



## **CL2.1/AS1.21: Urban Climate, urban heat island and urban biometeorology**

Interaction between Cities and Climate Change:  
Modelling Urban Morphology and Local Urban  
Planning Scenarios from Open Datasets across  
European Cities

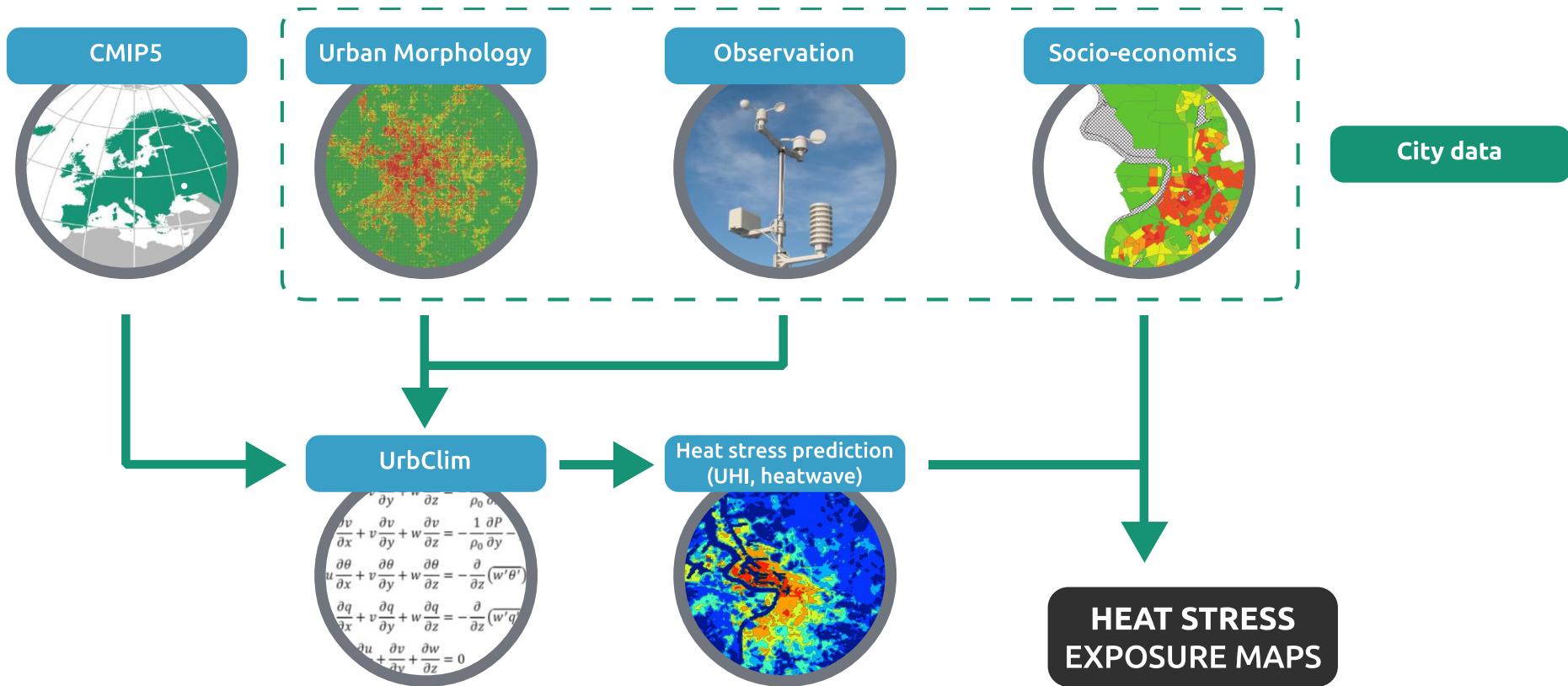
Bart Thomas, Catherine Stevens, Mart Grommen

# NACLIM fact sheet

- **ECOMS** = European initiative for climate service observation and modelling
  - **NACLIM**
  - SPECS
  - EUPORIAS
- **NACLIM** = North Atlantic Climate
- FP7 Collaborative Project
- Project lifetime: 11/2012 – 02/2017
- Research focus:
  - Assessment of decadal climate forecasts
  - North Atlantic / European sector
- 19 research institutes / 10 European countries
- 5 Core themes / 12 work packages
  - **WP4.2: Impact on European urban societies** of predicted North Atlantic/Arctic Ocean variability
  - Case Cities: Antwerp (BE), Berlin (DE), Almada (PT)

