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Do dense cities have enough space to accommodate Nature-based Solutions? A European wide data-based approach for their spatial localisation

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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

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SESSION 10 | Impact Assessment of Nature Based Solutions in Cities_ Theoretical, Methodological and Practical Perspectives

Pavia – September 09, 2025

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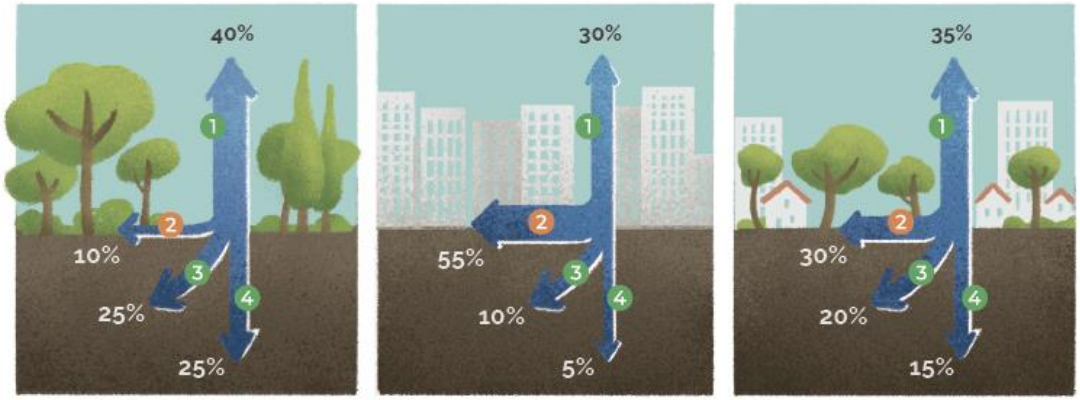
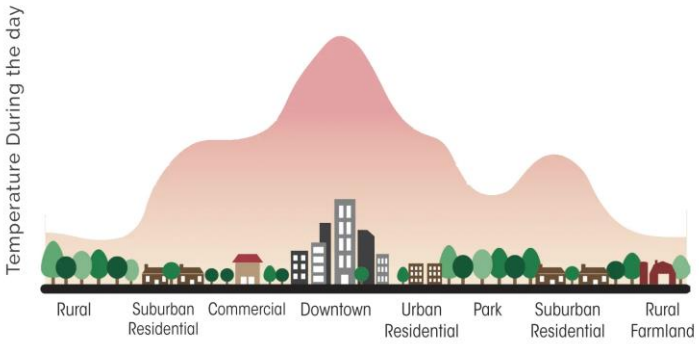
Introduction

The urgent issues to cope with **climate change** related risks in urban areas is massively driving toward the exploration and implementation of strategies for adapting cities to the main impacts such as **heat waves** and **floodings**.





Nature Based Solutions (NBS) can help to storage and sequester carbon, purify water and air, **reduce urban heat islands and water runoff**.
NBS are intended as engineered green measures inspired by nature in a way to meet the improvement of sustainable urbanisation as a priority aim.
NBS include a wide range of components such as green roofs and green walls, street trees, rain gardens, vegetated swales, stormwater planter boxes and permeable pavements.

Introduction

Portion of historic centre of Catania (source: Google Satelite)

Portion of historic centre of Alicante (source: Google Satelite)

Historic centers are extremely complex parts of the contemporary cities.

Deep weaknesses:

- limited accessibility;
- building stock with inadequate housing standards;
- scarce green and open spaces endowment;
- high levels of natural risk exposure;
- complex urban morphology;
- high level of density.

