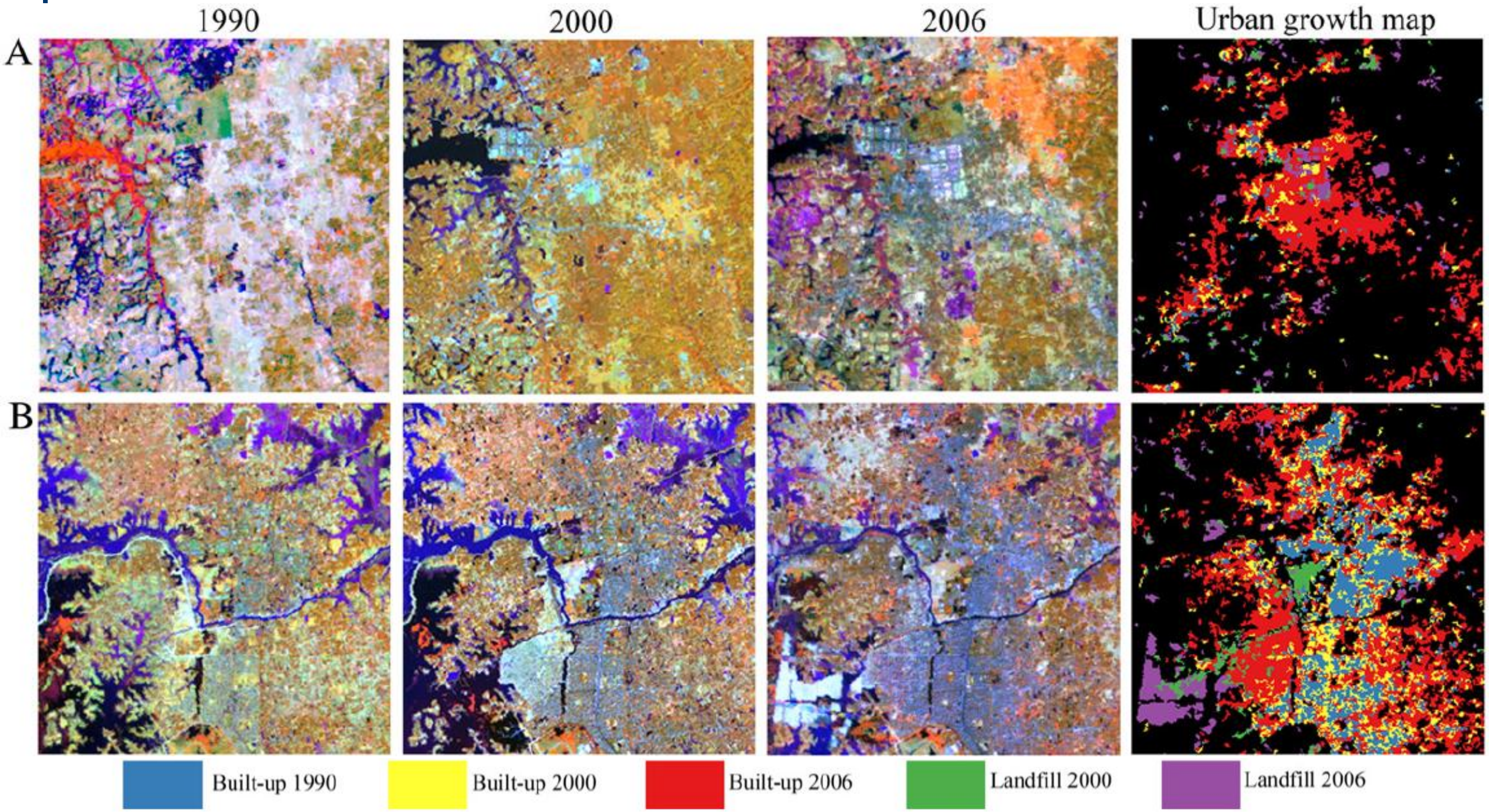
Karachi, Pakistan



Taubenböck et al. 2012 used data from TerraSAR-X and Landsat to **quantify urban growth for global mega cities** since 1975 in four time steps.

State-of-the-art remote sensing in urban mapping

Optical RS and SAR - Urban surface classification

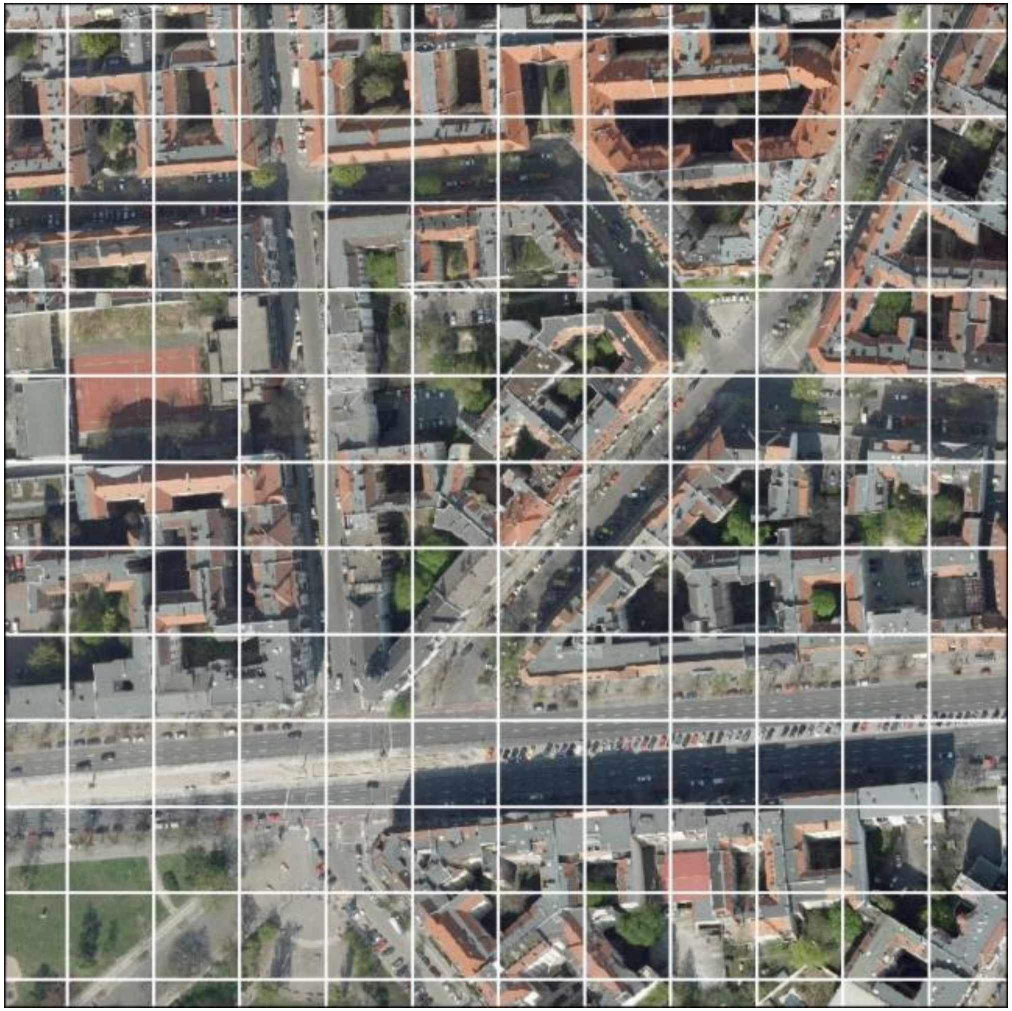


Griffiths et al. 2010 monitored the **growth of Dhaka** from 1990 to 2006 using fused optical and SAR data (here: Landsat TM/ETM+ & ERS-1/ASAR).

