Exploratory modeling for handling deep uncertainty in multi-formalism models

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Decision making on societal challenges

Decision making : multi-actor, cross-scale and distributed

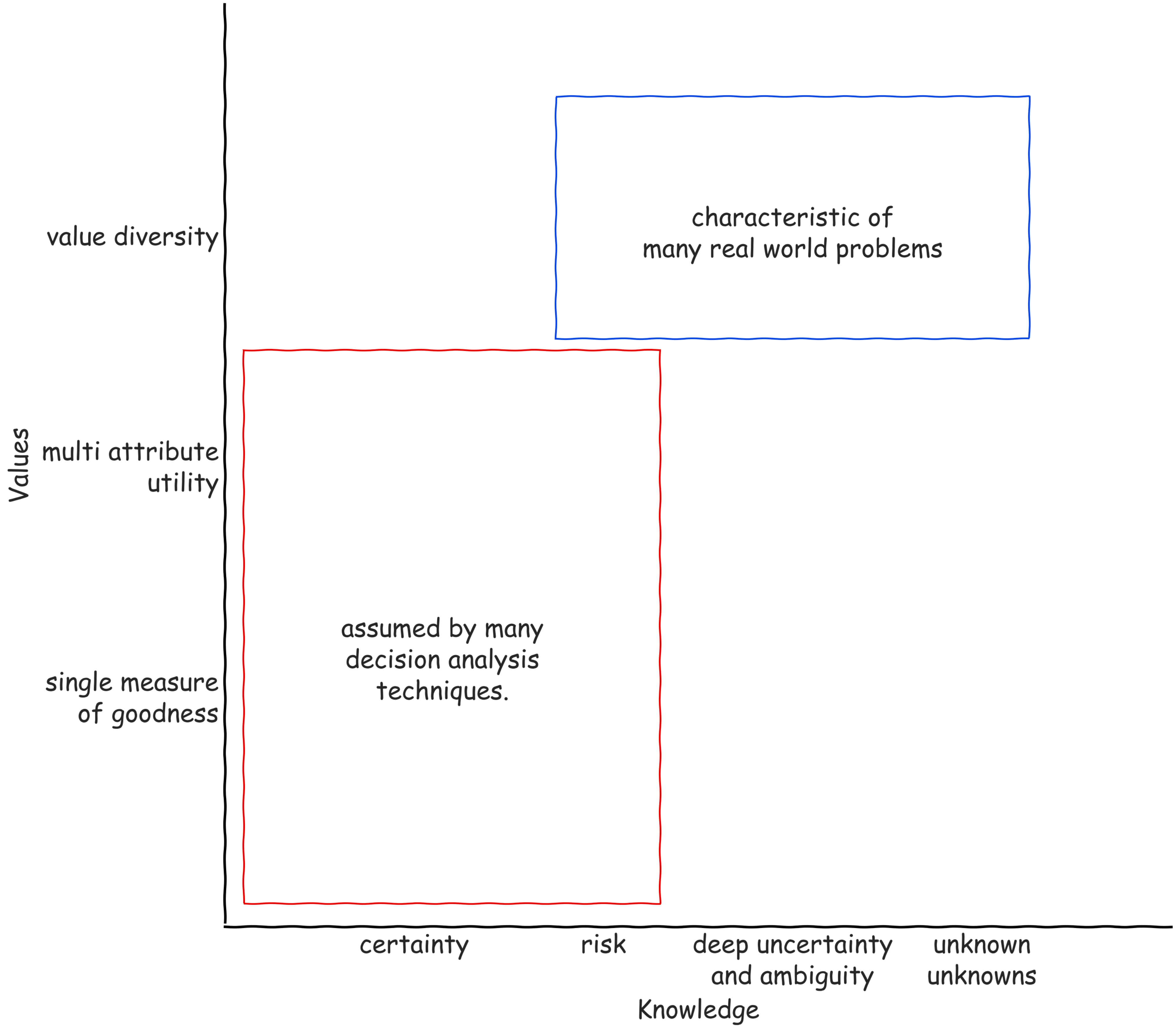
Values : diverse and incommensurable

Knowledge : uncertain and contested

Various valid but incommensurable perspectives on what the challenge is

→ problem formulation and problem solving are intertwined

Also known as: wicked problems or societal messes


value diversity
multi attribute utility
single measure of goodness
Values
characteristic of many real world problems
assumed by many decision analysis techniques.
certainty
risk
deep uncertainty and ambiguity
unknown unknowns
Knowledge

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Why use models?

Argument from complexity

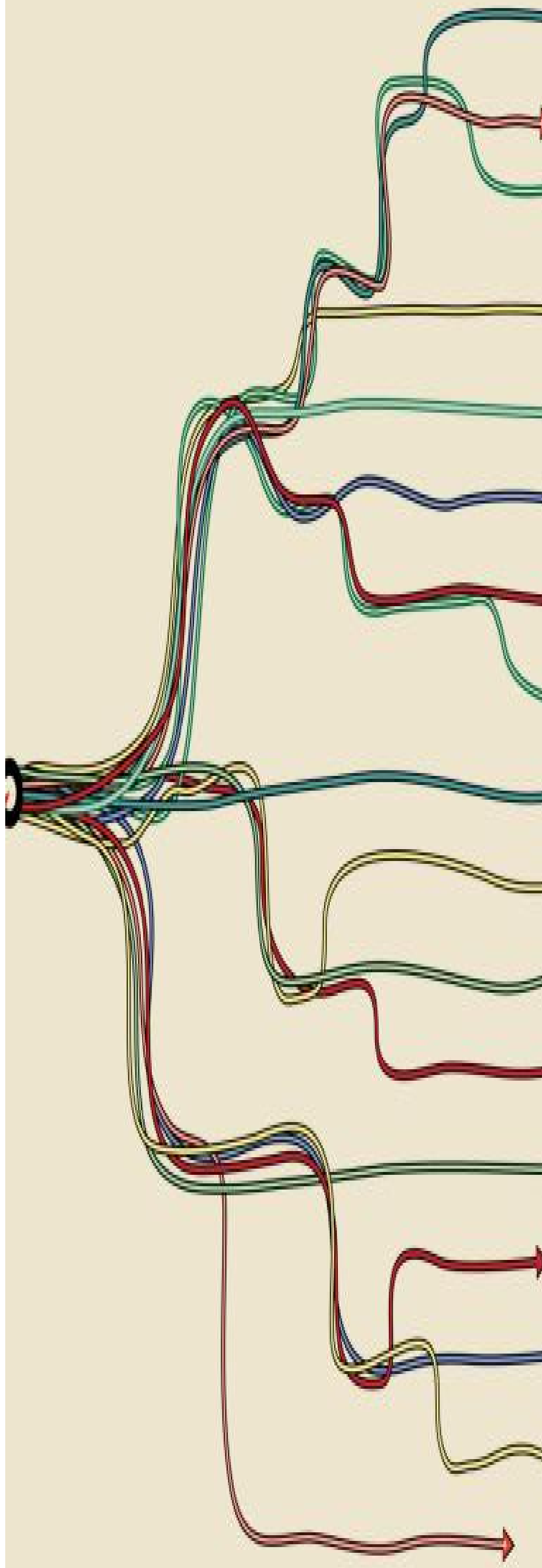
Because the system of interest is often complex, there is a need supplement human reasoning

Sensitivity to initial conditions (both parameters and structure)

Multi-faceted nature of system cannot be captured in a single model

Argument from uncertainty

When confronted with uncertainty, instead of making an assumption, explore systematically the consequences of alternative assumptions in order to identify differences that make a difference



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Deep uncertainty

Deep uncertainty exists when parties to a decision do not know, or cannot agree on, the system model that relates action to consequences, the probability distributions to place over the inputs to these models, which consequences to consider and their relative importance. Deep uncertainty often involves decisions that are made over time in dynamic interaction with the system.

Also known as Knightian uncertainty, uncertainty proper, or severe uncertainty

Implication: set of plausible models of the system, set of outcomes of interest without a priori weighting, and sets of scenarios

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Kwakkel et al. 2016, doi:10.1061/(ASCE)WR.1943-5452.0000626

from **Predict** and **Act** to **Explore** and **Adapt**

from **predict** to **explore**

- Scenario discovery (Bryant & Lempert 2010)
- Robust multi-objective optimization (Kwakkel et al. 2015)
- Info-Gap decision theory (Ben Haim, 2001; Hall et al. 2012)
- Adaptation tipping points (Kwadijk et al 2010)
- Decision scaling (Brown et al. 2012; LeRoy Poff et al. 2015)

from **act** to **adapt**

- Assumption-Based Planning (Dewar et al.1993)
- Adaptive Policymaking (Kwakkel et al 2010)
- Dynamic Adaptive Policy Pathways (Haasnoot et al. 2013)
- Robust Decision Making (Lempert & Collins 2007)

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Walker, W.E., M. Haasnoot, and J.H. Kwakkel (2013) https://dx.doi.org/10.3390/su5030955

What is exploratory modelling?