Limits to the implementation of NBS:

- policies and programmes constraints
- to find suitable locations

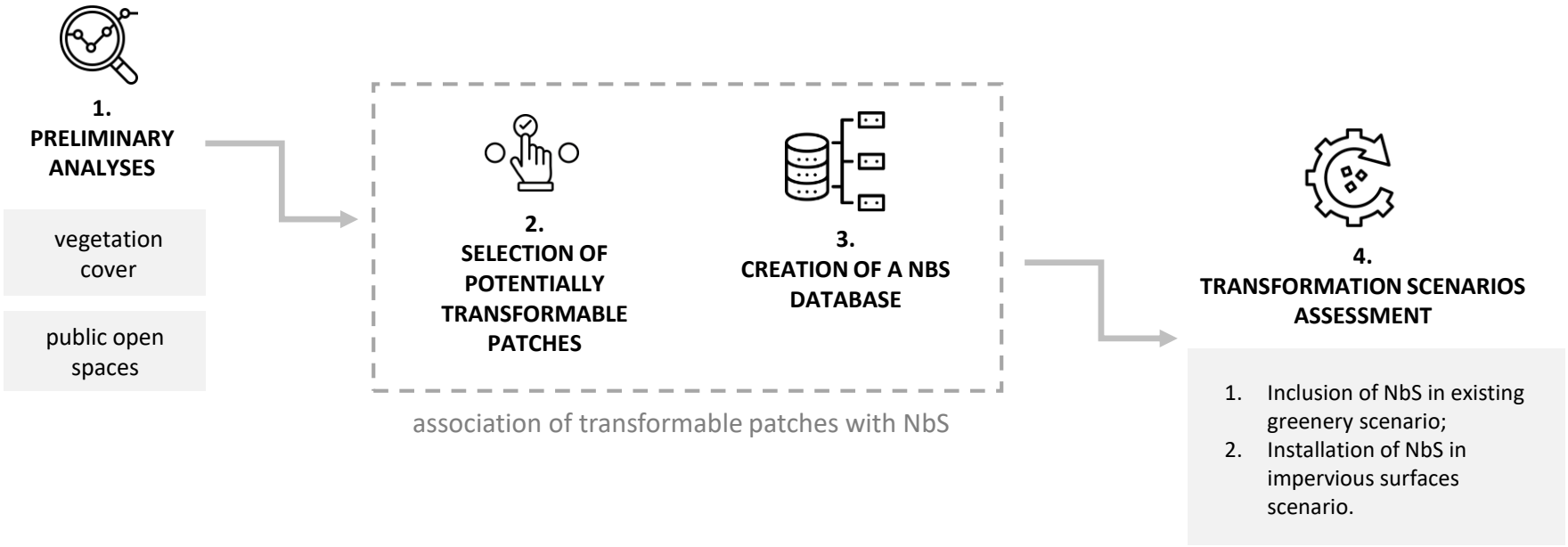
Opportunities for built heritage conservation to be integrated to the wider delivery of NBS in cities are **rarely discussed**.

Case studies

Case studies selection criteria:

- Euro-Mediterranean cities (with similar climatic characteristics);
- Similar number of inhabitants;
- Presence of a dense historic centre with heritage values.

