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Regional Development

EnviLink 2024 - Sękocin Stary

Advancing Urban Forest Management to the Third Dimension: Integrating High-Resolution Mapping and Ecosystem Service Assessment

Markus Münzinger, 15.05.2024


How can we use High-Resolution (3D) Remote Sensing Data
to assess the Impacts of Urban Vegetation?

Dresden 3D - Solarpotential (c) Landeshauptstadt Dresden Solarpotential im Themenstadtplan (2D) Details zum 3D-Stadtmodell

Agenda

- Introduction
- Motivation to deal with Urban Forests
- Availability LiDAR Data in Europe
- Workflow Urban Forest Mapping
- Applications of 3D Tree Models

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Image: S. Schwarz/IOER Media

Leibniz Institute of Ecological Urban and Regional Development

We research for the sustainable transformation of neighbourhoods, cities and regions

The Research Area **Spatial Information and Modelling** develops and uses data-intensive and data-integrating approaches to describe, interpret and evaluate trends in settlement and open space development.

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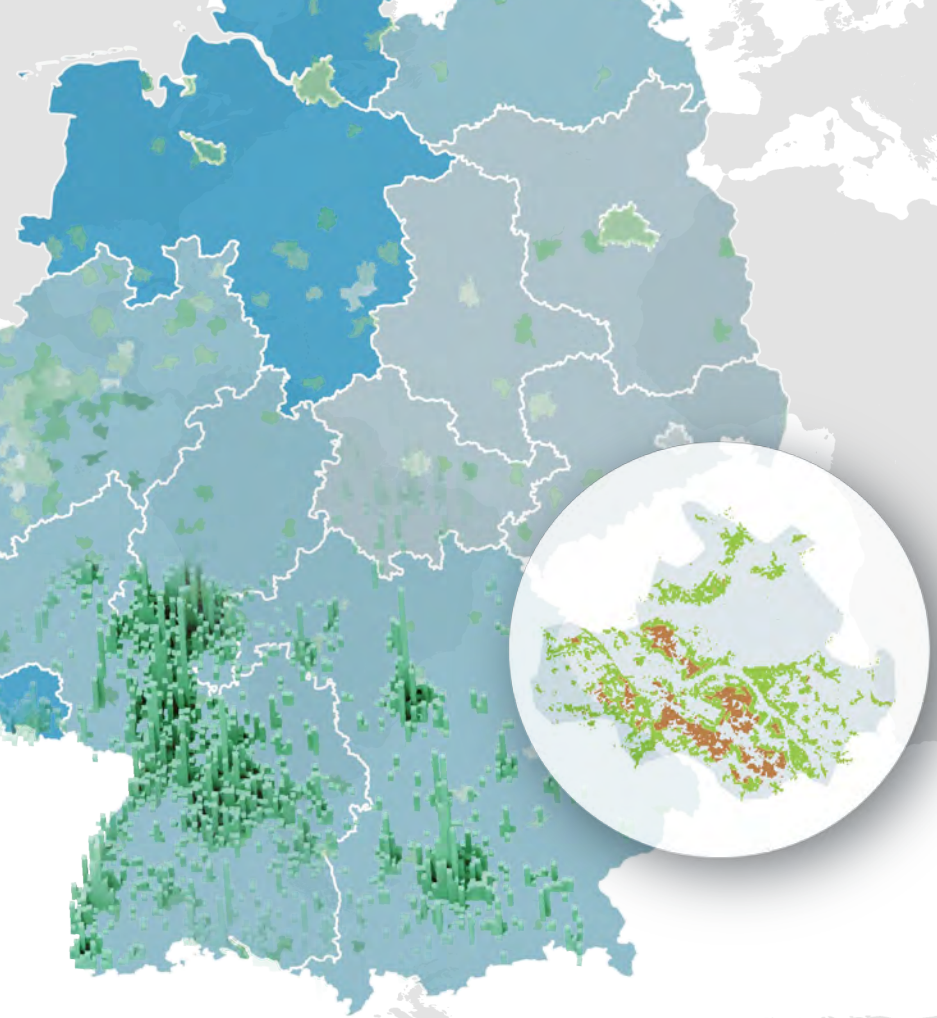

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The IOER Research Data Centre

Data, Simulations and Tools

Topics:

Land Use, Settlements, Buildings, Ecosystems ...

