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Nature's integration
in cities' hydrologies,
ecologies and societies

Runoff, Heat and Habitat: Modelling potential of multifunctional NbS

Speaker: Svetlana Khromova
Authors: Khromova S., Busse S., Benati G., Herreros Cantis P., Segura-Barrero R., Ventura S., Eckelman M. J., Villalba Méndez G., Langemeyer J.

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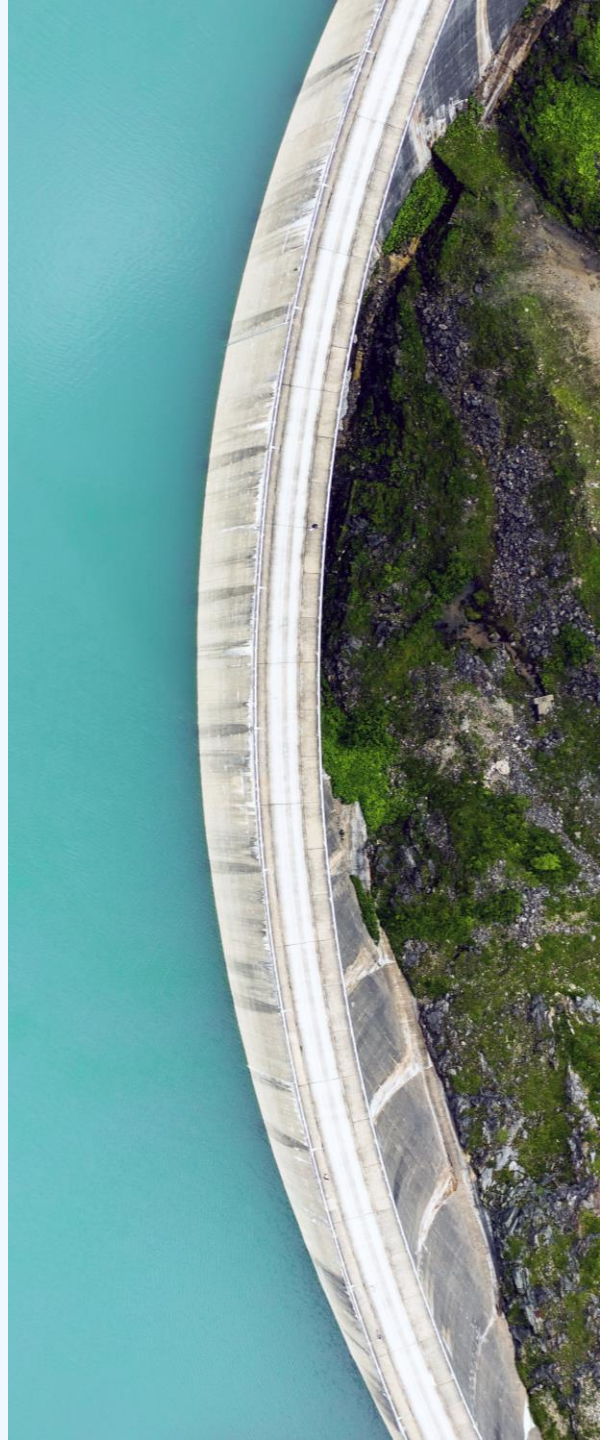

Multi-Criteria Decision Analysis (MCDA) framework

Step1

Identification of urban needs
(SETS Risk assessment)

Step2

Site specific allocation of NBS
(SETS Feasibility assessment)

Step3

NBS performance
(Rainfall-Runoff modelling)

Step4

Co-benefits Assessment
(Modelling of thermal comfort, water storage, water quality, habitat quality, nature access)

Inspired by Langemeyer, 2016

Case study cities

(Step 2) Site specific allocation of NBS

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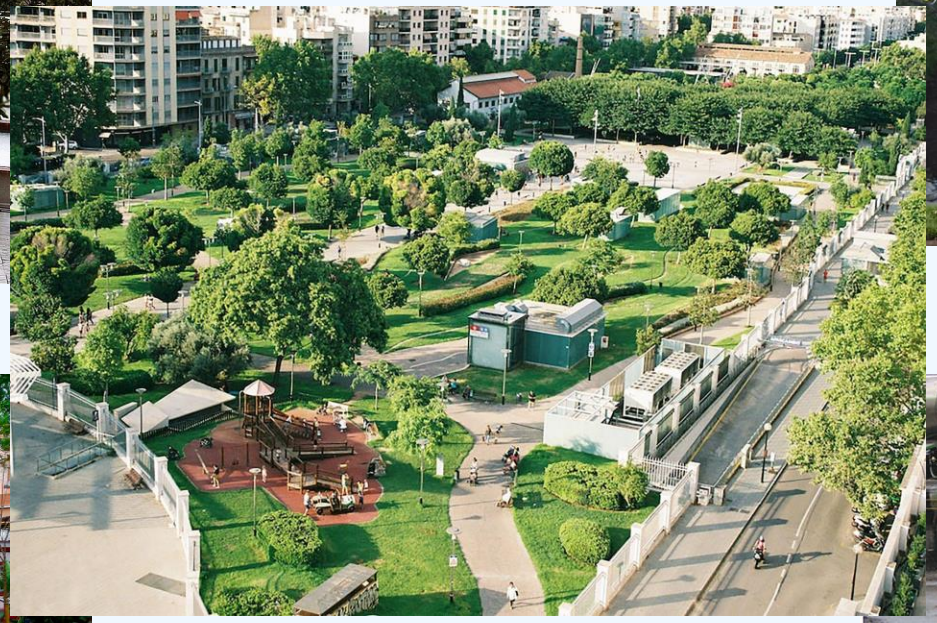
Journal: To be defined