Method

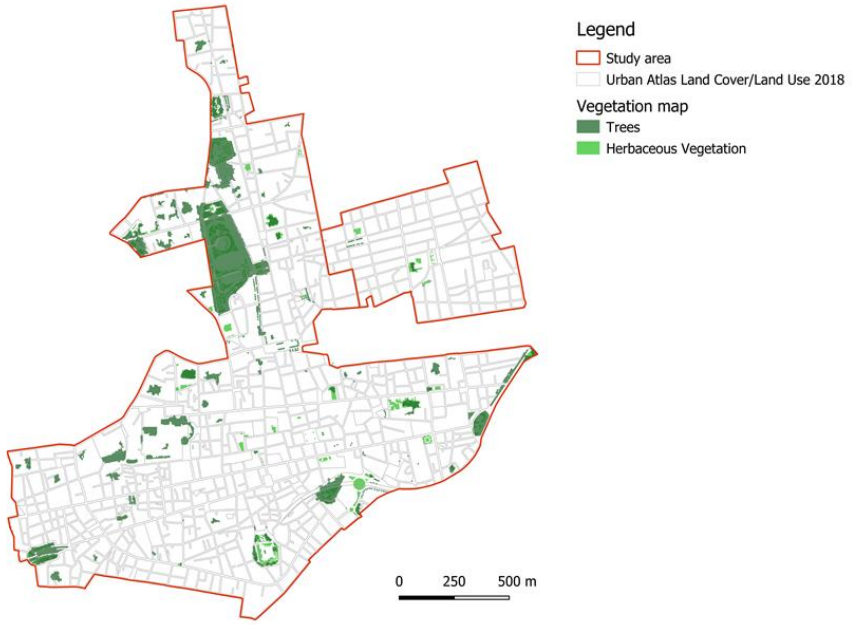


The complex urban morphology of historic centres stimulated the need for **multi-source geospatial data fusion**, to catch every small component. Fusing data from different sources is an alternative approach to build analysis in high-density cities.

Method

1. Vegetation cover analysis

Data sources	Land-use land cover layers	Vegetation cover categories: Trees	Shrubs	Herbaceous vegetation
Urban Atlas	Land use/Land cover	x	x	x
	Street tree layer	x		
Copernicus	Grassland			x
	Herbaceous vegetation			x
	Small Woody Features	x		
	natural/tree	x		
	natural/tree_row	x		
	natural/shrub		x	
Quick Open Street Map	land use/grass			x
	land use/flowerbed			x
	leisure/garden			x
	leisure/park	x		



Vegetation cover analysis in the historic centre of Catania

Vegetation cover analysis in the historic centre of Alicante

1. Public open spaces analysis

The polygons of the **squares** used in this study are obtained from **Quick OpenStreetMap**, a plug-in of QGIS.

The **roads** were obtained as the difference between the "Other roads and associated land" polygon of «**Urban Atlas** Land Cover/Land Use 2018 (vector), Europe, 6-yearly» and the squares of OpenStreetMap.

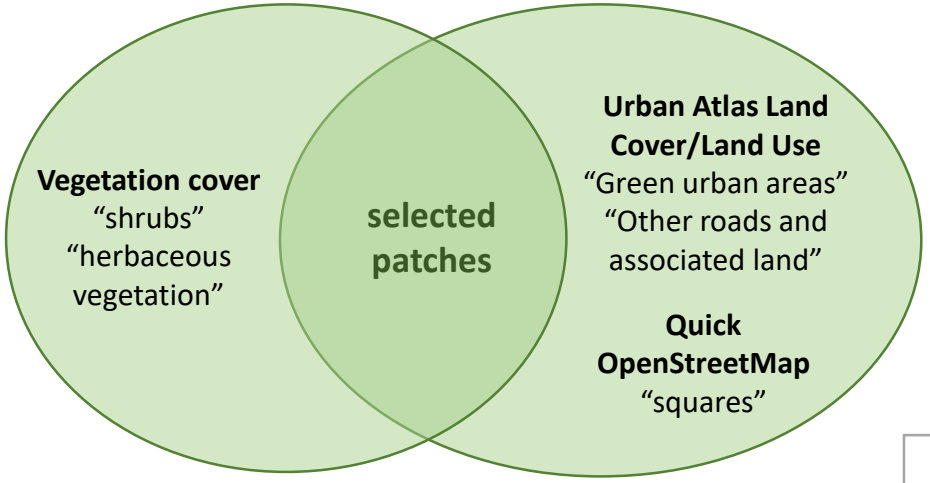
Public open spaces analysis in the historic centre of Alicante

