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IN INGEGNERIA CIVILE E ARCHITETTURA

CICLO XXXVII

Climate change adaptation in urban regeneration practices.
The contribution of soil desealing in reducing the urban pluvial flood risk

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积土成山，积水成渊

(Jī tǔ chéng shān, jī shuǐ chéng yuān)

Xunzi (310 B.C. - 220 B.C.),
in 'Encouraging learning'

This Chinese phrase can be translated as "accumulated earth becomes a mountain, accumulated water becomes a deep abyss".

It conveys the idea that small, consistent efforts can lead to significant outcomes over time.

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Abstract

Over the past century, urbanisation has led to increasing soil sealing and consumption, exacerbating phenomena such as the urban heat island effect and urban flooding. Combined with rising temperatures and rainfall due to climate change, these challenges threaten the environmental, social, and economic sustainability of European and Italian cities. Among climate change adaptation strategies, soil desealing – i.e., the restoration of soil permeability through the removal of its impervious layer - has emerged in the scientific literature as a promising solution for mitigating these impacts by reducing surface runoff, urban temperatures, and restoring ecosystem services and functions.

This research, conducted within the Ph.D. programme in Civil Engineering and Architecture at the University of Parma, explores priorities and criteria for implementing soil desealing interventions to mitigate urban pluvial flood risk, focusing on medium-sized Italian cities. Being home to a significant portion of the European population, they serve as relevant contexts for testing and implementing innovative urban strategies, contributing to polycentric and balanced territorial development. This study examines the scientific literature and the legislative and strategic frameworks addressing soil sealing and desealing, drawing on regional instruments such as Regional Law No. 24/2017 of the Emilia-Romagna Region, alongside national and European instruments, highlighting the multi-scalar and integrated approach required to address soil desealing and climate change adaptation in urban planning for mitigating the urban pluvial flood risk.

Furthermore, this research tries to contribute to the challenge of defining appropriate localisation and intervention criteria for soil desealing. An additional challenge is the identification of the relevant tools for the implementation of this actions to reduce the urban pluvial flood risk, in a context that lacks a structured national framework that relies on more or less effective local initiatives and approaches.

This thesis presents a research methodology that builds upon a literature review on soil sealing, desealing, and closely related topics such as flood management. It integrates quantitative and qualitative analyses, including urban pluvial flood risk, damage, and transformation potential assessments, and the identification of strategies for involving citizens of different ages to explore their perceptions and preferences. Insights into practices for enhancing public participation in urban climate change adaptation were further enriched through research experiences at Eindhoven University of Technology and the science centre 'AmbienteParco'.

The research focuses on two case studies: Parma and Brescia. In Parma, the urban flood risk, damage and transformation potential were assessed alongside participatory initiatives such as co-design sessions, outreach activities and surveys, analysing and comparing their outcomes to define priorities and criteria for the implementation of soil desealing. Furthermore, soil desealing interventions were simulated in two urban subcatchments to complete the analyses and test the proposed approaches.

The efforts of the Municipality of Brescia in promoting soil desealing, as well as the Climate transition strategy and public participation framework of the city provided a comparative lens, offering further insights into the integration of soil desealing within urban planning.

This thesis concludes by offering guidelines to integrate soil desealing into urban regeneration practices, both from the administrations and citizens' point of views.

Italian abstract

Nel corso dello scorso secolo, l'urbanizzazione ha portato a un aumento dell'impermeabilizzazione e del consumo di suolo, aggravando fenomeni come l'effetto isola di calore urbano e le inondazioni. Tali questioni, unite all'aumento delle temperature e delle precipitazioni dovuto ai cambiamenti climatici, pongono a rischio la sostenibilità ambientale, sociale ed economica delle città europee e italiane. Tra le strategie di adattamento ai cambiamenti climatici, la desigillazione del suolo – ovvero il ripristino della permeabilità del suolo tramite la rimozione dello strato impermeabile – è emersa nella letteratura scientifica come una soluzione promettente per mitigare questi impatti, riducendo il deflusso superficiale e le temperature urbane, e ripristinando i servizi e le funzioni ecosistemiche.

Questa ricerca, condotta nell'ambito del programma di Dottorato in Ingegneria civile e Architettura dell'Università di Parma, esplora le priorità e i criteri per l'implementazione di interventi di desigillazione del suolo finalizzati a mitigare il rischio idraulico urbano di natura pluviale, focalizzandosi sulle città italiane di medie dimensioni. Queste città, che ospitano una parte significativa della popolazione europea, costituiscono contesti rilevanti per testare e attuare strategie urbane innovative contribuendo a uno sviluppo territoriale policentrico ed equilibrato. Lo studio analizza letteratura scientifica e i quadri normativi e strategici relativi all'impermeabilizzazione e alla desigillazione del suolo, attingendo a strumenti regionali, come la Legge Regionale n. 24/2017 della Regione Emilia-Romagna, nonché a strumenti nazionali ed europei, evidenziando l'approccio multi-scalare e integrato necessario per affrontare la desigillazione del suolo e l'adattamento ai cambiamenti climatici nella pianificazione urbana per la mitigazione del rischio idraulico urbano di natura pluviale.

Questa ricerca si propone di contribuire alla sfida di definire criteri appropriati per la localizzazione e l'implementazione degli interventi di desigillazione del suolo. Un ulteriore obiettivo è l'identificazione degli strumenti rilevanti per l'attuazione di queste azioni al fine di ridurre il rischio idraulico urbano di natura pluviale, in un contesto che manca di un quadro nazionale strutturato e si affida a iniziative e approcci locali più o meno efficaci.

Questa tesi propone una metodologia di ricerca che si basa su una revisione della letteratura sull'impermeabilizzazione e la desigillazione del suolo, nonché su tematiche strettamente correlate come la gestione del rischio di alluvioni. Inoltre, integra analisi quantitative e qualitative, comprese valutazioni del rischio, del danno e *del potenziale di trasformazione urbano nonché l'identificazione di strategie per il coinvolgimento dei cittadini di diverse età, volte a esplorarne percezioni e preferenze. Le esperienze di ricerca presso la Eindhoven University of Technology e lo science centre 'AmbienteParco' hanno ulteriormente arricchito la comprensione delle pratiche mirate a rafforzare la partecipazione pubblica nell'adattamento climatico urbano.*

La ricerca si concentra su due casi studio: Parma e Brescia. In Parma, sono stati analizzati il rischio di idraulico urbano di natura pluviale, il danno e il potenziale di trasformazione urbana, insieme a iniziative partecipative come sessioni di co-design, attività di sensibilizzazione e questionari, confrontandone i risultati per definire priorità e criteri per l'implementazione della desigillazione del suolo. Inoltre, in due sottobacini urbani sono stati simulati interventi di desigillazione del suolo per completare le analisi e testare l'approccio proposto.

Infine, gli sforzi del Comune di Brescia nella promozione della desigillazione, insieme alla Strategia di transizione climatica e alle esperienze di partecipazione pubblica della città in questo contesto, hanno fornito una lente comparativa offrendo ulteriori spunti sull'integrazione della desigillazione del suolo nella pianificazione urbana.

Questa tesi si conclude offrendo delle linee guida per integrare la desigillazione del suolo nelle pratiche di rigenerazione urbana, sia dal punto di vista delle amministrazioni che da quello dei cittadini.

Outline of the thesis

This research, titled 'Climate change adaptation in urban regeneration practices. The contribution of soil desealing in reducing the urban pluvial flood risk' is the result of a three-year old research carried out within the Ph.D. programme in Civil Engineering and Architecture at the Department of Engineering and Architecture of the University of Parma. Co-funded with resources from the National Operational Programme for Research and Innovation 2014-2020, ESF REACT-EU resources, Action IV.4 "Doctorates and research contracts on innovation topics" and Action IV.5 "Doctorates on Green topics", this path was shared with the fellow Ph.D. student Marianna Ceci, who investigated the role of soil desealing in mitigating the urban heat island effect.
The two studies, carried out within the research group in Urban and regional planning of the University of Parma, began with a literature review on soil desealing conducted collaboratively. They then diverged to focus on the respective specific objectives - i.e., the mitigation of the urban pluvial flood and heat island risk - eventually converging in the comparison of their insights and findings.
Furthermore, two experiences allowed to deepen this research with regard to citizens' involvement and climate change adaptation. The first consists of a research semester spent at the Department of the Built Environment at Eindhoven University of Technology. This opportunity allowed to investigate both qualitative and quantitative approaches to gather insight about citizens' preferences and perceptions regarding climate change and its effects in the context of soil desealing.
The second experience involved a semester-long collaboration with the 'AmbienteParco' science centre, located in Brescia. This provided the chance to engage with another urban context sharing similarities with Parma, particularly in terms of soil desealing practices, and to learn about the role of citizens' involvement in these processes within the broader context of the Climate transition strategy of Brescia.

Within this framework, this section outlines the objectives, methodology, and structure of the thesis, which are summarised in Figure I.1.

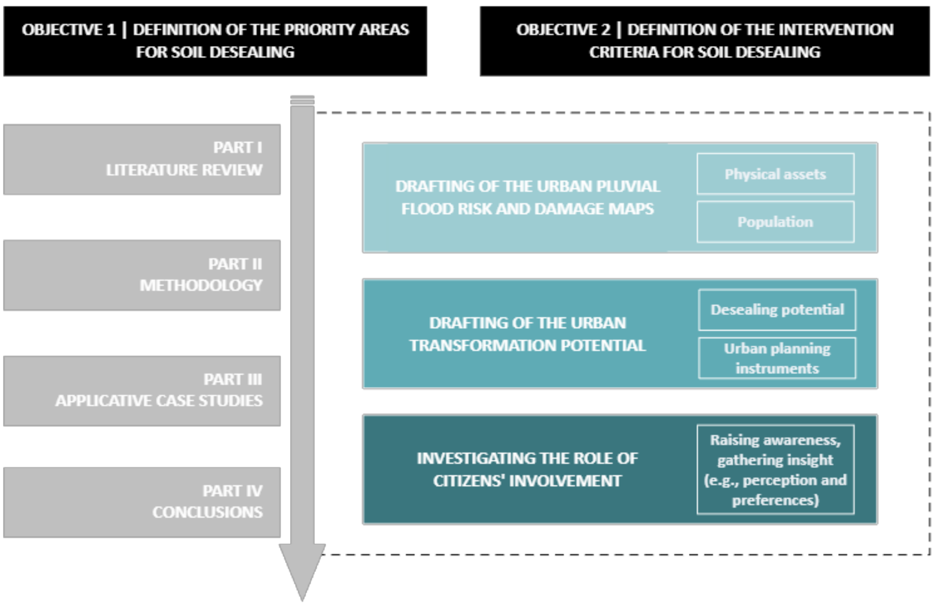

Figure I.1 | Objectives, methodology and structure of the thesis. Source: author's elaboration.

Objectives

In the last century, soil consumption and the consequent soil sealing have affected the challenges that urban areas have to address. The increasing imperviousness of the cities, together with the growing temperatures and precipitation quantities caused by climate change have been identified in Europe as the cause of phenomena such as the urban heat island and urban pluvial floods (EEA, 2023a). Climate change adaptation has been recognised as one of the answers to these issues, as it allows to mitigate the environmental, social and economic damages posed to European and Italian cities (IPCC, 2023).

In the Italian legislation, the challenges caused by soil sealing are currently being addressed mainly with policies and regulations attempting to contain soil consumption, thus only limiting further soil sealing. Despite its recognition as an effective strategy to restore the ecosystem services and functions provided by the natural environment, soil desealing – i.e., the concept of intervening on the urbanised lands to restore their permeability - has not been systematically implemented in urban planning and transformation tools and practices. Soil desealing has been addressed only in the most recent regional framework (i.a., Regional Law No. 24/2017 of the Emilia-Romagna Region and Regional Law No. 31/2014 of the Lombardy Region), while only being proposed in draft in national legislation, i.e., Senate Act No. 1028/XIX (2024), the Draft Law 'Urban regeneration and sustainable land use' (*Rigenerazione urbana e uso sostenibile del suolo*).

On the steps of the Regional Law No. 24/2017 'Regional discipline on the protection and use of the territory' (*Disciplina regionale sulla tutela e l'uso del territorio*) of the Emilia-Romagna Region, this research aims at identifying criteria for effectively implementing soil desealing to mitigate the urban pluvial flood risk in the Italian urban planning scenario, within the broader perspective of fostering the activation of virtuous climate change adaptation processes in the Italian urban regeneration practices.

More specifically, this thesis proposes a methodology to i) define the priority soil desealing areas and ii) identify tools and criteria for mainstreaming soil desealing interventions with the appropriate urban planning instruments.

The role of citizens' involvement and participatory processes is investigated not only in the definition of the priority intervention areas, but also in the implementation of soil desealing in the future urban planning scenarios, with the objective of exploring how citizens can help to impact the decision-making process.

Finally, this thesis aims to validate the proposed methodology applications on medium-sized cities. Specifically, the case studies consist of the Italian cities of i) Parma, located in the Emilia-Romagna region, and ii) Brescia, located in Lombardy. While Parma represents the main case study, Brescia presented opportunities that allowed for a comparison with the outcomes of the research in Parma, especially for what concerns the citizens' involvement processes and the identification of priorities for soil desealing.

Methodology and structure of the research

The research is structured in four parts. Part I consists of a literature review aimed at:

i) developing a knowledge framework of the state of the art concerning soil sealing (Chapter §1) and desealing (Chapter §2) in urban areas, as well as their relationship with climate change and their role in climate change adaptation strategies. It also identifies virtuous case studies and practices, emphasising the importance of citizens' involvement;

ii) defining the European and Italian legislative and normative framework for soil desealing (Chapter §3).

On this basis, Chapter §4 identifies in medium-sized cities a relevant context for investigating the role of soil desealing in the framework of urban regeneration practices. Home to a fifth of the European population (Selada et al., 2013), these cities have been the focus of a number of Italian and European programmes, and they have been recognised to provide an essential contribution in territorial polycentric and balanced development (Clerici, 2017; Tedeschi, 2023).

Part II shifts then the focus on defining a methodology tailored for these cities. The approach is divided into the following main sub-phases:

i) quantitative urban pluvial flood risk and damage assessment, which includes the definition of their components (i.e., urban pluvial flood hazard, exposure, and vulnerability) and related indicators (Chapter §5). The definition of the indicators, and thus of the risk and damage components, is based on a literature review and analysis that was carried out for this specific purpose;

ii) identification of the urban transformation potential with respect to soil desealing, through the definition of the desealing potential (and related indicators), and the identification of the suitable urban planning instruments for its implementation (Chapter §6);

iii) investigation of public participation strategies and experiences for impacting the decision-making process, thus exploring the role of citizens' involvement, perception, and preferences, through tools such as surveys and laboratories (Chapter §7).

Chapter §8 presents the conclusions of Part II, offering insights into urban pluvial flood risk, damage, and transformation potential assessments and their role, as well as into the importance of citizens' involvement in defining priority areas and intervention criteria for soil desealing.

These phases delineate a quantitative and qualitative framework for the definition of priority intervention areas and criteria, in the framework of activating soil desealing interventions in the Italian urban planning scenario of medium-sized cities.

Part III encompasses two applicative case studies on Italian medium-sized cities, namely Parma (Chapter §9) and Brescia (Chapter §10). After tracing an overview of the territorial context and existing knowledge framework in Section §9.1, Chapter §9 describes how the urban pluvial flood risk and damage assessments were carried out on the basis of the available literature, data and own calculations. Furthermore, when more than one method was employed, it provides insight on their relationships (Section §9.2). Section §9.3 presents the steps for the evaluation of the urban transformation potential, through the assessment of both the urban desealing potential and available urban planning tools. Section §9.4 describes practical experiences that dealt with involving, raising awareness and gathering insight from the citizens (e.g., the 'Green in Parma' community project, in which the research group in Urban and regional planning collaborates in setting up participatory processes aimed at soil desealing). Section §9.5 describes the identified priorities for soil desealing and proposes the simulation of the implementation of soil desealing interventions in two urban subcatchments.

Chapter §10 presents the applicative case study of Brescia. After describing its territorial context and knowledge framework in Section §10.1, experiences and tools related to soil desealing carried out in Brescia are presented, with specific reference to flood risk assessments and opportunities for urban transformation (Section §10.2), as well as to citizens' involvement processes. Examples of these processes are those involved with Climate transition strategy of Brescia, which presents a 30-year vision to advance the urban climate adaptation and mitigation, improve citizens' understanding of climate change and encourage participatory processes (*Un Filo Naturale*, n.d.).

Chapter §11 includes the final considerations on the two applicative case studies, including also their comparison.

Part IV concludes the research, beginning with reflections on the relationship between mitigating urban pluvial flood and heat island risks within the context of soil desealing (Chapter §12). It then defines guidelines and criteria - for both the administrations and the citizens - aimed at fostering the implementation of soil desealing in the urban regeneration practices of medium-sized Italian cities (Chapter §13). Finally, Chapter §14 addresses the limitations of the study and explores potential future developments of the research.

Glossary

This glossary provides the English translations of Italian urban planning instruments that were used in the framework of this research. The instruments are organised by level, and are accompanied by a list of translated names and acronyms of institutions as they are cited in the references. It should be noted that, as the thesis focuses on the Italian context, a primarily literal translation approach has been used as the aim is to preserve the original meaning and details relevant to the research.

Urban planning instruments

Regional or provincial level

Regional or provincial urban plans (*piani urbanistici regionali o provinciali*)

- Provincial coordination territorial plan (*piano territoriale di coordinamento provinciale - PTCP*)

Municipal level

Municipal urban plans (*piani urbanistici comunali*)

- General urban plan (*piano regolatore generale – PRG* or *piano urbanistico generale – PUG for the Emilia-Romagna region*)
- Municipal structural plan (*piano strutturale comunale - PSC*)
- Territorial governance plan (*piano di governo del territorio - PGT*)

Associated instruments

- Operational municipal plan (*piano operativo comunale - POC*)
- Building regulation (*regolamento edilizio – RE*)
- Urban planning and building regulation (*regolamento urbanistico ed edilizio - RUE*)
- Municipal sanitary regulation (*regolamenti igienico sanitari*)
- Technical implementation standards (*norme tecniche di attuazione - NTA*)

Sector-specific plans (*piani di settore*)

- Green plan (*piano del verde*)
- Services plan (*piano dei servizi*)

Sub-municipal level

Implementation plans or instruments (*piani o strumenti attuativi*)

- Implementation plan (*piano degli interventi/piano attuativo/piano particolareggiato*)

Other instruments

Civil protection plan (*piano di protezione civile*)

Climate transition strategy (*strategia di transizione climatica*)

Flood risk management plan (*piano di gestione del rischio di alluvioni – PGRA*)

Hydrogeological structure plan (*piano di assetto idrogeologico – PAI*)

Integrated urban plan (*piano urbano integrato*)

Municipal emergency plan (*piano di emergenza comunale*)

National climate change adaptation plan (*Piano nazionale di adattamento ai cambiamenti climatici - PNACC*)

National climate change adaptation strategy (*Strategia nazionale di adattamento ai cambiamenti climatici - SNAC*)

Public work maintenance plan (*piano di manutenzione di un'opera pubblica*)

Regional energy plan (*piano energetico regionale*)

River contract (*contratto di fiume*)

Three-year public works programmes (*programmi triennali dei lavori pubblici*)

Other terminology

Construction charges from urbanisation works (*oneri di urbanizzazione*)

Buildability (*edificabilità*)

Building charges (*contributo di costruzione*)

Building permits (*titoli abilitativi*)

Urban planning standards (*standard urbanistici*)

Varianti (*variants*)

Institutions

Directorate General for the Environment (DGE or *DGA* in Italian)

European Commission (EC or *CE* in Italian)

European Environmental Agency (EEA)

European Union (EU or *UE* in Italian)

Food and Agriculture Organization of the United Nations (FAO)

German Society for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit - GIZ*)

Institute for Environmental Protection and Research (*Istituto Superiore per la Protezione e la Ricerca Ambientale – ISPRA*)

Intergovernmental Panel on Climate Change (IPCC)

Italian Ministry of the environment and energy security (*Ministero dell'ambiente e della sicurezza energetica - MASE*) [previously Ministry of the Environment and Protection of Land and Sea (*Ministero dell'ambiente e della tutela del territorio e del mare* – MATTM)]

Italian national research council – (*Consiglio Nazionale delle Ricerche - CNR*)

Natural Resources Conservation Service of the United States Department of Agriculture (NRCSUSDA)

National System for Environmental Protection (*Sistema nazionale protezione ambiente – SNPA*)

Organization for Economic Co-operation and Development (OECD)

Soil Conservation Service (SCS)

United States Environmental Protection Agency (USEPA)

Virginia Association of Soil and Water Conservation Districts (VASWCD)

I | Soil desealing and climate change adaptation in urban areas

Part I of this thesis proposes a reconstruction of the knowledge framework concerning soil sealing, desealing and climate change adaptation in urban areas.

First, the issue of soil consumption and climate change in urban areas is defined in Chapter §1. Starting from the definition of soil, the chapter outlines the problem (Section §1.1), the terminology and describes the situation in Europe and Italy, as well as the existing legislative framework on this topic. The urban pluvial flood risk (Section §1.2) and the urban heat island phenomenon (Section §1.3) are then discussed as relevant issues to be addressed in the context of urban planning, identifying - in the case of the urban pluvial flood risk - the available approaches and instruments to assess it. These sections then open to Section §2, which provides a literature review on soil desealing and climate change adaptation by addressing the terminology (Section §2.1), the state of the art (Section §2.2), the role of public participation (Section §2.3) and eventually highlighting lights and shadows entailed by increasing the urban permeability (Section §2.4). Chapter §3 investigates the European and Italian legislative frameworks, while Chapter §4 programmatically closes Part I discussing soil desealing in relation to urban regeneration and urban planning, identifying the role of medium-sized cities as a relevant test field for the research.