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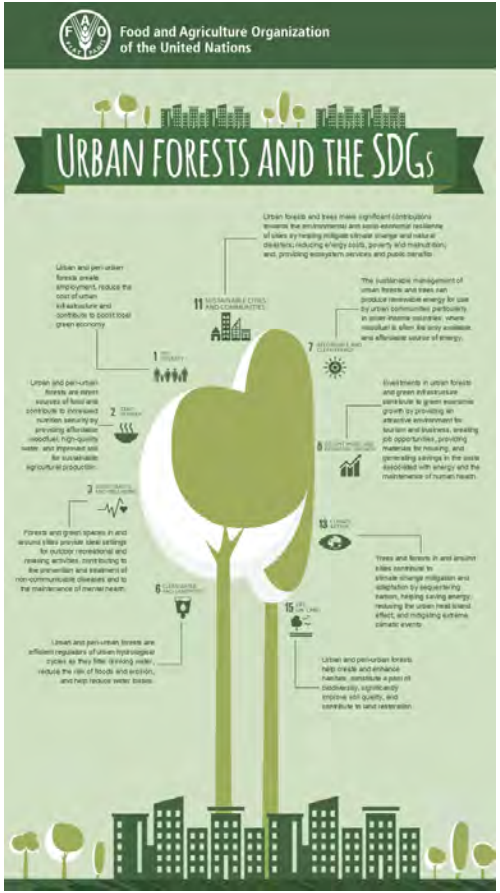
* Image credit: SangyaPundir shared under CC-BY-SA 4.0

Urban Forests

"… comprise all trees in urban and peri-urban areas (FAO 2016)."

- As a component of **Urban Green Infrastructure** it provides important **Ecosystem Services (ES)**
- As a **Nature-Based Solution** critical for climate change adaptation and sustainable land use planning



© FAO, 2016

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Assessment and Monitoring of Urban Green Spaces

Political and Legal Instruments requiring a High-Resolution Data Basis

- **EU Nature Restoration Law (2024)**

  "No net loss in the total national area of **urban green space and of urban tree canopy by 2030**, and an increase in the total area covered by green urban space by 2040 and 2050."

- **UN - System of Environmental-Economic Accounting (2021)**

  „Spatially detailed Urban Ecosystem Accounts at local scale can provide **data to support trade-off analysis or benefit-cost analysis** for spatial planning and design of policy instruments ..."

- **BBSR - Action goals for urban greenery and their empirical evidence (2018)**

  „A key element for the long-term preservation of green spaces is the **linking of objectives with indicators** supported by quantitative metrics."

Indicator	Description
Green Infrastructure	Share of green space in urban area
Green Space Provision	Green area per capita
Green Accessibility	Catchment area around public green linked to minimum size
Green Volume	Vegetation height per m^2 reference area
...	

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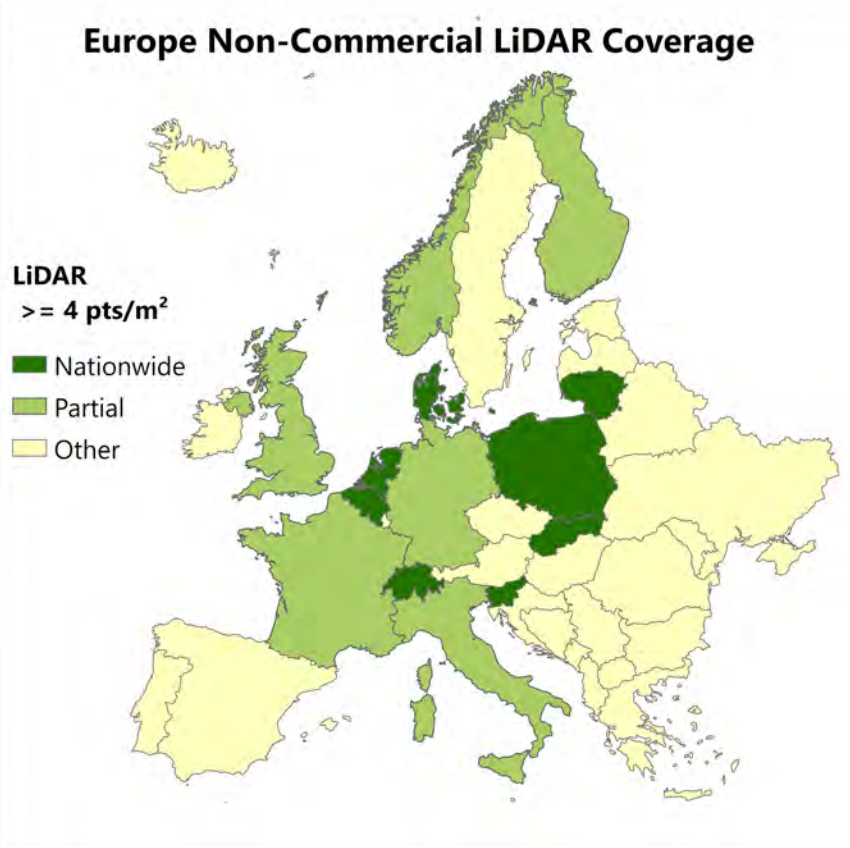
Open Data Availability