State-of-the-art remote sensing in urban mapping

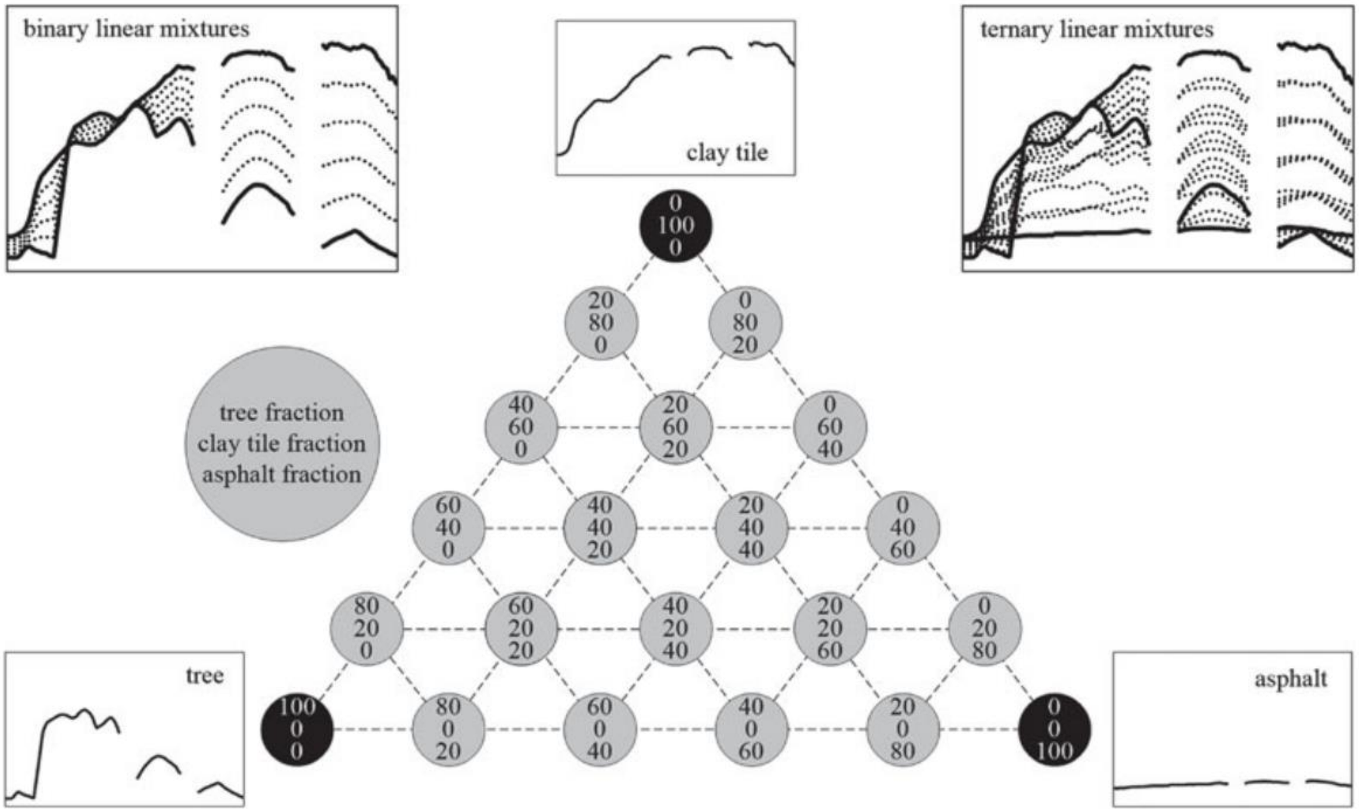
Optical RS - Urban surface classification and fractions

Most urban areas are composed of objects that are smaller than pixel size: mixed pixel problem.



State-of-the-art remote sensing in urban mapping

Optical RS - Urban surface classification and fractions

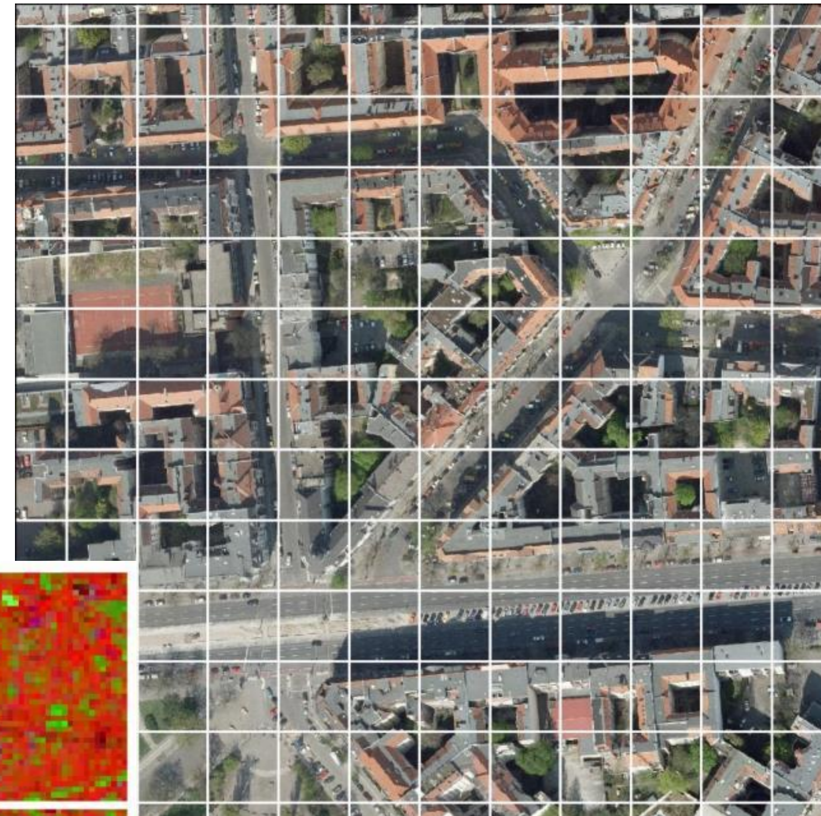


Okujeni et al. 2017 used a Support Vector Regression approach with synthetic spectral mixing to derive **surface fractions** for gradual urban mapping and thematic enhancement.

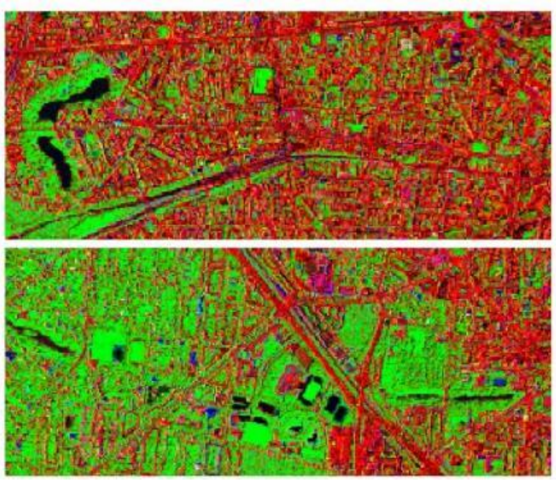
State-of-the-art remote sensing in urban mapping

Optical RS - Urban surface classification and fractions

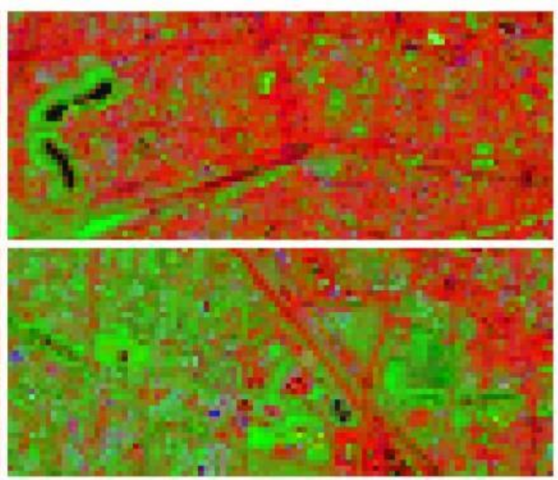
… This helps to quantify land cover and counteract the mixed pixel problem.