NBS selection

Green roofs

Urban parks



Rain gardens

Bioswales

Permeable pavement

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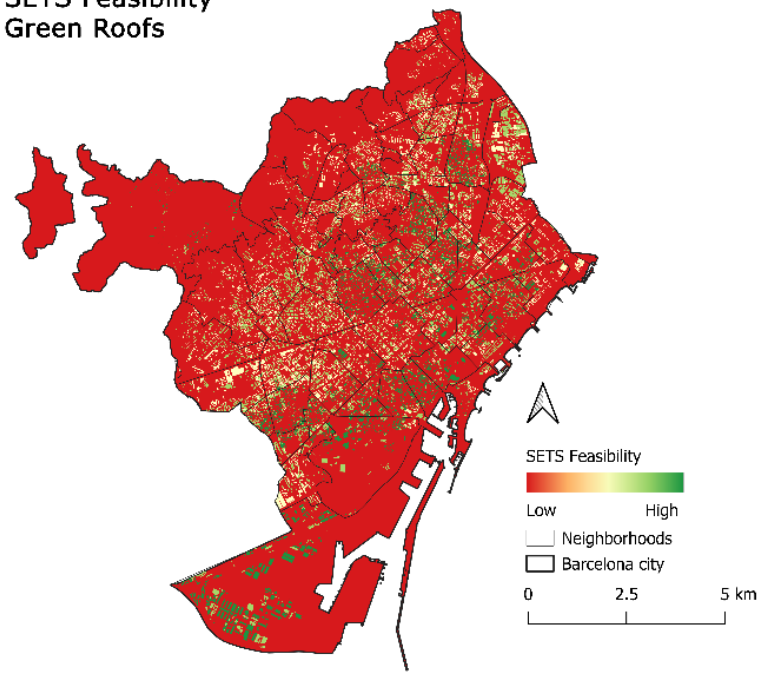
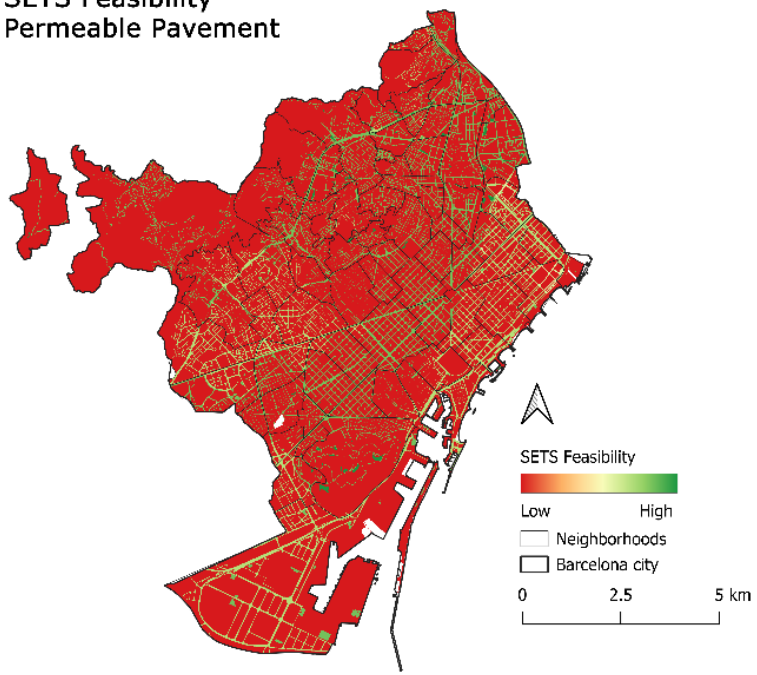
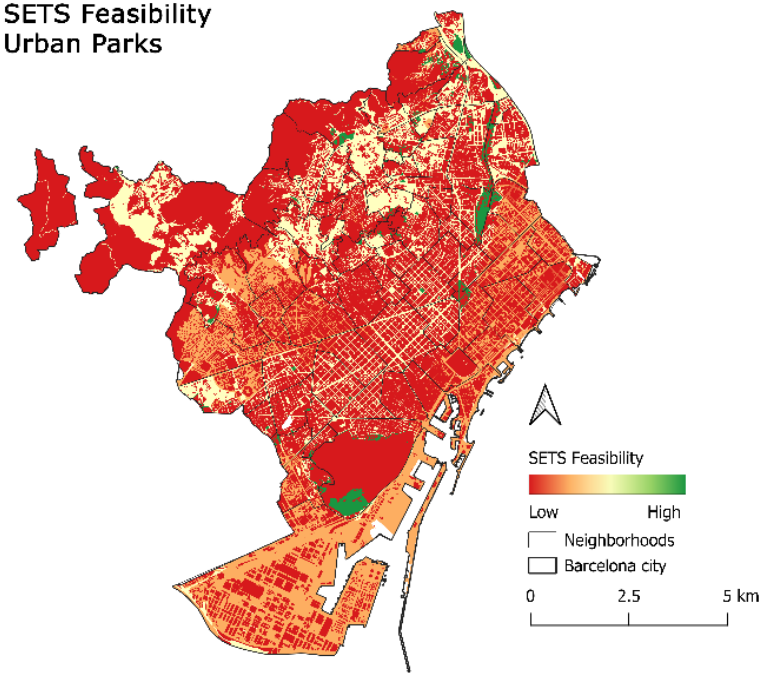
SETS Feasibility
Green Roofs



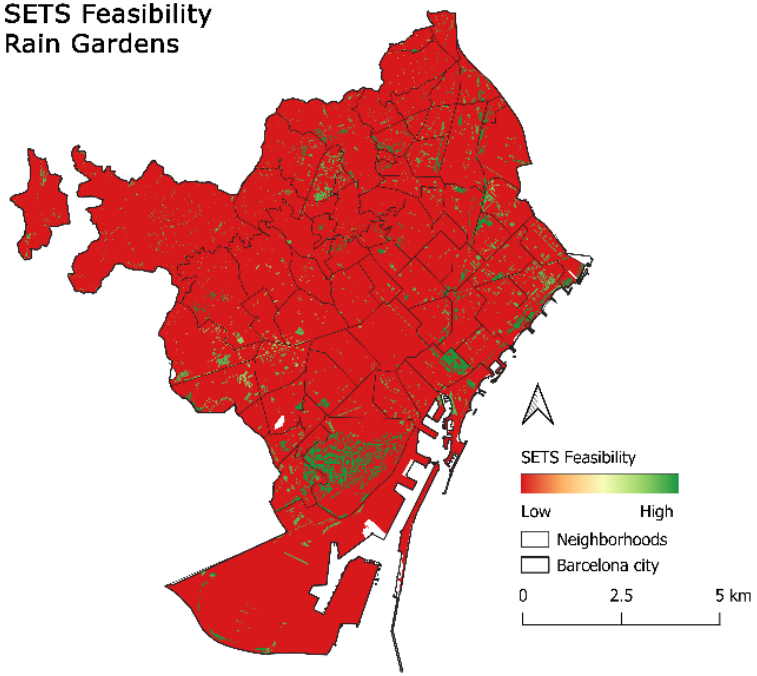
SETS Feasibility
Permeable Pavement



SETS Feasibility
Urban Parks



SETS Feasibility
Rain Gardens



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Proportion between area of S1 and S2