1 The issues of soil consumption and climate change

Soil constitutes the outermost layer of the earth crust and the interface between land, air and water, and hosts a large part of the biosphere (Science for Environment Policy, 2016). Over time, researchers and policy-makers have recognised the importance of valuing this resource, which is considered non-renewable due to its formation that takes place over extremely long periods of time (EC, 2006c; EEA, 2004).

The definitions given to soil - i.e., a heterogeneous mixture which consists of solid, liquid and gaseous components - reflect its complexity. They take into account not only its physical properties, but also the environmental, social, economic and cultural services and functions provided to humankind (Table I.1): from its outermost to innermost layers, soil has been associated with a variety of ecosystem functions, such as i) habitat for living beings; ii) element of the nutrient cycle; iii) physical foundation of human settlements; and iv) container of geological and cultural heritage. Soil has also been identified as the provider of supply, regulation, maintenance and cultural ecosystem services, involving processes such as the water cycle and meteorological conditions.

SOIL	*Author, year*	*Set of physical characteristics*	*Limited and/or non-renewable resource*	*Provider of services and/or functions*	*Common good*	*Ecosystem and/or habitat*	*(Dynamic) system*	*Natural capital*	*Element related to human society or activities*	*Medium*	*Provider of support, sustenance or raw materials*
GLOBAL LEVEL	United Nations, 2012			•					•		•
EUROPEAN LEVEL	EEA, 2004	•		•					•	•	
	Science for Environment Policy, 2016		•	•			•		•		•
	Council Of Europe, 1973	•	•	•			•		•	•	
	EC, 2006b	•	•	•		•			•	•	•
	EC, 2006a		•	•			•		•		
	EC, 2002	•	•	•		•			•		•
ITALIAN LEVEL	Forum nazionale Salviamo il Paesaggio, 2018		•	•					•		•
	Senate Act No. 164/XVIII, 2018		•			•		•	•		
	Forum nazionale Salviamo il Paesaggio, 2018	•	•								
	Chamber Act No. 2039/XVII, 2016		•								
	Senate Act No. 3601/XVI, 2012		•	•	•				•		•

SOIL	Author, year	Set of physical characteristics	Limited and/or non-renewable resource	Provider of services and/or functions	Common good	Ecosystem and/or habitat	(Dynamic) system	Natural capital	Element related to human society or activities	Medium	Provider of support, sustenance or raw materials
	Legislative Decree No. 152/2006 *Norme in materia ambientale*	•							•		
	Consumo Di Suolo, Dinamiche Territoriali e Servizi Ecosistemici, 2021		•								
LITERATURE	SOS4LIFE, 2017a			•				•			
	Munafò & Tombolini, 2014	•	•	•		•			•	•	•
	Kibblewhite et al., 2008			•							•
	Nortcliff et al., 2006	•		•		•	•		•	•	•
	Blum, 2005		•	•					•		•
	Carter et al., 1997								•		•

Table I.1 | Literature review of the definitions concerning the concept of soil. Source: result of a joint collaboration between the author and Marianna Ceci.

Degradation processes such as erosion, compaction, reduction of organic matter, pollution, loss of biodiversity, salinisation, and sealing constitute a threat to the European soil and its ecosystem functions and services. Despite its ecosystem value and vital relevance for humankind, between 60% and 70% of soil in the European Union is not in good health (EC, 2021; Consumo Di Suolo, Dinamiche Territoriali e Servizi Ecosistemici, 2022): human activities, although directly benefitting from the ecosystem functions and services provided by the soil, embody also one the main causes of soil degradation. With particular relevance for urban and regional planners, soil consumption and soil sealing – being direct consequence of the urbanisation and urban transformation processes - have been recognised in literature as threatening soil health by affecting its natural features, and thus as relevant issues that need to be managed (EC, 2021; Consumo Di Suolo, Dinamiche Territoriali e Servizi Ecosistemici, 2022).

Within this context, extreme events such as storms, heatwaves and floods have been identified as the cause of between 85,000 and 145,000 human fatalities across Europe over the past 40 years, with an estimated economic loss related to climate and weather corresponding to half a trillion euros (EEA, 2024). Climate change exacerbates these issues and leads to higher observed and projected climate-related impacts and risks (IPCC, 2022). In the framework of climate change adaptation, the preservation and restoration of the soil ecosystem services and functions appears therefore of utmost importance to avoid the environmental and socio-economic impacts entailed the loss of this valuable resource and by climate change. Furthermore, the Covid-19 pandemic has raised further awareness of the importance of green spaces for public health and wellbeing. This emphasises the crucial role of urban planners and decision-makers in identifying opportunities within urban areas to create spaces that benefit users, making their role even more relevant in contemporary planning (Haughton et al., 2020; Kemperman & Timmermans, 2014).

1.1 Problem statement

Defining the issue of the growing urbanisation and soil consumption in the framework of climate change requires dealing with different concepts such as the concepts of 'soil consumption' (or 'land take'), 'soil sealing', 'land use' and 'land cover', that - directly connected to the loss of agricultural and natural areas - require adequate considerations.

Section §1.1 provides an overview and a review of the definitions (Subsection §1.1.1), describes the context of soil consumption in Europe, based on the European and Italian soil consumption trends (Subsection §1.1.2). The soil consumption impacts on the ecosystem services and functions are investigated in Subsection §1.1.3, while the legislative and strategic countermeasures that have been taken – nationally and internationally - to mitigate them are addressed in Subsection §1.1.4.

Figure I.2 describes – with a touch of humour – the inherent (sad) irony of soil consumption. As the transition of the population from agricultural to urban areas is accompanied by the growth of cities, this also means that they expand towards where people left from.

Figure I.2 | The (sad) irony of the urbanisation phenomenon. Source: unknown author[1].

[1] Efforts were made to locate the author of this cartoon, used here under fair use for educational purposes – but the original source remains unknown.

1.1.1 An overview of the definitions

Analysing the definitions that have been attributed to the concepts revolving around soil consumption and climate change adaptation is helpful to gain insight about the different sensitivities and depths with which they have been addressed. The following paragraphs provide an overview on some of the definitions that have been given in literature to 'soil consumption', 'land use', introducing also the closely related concepts 'soil sealing' and 'net land take'.

Soil consumption

Already at the level of its definition, scholars and policy-makers who investigated **soil consumption**[2] have associated it with processes and issues that are potentially harmful for the ecosystem services and functions. For instance, Munafò (2022) referenced the aforementioned loss of a non-renewable resource (Consumo Di Suolo, Dinamiche Territoriali e Servizi Ecosistemici, 2022), while other authors have linked the definition with urbanisation process, thus with the increase of artificial surfaces and the reduction of agricultural lands (i.a., Directorate General for Environment (European Commission), 2012; Science for Environment Policy, 2016; Jobstmann et al., 2011; Losco & de Biase, 2021; AS 3601/XVI - Ddl Valorizzazione delle aree agricole e contenimento del consumo del suolo, 2012; Forum nazionale Salviamo il Paesaggio, 2018). Furthermore, soil consumption has been associated with densification (EC & DGE, 2012a); development (Science for Environment Policy, 2016); and landscape contamination. Other authors have emphasised the loss of quality and beauty connected to soil consumption (Losco & de Biase, 2021), thus emphasising the cultural services provided by this resource. When dealing with this issue, technical aspects such as the intended meaning of 'consumed soil' should be considered as well. With this term, scholars generally refer to the whole area which is transformed for an intended purpose. This means that – counterintuitively – urban green areas are generally included in the calculations that account for soil consumption, depending however on the local circumstances.

An overview of the concepts that have been linked with the definition of soil consumption is encompassed by Table I.2, highlighting their recurrence in the analysed literature.

[2] The literature review was carried out in both English and Italian, with the keywords '*consumo di suolo*' (lit. 'soil consumption'), 'land take' and 'land consumption'. For the purpose of this thesis, 'land take' and 'soil consumption' are intended as synonyms.

SOIL COSUMPTION	Author, year	Reduction of agricultural or rural area	Sealing	Urbanisation	Edification	Increase of artificial surfaces	Increase of settlements over time	Landscape contamination, loss of quality and beauty	Densification	Loss of the soil resource	Transition from undeveloped to developed soil
EUROPEAN LEVEL	Science for Environment Policy, 2016	•	•	•	•	•*					•
	EC & DGE, 2012a	•*	•	•			•		•		
	Jobstmann et al., 2011b	•	•	•		•	•				
ITALIAN LEVEL	Forum nazionale Salviamo il Paesaggio, 2018	•	•		•						
	Senate Act No. 3601/XVI, 2012	•	•	•	•						
LITERATURE	Losco & de Biase, 2021	•		•				•			
	Consumo Di Suolo, Dinamiche Territoriali e Servizi Ecosistemici, 2021	•	•	•	•	•	•		•	•	•
	Tobias et al., 2018			•	•						
	Munafò & Tombolini, 2014	•		•	•	•	•		•	•	•
	Artmann, 2014				•*						

* the definition underlines that land take may include green areas or unsealed soil.

Table I.2 | Literature review of the definitions concerning the concept of 'soil consumption'. Source: result of a joint collaboration between the author and Marianna Ceci.

Soil sealing

Closely connected to the concept of 'soil consumption', the notion of '**soil sealing**' emerged at the European and Italian level to address the land portion which is effectively covered with artificial impervious materials, thus the area which ability to provide for ecosystem services and functions was hampered (EC & DGE, 2012a; Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023).

Net land take

Furthermore, the concept of '**net land take**' introduces the idea of reverse land consumption, which - as opposed to soil consumption - is used to refer to urban areas which are (re)converted to semi-natural land. More specifically, net land take accounts for restored land, and is calculated by subtracting the restored area to the consumed areas for a given period (EEA, 2023b).

Land use and land cover

Closely connected to the previous topics, the concept of '**land use**' refers to how people utilise land. Furthermore, the term 'land cover' is used to refer to the physical land types. While some documents and studies indiscriminately use these terms (EC, 2002; C. Park, 2007), land use expresses a clear anthropic action. The connotation of this term emerges for instance when European entities identify intensive land use as a threat to biodiversity and an influence on the climate (EC & DGE, 2012a; EEA, 2019; EU, 2013).

Table I.3 encompasses the main concepts that were associated with the definition of land use in the reviewed literature.

LAND USE	*Author, year*	*Set of human actions undertaken in a certain type of land cover (also for social / cultural / economic purposes)*	*Geographical database for sustainable spatial planning / for analysis of economic and environmental impacts*	*Threat to biodiversity / influence on climate (if intensive-non-sustainable land use)*	*Policies to protect soil resources*	*= land cover*	*≠ land cover*
GLOBAL LEVEL	ESRI, n.d.	•					
	USEPA, 2017	•					•
	Pachauri et al., 2014	•					•
	(FAO, 1997)	•	•				•
EUROPEAN LEVEL	EEA, 2019	•	•	•			
	EU, 2013			•			
	EC & DGE, 2012a	•	•	•			
	EC, 2012					•	
	(EC, 2011a)					•	
	EC, 2011b	•					
	Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the Assessment and Management of Flood Risks, 2007	•					
	EEA, 2004	•					•
	EC, 2002				•		
ITALIAN LEVEL	ISPRA, n.d.		•				
	ISPRA, 2021	•	•				•
	Consumo Di Suolo, Dinamiche Territoriali e Servizi Ecosistemici, 2021	•	•				•
LITERATURE	Vargas-Hernández & Orozco-Quijano, 2022	•	•				
	Mohanty et al., 2021	•					
	Henriques, 2021	•					
	Rodrigues Tomás et al., 2021	•					
	Santos et al., 2021	•					·
	Vargas-Hernández & Danish, 2021	•	•				
	Horta et al., 2020	•					

LAND USE	Author, year	Set of human actions undertaken in a certain type of land cover (also for social / cultural / economic purposes)	Geographical database for sustainable spatial planning / for analysis of economic and environmental impacts	Threat to biodiversity / influence on climate (if intensive-non-sustainable land use)	Policies to protect soil resources	= land cover	≠ land cover
	Jember, 2019	•					
	Meyfroidt et al., 2018	•					
	Gharbi et al., 2017	•					
	Munafò & Tombolini, 2014	•					•
	C. Park, 2007	•				•	
	Choudhury & Jansen, 1998	•					•
	Dickinson & Shaw, 1977	•	•				
	Guttenberg, 1959		•				

Table I.3 | Literature review of the definitions concerning the concept of ‘land use’. Source: result of a joint collaboration between the author and Marianna Ceci.

1.1.2 European and Italian trends

In Europe, large areas of territory are consumed every day (EC & DGE, 2012a). The following paragraphs address the roots of the issue and provide an overview on European and Italian trends.

The roots of the issue

The origins of the current and increasing soil consumption rates can be traced back to a process that started in the 19th century. Between the 19th and 20th centuries, city walls were demolished in European and Italian cities. This led to overcome the traditional city conception, which had thus far reflected a compact entity, enclosed in a well-defined perimeter. The demolition of the city walls opened the field to the urban expansion into the rural areas, and thus to the loss of defined rural-urban limits. World War II can be marked as the acknowledgement of both the end of the traditional urban development patterns, and the need (and therefore the existence) of instruments and actors that are responsible of urban planning (Zazzi, 2019). Furthermore, the urbanisation phenomenon was accompanied by a parallel dynamic, namely the transition of the population from agricultural to urban areas (*urbanesimo* in Italian). The population, attracted by the opportunities offered by the city, contributed to the development of the 20th century city ‘out of the urban walls’. This led to the growth of the so-called ‘peripheries’ in the outskirts of the city, acknowledged to represent the loss of the traditional urban identity and development patterns. Following this process, the rural fringes of the city change shape and fragment into generally independent, low-density, discontinuous and mono-functional areas, favoured by the emergence of new transportation means such as motorised systems and a new conception of travel distances and times. Peripheries -

governed by cost-effectiveness mechanisms that involve their localisation and relationship - consist of an extensive succession of residential, commercial and industrial buildings, infrastructure and 'urban voids'. 'Urban sprawl' is the term that has been used to refer to this low-density and land-consuming urban expansion, and has been identified as a significant cause of soil sealing in suburban areas (Zazzi, 2019; EC & DGE, 2012b, 2012a; Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023).

While the growing urbanisation entails economic and social benefits such as new industrial and commercial hubs and less crowded living (for some), it encompasses also consequences. These include the loss of ecosystem services and functions, as well as the traditional identity and characteristics of the rural-urban territory, motivated by soil sealing and consumption.

European trends

Data show that, between 2012 and 2018[3], the European net land take amounted to 450 km^2 per year. In general, a decrease of croplands, pastures and forests in favour of urban and commuting areas was observed. Data from the European Environmental Agency show that, in 2006, 1.4% of the total area covered by the EEA-39 countries was sealed. In 2015 this value increased to 1.5%. An increase in the percentage of soil sealing when comparing the years 2006, 2009, 2012 and 2015[4] can be observed in almost all the EEA-39 countries (Table I.4). However, this trend and its peculiarities vary depending on the social, cultural, environmental and economic circumstances of the Member states, controlled by factors such as the dominant land use and land use history, the population and its associated dynamics, the physical characteristics of the country and the economic dynamics (EEA, 2021, 2023b).

Country	***Percentage sealing in 2006***	***Percentage sealing in 2009***	***Percentage sealing in 2012***	***Percentage sealing in 2015***	***Change (+/-)***
Low sealed area (<1%)					
Iceland	0.06	0.06	0.06	0.07	+
Norway	0.22	0.23	0.23	0.24	+
Latvia	0.37	0.37	0.38	0.38	+
Sweden	0.37	0.38	0.38	0.38	+
Finland	0.4	0.4	0.41	0.41	+
Estonia	0.41	0.42	0.42	0.43	+
Montenegro	0.47	0.47	0.47	0.47	
Turkey	0.57	0.58	0.6	0.64	+
Albania	0.57	0.58	0.6	0.61	+
North Macedonia	0.59	0.6	0.62	0.63	+
Bosnia and Herzegovina	0.59	0.6	0.61	0.62	+
Lithuania	0.73	0.74	0.75	0.76	+
Romania	0.82	0.83	0.85	0.87	+

[3] The EEA currently calculates the land take indicator with data from the Urban Atlas dataset of the Copernicus Land Monitoring Service (for 2012 and 2018), monitoring changes from agriculture, forest and semi-natural/natural land, wetlands or water to urban areas (EEA, 2023b).
[4] Data are based on the 'Imperviousness density 2009-2012' aggregated to 10 km grid cells and the 'Copernicus aggregated Imperviousness change information 2006-2015' provided by the European Environmental Agency.

Country	Percentage sealing in 2006	Percentage sealing in 2009	Percentage sealing in 2012	Percentage sealing in 2015	Change (+/-)
Bulgaria	0.85	0.86	0.88	0.89	+
Kosovo	0.92	0.93	0.96	1.04	+
Greece	0.93	0.94	0.96	0.97	+
Medium sealed area (>1% and <3%)					
Ireland	0.99	1.01	1.02	1.03	+
Serbia	1.01	1.01	1.02	1.04	+
Spain	1.15	1.2	1.22	1.23	+
Croatia	1.19	1.21	1.23	1.24	+
Poland	1.33	1.35	1.4	1.44	+
Slovakia	1.42	1.45	1.49	1.51	+
Hungary	1.43	1.45	1.48	1.5	+
Slovenia	1.62	1.66	1.68	1.68	+
Austria	1.72	1.75	1.77	1.78	+
Cyprus	1.81	1.87	1.95	2.06	+
Portugal	2.03	2.07	2.1	2.12	+
France	2.09	2.14	2.17	2.19	+
Czechia	2.31	2.35	2.38	2.39	+
Italy	2.66	2.7	2.73	2.74	+
Switzerland	2.69	2.71	2.78	2.79	+
Denmark	2.77	2.81	2.85	2.86	+
High sealed area (>3%)					
United Kingdom	3.04	3.05	3.08	3.1	+
Luxembourg	4.04	4.17	4.24	4.26	+
Germany	4.18	4.23	4.29	4.31	+
Liechtenstein	4.43	4.44	4.5	4.51	+
Belgium	5.88	5.93	6.01	6.04	+
Netherlands	7.09	7.19	7.33	7.35	+
Malta	16.02	16.04	16.13	16.15	+

Table I.4 | Percentage soil sealing by country. Source: own elaboration based on data retrieved from the EEA (2020).

The average annual change in soil sealing between 2006 and 2015 shows similar trends, while highlighting the hotspots where it took place[5] (Figure I.3).

[5] Data are based on the 'Copernicus Land Monitoring Service - High Resolution Layers – Imperviousness' provided by the European Union and on the 'Copernicus 10 km grid' provided by the European Environmental Agency.

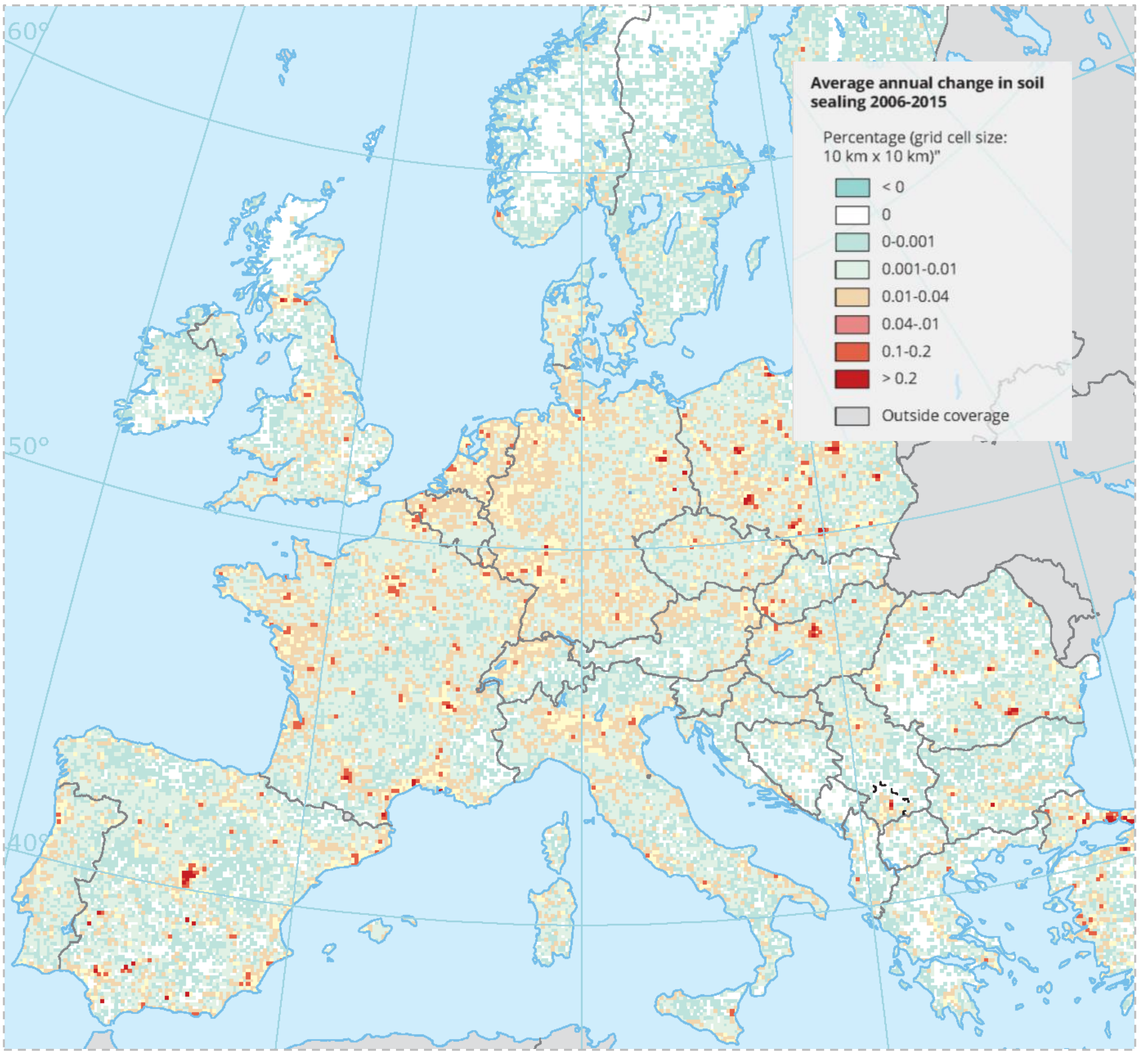

Figure I.3 | Average annual change in soil sealing 2006-2015. Source: EEA, n.d..

