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Resilience Adaptation Pathways for Near-Term and Long-Term Management of Urban Wastewater Systems

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Outline

- Introduction
- Adaptation Vs Adaptation Pathways
- Definition of Terms
- Study Aim
- Methodology
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Introduction

- **Traditional approach (Casal-Campos et al. 2015a):**
  - ➢ Knowledge of the past is enough to accurately predict and manage future conditions.
  - ➢ Reliable water infrastructure is sufficient to deliver sustainable water services.
- **Problems**:
  - ➢ Knowledge of the past is incomplete and future conditions are deeply uncertain.
  - ➢ Reliability may reduce failure frequency but not necessarily the impacts and consequences of failure.
- **Approaches:**
  - ➢ Recognise system vulnerabilities and future uncertainties for failure management.
  - ➢ Incorporate multiple objectives.
  - ➢ Reliable, resilient… sustainable? What types of interventions & for how long?

Adaptation Vs Adaptation Pathways:

- **Adaptation:** any action taken to modify specific properties of the water system to enhance its capability to maintain levels of service under varying conditions (Butler et al. 2017).

- **Adaptation Pathway (AP) method: introduces the time aspect into adaptation planning (van Veelen et al. 2015)**

when in time adaptation is necessary

what (combinations of) measures are the most effective

- **large uncertainties** imply the need to examine adaptation the short-term (as well as the long-term) to avoid maladaptive lock-in, reduce potential regrets and allow flexibility as conditions change over time (Maru and Stafford, 2015).

Definition of Terms:

- **Reliability:** Ability of a system to minimise failure probability when subject to a threat.

- **Resilience:** Ability of a system to minimise the magnitude and duration of failure.

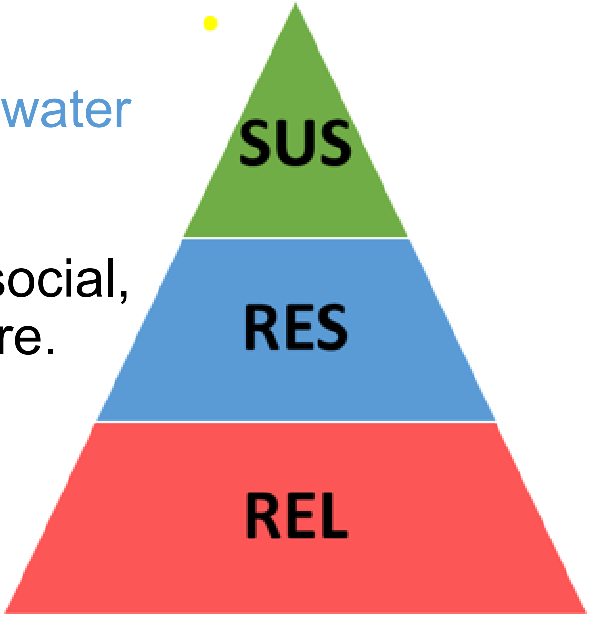
  Operational performance (*impacts*): Flooding, water quality and CSOs.

- **Sustainability:** Ability of a system to minimise the social, economic and environmental consequences of failure.

  Strategic performance (*consequences*):

  Flooding, water quality, CSOs,

  CO_2 emissions, cost and acceptability.



Study Aim:

Aim: to explore the near-term and long-term planning implications for the adaptation and management of the IUWWS using Adaptation Pathways (APs).

AP method developed: to explore/assess the dynamic compliance and adaptability of a number of grey, green and hybrid strategies along pathways of transient scenarios for resilience.

Methodology:

1. Evaluation of the domain size of resilience
2. Further assessment of the strategies

STEP 1: Specify the system & identify the variables

STEP 2: Identify the future scenarios & their differing elements

STEP 3: Identify adaptation strategies

STEP 4: Identify objectives & indicators with respect to Rel. Res. & Sust.