Consolidative modelling is the consolidation of known facts into a single package and using this as a surrogate for the actual system

- Used in a **predict-and-act** policy framework

Exploratory modelling is the use of computational experimentation to explore the implications of varying assumptions about uncertain, contested, or unknown model parameters and mechanisms

- Used in an **explore-and-adapt** policy framework
- Underpinning of all model-based approaches for supporting **decision making under deep uncertainty**

AQUIFER THERMAL ENERGY SYSTEMS

Dr.ir. Marc Jaxa-Rozen

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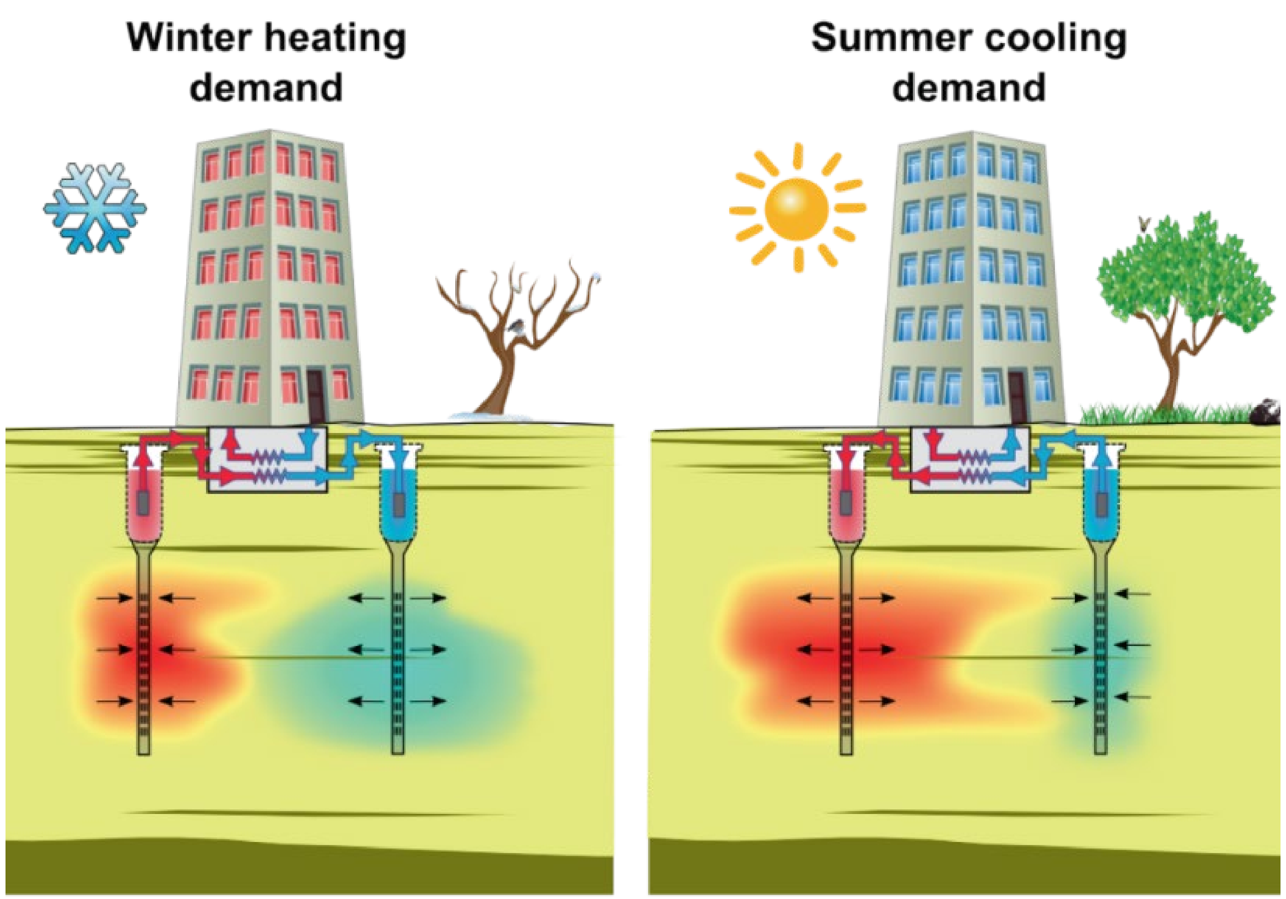
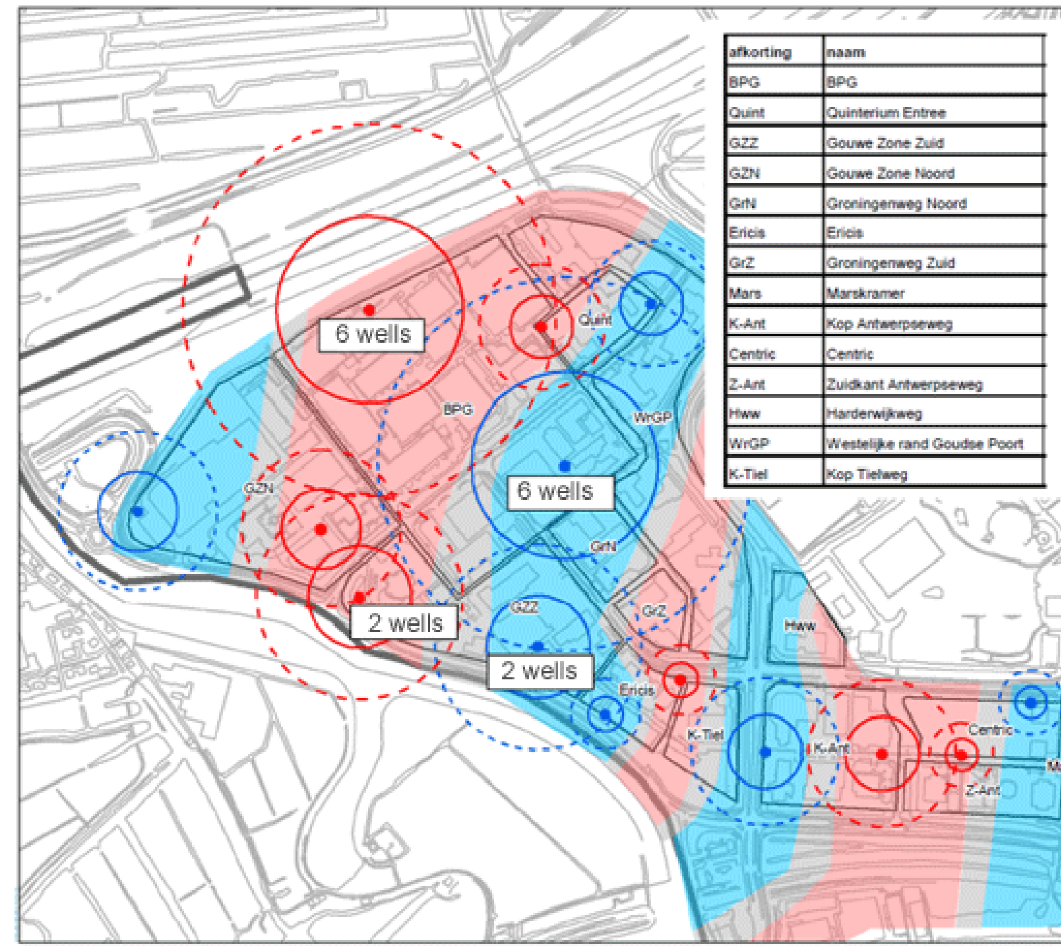
Aquifer Thermal Energy Storage (ATES) in the Netherlands





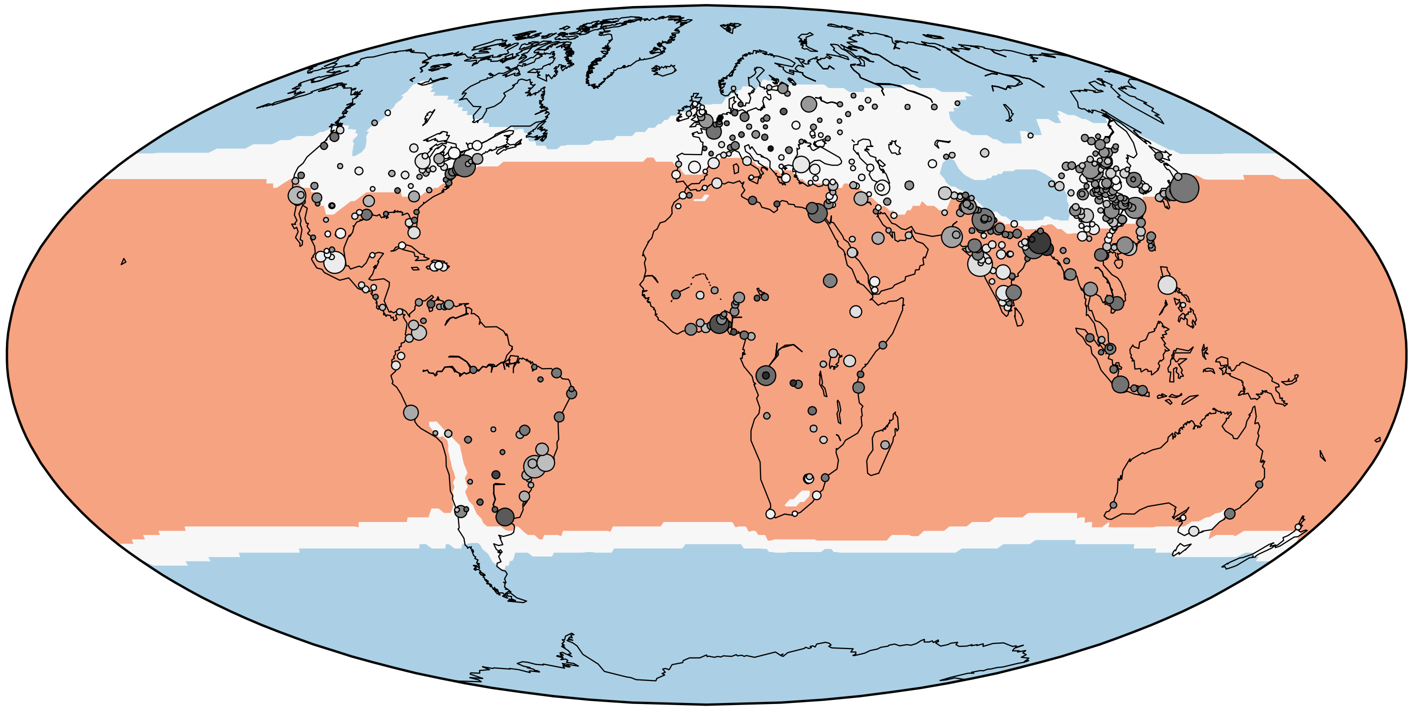
afkorting	naam
BPG	BPG
Quint	Quinterium Entree
GZZ	Gouwe Zone Zuid
GZN	Gouwe Zone Noord
GrN	Groningenweg Noord
Ericis	Ericis
GrZ	Groningenweg Zuid
Mars	Marskramer
K-Ant	Kop Antwerpseweg
Centric	Centric
Z-Ant	Zuidkant Antwerpseweg
Hww	Harderwijkweg
WrGP	Westelijke rand Goudse Poort
K-Tiel	Kop Tielweg