Italian trends

In the Italian context, site- and context-specific policies and dynamics were the cause of increasing soil consumption trends and allowed transformations that favoured the 'property income' (*rendita* in Italian) mechanism and depended on the optimisation of the cost-effectiveness of the interventions location (Zazzi, 2019). The Italian context is traditionally characterised by the contrast between the public and private interest; the relevance of banks and enterprises economic interests (represented for instance by the importance of the Italian cement industry); the principle of free economic initiative that has led to the attraction of money of questionable origin into the building sector; and by the already mentioned 'property income' (*rendita* in Italian) mechanism which is closely connected to building speculation (Zanon, 2008).

The Italian urbanisation phenomenon peaked from the 1950s to the 1970s – the years of the so-called 'economic boom' - and slowed down in the following decades, regaining relevance in the 2000s. This emphasised the need for a new conception of the urban soil, that needs to address environmental issues aiming for a 'slow decrease' and thus an inversion of the consumption trends (Zazzi, 2019), especially where the observed increasing soil consumption of the recent years is not reflected by an increase in the population (Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023).

Despite their relevance, soil consumption trends have been monitored only from the recent decades. The first report on soil consumption was published in 2009 by the National Observatory on Soil Consumption (*Osservatorio Nazionale sui Consumi di Suolo*), promoted by the Polytechnic of Milan, the National Institute of Urban Planning (*Istituto Nazionale di Urbanistica*) and by the environmental organisation Legambiente. Since then, the Institute for Environmental Protection and Research (*Istituto Superiore per la Protezione e la Ricerca Ambientale*) has curated the annual reports on the Italian soil consumption, based on data from National System for Environmental Protection (*Sistema Nazionale Protezione Ambiente*).

According to the last 'Report on Soil consumption, territorial dynamics and ecosystem services' (*Consumo di suolo, dinamiche territoriali e servizi ecosistemici*), soil consumption shows increasing values despite the decreasing demographic trends (Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023). The report emphasises that, between 2021 and 2022, 76.8 km^2 (were covered by artificial surfaces (i.e., more than 20 hectares per day). These values represent the highest values of the last 11 years, during which the daily soil consumption never overcame 20 hectares. Furthermore, the net land take equals 19.4 hectares per day and represents the highest value from 2012. The peculiar orography of the Italian peninsula exacerbates the meaning of these trends: the Italian 'usable soil'[6] (*suolo utile* in Italian) corresponds to only 59.9% of the total territory. As reflected also by Figure I.4, these areas generally correspond to lowlands, such as the Northern Padana Valley and the coastal plains, which are characterised by both a high soil quality and urban and infrastructure expansion pressure.

In this context, the concept of 'Po Valley Megalopolis' (*Megalopoli Padana*) acquires relevance, defined by Turri (2001) as the urbanised system that characterises the Padana Valley (Figure I.5). In the *Megalopoli Padana* a dual linear city extends from its western vertex in Piedmont to the Adriatic sea, at the feet of both the Apennines and of the Alps. These linear urbanised areas are characterised by diffuse urbanisation where natural and agricultural areas represent the interstices of the built-up space. This 'diffuse city' corresponds also to the area where the Italian municipal soil consumption percentages are higher (Figure I.4).

[6] Usable soil represents the Italian territory, excluding areas with a slope higher than 50%, rivers, wetlands, protected areas and areas which present a high hydrogeological hazard (Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023).

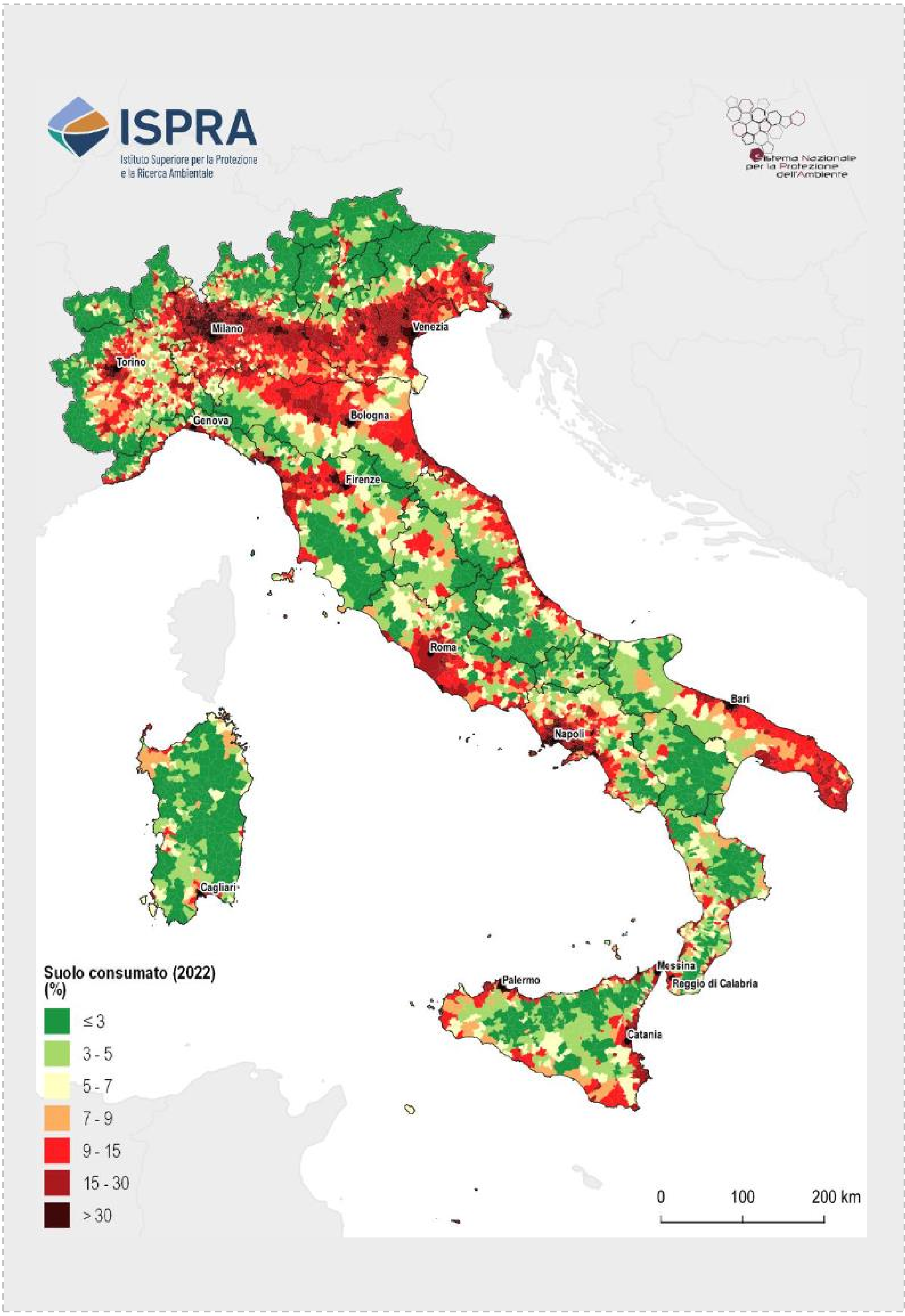

Figure I.4 | Soil consumption in the Italian peninsula at the municipal level. Source: Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023..

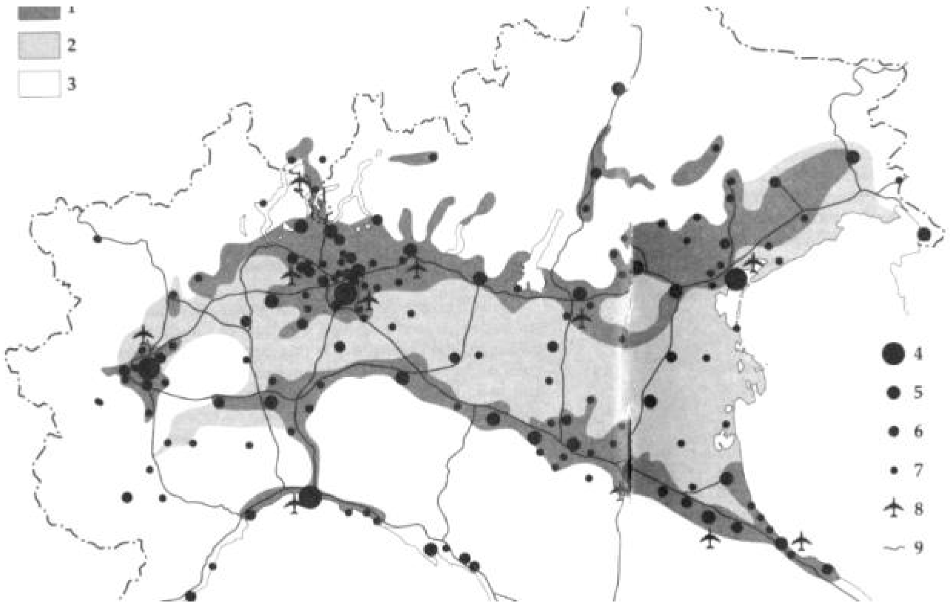

Figure I.5 | The 'Po Valley Megalopolis' (*Megalopoli Padana*). Source: Turri, 2001.

1.1.3 Effects on the ecosystem services and functions

The increasing soil sealing affects the hydrological cycle and the microclimate, significantly altering the ecological performance of urban areas compared to the natural environment. Artificial impervious surfaces affect the water balance and regulation at both the local and watershed scale, hampering the infiltration and evapotranspiration of the precipitation into the soil and resulting in higher surface runoff (Figure I.6). This increases streamflow volumes and stream peak flows rates, causing – when these are not adequately managed – floods and an increased amount of sediments and pollution delivered to the receptor bodies. Similarly, the substitution of natural areas with artificial surfaces reduces the ability of the urban environment to regulate the microclimate through the cooling effect of water evaporation, resulting in adverse effects such as, for instance, higher temperatures and discomfort for the users, i.e., heat waves and the urban heat island effect. Furthermore, the reduced infiltration decreases the amount of water that recharges groundwater (i.a.,EC & DGE, 2012b; Gerundo, 2018; Gibelli et al., 2015).

These environmental, social and economic issues deeply affect the overall quality of life of the urban population. As an example, the lack of green areas has been recognised to be closely tied to the quality of life, especially for older people (Kemperman & Timmermans, 2014).

The role of climate change

Urbanisation constitutes also one of the main causes of anthropogenic climate change, as cities have been recognised as one of the main producers of greenhouse gases emissions (World Bank, 2010). With varying impacts all over the world, climate change results in the exacerbation of extreme weather events on the European and Italian territory (European Parliament, 2024). Among the observed and predicted climate hazards, heat waves, heavy precipitations and floods represent acute hazards that are significantly increasing (EEA, 2023a). Furthermore, it was noted at the beginning of Chapter §1 that events such as storms, heatwaves and floods have been identified as the cause of between 85,000 and 145,000 human fatalities across Europe over the past 40 years, with an estimated economic loss related to climate and weather corresponding to half a trillion euros (EEA, 2024). Furthermore, with 74.8% of the European population and 82.9% of the Italian population living in cities, towns or suburbs (EC, 2022a), urban areas are characterised by the presence of physical features and environmental, social and economic dynamics that are greatly impacted by the adverse effects entailed by soil consumption and climate change (EEA, 2012). For their peculiarity of being both the cause and a critical place for the manifestation of the adverse effects caused by climate change, cities and urbanised lands should be considered the hotspots for the fight against climate change and related phenomena, which the actors of the urban transformation processes need to acknowledge contextually to urbanisation and soil consumption (EC & DGE, 2012b) by employing climate change adaptation and mitigation strategies[7]. In the framework of climate change adaptation, the preservation and restoration of the soil ecosystem services and functions appears of utmost importance to avoid the environmental and socio-economic impacts entailed by climate change and the loss of this valuable resource.

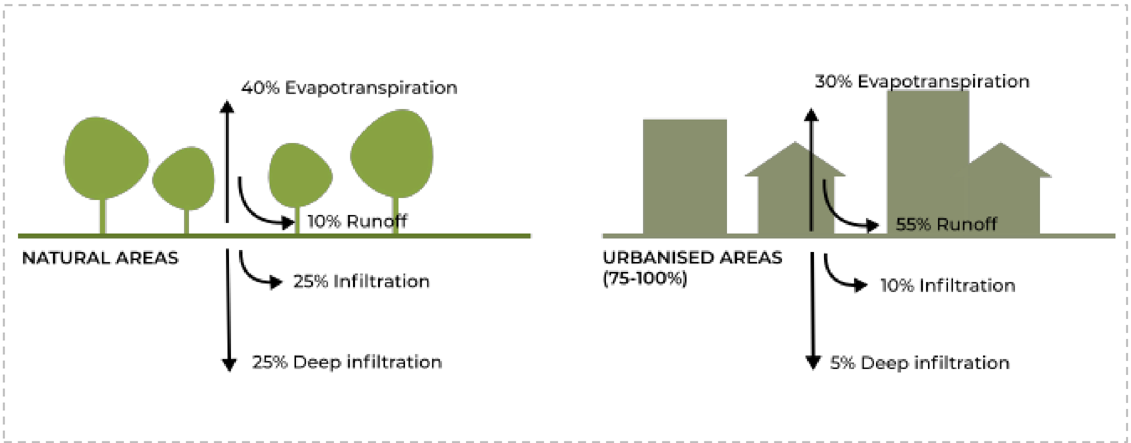

Figure I.6 | Quantitative representation of the main water cycle components in the natural environment and urban areas. Source: adaption by the author based on Gibelli, G. et al. (2015).

1.1.4 Legislative and strategic countermeasures

At the European level and in accordance with the Agenda 2030 goals (United Nations, 2015), several tools have been proposed address the increasing soil consumption. Starting from 1972, the 'European Soil Charter' was approved by the Council of Europe (Council Of Europe, 1973). This document recognised the value of the resource soil, emphasising its relationship with human activities.

The EU Soil Strategy for 2030

Half a century after the approval of the 'European Soil Charter', the 'EU Soil Strategy for 2030'[8] established a framework of concrete measures to protect and restore soil - in the

[7] See Chapter §2 for the definitions of climate change mitigation and adaptation.
[8] The Strategy is one of the outcomes of the EU Biodiversity Strategy for 2030, which refers to land take as one of the main threats to biodiversity (EC, 2020).

framework of achieving the goals of the European Green Deal (EC, 2021). Similarly to what was envisaged in 2011 by the documents ‘Overview of best practices for limiting soil sealing or mitigating its effects’ (Jobstmann et al., 2011a) and ‘Guidelines on best practices to limit, mitigate or compensate soil sealing’ (EC & DGE, 2012a), the ‘EU Soil Strategy for 2030’ sets goals for both 2030 and 2050 (an example is the target of ‘no net land take’ by 2050), with the aim of achieving good health for all the ecosystems connected to soil by 2050. Among the actions that address soil consumption and sealing, the ‘EU Soil Strategy for 2030’ recognises the need of setting national, regional and local goals to reduce their net land take and defines a precise order of priorities to address the established processes that, at the local scale, favour soil consumption and sealing. The proposed hierarchy, meant to be implemented in the municipal urban planning instruments, consists of four points:

- avoid land consumption and sealing if it is not possible to avoid land consumption and sealing;
- reuse previously consumed and sealed land;
- or use already degraded areas;
- finally, only for unavoidable interventions, apply mitigation measures to minimise the loss of ecosystem services and compensate for them through actions such as the renaturalisation of an area with the same ecological quality and function.

As envisaged by the ‘EU Soil Strategy for 2030’, in July 2023 the European Commission has adopted the ‘Draft Directive on Soil Monitoring and Resilience’, which aims at regulating the monitoring and evaluation of the European soil quality. The Directive sets three main goals: i) the creation of a coherent soil monitoring system; ii) the adoption of sustainable soil management practices; iii) the management of contaminated sites. It also foresees to put in action binding limits in the evaluation phase of the Directive (EC, 2023).

The steps that lead to the EU Soil Strategy for 2030

After the publication of the ‘European Soil Charter’ in 1973, the steps that led to the adoption of the ‘Draft Directive on Soil Monitoring and Resilience’ are represented by various documents, such as the communications ‘Towards a Thematic Strategy for Soil Protection’ (EC, 2002) and ‘Thematic Strategy for Soil Protection’ (EC, 2006c). The latter was followed by the ‘Proposal for a directive establishing a framework for the protection of soil and amending Directive 2004/35/EC’, with the aim of resulting in the approval of a directive (EC, 2006a), but did not succeed due to the opposition of some Member States (Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023). In this framework, the European Commission proposed a further instrument, the ‘Nature Restoration Law’ which goal is to ensure no net loss of urban green spaces, achieve a 5% increase by 2050, and establish a minimum of 10% tree canopy cover in all European urban areas (EC, 2022b).

Despite these promising steps, the European and Italian soil consumption trends appear to continue to follow an opposite direction. This may be motivated by the succession of strategies and by the lack (at least thus far [2024][9]) of proper directives able to co-ordinately orient the Member States urban planning scenarios towards effectively stopping soil consumption and protecting of this precious resource (Maiellaro & Costantino, 2023; Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023).

[9] The use of ‘[2024]’ explicitly establishes the temporal context of the current research.

The Italian framework

In Italy, the increasing soil consumption trend finds further motivation in various dynamics that have their roots in legislation. First of all, the Italian legislative system consists of a complex and articulated framework that includes several urban planning laws and regulations - starting from those laws that are considered at the basis of the Italian urban planning: Law No. 1089/1939, the Law on the 'Protection of things of artistic or historical interest' (*Tutela delle cose di interesse artistico o storico*), Law No. 1497/1939, the Law on the 'Protection of natural beauty' (*Protezione delle bellezze naturali*) and Law No. 1150/1942, the 'National urban planning law' (*Legge urbanistica nazionale*).

Despite the Law No. 1150/1942 constituting a first attempt to regulate the building processes by introducing the compulsoriness of general urban plans (*piani regolatori generali*) for municipalities, the Italian regulation, instead of coordinating the processes of the local administrations, has historically left space to phenomena such as speculation and building violations. These phenomena have been observed since the reconstruction years after World War II and the 'economic boom' (Zanon, 2008). Furthermore, general urban plans are – by nature – rigid instruments that can be modified only by the so called 'variants' (*varianti* in Italian). Variants require specific procedures to be put in action, thus increasing the difficulty of adapting general urban plans to the changing context. These structural matters are accompanied by the socio-economic issues and dynamics that have historically characterised the Italian building sector, as reported (see Subsection §1.1.1).

Since the 1960s, the necessity of reforming the Italian urban planning system was acknowledged. On this basis, draft laws were proposed, without success in this regard. On the contrary, the construction activity flourished in those years (Zanon, 2008). The hydrogeological disasters which were observed in Italy in 1966 led to the approval of the Law No. 765/1967, Law 'Ponte', which aimed at stopping the fervid construction activity of those years, also with the establishment of the 'urban planning standards' (*standard urbanistici* in Italian) through the Ministerial Decree No. 1444/1968. However, due to a one-year moratorium, Law 'Ponte' had, once again, opposite effects to those intended (Zanon, 2008). In accordance with the Articles No. 115 and 177 of the Italian Constitution, in 1972 the administrative functions regarding urban planning were transferred to the Italian regions, while the coordination and guidance functions remained at the state level. Law No. 10/1977, the Law 'Bucalossi', aimed to regulate the buildability (*edificabilità* in Italian) of land, but resulted - once again - in opposite effects due to the building charges (*contributo di costruzione*) that it introduced. The public administration was recognised to foster the building activity, in particular after the introduction of the 'Single text of the laws and regulations on building' (*Testo unico delle disposizioni legislative e regolamentari in materia edilizia*) in 2001, which shifted the use of these construction charges from urbanisation works (*oneri di urbanizzazione*) to a municipal budget item.

Figure I.7, elaborated by the market research centre CRESME, shows the construction cycles that characterised the Italian context since the 1950s.

However, a shift started to be observed in 1985 with the Law No. 431/1985, Law 'Galasso', which revisited environmental matters. This Law led to the current Legislative Decree No. 42/2004, the 'Cultural heritage and landscape code' (*Codice dei beni culturali e del paesaggio),* which implements the 'European Landscape Convention' into the Italian legislation.

As of this day, the lack of national regulations on soil consumption and urban regeneration (see also Section §4.2) results in the lack of a regional, provincial and municipal coordination that may partially explain the phenomena described in this chapter. Various draft laws have attempted to address this absence, highlighting the necessity of a national instrument that coordinates the public administration. Examples are the Senate Act No. 3601/XVI (2012), the Draft Law ‘Enhancing agricultural areas and limiting soil consumption’ (*Valorizzazione delle aree agricole e contenimento del consumo del suolo*); the Chamber Act No. 2039/XVII (2016), the Draft Law ‘Containment of soil consumption and reuse of built-up land’ (*Contenimento del consumo del suolo e riuso del suolo edificato*); the Senate Act No. 164/XVIII (2018), the ‘Provisions for stopping land consumption, reuse of built-up land and landscape protection’ (*Disposizioni per l’arresto del consumo di suolo, di riuso del suolo edificato e per la tutela del paesaggio*); and the Senate Act No. 1028/XIX (2024), the Draft Law ‘Urban regeneration and sustainable land use’ (*Rigenerazione urbana e uso sostenibile del suolo*).

In this framework, also local initiatives such as regional laws have, with varying levels of effort, addressed these issues. The Regional urban planning law of the Emilia-Romagna Region, Regional Law No. 24/2017 ‘Regional discipline on the protection and use of the territory’ (*Disciplina regionale sulla tutela e l’uso del territorio*), represents an interesting case, as - in order to address the increasing soil consumption - requires municipalities to equip themselves within a certain and short timeframe with a planning office and a new urban plan. This is represented by the general urban plan (*piano urbanistico generale*) which replaces the old municipal structural plan (*piano strutturale comunale*), urban planning and building regulations (*regolamento urbanistico edilizio*) and operational municipal plan (*piano operativo comunale*). The general urban plan must:

- be oriented towards the reuse and regeneration of the urbanised territory;
- establish a strategy for the qualification of the public areas of the city;
- limit and discourage the possibility of new expanding settlements;
- simplify plan contents and delegate the definition of detailed urban discipline to the implementation tools (*strumenti attuativi*).