HyMap (9 m)

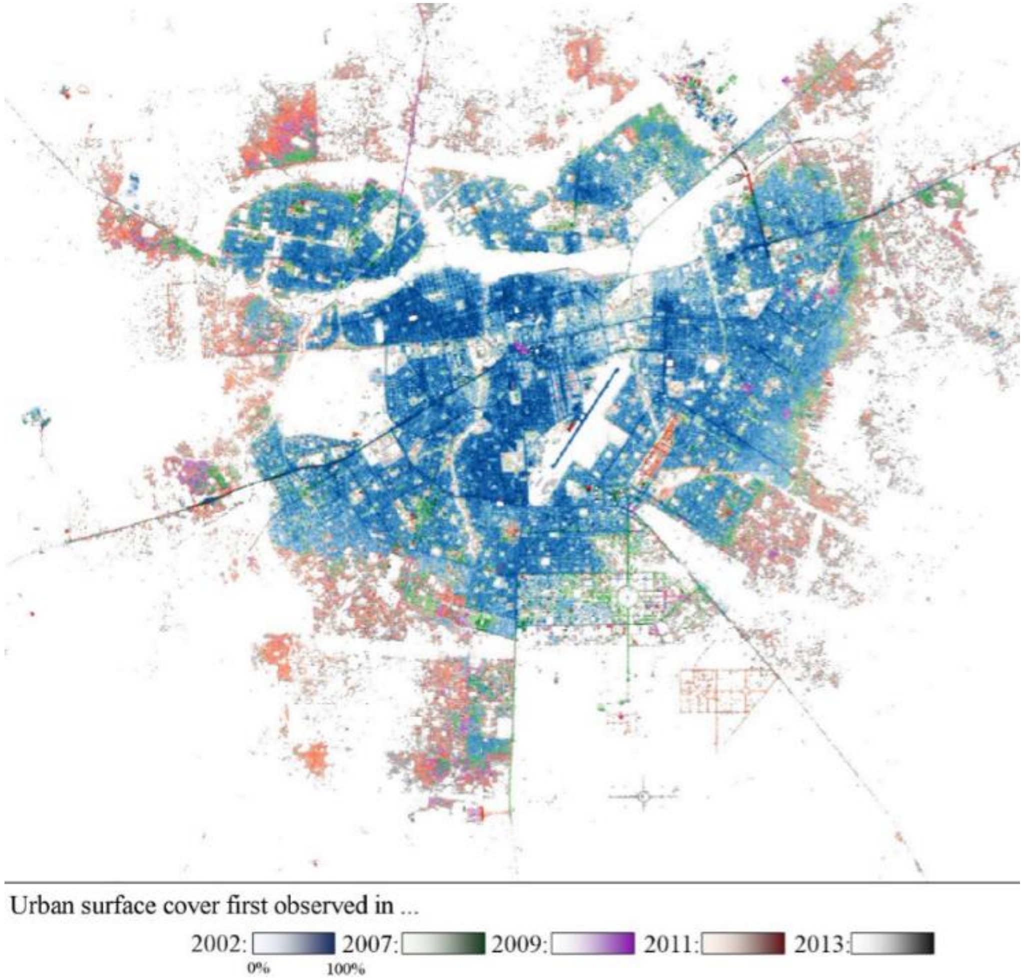


Landsat (30 m)



State-of-the-art remote sensing in urban mapping

Optical RS - Urban surface classification and fractions

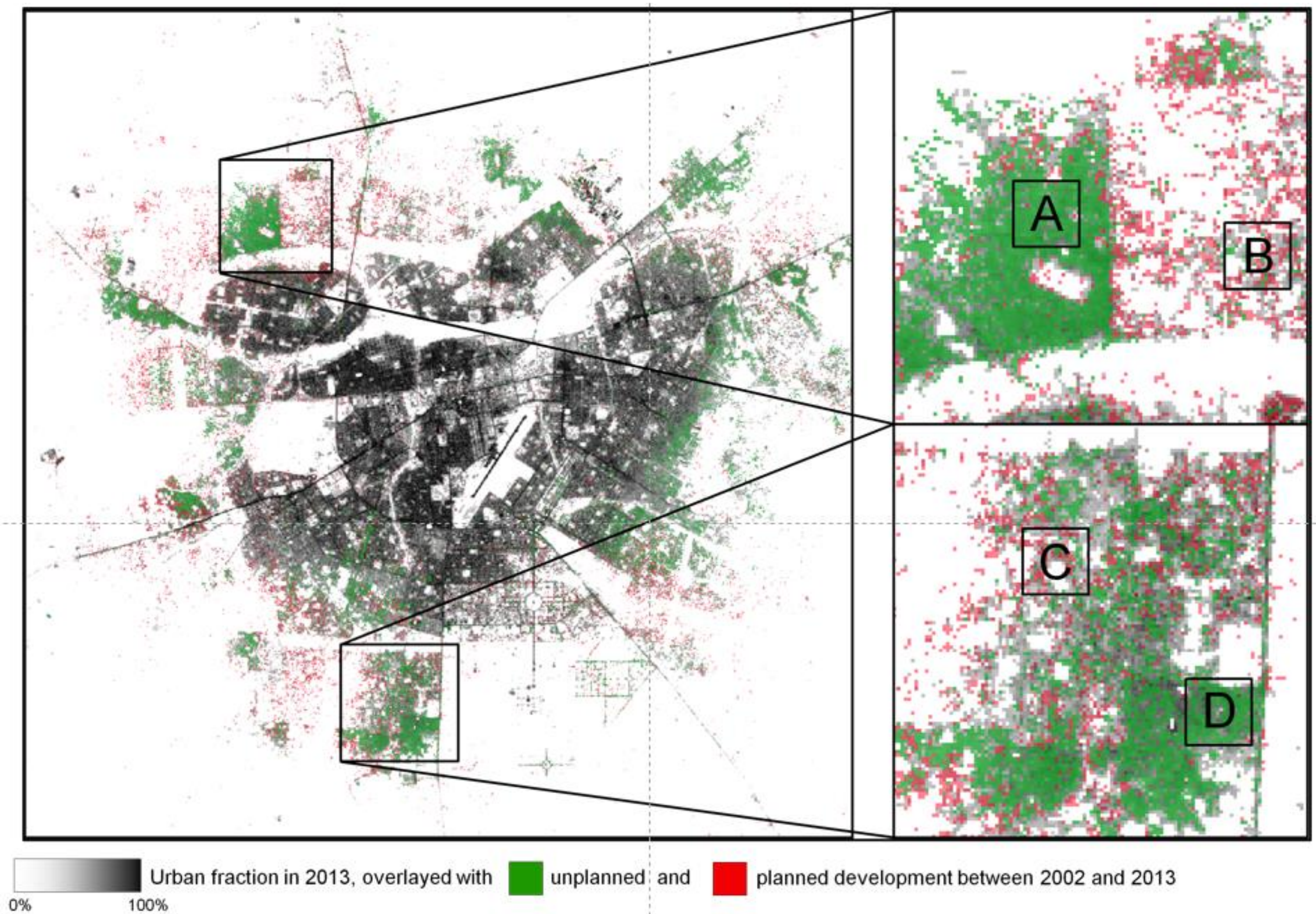


Schug et al. 2018

Combined with historic satellite data, gradual LC information can serve to identify the age and density of settlements.