Bonte, 2014

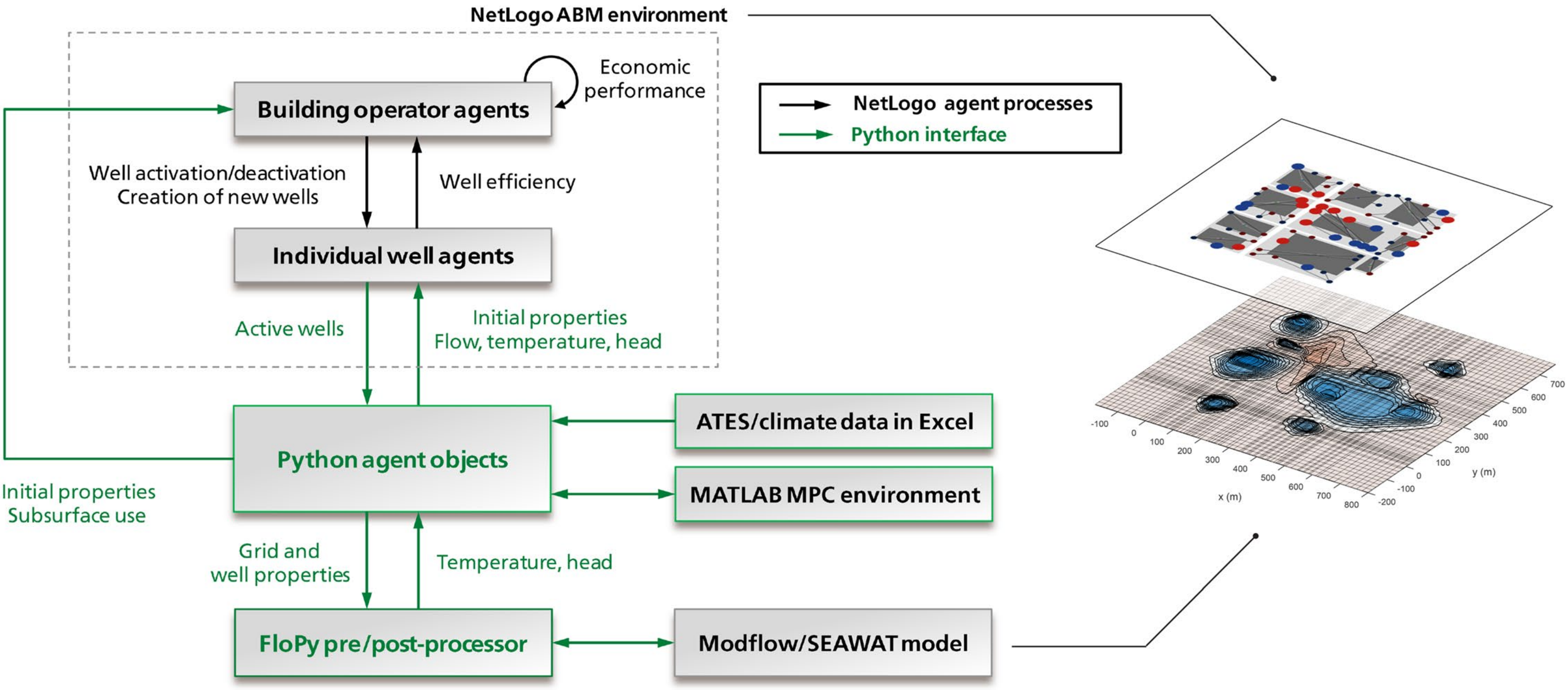
Can reduce energy use/GHG emissions by 50%+ for large buildings

> 2,500 systems in function – may become largest user of groundwater by 2025 in The Netherlands

How to manage this technology at a larger scale?



Coupled agent-based/geohydrological simulation



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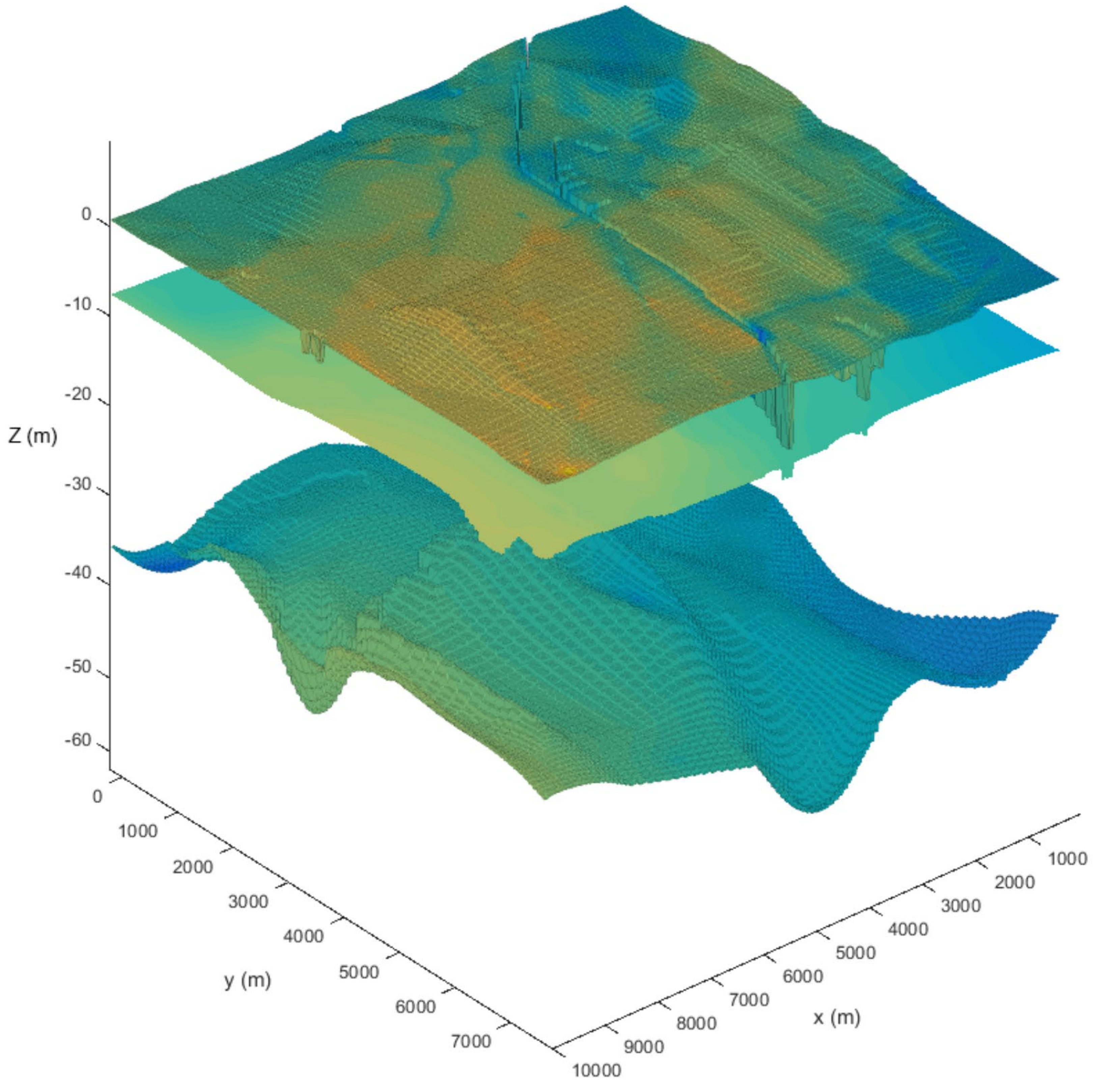
Jaxa-Rozen et al (2019) https://doi.org/10.1016/j.envsoft.2019.01.020

Utrecht case

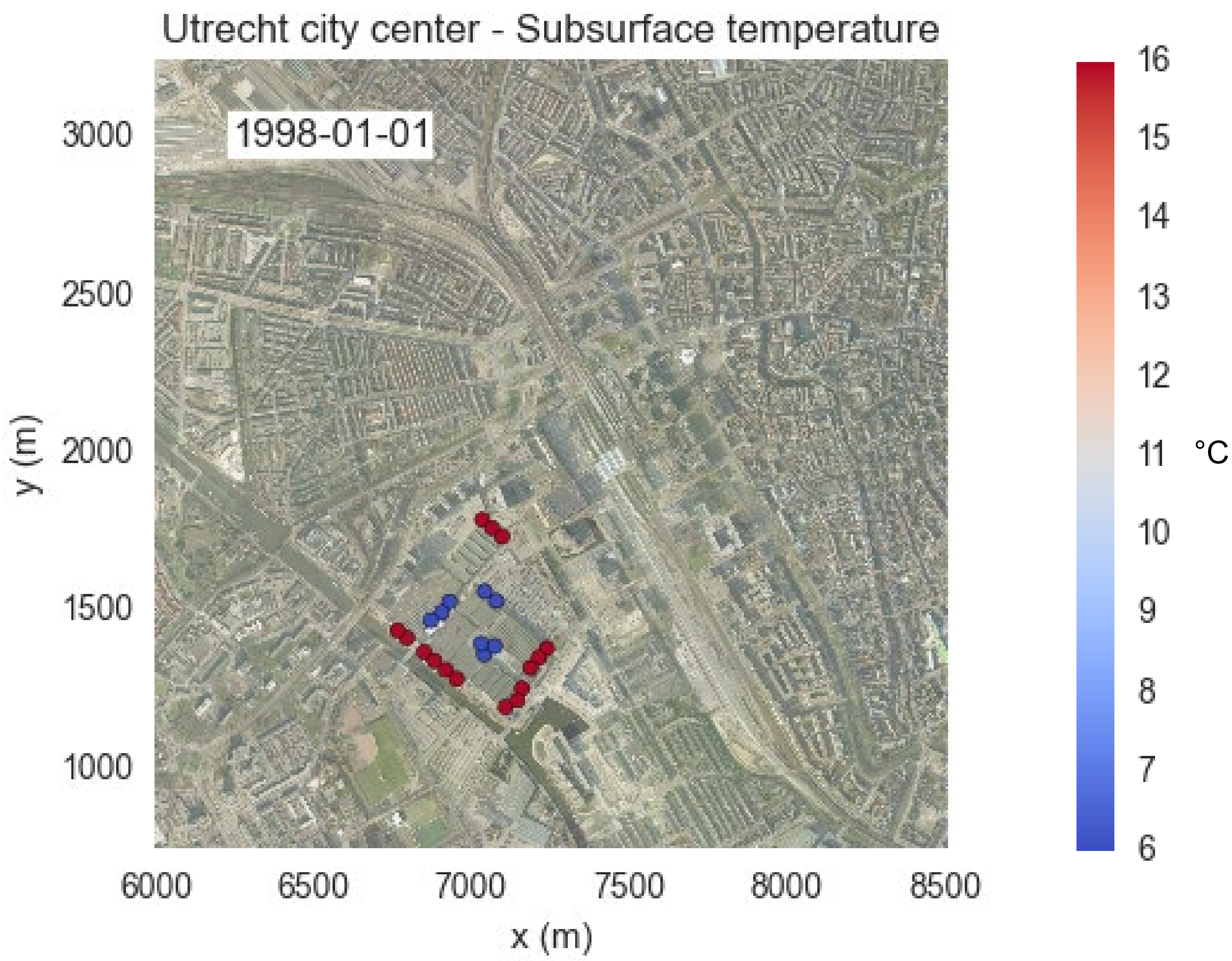
- How do current ATES permit policies perform in a dense urban environment?

