A multi-level, multi-scenario perspective on the interplay between urban planning and flood risk management

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A multi-level, multi-scenario perspective on the interplay between urban planning and flood risk
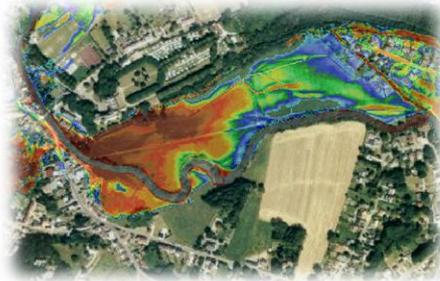
Regional level

Urbanization increases vulnerability in the floodplains.

District level

The layout of buildings also affects the flow conveyance.

A complete modelling chain was set up, involving hydraulic, urbanisation and damage modelling
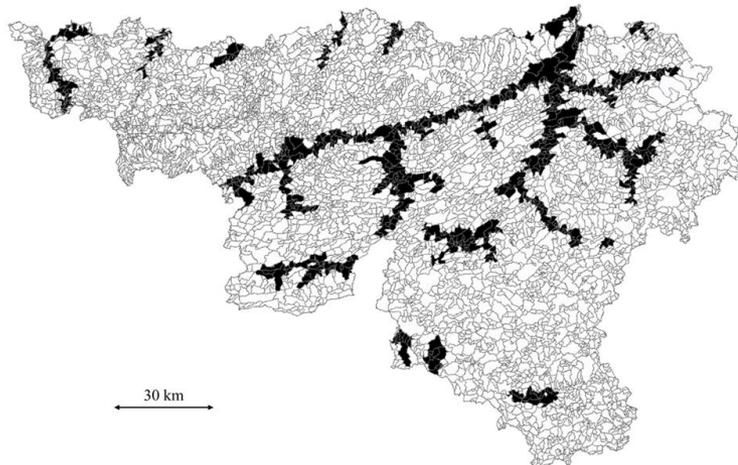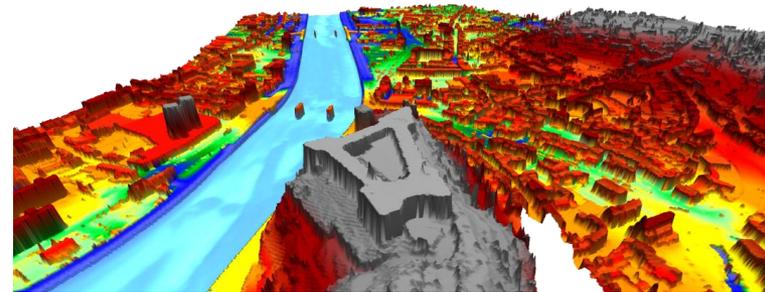

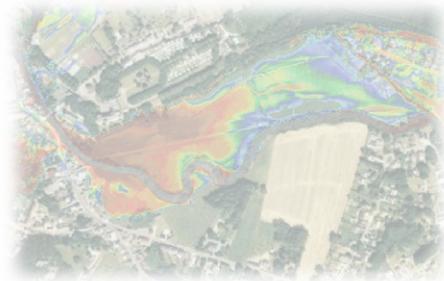*Hydraulic model* → *Urbanisation model* → *Damage model*

- Fully dynamic shallow-water model

- Based on laser altimetry (decimetre-scale vertical accuracy)

30 km

- Applied to all main rivers in the southern part of Belgium (1,300+ km)