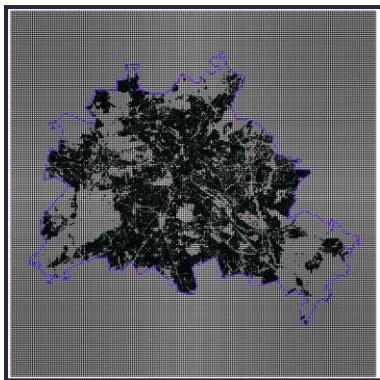


## WP4.2: Impact on urban societies



## Previous work

- Calculation of Planar Area Index (**PAI**) and Frontal Area Index (**FAI**) on 250x250m grid
- **Relationship** between:
  - Surface Soil Sealing (EEA SSL) and PAI ( $R^2 \sim 75\%$ )
  - EEA SSL and FAI ( $R^2 \sim 65\%$ )
- PAI: Stable relationship (all cities)
- FAI: More variation in relation across cities
- Flexible approach:
  - **Exact calculation** when 3D city models are available  
> calibration on local data
  - **Extrapolation** for other regions (outside AOI)
  - Possibility of **downscaling** urban climate simulations to higher resolution



## Present work

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1. Increase  $R^2$  of the relationships between generic / **open** EU-datasets and urban morphology indices by combining **EEA SSL** and **population** data in the regression analysis
  
2. Extract **other** urban morphology **indices**
  
3. Estimate the UHI for local **urban planning scenarios** by **updating** urban morphology

# Regression using EEA SSL and population

Antwerp

PAI			
	PAI (y) - EEA SSL (x)	PAI (y) - POP DENS (z)	PAI (y) - EEA SSL (x) - POP DENS (z)
equation	$y=0.0033x$	$y= 0.0038z + 0.0479$	$y= 0.0022x + 0.0025z + 0.0018$
$R^2$	0.64	0.61	0.82

FAI			
	FAI (y) - EEA SSL (x)	FAI (y) - POP DENS (z)	FAI (y) - EEA SSL (x) - POP DENS (z)
Equation	$y=0.0008x$	$y= 0.0011z + 0.0131$	$y=0.00028x + 0.00091z + 0.0071$
$R^2$	0.42	0.74	0.79

## Source used datasets

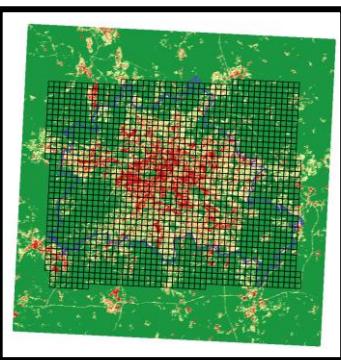
European Environment Agency, Population Density data, disaggregated with CLC 2000, [www.eea.europa.eu](http://www.eea.europa.eu)  
European Environment Agency, Surface Soil Sealing data, 2010, [www.eea.europa.eu](http://www.eea.europa.eu)

# Other urban morphology indices

Considered land surface parameters:

- ▶ Planar area index (PAI)
- ▶ Frontal area index (FAI)
- ▶ Average building height (AVG\_H)
- ▶ Standard deviation building height (STD\_H)
- ▶ Sky view factor (SVF)
- ▶ Fraction vegetation cover (F\_VEG)
- ▶ Fraction urban land use (F\_ULU)
- ▶ Vegetation type (LULC)
- ▶ ...

**3D city models**



Relationship between morphology indices and EEA SSL  
on 1x1km grid

# Other morphology indices

	<b>PAI</b>		<b>FAI</b>	
	<i>Equation</i>	<i>R</i> <sup>2</sup>	<i>Equation</i>	<i>R</i> <sup>2</sup>
<b>Berlin</b>	y=0.003x	0.81	y=0.0018x	0.69
<b>Antwerp</b>	y=0.0033x	0.64	y=0.0008x	0.42
<b>Almada</b>	y=0.0027x	0.77	y=0.0016x	0.81

	<b>AVG_H</b>		<b>STD_H</b>	
	<i>Equation</i>	<i>R</i> <sup>2</sup>	<i>Equation</i>	<i>R</i> <sup>2</sup>
<b>Berlin</b>	y=0.1432x+4.2573	0.51	y=0.1437x+4.2394	0.5
<b>Antwerp</b>	y=0.0533x+4.5515	0.34	y=0.0285x+2.4538	0.16
<b>Almada</b>	y=0.0738x+4.9585	0.41	y=0.0617x+1.7292	0.42