- Model uses data for 89 actual and planned wells in Utrecht city center for 1998-2016
- GIS data for building plots and spatial constraints over a 2500 x 2500m area

Integration of geohydrological model

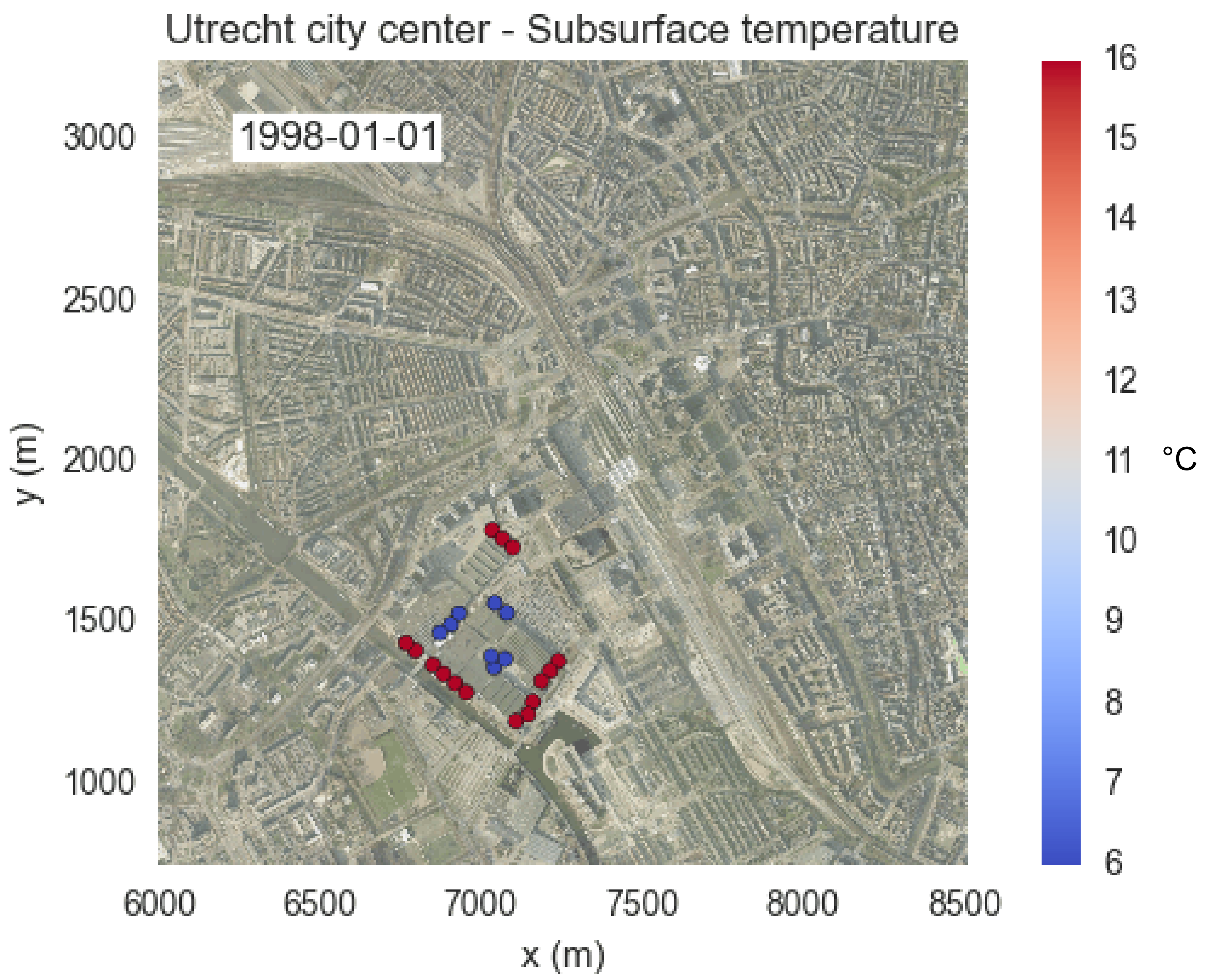


Historical ATES use



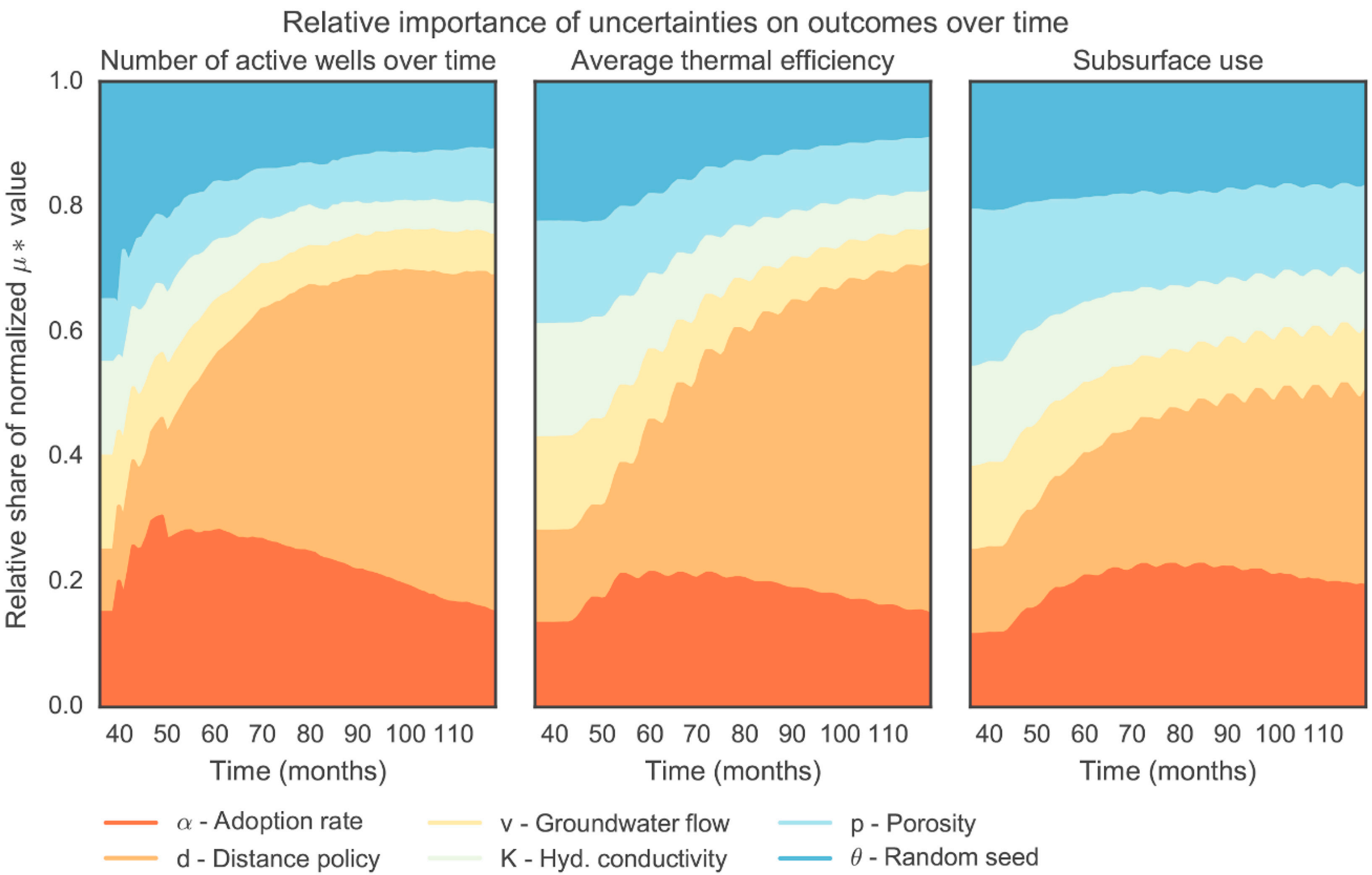
- As of 2017: lack of space for new systems under current design guidelines