STEP 5: Define the adaptation thresholds

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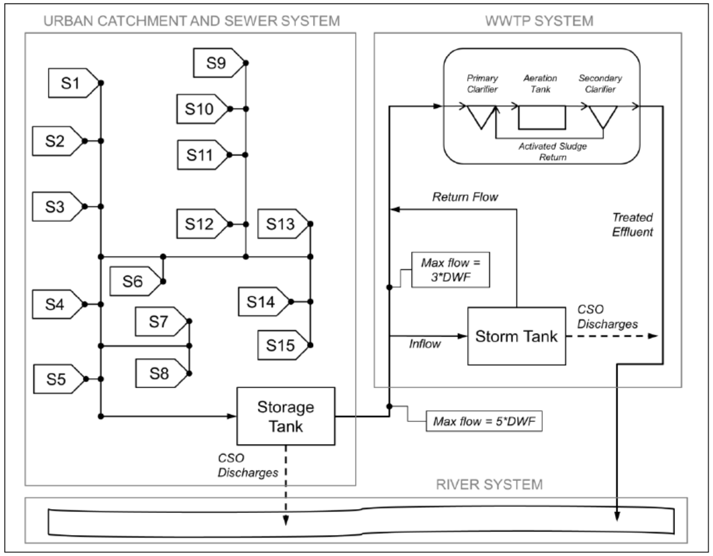
An Integrated Environmental Assessment of Green and Gray Infrastructure Strategies for Robust Decision Making

Arturo Casal-Campos,*,† Guangtao Fu,† David Butler,*,† and Andrew Moore‡

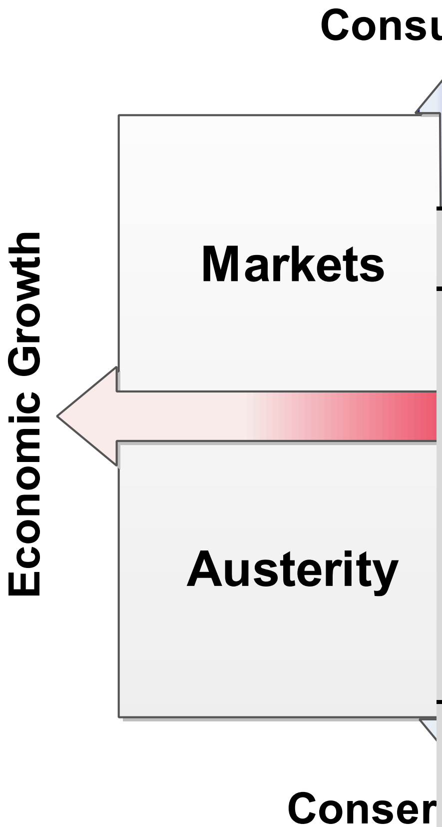
STEP 1:
Specify the system & identify the variables

Integrated Urban Wastewater System (IUWWS)

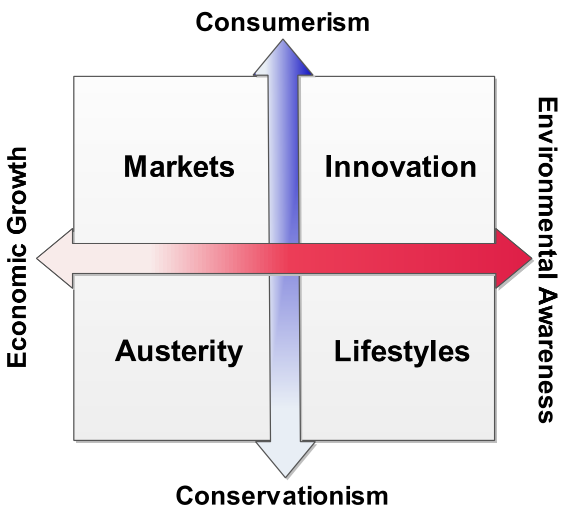
- 15 individual sub-catchments.
- A simplified combined sewer network:
- A pass-through tank connected to a CSO.
- The tank forwards flow to the treatment plant
- Overflows to the river system



STEP 2: Identify the future scenarios & their differing elements



Future scenarios	Market	Innovation	Austerity	Lifestyles
Characteristics of society	Low value on resources Lenient regulations to maintain unrestricted economic growth Highly consumerist society	Reliance on technology Innovative and centralized efficiency to address stringent policy issues whilst enjoying prosperous life	High value on resources due to economic decline Weak regulations and lack of investment in public infrastructure	High value on resources Individual lifestyles are key means to address strict regulations and support sustainable development
Characteristics of IUWWS	Low regulations Medium maintenance Low public attitude Medium technology	High regulations High maintenance Low public attitude High technology	Low regulations Low maintenance Medium public attitudes Low technology	High regulations Med-low maintenance High public attitude Low technology



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STEP 3: Identify adaptation strategies

Mono-concept strategies (Casal-Campos et al., 2015b)