Specifically, it envisions measures for environmental compensation and ecological and environmental urban equipment, which cannot be monetised and may not be separated from the urbanisation charges. Furthermore, in the perspective of limiting the expansion of the urban areas, it promotes reuse and regeneration interventions, thus disincentivising the expansion ones. It also limits the planned urban expansion to a maximum of 3% of the urbanised area by 2050.

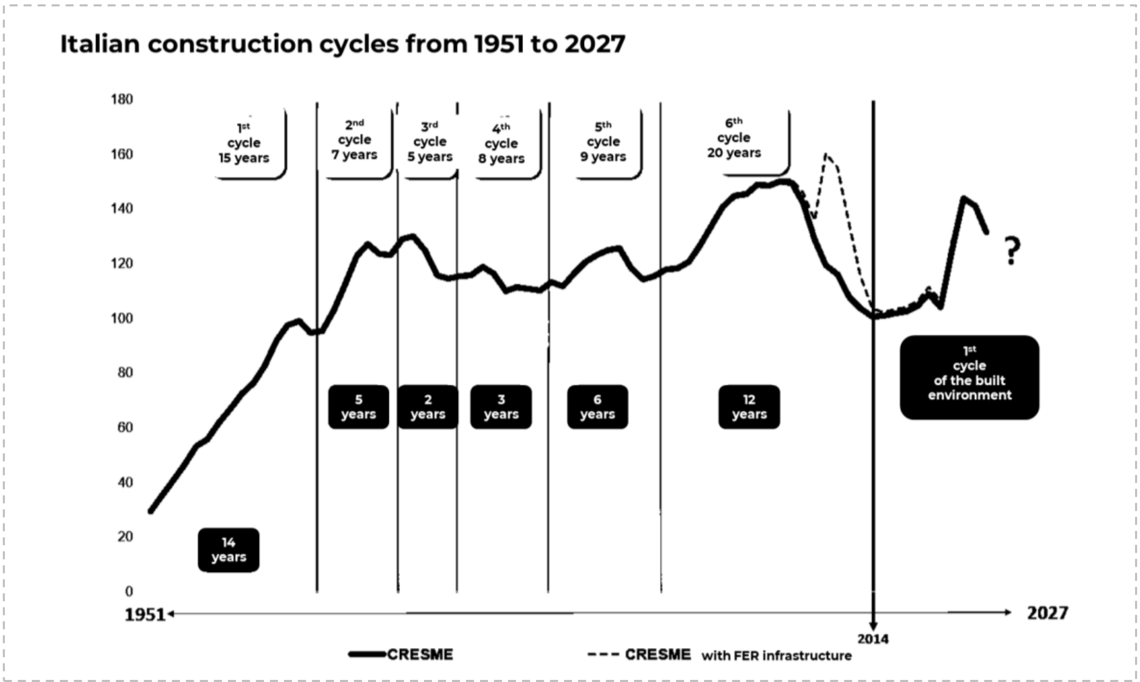

Figure I.7 | Italian construction cycles. Source: elaboration and translation based on CRESME (2024).

1.2 The urban pluvial flood risk

Floods are among the most frequent and destructive natural disasters in Europe. Climate change and the anthropogenic actions such as land take are exacerbating this issue, which is expected to increase further in the next decades with great environmental, social and economic damages. The Intergovernmental Panel on Climate Change defined risk as the "potential for adverse consequences for human or ecological systems [...]" (IPCC, 2023). In the context of climate change, risks can arise from both the potential impacts of climate change as well as from human responses to it. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing; economic, social and cultural assets and investments; infrastructure, services (including ecosystem services), ecosystems and species.

The definition and understanding of risk vary among literature. As an example, a first viewpoint understands it as the result of the interaction of the hazard, exposure, and vulnerability, thus as the adverse effects of a potentially damaging event on vulnerable and/or exposed population and assets. However, as highlighted by the Intergovernmental Panel on Climate Change (2012), a second school of thought defines risk a decision (by an individual or group) to act in a way that results in harmful effects (Cardona et al., 2012).

This thesis puts its roots in theoretical framework outlined in 2018 by the Intergovernmental Panel on Climate Change that identifies hazard, exposure and vulnerability as the factors which dynamic interaction results in a risk (IPCC, 2018). According to the Intergovernmental Panel on Climate Change, the risk components can be defined as follows:

- **hazard** is intended as the potential occurrence of an event or trend that may cause damages or loss to live beings, assets, as well as to environmental functions, service and resources;

- **exposure** represents the presence of living being, assets, as well as environmental functions, services and resources that may be adversely affected by the hazard;
- lastly, **vulnerability** is the propensity or predisposition of being adversely affected, and encompasses a variety of aspects such as the sensitivity, susceptibility, and inability to cope or adapt.

Following this reasoning, the **urban pluvial flood risk**, i.e., the risk posed by precipitations to urban areas, is related to the occurrence of meteorological events that may cause floods resulting in adverse effect to living being, assets, environmental functions, services and resources present in the urban area, due to their propensity or predisposition of being adversely affected.

1.2.1 The European and Italian legislative framework

This subsection provides an overview on the European and Italian legislative instruments that deal with assessing and managing the flood risk.

Directive 2007/60/EC on the assessment and management of flood risks

In Europe, the legislative framework concerning the flood risk is represented by the 'Directive 2007/60/EC on the assessment and management of flood risks', which directs the coordination and reduction of the flood risk at the river basin level. The document recognises land take as a contributing factor of the increase in the likelihood and adverse impacts of flood events, and it directly refers to climate change and its effects when it deals with the topic of the occurrence of floods. It further considers a differentiation on the territory of the flood types (river floods, flash floods, urban floods and floods from the sea in coastal areas). The Directive 2007/60/EC is closely connected with the Directive 2000/60/CE 'Water Framework Directive' for what regards, for instance, water quality standards and public participation.

In practical terms, the Law requires European Union countries to

i) identify the areas where significant floods may occur;
ii) map their extent, the population and assets as risk;
iii) take measures to reduce the risk.

Furthermore, the Directive 2007/60/CE guides the design and update of flood risk management plans (*piani di gestione del rischio di alluvioni* in Italian). The flood risk management plan must include

i) the objectives for managing flood risk and reducing its adverse effects;
ii) the measures chosen by the member states to manage flood risk (prevention, protection, preparation, reconstruction and post-event evaluation).

These plans may also promote sustainable land use practices and for improving land retention.

The law set a first update and review of the flood risk management plans in 2015, and a second in 2021. Since the second review and update in 2021, the flood risk management plans need to account for the impacts of climate change on the occurrence of floods as well. After the first two sets of reviews and updates, the Directive envisions this process to take place every six years.

The Italian flood risk management plans (piani di gestione del rischio di alluvioni)

In Italy, the Legislative Decree No. 49/2010, the 'Implementation of Directive 2007/60/EC on the assessment and management of flood risks' (*Attuazione della direttiva 2007/60/CE relativa alla valutazione e alla gestione dei rischi di alluvioni*) received the Directive 2007/60/EC, in compliance with the Legislative Decree No. 152/2006, the 'Environmental regulations' (*Norme in materia ambientale*). In Italy, flood risk management plans (*piani di gestione del rischio di alluvioni*) refer to seven river basins (or hydrographic districts) that include one or more unit of managements. The following table (Table I.5) encompasses the seven river basins and the considered flood risk origins that were considered in the respective flood risk management plans (fluvial, marine, pluvial or related to the drainage infrastructure). The Flood risk management plans of the Southern Apennines and of Sicily are the only ones that considered the risk related to precipitation in their analyses.

River basin (2021 update)	***Origin of the analysed risk***			
	Fluvial	***Marine***	***Pluvial***	***Drainage infrastructure***
Eastern Alps	•	•		
Po River	•	•		
Northern Apennines	•	•		
Central Apennines	•	•		
Southern Apennines	•	•	•	•
Sardinia	•	•		
Sicily	•		•	

Table I.5 | The Italian seven river basins and the origins of the flood risk analysed by their Flood Risk Management Plans. Source: elaboration based on data from Lastoria et al. (2021).

In Italy, Regions and Autonomous Provinces, as well as the River basin authorities are the responsible entities for putting in action the flood risk management plans, which can be considered strategic instruments and do not include technical implementation standards (*norme tecniche di attuazione*). The flood risk management plans are overarching tools that entail the revision of the subordinated urban planning instruments, such as the provincial coordination territorial plans (*piani territoriali di coordinamento provinciale*). At the river basin level, Regions have sometimes equipped themselves with additional instruments. As an example, the hydrogeological structure plans (*piani di assetto idrogeologico*) of the Emilia-Romagna Region (and their variants) are tools that work synergically with the flood risk management plans and include components of the hydrogeological risk that are not encompassed in the flood risk management plans. Examples are the hydrogeological instability and the technical implementation standards.

Areas where significant floods may occur

In compliance with the Directive 2007/60/CE and the Legislative Decree No. 49/2010, the Institute for environmental protection and research (*Istituto Superiore per la Protezione e la Ricerca Ambientale*) produced a mosaicking of the maps of the areas where significant floods may occur for the three scenarios:

i) high probability hazard, for return periods between 20 and 50 years;
ii) medium probability hazard, for return periods between 100 and 200 years;
iii) low probability hazard, for return periods higher than 200 years.

In Italy, 5.4% (16,223 km^2) of the territory is classified as high probability hazard areas, 10.0% (30,195.6 km^2) as medium probability hazard areas, and 14.0% (42,375.7 km^2) as low probability hazard areas (Lastoria et al., 2021; Trigila et al., 2021). In accordance with the Directive 2007/60/CE, the Italian hazard maps include information on i) the flood extent; ii) water depths or levels; iii) the flow velocity or relevant water flow (where appropriate). Table I.6 provides data for the Emilia-Romagna region.

Region	***Regional area (km^2)***	***Areas where significant floods may occur***					
		High probability hazard		***Medium probability hazard***		***Low probability hazard***	
		km^2	***%***	***km^2***	***%***	***km^2***	***%***
Emilia-Romagna	22445	2,599.6	11.6	10,235.4	45.6	10,617.6	47.3

Table I.6 | Areas where significant floods may occur in the Emilia-Romagna region. Source: elaboration based on data from Lastoria et al. (2021).

Furthermore, the Institute for environmental protection and research (*Istituto Superiore per la Protezione e la Ricerca Ambientale*) dealt with identifying flood risk indicators to identify the exposed assets to flood risk, again in accordance with both the Directive 2007/60/CE and the Legislative Decree No. 49/2010. Table I.7 encompasses the exposed assets identified by the two laws. The '2021 Report on the flood hazard conditions and associated risk indicators in Italy' of the Institute for environmental protection and research (*Istituto Superiore per la Protezione e la Ricerca Ambientale*) provided a mosaicking of the exposed assets, divided by population, cultural assets and pollution sources, for the municipal, provincial, regional and national level.

Exposed assets in the Directive 2007/60/CE	***Exposed assets in the Legislative Decree No. 49/2010***
Indicative number of inhabitants potentially affected	Indicative number of inhabitants potentially affected
Type of economic activity potentially affected	Distribution and type of the economic activities located in the area potentially affected
Installations [...] concerning pollution prevention and control which may cause accidental pollution in case of flooding and potentially affected protected areas [...]	Installations [...] concerning pollution prevention and control which may cause accidental pollution in case of flooding and potentially affected protected areas [...]
Other information	Infrastructure and strategic assets
	Environmental, historical and cultural assets located in the area potentially affected

Table I.7 | The exposed assets identified by the Directive 2007/60/CE and by the Legislative Decree No. 49/2010.

Local instruments that deal with the urban pluvial flood risk

Further analyses and considerations at the local level concerning the urban flood risk may be encompassed by municipal tools such as the civil protection plans (*piani di protezione civile*) and the municipal sanitary regulations (*regolamenti igienico sanitari*).

For instance, civil protection plans are instruments that encompass the operative processes needed to face any disaster that may occur in a given territory (Dipartimento della Protezione Civile, 2016). Based on a knowledge framework of the area, they must therefore consider its evolution and the expected scenarios. Civil protection plans are envisaged for the national, regional, provincial, over-municipal and municipal level. At the municipal level, they encompass the coordination of all the municipal administrative sectors, and are coordinated by, if present, the municipal civil protection services (*servizi di protezione civile comunali*). These plans are one of the municipal documents that take into account and receive the information of the overarching instruments concerning the urban flood risk in order to manage the response of organisations and individuals. Therefore, they may update the existing information about risk with more specific data, also obtained from field/practical experiences. The municipal sanitary regulations are another tool that, encompassed by the municipal regulations (*regolamenti edilizi*), may provide or include further regulations and/or specification regarding the urban pluvial flood risk management. They may, for instance, contain specifications for what concerns the urban drainage network.

1.2.2 Assessing the urban pluvial flood risk

Literature that focuses on assessing the urban flood risk has consequently dealt with the different causes of the urban flood risk - namely river floods; flash floods; urban floods; and floods from the sea - alone or in combination. Moreover, authors have sometimes considered these events with multi-risk approaches, including, for instance, the urban heat island risk.

In this framework, this thesis focuses on the urban pluvial flood risk (and its components) as well as on its assessment and mitigation. Assessing risk has a strategic relevance in disaster risk reduction and climate change adaptation, as it provides reliable data and information to reduce the adverse effects on the urban population and assets (Cardona et al., 2012).

The methods and instruments for flood risk assessment vary among literature and refer to different scales (from the national to the local one) and to different approaches (from the more technocratic indicator-based ones to those involving the population with, for instance, participatory processes). In this regard, the Intergovernmental Panel on Climate Change (2012) has underlined the importance of involving the population, especially in local risk assessments that may lack environmental and/or socio-economic data and a deep understanding of the underlying local dynamics between them (Cardona et al., 2012).

Among the various resources available for risk assessment, the International Standard 'ISO 14091' and 'ISO 14092' establish standards for different methodologies and outcomes of risk assessments, at both regional and local levels. Furthermore, European institutions provide extensive assortment data and information, also about the implemented approaches. As an example, the 'European Climate Adaptation Platform Climate-ADAPT' constitutes a partnership between the European Commission and the European Environmental Agency to help users to access a variety of data and information such as climate change related risk assessments. Independent resources have been published as well, such as the 'Vulnerability Sourcebook and the Risk Supplement to the Vulnerability Sourcebook' developed by the German Society for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*) and by the research centre Eurac Research, which provides concepts and guidelines for the standardisations of vulnerability assessments in accordance with the risk concept of the Intergovernmental Panel on Climate Change '5th Assessment Report' (GIZ & EURAC, 2017).

Li et al. (2023) have proposed a classification of the urban flood risk assessments methods which includes the 'historical disaster mathematical statistics' method; the 'multi-criteria analysis' method; the 'hydrological-hydraulic modelling' method and the 'geographical information systems and remote sensing technologies' method, emphasising also their respective limitations. For instance, the 'historical disaster mathematical statistics' method presents limitations due to the large amount of data required and its dependence on the accuracy of the historical records. Furthermore, it does not guarantee the accuracy of its results and it does not account for spatial changes. The 'multi-criteria analysis' method lacks universal applicability due to the extensiveness (and thus specificity) of the required data. The 'hydrological-hydraulic' method requires complex calculations and accurate data, thus lacking a universal applicability as well. The 'geographical information systems and remote sensing technologies' method also needs high data accuracy and entail difficulties in calculating the water depth.

In this framework, the following paragraphs include a non-exhaustive but representative review of urban pluvial flood risk assessments that were used in the context of urban planning[10]. The following table (Table I.8) summarises the author, the title of the reference publication and the scale (regional/urban) of each considered study.

Author, year	***Title***	***Scale***
Hu, 2016	Rainstorm flash flood risk assessment using genetic programming: a case study of risk zoning in Beijing	Urban scale
Elboshy et al., 2019	A framework for pluvial flood risk assessment in Alexandria considering the coping capacity	Urban/District scale
Marta et al., 2020	Past and future hydrogeological risk assessment under climate change conditions over urban settlements and infrastructure systems: the case of a sub-regional area of Piedmont, Italy	Subregional scale
Essenfelder et al., 2022	Probabilistic Assessment of Pluvial Flood Risk Across 20 European Cities: A Demonstrator of the Copernicus Disaster Risk Reduction Service for Pluvial Flood Risk in Urban Areas	Urban scale
Loli et al., 2022	Flood risk for urban mobility in Maputo, Mozambique: Regional-scale indexing based on earth observation and demographic data	Regional scale
Mabrouk & Haoying, 2023	Urban resilience assessment: A multicriteria approach for identifying urban flood-exposed risky districts using multiple-criteria decision-making tools (MCDM)	Urban/District scale
Sambo et al., 2023	Framework for multirisk climate scenarios across system receptors with application to the Metropolitan City of Venice	Metropolitan city scale
De Risi et al., 2020	From flood risk mapping toward reducing vulnerability: the case of Addis Ababa	Urban scale

[10] The relevant studies were identified through a literature review that was conducted on Scopus using the following string: *TITLE-ABS-KEY (urban OR city AND hydraulic OR flood AND risk AND assessment OR evaluation AND pluvial* OR rain* AND plan*) AND (LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "EART") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MULT"))*. The aim was to limit the results to researchers that focused on assessing the flood risk in urban areas, more specifically on the flood risk posed by precipitation. The subject areas were limited to environmental sciences, engineering, earth sciences, social sciences, decisional sciences and multidisciplinary subjects. The 473 results were filtered during multiple phases and led to obtain a list of 19 results which were relevant for this thesis, thus those publications which provide a method or an approach of urban pluvial flood risk assessment in urban planning.

Author, year	*Title*	*Scale*
Sperotto et al., 2016	A multi-disciplinary approach to evaluate pluvial floods risk under changing climate: The case study of the municipality of Venice (Italy)	Metropolitan city scale
Bibi et al., 2018	Flood risk assessment of river Kabul and SWAT catchment area: District Charsadda, Pakistan.	Regional scale
Othmer et al., 2020	A methodological approach to municipal pluvial flood risk assessment based on a small city case study	Urban scale
Weerasinghe et al., 2018	Qualitative Flood Risk assessment for the Western Province of Sri Lanka	Regional scale
K. Park et al., 2021	Risk type analysis of building on urban flood damage	Urban scale
Kassem et al., 2022	Flash Flood Risk Assessment for Girne Region, Northern Cyprus	Regional scale
Rincón et al., 2022	Stochastic Flood Risk Assessment under Climate Change Scenarios for Toronto, Canada Using CAPRA	Urban/District scale
Kim et al., 2022	Determining the Risk Level of Heavy Rain Damage by Region in South Korea	National/Regional scale
Ceragene et al., 2023	A Risk-Based Approach for the Analysis of Flood Impact in Villahermosa (Tabasco, Mexico)	Urban scale
Li et al., 2023	Urban flood risk assessment based on DBSCAN and K-means clustering algorithm	Urban/Regional scale
Rivosecchi & Singh, 2023	Small Island City Flood Risk Assessment: The Case of Kingston, Jamaica	Urban scale

Table I.8 | The 19 publications that were analysed in the literature review on urban (pluvial) flood risk assessment methods.

Hu (2016) employed an algorithm to zone the flash flood risk in Beijing, referencing the formula $Risk = Probability \cdot Vulnerability$ and its specification $Risk = Probability \cdot Sensitivity \cdot Exposure$. The researcher identified a rainstorm hazard index value and its predictors, namely physical vulnerability, terrain factor, impervious surface area and population density.

Elboshy et al. (2019) proposed a framework for assessing the urban pluvial flood risk encompassing a i) pluvial flood inundation model; ii) building and social vulnerabilities; and iii) coping capacity indicators. Firstly, the authors developed a flood hazard model consisting of flood exposure maps that identify the hazard level per hour for each block during the disaster event. Furthermore, the researchers assessed the social and building vulnerability based on various indicators. Finally, they calculated a risk index with reference to the formula $Risk = Hazard \cdot Vulnerability \cdot Lack\ of\ coping\ capacity$, which was then attributed to each city block. The lack of coping capacity was defined as the available resources and abilities to face adverse conditions.

Ellena et al. (2020) developed a methodology to assess the hydrogeological risk following the $Risk = Hazard \cdot Exposure \cdot Vulnerability$ equation and preparing, for each of these factors, a set of variables. Following the Intergovernmental Panel on Climate Change '5th Assessment Report' concept, they considered vulnerability as a combination of sensitivity and adaptive capacity indicators. After evaluating each factor, the authors determined a risk index.

Essenfelder et al. (2022) presented a methodology for assessing the pluvial flood hazard and risk in urban areas based on i) the computation of intensity-frequency curves (that allow to obtain the precipitation depth); ii) the modelling of flood using the raster data of an urban area; and iii) the estimation of tangible damages to buildings through depth-damage functions. The depth-damage functions allow to define the vulnerability of buildings (which were considered the exposed assets) based on the hazard (i.e., the flood depth), and, taking into account the reconstruction cost, allow to define risk maps at the building scale.

Loli et al. (2022) assessed the Flood Risk Index of a region in Mozambique based on the use of geographical information systems and the collection of geospatial datasets which included the historic floods reported by residents. Using the equation $Risk = Hazard \cdot Exposure) \cdot Vulnerability \cdot Lack\ of\ coping\ capacity$, the authors evaluated a flood risk index. More specifically, they assessed a flood hazard index using the 'analytical hierarchy process'[11] method, and identified the impacted assets (i.e., the exposure), the inequality factors (i.e., the vulnerability) and the infrastructure (i.e., the lack of coping capacity).