Historical ATES use

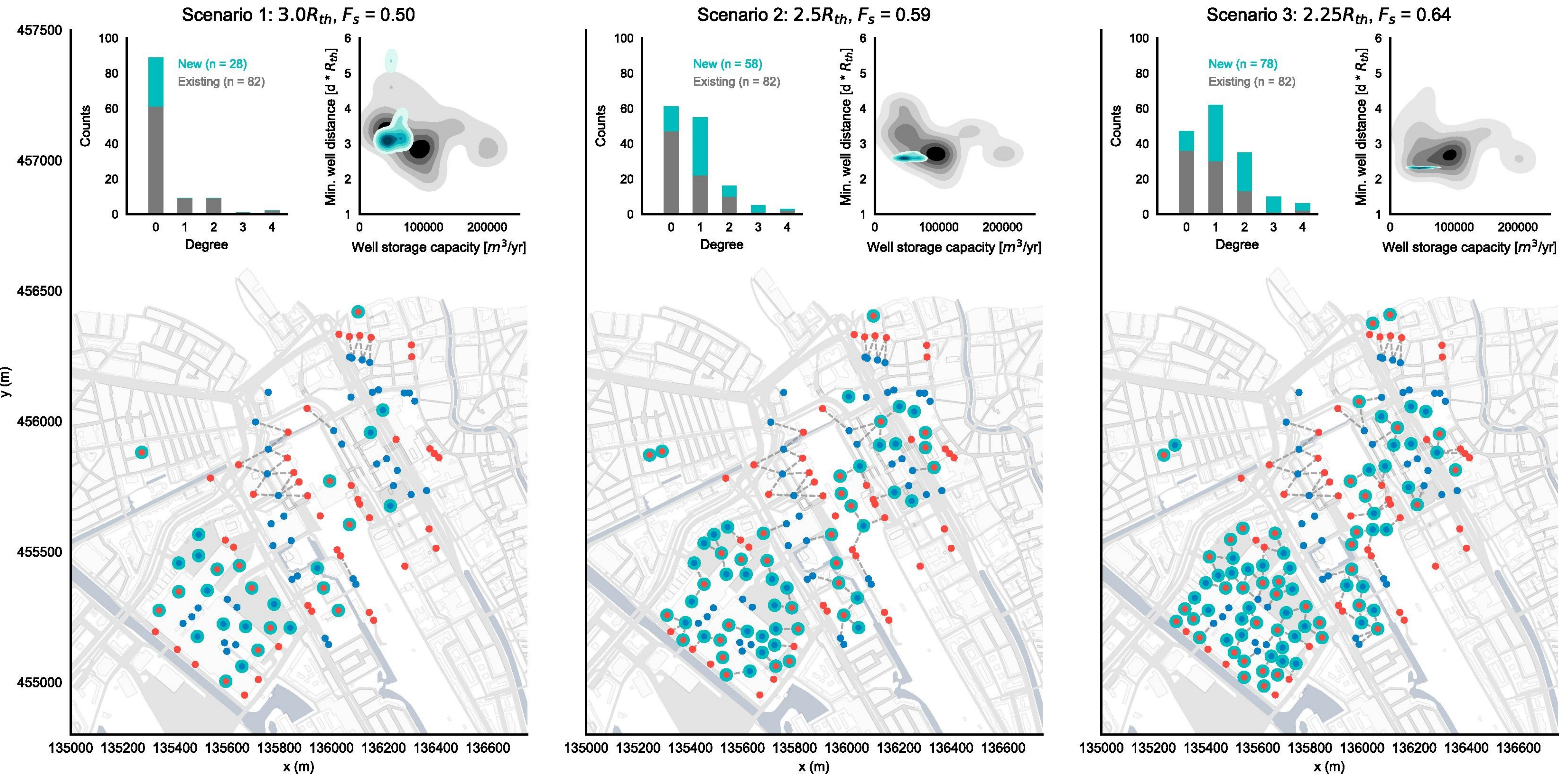


- As of 2017: lack of space for new systems under current design guidelines

Global Sensitivity Analysis

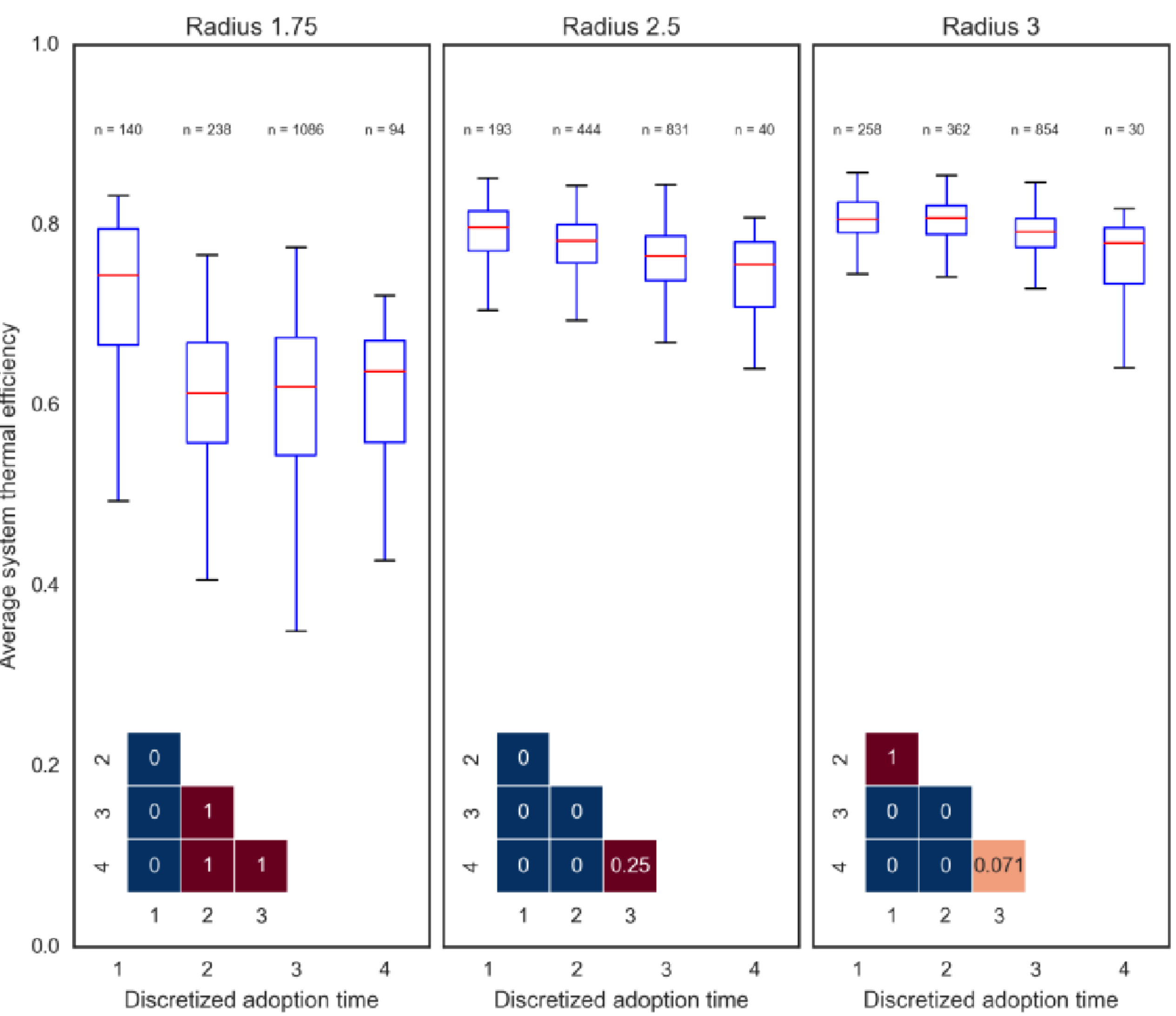


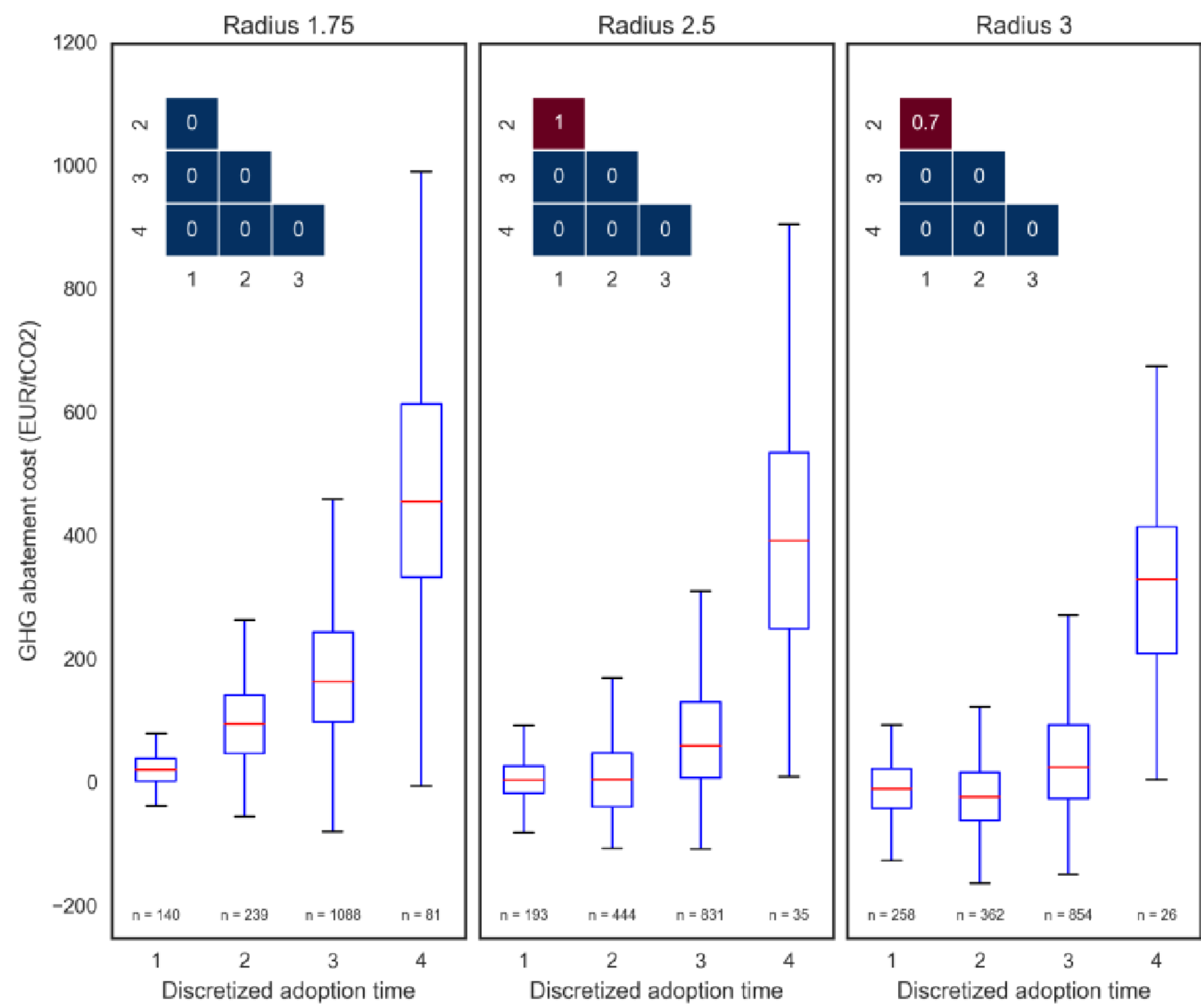
Alternative spatial planning rules



Rostampour et al (2019) https://doi.org/10.1016/j.apenergy.2019.03.110

Alternative spatial planning rules





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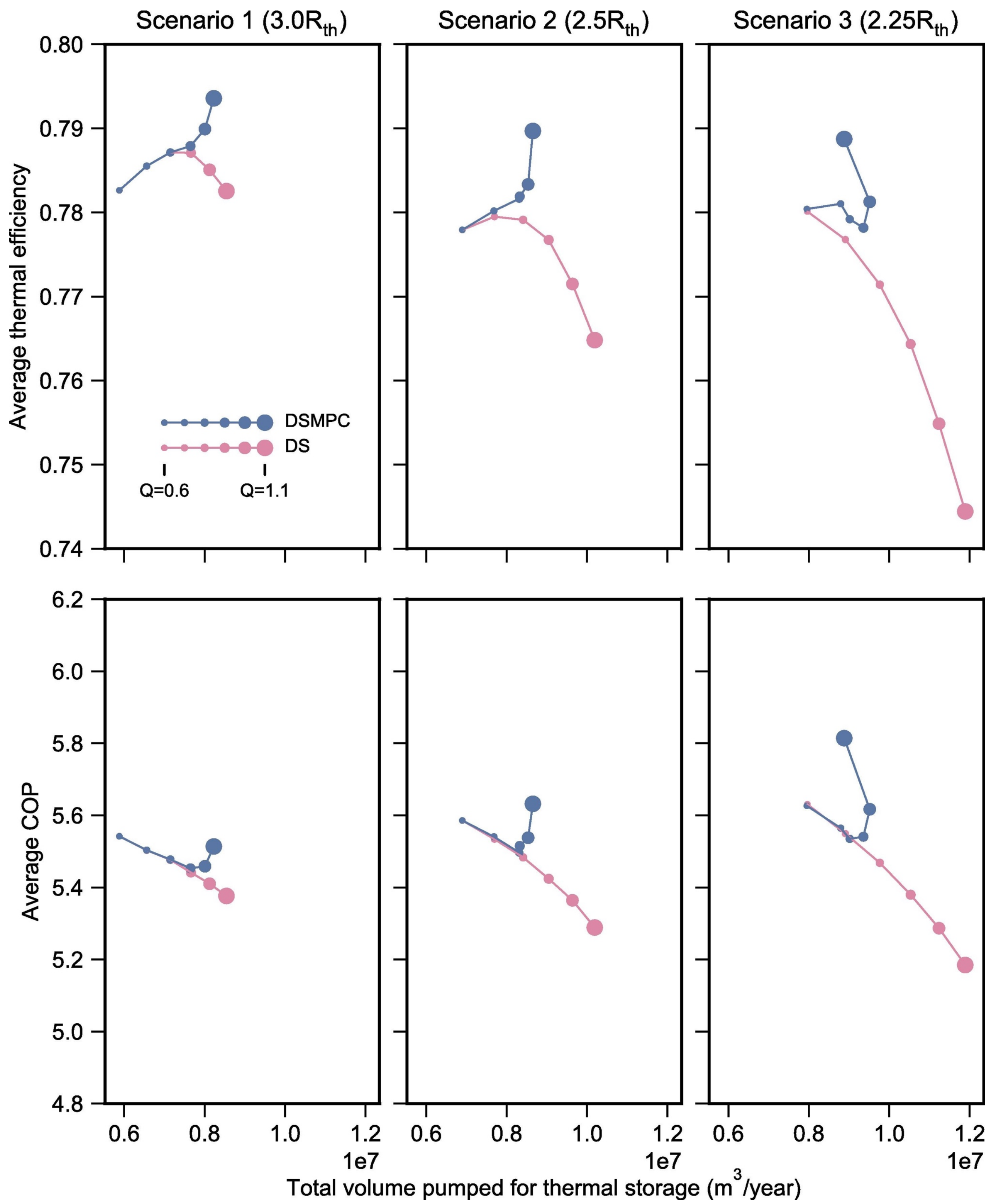
Distributed MPC to resolve tensions between personal and public benefits



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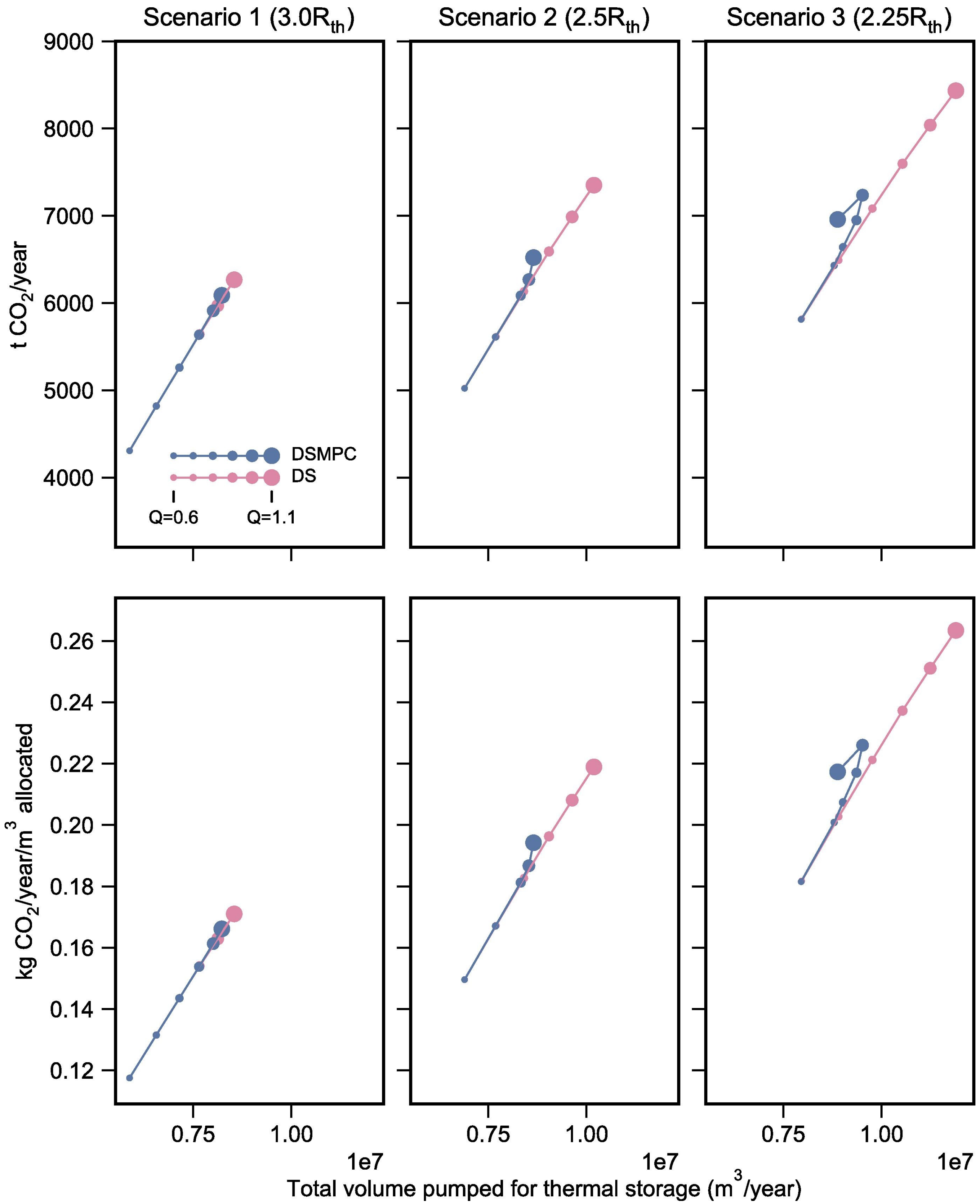

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WHAT ARE THE MERITS OF ENDOGENOUS LAND USE CHANGE IN FLOOD RISK ASSESSMENTS?

