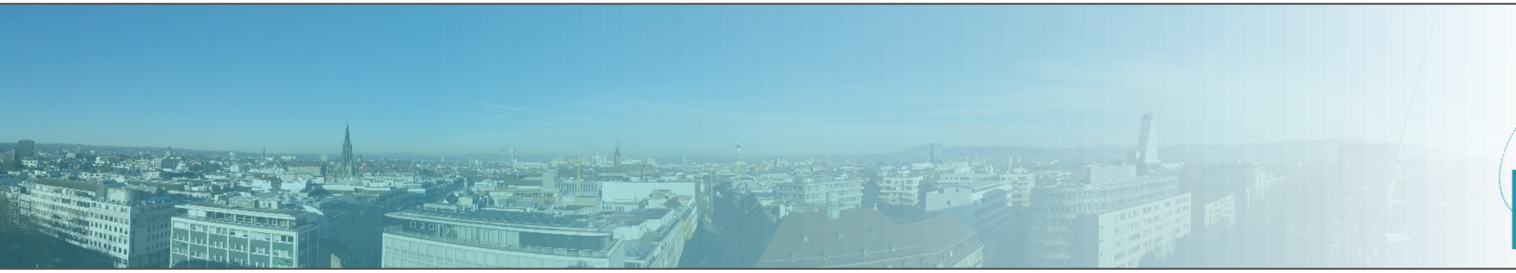

FUME
Urban carbon dioxide Flux Monitoring using Eddy Covariance and Earth Observation

Quantifying biogenic carbon dioxide fluxes in an urban area

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ICOS Virtual Science Conference 2020

15.09.2020

mcr meteorology climatology remote sensing

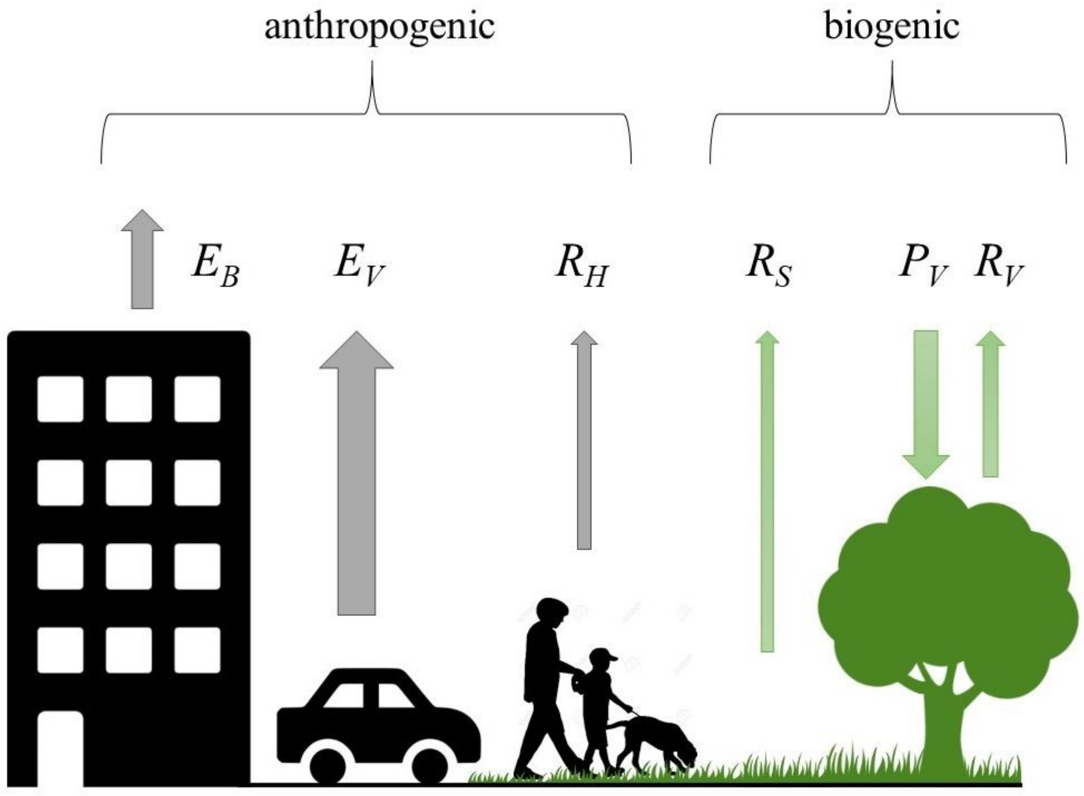
University of Basel

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 836443

Introduction

Quantifying urban biogenic fluxes:

- *Partitioning urban CO_2 flux*
- *Discriminate the anthropogenic emissions*
- *Recognise the seasonal and interannual CO_2 emission variability and trends*
- *Enhance our current understanding on urban metabolism and function*
- *Improve the urban emission inventories*



$$F_C = E_V + E_B + R_H + R_S + (R_V - P_V)$$

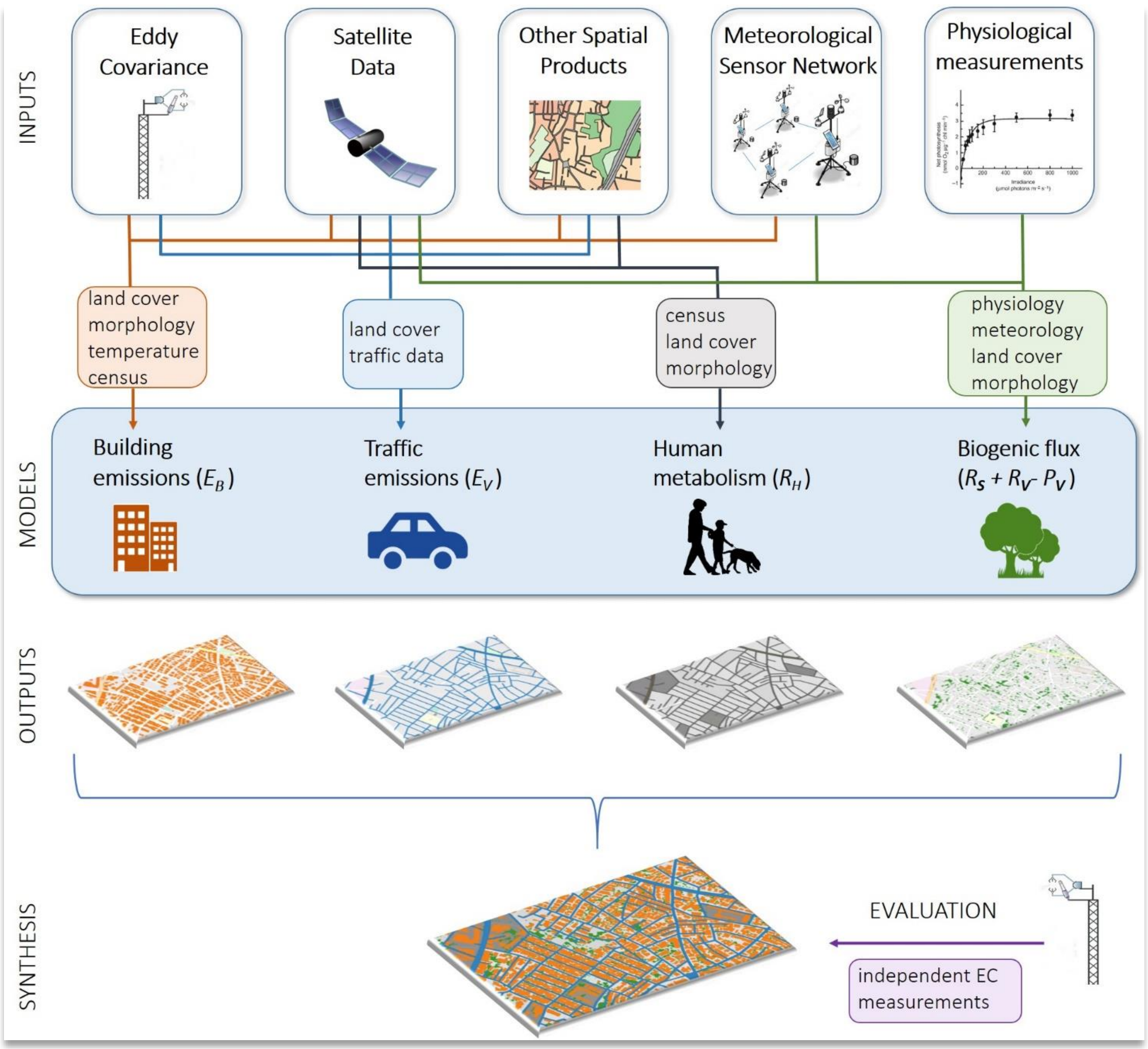
Introduction

Anthropogenic emissions:

- *Eddy Covariance*
- *traffic counts*
- *temperature*
- *population density*

Biogenic fluxes:

- *meteorology*
- *vegetation classification*
- *canopy 3D structure*
- *field measurements*



iFUME

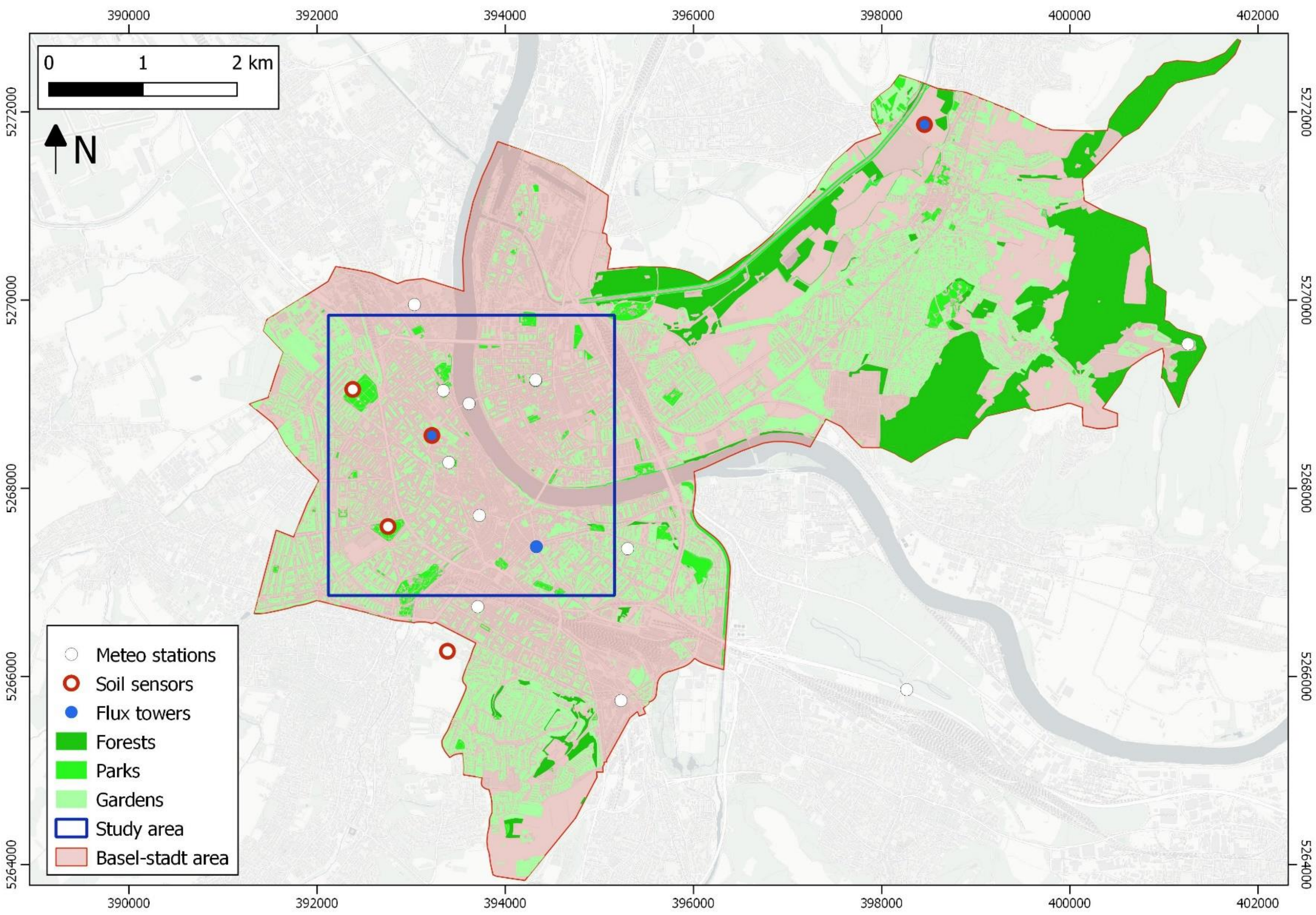
Methods

Methods

Study area

- *Basel city centre*
- *2 urban flux tower sites*
- *1 rural (grassland) flux site*
- *10 meteorological stations (street and UCL level)*

	LC type	ha	%	Sum
Impervious Surfaces	Buildings	289	32	66
	Roads	115	13	
	Pavements	57	6	
	Other	138	16	
Pervious Surfaces	Trees	110	12	34
	Soil/low vegetation	137	15	
	Water	59	7	



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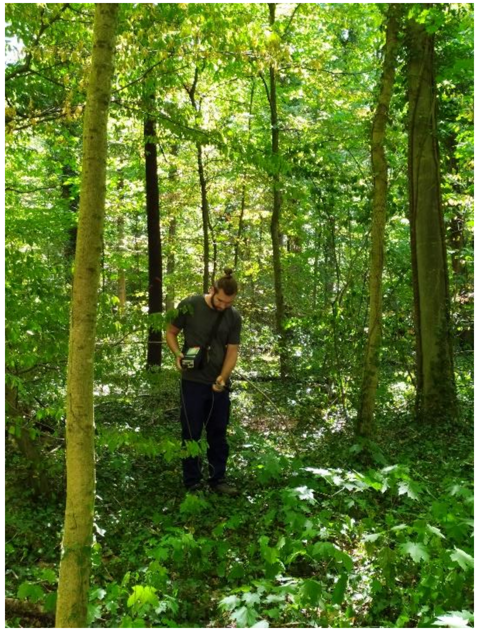
Methods

Field measurements

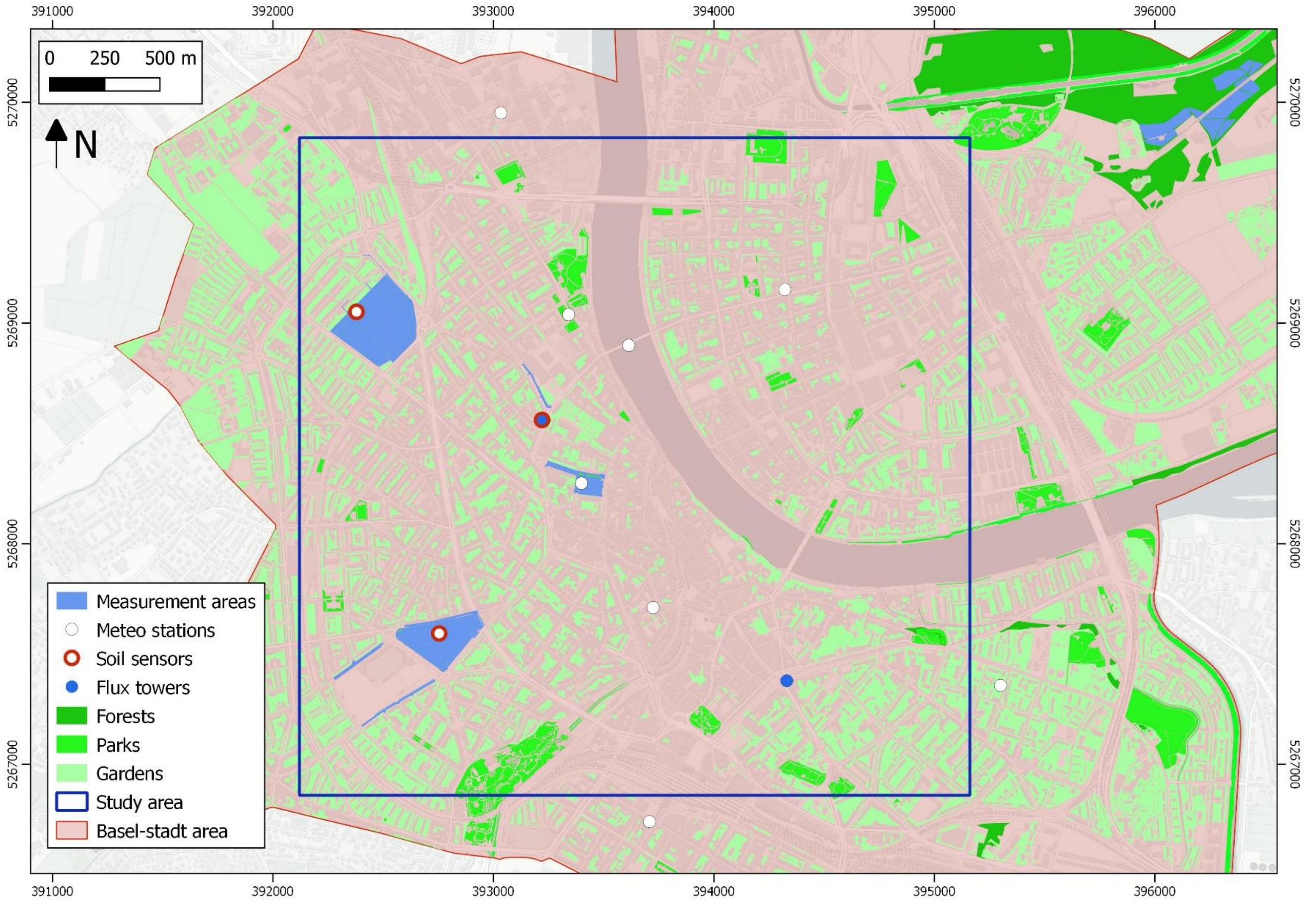
- *Leaf photosynthesis*
  - A_{max}, *A-PAR*, *A-*T_{air}
- *Leaf respiration*
  - R_{leaf}, *R-T*
- *Soil respiration*
  - R_{soil}, ϑ, T_{soil}
- *Soil Organic Carbon content*
- *Leaf Area Index (LAI)*