State-of-the-art remote sensing in urban mapping

Urban development patterns and typology



A & D:

Unplanned development

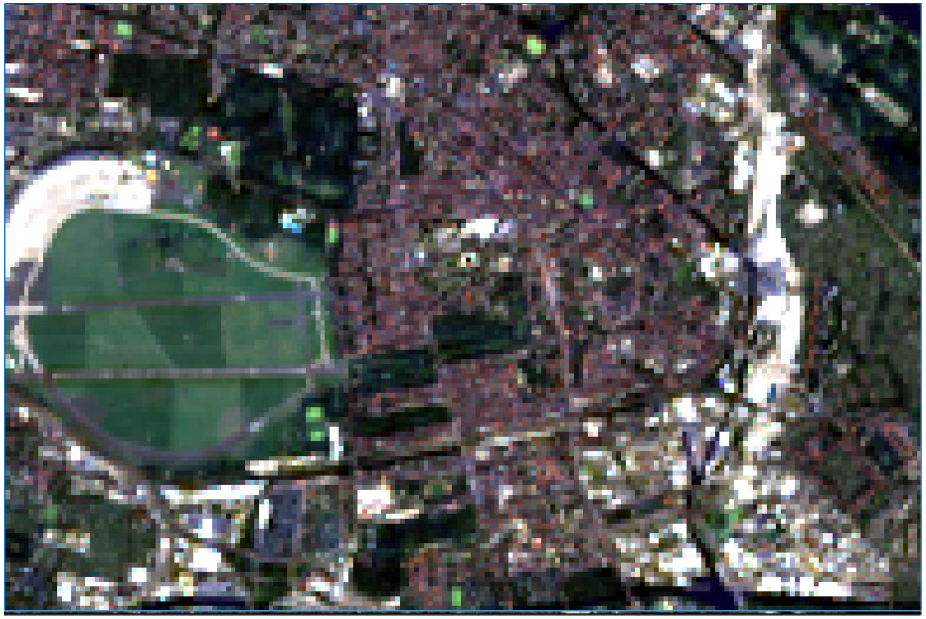
B & C:

Planned development

Indices and metrics can then be used to identify types of urban development.

Remote sensing data and indicators

Sensors (Selection)



Sentinel-2

High res. multi-spectral images w/ global coverage + high revisit rate. Similar processing to Landsat 8.

Spatial coverage: global (56° S – 83° N)

Best temporal coverage: max 5/10 days since 2017

Spatial resolution: 10m / 20m

Spectral bands: 10 (13)

Landsat 8 OLI

Long-term earth observation data with approved methods, widely used, now in its 8th generation.

Spatial coverage: global (85° S – 85° N)

Best temporal coverage: 16 days since ~ 2013

Spatial resolution: 30m

Spectral bands: 8 (11)

Remote sensing data and indicators

Sensors (Selection)

Source: *Small et al., 2018*

Night-Time Lights

Settlement and activity detection through night time illumination. Population estimates.

Spatial coverage: global (ca. 85° S – 85° N)

Best temporal coverage: composites since 2016

Spatial resolution: 750m

Technology: e.g. from Suomi NPP

Sentinel-1

Global SAR with high revisit rate, independent of clouds, particular backscatter from built objects.

Spatial coverage: nearly global

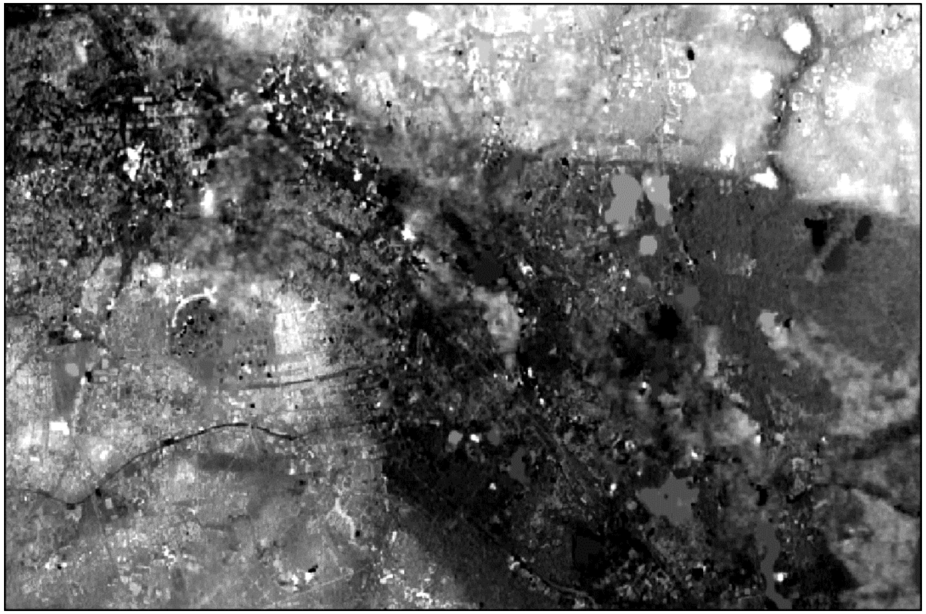
Best temporal coverage: 1-3 days since ~ 2014/16

Spatial resolution: 10m

Technology: C-Band SAR

Remote sensing data and indicators

Height Models - Global



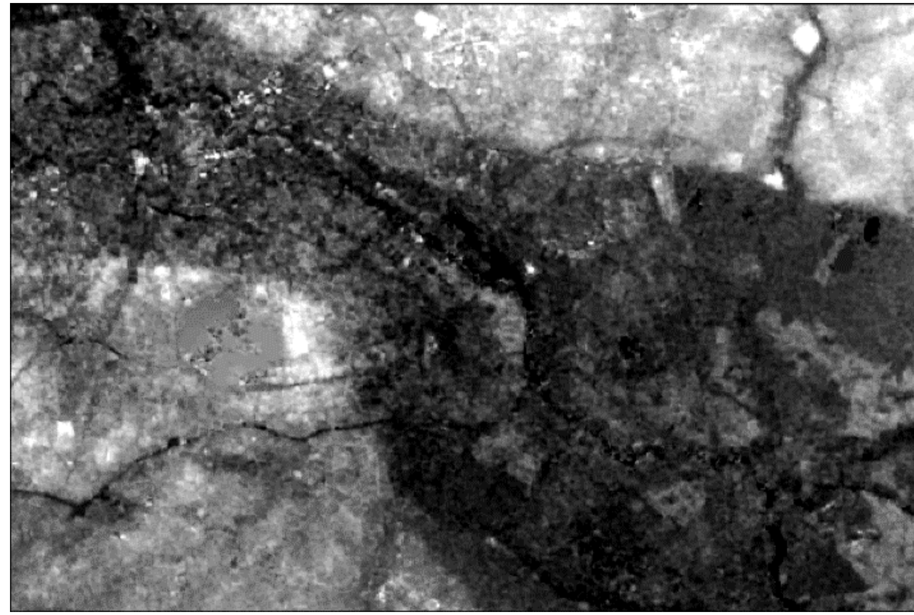
ALOS (Advanced Land Observation Satellite)

Globally available surface model (elevation model is paid) with ca. 5m vertical accuracy (1 sigma).

Spatial coverage: global

Best temporal coverage: single date (2005 – 2011)

Spatial resolution: 5m (paid) / 30m (free of charge)



SRTM (Shuttle Radar Topography Mission)

Globally available surface model with < 16m vertical accuracy.

Spatial coverage: global (56° S – 60° N)

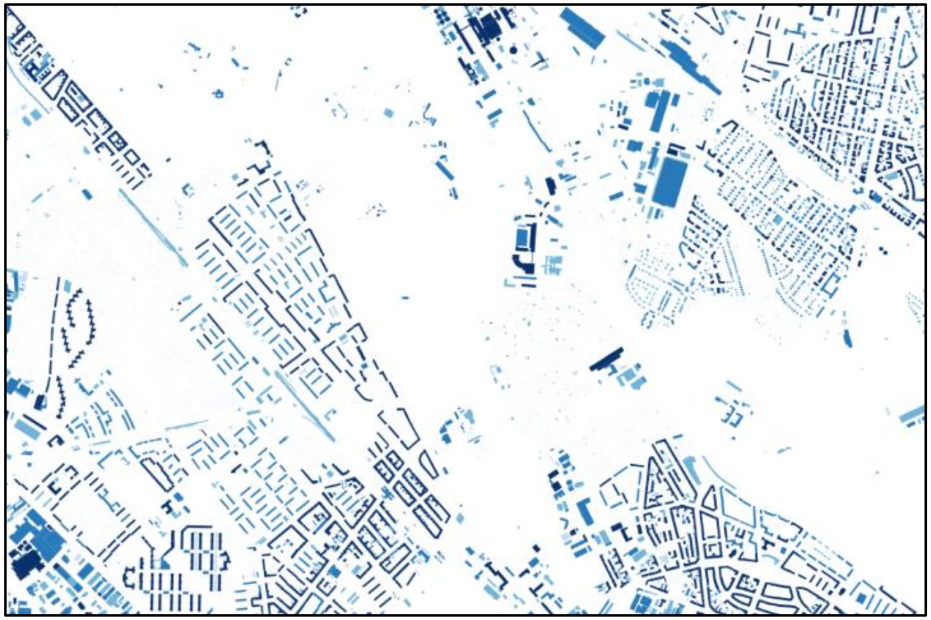
Best temporal coverage: single date (2000)

Spatial resolution: 30m

Technology: Interferometric SAR

Remote sensing data and indicators

Height Models - Local



Berlin SenStadt Building Heights

Highly accurate and detailed height information.
Stock/Volume information from area and height?