Ir. Bramka Arga Jafino

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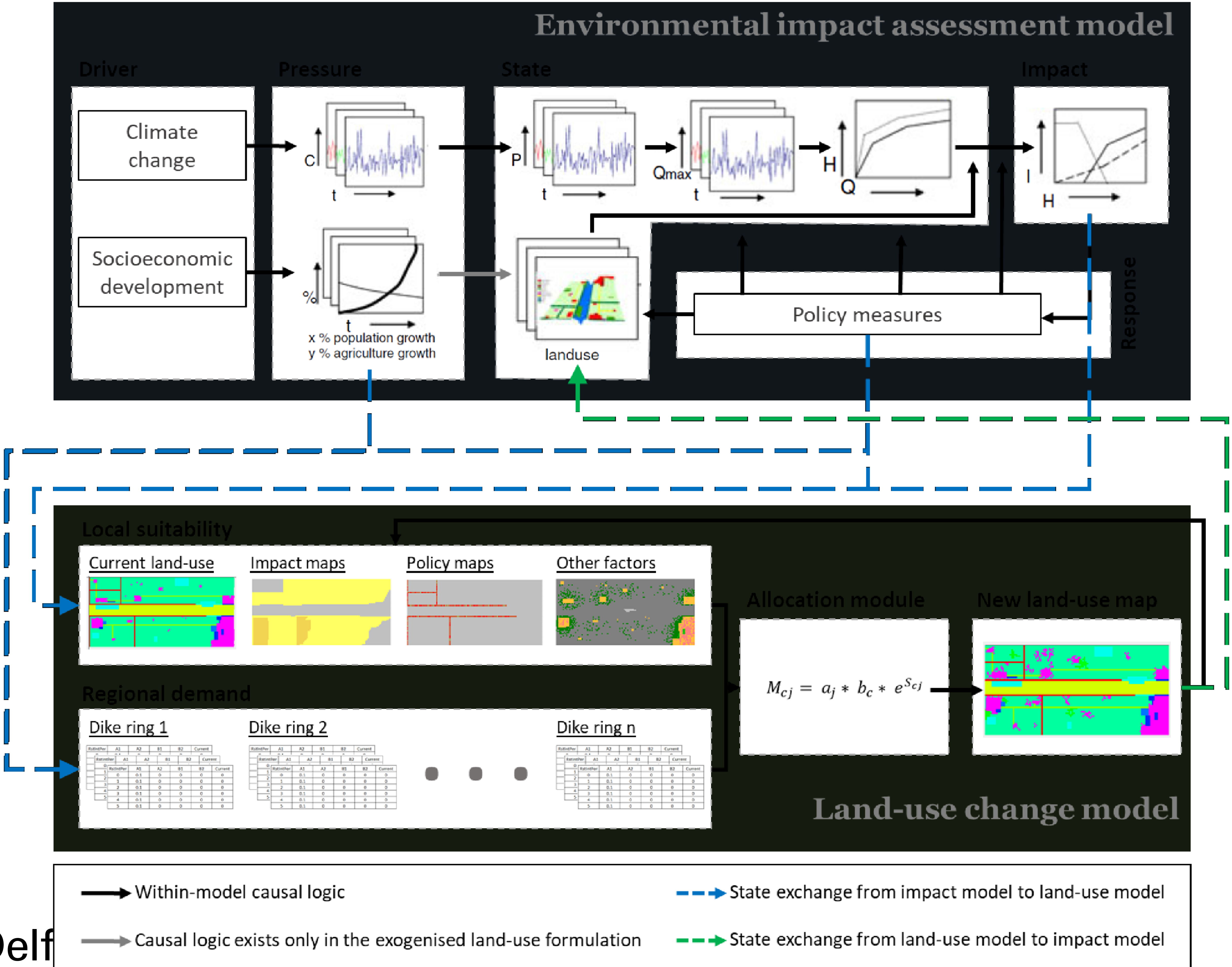
Environmental impact assessment model
Driver
Pressure
State
Impact
Climate change
Socioeconomic development
C
t
P
t
Qmax
t
H
Q
I
H
%
t
x % population growth
y % agriculture growth
landuse
Policy measures
Response
Local suitability
Current land-use
Impact maps
Policy maps
Other factors
Allocation module
New land-use map
$M_{cj} = a_j * b_c * e^{S_{cj}}$
Regional demand
Dike ring 1
Dike ring 2
Dike ring n
Land-use change model
Within-model causal logic
Causal logic exists only in the exogenised land-use formulation
State exchange from impact model to land-use model
State exchange from land-use model to impact model