Public open spaces analysis in the historic centre of Catania

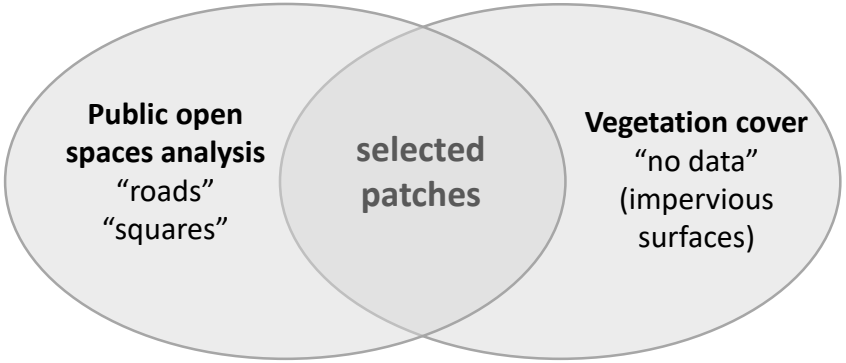
Method

2. Transformable land patches selection

Vegetation cover analysis



Public open spaces analysis



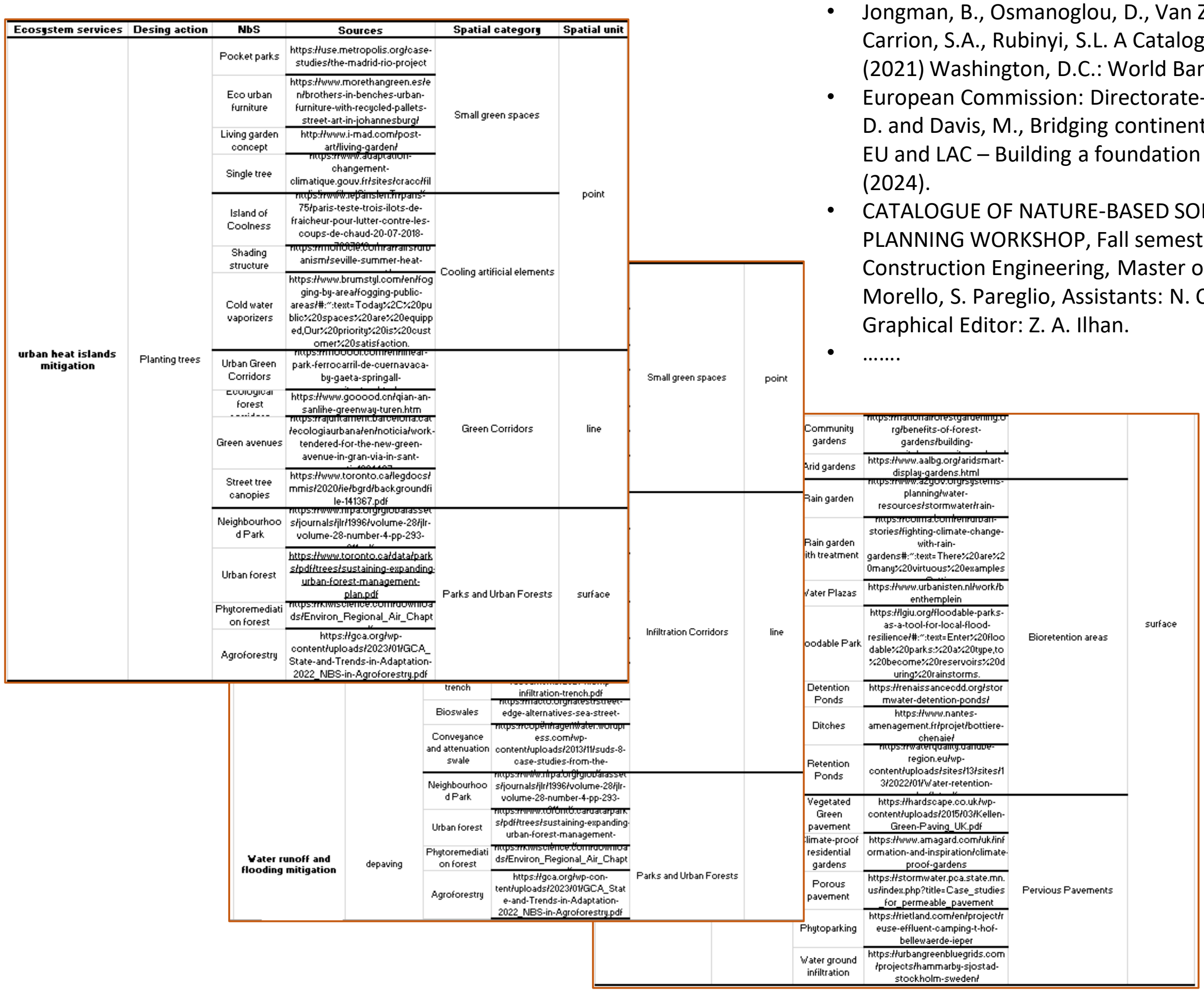
The selected patches were divided according to their geometric characteristics.