Green

SCR: Rain gardens infiltrate half of roof runoff

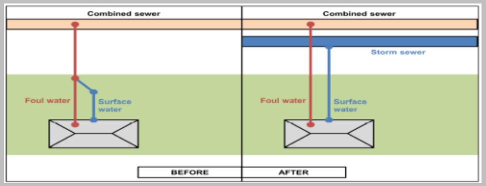
SCP: Bio-retention planters infiltrate half of road runoff

SCC: Urban creep mitigation

Grey

CST: Sewer rehabilitation & centralised storage and **CS:** sewer rehabilitation ONLY

SS: Sewer separation of half of the catchment



OT: On-site treatment

Hybrid strategies (Casal-Campos et al., UNDER REVIEW)

Hybrid strategies as the combined fractions of selected mono-concept strategies:

Hybrid 1 (H1): SCR + OT
Hybrid 2 (H2): SCR + SS
Hybrid 3 (H3): SS + OT
Hybrid 4(H4): SCR + CS

STEP 4: Identify objectives & indicators

Objectives	Sewer Flooding	River DO	River AMM	CSO	River Flooding
Resilience Indicators	Summation of duration-weighted flood volumes [m^3]	Summation of duration weighted DO minima [mg/l]	Summation of duration weighted AMM minima [mg/l]	Summation of duration-weighted spill volumes [m^3]	Summation of duration-weighted flood volumes [m^3]

DO: Dissolved Oxygen; AMM: River Total Ammonia; GHG: Green House Gas

STEP 5:
Define the adaptation Thresholds

- Adaptation threshold will be used to evaluate the compliance of strategies along the planning timeline (2015-2050).
- The performance of the IUWWS in 2015 (the baseline performance) was considered as the acceptable level of performance for the future (the thresholds are assumed based on this year's performance).

	Sewer Flooding	CSOs	River Flooding
Resilience	5.4 [m^3]	1565.4 [m^3]	185.3 [m^3]
Resilience thresholds are presented as duration-weighted magnitudes of failure			

- Once the adaptation threshold (target) of an objective is reached, the current management strategy is no longer able to meet that objective and new adaptation measures are needed **(van Veelen et al 2015)**.

Methodology:

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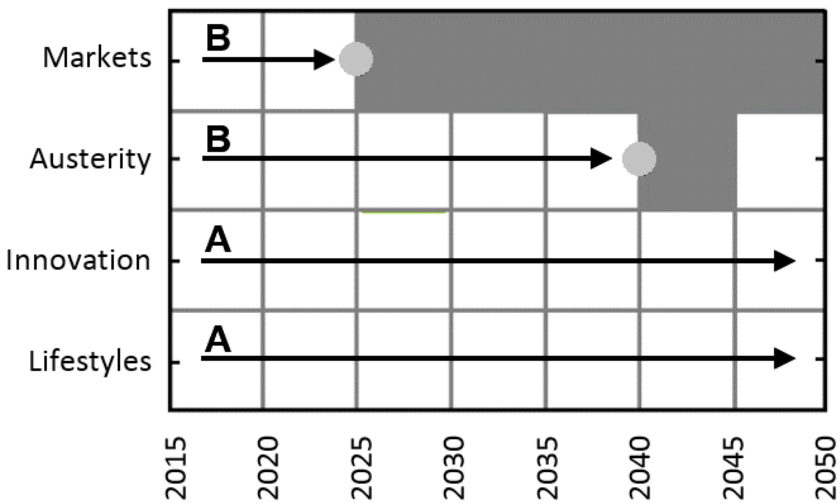
1 Evaluation of the domain size of resilience