Nationwide LiDAR with Densities >= 4 pts/m²

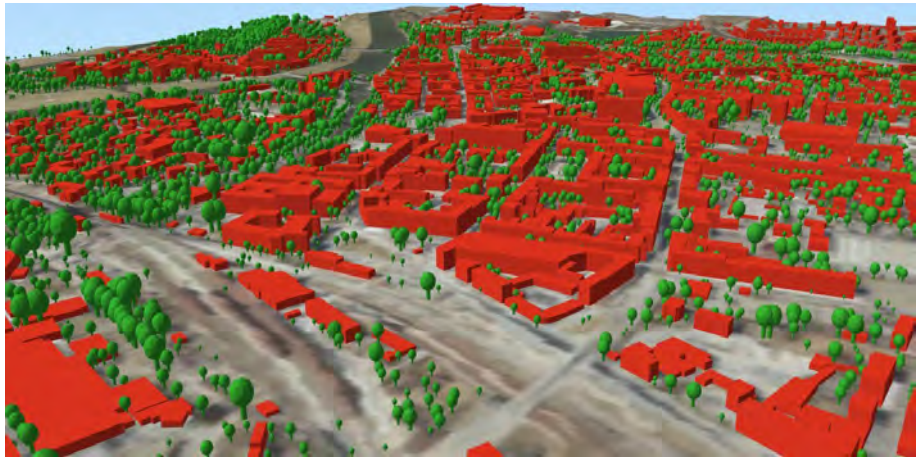
©EC, 2021



GUGiK - 3D Tree Model Poland

Automatically Generated 3D Tree Models

- Głównego Urzędu Geodezji i Kartografii (GUGiK) / Head Office of Geodesy and Cartography releases 3D models of trees for the Opole Voivodeship
- Models for Trees with Heights above 4 m
- https://www.geoportal.gov.pl/pl/dane/inne-dane/modele-3d-drzew/



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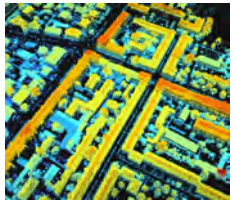
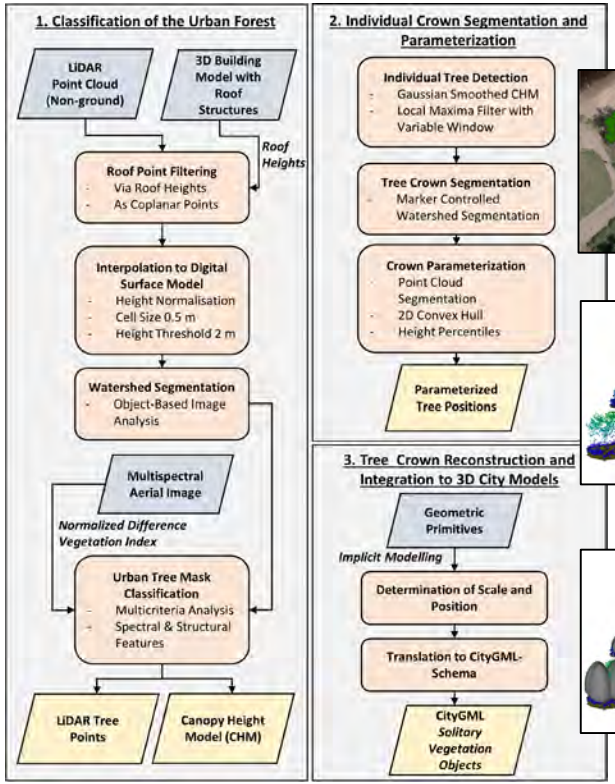
Overview: 3D Tree Model Processing from LiDAR

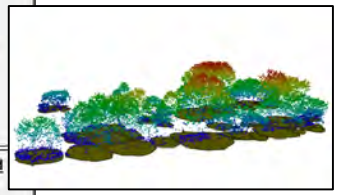
Regional-Scale Modeling

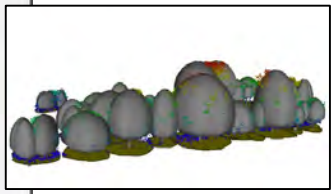
- Workflow from point cloud to 3D city model
- Design for large-scale processing
  - Point clouds with resolution >= 4 pts/m^2
- Currently focusing on urban areas

GitHub https://github.com/markusmnzngr/LiDAR-3D-Urban-Forest-Mapping









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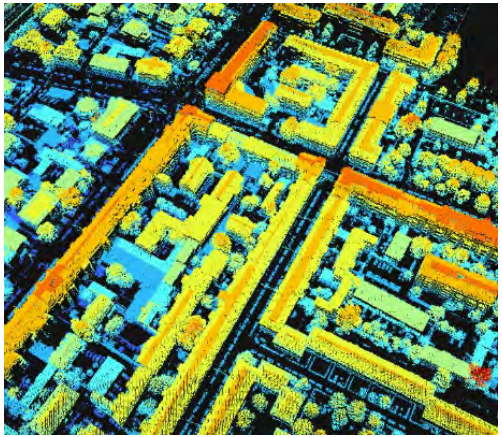
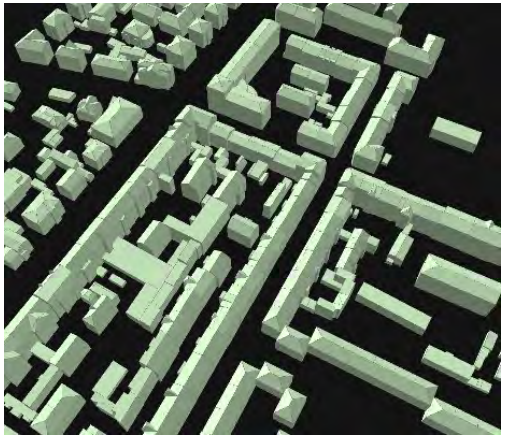
Urban Forest Modeling