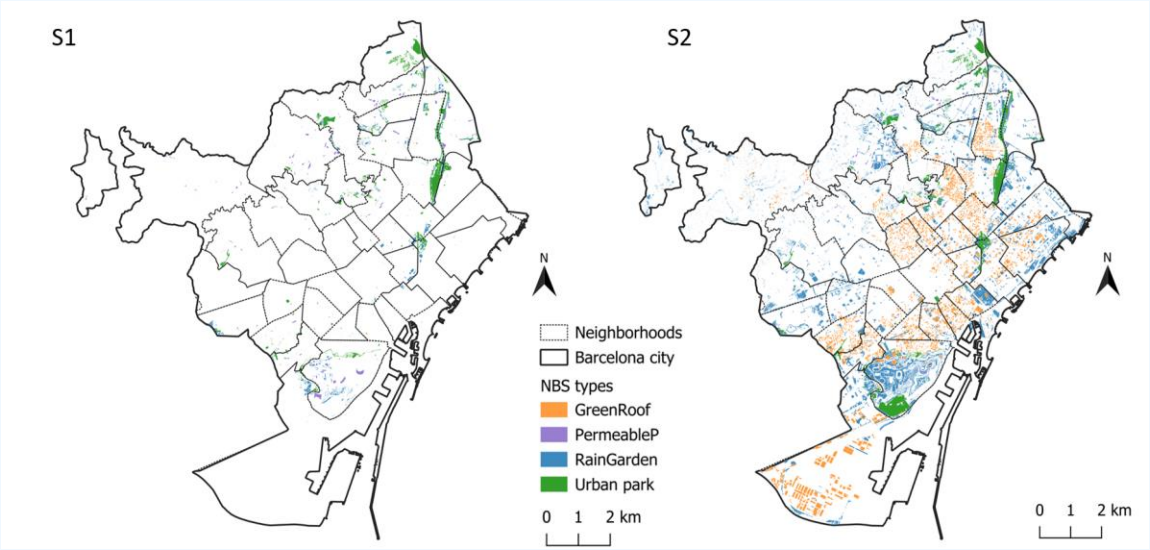
Scenario 1

Pla Natura (2021-2030)

1m² of greenery per resident by 2030, equivalent to 160 hectares of new green spaces

Scenario 2

Top 25% by highest feasibility score



S1: 160ha

S2: 2498ha

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(Step 3) NBS performance

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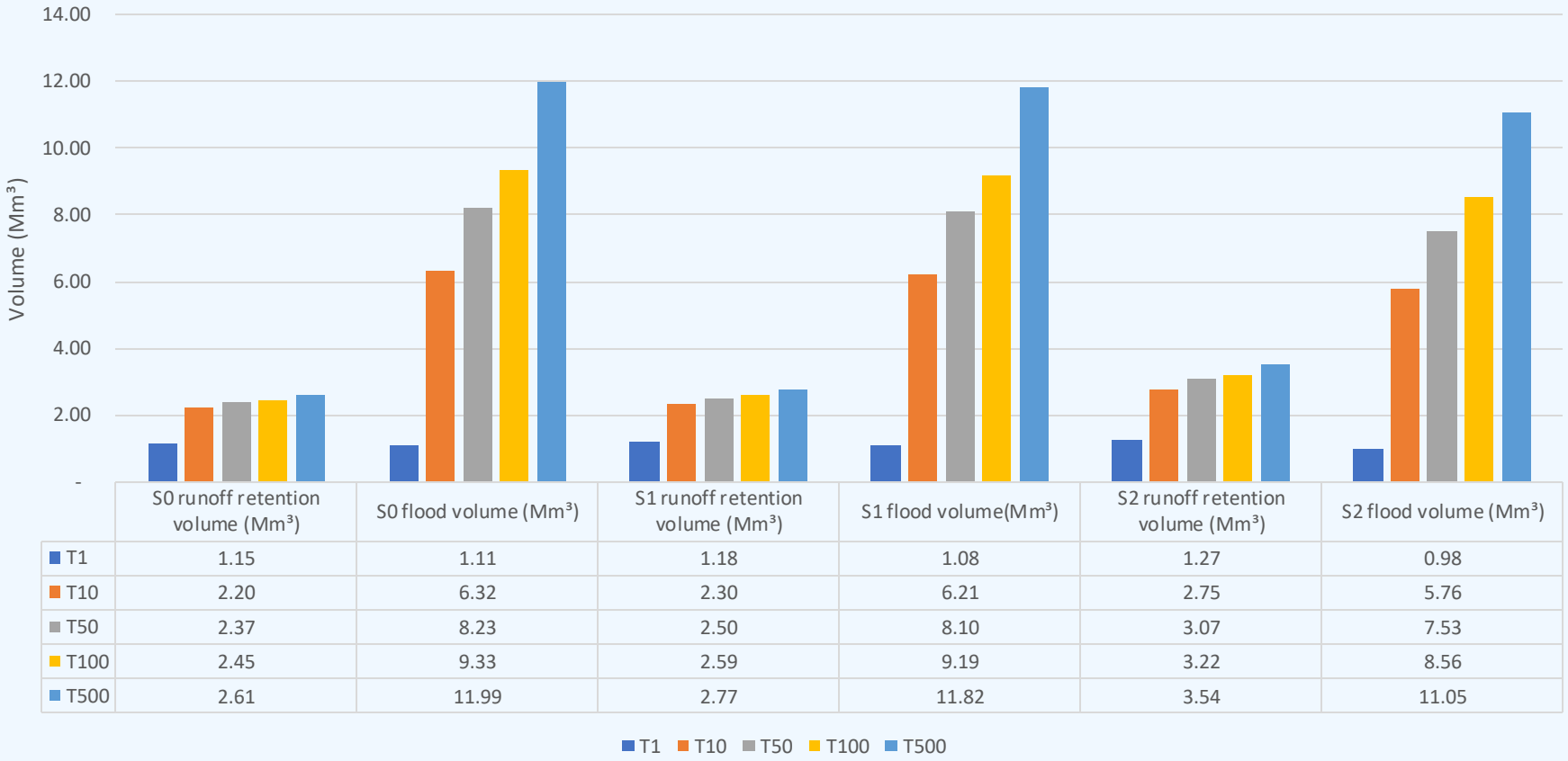
Performance assessment results for runoff retention volume and flood volume