Strategy A



2 Further assessment of the strategies

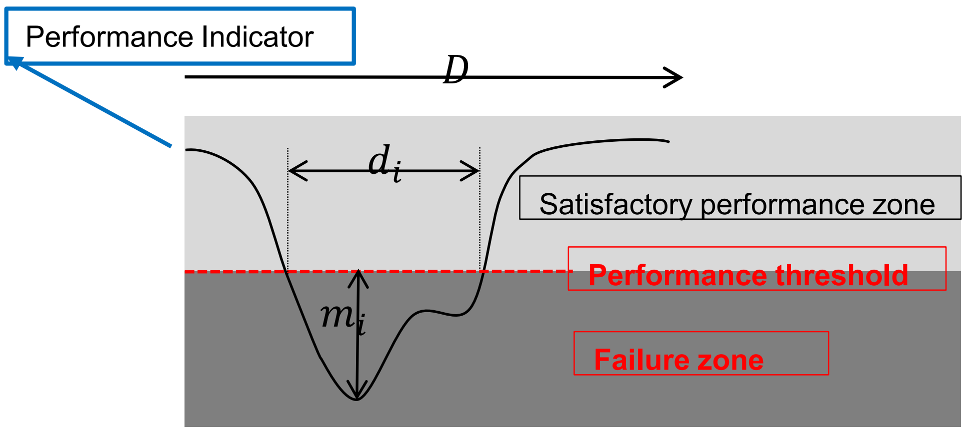
Strategy A

A: Uninterrupted compliant pathways of transient scenarios

B: Interrupted compliant pathways of transient scenarios (with sell-by-dates)

●: Sell-by-dates **NC**: Non-complaint domains (in grey colour)

2 **Further assessment of strategies:** with the help of a regret based MCA method



Summation of duration-weighted failure magnitudes

Resilience: $\sum_i \frac{(m_i * d_i)}{D}$

Resilience Index
Duration-weighted flood volume
Duration-weighted DO minimum under threshold
Duration-weighted AMM maximum over threshold
Duration-weighted spill volume
Duration-weighted flood volume

d_i: Failure duration for failure event *I* m_i: Failure magnitude for failure event *I* D: Total duration

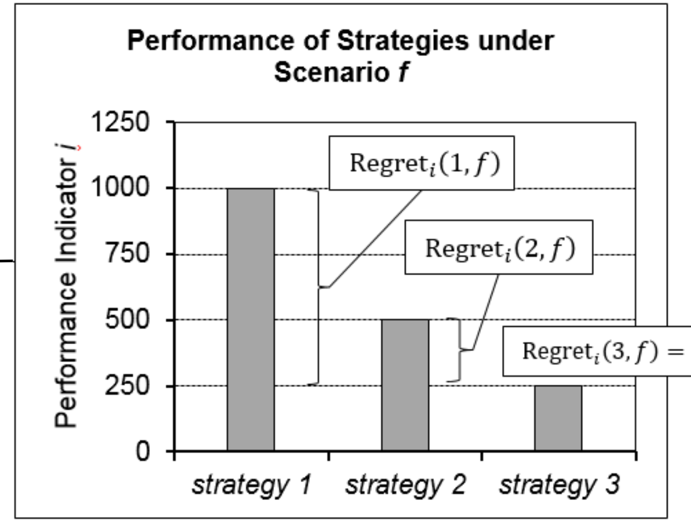
Casal-Campos et al. (2015a)

2 **Further assessment of strategies:** with the help of a regret based MCA method

Step 1: Category Regrets (3.5.1)

$$\text{Regret}_i(s,f) = |max_{s'}[\text{Performance}_i(s',f)] - \text{Performance}_i(s,f)|$$

$\text{Regret}_i(1,f) = 750$
$\text{Regret}_i(2,f) = 250$
$\text{Regret}_i(3,f) = 0$



Step 2: Normalised Category Regrets (3.5.2)

$$R_i(s,f) = \frac{\text{[redacted]}}{\max_{s^*}[\text{Regret}_i(s^*,f)]}$$

$$R_i(1,f) = \frac{750}{750} = 1 \text{ (most regrettable)}$$

$$R_i(2,f) = \frac{250}{750} = 0.3$$

$$R_i(1,f) = \frac{0}{750} = 0 \text{ (least regrettable)}$$

Casal-Campos et al. (2015a)

2 **Further assessment of strategies:** with the help of a regret based MCA method

Step 1: Category Regrets

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Step 2: Normalised Category Regrets

$$R_i(s,f) = \frac{\quad}{\max\limits_{s^*}[\text{Regret}_i(s^*,f)]} \rightarrow Res_j(s,f)$$

Step 3: Scenario Indexes

$$\overline{Res}(s,f) = \sum_i (\quad) \rightarrow \overline{Res}(s,f) = \left(w_1^f\, Res_1(s,f) + \cdots + w_5^f\, Res_5(s,f)\right)$$

Weight to each indicator

Casal-Campos et al. (2015a)