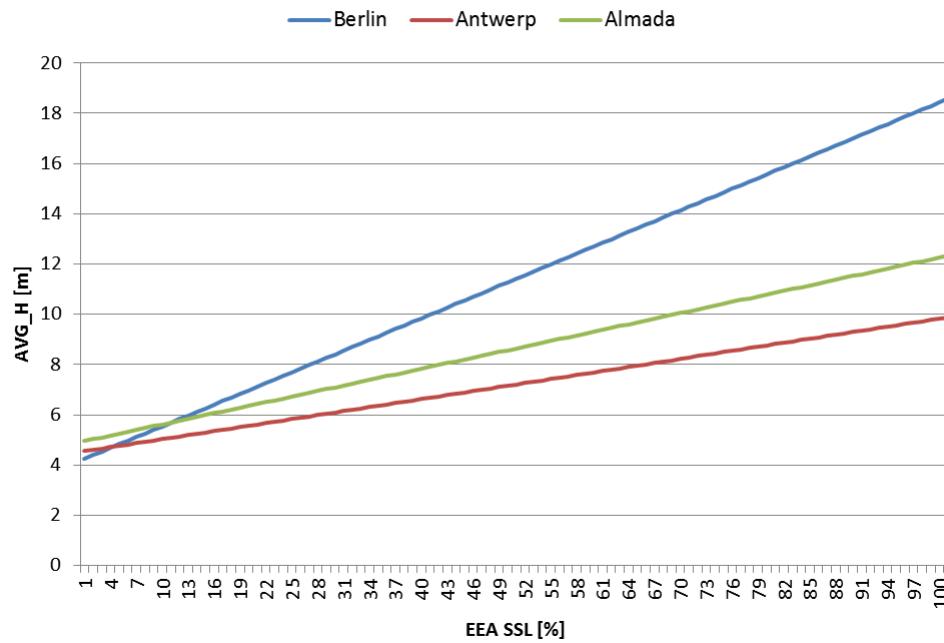
	<b>F_VEG</b>		<b>F_ULU</b>	
	<i>Equation</i>	<i>R</i> <sup>2</sup>	<i>Equation</i>	<i>R</i> <sup>2</sup>
<b>Berlin</b>	y=-0.0073x+0.8739	0.79	y=0.0098x	0.95
<b>Antwerp</b>	y=-0.0059x+0.6802	0.9	y=0.0096x	0.89
<b>Almada</b>	y=-0.0078x+0.8249	0.74	y=0.0093x	0.79

	<b>SVF</b>	
	<i>Equation</i>	<i>R</i> <sup>2</sup>
<b>Berlin</b>	y=-3E-05x <sup>2</sup> -0.0013x+0.9936	0.71
<b>Antwerp</b>	y=-2E-05x <sup>2</sup> -0.0005x+0.9825	0.47
<b>Almada</b>	y=-2E-05x <sup>2</sup> -0.0006x+0.9692	0.68