Methods

Field measurements

	Measurement sites	Tree species	Soil collars
Urban Parks	Kannenfeld Park	*A. hippocastanum* *A. platanoides* *P. x hispanica*	4 collars
	Schützenmatt Park	*A. hippocastanum*	4 collars
	Petersplatz	*A. platanoides* *T. euchlora* *T. platyphyllos* *P. x hispanica*	2 collars
Street	General Guisan-Strasse	*A. platanoides*	-
	Neubadstrasse	*T. euchlora*	2 collars
	Klingelbergstrasse	*A. hippocastanum*	2 collars
Forest	Lange Erlen	*A. platanoides*	4 collars forest 2 collars grassland



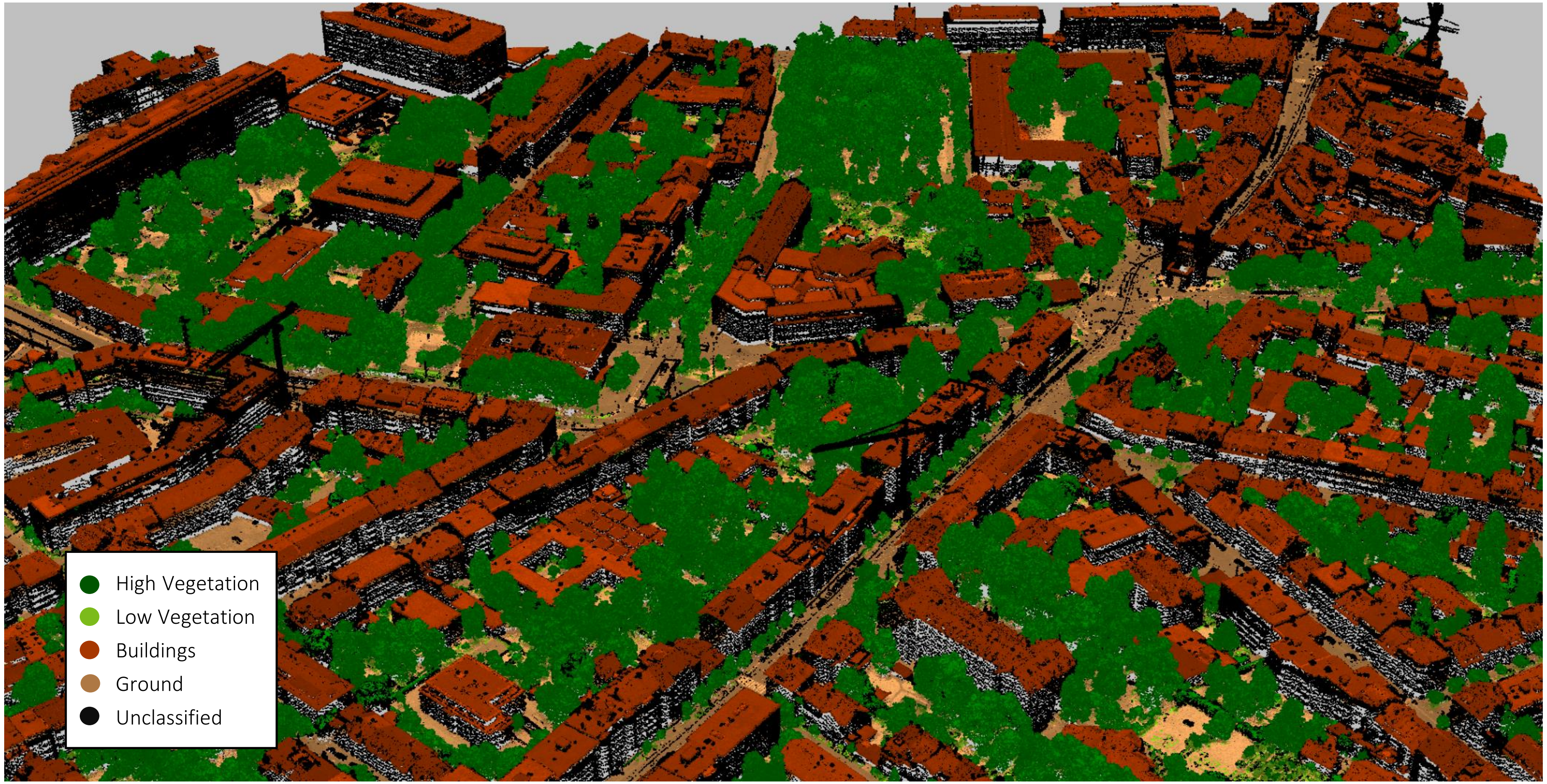
Methods

Urban Morphology

- *Digital Terrain Model*
- *Digital Surface Model*
  - *Building Height*
  - *Tree Height*
- *Resolution 1 m*

LAStools,
Rapidlasso GmbH ©

aerial LiDAR point cloud



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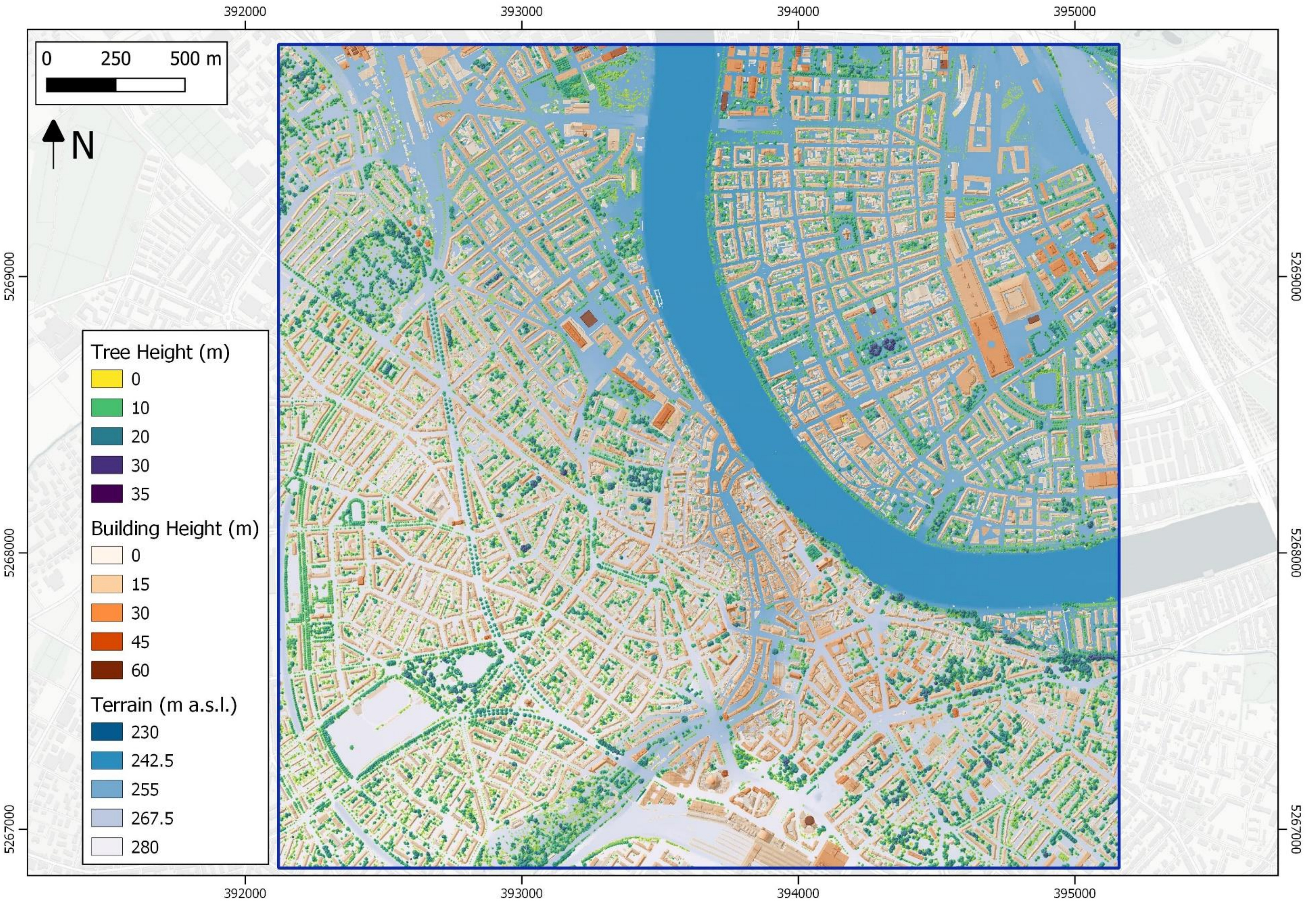