Spatial coverage: local

Best temporal coverage: single date (2014)

Spatial resolution: 0.3m

Technology: Stereo-Orthoimagery

Berlin SenStadt Vegetation Heights

Highly accurate and detailed height information.
Indicator for type of neighborhood?

Spatial coverage: local

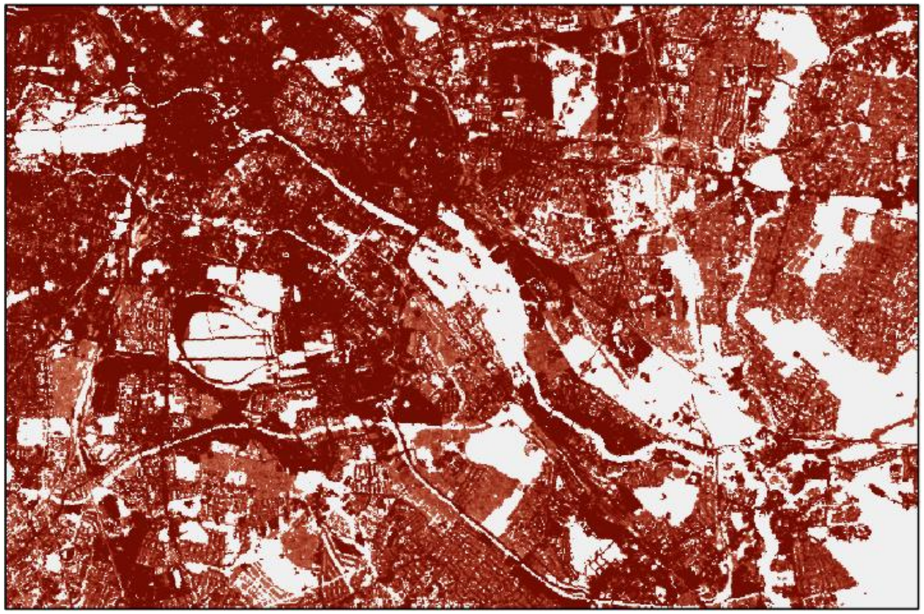
Best temporal coverage: single date (2014)

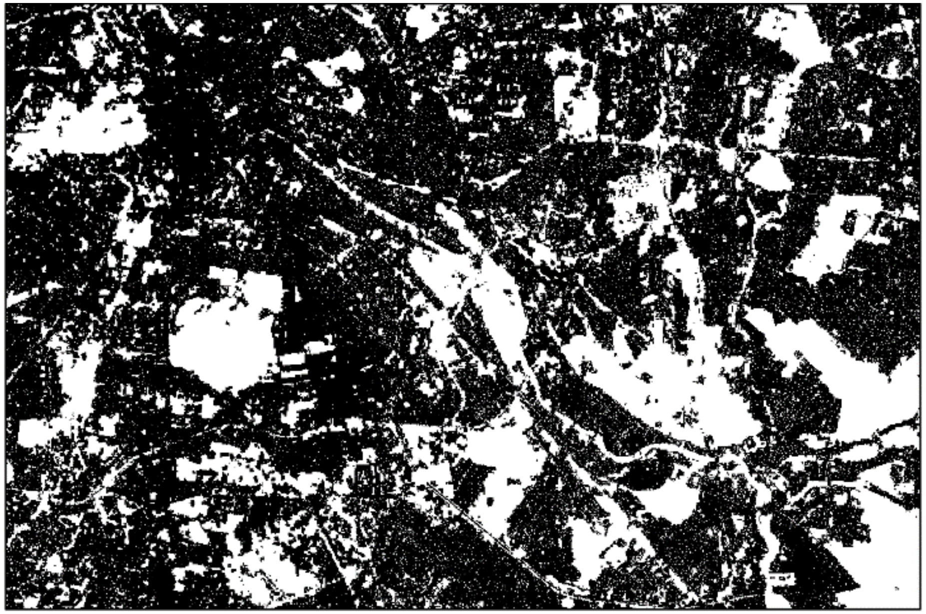
Spatial resolution: 0.3m

Technology: Stereo-Orthoimagery

Remote sensing data and indicators

Ready-to-use products – Regional and Global





Copernicus Imperviousness Layer

Gradual imperviousness information. Validated based on LUCAS scheme.

Spatial coverage: EEA 39

Best temporal coverage: 3 years (2006 – 2012)

Spatial resolution: 20m

Technology: NDVI, CLC and "additional EO data"

Global Urban Footprint

Globally available product mapping vertical structures.

Spatial coverage: global

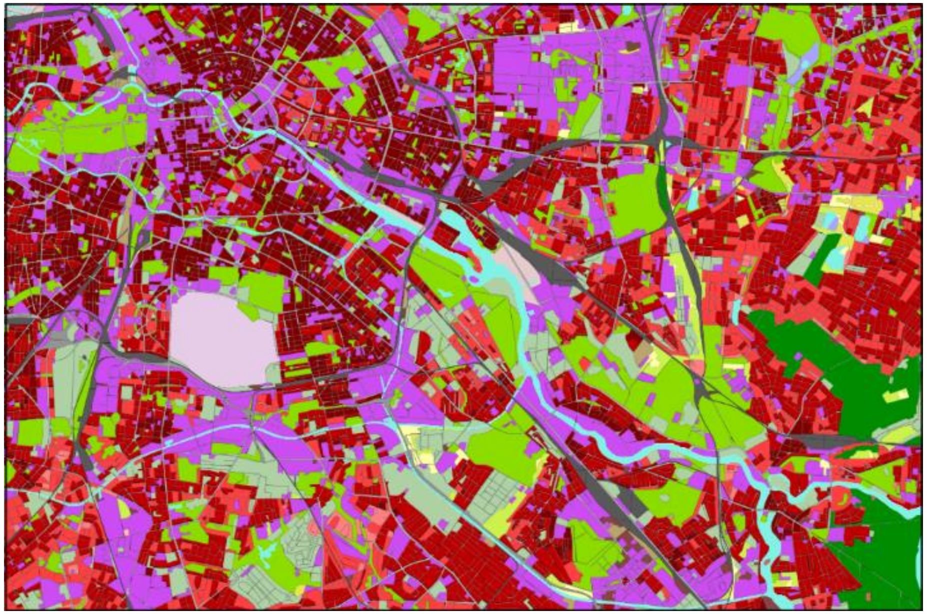
Best temporal coverage: single date (2012)