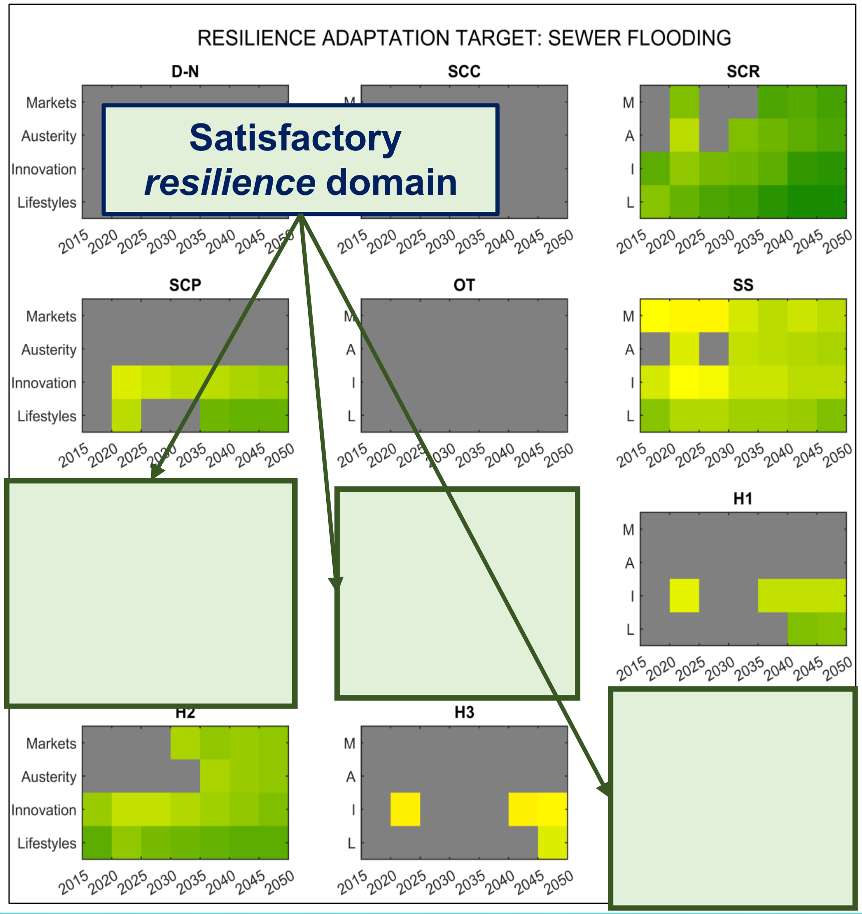
Results: Adaptation Pathways for Resilience

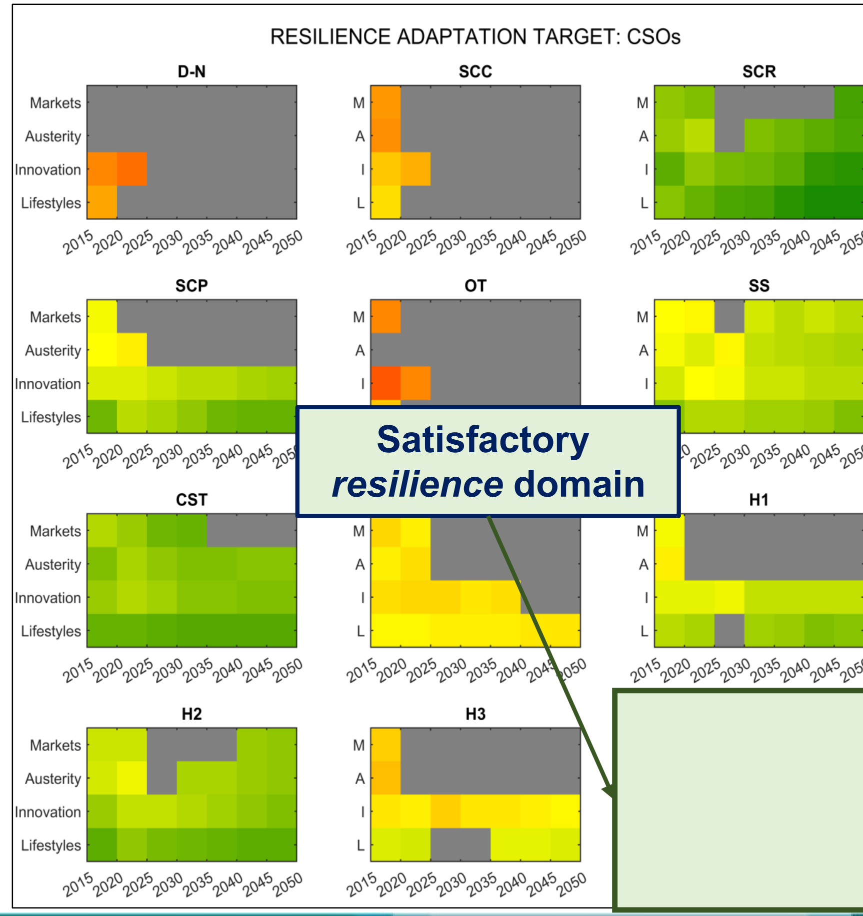
i. For one adaptation threshold
   a) Sewer flooding
   b) CSO
   c) River flooding