- Roads were assimilated to **lines**;
- Squares and green selected areas were divided into two classes.

Jenks classification (Natural Breaks):

1. **Points**: polygons with smaller area values;
2. **Surface**: polygons with larger area values.

3. NbS database



Ecosystem services	Desing action	NbS	Sources	Spatial category	Spatial unit
urban heat islands mitigation	Planting trees	Pocket parks	https://use.metropolis.org/case-studies/the-madrid-rio-project	Small green spaces	point
		Eco urban furniture	https://www.morethangreen.es/en/brothers-in-benches-urban-furniture-with-recycled-pallets-street-art-in-johannesburg/		
		Living garden concept	http://www.i-mad.com/post-art/living-garden/		
		Single tree	changement-climatique.gouv.fr/sites/cracc/fil		
		Island of Coolness	75/paris-teste-trois-ilots-de-fraicheur-pour-lutter-contre-les-coups-de-chaud-20-07-2018-	Cooling artificial elements	
		Shading structure	anism/seville-summer-heat-		
		Cold water vaporizers	https://www.brumstyl.com/en/fogging-by-area/fogging-public-areas/#:~:text=Today%2C%20public%20spaces%20are%20equipped,Our%20priority%20is%20customer%20satisfaction.		
		Urban Green Corridors	park-ferrocarril-de-cuernavaca-by-gaeta-springall-	Green Corridors	line
		Ecological forest	https://www.gooood.cn/qian-an-sanlihe-greenway-turen.htm		
		Green avenues	/ecologiaurbana/en/noticia/work-tendered-for-the-new-green-avenue-in-gran-via-in-sant-		
		Street tree canopies	https://www.toronto.ca/legdocs/mmis/2020/ie/bgrd/backgroundfile-141367.pdf		
		Neighbourhood Park	s/journals/jlr/1996/volume-28/jlr-volume-28-number-4-pp-293-	Parks and Urban Forests	surface
		Urban forest	https://www.toronto.ca/data/parks/pdf/trees/sustaining-expanding-urban-forest-management-plan.pdf		
		Phytoremediation forest	ds/Environ_Regional_Air_Chapt		
		Agroforestry	https://gca.org/wp-content/uploads/2023/01/GCA_State-and-Trends-in-Adaptation-2022_NBS-in-Agroforestry.pdf		

Water runoff and flooding mitigation	depaving			Small green spaces	point
		trench	infiltration-trench.pdf	Infiltration Corridors	line
		Bioswales	edge-alternatives-sea-street-		
		Conveyance and attenuation swale	ess.com/wp-content/uploads/2013/11/suds-8-case-studies-from-the-		
		Neighbourhood Park	s/journals/jlr/1996/volume-28/jlr-volume-28-number-4-pp-293-	Parks and Urban Forests	
		Urban forest	s/pdf/trees/sustaining-expanding-urban-forest-management-		
		Phytoremediation forest	ds/Environ_Regional_Air_Chapt		
		Agroforestry	https://gca.org/wp-con-tent/uploads/2023/01/GCA_State-and-Trends-in-Adaptation-2022_NBS-in-Agroforestry.pdf		