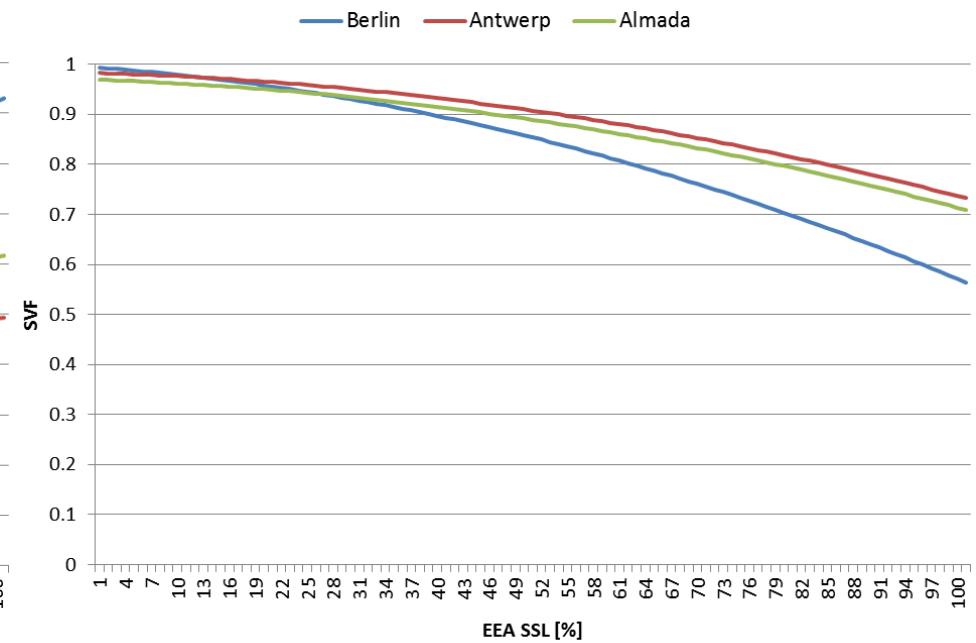
x = EEA SSL

# Other morphology indices

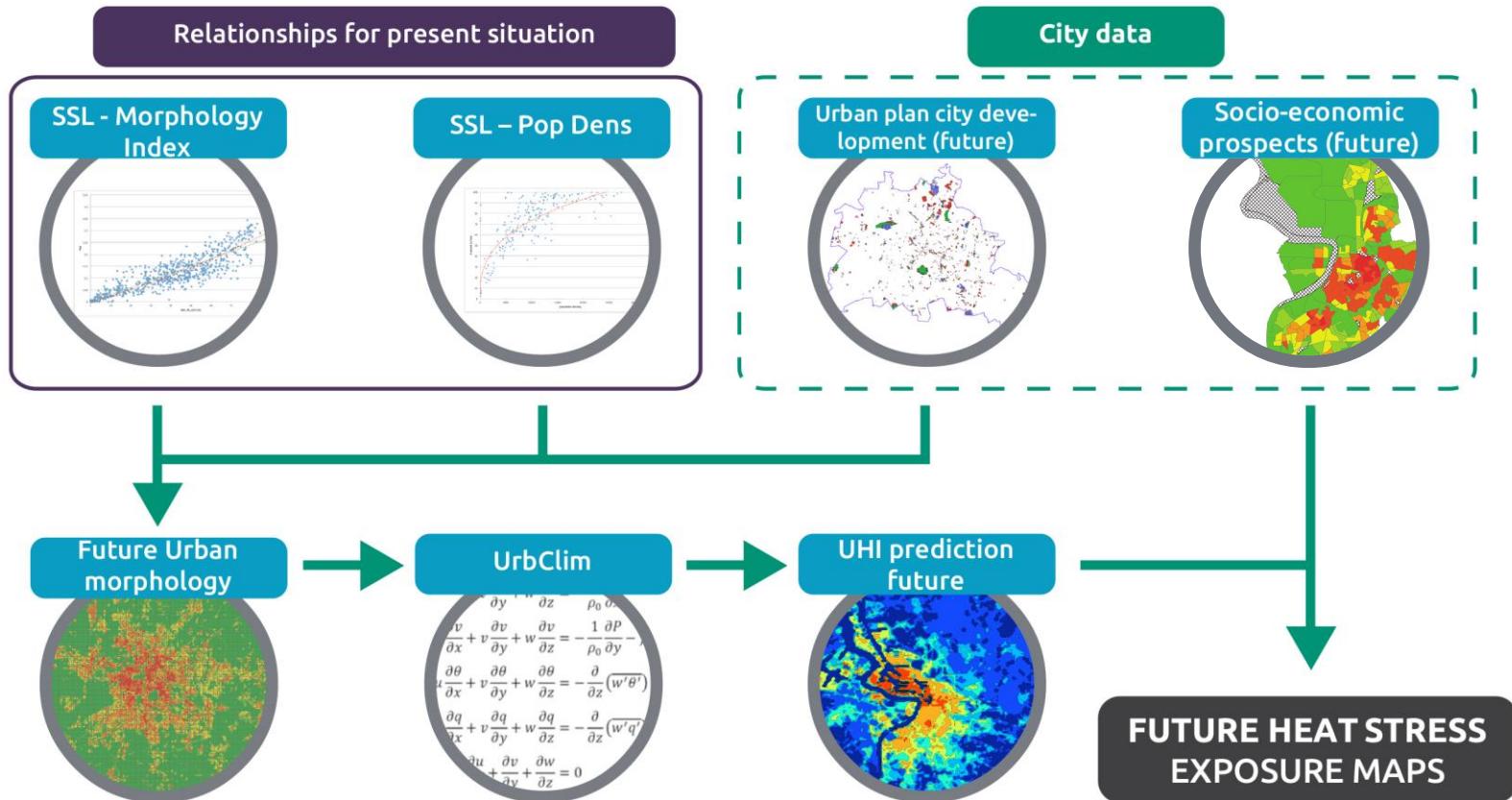
Trendlines Relation Surface Soil Sealing and Average Building Height for 3 use case cities