Methods

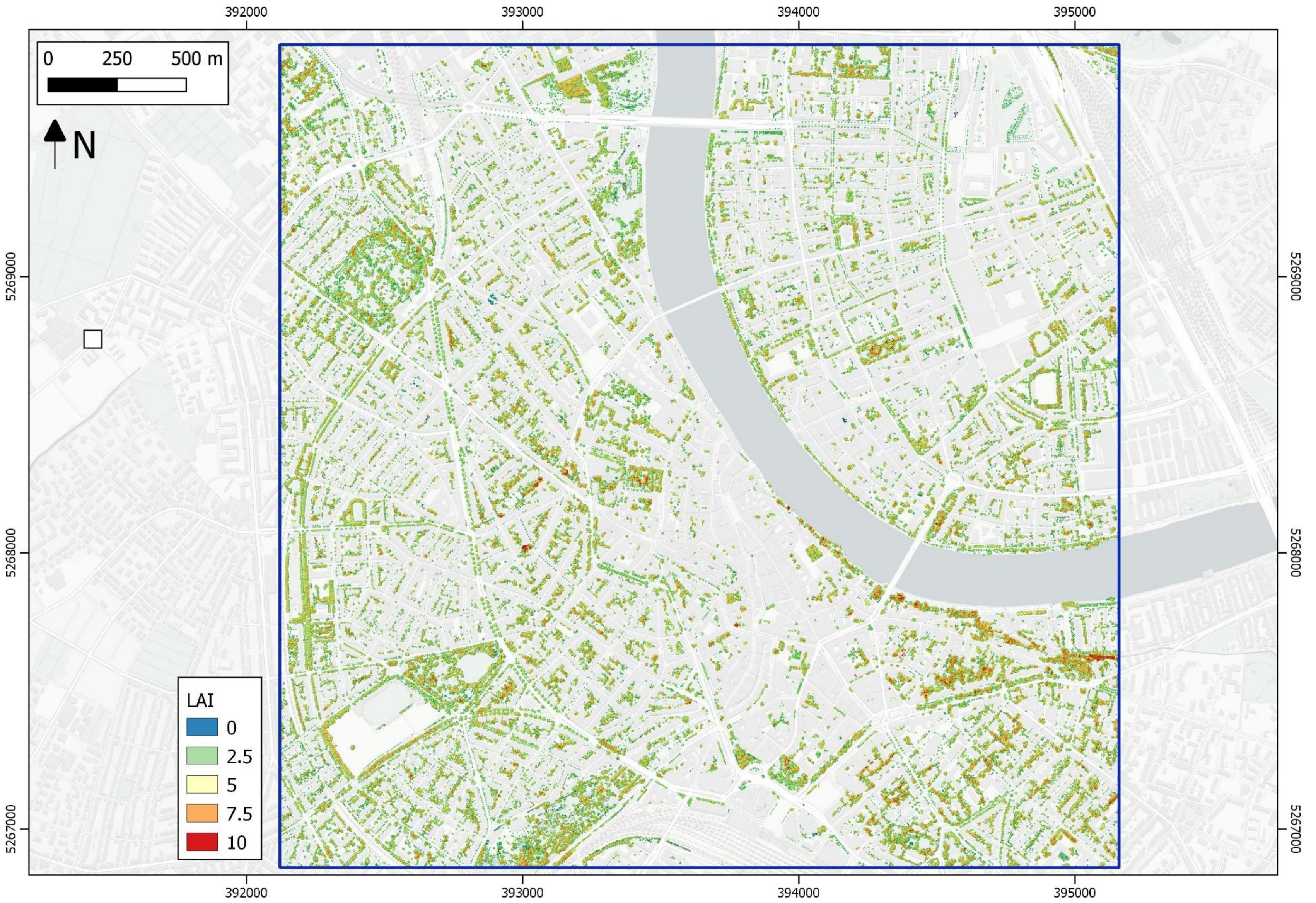
Leaf Area Index (LAI)

- *Beer-Lambert law approach for discrete-return LiDAR (Solberg et al. 2006):*

$$L_e = -\beta \ln(R_g/R_t)$$

R_g: *ground returns*
R_t: *total returns*
β: constant, set to 2

- *Estimated in 1 m resolution*

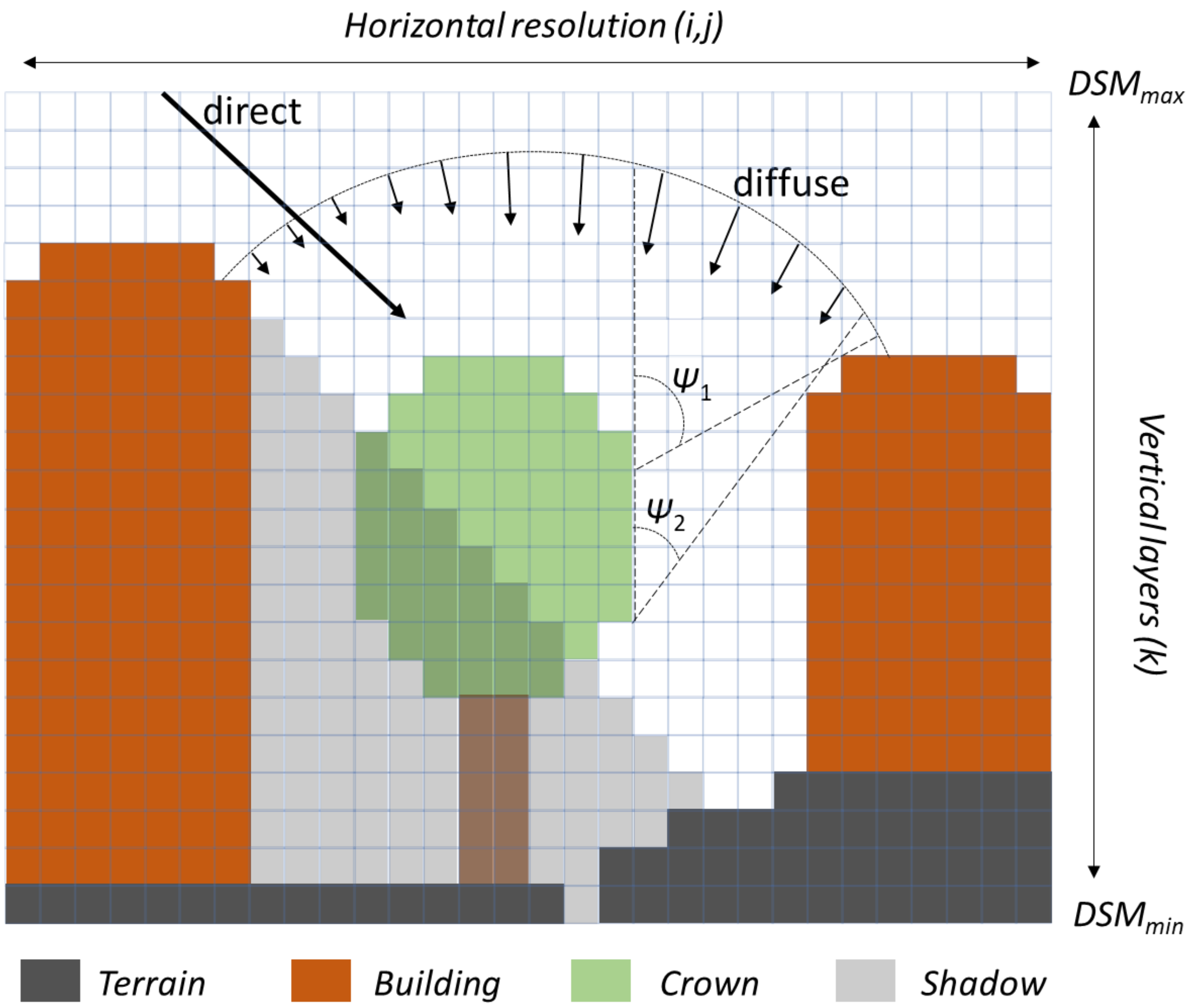


Methods

Urban Canopy Photosynthesis Model

(under development)