Community gardens	rg/benefits-of-forest-gardens/building-		surface
Arid gardens	https://www.aalbg.org/aridsmart-display-gardens.html		
Rain garden	planning/water-resources/stormwater/rain-	Bioretention areas	
Rain garden ith treatment	stories/fighting-climate-change-with-rain-gardens#:~:text=There%20are%20many%20virtuous%20examples		
Vater Plazas	https://www.urbanisten.nl/work/benthemplein		
oodable Park	https://lgiu.org/floodable-parks-as-a-tool-for-local-flood-resilience/#:~:text=Enter%20floodable%20parks%3A%20a%20type,to%20become%20reservoirs%20during%20rainstorms.		
Detention Ponds	https://renaissanceodd.org/stormwater-detention-ponds/		
Ditches	https://www.nantes-amenagement.fr/projet/bottiere-chenaie/		
Retention Ponds	region.eu/wp-content/uploads/sites/13/sites/13/2022/01/Water-retention-		
Vegetated Green pavement	https://hardscape.co.uk/wp-content/uploads/2015/03/Kellen-Green-Paving_UK.pdf	Pervious Pavements	
limate-proof residential gardens	https://www.amagard.com/uk/information-and-inspiration/climate-proof-gardens		
Porous pavement	https://stormwater.pca.state.mn.us/index.php?title=Case_studies_for_permeable_pavement		
Phytoparking	https://rietland.com/en/project/reuse-effluent-camping-t-hof-bellewaerde-ieper		
Water ground infiltration	https://urbangreenbluegrids.com/projects/hammarby-sjostad-stockholm-sweden/		

Literature review by investigating existing catalogues:

- Jongman, B., Osmanoglou, D., Van Zanten, B.T., Gonzalez Reguero, B., Macfarlane, D.M.; Duma, L.J., Carrion, S.A., Rubinyi, S.L. A Catalogue of Nature-based Solutions for Urban Resilience (English). (2021) Washington, D.C.: World Bank Group.
- European Commission: Directorate-General for Research and Innovation, Burgos Cue-vas, N., Rizzi, D. and Davis, M., Bridging continents – Exploring the state-of-play of nature-based solutions in the EU and LAC – Building a foundation for collaboration, Publications Office of the European Union, (2024).
- CATALOGUE OF NATURE-BASED SOLUTIONS FOR URBAN REGENERATION, ENERGY & URBAN PLANNING WORKSHOP, Fall semesters 2018 & 2019, School of Architecture Urban Planning and Construction Engineering, Master of Science in Ur-ban Planning and Policy Design. Instructors: E. Morello, S. Pareglio, Assistants: N. Col-aninno, I. Mahmoud, M. A. Rudini, A. ElDesoky, F. Rotondo. Graphical Editor: Z. A. Ilhan.
- ....

selection of NbS aimed at mitigating urban heat islands and flooding

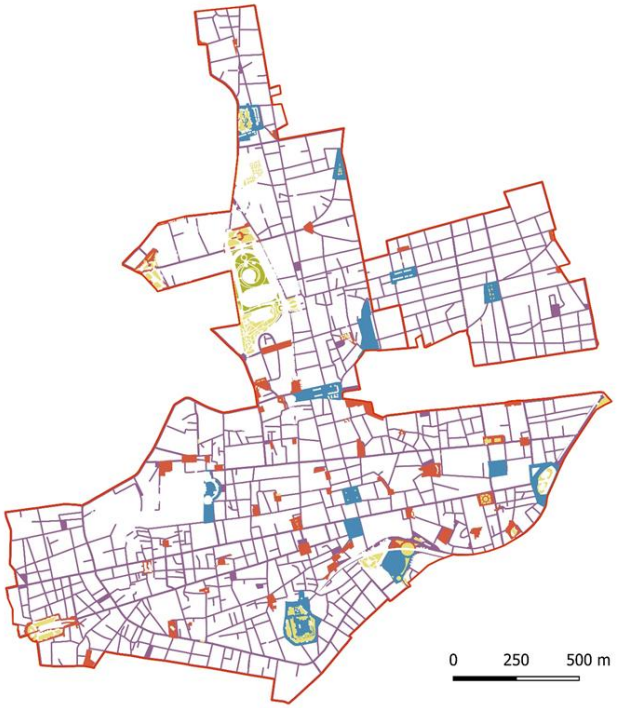
Each NbS was associated with a design action ('planting trees' and 'depaving') and a spatial category of intervention.
Each NbS has specific spatial and geometric characteristics, that in this study, are approximated to three spatial units (**point, line and surface**) depending on the physical space and shape required for their construction and functioning.