Mabrouk & Haoying (2023) provided a methodology for identifying flood exposed/vulnerable districts with multi-criteria decision-making tools. Specifically, the researchers i) investigated 113 flood vulnerability and exposure indicators; ii) selected 44 of them; and iii) characterised the neighbourhoods to identify the flood prone ones. Furthermore, they iv) validated the methodology comparing the results with those of a precipitation-based approach.

Within the context of climate change and its future scenarios, Sambo et al. (2023) developed a framework for the analysis of climate hazard, exposure, vulnerability and risk. The authors employed a multi-risk approach and focused on specific receptors (i.e., assets prone to be subjected to adverse effects). Based on the available datasets, they investigated four hazards, namely storm surge, pluvial floods, heat waves and drought and they then assessed exposure and vulnerability. The exposure and vulnerability factors (or indicators) were categorised, associated with the receptors and attributed a score. As a last phase, the risk was calculated integrating information about the hazards and their climate scenario with exposure and vulnerability of the receptors, by multiplying the three components.

De Risi et al. (2020) focused on developing risk maps in the data scarce urban context of the developing countries. After a probabilistic assessment of the flood hazard, the authors identified the exposure and the structural vulnerability of buildings with collapse-fragility curves, which are function of the flood depth. Finally, they evaluated the flood risk by assessing the expected number of people in the area exposed to flooding risk.

Sperotto et al. (2016) proposed an integrated analysis of the pluvial flood hazard, exposure, vulnerability and risk for the territory of the Municipality of Venice, based on changing climate scenarios and the bottom-up involvement of the stakeholders. The hazard was assessed to estimate the number of rain events that exceed the local threshold of emergency. Exposure was identified with the localisation of the receptors (i.e., the elements potentially at risk). The physical and vulnerability assessment was carried out keeping into consideration the slope, soil permeability and recently flooded areas. The risk was finally assessed with the equation $Risk = Hazard \cdot Exposure \cdot Vulnerability$.

[11] The 'analytical hierarchy process' method was developed in the 1970ies by T. L. Saaty and consists of a multicriteria method that allows to support decision-making processes providing a global evaluation and ranking of different alternatives. On the basis of multiple criteria, the alternatives can be ordered according to the chosen parameters and their attributed weights.

Bibi et al. (2018) determined the flood risk index for a district in Pakistan assessing hazard, vulnerability and exposure. In their analyses, the authors kept into account also data gathered from the population, as well as historical data.

Othmer et al. (2020) assessed the pluvial flood risk for a small city in Germany based on the combination of hazard and vulnerability. The researchers did not directly account for the exposure, having focused the research on the urban area. They modelled the flood hazard using an existing heavy rain hazard map in addition to a flow path and a sink analysis, and the calculation of the surface runoff. Furthermore, they conducted a vulnerability assessment evaluating the damage potential and the population sensitivity by using indicators. Within a laboratory, the authors coordinated the research with the urban administration, recognising the value of science-policy coordination.

Weerasinghe et al. (2018) assessed the flood risk levels with a statistical expression of hazard, exposure and vulnerability. The authors evaluated the flood hazard using precipitation, topographic, land cover and geology data and weighed them with the 'analytical hierarchy process' method. The flood hazard index was then calculated with historical flood inundation data. Furthermore, the exposure was assessed keeping into consideration both the population and housing units located in hazardous areas, attributing an exposure index to each of them. The social (age groups), economic (employment) and physical (permanence of housing) vulnerability were then assessed and the risk index was calculated with the formula $Risk\ index = Hazard\ index \cdot Exposure\ index \cdot Vulnerability\ index$.

Park et al. (2021) analysed the flood risk effect on buildings, based on the formula proposed by Eurac Research in 2017, i.e., $Risk = Hazard + Vulnerability + Exposure$ (GIZ & EURAC, 2017). The researchers determined the buildings vulnerability based on their characteristics (e.g., land price and underground area), their exposure based on their location and the flood hazard based on the flood depth and range, which was calculated through hydraulic modelling.

Kassem et al. (2022) presented a study to assess the flash flood risk in Northern Cyprus. The research encompassed the evaluation of the flood hazard with a surface runoff model and a hydrologic model to evaluate the flood prone areas. The authors also propose a risk matrix that allows to define flood risk maps based on the potential consequences of the flood depth and its likelihood of occurrence.

Rincón et al. (2022) proposed a stochastic method for flood risk assessment. The researchers considered climate change scenarios with a comprehensive approach to probabilistic risk assessment. The authors determined the flood hazard based on future precipitation for three future time periods and identified the exposed assets and vulnerability functions. The researchers analysed the hazard identifying depth-area-duration-frequency curves and then defined the flood hazard maps putting into relationship the flood depth and the probability of occurrence. The flood hazard maps, i.e., the extent of flooded areas, were defined for different return periods. The exposure vas calculated in relationship to buildings and the economic value of each of their categories, as well as the presence of population. Finally, the economic vulnerability of buildings, as well as the social vulnerability were evaluated with depth-damage curves and depth-population affected curves, respectively. The flood risk equation ($Risk = Hazard \cdot Exposure \cdot Vulnerability$) was simplified in $Risk = Probability \cdot Consequences$, and the authors evaluated the damage in terms of losses for each stochastic precipitation event.

Kim et al. (2022) qualitatively assessed flood risk with a heavy rain damage index. Furthermore, they used historical damage data to assess major damage types which were previously not accounted for. The researchers identified hazard, exposure, vulnerability and capacity indicators which were selected with specific principles, weighted and combined to obtain a heavy rain damage index. The risk level was calculated and linked to the damage type identified for each region.

Ceragene et al. (2023) presented a study to foster the flood risk perception of the population of Villhermosa (Mexico). The research involved the construction of flood risk maps based on a hydraulic study, the construction of hazard maps and the analysis of social vulnerability and severity indexes for hazard maps. Finally, the results were put into relationship with the economic damage.

Li et al. (2023) proposed an efficient risk assessment method for classifying the levels of flood risk and identifying areas interested by flood risk. After highlighting the existing assessment methods[12], the authors evaluated an urban flood risk assessment index in a risk-vulnerability framework and proposed a data mining strategy to gather data from extensive datasets with a cluster analysis[13].

Rivosecchi & Singh (2023) investigated the pluvial and coastal flood risk of an island city with the software InVEST[14]. For what concerns the pluvial flood risk, the authors evaluated the surface runoff generation and retention for each of the city drainage basins and calculated a flood vulnerability index that accounted for physical and socio-economic indicators such as the building footprint, the population density and a deprivation index. Furthermore, the flood vulnerability index was calculated for different return periods.

The literature review highlighted recurring and varying aspects of the flood risk assessment methods, summarised in the following table (Table I.9).

Recurring aspects	*Varying aspects*
- Acknowledgement of the risk formula proposed by the Intergovernmental Panel on Climate Change '5th Assessment Report'; - recognition of buildings and people as the exposed assets; - use of indicators; - use of multi-criteria methods; - probabilistic approach to precipitation data (return times, intensity-duration-frequency curves); - acknowledgement of data scarcity and lack of straight forward instruments for flood risk assessment.	- Climate scenarios/consideration of climate change; - risks considered (i.e., single or multi-risk approaches) - different concepts of hazard, exposure and vulnerability; - indicators and data availability; - focus and objectives; - citizens' involvement; - scale of the analysis.

Table I.9 | Recurring and varying aspects of the analysed flood risk assessment methods.

Most authors acknowledged and based their research on the concept of risk as expressed by the Intergovernmental Panel on Climate Change '5th Assessment Report', even though some variations based on the context, data availability, approach and objectives have emerged. When dealing with the urban pluvial flood risk, researchers assessed it alone or

[12] The already cited i) 'historical disaster mathematical statistics'; ii) 'multi-criteria analysis'; iii) 'hydrological-hydraulic modelling' and iv) 'GIS and remote sensing technologies' methods.
[13] Cluster analysis is a statistical method used in data processing that encompasses the organisation of items into clusters (groups) based on their association.
[14] http://releases.naturalcapitalproject.org/invest-userguide/latest/

in combination with other kind of risks (i.e., risk of adverse effects caused by heat waves), thus using multi-risk approaches that accounted for multiple causes and adverse effects. Focusing on the urban pluvial flood risk, authors generally considered the uncertainty associated with climate data, assessing the hazard with probabilistic approaches that encompassed, for instance, the calculation of intensity-duration-frequency curves. When dealing with the evaluation of the exposure and vulnerability, researchers often focused on people and/or buildings, defining the variables and indicators accordingly. The multiplicity of the considered variables and indicators, as well as the complexity of the topic was recognised and often dealt with by the authors with multi-criteria assessment methods that encompassed, for instance, weighting the indicators or setting thresholds. In general, the studies recognise two issues, consisting of i) the data scarcity and ii) the lack of consolidated unique methods for assessing flood risk in urban areas, thus placing their research within a context of contributing to the advancement in this field. The studies presented differences in the accounting for climate change and future climate scenarios, which - similarly to the location-specific historical flood events - are not always kept into consideration. Furthermore, it appears relevant to underline that, in literature, the risk components (i.e., hazard, exposure and vulnerability) are heterogeneously dealt with, their precise definitions vary and the boundaries of these concepts are not always clear. For instance, when conducting a risk assessment, *should the age of the population – if considered a relevant characteristic – represent a vulnerability indicator, or should it be treated as an exposure indicator?* Based on literature, it could be argued that if the considered risk concerns only certain age groups, age should be considered an exposure indicator. If, on the contrary, risk impacts the whole population with more intensity to certain age groups, age may be considered a vulnerability indicator.

Finally, a relevant matter to discuss is the involvement of the population and stakeholders in the risk assessments. The involvement of different actors does not represent a widespread practice and is put in place with different levels and forms: as an example, the administration is sometimes involved in the research, while other times the population is interviewed to gather data concerning the historical flood risks.

1.3 The urban heat island effect[15]

The urban heat island effect (or phenomenon) has been first acknowledged by the British chemist and meteorologist Luke Howard (1772-1864) who, in the 19th century London, concluded that the temperature in cities should be distinguished from the climate, as it entails an artificial warmth induced by the urban structure, population, and consumption of great quantities of fuel (Howard, 1833a).

Between approximately 1807 and 1830, Howard monitored the temperature, the humidity, the atmospheric pressure and precipitation in three locations in the outskirts of London (i.e., Plaistow, Tottenham, Stratford), and compared them to urban temperatures measured at the Royal Society of London. Despite the inaccuracy and lack of rigor that can be recognised today in these first measurements, Howard is attributed the role of a pioneer in the acknowledgement of the existence of the urban heat island effect. Howard developed his studies and, in the 1830s edition of 'The Climate of London', demonstrated

[15] Section §1.3 has been adapted by the author based on Marianna Ceci's research 'Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana.* [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.

the urban effects on the climate, i.e., the increase in temperatures from the rural to urban areas (Howard, 1833a, 1833b).

In Italy, de Bartolomeis is considered the first author that, similarly to Howard, acknowledged a difference between the rural and urban temperature - specifically for the case of Torino. De Bartolomeis stated that "the temperature in cities is higher than in the countryside and in the soft land covered with grasses and plants, because in the former the direct heat is combined with the reflected heat of the sun rays reflected off the walls, floors, floating gases and the large number of people, as is the case in the city of Turin; whereas in the latter there is more concentration than reflection of the sun rays, and the plants and vegetables themselves absorb a large part of the heat" (Bartolomeis, 1847).

The urban heat island was further studied over the course of the 20th century (Chandler, 1970), when Manely conducted further research on the temperature differences between urban and rural areas (Manley, 1958). The term 'urban heat island' was defined (Landsberg, 1981a), acquiring more and more relevance in the scientific and political context (Leone et al., 2023; Stewart, 2011)[16]. Landsberg, a German climatologist, collected all the previous studies about the phenomena involving the city and the climate in document titled 'The Urban Climate'. This broad-scope work ranges from meteorology to urban climatology and urban planning (Landsberg, 1981b), and includes Landsberg's similitude that explains the name attributed to the urban heat island effect: when representing the temperature recorded over an area through isotherms, the urban area appears as an 'island' with higher temperatures in the cooler 'sea' of the surrounding countryside (Figure I.8).

Researchers have emphasised that this phenomenon can be observed with varying vertical scales (Gaglione, 2022; Kalogeropoulos et al., 2022; Vujovic et al., 2021), i.e., the mesoscale or city scale; the local or neighbourhood scale; and the microscale or road canyon scale. Among them, different types of urban heat islands can be found. Vujovic et al. (2021) identified two macro categories based on their formation, impacts and analysis techniques - namely the 'surface urban heat island' and the 'atmospheric urban heat island'. The latter can be divided in two layers, the 'urban canopy layer' and the 'urban boundary layer'. The urban canopy layer represents closest layer to the earth surface and is described by the air temperature from the ground level up until the average height of the buildings. The urban boundary layer represents, as the name says, the boundary layer over the building, and is characterised by the heat emitted by the buildings themselves. The 'urban plume' is the boundary line that indicates where the atmospheric characteristics start not to be influenced by the urban area.

The urban heat island effect is especially relevant in densely urbanised areas and during summer months, when cities are characterised by high (if not extreme) temperatures. High temperatures are the source of discomfort for the population, especially for the most fragile and sensitive categories. The layer that has been identified for dealing with people's wellbeing is the urban canopy layer, as it corresponds the air layer in which most outdoor human activities take place.

[16] As of today [2024], the Italian Vocabolario Treccani included the word 'urban heat island' among the neologisms of the year 2023 ('Isola di calore urbano', n.d.). Furthermore, in the Italian legislation, this effect is mentioned in the Senate Act No. 1028/XIX (2024), the Draft Law 'Urban regeneration and sustainable land use' (*Rigenerazione urbana e uso sostenibile del suolo*), as "an increase in temperature when moving from rural areas to the city centre, creating a warmer microclimate, which persists even at night, within urban areas compared to the surrounding rural peripheral areas, with differences of up to 5 degrees".

In the framework of studying the urban heat island effect, air temperatures are locally monitored through a network of meteorological instruments and stations. If the urban temperatures measured between 1.5 m and 3 m above the ground are higher than those measured at the same height in a nearby rural areas, it means that the considered area is characterised by the presence of the canopy layer urban heat island effect. The surface temperatures of an area depend on its materials and can be registered through infrared thermal measurements. In general, it has been observed that surface temperatures reach much higher levels than air temperatures.

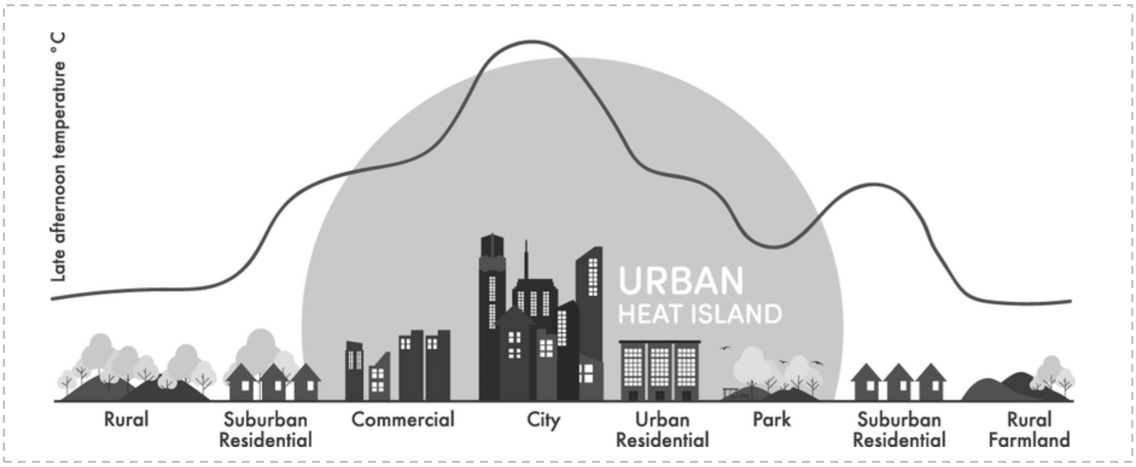

Figure I.8 | The urban heat island effect. Source: World Meteorological Organisation.

Figure I.9 shows how the surface and atmospheric temperatures vary during the day and night according to the urban cover. The surface temperature graphs, which reflect the complexity and variety of the urban permeable and impervious surfaces, are more jagged and detailed compared to the air temperature ones. Furthermore, the picture shows that water and green areas mitigate the temperatures during the day. The figure also shows that the urban heat island effect persists during the night hours and that the surface and atmospheric temperatures are more aligned compared to the day. This condition is motivated by the lack of direct solar radiation.

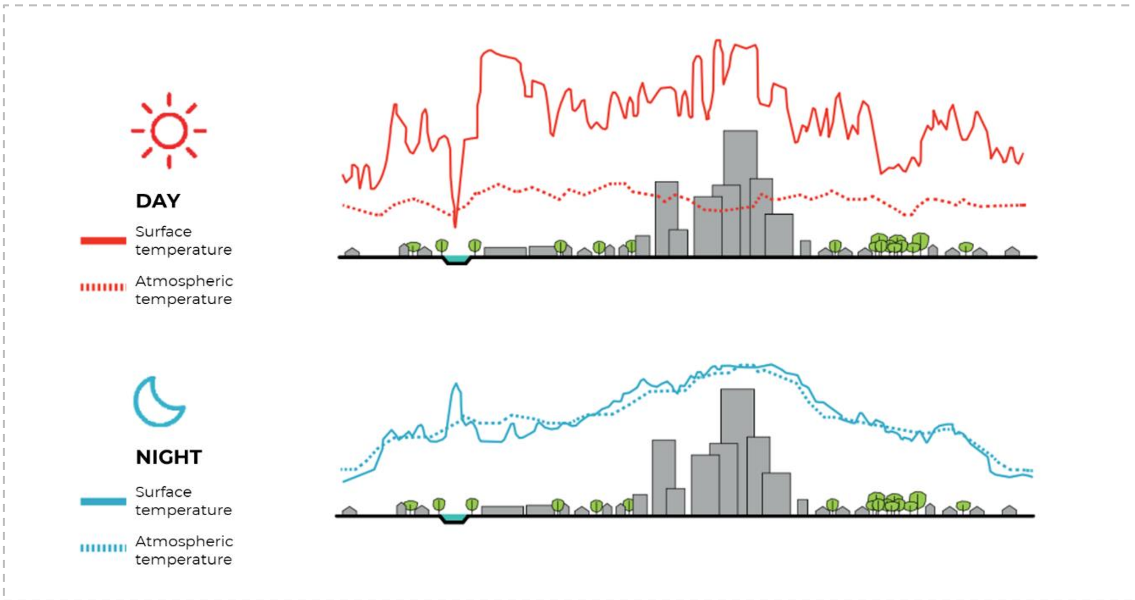

Figure I.9 | Diagram representing the variations in surface and atmospheric temperatures between day and night in various contexts. Source: author's translation from Regione Emilia-Romagna & SOS4LIFE (2020).

1.3.1 Causes and effects

The urban heat island effect is a complex phenomenon. It involves the interaction of various factors and is characterised by varying thermal, reflective and emissive features that differ from the rural areas (Vujovic et al., 2021). Undoubtedly, relationships between the characteristics of the built environment and the intensity of heat distribution and users' perception can be found (Nardino et al., 2022; Oke, 1982; J. A. Voogt & Oke, 2003).

Causes

Specific factors increase the urban heat island effect acting as 'urban heat multipliers' (Varlese, 2023). Table I.10 includes a classification of these factors into categories, which were identified on the basis of the research of, i.a., Almeida et al. (2021), Musco & Fregolent (2014), Nuruzzaman (2015), Syafitri et al. (2021), J. Voogt (2008), and Yang et al., 2023.

During the hottest hours of the day and heat waves, the direct radiation from the sun intensifies the urban heat island effect. Furthermore, tropical nights – which represent those days with daily minimum temperatures above 20°C – induce, with their associated humidity conditions, thermal discomfort in the population. Therefore, their count can be used as a climate indicator (MASE, 2023b). For what concerns soil imperviousness, the impervious and dark materials that often characterise roads and parking lots absorb solar radiation due to their low albedo[17] values (Fokaides et al., 2016; Irmak et al., 2017; Mohajerani et al., 2017). Consequently, they are prone to release the absorbed heat in the surrounding area. When their thermal inertia[18] is high, there is a shift in the release of the absorbed heat, which, accumulated during the day, is returned to the environment during the night. Overall, the temperature increases as the artificial cover density increases. The buildings cladding and roofing materials have been therefore also identified as

[17] The albedo is the fraction of light reflected by a body or surface.
[18] The thermal inertia is the property of a material that expresses the degree of slowness with which its temperature reaches that of the environment ('Thermal Inertia', n.d.).

influencing factors. On the other hand, green and blue infrastructure play a beneficial role in mitigating heat. In summer, trees with foliage improve the microclimate through the evapotranspiration process. Furthermore, they provide shade, absorb CO_2 and decrease air pollution. The presence of small or large water bodies mitigates the temperatures of surrounding areas and increase the thermal comfort.

Category	*Factors influencing the urban heat island*
Localisation	Topography of the surrounding urban and rural context
	Local climate
Atmospheric conditions	Solar radiation
	Wind
	Cloud cover
	Humidity
Time period	Day/night
	Season
Urban morphology	Building shape, height, position and orientation
	Building density
	Road size
	Sky View Factor[19]
	Urban canyons[20]
Urban cover	Soil imperviousness
	Building material
Blue and green infrastructure	Green, vegetated and permeable areas, horizontal and vertical
	Water
Daily activities that release anthropogenic heat	Industrial processes (e.g., engines and generators)
	Heat and ventilation air conditioning
	Mobility and car traffic
	Metabolic activities of the city users
	Night lights

Table I.10 | Factors influencing the urban heat island and their category.

The first three categories in which the factors have been divided (i.e., localisation, atmospheric conditions and time period) include climate influencing factors that do not depend on human action and, as reported by Rizwan et al. (2008), can be defined as the 'uncontrollable variables' of the urban heat island. On the contrary, the remaining factors correspond to 'controllable variables': urban stakeholders, decision- and policy-makers can act both the structural causes of the urban heat island (e.g., the shape of the city), and on those factors that actively produce heat (e.g., the functions of the city) by encouraging policies that aim - for instance - to:

- decrease the heat-absorbing surfaces;
- mitigate heat-generating activities and processes, which range from intervening on industrial activities to improving the technical characteristics of buildings;
- increase surfaces that provide natural cooling, such as green roofs or areas.