- Considered flood frequencies: 25-year, 50-year & 100-year floods

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A complete modelling chain was set up, involving hydraulic, urbanisation and damage modelling
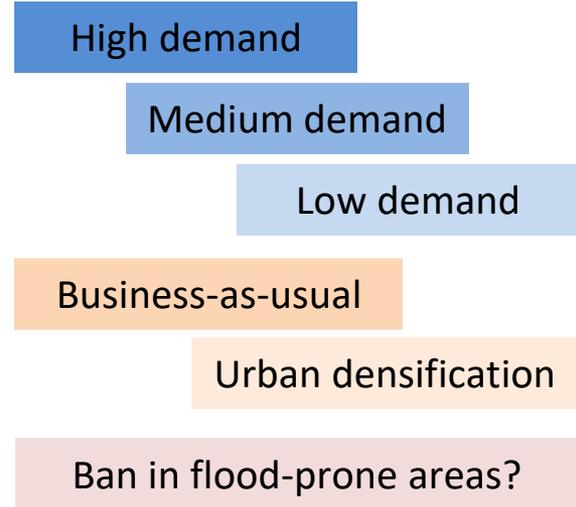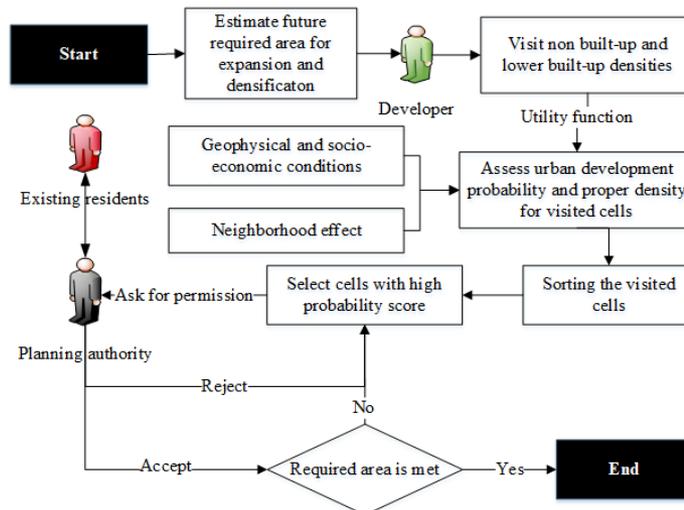

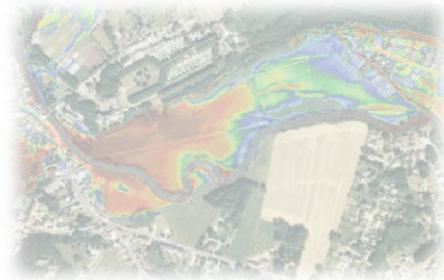*Hydraulic model* → **Urbanisation model** → *Damage model*

- Hybrid urbanization model, coupling cellular automata and agent-based modelling (Mustafa et al. 2017)

- Considering various scenarios for demand and allocation

High demand

Medium demand

Low demand

Business-as-usual

Urban densification

Ban in flood-prone areas?

A complete modelling chain was set up, involving hydraulic, urbanisation and damage modelling
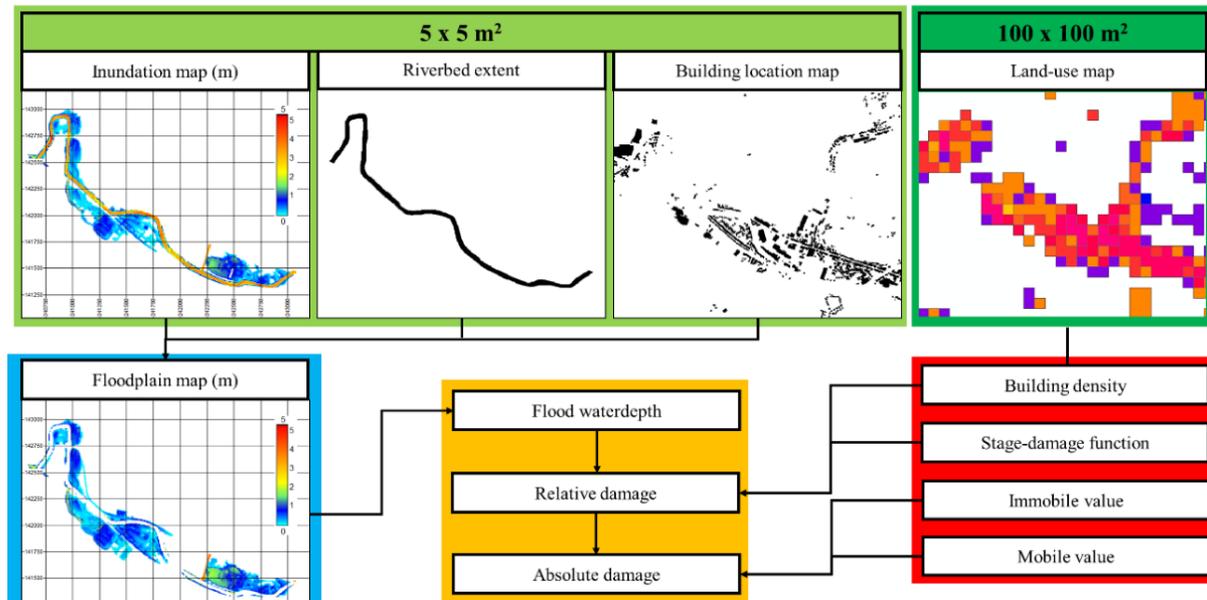