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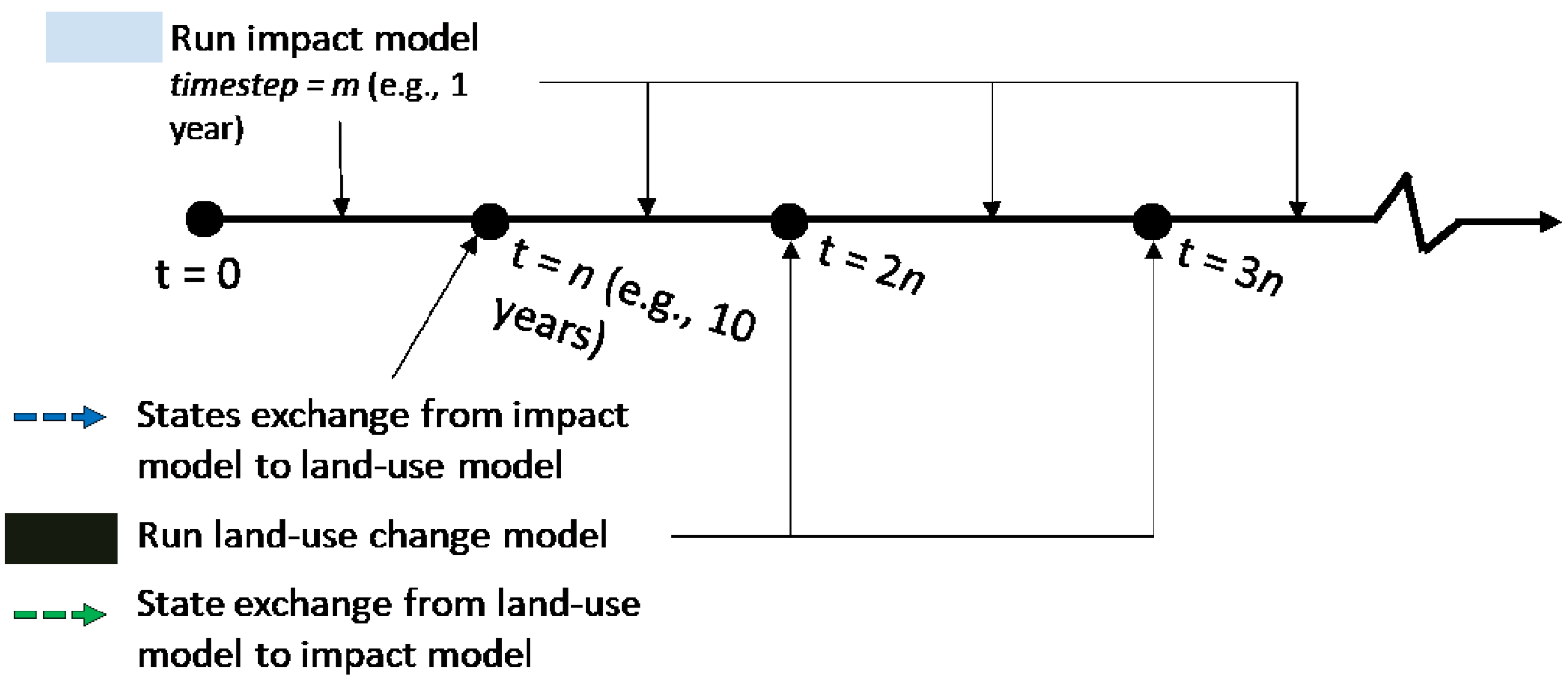
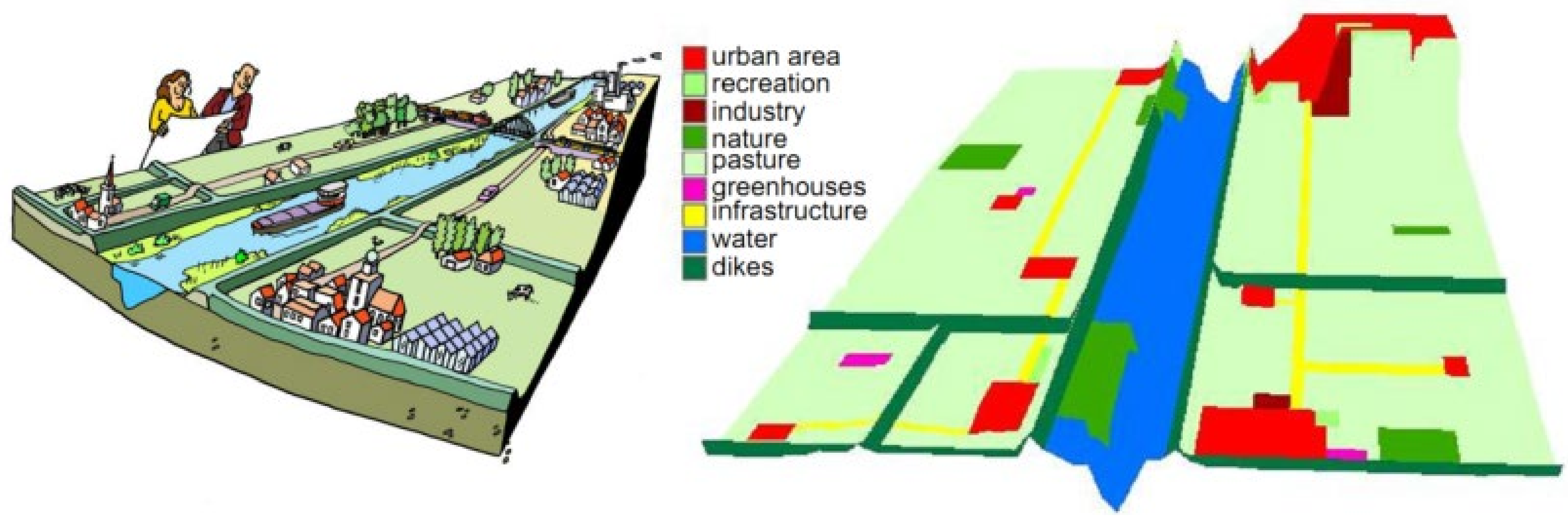
Time synchronization



Waas Case

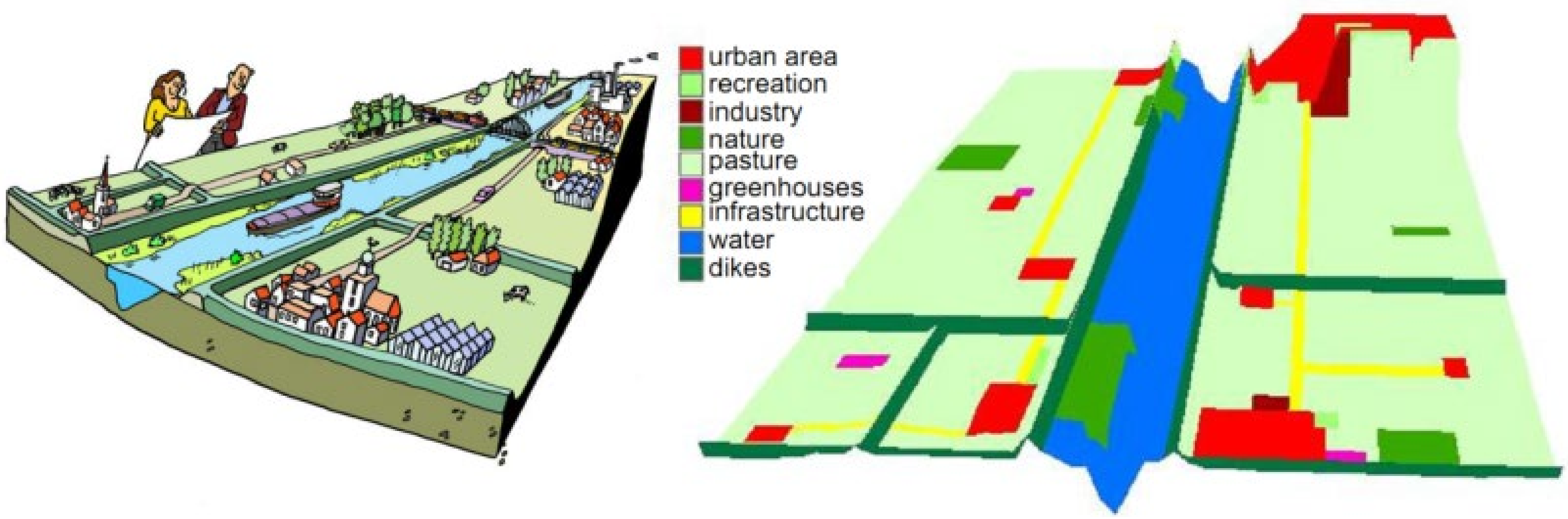


Haasnoot et al (2012) doi10.1007/s10584-012-0444-2

Waas Case

Policy options:

- Strengthening and heightening of dikes
- Room for the river
- Multi-level safety
- River basin management



Uncertainties

- River runoff
- Relationship between water levels and failure of dikes
- Relationship between flood levels and economic damage
- Efficacy of actions

Outcomes:

- Casualties
- Economic damage
- Costs

Haasnoot et al (2012) doi10.1007/s10584-012-0444-2

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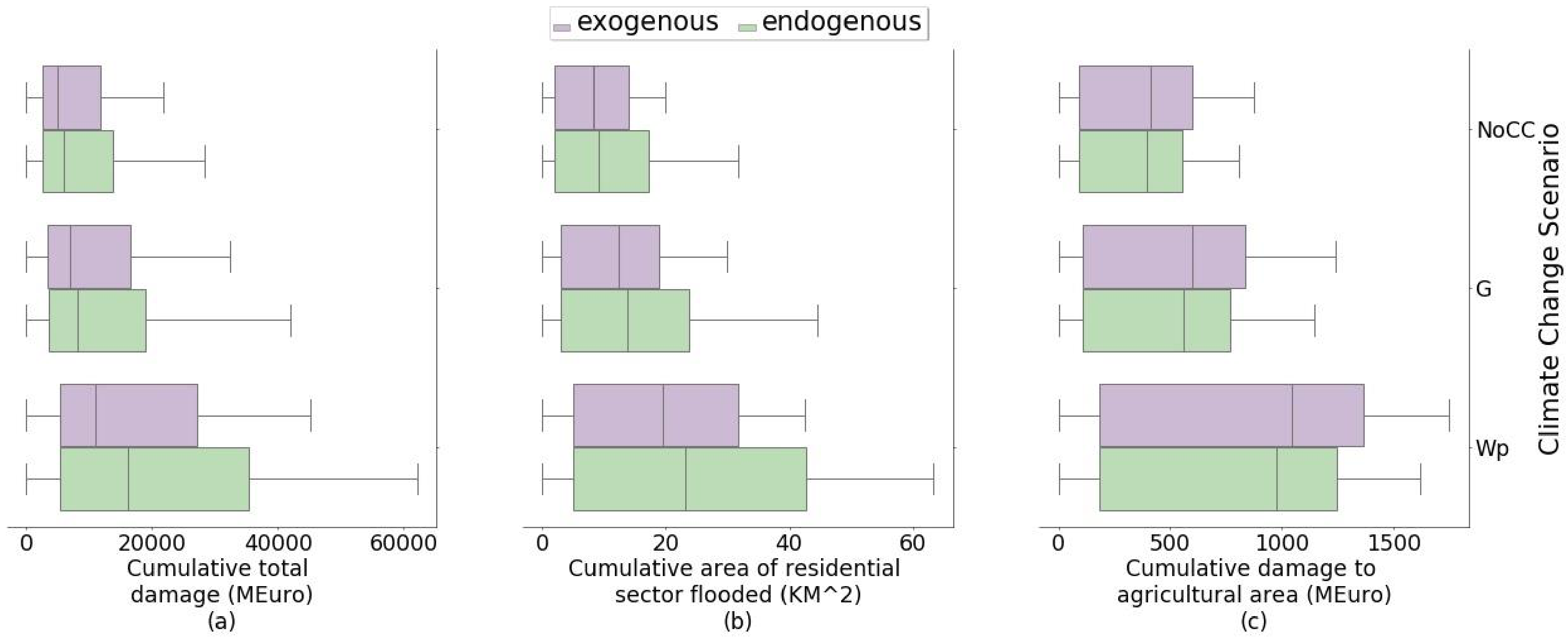
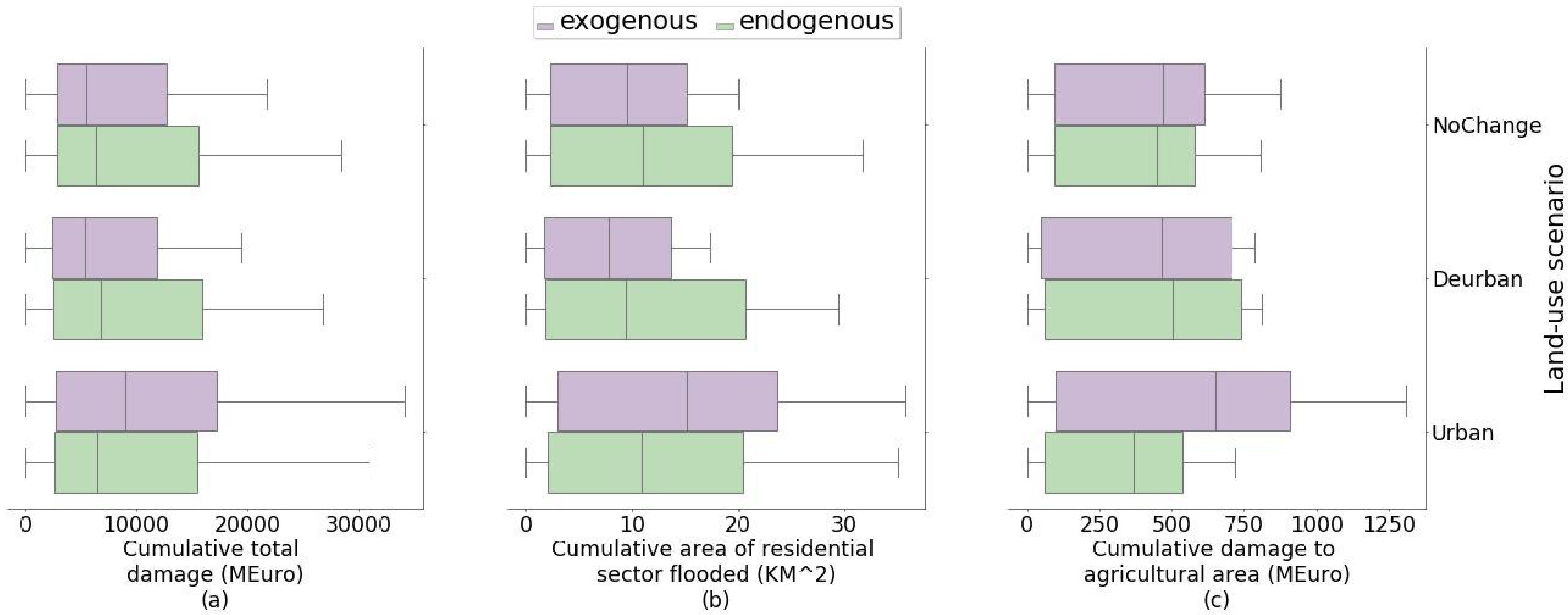
How does it change model outcomes?





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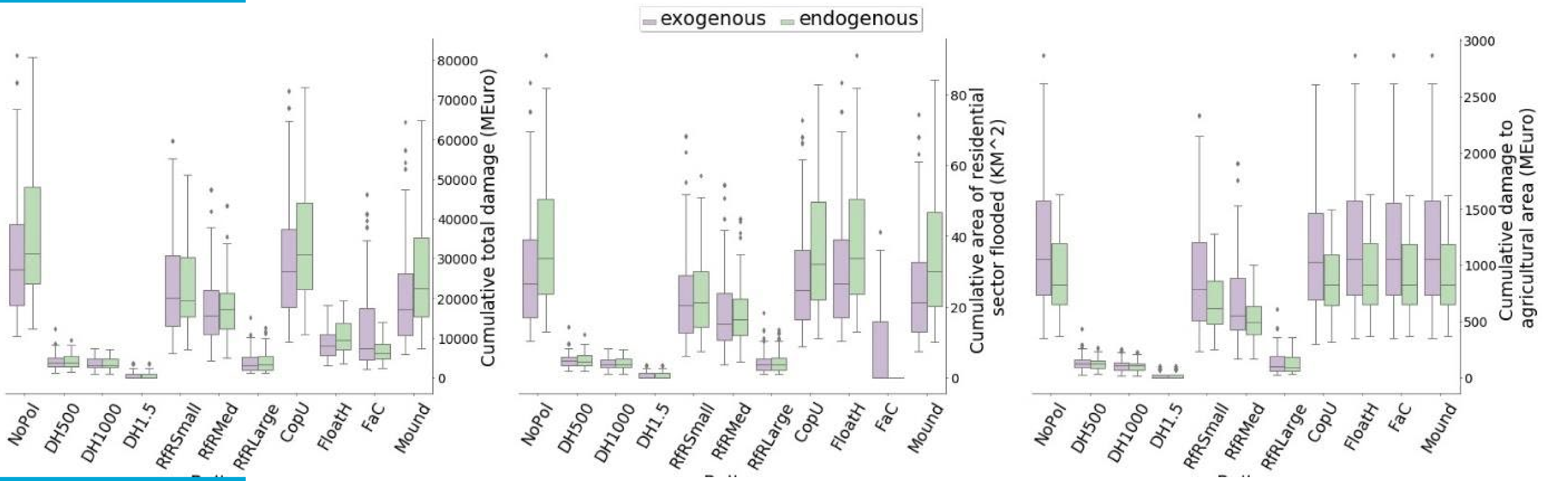
Does it change policy performance?



Concluding remarks

Many systems of interest cannot adequately be described using a single modeling formalism

- But is needed to adequately assess policy options

Model coupling is currently often ad-hoc, case specific, and not generalizable → need for a toolkit for model coupling

- Distributed a-synchronous bi-directional communication
- Checking of units
- Tracing, debugging, profiling
- Problem of epistemic opacity

Large scale computational experimentation for exploring impact of uncertainties using multi-models is feasible, non-trivial, yet produces decision relevant insights

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