Overview Input Data

LiDAR Point Cloud
Min. Density 4 pts./m^2
Surface Points



3D Building Model
Level of Detail (LoD) 2
CityGML



Aerial Imagery
Multispectral (RGBI)
20 cm Resolution

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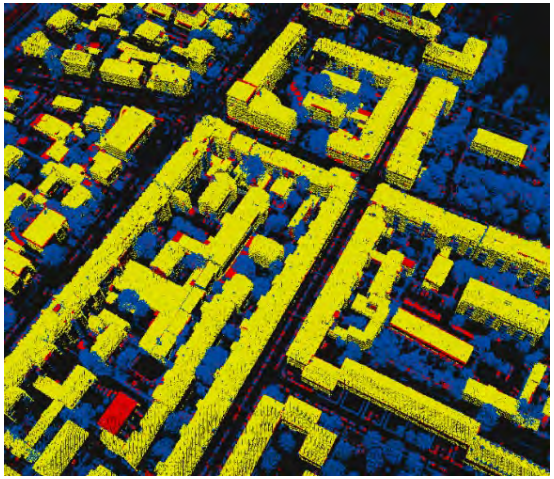
Classification of the Urban Forest

Roof Point Filtering

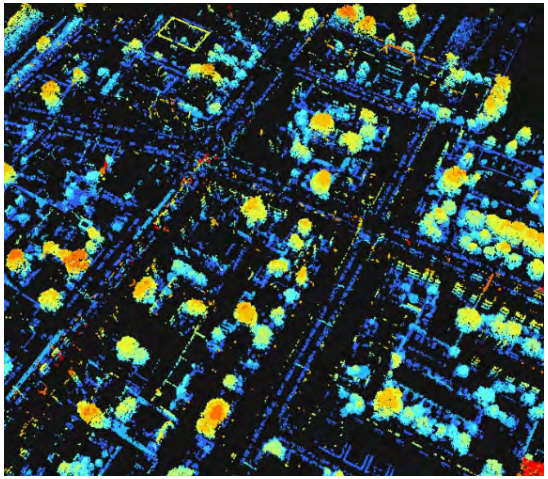
- Classification via 3D Building Model
- Classification via Coplanarity of Points
- Tree crowns above building roofs stay in the point cloud
- Point cloud still contains various anthropogenic objects



Classified Point Cloud

- Potential Tree Points
- Classified via 3D Building Model
- Coplanar and not in 3D Building Model

Filtered Point Cloud



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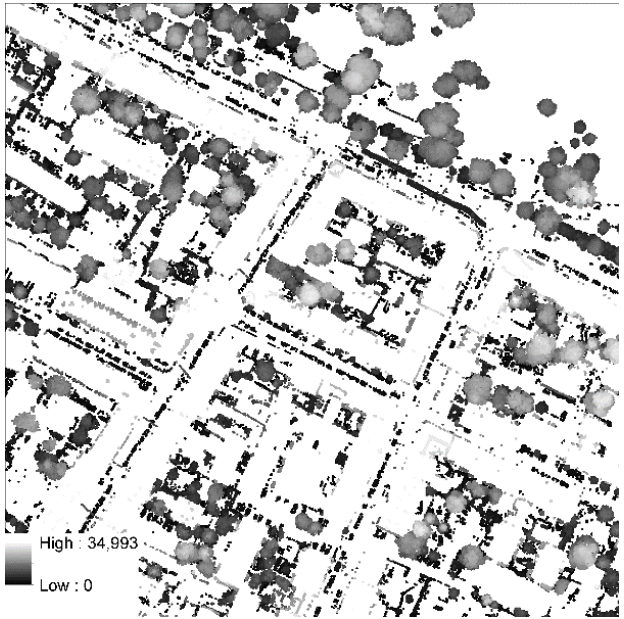
Classification of the Urban Forest

Interpolation to Digital Surface Model (nDSM)