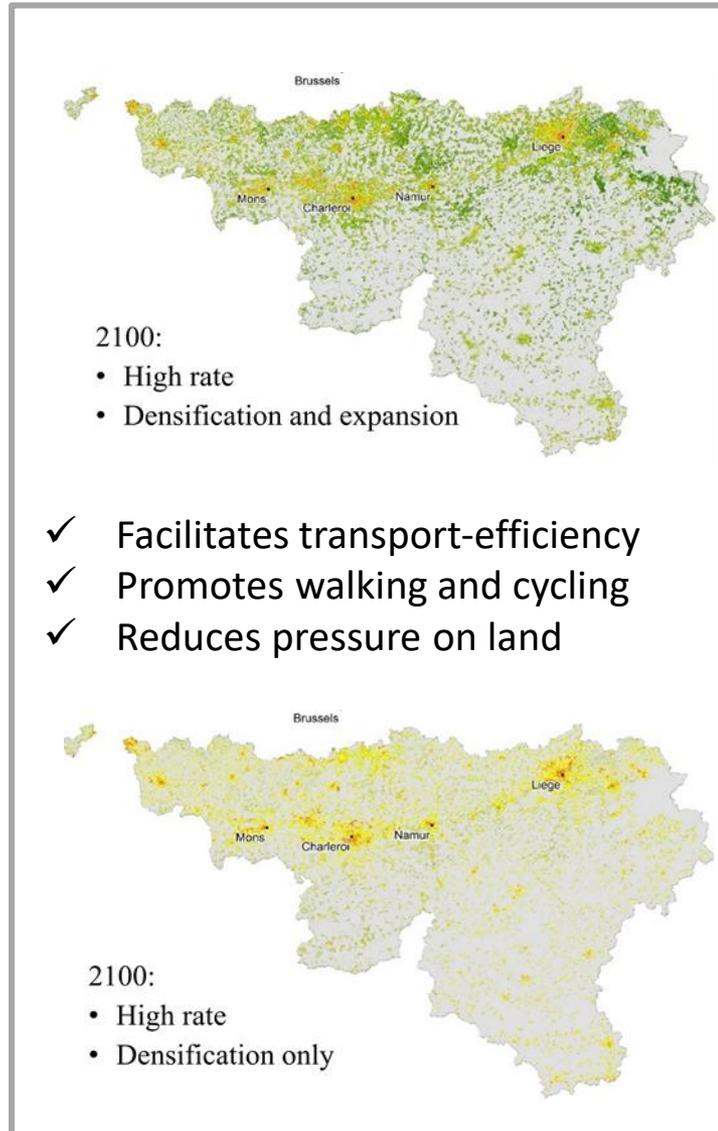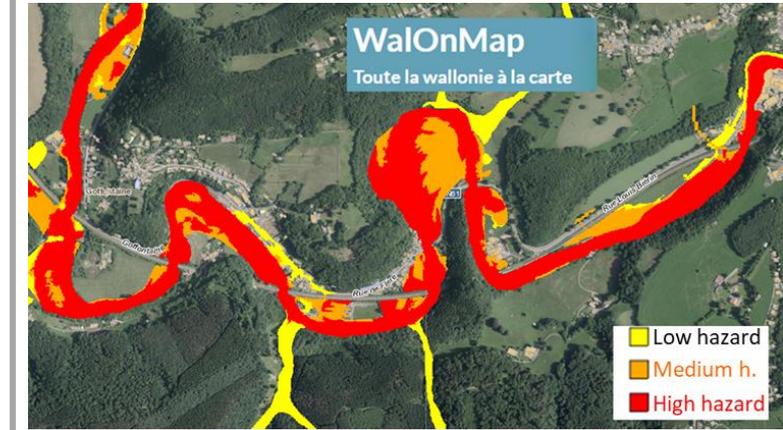*Hydraulic model*   *Urbanisation model*   ***Damage model***