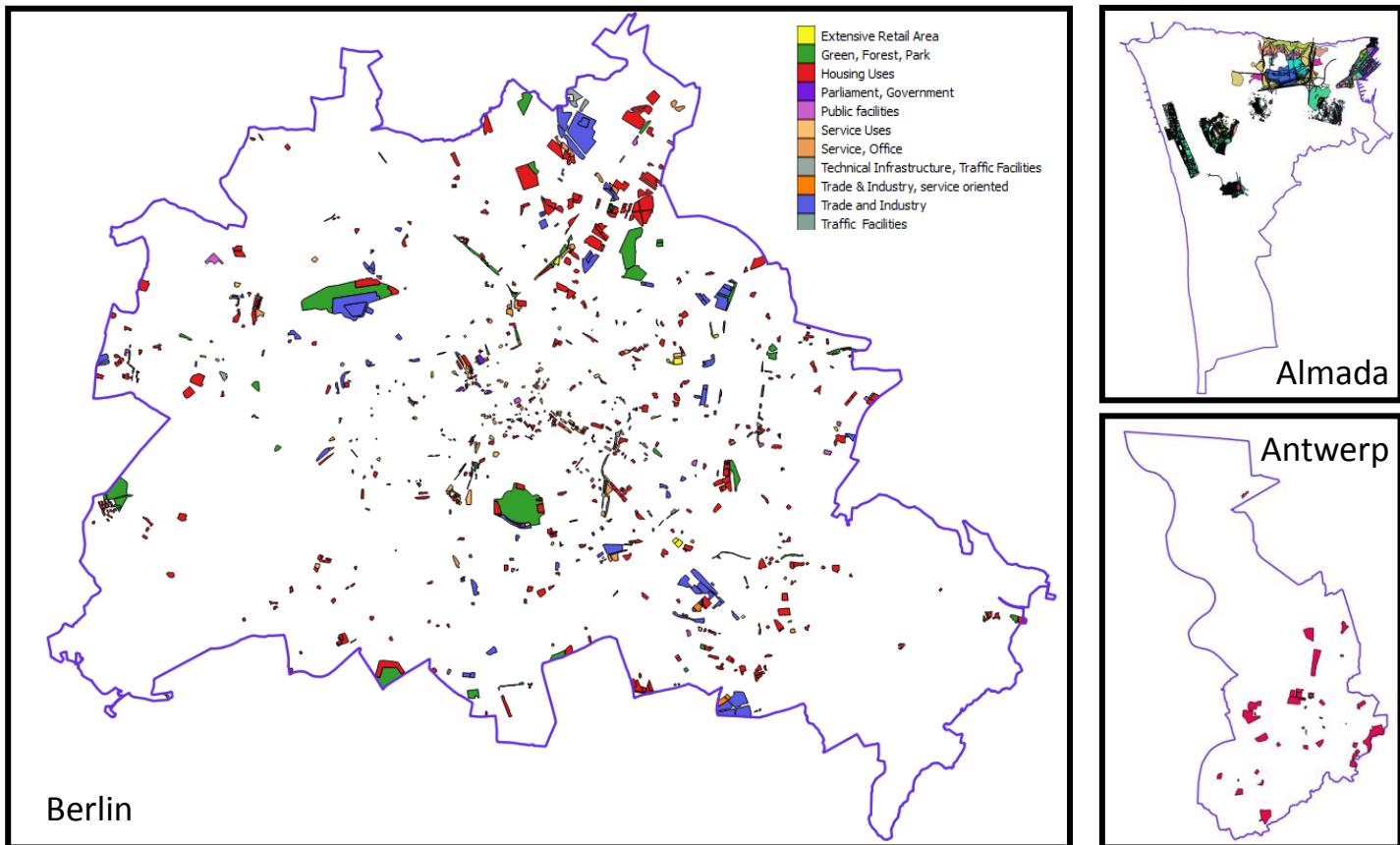
Trendlines Relation Surface Soil Sealing and Sky View Factor for 3 use case cities