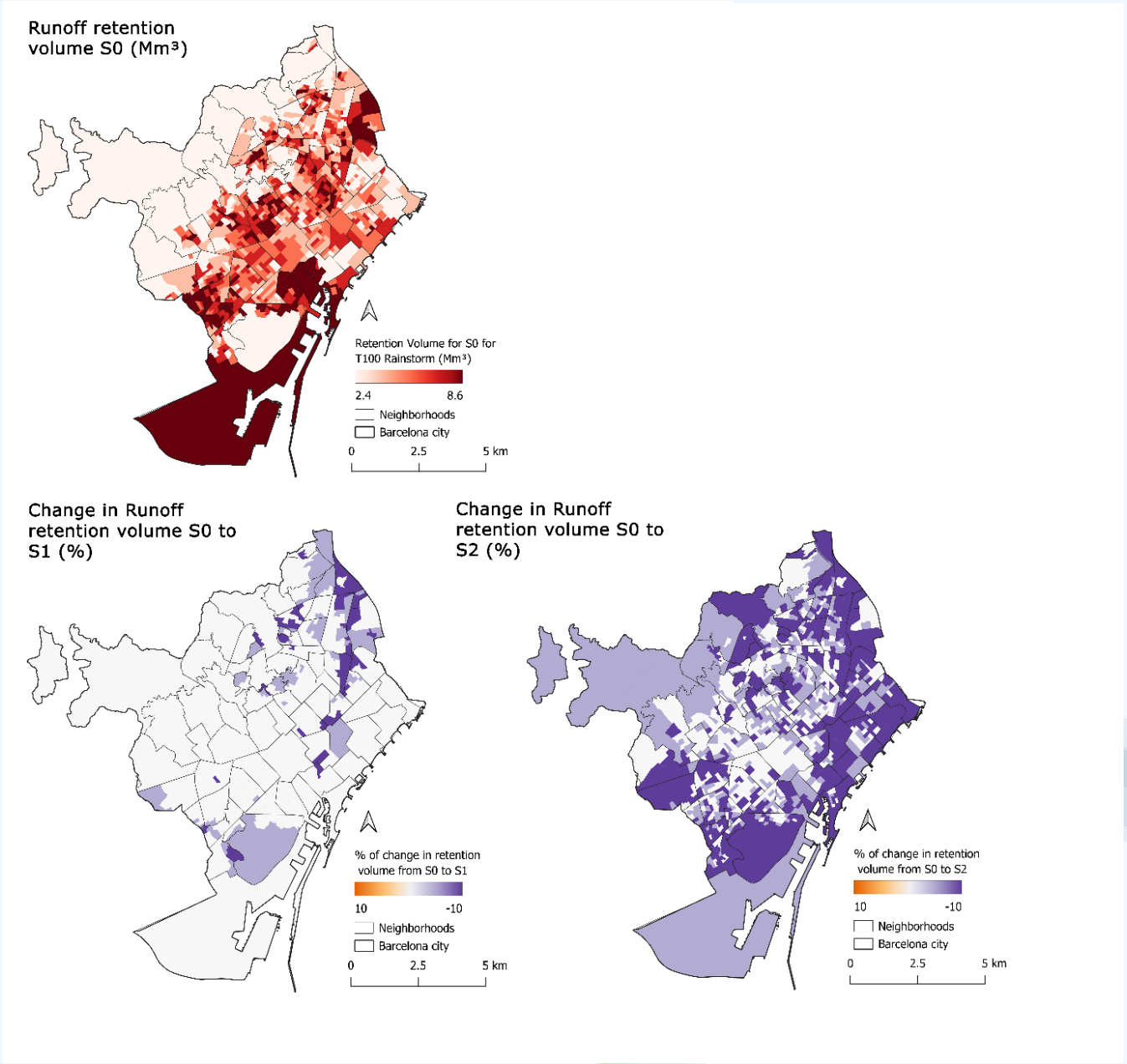
	S0 runoff retention volume (Mm³)	S0 flood volume (Mm³)	S1 runoff retention volume (Mm³)	S1 flood volume(Mm³)	S2 runoff retention volume (Mm³)	S2 flood volume (Mm³)
T1	1.15	1.11	1.18	1.08	1.27	0.98
T10	2.20	6.32	2.30	6.21	2.75	5.76
T50	2.37	8.23	2.50	8.10	3.07	7.53
T100	2.45	9.33	2.59	9.19	3.22	8.56
T500	2.61	11.99	2.77	11.82	3.54	11.05

Return Period	Rainfall depth for current climate conditions (mm)
T1	22.17
T10	83.72
T50	104.15
T100	115.81
T500	143.41

Information with model input on rainfall volumes for different T (Russo, 2020).

Modelling results from InVEST® Urban Flood Risk Mitigation module version 3.14.2 (Natural Capital Project, 2023)