ii. For two adaptation thresholds

iii. For three adaptation thresholds

Resilience domains for single adaptation target

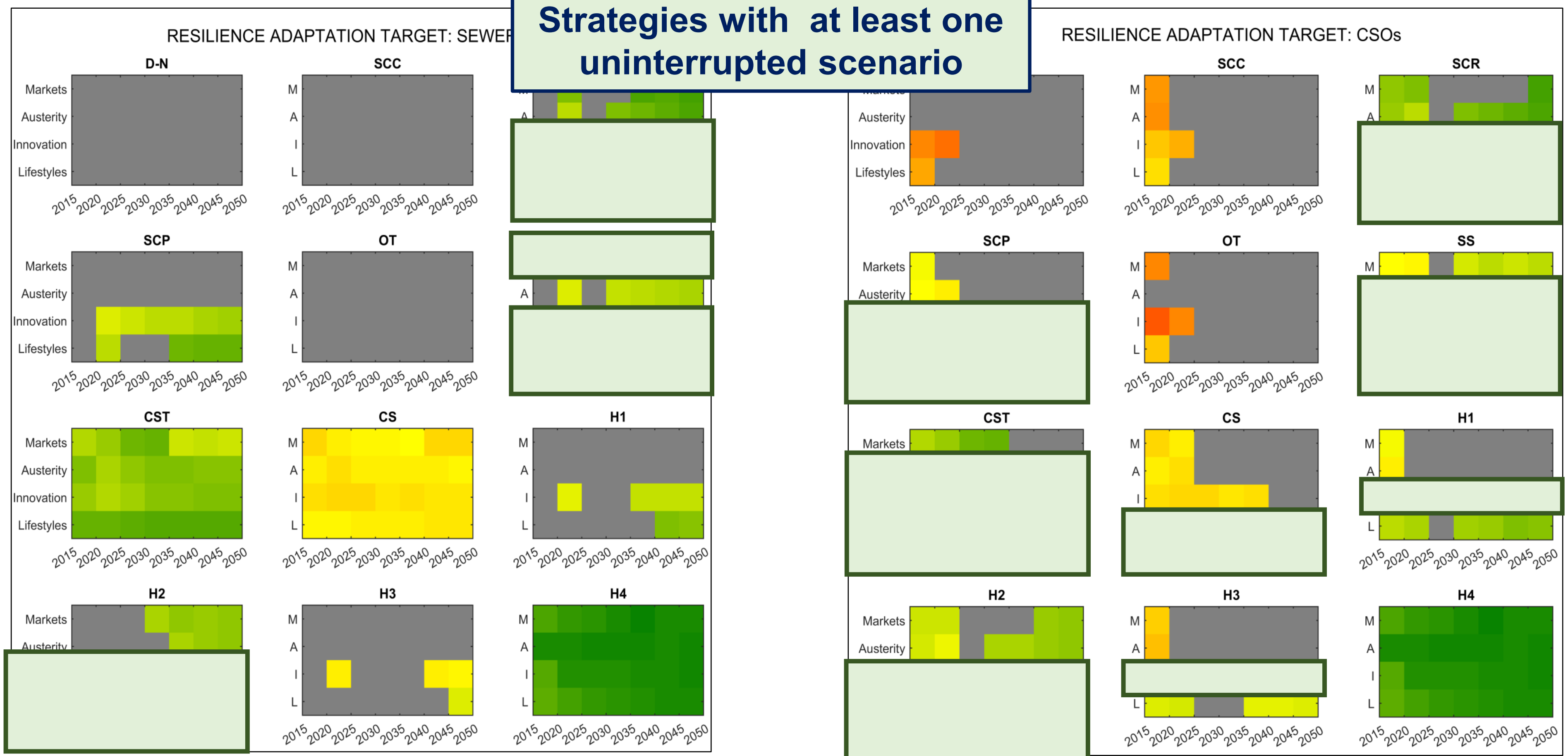




Scenarios [M: Markets; A: Austerity; I: Innovation; L: Lifestyles] - Strategies [D-N: do-nothing; SCR: roof gardens; SCC: permeable pavment; SCP: bio-retention planters; SS: sewer separation; CST: improved sewer capacity & storage tank; CS: improved sewer capacity; OT: on-site treatment; H1: SCR+OT; H2: SCR+SS; H3: SS+OT; H4: SCR+CS]