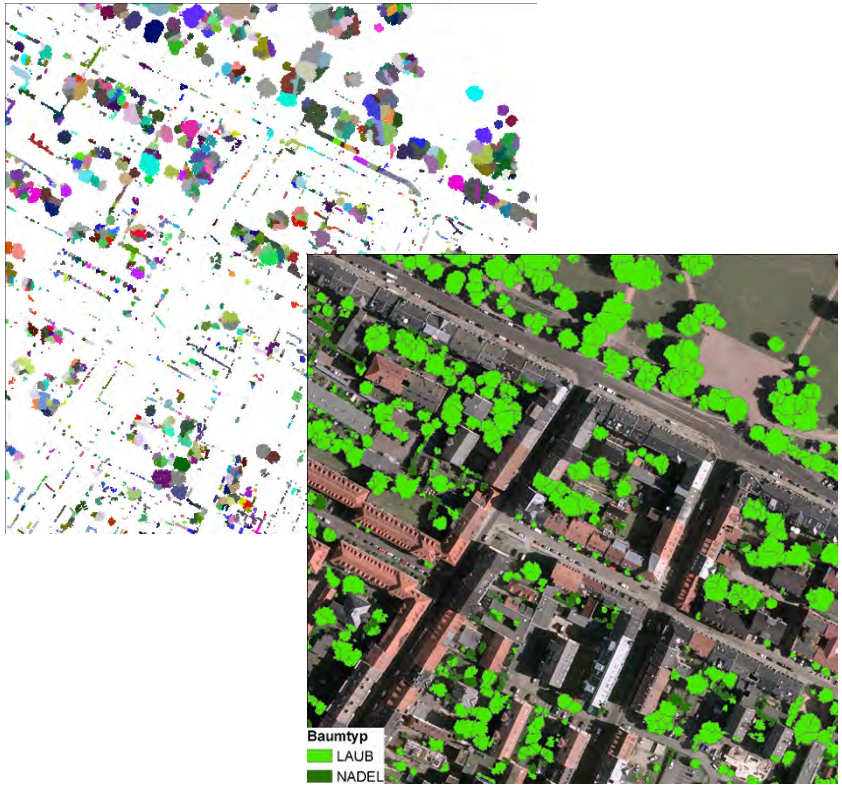
- Height normalize point cloud
- Rasterize with 0.5m cell size
- Value of highest point in each cell
- Digital Surface Model (nDSM)
- Height threshold of 2m on nDSM



Classification of the Urban Forest

Multicriteria Analysis

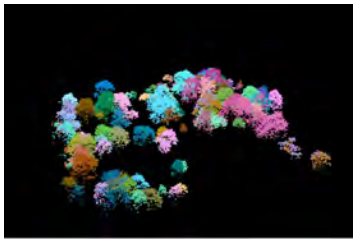
- Watershed – Segmentation
  - Approximation of crown shape
- Classification based on multiple features
- Calculated features:
  - Mean Number of Returns
  - Mean NDVI
  - Compactness of the segment weighted by size
  - Difference between first and last pulse



Individual Crown Segmentation

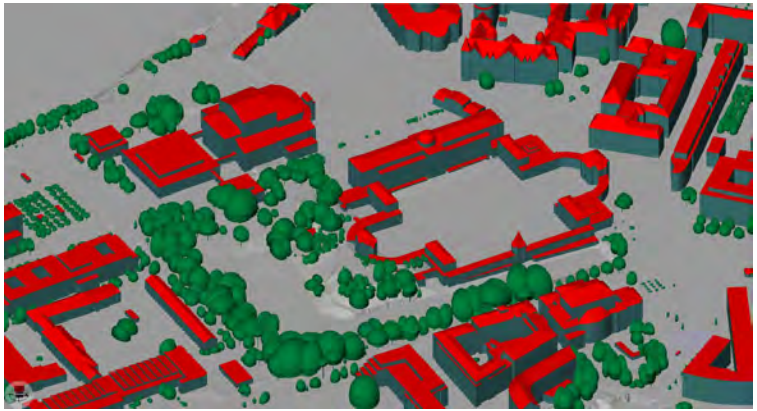
Parameterization & 3D-Reconstruction

- Individual Crown Segmentation
  - Local Maxima Filter + Marker-Controlled Watershed-Segmentation
- Point cloud segmentation and calculation of 3D dimensions of tree crowns
- Parametric modeling in CityGML as SolitaryVegetationObjects using implicit geometries



Segmented Point Cloud

© Google Earth (2019)



3D City Model with Trees

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Vegetation - High-Resolution (3D) Remote Sensing Data

What can we do with this data ?

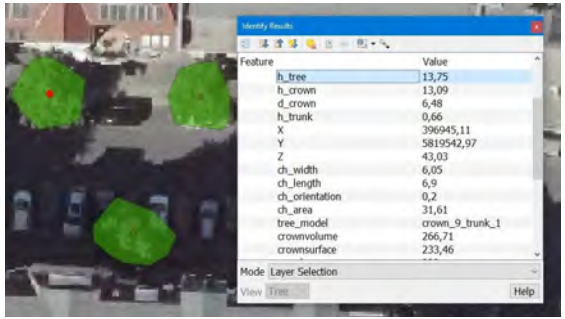
- Spatially explicit modeling of urban forest structure
- Segmentation and geometric parameterization of individual tree crowns

What products can we derive from it ?