Spatially explicit performance assessment results of runoff retention volume



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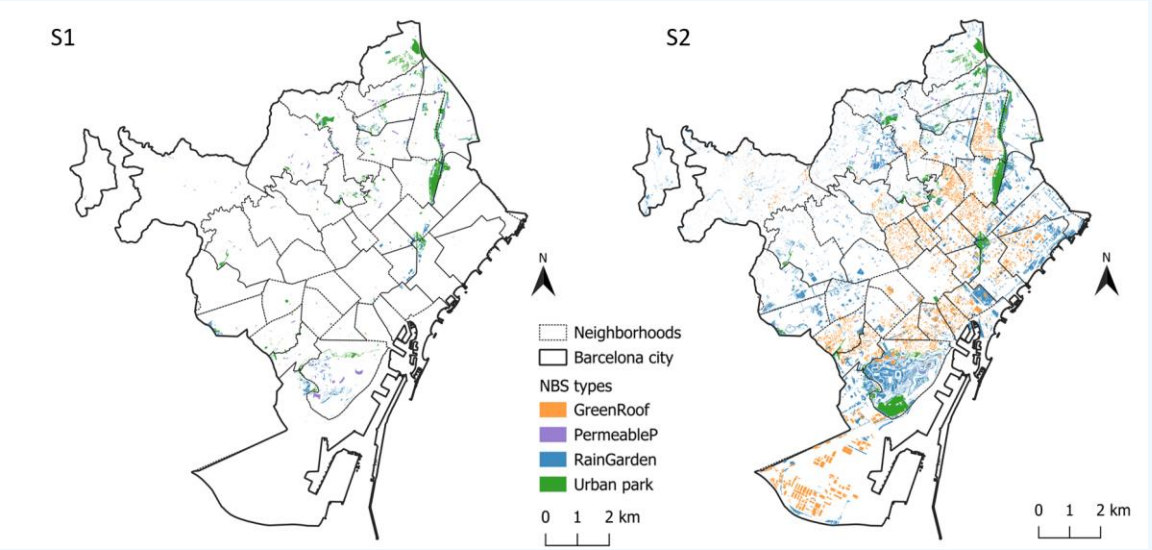
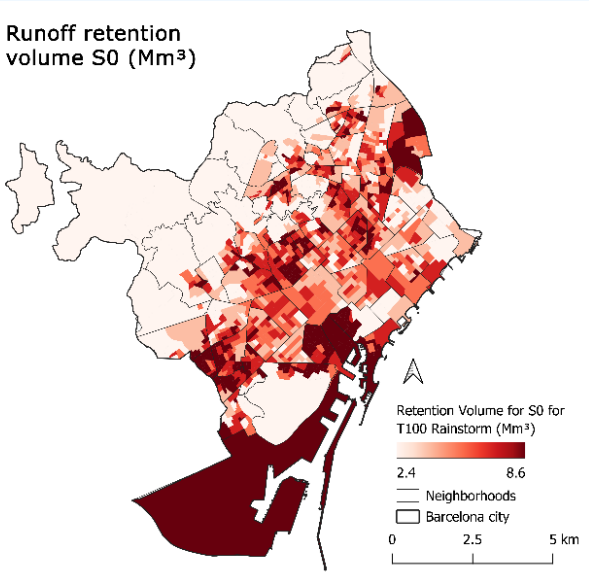
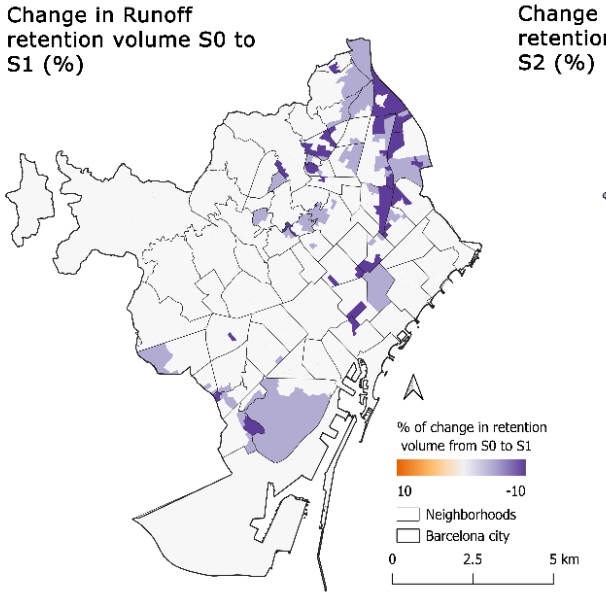
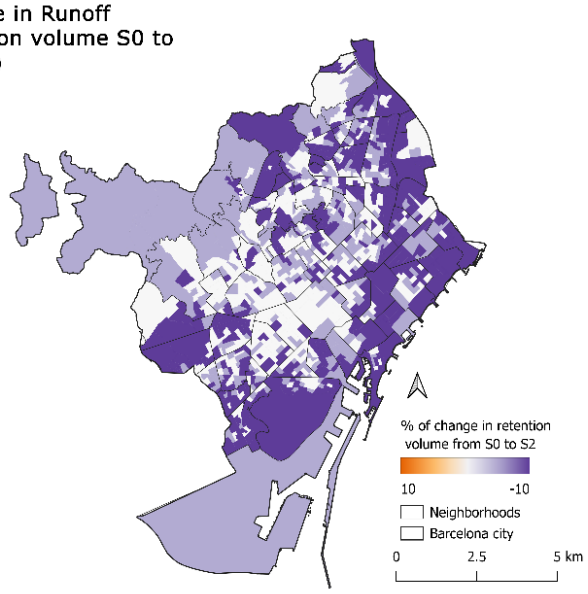