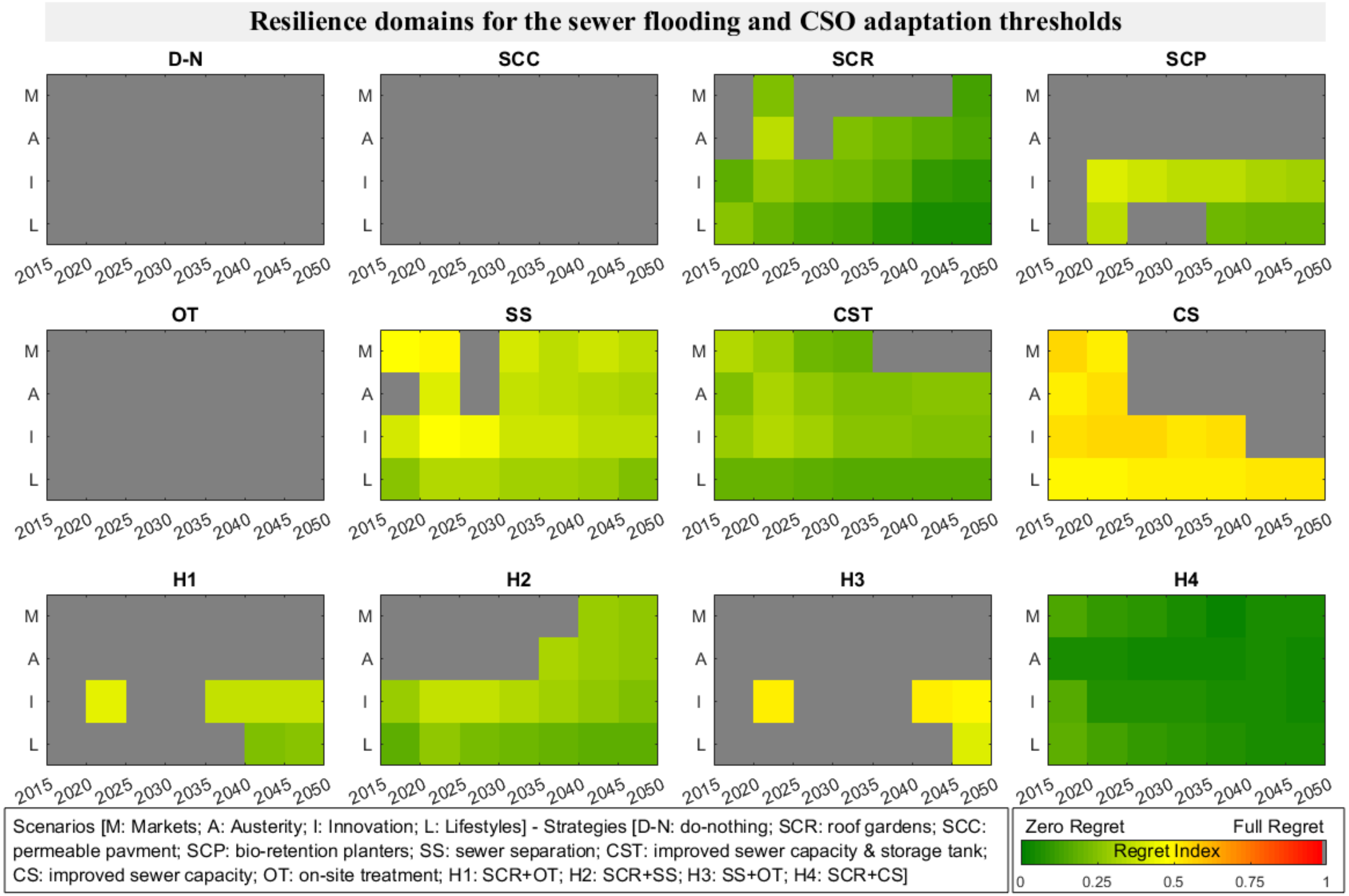
Resilience domains for single adaptation targets