# Urban plans – future urban morphology



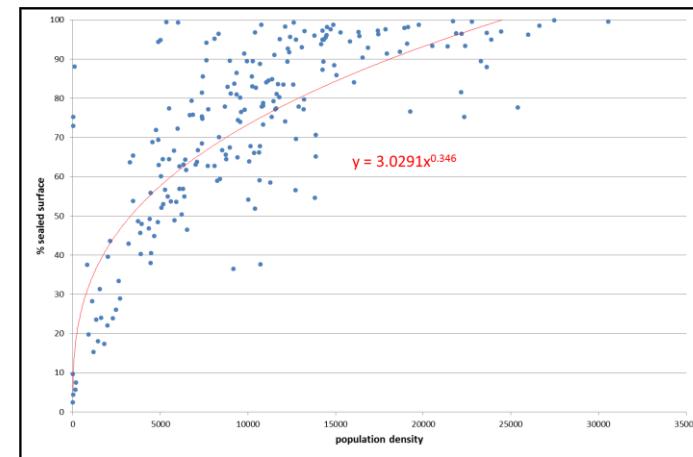
### 3. Urban plans – future urban morphology



# Urban plans – future urban morphology

## Methodology

- Assign future LULC to urban plans
- Overlap with analysis grid (250x250m)
- Calculate future SSL for grid cells covered by urban plans
  - As average EEA SSL of the current grid cells with similar LULC
  - *Or if future population data available:* use relation between EEA SSL and population density (current situation)

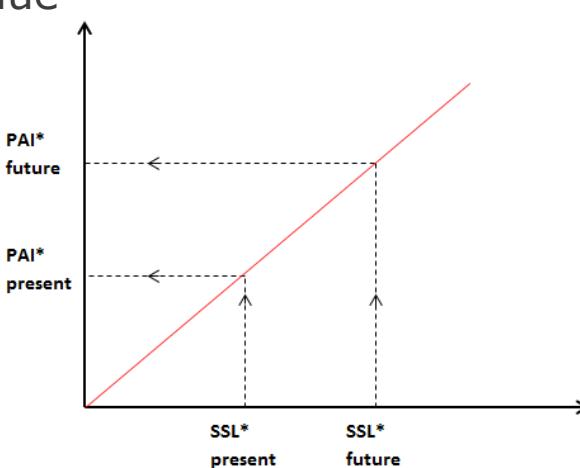
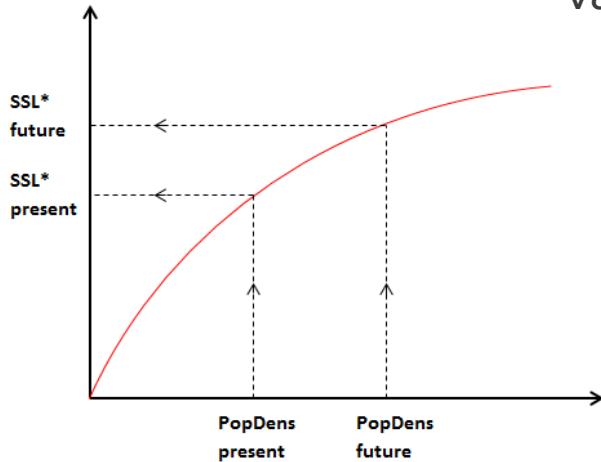


Antwerp

# Urban plans – future urban morphology

## Methodology

- Estimate the future morphology index value
  - From the established relationship with the EEA SSL
  - *Or if future population data available:* estimate an evolution factor ( $r$ ) for each index based on the changes in population density (and hence soil sealing) and apply this factor to the present index value