- Classified LiDAR point clouds
- Canopy Height Models
- Parameterized tree positions
- Semantic 3D tree models

What do we use these products for ?

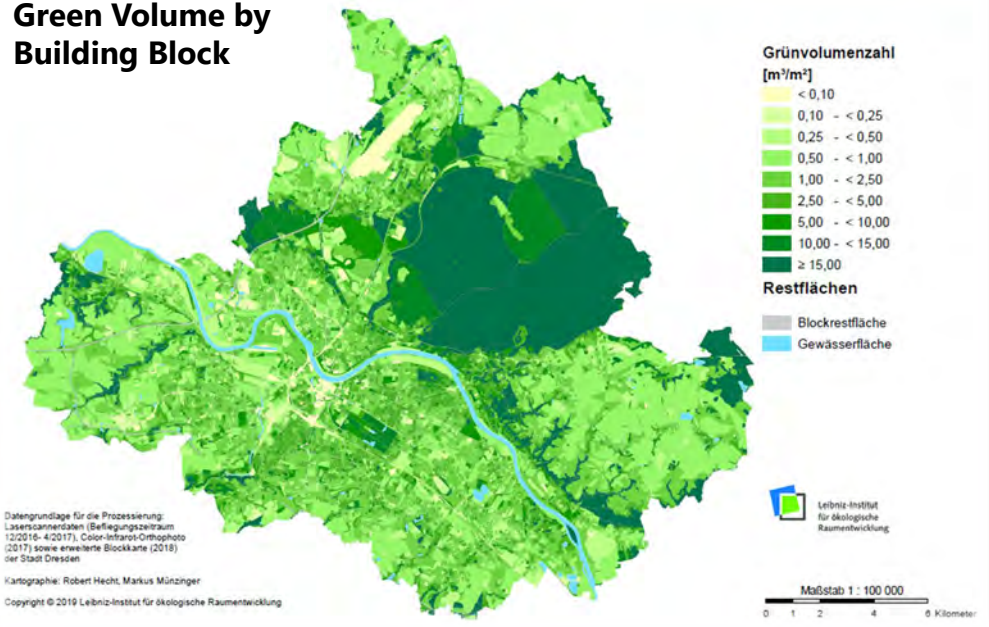
- Small-scale indicators (urban green volume, canopy coverage)
- Integration of trees in 3D shading simulations
- Modeling of the urban climate



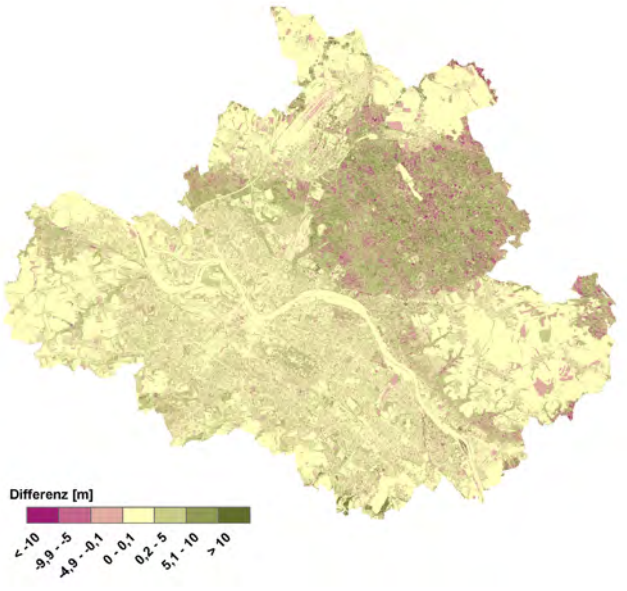
Urban Green Volume – City of Dresden (Germany)

Versatile Parameter for Urban Ecology

Green Volume by Building Block



Change Vegetation Heights 2009 - 2017



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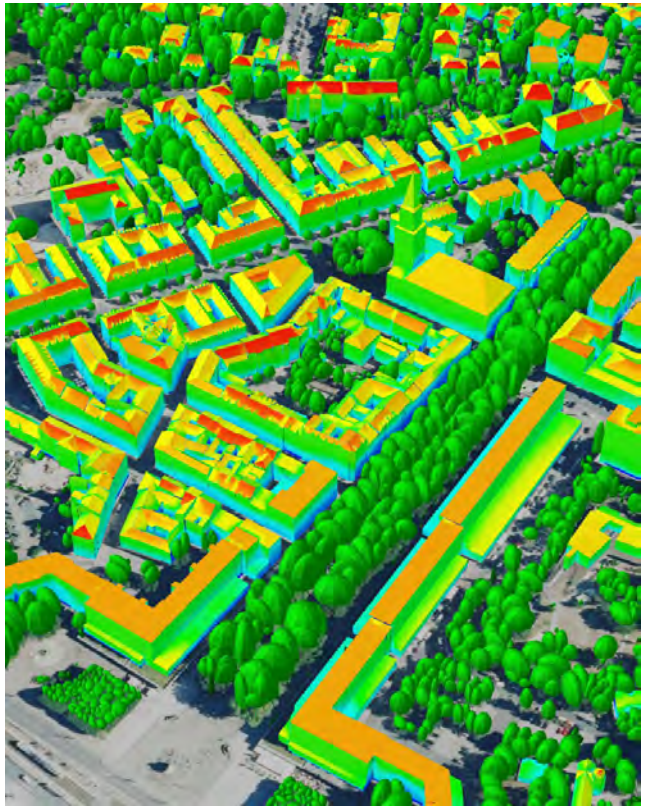
Standard-BIPV-System