4. Transformation scenarios assessment

Alicante

Transformation scenarios assessment in the historic centre of Alicante

Catania



Transformation scenarios assessment in the historic centre of Catania

Transformation scenarios assessment

Alicante

Transformation scenarios	m²	% over the case study area	% on transformation scenarios
1. Inclusion of NbS in existing greenery			
Herbaceous vegetation			
point	4,338	0.6	2.5
surface	7,112	1.0	4.2
2. Installation of NbS in impervious surfaces			
Roads			
line	155,092	22.8	**91.1**
Squares			
point	336	0.05	0.2
surface	3,422	0.5	2.0
		24.95	

Catania

Transformation scenarios	m²	% over the case study area	% on transformation scenarios
1. Inclusion of NbS in existing greenery			
Herbaceous vegetation			
point	43,082	1.5	6.0
surface	10,725	0.4	1.5
2. Installation of NbS in impervious surfaces			
Roads			
line	491,908	16.8	**68.2**
Squares			
point	83,038	2.8	11.5
surface	92,715	3.2	12.9
		24.70	

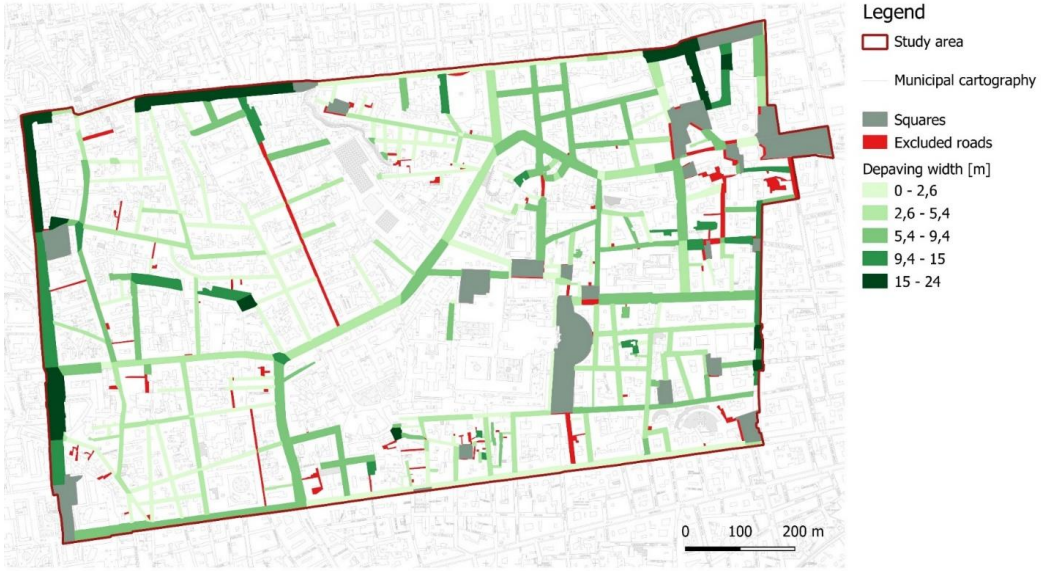
- The percentage of transformable surface area within each of the two case studies is similar.
- In both case studies the second scenario contributed more overall than the first scenario.
- Within the second scenario, roads transformation makes the largest contribution in both case studies.

Discussion

Some method limitations:

- It is applicable exclusively to cities with at least 50,000 inhabitants, since the Copernicus Urban Atlas data is only available for urban centers with this size features;
- the open public spaces areas selected as transformable are not totally transformable: operating on the complex context of the historic centre, both roads and squares could be subjected to transformation constraints due to the presence of pavements to be protected and preserved; moreover, the roads must guarantee vehicular traffic, so their surface will not be totally transformable. Therefore, even considering the impervious areas, in the context under examination, the possibility of introducing NbS remains limited.

Each road was classified according to its road section and the space actually available for the addition of new greenery. In this way, some roads are excluded from the transformation, while others contribute to different extent depending on the space actually available. However, the increased level of detail in the methodology implied that some road data was missing, which required manual data construction.



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