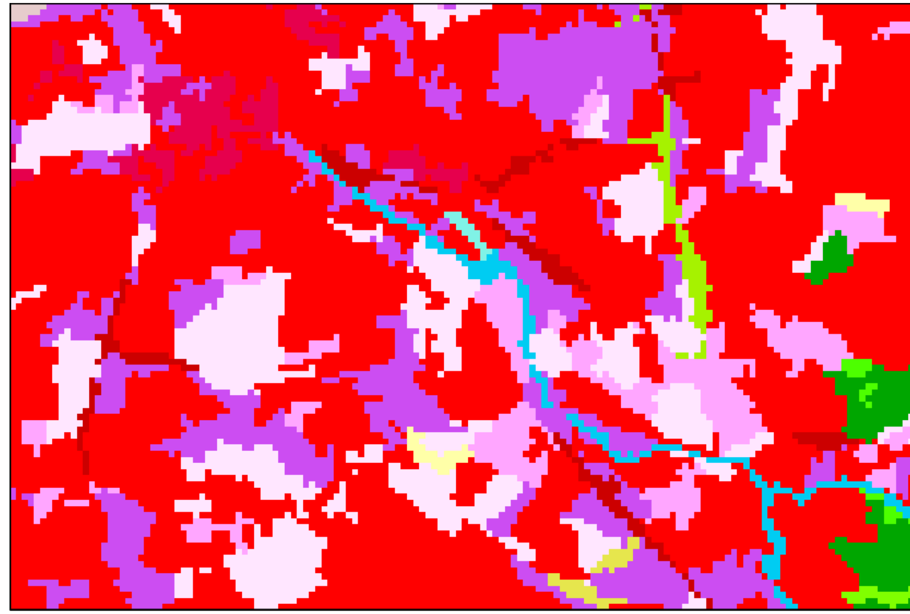
Spatial resolution: 0.4 arc sec (~ 12m – 84m)

Technology: TerraSAR-X and TanDEM-X

Remote sensing data and indicators

Ready-to-use products – Local and Regional (e.g. Europe)





EEA Urban Atlas

27 classes, 15 related to built infrastructure. 85% accuracy for "artificial surfaces".

Spatial coverage: EEA 39 where pop. > 50.000

Best temporal coverage: 6 years (2006 – 2012)

Min. mapping unit: 0.25 ha

Technology: SPOT 5/6 + Formosat 2 Classification

CORINE Land Cover

44 land cover classes, ~ 12 related to infra-structure. "≥ 85%" accuracy.

Spatial coverage: EEA 39

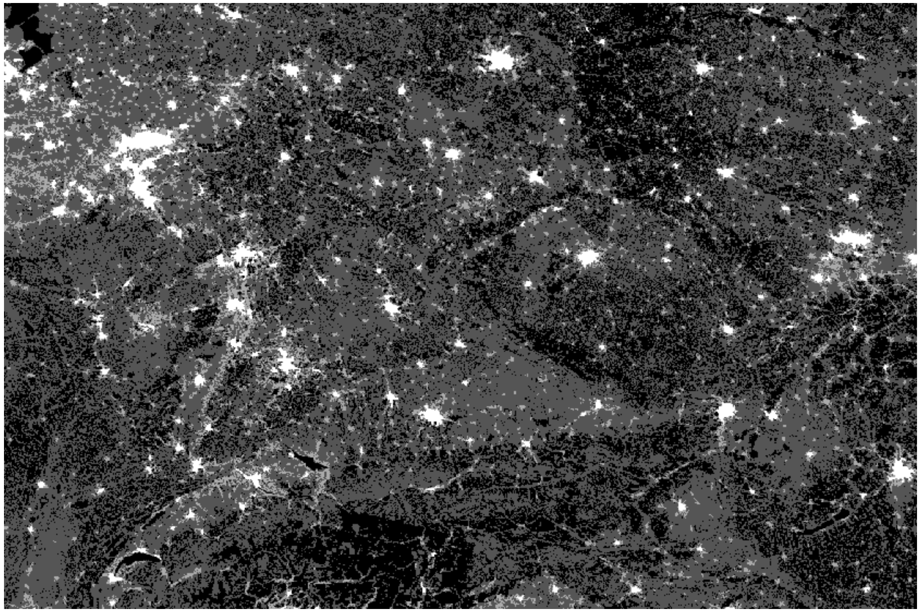
Best temporal coverage: 6-10 years (1990 – 2012)

Min. mapping unit: 25 ha

Technology: IRS P6 LISS III and RapidEye (2012)

Remote sensing data and indicators

Ready-to-use products - Global



Global Human Settlement Layer

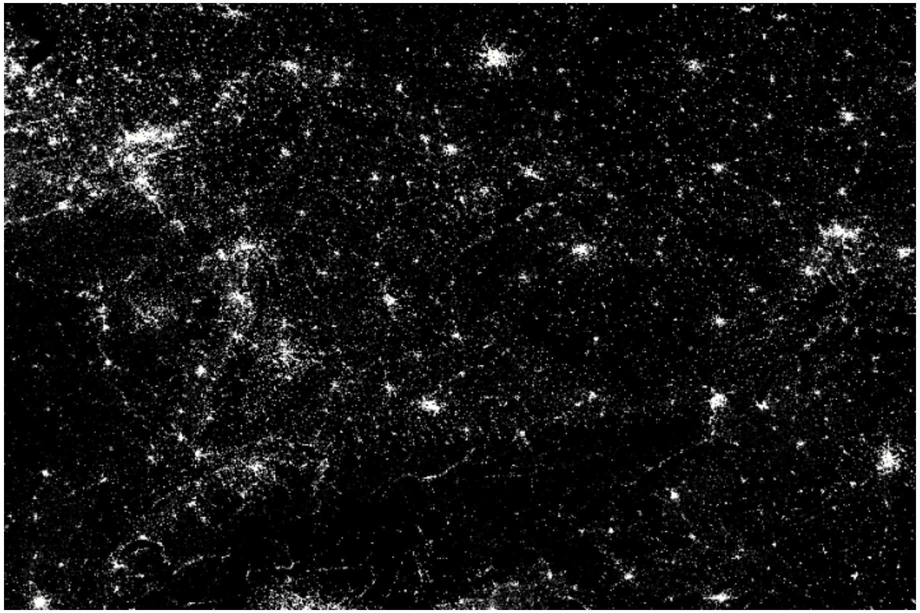
Settlement product maps rural areas, urban clusters and urban centers (3 classes).

Spatial coverage: global

Best temporal coverage: 10-15 years (1975 - 2015)

Spatial resolution: 1000m

Technology: GHS Built-Up & Population Layer



Global Human Settlement Layer

Population product maps population per area in absolute numbers.

Spatial coverage: global

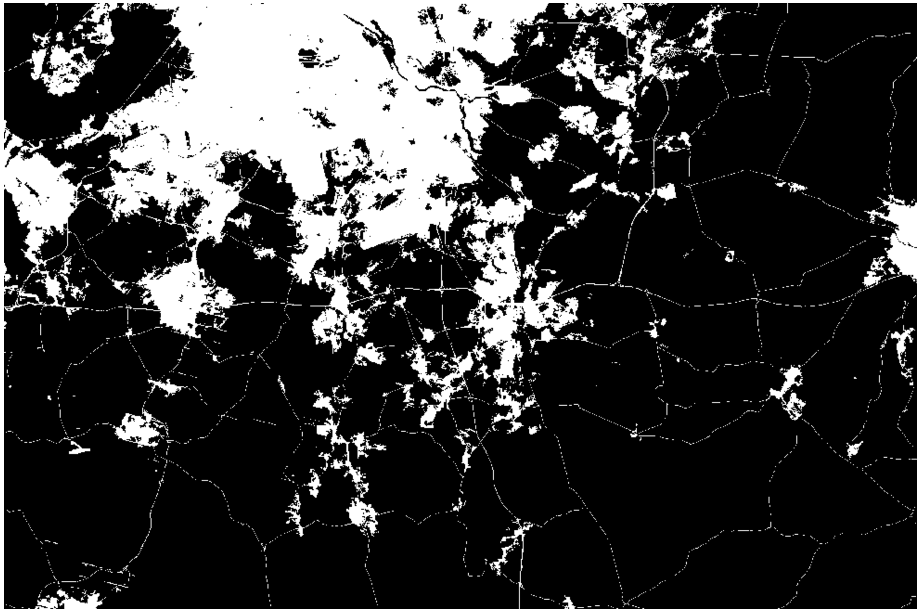
Best temporal coverage: 10-15 years (1975 - 2015)

Spatial resolution: 250m

Technology: EUROSTAT, GPW, GHS Built-Up Layer

Remote sensing data and indicators

Ready-to-use products - Global



HBASE (Glob. Hum. Built-up And Settlement Ext.)