- *UCL expressed as 3D voxel grid*
- *Direct radiation modelling according to a ray tracing algorithm (Amanatides & Woo, 1987)*
- *Diffuse radiation modelling according to Sky View Factors (SVFs) per horizontal level and direction (Lindberg & Grimmond, 2011)*
- *30 min step, 5 m resolution (horizontal & vertical)*



Methods

Urban Canopy Photosynthesis Model

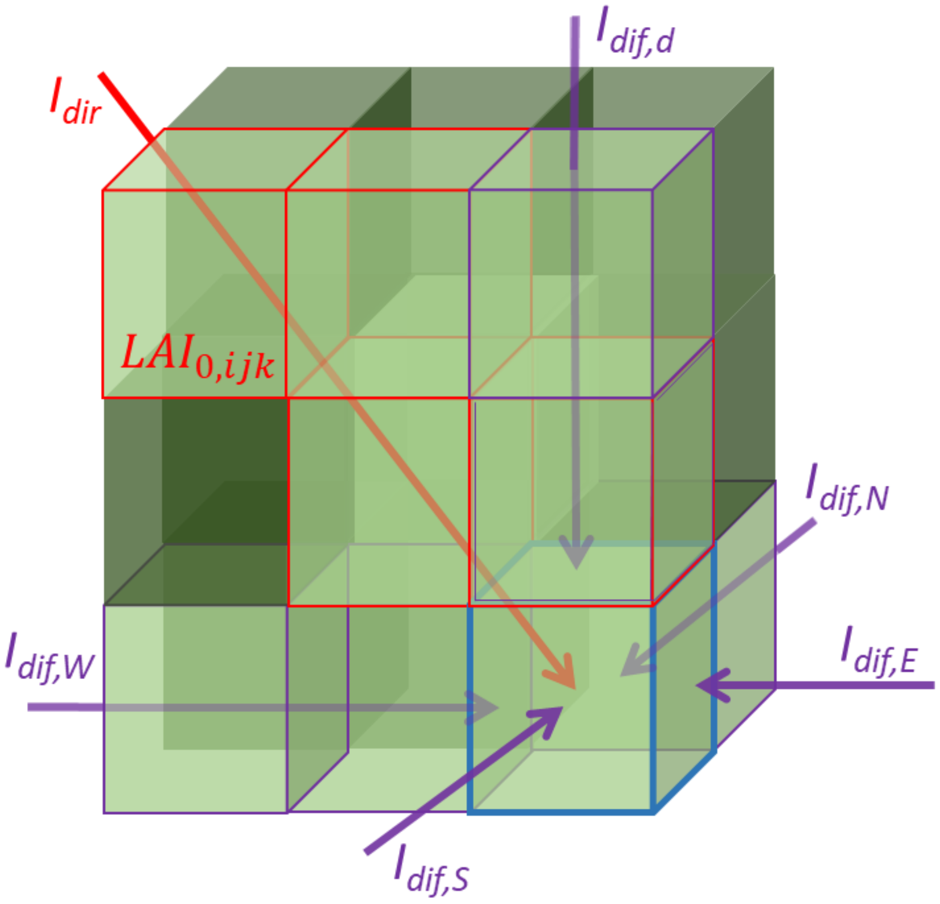
(under development)

- *Beer-Lambert law for radiation reduction inside the canopy (Campbell and Norman, 1998)*
- *Fractions of the sunlit and shaded LAI per voxel*

$$LAI_{sun,ijk} = \frac{1}{k_b} * e^{-k_b LAI_{0,ijk}} * \left(1 - e^{-k_b LAI_{ijk}}\right) * Sh_{ijk}$$

- *Leaf photosynthesis based on PAR (Ögren and Evans 1993) and temperature (June et al. 2004) per voxel*
- *Canopy photosynthesis: sum of all horizontal layers*

$$P_{V,ij} = \sum_{k=1}^{n} (A_{gross,I_{sun},ijk} * LAI_{sun,ijk} + A_{gross,I_{shade},ijk} * LAI_{shade,ijk})$$



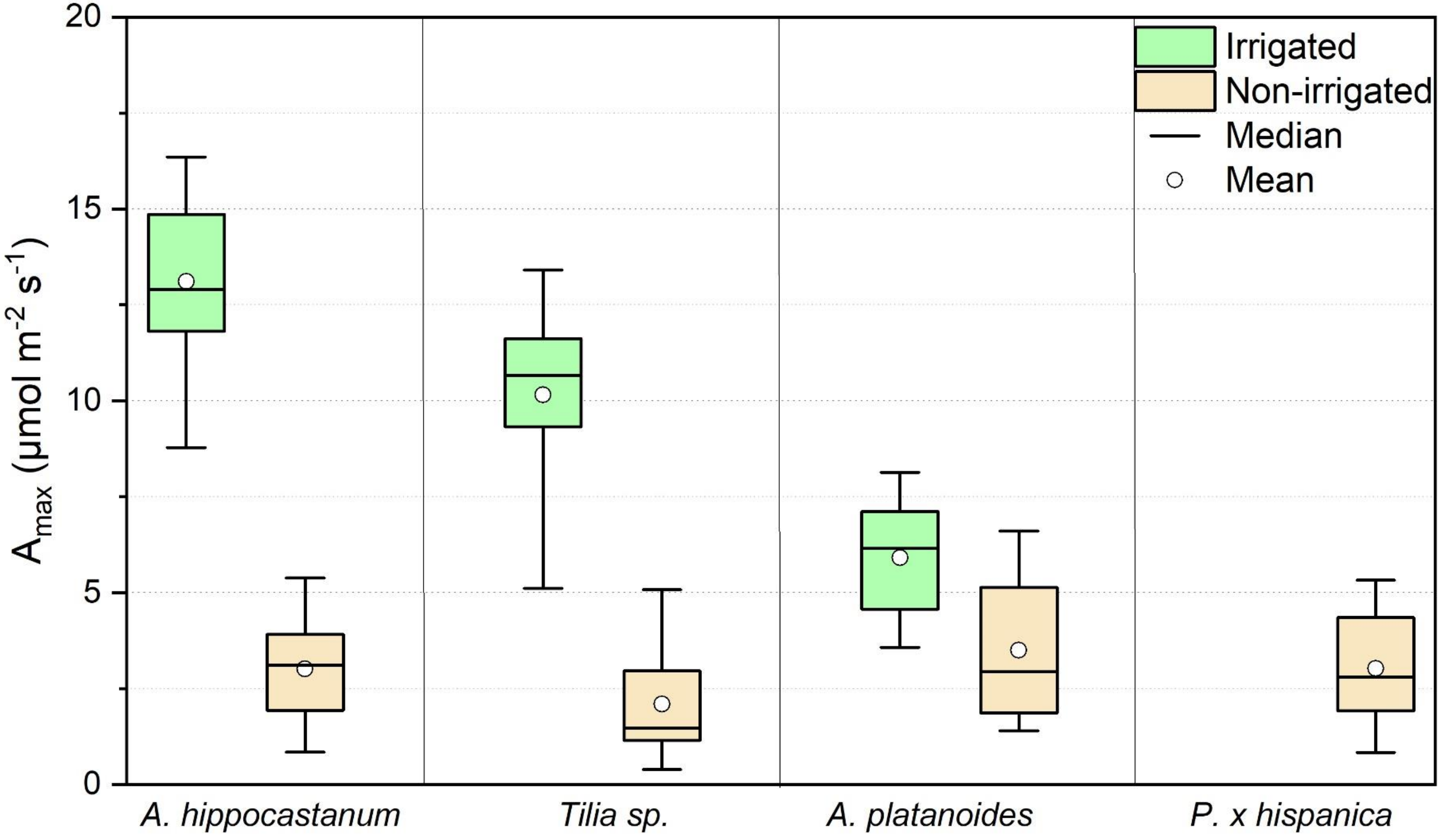
Results

Results

Field measurements

- *Extreme variability in photosynthetic rates between irrigated and non-irrigated areas and across trees - species*
- *Higher A_{max} during morning measurements (lower temperature, water saving strategies)*
- *Only parks are regularly irrigated, street trees are probably constantly under water limiting conditions*