[19] The Sky View Factor describes the portion of the sky visible from a given position on the earth surface.
[20] Urban canyons represent locations that are prone to give rise to thermal breezes.

Effects

Several scholars have investigated the issues caused by the urban heat island effect (i.a., Mohajerani et al., 2017; Ningrum, 2018; Nuruzzaman, 2015), such a discomfort for the city users and poor liveability of the urban area. In particular, according to Almeida et al. (2021), the main adverse consequences of the urban heat island effect can be divided into environmental, economic and social consequences.

The environmental consequences can be divided as follows:

- decreased air quality: excessive heat results in high levels of pollutants such as ozone and particulate matter, which concentrate in urban areas rather than in the surrounding rural areas (Arunab & Mathew, 2024). Furthermore, issues related to air circulation and atmospheric instability may develop. The air warmed up by the earth rises and may result in rainfall (Almeida et al., 2021), contributing to increasing the urban pluvial flood risk;
- threat to biodiversity: the lack of vegetated areas in highly urbanised settings decreases the urban biodiversity (Musco, 2014);
- threat to water availability: high temperatures may lead to droughts; thus, they may reduce water availability. Furthermore, contamination risks may increase. This can result in severe inconveniences for the population and the environment, as well as considerable increases in the supply costs (Manik & Syaukat, 2015; Musco & Fregolent, 2014).

The economic consequences consist in:

- increased energy demand and associated costs: during intense heat periods, an increase in electricity consumption for cooling public and private buildings with air conditioning systems can be observed;
- damage to buildings and infrastructure and associated costs: high temperatures may damage roofing materials and cause the deformation of pavements, the degradation of building materials and a decreased efficiency of electrical equipment (Mayor’s Office of Sustainability and ICF International, 2015);

The social consequences are probably the most serious impacts - among which figure the consequences on human health due to excessive heat. However, not all the population is exposed to this phenomenon in the same way: for instance, outdoor workers are more exposed compared to those who work indoors. Furthermore, vulnerability varies among the population groups according - for instance - to age and health. In the worst cases, excessive heat can lead even to death (Ellena et al., 2023; Harlan et al., 2013; MASE, 2023b; Musco & Fregolent, 2014).

Rotterdam (the Netherlands) tram line and green infrastructure. Source: photo taken by the author (2023).

2 Soil desealing and climate change adaptation

Already in 1969 with the first edition of 'Design with nature', the Scottish urban planner, architect, landscape architect and 'inspired ecologist' Ian L. McHarg denounced water shortages, droughts, floods and high temperatures in several cities. These conditions and phenomena have been later been acknowledged as adverse effects of climate change (Ceci, 2025).

Within this framework, soil consumption and climate change related issues in urban areas have been addressed with both climate change adaptation and mitigation strategies. **Climate change adaptation** has been defined by the Intergovernmental Panel on Climate Change (2023) as the process, in human systems, "of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities". In natural systems, the Intergovernmental Panel on Climate Change defined it as "the process of adjustment to actual climate and its effects".

Climate change mitigation, on the other hand, has been defined as the "human intervention to reduce emissions or enhance the sinks of greenhouse gases" (IPCC, 2023).

McHarg (2007) emphasised the centrality of directly linking urban design to nature, implying is his work 'Design with Nature'. The relevance of human cooperation with nature is also acknowledged by, i.a., Dessì et al. (2017), Saber et al. (2022) and the World Health Organization (2016), which recognise the role of introducing natural elements in urban design and restoring nature in cities to address the challenges posed by climate change, integrating both adaptation and mitigation strategies (Ceci, 2025) (Figure I.10).

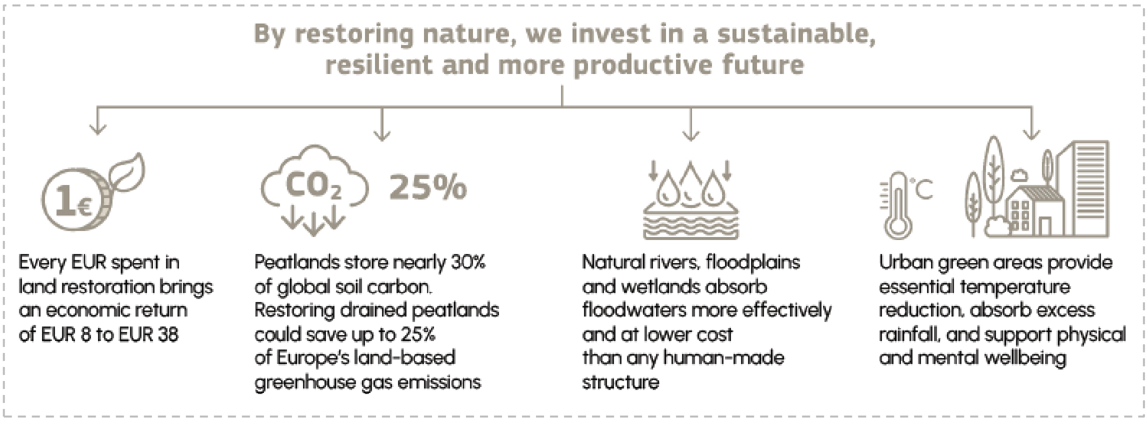

Figure I.10 | Benefits of restoring nature in urban areas. Source: Marianna Ceci's elaboration based on EC and DGE (2022).

Adaptation plays a relevant role in urban planning and involves the use and promotion of strategies such as green infrastructure, green and blue infrastructure and nature-based solutions. In the context of addressing the increasing soil consumption and mitigating its associated risks related to climate change, these strategies are mainly designed to address their consequences. However, they contribute to climate change mitigation as well, as adaptation measures contribute to absorb the urban greenhouse gases emissions (Biesbroek et al., 2009).

Under the umbrella of nature-based solutions, the so-called 'sustainable urban drainage systems', 'low impact development' practices, 'best management practices', and 'water sensitive urban design' involve the use of devices such as vegetated infiltration systems, detention basins, permeable pavements and green roofs, which represent strategies that are aimed or entail the increase of soil perviousness, thus reducing the surface runoff and pollutants (Pelorosso et al., 2013). Gibelli et al. (2015) developed a manual for a sustainable urban water management that includes a classification of the available interventions and strategies based on their scale of application, purpose and application to the public or private space (Gibelli et al., 2015). The implementation of these devices in urban areas allows to minimise the adverse effects of urban pluvial floods and their probability of occurrence (Figure I.11).

PUBLIC – PRIVATE

	MINIMIZING THE PROBABILITY	MINIMIZING THE EFFECTS	STIMULATING RESILIENCE
SUB-CATCHMENT (S)	Give space to the river, from regulated to natural rivers	Lamination ponds and local widenings	Green and blue infrastructure systems
CITY (C)	Greening cities, increasing infiltration areas	Build artefacts that can be submerged (urban furnishing, areas, materials)	Create alternatives (e.g. streets), dedicated insurances, reconnecting small hydrographic networks and devices for a fast disposal of flood water
NEIGHBORHOOD (Q)	Water resistant buildings (materials)	Rain gardens, infiltration areas	Pumps
BUILDING (E)	Green roofs, barrels	Adaptive building design	Pumps

Figure I.11 | Actions and strategies identified by Gibelli et al. (2015) in the framework of sustainable urban water management. Source: adapted by the author based on Gibelli et al. (2015).

In this theoretical framework, soil desealing emerges as a relatively new concept that promotes the restoration of the urban soil and related ecosystem services and functions, thus increasing the urban resilience and specifically contributing to mitigate the urban pluvial flood[21] and heat island risks (Figure I.12). Furthermore, within the context of the urban landscape, soil desealing gains relevance as a transformative process that reshapes the urban environment drawing inspiration from the natural one, thus enhancing the

[21] In this thesis, soil desealing is investigated within the context of urban pluvial flood risk. While soil desealing generally enhances soil permeability, its quantitative role in mitigating other types of floods (e.g., fluvial and marine) is not assessed in this study. However, it can be qualitatively said that increasing infiltration plays a role in reducing also the fluvial flood risk, as it reduces runoff and drainage systems outflow, thus the water quantities delivered to receptor bodies (De Noia, 2021; De Noia et al., 2022).

relationship between the built and natural systems and introducing ecological principles that foster urban resilience. Soil desealing promotes the replacement of the artificial and impervious surfaces with green lawns, bushes and rows of trees, recovering the evapotranspiration processes, fostering the infiltration of water into the soil and mitigating the increase of surface runoff entailed by covering the soil with artificial surfaces (Aimar, 2023; De Noia et al., 2022; EC & DGE, 2012b; Gibelli et al., 2015). Furthermore, soil desealing fosters the storage of CO_2, allows to provide shade and improves the microclimate (Ceci, 2025).

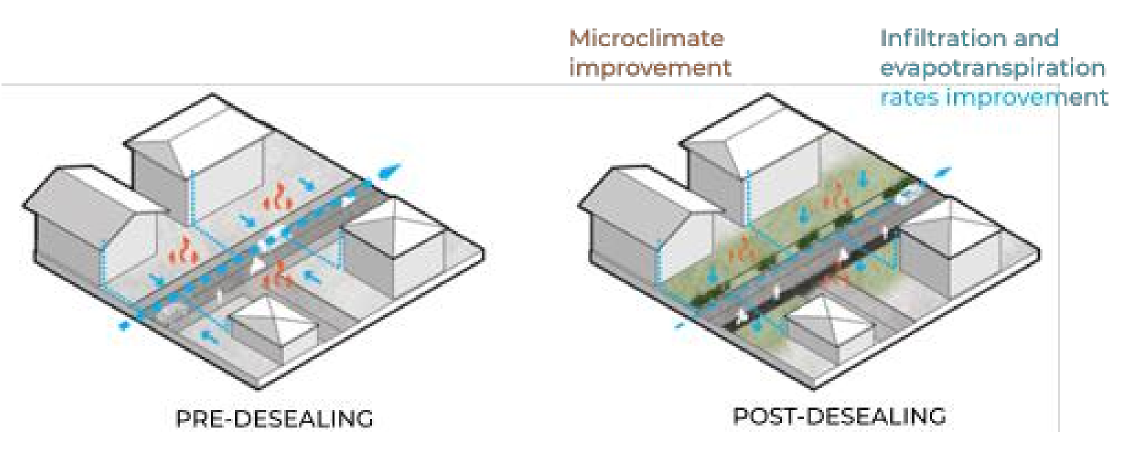

Figure I.12 | Soil desealing and its benefits. Source: author's elaboration.

For what concerns specifically the management of the surface runoff and thus the mitigation of the urban pluvial flood risk, some Italian regions such as Lombardy (e.g., Regional Law No. 4/2016 of the Lombardy Region) and Emilia-Romagna have introduced the concepts of hydraulic and hydrologic invariance[22], that - on new urban developments or in the context of urban regeneration - allow to control surface runoff volumes and flows. As shown in the following figure, transforming the city according to these concepts allows to control the peak flows and volumes produced by the urban area (Figure I.13).

[22] Hydraulic invariance is the principle according to which the maximum surface runoff discharged from urbanised areas into natural or artificial downstream receptors shall not be greater than those pre-existing before urbanisation.
Hydrological invariance is the principle according to which not only flow rates but also surface runoff volumes shall not be greater than pre-existing ones.

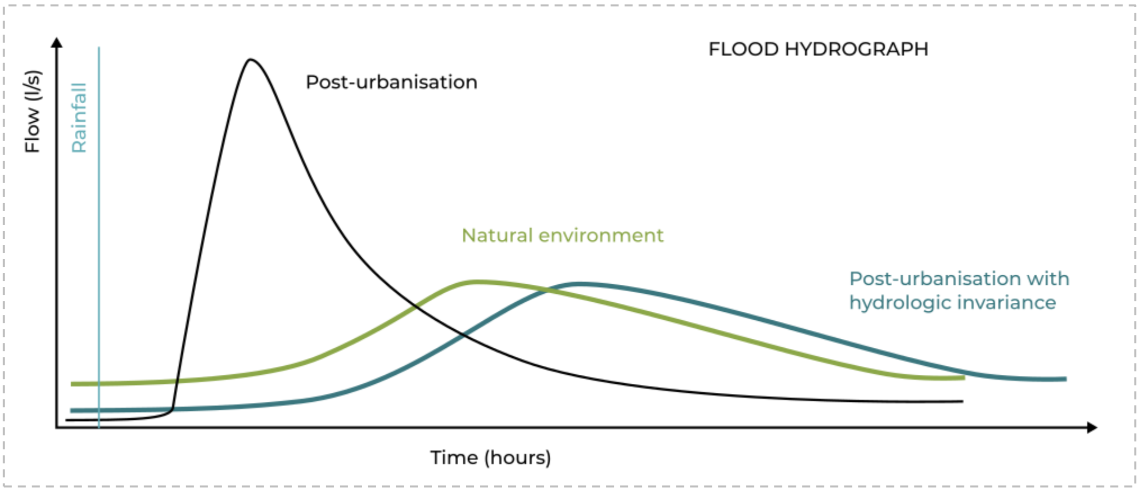

Figure I.13 | Comparison between the flood hydrographs in the natural environment and in post-urbanisation with and without hydrologic invariance conditions. Source: author's elaboration.

As noted by Magni (2023), the European Landscape Convention defines landscape as an area perceived by people, shaped by the interaction of natural and human factors (Council of Europe, 2000). This definition highlights the dynamic and evolving nature of landscapes as cultural constructs distinct from the environment (*ambiente* in Italian). In this context, soil desealing promotes both the tangible ecological benefits of natural systems and the intangible cultural significance of urban landscapes. It reclaims – for instance - spaces for the citizens and the communities, thus bridging environmental sustainability and the socio-cultural identity of urban spaces. Hence emerges the importance of involving citizens and the communities in the decision-making and implementation processes of soil desealing in the urban planning scenario. This is also relevant in the broader context of nature-based solutions, which have been recognised - along with an interdisciplinary approach and a holistic, synergistic vision of urban environmental and climate change issues - as the only way to ensure a sustainable and climate-resilient future, in contrast to the traditional grey infrastructure approaches (Magni, 2023).

In this framework, the relatively recent emergence of soil desealing as a concept – which has been addressed in the scientific literature only since the 1990s (see Section §2.2) - is part of a broader scientific debate. The following sections of Part I will elaborate on this discussion through the definition of the concept (Section §2.1), a literature review of scientific studies and virtuous case studies (Section §2.2), the recognition of the role of public participation (Section §2.3), and a conclusion that explores both the emerging opportunities and challenges associated with this topic.

Watersquare Benthemplein (De Urbanisten), Rotterdam, the Netherlands. Source: photo taken by the author (2023).

2.1 Definition and purpose[23]

The history of the concept of soil desealing can be reconstructed starting from the terms and definitions that have been used to refer to it. **Soil 'desealing/de-sealing'** or **'unsealing'**, **'depaving/de-paving'** - and the Italian ***'desigillazione'***, ***'de-impermeabilizzazione'*** or ***'deimpermeabilizzazione'***[24] - are terms which have been used interchangeably in literature to refer the action of restoring the initial properties of the urban soil, by removing - in general terms - its impervious artificial layer.

Figure I.14 shows an example of a soil desealing intervention in Strijp-S, designed in the context of the regeneration of the former Philips industrial park in Eindhoven, the Netherlands.

Figure I.14 | Strijp-S regeneration site, Eindhoven, the Netherlands. Source: photo taken by the author (2023).

The search engines Google, Google Scholar, Web of Science and Scopus were employed to conduct a preliminary literature review on the concept of soil desealing, including also results pertaining to the so-called 'grey literature', i.e., non-strictly scientific research such as reports of research projects, directives and laws (Tobias et al., 2018). Table I.11 encompasses the analysis results of eighteen documents that, between 2011 and 2021, proposed a definition of soil desealing. The analysis highlighted the main themes that

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[23] Section §2.1 has been adapted by the author based on 'Caselli, B., Ceci, M., De Noia, I., Garda, E., & Zazzi, M. (2024). Towards the Integration of Soil Desealing in the Urban Areas' Transformation Processes. In A. Marucci, F. Zullo, L. Fiorini, & L. Saganeiti (Eds.), Innovation in Urban and Regional Planning (pp. 286–298). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54118-6_27', a publication in which she is co-author. The published article encompasses the full attributions of the work.

[24] The term '*desigillazione*' has been identified to be among the first Italian translations of this concept (e.g., Jobstmann et al., 2011a).

emerged in the definitions provided by the authors in the documents. Specifically, four documents pertained to the European framework, one to the Italian, while the remaining consisted of scientific literature.

The term 'desealing' is the most recurring one, and has been defined by the Directorate General for the Environment of the European Union as corresponding to "restoring part of the former soil profile by removing sealing layers such as asphalt or concrete, loosening the underlying soil, removing foreign materials and restructuring the profile" (EC & DGE, 2012a). Furthermore, this concept has been used to refer as the removal of the artificial elements that hinder the soil properties and functions (Tobias et al., 2018; DGE, 2013; Adobati & Garda, 2018; Oliveira et al., 2018; Garda, 2019; Fabbri et al., 2021; Adobati & Garda, 2019a, 2019b, 2020). Soil 'unsealing' has been defined as "a process intended to remove the artificial surface and convert the area […], or to restore soil […]" (Oliveira et al., 2018) and also as "removing the artificial surface and converting the area to a new (mostly) undeveloped land use" (Tobias et al., 2018). In the definitions present in literature, soil desealing has also appeared as a mean to restore the ecosystem services (Alleanza Italiana per lo Sviluppo Sostenibile, 2019; Dessì et al., 2017; Fabbri et al., 2021; Maienza et al., 2021; SOS4LIFE, 2017b); as an opportunity for increasing the resilience to climate change of the urban environment (i.a., Adobati & Garda, 2020; Zluwa & Pitha, 2021); as well as an action that produces waste that needs to be managed (SOS4LIFE, 2017a). The action of soil desealing has also been intended as a compensation measure in urban planning, for instance in the context of urban regeneration processes: compensation has been addressed by the European Commission as an action that "can take the form of renaturation projects or desealing measures in built areas, where soil sealing is no longer necessary" (Science for Environment Policy, 2016).

SOIL DESEALING	*Author, year*	*Impermeable layers removal*	*Compensation measure*	*Ecosystem services restoration*	*Urban environmental quality improvement*	*Urban resilience improvement*	*Urban redesign opportunity*	*Inert/contaminated waste production*
EUROPEAN LEVEL	Science for Environment Policy, 2016		•					
	EC & DGE, 2012a	•	•	•			•	
	DGE, 2013	•		•	•		•	
	Jobstmann et al., 2011a		•					
ITALIAN LEVEL	Alleanza Italiana per lo Sviluppo Sostenibile, 2019			•		•		
LITERAURE	Fabbri et al., 2021	•	•	•	•			
	Zluwa & Pitha, 2021					•		
	Adobati & Garda, 2020	•		•	•	•		
	Adobati & Garda, 2018	•	•	•			•	
	Oliveira et al., 2018	•		•				

SOIL DESEALING	Author, year	Impermeable layers removal	Compensation measure	Ecosystem services restoration	Urban environmental quality improvement	Urban resilience improvement	Urban redesign opportunity	Inert/contaminated waste production
	Tobias et al., 2018	•						
	Dessì et al., 2017			•		•		
	SOS4LIFE, 2017a		•					•
	SOS4LIFE, 2017b			•	•	•	•	•

Table I.11 | Review of the definitions of the desealing concepts classified by theme and author. Source: result of a joint collaboration between the author and Marianna Ceci.

Overall, soil desealing can be intended as an action entailing the purpose of increasing the urban soil permeability through the removal of an (artificial) impervious layer. The benefits of this action that can be inferred by its definitions consist of the restoration of the lost ecosystem services and functions of the soil. Furthermore, soil desealing can be considered as a compensation measure and adaptation intervention in urban regeneration processes. Figure I.15 and Figure I.16 show another example of a Dutch soil desealing intervention), which resulted in removal of the artificial surface of Clausplein square in Eindhoven (the Netherlands) and their replacement with permeable pavements and vegetation, allowing for the creation of new green and social spaces.

Figure I.15 | The soil desealing intervention in Clausplein in Eindhoven, the Netherlands. Source: photo taken by the author (2023).

Figure I.16 | A detail of the new permeable pavement and vegetation introduced with the soil desealing intervention in Clausplein in Eindhoven, the Netherlands. Source: photo taken by the author (2023).

2.2 State of the art[25]

Soil desealing as a concept has been referenced in the scientific literature since the 1990s, acquiring a stronger role over the years. However, interventions on the urban environment have entailed the restoration of soil permeability also in earlier years. For example, the creation of Central Park in New York City (United States) involved the removal of built-up areas to establish the park (Kang, 2017). Similarly, the literature highlights that soil desealing is often incorporated into the implementation of nature-based solutions. However, as both literature and practice have not always – and still do not consistently – use this term to describe the increase in urban permeability, soil desealing remains a partially 'submerged topic'.

Nonetheless, as highlighted in the state of the art review presented in the following subsections, the importance of soil desealing has been increasingly recognised, even though a consensus on its definition and terminology has yet to be established.

2.2.1 Scientific literature review

The scientific literature review on soil sealing began with a web-based search on the Web of Science and Scopus platforms, focusing on keywords, titles, and abstracts.

The search strings used to carry out the investigation consisted in 'depaving', 'desealing' and 'unsealing' (both with and without the hyphen), and their verbal, adjective and participle forms (e.g., 'deseal', 'desealed'). Furthermore, the research was aimed at the urban areas, thus including the words 'urban' or 'city/cities'[26]. For what concerns the results, those that were found to be completely unrelated to urban planning were excluded. It was also observed that constraining the search to urban areas highly reduced the number of results. For instance, taking the search of Web of Science as an example, 124 publications resulted for 2021 when not limiting the research, and just 12 with the constraint of urban areas.