Geodata-Based Solar Potential on Buildings

- **Aim:** Determining the potential for Building-Integrated Photovoltaics (BIPV)
- Digital twin as basis for analysis
  - Comprising buildings, **trees** and terrain
  - Modeling solar radiation for roofs and facades
- Modeling enables neighborhood and building-specific analyses
  - Identification of easily accessible potentials
  - Consideration of ownership structures, heritage conservation



Visualization of solar irradiation in the 3D city model: Innere Neustadt Dresden. (© TUM, Chair of Geoinformatics, 2022)

standard BIPV

Bundesministerium für Wirtschaft und Klimaschutz

FKZ: 03EE1061C

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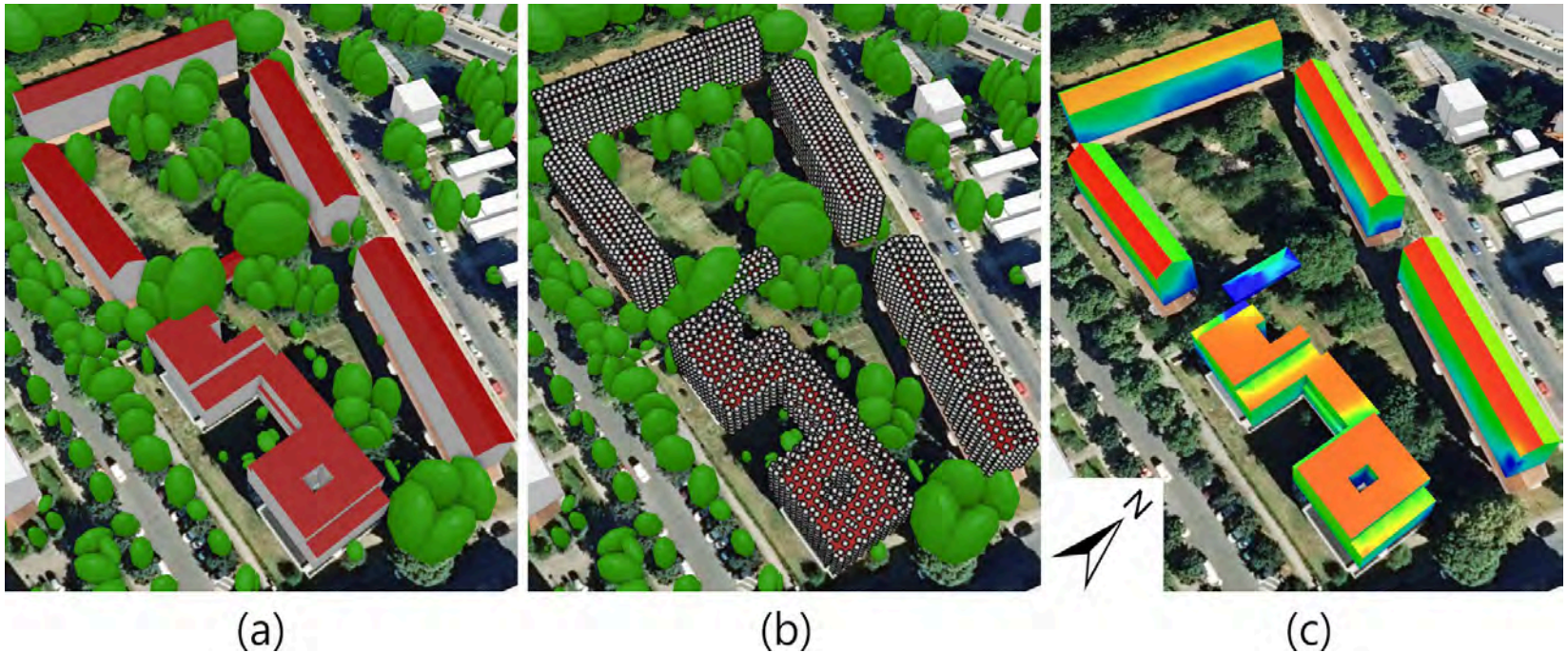
3D Solar Radiation Modeling