Lift campaign 23 – 25 July 2020



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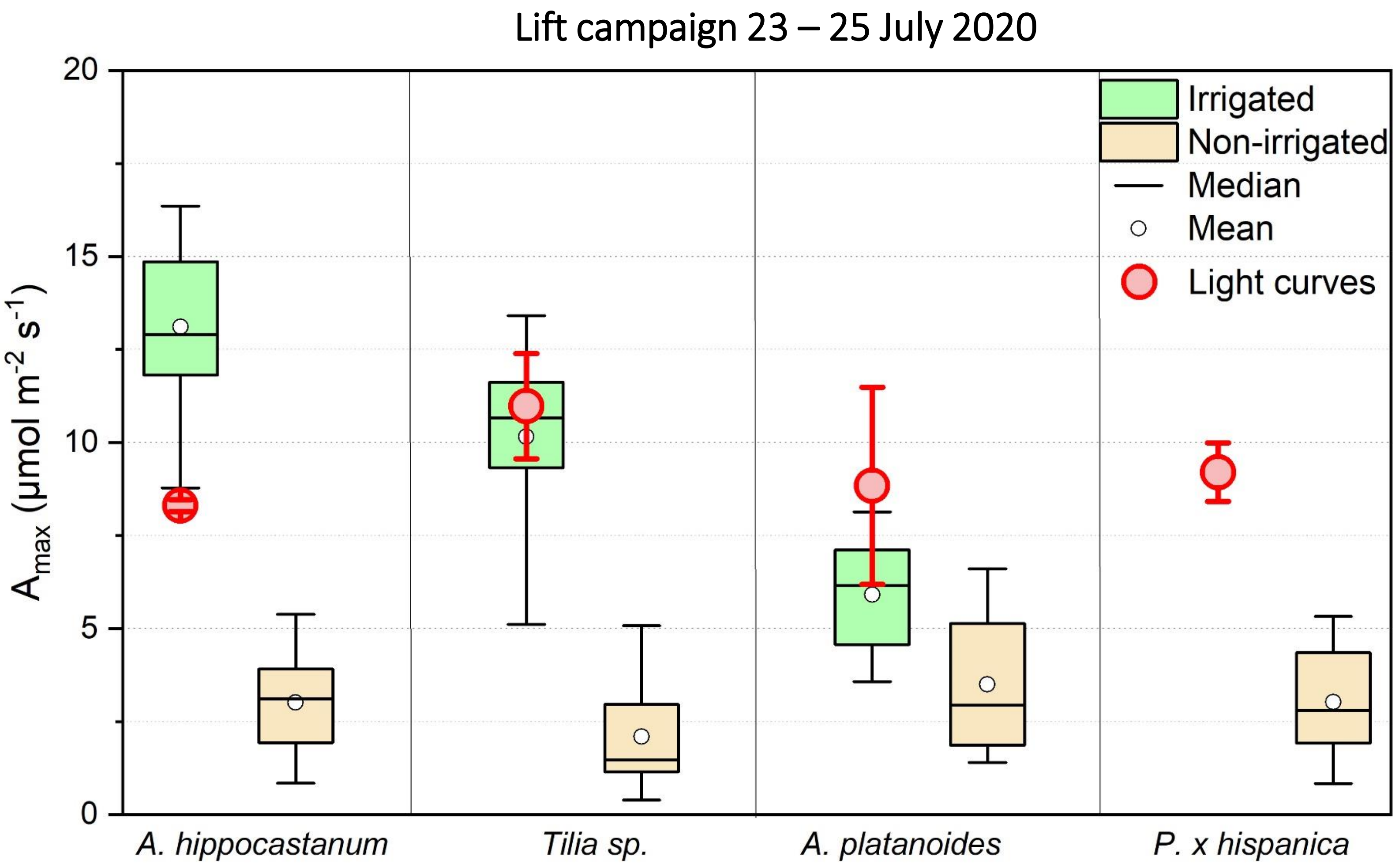
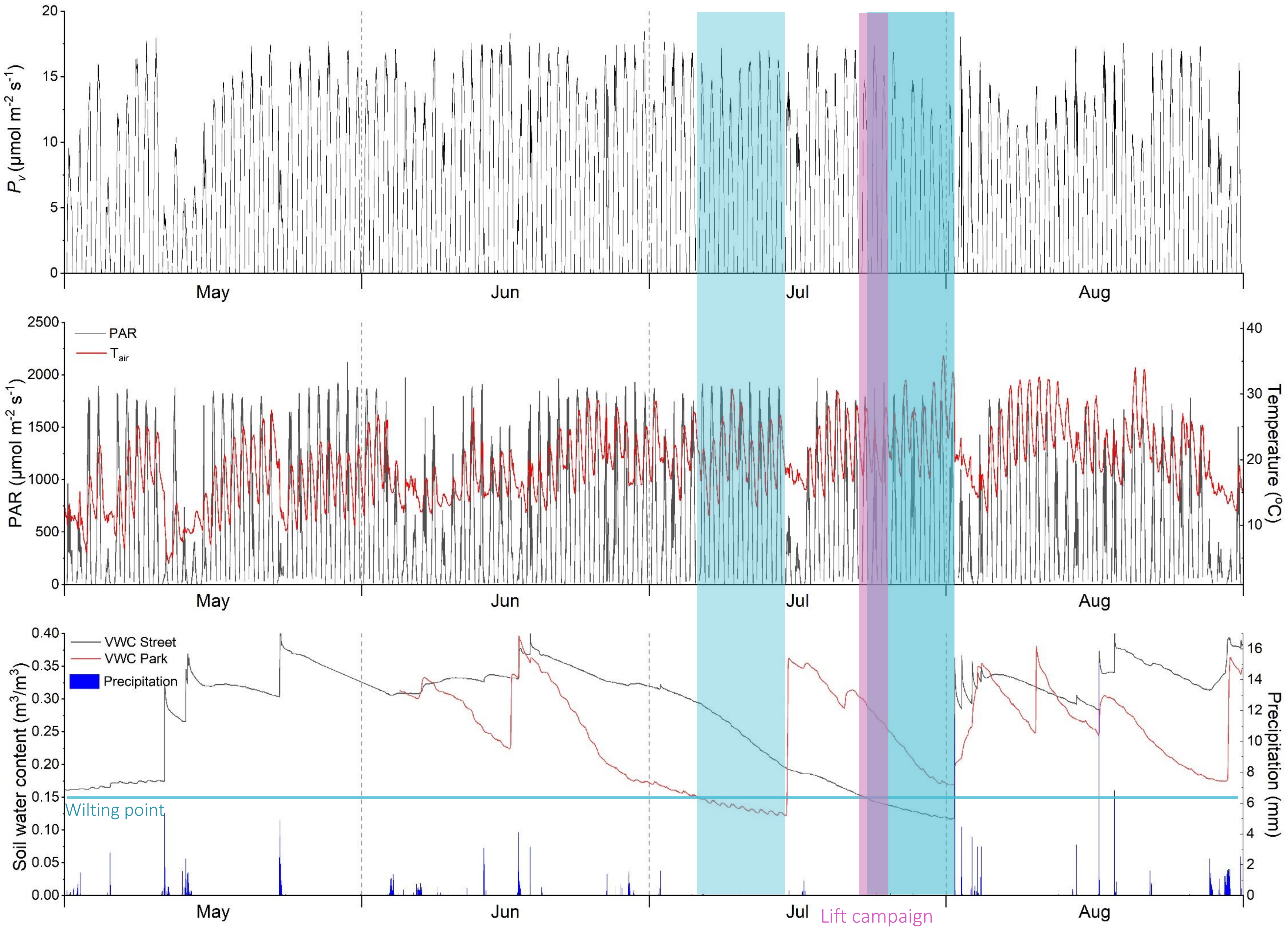