- Depth-damage functions

- Specific value correlated with the urban density

"Sustainable spatial planning" policies tend to promote urban densification, as opposed to urban sprawl

2100:
- High rate
- Densification and expansion

✓ Facilitates transport-efficiency
✓ Promotes walking and cycling
✓ Reduces pressure on land

Urban density

High — Low

0 10 20 40 km

2100:
- High rate
- Densification only

① WalOnMap
Toute la wallonie à la carte

Low hazard
Medium h.
High hazard

② Densification promotes urbanization around existing urban areas mainly located close to the rivers

⇨ ↗ flood risk

(10-15 percentage points)

A multi-level, multi-scenario perspective on the interplay between urban planning and flood risk

Regional level

Urbanization increases vulnerability in the floodplains.

District level

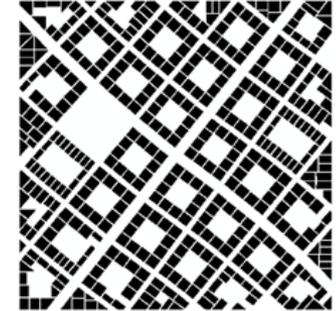The layout of buildings also affects the flow conveyance.

Does the layout of buildings (*urban form*) have a substantial influence on flooding severity?

$i = 2.8\% - T = 15$ and 50 years

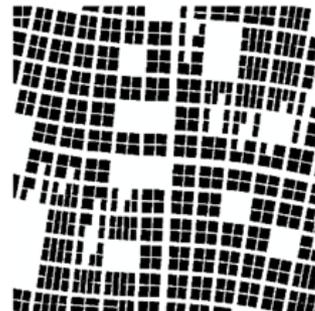$i = 1.4\% - T = 50$ years

$i = 1.4\%$ and $2.8\% - T = 100$ years