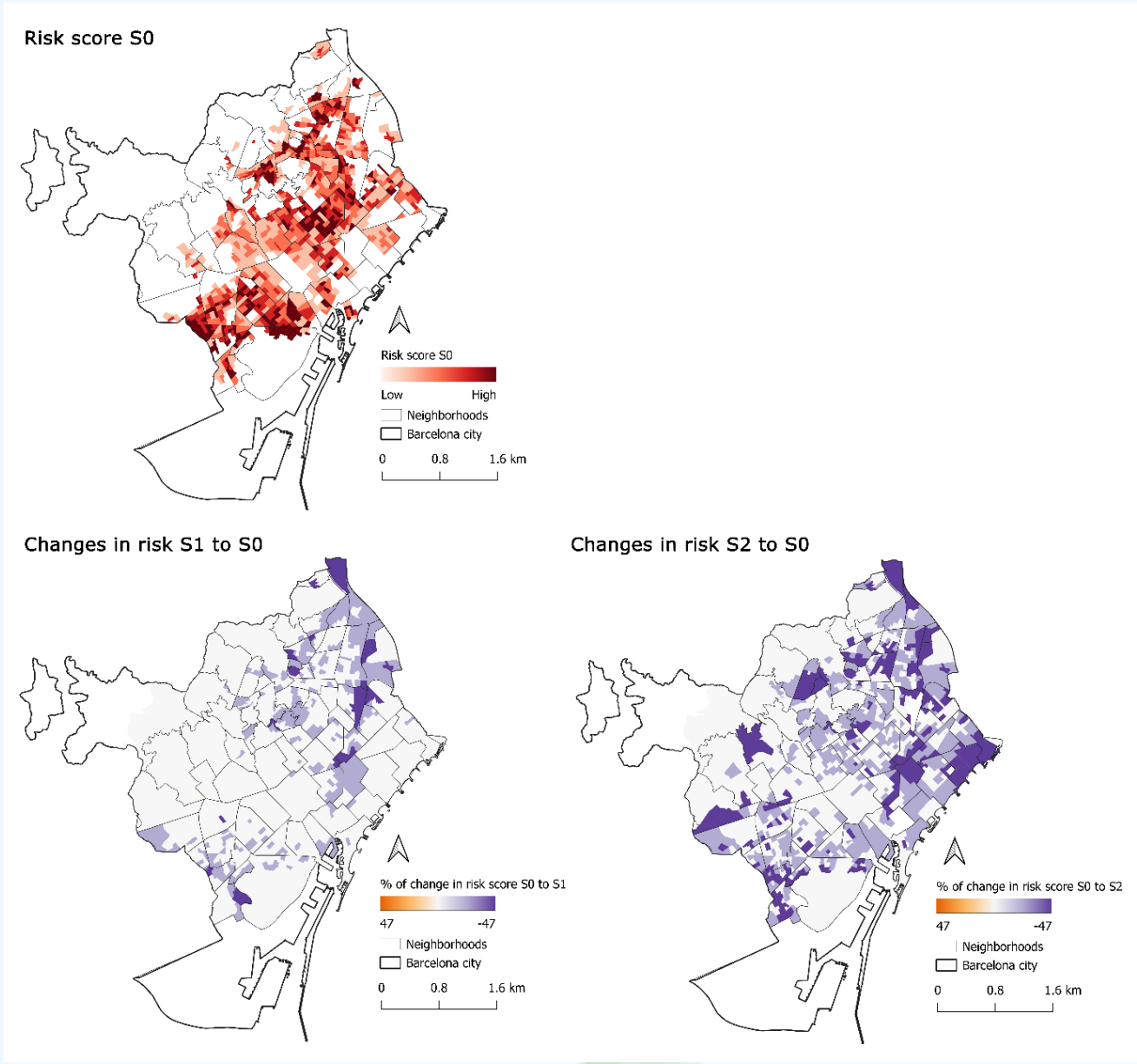




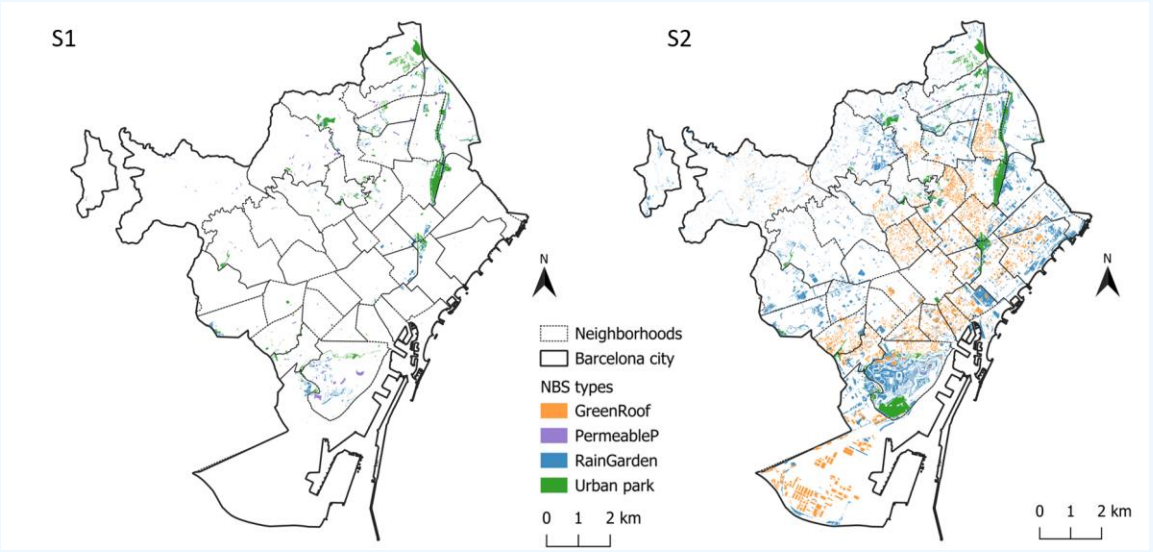


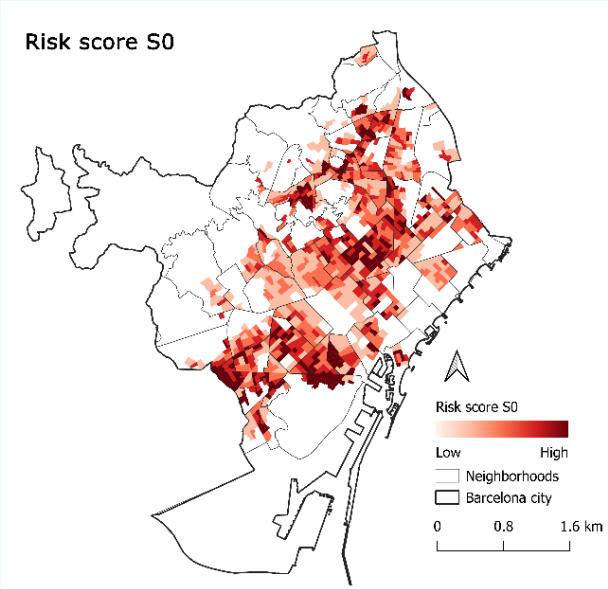
Modelling results from InVEST® Urban Flood Risk Mitigation module version 3.14.2 (Natural Capital Project, 2023)

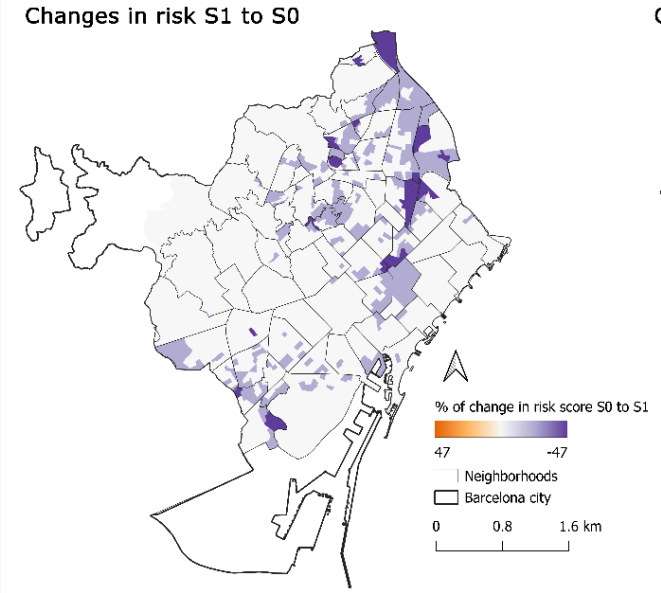
Changes across scenarios S1 and S2 compared to S0 in spatial distribution of risk

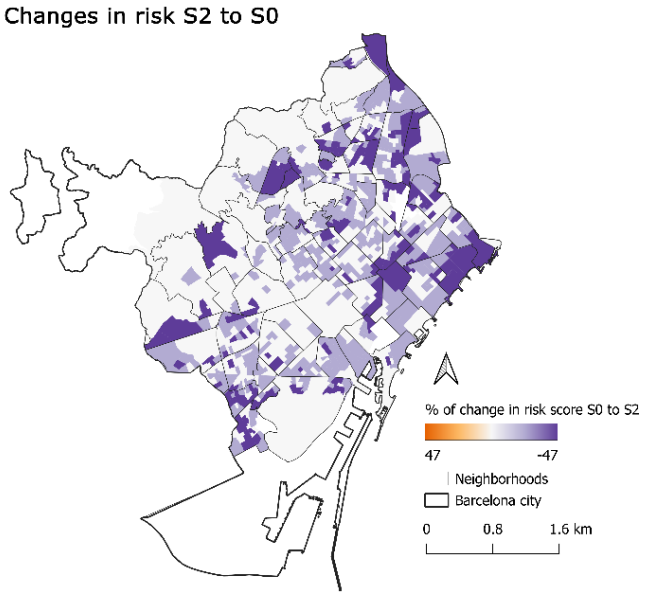


Changes across scenarios S1 and S2 compared to S0 in spatial distribution of risk