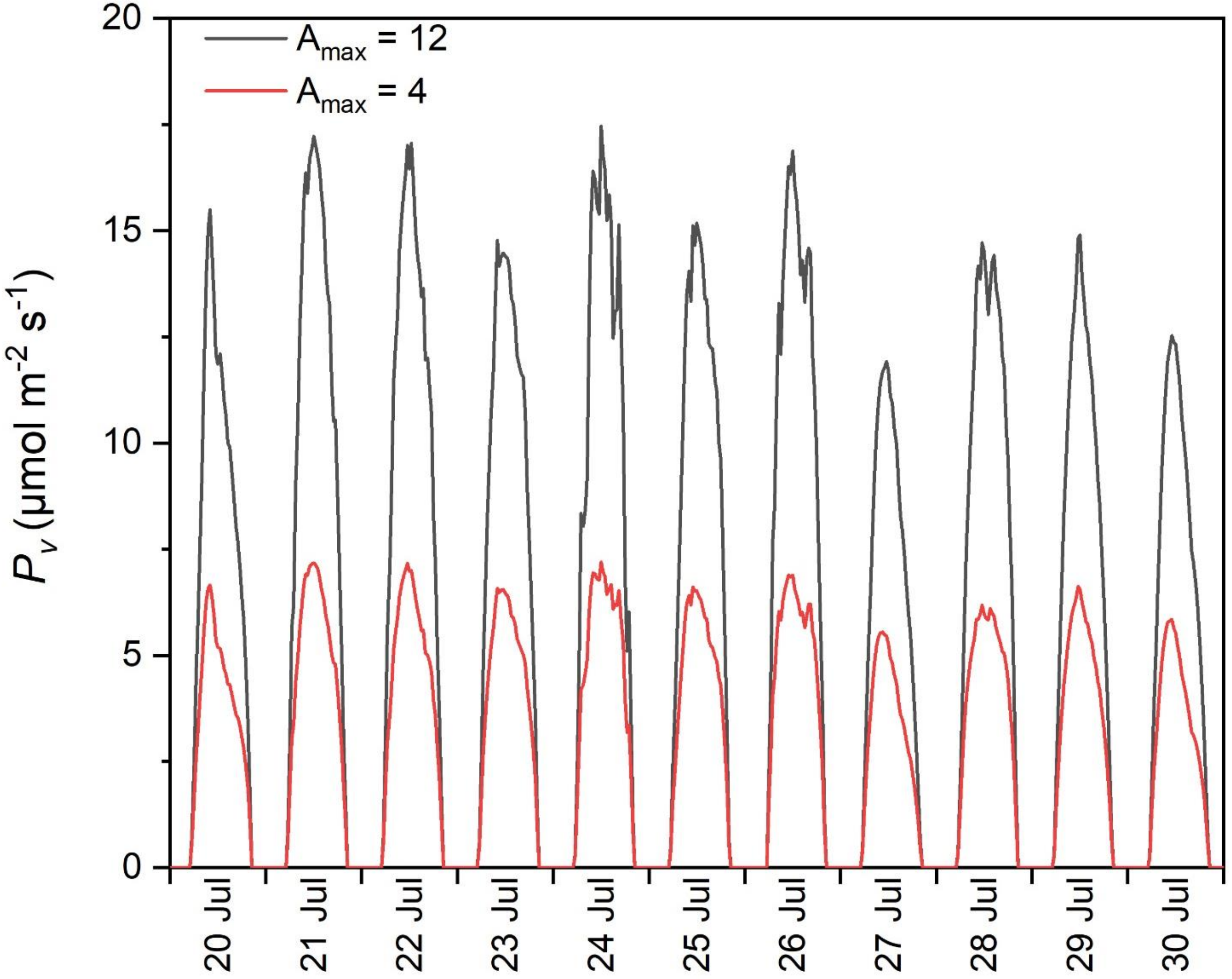
Canopy Photosynthesis model



Results

Canopy Photosynthesis model

Replacing A_{max} with measured values for non-irrigated trees during the extreme drought period (VWC < 0.15 m^3/m^3) results to a ***decrease of ~ 55 % in P_v***



VWC < 0.15 m^3/m^3

A_{max} is a critical parameter for Canopy Photosynthesis modelling, which is hard to assess in the highly heterogenous urban environment

Results

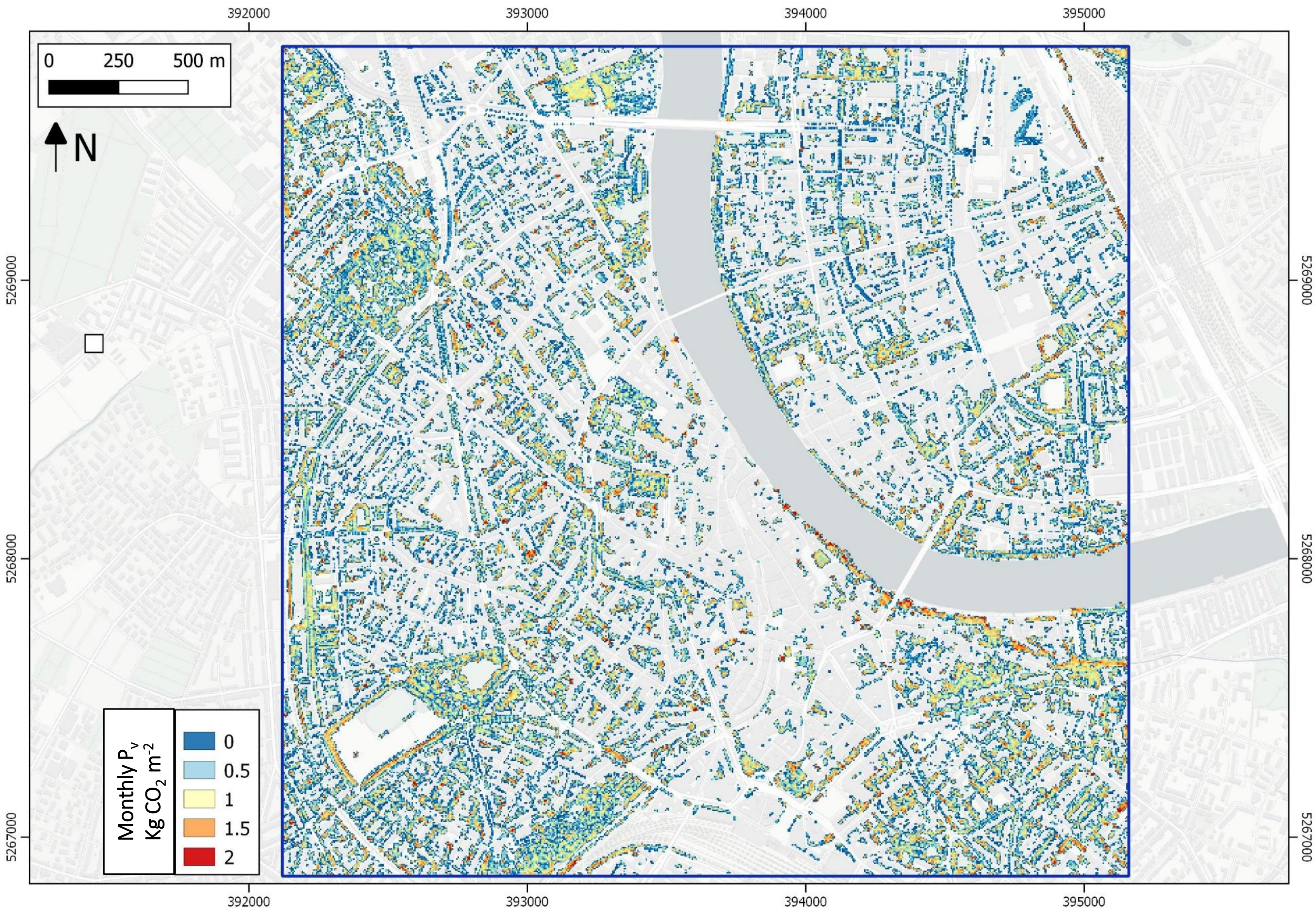
Canopy Photosynthesis model

- Open areas seem more productive
- Mean monthly gross sequestration:

  $- 0.55 \text{ kg } CO_2 \text{ m}^{-2}$

- Balance in BKLI:

  $1.28 \text{ kg } CO_2 \text{ m}^{-2}$



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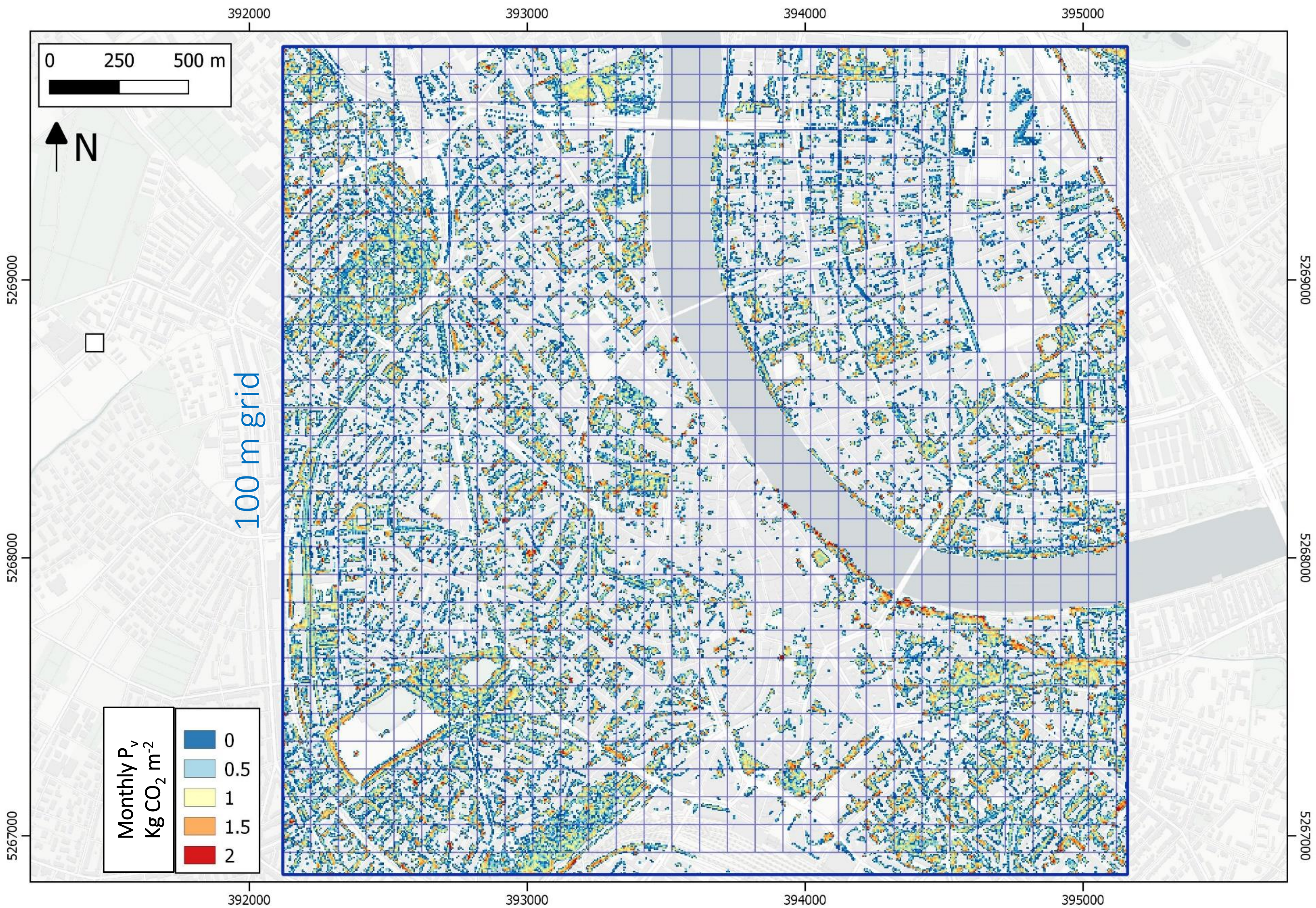
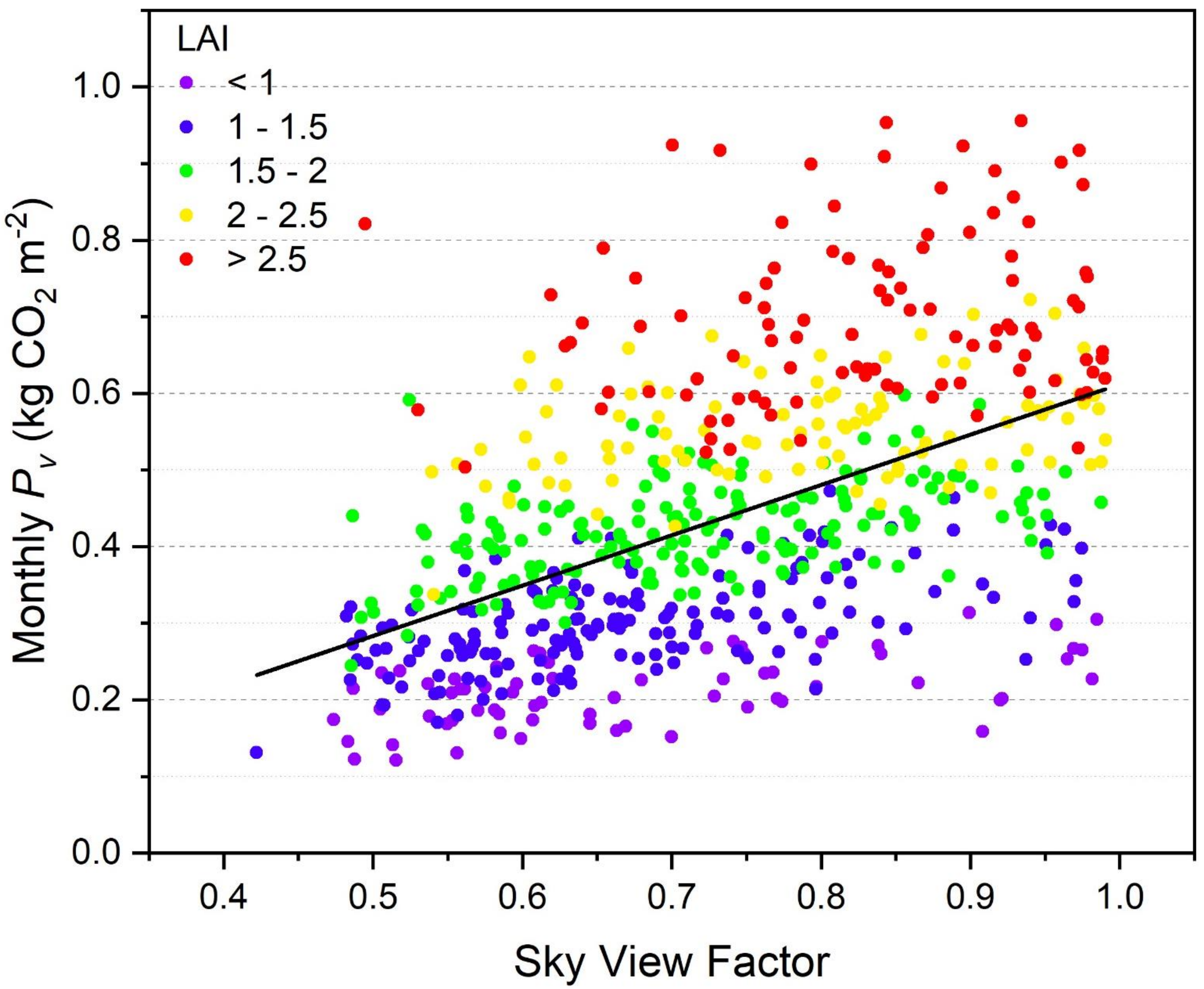


Results

100 m grid spatial analysis

Keeping A_{max} constant, P_v spatial variability is related to LAI and Sky View Factor

Urban morphology suppresses carbon sequestration by reducing light availability to plant canopies



Conclusions

- Urban canopy photosynthesis modeling using detailed morphological and meteorological datasets is a significant tool for the spatiotemporal investigation of urban biogenic fluxes
- Modeling urban vegetation physiological responses to climate variables (especially water availability) is challenging
- Photosynthetic rates (A_{max}) are extremely variable according to irrigation management
- Carbon sequestration during drought conditions can be significantly reduced
- Photosynthesis can potentially offset urban emissions up to 30 % during summer months
- Sky view factor is an important urban attribute affecting canopy photosynthesis

Model updates and evaluation

- Tree species classification using hyperspectral aerial imagery – Species-specific A_{max}
- LAI temporal variability according to Sentinel-2 imagery
- Include understorey vegetation and grasses
- A_{max} reduction according to soil water content and VPD measurements
- Stress detection using remote sensing indices (Sentinel-2)
- Evaluation with Eddy Covariance (temporary installation) in an urban green area (summer 2021)

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Acknowledgements

The Civil Engineering Office of Basel-Stadt is acknowledged for providing the airborne Lidar dataset. PhD student Robert Spirig is acknowledged for his continuous efforts on developing and updating the mcr meteorological database. Günter Bing is acknowledged for the technical support.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 836443