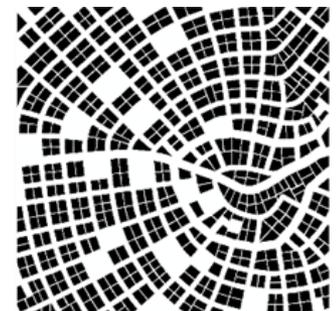$i = 2.8\% - T = 50$ years

$i = 1.4\% - T = 15, 50$ and 100 years

$i = 2.8\% - T = 15$ years

$i = 1.4\% - T = 50$ years
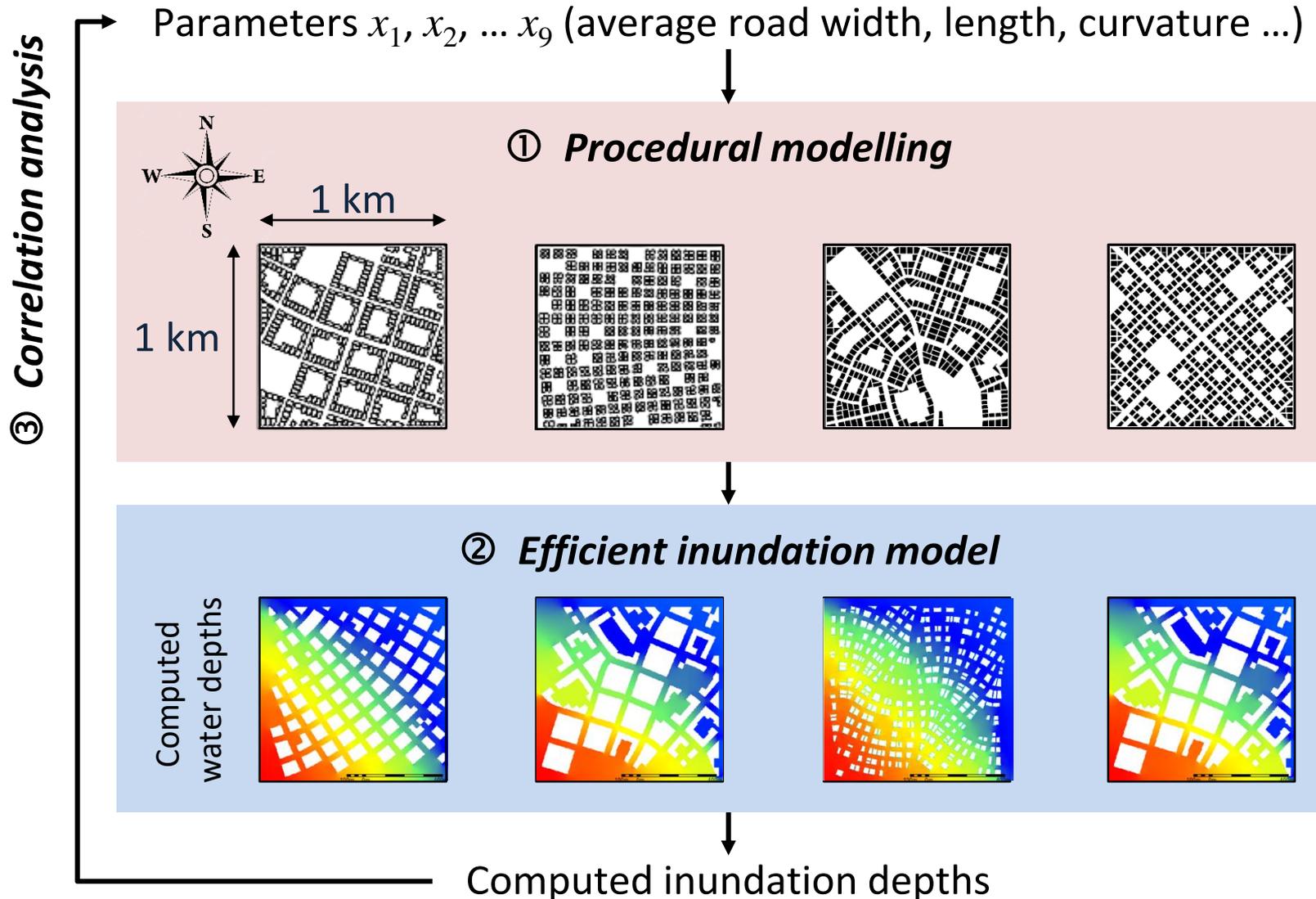$i = 2.8\% - T = 15, 50$ and 100 years

$i = 1.4\% - T = 15$ and 100 years

$i = 1.4\% - T = 15$ years

The analysis is based on two modelling tools, complemented by statistical analysis

③ *Correlation analysis*

Parameters x_1, x_2, … x_9 (average road width, length, curvature …)

① *Procedural modelling*

N
W   E
S

1 km

1 km

② *Efficient inundation model*

Computed water depths

Computed inundation depths

The urban pattern generator uses nine input parameters, the ranges of which were calibrated on real-world data

ID	Characteristic	Minimum value	Maximum value
x_1	Street length	40 m	400 m
x_2	Street orientation	0	180°
x_3	Street curvature	0 km^{-1}	10 km^{-1}
x_4	Major street width		
x_5	Minor street width		
x_6	Mean parcel area	3	
x_7	Building rear setback		
x_8	Building side setback		
x_9	Building coverage		

Offset from the parcel limits

Parcel

Building

x_7

$\vec{x_8}$
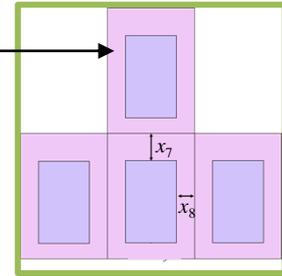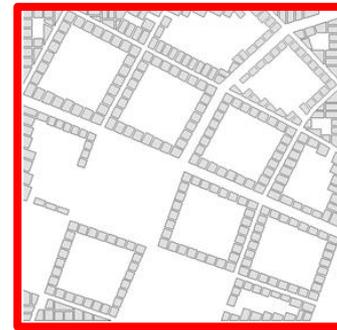
From land registry data (Belgium)