Strategies with at least one uninterrupted scenario



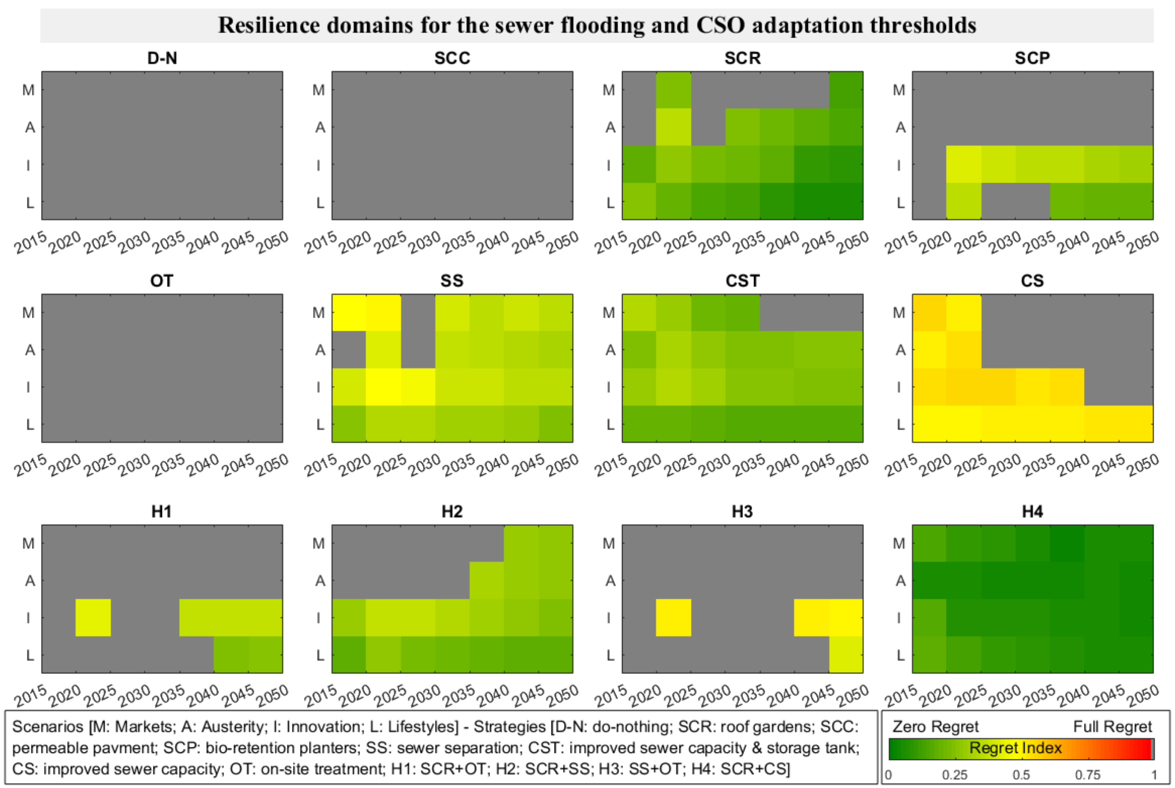
Scenarios [M: Markets; A: Austerity; I: Innovation; L: Lifestyles] - Strategies [D-N: do-nothing; SCR: roof gardens; SCC: permeable pavment; SCP: bio-retention planters; SS: sewer separation; CST: improved sewer capacity & storage tank; CS: improved sewer capacity; OT: on-site treatment; H1: SCR+OT; H2: SCR+SS; H3: SS+OT; H4: SCR+CS]

Resilience domains for sewer flooding and CSO thresholds



Resilience domains for sewer flooding and CSO thresholds

Again Strategy H4 has the longest uninterrupted pathways in various scenarios.



Combination of strategies to comply with adaptation thresholds: H4 strategy (rain gardens and sewer expansion) could be implemented for the first three epochs (until 2025) to ensure compliance and, if future conditions are lenient toward Lifestyles scenario, continue with SCR alone (Why?? Less investment).

Final remarks:

Adaptation Pathway method introduces the time aspect into adaptation planning.

How is this useful? By testing/identifying:

1. Robustness of different pathways (ability to deal with a wide range of possible futures),
2. Flexibility of the system (ability to switch from one measure to another), and
3. Possible lock-in situations (no options left for switching between measures).

Thank you

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