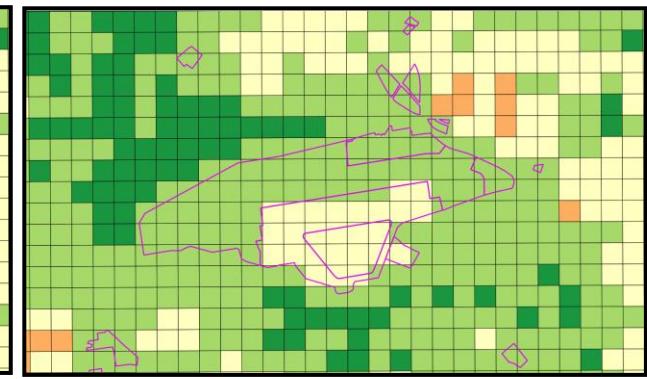
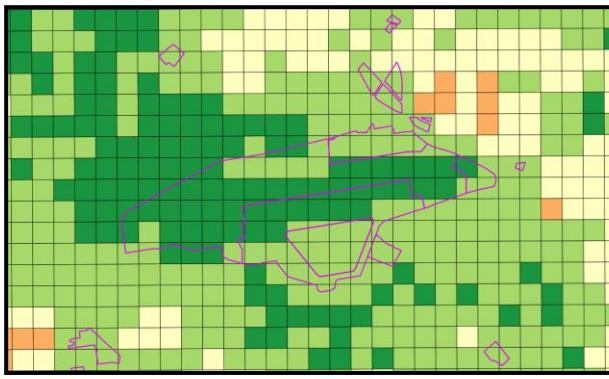
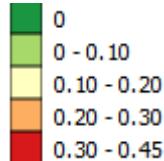
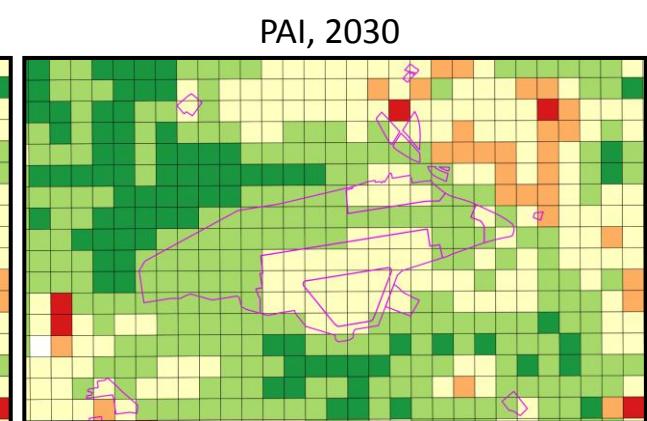
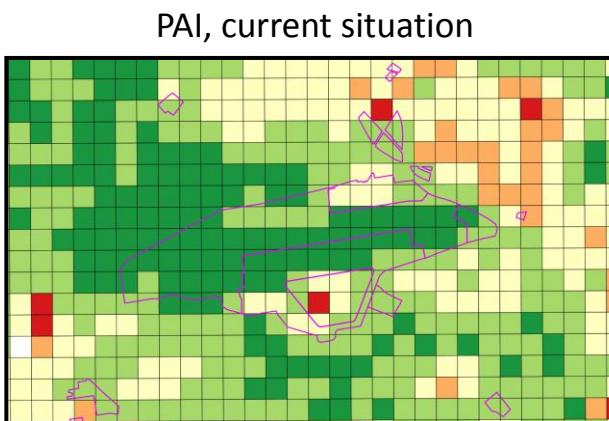
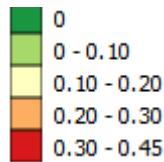


$$r = \frac{PAI^*_{future}}{PAI^*_{present}}$$

$$PAI_{future} = r \times PAI_{present}$$

# Current situation vs future situation

e.g. Berlin, urban plan Airport Berlin - Tegel



# Conclusions

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## Regression analysis

- Considerable increase in  $R^2$  when including population data in the regression analyses together with EEA SSL

## Morphology indices

- Significant relationships between variables and EEA SSL
  - Depending on urban morphology index (e.g. AVG\_H lower than F\_VEG)
  - Depending on the city (e.g. higher  $R^2$  for Berlin than for Antwerp)

## Urban Plans

- Limited changes on UHI effect on 250m grid → local effects are however significant but not captured at this resolution
- Resolution independent methodology – flexibility

## Future work

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- Integration of the **population density** in the relationships for all urban morphology indices
- **Higher resolution** modelling
  - Individual buildings or blocks?
  - Complexity versus performance
  - Take high resolution effects into consideration (shadow, radiation from buildings, ...)
  - Resolution → meter(s)?
  - Applicability relationships at meter scale?
- **Other** indices / use of **satellite** imagery?
- Combination of **heat stress parameters** (UHI, # heatwave days) with **socio-economic** data to produce heat stress **exposure** maps



## Questions?

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Thank you for your attention!

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## NACLIM

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NACLIM [www.naclim.eu](http://www.naclim.eu)