The following image represents the obtained results and shows the appearance of the term desealing in the scientific literature in the 1990s, as well as the increasing attention that it has been given over the years[27] (Figure I.17).

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[25] The introduction of Section §2.2 and Subsection §2.2.1 have been adapted by the author based on 'Caselli, B., Ceci, M., De Noia, I., Garda, E., & Zazzi, M. (2024). Towards the Integration of Soil Desealing in the Urban Areas' Transformation Processes. In A. Marucci, F. Zullo, L. Fiorini, & L. Saganeiti (Eds.), Innovation in Urban and Regional Planning (pp. 286–298). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54118-6_27' in which she is co-author. The published article encompasses the full attributions of the work.

[26] The search string was iteratively adjusted accordingly to the pertinence that was observed in the results, and consisted in the following formulas:

- Search string for Web of Science: (*TI=(de-pav*) OR AB=(de-pav*) OR KP=(de-pav*) OR TI=(depav*) OR AB=(depav*) OR KP=(depav*) OR TI=(de-seal*) OR AB=(de-seal*) OR KP=(de-seal*) OR TI=(deseal*) OR AB=(deseal*) OR KP=(deseal*) OR TI=(unseal*) OR AB=(unseal*) OR KP=(unseal*) OR TI=(un-seal*) OR AB=(un-seal*) OR KP=(un-seal*)) AND (TI=(urban) OR AB=(urban) OR KP=(urban) OR TI=(city) OR AB=(city) OR KP=(city) OR TI=(cities) OR AB=(cities) OR KP=(cities));*
- Search string for Scopus: (*TITLE-ABS-KEY (de-pav*) OR TITLE-ABS-KEY (depav*) OR TITLE-ABS-KEY (de-seal*) OR TITLE-ABS-KEY (deseal*) OR TITLE-ABS-KEY (unseal*) OR TITLE-ABS-KEY (un-seal*)) AND (TITLE-ABS-KEY (urban) OR TITLE-ABS-KEY (city) OR TITLE-ABS-KEY (cities)).*

[27] In Italy, the catalogue of the exhibition 'Asfalto' (Triennale di Milano, March 4 - July 27, 2003) '*Asfalto, il carattere della città*' (lit. Asphalt: the character of the city) dedicated one chapter to 'depaving' in 2001, collecting, among the others, the experiences of Richard Register, founder and president of the educational no profit organisations 'Urban Ecology' (1975) and 'Ecocity Builders (1992-2014), who promoted soil desealing in the United States since 1992 (Zardini, 2003).

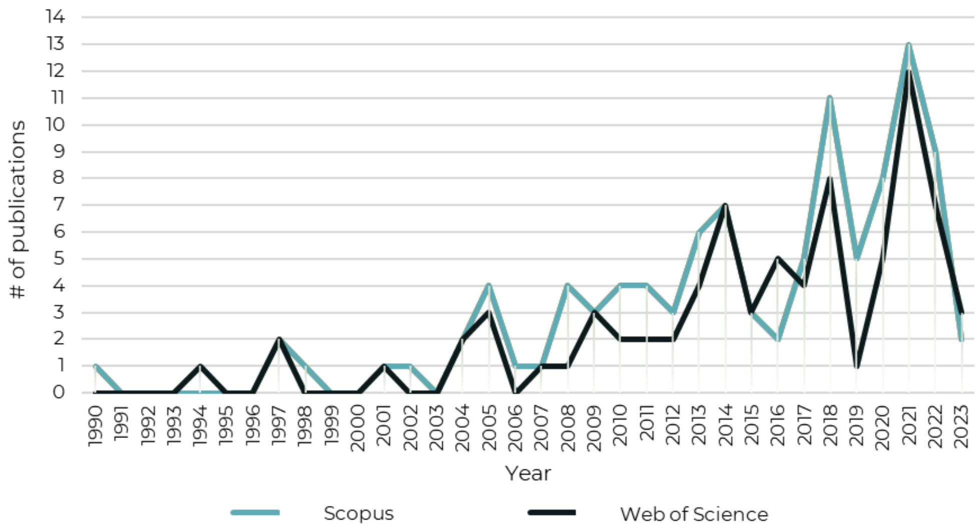

Figure I.17 | Results of the search in Web of Science and Scopus (updated to 08/06/2023). Source: author's elaboration.

As already evident from the review of its definitions, authors have dealt with soil desealing from a variety of different perspectives and with various approaches. Other than proposing a definition for this action, researchers analysed the existing approaches and the role played by these interventions in legislation and regulations, such as its role as a compensation measure for interventions that encompass an increase of the urban sealed surfaces (i.a., Artmann, 2014; Adobati & Garda, 2019b; Fabbri et al., 2021; Smith et al., 2016).

With reference to the strategic and legislative framework, the Italian researchers Munafò (2022) and Pileri (2018) investigated the role of soil desealing as a countermeasure for land take and its role in the Italian legislation and strategies (Consumo Di Suolo, Dinamiche Territoriali e Servizi Ecosistemici, 2022; Pileri, 2018). Within the same perspective, Garda (2022) proposed a review on the Italian regional laws that involved soil desealing, as well as their outcomes and connections with the other planning levels (Garda, 2022). In Germany, Zingraff-Hamed et al. (2021) mentioned the so-called 'desealing cities' in their review of nature-based solutions implementation in the German context of the mitigation of climate change, aiming to identify the applied governance models (Zingraff-Hamed et al., 2021). In Belgium, researchers identified and recognised the commitment of the government to reduce soil sealing (Cockx et al., 2023; Joye & Notteboom, 2018).

Within the planning context, Aimar (2023) recognised the importance of national campaigns for promoting desealing and green infrastructure among the citizens. Furthermore, also Leinfelder (2018) recognised the role of planning in the promotion of soil desealing.

A relevant matter that has been discussed in literature is the concretisation of the acknowledgment of the necessity of concretising soil desealing into real, localised actions. The identification of the priority areas for soil desealing interventions has started to be discussed and recognised (Aimar, 2023; Ceci, Caselli, et al., 2023), and, while emphasising their environmental and social benefits, scholars have proposed parking lots, squares and road infrastructure as the most suitable locations for putting in action soil desealing interventions (Dessì et al., 2017). In this regard, some researchers investigated the role of ecological analyses in supporting the decision-making process (C. Couch et al., 2003; V. T. Couch et al., 2023), while others studied the connection between soil desealing strategies and the soil properties (Le Guern et al., 2022).

Soil desealing project and initiatives have been studied and reviewed by various authors, who have sometimes proposed their characterisation and classification. For instance, Garda (2019, 2020) studied the top-down and bottom-up approaches connected to soil desealing with an in international perspective. A relevant document that was redacted in the framework of the Italian 'SOS4LIFE'[28] project encompasses a review of European case studies[29] of soil desealing, divided and analysed based on their features, such as dimension, employed design instruments and presence of a citizens' involvement process (SOS4LIFE, 2017b). Furthermore, Garda (2020) proposed a classification based on the contribution of these action to the needs of the communities, while Adobati and Garda (2019) divided them in five families, i.e., soil-sealing compensation initiatives; brownfield redevelopments; mitigation and displacement processes; low impact development measures; rivers rehabilitation interventions (Adobati & Garda, 2019a). Romano and Zullo (2020) emphasised the parallelism between soil desealing and urban densification, presenting them as partially interdependent actions which goal is reducing land take, maximising evapotranspiration and infiltration (Romano & Zullo, 2020). Other authors connected the action of soil desealing with brownfield regeneration (Meuser, 2013; Tobias et al., 2018) and with the renaturalisation of disused mines, highlighting their social and environmental relevance in urban, industrial, traffic, mining and military areas (Nestroy, 2006).

For what concerns the functions and services connected to soil desealing, researchers have emphasised its role in enhancing soil fertility and the restoration of the ecosystem services and functions originally provided by the natural environment (Maienza et al., 2021). The evaluation of the performance of soil desealing and the related devices have been addressed in studies that dealt with permeable pavements and in the quantification of their performance (Leinfelder, 2018; Dierkes, 2015; De Noia et al., 2022), and Musco and Fregolent (2014) have argued that soil desealing cannot be effectively implemented to increase the functionality of spaces without a focus on increasing infiltration, evapotranspiration and reducing albedo (Musco & Fregolent, 2014). Similarly, Pileri (2018) stated that the removal of the impervious layer of the soil does not inherently entail the restoration of the ecosystem services of the soil, as the soil compaction properties must be taken into account as well. Furthermore, the relevance of an appropriate management of contaminated soil, such as those resulting from brownfield restoration and desealing, was emphasised (Tobias et al., 2018). In this regard, a relevant issue highlighted in the literature, such as in the reports from the 'SOS4LIFE' projects, is that soil desealing involves the removal of an impervious layer which generates physical material that transforms into waste.

2.2.2 Virtuous case studies

This subsection examines exemplary case studies involving soil desealing. Across the globe, municipalities and stakeholders have highlighted the importance of promoting urban permeability and addressing the adverse effects of excessive soil sealing, such as

[28] https://www.sos4life.it
[29] The review encompassed French, German, Danish and Belgian case studies.

mitigating the urban flood and heat island effect risk. Using various concepts or slogans (e.g., the recurring use of the concept of 'sponge cities' has emerged in various contexts), cities have directly or indirectly[30] promoted actions that involve the removal of the impervious artificial layers of the soil. The next paragraphs include an overview of some cases that, stemming either from a public or private initiative, promoted soil desealing with practical projects, programmes or policies.

Germany

In Germany, the concept of soil desealing has been considered since the 1990s (Mohs & Meiners, 1994) and scholars have emphasised the importance of the issue of soil sealing for this country, as well as the expertise of its researchers in addressing it (Adobati & Garda, 2018; Meyer, 2011). In addition to the adoption of strict national policies for limiting soil sealing and for increasing the urban soil permeability with urban planning instruments, Germany has de-centred the management and promotion of resilience strategies. The responsibility was shifted to the regions (*Länder* in German), which have adopted technical and economic tools (e.g., incentives and compensation measures) to promote urban soil permeability – with actions such as soil desealing – both at the regional and municipal scales.

The 'Bodenausgleichskonto' policy, Dresden[31]

A first example of the aforementioned German policies is the 'soil offset account' (*Bodenausgleichskonto* in German) of Dresden, where the river Elbe flooded in 2002. Since then, the city defined a long-term strategy that aims to limit the soil consumption to 40% of the urban area with various policies (Bundesministerium für Bildung und Forschung, 2013). The 'soil offset account' policy states that each intervention that encompasses an increase in soil sealing[32] must be associated with the desealing, renaturalisation or greening intervention on an equal surface area within the municipality boundary (EC & DGE, 2012a; Prokop et al., 2011). The suitable areas are registered in the 'Climate change adaptation plan' of the city, and are chosen according to the size and value of the new urbanisation that they are associated with (Righini, 2016).

The 'Ökokonto' policy, Bavaria[33]

Since 2003, also Bavaria has adopted regulations that aim to compensate new soil sealing. The 'ecological compensation account' (*Ökokonto* in German) policy accounts for every new intervention that involves an ecological impact with a compensation factor that varies depending on the soil quality and the amount of sealed surface (Bayerisches Landesamt für Umwelt, n.d.). Similarly to Dresden, new interventions must be preceded

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[30] Sometimes, the term 'soil desealing' and related expressions are used directly, while other times the concept is conveyed indirectly through phrases such as 'increasing urban soil permeability'.

[31] This subsection has been adapted by the author based on Marianna Ceci's research 'Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana.* [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.

[32] Urban regeneration and requalification interventions are excluded as they involve already consumed soil.

[33] This subsection has been adapted by the author based on Marianna Ceci's research 'Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana.* [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.

by the renaturalisation of an area registered in an ecological areas cadastre (*Ökoflächenkataster* in German) (Bayerisches Landesamt für Umwelt, n.d.).

Other policies and databases of 'desealable' areas, Stuttgart and Berlin[34]

Since 2006, Stuttgart has put in action measures for reducing soil sealing and promoting a more responsible use of this resource. For this purpose, it developed two tools, namely a soil quality map and a soil index - the German '*Bodenindication*'. This index accounts for the quality and amount of soil consumed by new interventions. Similarly to Dresden and Bavaria, Stuttgart foresees compensation measures that include the desealing of small, sealed areas and the restoration of industrial zones. These are included in a constantly updated database of 'unnecessarily sealed' or 'desealable'[35] areas. On a similar note, Berlin developed the project 'Potentials for impervious coverage reduction' that aims to reduce the urban sealed surfaces. A database of unnecessarily sealed areas was developed, after an evaluation of all the urban areas that may be potentially renaturalised with the removal of the impervious layer. This constantly updated database is accessible also by the private landowners which can also implement their propriety into the system (Osservatorio del Paesaggio trentino, 2022; Senatsverwaltung für & Umwelt, Mobilität, Verbraucher und Klimaschutz, 2022; SOS4LIFE, 2017b).

United States[36]

Soil desealing has been fostered also in the United States through climate change adaptation plans, strategies, programmes and actions such as the 'Greenstreets' programme or the 'Depave' project.

The 'Greenstreets' programme, New York and Philadelphia

The 'Greenstreets' programme takes place in both New York, where it integrates the 'NYC Green infrastructure plan' and in Philadelphia. The programme focuses on restoring the urban green areas that were replaced by paved road infrastructure (e.g., traffic islands). The underlying goals include improving the surface runoff, increasing the urban green areas, improving the drainage system performance and the urban landscape (City of New York, 2024b, 2024a; City of Philadelphia, 2014; Mott, n.d.).

The 'Impervious surface removal' and 'RiverSmart Homes' programme, Washington D.C.

The Municipality of Washington has developed the 'Impervious surface removal' programme, i.e., a financing programme for desealing private areas. The programme allows citizens who want to put in action soil desealing interventions in their property to be reimbursed by the Municipality. The interventions include, for instance, rain gardens and the implementation cultivated areas (VASWCD, n.d.; Washington State Department of Natural Resources, n.d.). Furthermore, the 'RiverSmart Homes' programme envisions a wide set of interventions and sustainable practices for reducing the water runoff in

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[34] *Ut supra.*
[35] From this point forward, 'desealability' is intended as the potential of an area to be desealed.
[36] *Ut supra.*

private areas, specifically for the District of Columbia (Washington D.C. Department of Energy & Environment, n.d.).

'Depave' project, Portland

'Depave'[37] is a project that began in 2007 in Portland (Oregon, USA) and promotes the desealing (or depaving) of unused and underutilised areas by volunteers. After desealing, the spaces are converted into green, collective spaces. Focusing on the urban peripheries, the project aims both to redevelop the urban space and to limit soil sealing, while creating a space for socialisation and contributing to mitigate social issues. The 'Depave' actions are intended as proper events and include the engagement and the inspiration of communities, the recruitment and training of volunteers, and the creation of local committees for the dissemination of the project. On this basis, a stakeholder network arose and allowed for the identification of suitable desealable areas and for obtaining the necessary permissions (Garda, 2019; Puerari et al., 2013). The project, which stemmed from the local no-profit activism and a single small desealing intervention, is now sustained by the City of Portland and by the United States Environmental Protection Agency. 'Depave' constitutes a relevant case study for its capability to change scales (in 2019 more than 60 desealing interventions had already been put in action), both from a political and territorial point of view (Garda, 2019; Puerari et al., 2013).

Canada

Canada is home to two significant initiatives promoting urban permeability: the 'Depave Paradise' initiative and the 'Green Streets' project.

The 'Depave Paradise' initiative, Kingston

The 'Depave Paradise' initiative[38] was launched by Green Communities Canada in Ontario (Canada) in 2012, drawing inspiration from the 'Depave' project. In twelve years [2024], 80 sites and 16,385 m^2 were desealed and 32 communities and five provinces were involved. Similarly to 'Depave', also 'Depave paradise' provides a strong social network identity, focusing on involving and communicating with the stakeholders.

The 'Green Streets' project, Vancouver[39]

Based on similar objectives (i.e., creating new green spaces, reducing surface runoff, enhancing biodiversity, involving citizens) and following the setup of a pilot experiment in 1994, Vancouver has been increasing its urban permeable spaces. With the 'Green Streets' project, traffic islands, roundabouts or other road infrastructure areas are transformed into 'street gardens'. Citizens are actively involved into the project through voluntary gardening activities. The project fosters their motivation by promoting the social benefits that they receive in return, such as community building, neighbourhood beautification and the personal fulfilment and wellbeing achieved by taking part into

[37] https://depave.org/
[38] https://depaveparadise.ca/
[39] This paragraph has been adapted by the author based on Marianna Ceci's research 'Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana.* [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.

gardening activities and by frequently accessing green spaces (Nakao, 2019; Vancouver, n.d.).

The Netherlands

The next paragraphs present an interesting experience that came to life in the Netherlands, the '*Steenbreek*' programme. On different levels and with different strategies, the programme aims to involve citizens and stakeholders to decrease soil sealing.

The 'Steenbreek' programme

The private Dutch initiative '*Steenbreek*'[40] (lit. saxifrage) aims to change the attitude of those who own a garden, promoting a shift away from paved private areas towards more permeable surfaces. '*Steenbreek*', which was organised as a foundation, started to take form in Wageningen in 2014, when ecologists from the city, the *Stichting Entente Florale Nederland*, the University of Groningen, Wageningen Environmental Research and Van Hall Larenstein University of Applied Sciences grouped, with the aim to enhance the role of gardens for urban biodiversity, climate change adaptation and people's wellbeing. The foundation is nowadays representing Dutch non-governmental organisations and the state institute for nature *Staatsbosbeheer* on its board, and is connected by Municipalities, water boards and provinces. While playing a relevant role in developing and exchanging knowledge, stimulating and advising, '*Steenbreek*' effectiveness in changing the attitude of the citizens was still not fully developed in 2019 (Grashof, 2019; Stobbelaar et al., 2021), despite the promotion of actions such as the 'Exchanging a tile for a plant' programme. In January 2019, '*Steenbreek*' merged with the *Stichting Entente Florale Nederland* and widened its reach to the public space (*Stichting Steenbreek I Samen van verstening naar vergroening*, n.d.).

Italy

In Italy, various projects and initiatives have addressed soil desealing. The following paragraphs present three case studies of cities or regions that, through different approaches and practical actions, have recognised the importance of reducing urban impervious areas.

The 'Un filo naturale' project, Brescia[41]

In 2020, the Cariplo Foundation launched the 'Climate strategy' call for ideas, aimed at supporting medium and large municipalities in defining climate transition strategies. Brescia, through the project '*Un filo naturale*' (lit. A natural thread), developed its Climate transition strategy (approved in 2021) in collaboration with multiple partners and with

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[40] https://steenbreek.nl/

[41] This paragraph has been partially adapted by the author based on 'Cangiotti, C., Cepeda Guedea, A., De Noia, I., Ferraioli, E., Mangiulli, F., Pica, K., & Boglietti, S. (2023). I nuovi valori della trasformazione urbana resiliente. Il progetto Un Filo Naturale e la Strategia di Transizione Climatica di Brescia. In A. Richiedei (Ed.), *YoungerSIU2022 DARE VALORE AI VALORI IN URBANISTICA: i punti di vista degli attori della trasformazione urbana* (pp. 11–23). Planum Publisher and Società Italiana degli Urbanisti, Roma-Milano.' in which she is co-author. The published article encompasses the full attributions of the work. The last part of the paragraph has been adapted by the author based on Marianna Ceci's research 'Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana.* [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.

contributions from the Cariplo Foundation and the Lombardy Region[42]. The strategy, designed as a flexible and programmatic instrument, outlines a 30-year vision with the objectives to promote climate adaptation and mitigation, enhance citizens' knowledge of climate change, and foster participatory processes.
The strategy goals include transforming Brescia into an 'oasis city,' a 'sponge city,' and a 'city for people' through actions that improve the microclimate, restore soil permeability, reduce greenhouse gas emissions and engage the public. As part of this, the 'Soil desealing implementation plan' proposes restoring sealed urban areas through nature-based solutions, addressing the urban flood and heat island risks. Notably, soil desealing is framed not only as an adaptation measure but also as a means to support mitigation, governance, and participatory co-design processes (*Un Filo Naturale*, n.d.). The project *'Un filo naturale'* will be further discussed in Chapter §10 of this thesis.

The 'Piano Aria Clima' and the 'Progetto Spugna', Milano[43]

Soil desealing has also been promoted in the Municipality and Metropolitan City of Milan. Following the guidelines of the Air Climate Plan (*Piano Aria Clima*) – a voluntary instrument developed by the Municipality – and the 'Sponge Project' (*Progetto Spugna*) – an integrated urban plan (i.e., a plan dedicated to the peripheries of Italian metropolitan cities) – public areas have been, or will be selected for urban regeneration and soil desealing, particularly those characterised by high imperviousness and built-up density (Città metropolitana di Milano, 2022; Città metropolitana di Milano & CAP Holding spa, 2022; Comune di Milano, 2022). Furthermore, in the 'Strategic plan for the reduction of the atmospheric pollution and for safeguarding public health' (*Piano strategico per la riduzione dell'inquinamento atmosferico a tutela della salute e dell'ambiente*) of the Municipality of Milan[44] action 4.3.1 'Desealing: increasing the urban draining surfaces' (*Depavimentazione: aumento della superficie drenante in città*) focuses on soil desealing (Comune di Milano, 2022).

The 'SOS4LIFE – Save Our Soil for LIFE' project, Emilia-Romagna[45]

'SOS4LIFE - Save Our Soil for LIFE' is another project that emerged in the Italian scenario, specifically in the Emilia-Romagna region. This project, focused on the municipal scale, foresees the implementation of guidelines and urban environmental strategies that recognise the value of soil and urban regeneration in the framework of the 'Roadmap to a resource efficient Europe' (EC, 2011b). 'SOS4LIFE' constitutes an interesting case study for both its practical and theoretical outcomes. Not only it defines a regulatory framework and a set of guidelines for the municipalities that took part in the project (Carpi, Forlì, San

[42] The Lombardy Region has addressed the importance of soil desealing in the Regional Law No. 31/2014 'Provisions for the reduction of soil consumption and the redevelopment of degraded soil' (*Disposizioni per la riduzione del consumo di suolo e per la riqualificazione del suolo degradato*).
[43] This paragraph has been adapted by the author based on Marianna Ceci's research 'Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana.* [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.
[44] The plan was developed following the declaration of an 'urban climate emergency' (20th May 2019).
[45] This paragraph has been adapted by the author based on Marianna Ceci's research 'Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana.* [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.