▶ $[\ x_1,\ x_2,\ \dots\ x_9\ ]$
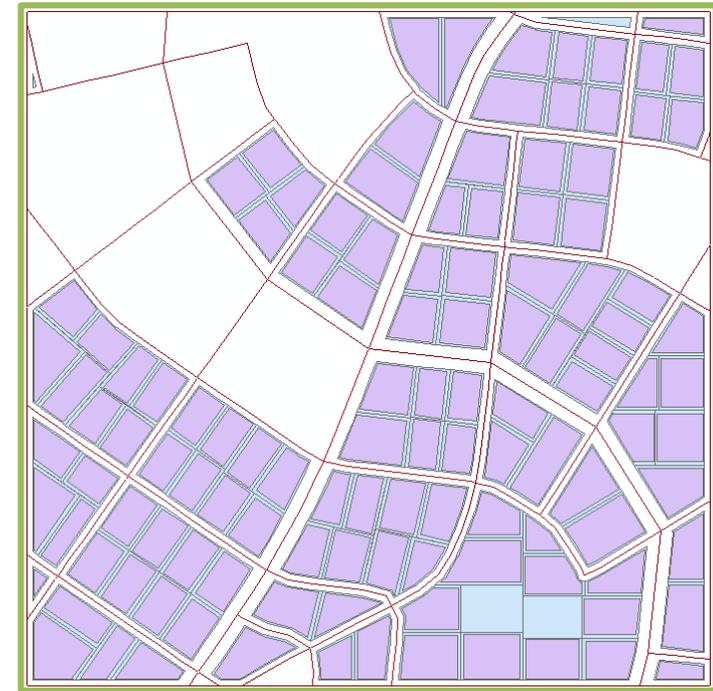
Computer Science Department, Purdue University, USA

Bruwier et al. (2017, STOTEN)

"Fragmented" building blocks tend to perform better, and distances between adjacent buildings are important
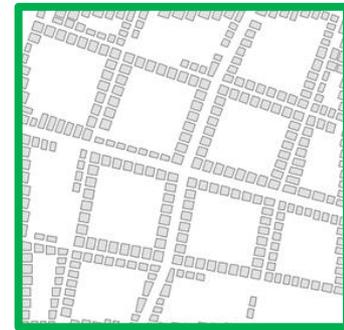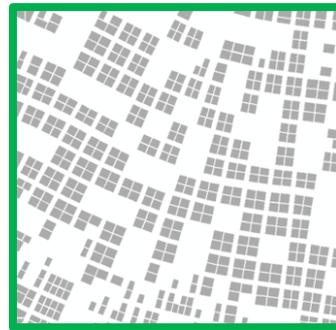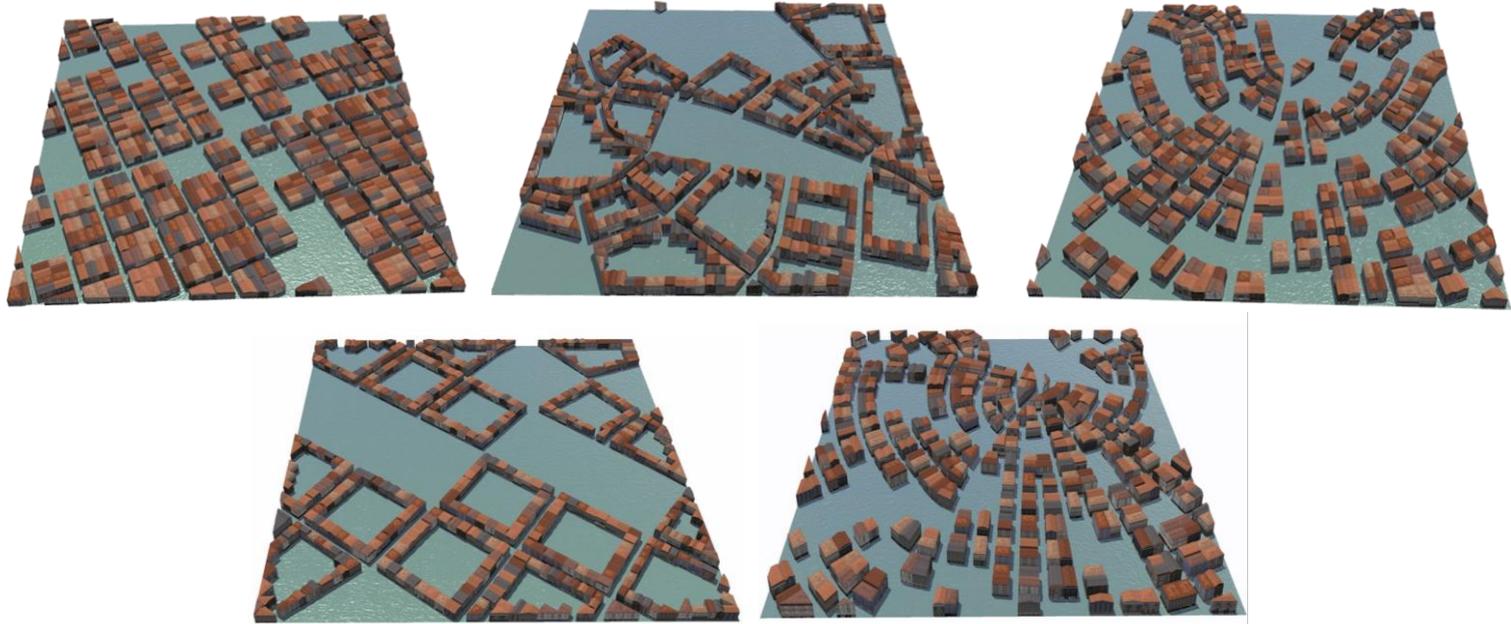
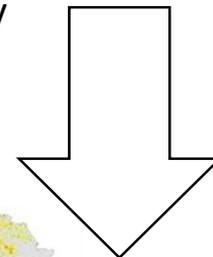# General good practices in sustainable urban planning must be modulated to accommodate flood-resilience