Maps built-up areas and roads separately in order to give an extent of built-up land cover.

Spatial coverage: global

Best temporal coverage: single date (2010)

Spatial resolution: 30m

Technology: Global Land Survey Landsat dataset

GMIS (Global Man-made Impervious Surface)

Maps imperviousness from 0 to 100 based on Landsat imagery.

Spatial coverage: global

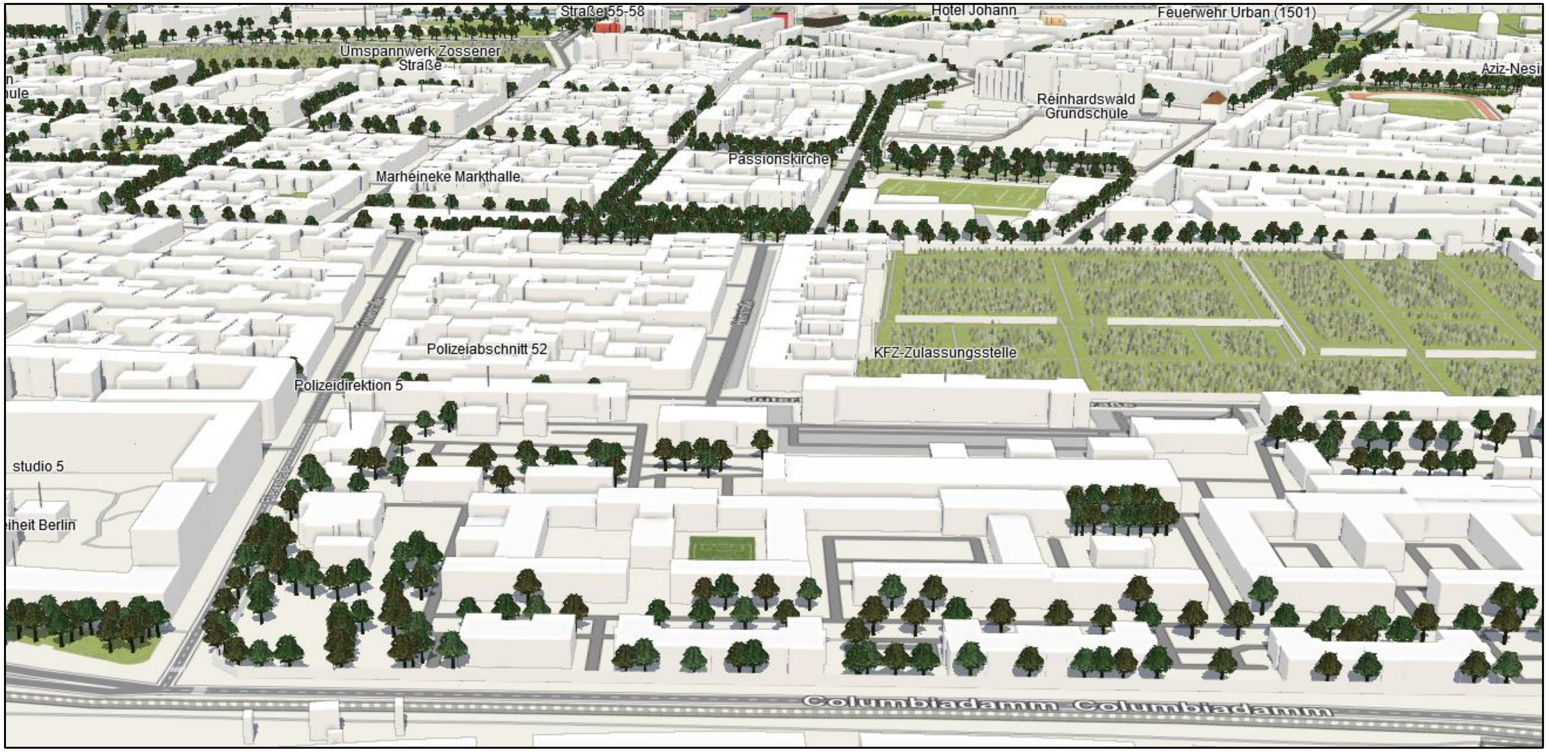
Best temporal coverage: single date (2010)

Spatial resolution: 30m

Technology: Landsat

Remote sensing data and indicators

Ready-to-use products – (Global)



OpenStreetMap

Contains very detailed height information for selected buildings and regions. Continuously evolving. Large regional differences in quality.

Spatial coverage: global

Remote sensing data and indicators

Further data

Very High resolution imagery (e.g. for object recognition)

Additional Surface Models (e.g. TanDEM-X DSM with 0.4 arc sec resolution)

Socio-Economic datasets (e.g. from Socioeconomic Data and Applications Center (SEDAC) on population, demography, settlements, hazardous waste sites, climate zones, …)

Additional land cover classifications (e.g. LUCAS, MODIS Land Cover Product, …)

Global Ecosystem Dynamics Investigation (GEDI) LiDAR. Global high resolution LiDAR product to be launched in late 2018.

…

Linking remote sensing to material stocks

Regional workflow differences

Best case	Intermediate case	Worst case
• Various remote sensing data, cloud-free in a high temporal resolution • Accurate additional data products for large areas and at high spatial resolution, e.g. surface models, OpenStreetMap • In-situ data validation possible • Accuracy and relevance of single products can be explored e.g. a European capital	• Various remote sensing data with acceptable temporal gaps • Single additional products to support metrics identification, e.g. basic OSM data • Remote data validation possible e.g. a larger area in a developed country	• Globally available remote sensing data at selected points in time • Globally available additional products, e.g. population density or Global Urban Footprint • Limited validation possible e.g. a rural area in a developing country

Module overview

Goals, research questions

- Establish wall-to-wall maps of the spatial material stock distribution based on remote sensing data
- Create a typology of spatial patterns of material stocks

Following steps

- Role out model to similar regions (iterative adaptation)
  - What are similar regions? (Archetypes)
- Role out model to worse cases (test global model on best cases)
- Excursus: annual mapping 1973-2018 for selected region

Linking remote sensing to material stocks

Status

Bachelor’s Thesis: The combined urban feature space of Sentinel-2 and height information

Data availability overview

Project planning and structuring

PostDoc: Application phase ends April 18th!

Upcoming dates

Sept. 2018 EARSeL Joint Workshop “Urban Rem. Sens. - Challenges & Solutions”, Bochum