(Step 4) Co-benefits Assessment

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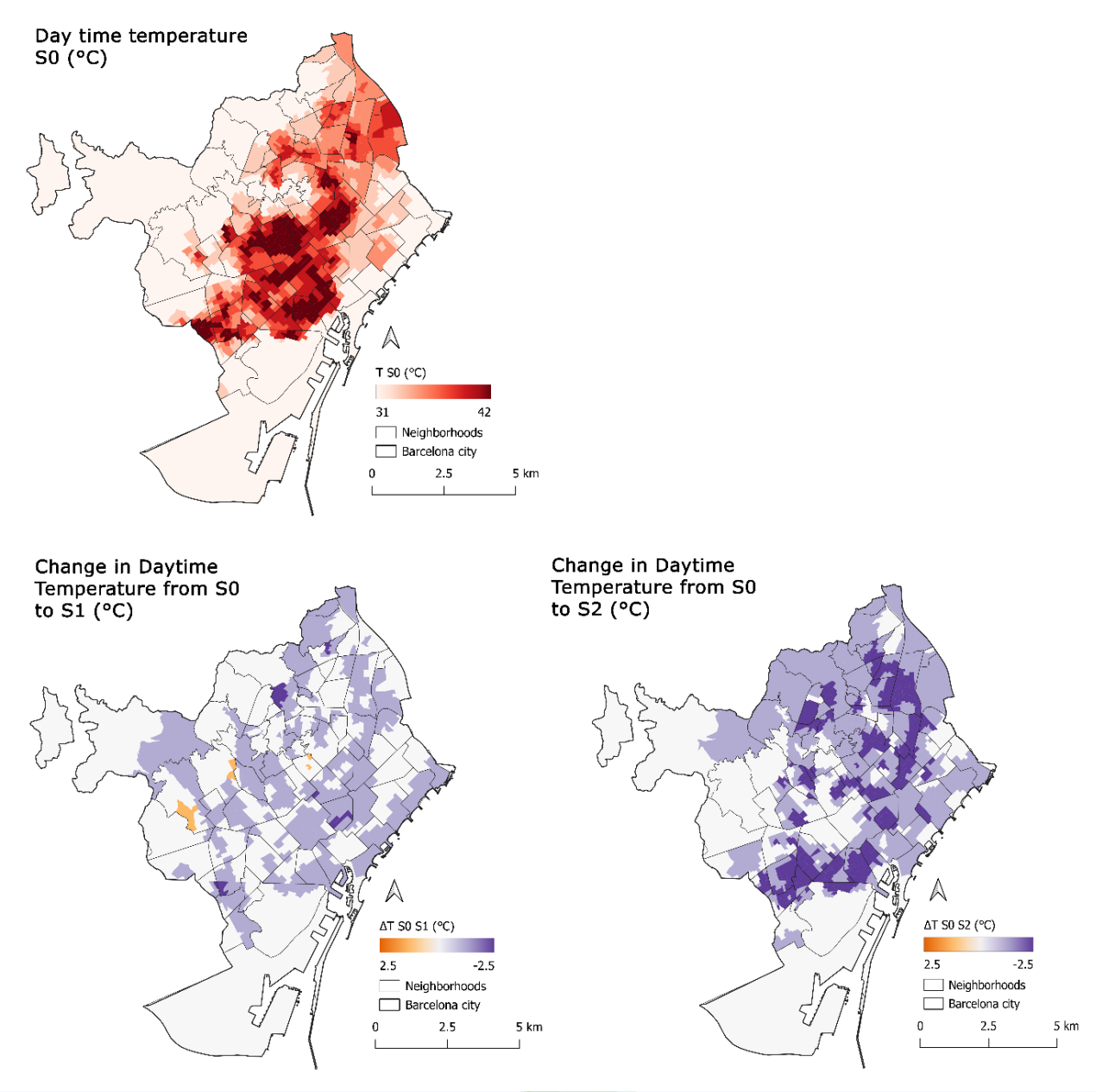
Journal: To be defined