Regional level
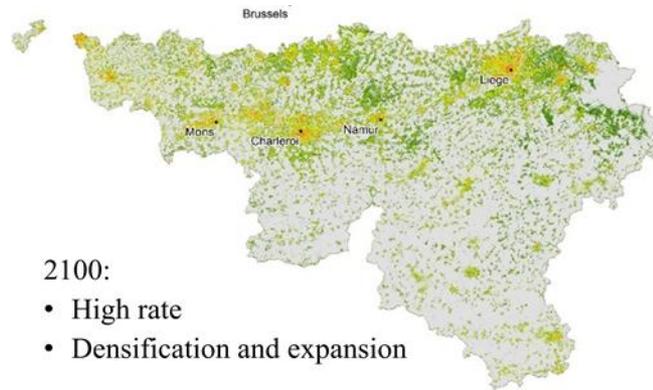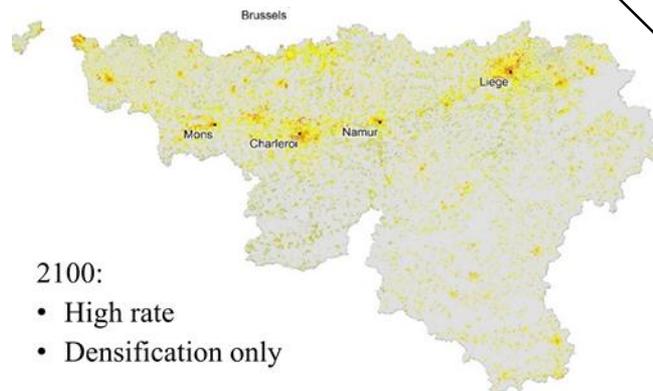
District level

2100:
- High rate
- Densification and expansion
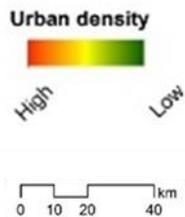

- ✓ Facilitates transport-efficiency
- ✓ Promotes walking and cycling
- ✓ Reduces pressure on land

- ✓ Enhances heating efficiency
- ✓ Improves efficiency of supply network (water, energy …)

Urban density

High   Low

| | km |
|0 10 20 | 40|

2100:
- High rate
- Densification only

Conclusion

At the **regional level**, we coupled an agent-based urbanisation model with inundation and risk modelling.

At the **district (or local) level**, a procedural model was coupled with inundation modelling.

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journal homepage: www.elsevier.com/locate/scitotenv

Influence of urban pattern on inundation flow in floodplains of lowland rivers

M. Bruwier [a,*], A. ... J. Teller [b], B. Dew...

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Research article

Effects of spatial planning on future flood risks in urban environments

Ahmed Mustafa[a,*], Martin Bruwier[b], Pierre Archambeau[b], Sébastian Erpicum[b], Michel Pirotton[b], Benjamin Dewals[b], Jacques Teller[a]

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