Model Tree Shadows on Building Roofs and Facades

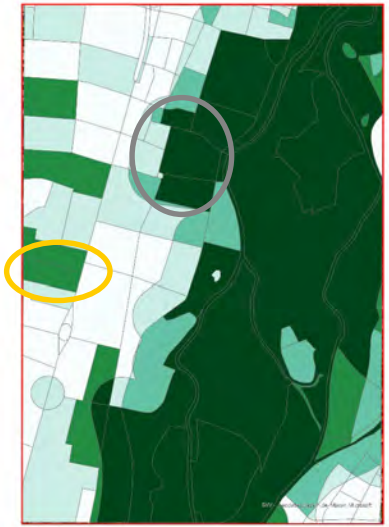


ES - Local Climate Regulation - City of Munich (Germany)

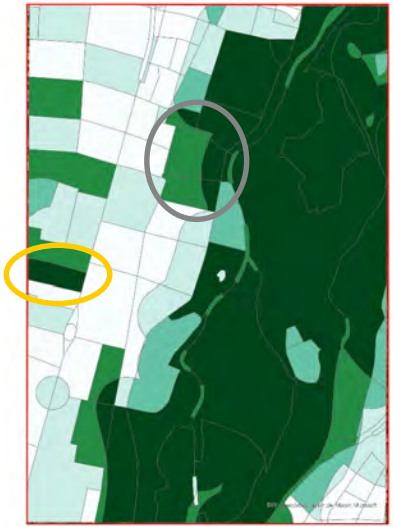
Analysis of Changes through Integration of High-Resolution Tree Heights

Englischer Garten 2022

2012



2022



Cooling Capacity Score

- 0 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

Meier, Sophie; Syrbe, Ralf-Uwe; Moyzes, Michelle; Grunewald, Karsten
Klimaregulation in Städten als Ökosystemleistung
In: Naturschutz und Landschaftsplanung 54 (2022) 10, S.20-29
https://doi.org/10.1399/NuL.2022.10.02

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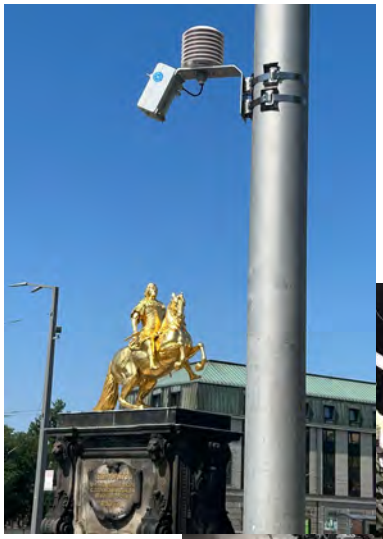
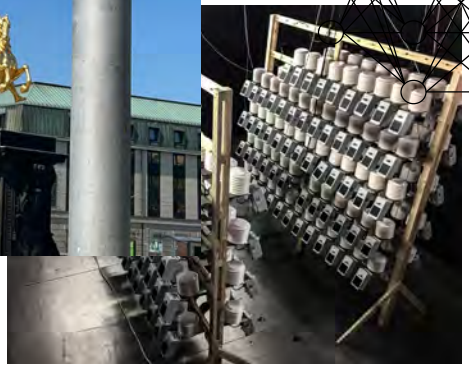
Changes in cooling capacity:

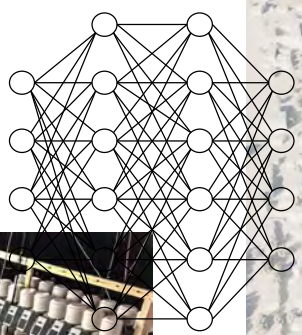
Increase due to tree growth & Decrease due to tree removal

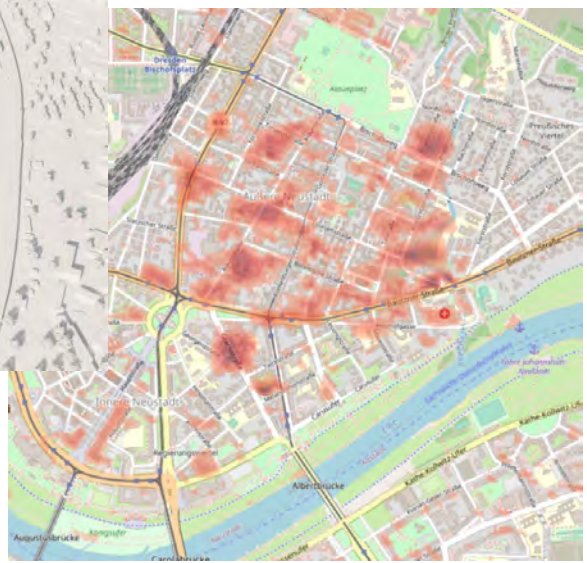
Localisation and Simulation of Urban Heat Islands

Linking Sensor Network with tree heights, urban structure, traffic and other weather and climate data









www.ioer.de/en/projects/klips

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Markus Münzinger
m.muenzinger@ioer.de

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