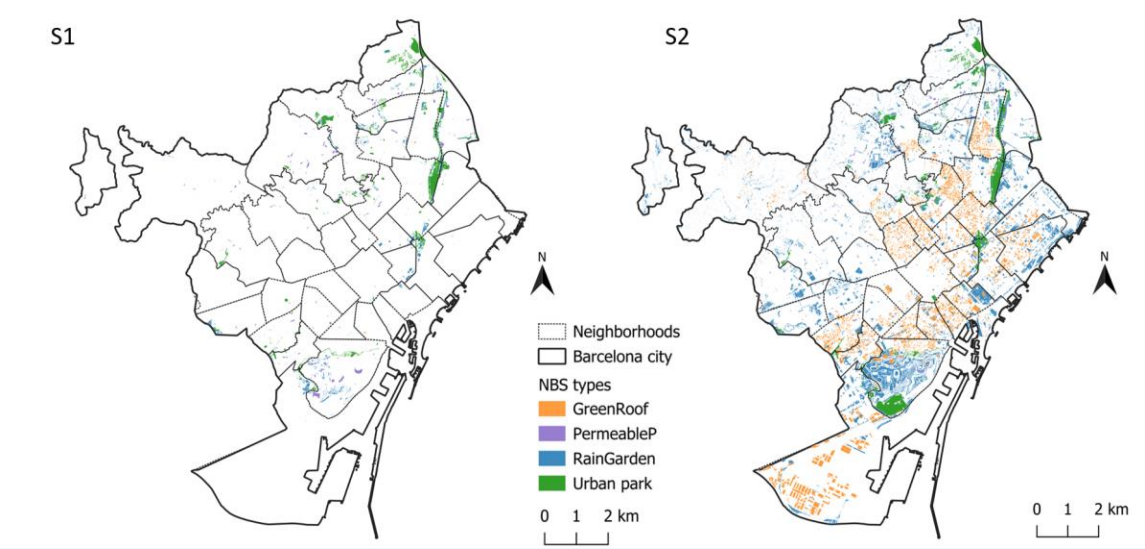
Mean temperature for heatwave event

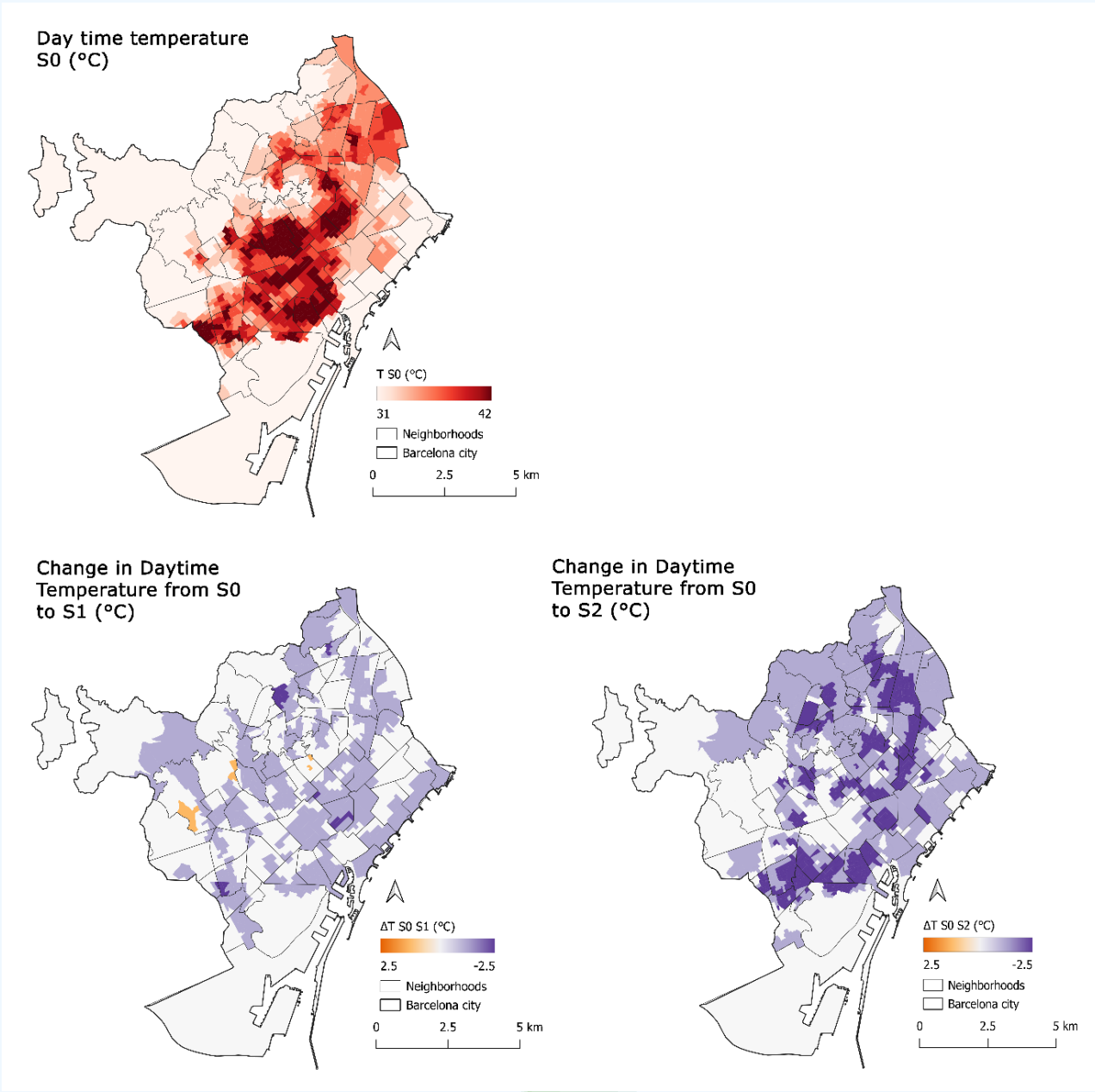
- **Rising Heatwave Intensity**: Future projections indicate more frequent and intense heat waves in Barcelona (del Río et al., 2007).
- **Role of NBS**: Most proposed Nature-Based Solutions (except permeable pavement) integrate vegetation, which helps mitigate heat through shade, transpiration, and solar energy absorption (Shao & Kim, 2022).
- **Temperature Assessment**: Analyzed daytime temperatures (°C) between 13:00 and 16:00 from July 4 to July 6 during the 2015 heatwave in the Metropolitan Area of Barcelona.



Modelling results from Weather Research and Forecasting (WRF) model (v4.3.3)

Mean temperature for heatwave event





Modelling results from Weather Research and Forecasting (WRF) model (v4.3.3)

Water quality

	S0	S1	S2	% S1 to S0	% S2 to S0
N surface load (kg/ year)	113947	111698.7	105599.4	-1.9	-7.3
N surface export (kg/ year)	31497.26	30689.4	28154.8	-2.5	-10.6
P surface load (kg/ year)	15692.03	15411.28	14609.06	-1.7	-6.9
P surface export (kg/ year)	4036.063	3937.71	3628.548	-2.4	-10.1

- **Stormwater Pollution Challenge**: Contaminated urban runoff in Barcelona limits the potential of stormwater as an alternative water source (Björklund et al., 2018).
- **NBS Co-benefits**: Assessment of nature-based solutions (NBS) in capturing nutrients (nitrogen and phosphorus) to mitigate pollution.

Modelling results nutrient delivery ratio (NDR) module of InVEST version 3.14.2 (Natural Capital Project, 2023)

Nature Access

	S0	S1	S2	% S1 to S0	% S2 to S0
Population undersupplied with urban nature	262.6	226.5	131.4	-13.7	-49.9

- **High Demand for Green Spaces**: Barcelona's dense urban structure limits outdoor recreational areas, increasing demand (Baró et al., 2014).
- **Well-being Benefits**: Green spaces are essential for residents' physical and mental health (Triguero-Mas et al., 2015).
- **NBS Co-benefits**: Assessment of nature-based solutions (NBS) in of green space supply
- **Per capita demand for urban nature:** 9m2 (target recommended by the WHO)

Modelling results from urban nature access module of InVEST version 3.14.2 (Natural Capital Project, 2023)

Water Storage

	S0	S1	S2	% S1 to S0	% S2 to S0
Total percolation volume (m^3/year)	3206250	3490291	5079064	8.9	58.4

- **Increasing Droughts in Barcelona**: Accelerated hydrological cycle leading to more frequent droughts (Russo et al., 2020).
- **Impact of Drought Contingencies**: Water restrictions for irrigation cause environmental, economic, and social challenges (Forero-Ortiz et al., 2020).
- **Groundwater as an Alternative**: Not commonly used in Barcelona due to low extraction rates and high concentrations of minerals and pollutants.
- **Role of Nature-Based Solutions (NBS)**: Selected NBS (except green roofs) enhance groundwater recharge, offering a potential future water source for irrigation.

Modelling results from Urban Stormwater Retention module of InVEST version 3.14.2 (Natural Capital Project, 2023)

Habitat Provisioning

	S0	S1	S2	% S1 to S0	% S2 to S0
Mean value for quality of ecosystems	0.0029	0.0030	0.0042	3.6	36.2

- **Limited Ecosystem Services in New Urban Areas**: Newly constructed areas in Barcelona offer minimal supply and biodiversity services, highlighting the need for expanded multi-functional green spaces (Zhang & Ramírez, 2019).

Modelling results from habitat quality and rarity module of InVEST version 3.14.2 (Natural Capital Project, 2023)

Discussion points:

- Limited mitigation capacity of NBS
- NBS as a hybrid solution
- Single hazard vs multiple hazards prioritization
- Role of NBS in systemic changes

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Thank You!

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