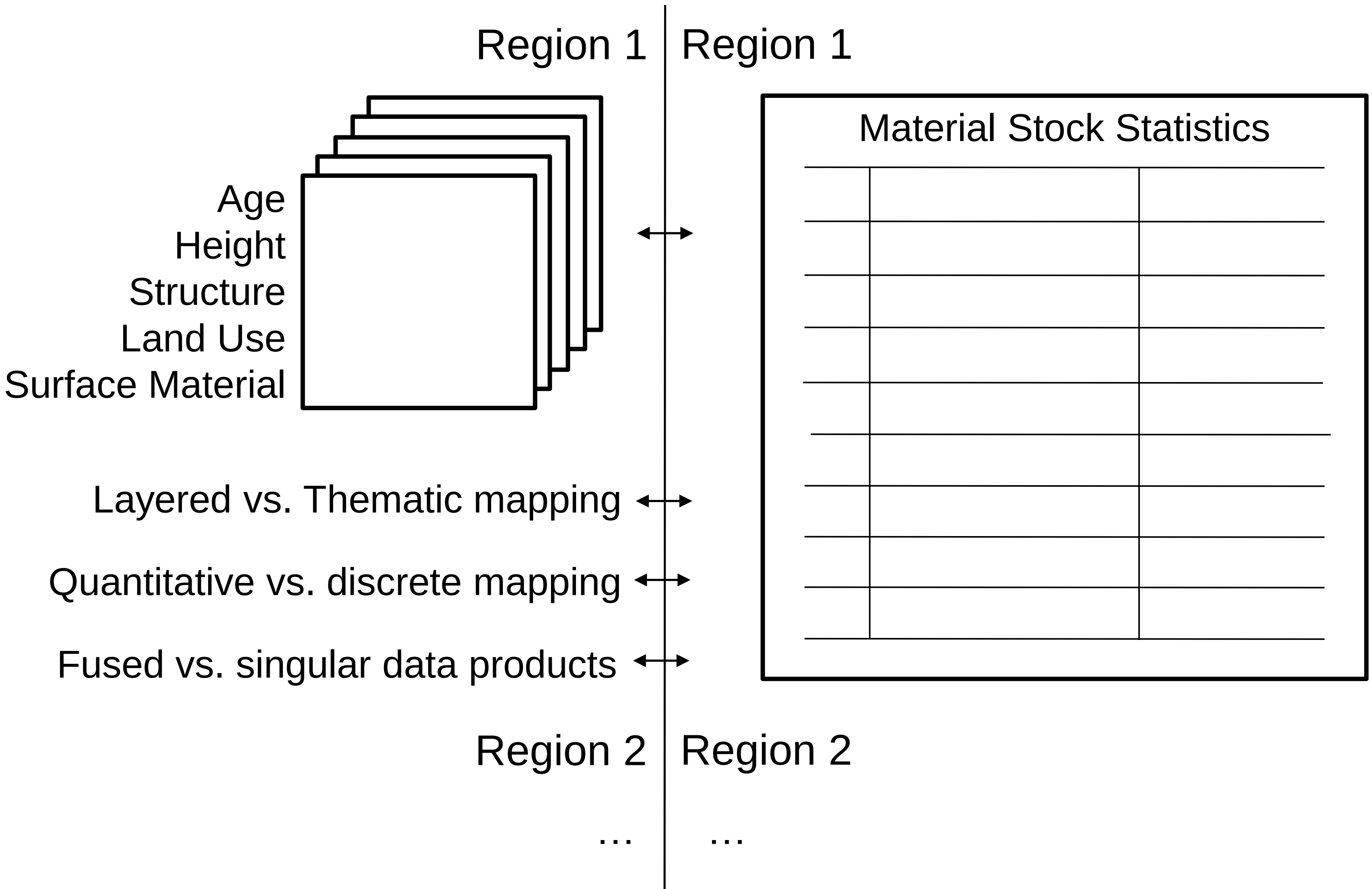
- Sentinel-2 data and machine learning regression at different spatial resolutions
- Support vector regression & bi-seasonal landsat time series for urban pattern mapping

Nov. 2018 Mapping Urban Areas From Space, Frascati, Italy

- Conceptual presentation: Linking remote sensing to material stock patterns

Linking remote sensing to material stocks

Discussion



Linking remote sensing to material stocks

Discussion

- What material categories or specific materials are crucial to material stocks research?
- What are possible indicators for material stock distribution (building heights, patch metrics, urban typology, human activity)?
- How to make the link between remote sensing and stocks (and services)?
- Regional preferences?
- Global vs. local and coverage vs. accuracy?
- Potential of urban archetype definition?

References

Small et al. (2018). In S. Liang: Comprehensive Remote Sensing. Elsevier.

Griffiths et al. (2010). Remote Sensing of Environment, 114, 426-439.

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MODULE 3 – ANALYZING THE STOCK-FLOW-SERVICE NEXUS

Activities

Overarching goal: Empirically analyze the SFS-nexus and relate it to economic (e.g. GDP, HDI), geographic and environmental variables, using statistical methods

- Across space for national-level and GIS/remote sensing data for a base year (2015?)
- Along temporal trajectories, based primarily on global and case-study long-term time series data
- using data from M1 and M2 as well as auxilliary data from many sources, e.g. CDIAC, World Bank, OECD, UN, climate & soil data, etc.

Out of the box thinking --- beyond IPAT, resource productivity, eco-efficiency

Stock-flow-service nexus

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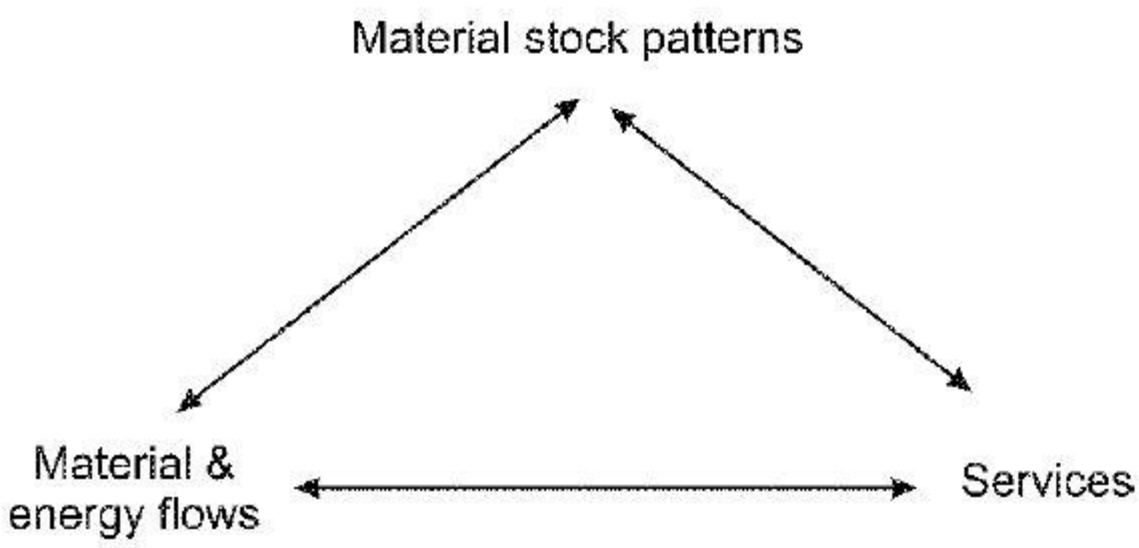

Systematic investigation of the SFS nexus will allow analyzing critical interrelations between the flows used to build-up, maintain and use these stocks and the services they provide

Questions to be asked (proposal)

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- **Minimum levels of material stocks** required to achieve selected SDGs
- The **role of spatial patterns** (typology of patterns, M2) for the SFS-nexus. E.g. network theory, density-diversity-design framework, entropy-based indices of economic concentration or inequality
- Test for **scaling laws** of social metabolism
- Analyze long-term trajectories using **index decomposition analysis**, **panel data analysis** or similar techniques

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MODULE 4 – MODELLING SCENARIOS

Goals for Module 4: dynamic modelling

Overarching goal: **Establish a global, dynamic model suitable to characterize option spaces for future socioeconomic metabolism (stocks, flows & services) until 2050, including a GHG module**

Specific goals:

- Calculate resource requirements resulting from estimates of future stocks required to achieve selected SDGs (2030 & beyond)
- Evaluate the implications of resource constraints respectively emission budgets compatible with 2.0°C and other targets for building up stocks and delivering services
- Calculate emission trajectories up to 2030/50 for selected scenarios

Highly relevant results for climate assessments, modelling communities and sustainability transformations

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Draft model specifications

- **System-dynamic simulation model** without cost-optimization integrating a stock-flow model (dynamic stock model) with the analysis of biophysical **option spaces** (similar to BioBaM)

- Calculate resource requirements, GHG emissions and recycling potentials in both „**what-if**" and „**forced future**" (backcasting) applications

- Can calculate stock trajectories from predefined changes in future input flows, and conversely, assess implications of resource scarcity or emission budgets on stock development

- 10-20 world regions

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MODULE 5 – TRANSFORMATION OF THE SFS NEXUS

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