Lazzaro di Savena) – which are however transferable to other urban context - but it also promotes concrete soil desealing interventions, thus demonstrating their effectiveness (SOS4LIFE, n.d., 2017b).

The 'Green in Parma' project, Parma

The 'Green in Parma' project is an example of a relatively small collaborative and community project involving soil desealing proposed in Parma, in the Emilia-Romagna region. 'Green in Parma' was initially promoted by the Centre for Environmental Ethics (*Centro Etica Ambientale*) of Parma in 2021, and it was then joined by other stakeholders such as the University of Parma. Among the aims of the project emerge the promotion of the urban greenery, as well as raising awareness of the local impacts of climate change. 'Green in Parma' resulted in two applicative soil desealing experiences (a failed one and a second *in progress* one) which will be further addressed in Part III and Part IV of this thesis. The experiences, which involve the setup of soil desealing interventions in the city of Parma, the development of participatory processes and the dialogue with the citizens and stakeholders have also encompassed third mission activities (Caselli et al., 2022; Ceci, De Noia, et al., 2023).

Belgium[46]

Since 2005, Belgium has addressed soil desealing in the Wallonia region. The regional urban plan has established a rule that each new sealed area must be compensated by soil desealing (*désartificialisation* in French) and the restoration of soil permeability (Wallonie, 2024).

Poland[47]

In Poland, the city of Kielce is vulnerable to extreme meteorological and hydrological events (i.e., floods, droughts and heat). Therefore, the city adopted in 2019 the Climate change adaptation plan (*Plan Adaptacji do zmian klimatu* in Polish) that envisions soil desealing as a measure to reduce the flood risk and foster water infiltration into the soil by means of biologically active areas (Kielce, 2018).

People's Republic of China

Inspired by similar concepts used worldwide (e.g., low impact development practices, sustainable urban drainage systems, best management practices, ...), the concept of 'sponge cities' was spread in China to contribute to flood risk reduction and mitigate the urban heat island effect. This concept envisions cities to act like sponges, thus "soaking up and retaining water during rain and storms, and releasing it slowly" (Rau, 2022).

The 'National Sponge City Pilot Program'

The 'National Sponge City Pilot Program' was launched in 2015 to support 30 pilot cities in becoming 'sponge cities'. The goal was for 20% of the urban area to be developed according to 'sponge city' standards, enabling the absorption and utilisation of 70% of rainfall on-site by 2020, with the target of 80% of the urban area covered by 2030. The programme is accompanied by a set of national guidelines that municipalities are suggested to follow to

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[46] *Ut supra.*
[47] *Ut supra.*

establish their 'Sponge City' work plan and standards. The measures that cities are called to implement include both nature-based solutions and grey infrastructure, and keep into account the improvement of water infiltration, retention, storage, purification, utilisation, and drainage. Municipalities can set up the interventions both in new urban districts and in built-up areas (Peng & Reilly, 2021; Rau, 2022), thus including urban regeneration processes and making the 'National Sponge City Pilot Program' appear relevant also in the framework of soil desealing.

2.3 The role of public participation[48]

The role of public participation and citizens' and stakeholders' involvement in urban transformation process has been underlined in the scientific literature since the last century (Paez, 2003). Its relevance has also emerged in the urban regeneration processes of highly urbanised regions, in the context of cities adaptation to climate change (Few et al., 2007) and increase of soil permeability, through both top-down and bottom-up approaches (Dessì et al., 2017; Cockx et al., 2023; Sibeud et al., 2018). Citizens' and urban stakeholders' knowledge, expertise, experience and perception appears crucial in the urban transformation processes (Ferraioli et al., 2020), allowing for the transition towards healthier and more resilient cities, as emphasised by the '2030 Agenda for Sustainable Development' (United Nations, 2015; Mouratidis, 2021).

Public participation has been defined by Smith (2014) as the inclusive process that grants those affected by a decision the opportunity to provide input into that decision (L. G. Smith, 1983). Public participation allows the interaction between the stakeholders, thus fostering the understanding of their aspiration, the sharing and stimulation of proposals and ideas, and the promotion of empowerment and awareness among the actors. While these advantages appear undoubtedly relevant for the achievement of an effective and qualitative urban planning (Semeraro et al., 2020), there are challenges that need to be considered in these kind of processes. *What and in what measures are citizens and stakeholders participating? Which processes can be defined as participatory processes?* Researchers and decision-makers who aim to set up participatory processes pertaining to the higher end of Arnstein's ladder (Arnstein, 1969) need to carefully evaluate and take into account the objectives entailed by participation. The features of some participatory processes make them susceptible to result in the instrumentalization and disregard of the emotions of the participants. Furthermore, giving the stakeholders illusions of power may imply feelings of dissatisfaction that should be avoided in participatory processes (Arnstein, 1969). In the highly uncertain and evolving context of climate change, this topic gains particular relevance (Few et al., 2007) and must be especially considered within the peculiarities of the Internet age in which new instruments and contexts emerge (Tang & Waters, 2005).

[48] The introduction of Section §2.3, and Subsections §2.3.1 and §2.3.2 have been adapted by the author based on 'De Noia, I., Caselli, B., Kemperman, A., Rossetti, S., & van der Waerden, P. (2024). Towards participatory urban planning: insights from citizens. Results of a public questionnaire on climate change and its local effects in Parma. *TeMA - Journal of Land Use, Mobility and Environment, 17*(2), 193-212. https://doi.org/10.6093/1970-9870/10836' in which she is co-author. The published article encompasses the full attributions of the work.

2.3.1 Top-down and bottom-up approaches

When considering public participation in urban transformation processes, the existence of bottom-up and top-down approaches can be recognised. Furthermore, processes that foster the integration of these two approaches are also recognisable.

In the framework of this research, **top-down models** are intended as those urban processes that include soil desealing in the urban planning and governanc e tools, thus reflecting the initiative of the administration, which may also promote the identification of the suitable areas to implement soil desealing. This means that the implementation of these actions can happen on a large scale and in a widespread manner (Caselli, Ceci, et al., 2024).

Bottom-up approaches are characterised by private individuals, associations or other stakeholders which recognise a need for these interventions and promote soil desealing actions. The initiative is therefore considered private and entail greater citizens' and stakeholders' involvement, and thus also a higher acceptance of the interventions. The interventions themselves are perceived as a tangible step towards urban resilience, as opposed to the development of instruments that may be perceived as more distant as they remain at a normative-programming level (Caselli, Ceci, et al., 2024). Bottom-up processes have been recognised in literature as capable of addressing many environmental, social and economic challenges posed by climate change (i.a., Strange et al., 2022; Vaňo et al., 2021; D'Ascanio & Palazzo, 2023), also within urban development and regeneration (i.a., Canesi et al., 2022; Mayrhofer, 2018). Authors have approached this topic from a variety of points of views, for instance investigating applicative case studies (i.a., Geropanta et al., 2022; Nicolini & Pinto, 2013; Vogt, 2002) or drafting taxonomies and reviews of the existing approaches (i.a., Seve, Redondo, et al., 2023; Meroni & Selloni, 2022).

Researchers (i.a., De Lange et al., 2020; Semeraro et al., 2020) have also highlighted the relevance of the integration of bottom-up processes in the traditional top-down practices as opposed to the traditional top-down processes. Furthermore, in both bottom-up and top-down public participation approaches, co-design and co-planning represent tools and strategies that allow the collaboration of the actors with digital or physical supports (Sharifi et al., 2017; Stelzle et al., 2017).

2.3.2 Emerging tools for citizens' involvement

In the context of co-design and co-planning - appearing especially relevant in the Information Age and in light of the lessons from the recent pandemic - the role of digital technologies has gained importance (Sharifi et al., 2017; Stelzle et al., 2017) allowing for a more flexible management of space and time constraints.

For instance, Ranjbar Nooshery et al. (2017) have investigated public participation geographical information systems in the context of increasing urban resilience, as well as a method to involve the citizens and systematically collect their spatialised input, similarly to those who studied participatory mapping (Schröter et al., 2023) to solicit the citizens' insight in participatory processes.

Furthermore, surveys have emerged as valuable tools for gathering social data from the citizens and characterising their attitude, also at the local scale (Balram & Dragićević 2005). Franco & Cappa (2021) highlighted the relevance of surveys as valuable instruments for quantitative outcomes in the framework of urban citizen science, believing in their ability to highlight the peculiar characteristics of the urban areas. In the framework of the

'Steinitz method' of landscape evaluation (i.e., a participatory method to foster the participants to understand and express their preferences about landscapes), Cervera et al. (2021) employed surveys to test the community perception before and after the implementation of bottom-up urban acupuncture interventions.

2.4 Lights and shadows[49]

The previous sections have emphasised how the definitions and state of the art associated with soil desealing highlight the lack of unanimity at the international level regarding the terminology and definitions used to refer to this topic. A similar situation exists at the national level in Italy, where a variety of terms (and their) variations are used, such as '*desigillazione*', '*depermeabilizzazione*', and '*rimozione dell'impermeabilizzazione*'.

This general lack of consensus is reflected in which actions are considered to constitute soil desealing interventions. For example, while some soil desealing actions are recognised by their specific identity, at other times they are simply referred to as a more general "increase of soil permeability". Here lie also the explanations behind the difficulty in mapping and surveying desealing actions, strategies and legislation. In this context, sustainable energy and climate action plans may represent relevant aggregators of information, actions and projects (Caselli et al., 2023) that could be helpful for this purpose.

Furthermore, it appears relevant to underline that, while desealing has been associated with assured environmental, social and economic benefits (Tobias et al., 2018; SOS4LIFE, 2017b; Fabbri et al., 2021; Dessì et al., 2017; Alleanza Italiana per lo Sviluppo Sostenibile, 2019; Maienza et al., 2021), it involves matters and consequences that are less addressed by researchers. For instance, the adequate management and disposal of the inert waste - which inevitably produced by the removal of a pavement - was not extensively addressed in literature (SOS4LIFE, 2017b).

The dependence of the effectiveness of soil desealing on the technical steps represents another open discussion. For instance, the characteristics of the underlying layers of the soil can influence the performance and outcomes of desealing interventions[50]. However, it seems safe to say that, supported by appropriate analyses ensuring both the effectiveness of the interventions and the non-occurrence of adverse effects, soil desealing is ensured to provide positive environmental, economic and social benefits. Even more so, when environmental benefits are partially hampered by technical choices or conditions, desealed surfaces entail an inherent representative, awareness-raising and social value.

Figure I.18 can serve as a prompt to open the debate on an important theme: *What is soil desealing?* The figure depicts the construction site of a street renovation project in Eindhoven, the Netherlands, showing a temporarily desealed road that briefly regained its original infiltration capacity. The street will then be repaved, with water collected by the infiltration channels on the sides of the road. In this context, the photograph highlights the contrast between 'proper' desealing actions and the role of technological devices. In

[49] Section §2.4 has been partially adapted by the author based on 'Caselli, B., Ceci, M., De Noia, I., Garda, E., & Zazzi, M. (2024). Towards the Integration of Soil Desealing in the Urban Areas' Transformation Processes. In A. Marucci, F. Zullo, L. Fiorini, & L. Saganeiti (Eds.), Innovation in Urban and Regional Planning (pp. 286–298). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54118-6_27' in which she is co-author. The published article encompasses the full attributions of the work.

[50] The presence of an impervious layer such as clay may hamper the precipitation infiltration into the soil following soil desealing interventions, thus possibly causing the occurrence of unmanaged surface runoff. Site-specific investigations are thus necessary to prevent these adverse effects with the appropriate countermeasures.

this thesis, **soil desealing** is intended as any action that involves the removal of an artificial layer from the soil in favour of a more permeable surface. Therefore, devices such as permeable pavements, green roofs[51], and detention ponds are considered part of desealing interventions due to their ability to restore and enhance the ecosystem services and functions provided by the natural environment. The varying performance levels and characteristics are, however, recognised.

Figure I.18 | Construction site of a street renovation in Eindhoven, the Netherlands. Source: photo taken by the author (2023).

Furthermore, both the usability of the desealed areas and the costs involved by desealing actions have not been extensively investigated in literature for the specificity of soil desealing. The literature and reference documents for the restoration of contaminated areas should be referenced when dealing with critical and delicate areas such potentially contaminated sites, and - while some documents attempt to estimate the costs of desealing interventions[52] (Gaßner et al., 2001; Ravanello, 2022; SOS4LIFE, 2020) - this framework still

[51] Green roofs present an interesting case of "z-axis offset" desealing interventions. Unlike traditional desealing methods, which focus on removing impervious surfaces, green roofs involve the removal of an artificial layer at the roof level and restore soil at the same height, linking it to drainage systems. If this detachment from the soil excludes green roofs from being classified as desealing measures, a similar debate could emerge regarding the desealing of parking lots, which similarly require water purification and collection before infiltration or storage. Therefore, the discussion would centre on the z-axis positioning and not on the fact that green roofs are able to (partially) restore conditions similar to those of the natural environment.

[52] Ravanello (2022) has provided the following insights into the costs associated with soil desealing: the costs of administrative measures aimed at reducing existing built-up areas and limiting new developments are confined to procedural expenses related to the planning process. For urban soil desealing, the removal of sealing materials is estimated at €16–20/m², including materials recycling, with an additional €5/m³ potentially required for excavating existing road foundations. The installation of permeable pavements involves €45–60/m³ for creating a filtering substrate and €70–80/m² for the new pavement. Greening a 1600 m² area includes costs of €8/m² for substrate installation, €48–50/m² for planting shrubs (8 per m² at €8 each), and €10/m² for planting trees (60 trees

raises concerns among some. Life cycle assessments of soil desealing interventions may therefore constitute a relevant research line to deepen the investigations about the benefits and issues entailed by these interventions and provide answers to these questions.

at €300 each). An additional €10/m² is needed for installing drip irrigation systems. Among the financial benefits, there are also the avoided costs and losses related to flooding of urban areas and those resulting from reduced rates of overheating in public areas.

3 Soil desealing in the European and Italian legislative and strategic framework[53]

Over the last decades, countries and international organisations have committed to reduce their greenhouse gases emissions (mitigation) and to adopt solutions to increase the resilience to climate change and its effects (adaptation). Adaptation and mitigation represent the two sides of the fight against climate change and, in order enhance their effectiveness, need to be reflected by intertwined actions (such as strategies, policies, plans, programmes and projects) at different scales. On one hand, climate change mitigation is generally addressed at the global or international level and is associated with radical changes that range from the individual scale to contingent investments on new technologies. On the other hand, climate change adaptation is generally addressed at the local level with specific actions that aim to reduce the environmental, social and economic vulnerabilities to the potential adverse effects of climate change (Bazan & Adelfio, 2015; Maragno et al., 2017), hence being especially relevant in urban planning.

This chapter investigates the European (Section §3.1) and Italian (Section §3.2) legislative and strategic scenarios that deal with soil desealing, in the wider framework of the fight against climate change and soil consumption[54].

3.1 The European framework

Within the context of the European fight against soil consumption, soil desealing can be found mainly among environmental compensation measures for new urbanisations, as seen also in the previous chapter. The 'Report on best practices for limiting soil sealing and mitigating its effects' promotes soil desealing in urban regeneration processes, highlighting, however, that it is still a rarely applied and costly practice (Jobstmann et al., 2011b). A few months after the publication of the report, these concepts were recalled and expanded in the document 'Roadmap to a Resource Efficient Europe' (EC, 2011b), in which the European Commission established the objective of 'No net land take' to be achieved by 2050. This goal, which envisions compensation mechanisms to offset the environmental impact of new constructions and permanent land transformations, is foreseen to be achieved with the creation of new green spaces, the restoration of natural systems and other initiatives that improve environmental quality (thus including also soil desealing actions). Six years after the 'Thematic Strategy for Soil Protection' and in response to the spreading environmental and climate concerns, the European Commission presented a set of guidelines to limit soil consumption (EC & DGE, 2012a), with the aim of helping local

[53] The introduction of Chapter §3 and Section §3.1 have been adapted by the author based on Marianna Ceci's research 'Ceci, M. (2025). Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana. [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.

[54] It is worth noting that, as certain aspects of the methodology which will be presented in this research reference the United States context, replacing impervious soil with permeable materials is also endorsed by institutions like the United States Environmental Protection Agency. In 2014, the Agency developed its first 'Adaptation Plan' in collaboration with other federal agencies, states, tribes, territories, local governments, and international partners to nationally and globally promote climate resilience (USEPA, 2014). Even in the latest '2024-2027 Climate Adaptation Plan', the Agency continues to encourage the incorporation of climate change adaptation into programmes, policies, regulations and processes that deal with built-up land. Examples are the promotion of nature-based solutions and green infrastructure, permeable pavements, restorations of contaminated sites and interventions on building envelopes (USEPA, 2024a, 2024b).

governments to implement spatial policies oriented towards more sustainable and strategic planning. The guidelines identify three approaches: limiting, compensating and mitigating the effects of soil sealing. The role of soil desealing appears once again as a compensation measure to restore soil and its functions. Furthermore, in this set of guidelines, soil desealing is associated with urban regeneration, envisioning the restoration of degraded urban fabric with new green spaces, thus increasing permeability and biodiversity. Similarly to the previous publications, the cost related limits of soil desealing are emphasised. In a subsequent document aimed at highlighting the issue of soil sealing, the landscape beautification that results from removing the impervious surfaces emerges as a further element (CE & DGA, 2013).

The promotion of soil desealing is also one of the priorities of the '7th Environment Action Programme (EAP) - Living well, within the limits of our planet', which deals with the protection of natural capital and ecosystem services (EU, 2013). Renaturalisation and soil desealing are encompassed among compensation measures for soil consumption also by a document from Science for Environment Policy (2016), which recalls - similarly to the '2030 Agenda' [55] - the relevance of urban and regional planning in addressing soil consumption (e.g., the 'no net land take' goal). Soil desealing can be contextualised also in the framework of the European 'Green Deal' and of the 'EU Adaptation Strategy', for what concerns both climate change adaptation and mitigation. In the 'EU Soil Strategy for 2030', the European Commission aims to - once again - give public authorities and private entities an orientation to reduce soil imperviousness and promote good soil desealing practices. Specifically, sharing good practices is encouraged as it allows to build a common methodology towards shared objectives (CE, 2021).

Despite the common underlying aim of addressing soil consumption, the 'Nature Restoration Law' brings a change of perspective with respect to the previous cases, as it promotes the increase of green areas rather than the reduction of sealed spaces (EC, 2022b). Here soil desealing finds, again, an appropriate setting for its inherent characteristic of increasing the permeable and green surfaces.

3.2 The Italian national and regional framework[56]

As recalled in the previous chapters, the limitation of soil consumption in Italy has been the aim of various draft laws that never lead to a clear legislative framework. More and more often, scholars and policy-makers emphasise the need of a national law that guarantees the protection of the environment, the territory and the Italian landscape, as well as an adequate future for the citizens. The law should foresee a sustainable land use and an increase in the urban areas resilience to be able to the face old and new challenges,

[55] The general principles and the 17 objectives of the global 2030 Agenda for Sustainable Development extensively reference a sustainable resource management. Soil desealing interventions can be associated with both Goal 11 'Make cities and human settlements inclusive, safe, resilient and sustainable' and Goal 13 'Take urgent action to combat climate change and its impacts' (United Nations, 2015). In order to foster cities and urban areas sustainability and inclusiveness, urban and regional planning need to take into account the protection of the world ecosystem and actions to restore degraded soil, similarly to what foreseen by the 'New Urban Agenda' (United Nations, 2015, 2016).

[56] Section §3.2 has been adapted and updated by the author and Marianna Ceci based on 'Caselli, B., Ceci, M., De Noia, I., Garda, E., & Zazzi, M. (2024). Towards the Integration of Soil Desealing in the Urban Areas' Transformation Processes. In A. Marucci, F. Zullo, L. Fiorini, & L. Saganeiti (Eds.), Innovation in Urban and Regional Planning (pp. 286–298). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54118-6_27' in which they are co-authors. The published article encompasses the full attributions of the work.

such as the mitigation of hydrogeological instability and the implementation of climate change adaptation policies (Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023). The Ministry of the environment and energy security (*Ministero dell'ambiente e della sicurezza energetica*) approved the 'National climate change adaptation plan' (*Piano nazionale di adattamento ai cambiamenti climatici*) (MASE, 2023b), which represents the implementation tool of the first Italian national climate change adaptation strategic plan, i.e., the 'National climate change adaptation strategy' (*Strategia nazionale di adattamento ai cambiamenti climatici*) (MATTM, 2015) developed by local entities according to the local specificities. Among the various multi-scale actions encompassed by the database attached to the Plan, actions such as sustainable water management, the increase of green spaces and soil permeability, and the improvement of the comfort and functionality of public areas can be found (MASE, 2023a).

However, climate change adaptation processes for the public space have been promoted at a local level well before the national instruments. For instance, far-sighted cities joined the Covenant of Mayors, developed sustainable energy and climate action plans, and updated their territorial governance plans (*piani di governo del territorio*) with rising attention for soil protection and a sustainable resource management, citing, among other actions, soil desealing. Italian regions (and autonomous provinces) have developed instruments to fill the gap left by the national legislative framework for dealing with the increasing soil consumption, starting to favour urban regeneration rather than expansion (Torelli, 2017). Within this context, Italian regional urban planning laws have been reflecting the European Commission '2050 no net land take' goal and have often included the concept of soil desealing and the increase of soil permeability. At the national level, soil desealing has been recently mentioned in the Senate Act No. 1028/XIX (2024), the Draft Law 'Urban regeneration and sustainable land use' (*Rigenerazione urbana e uso sostenibile del suolo*).

In order to investigate the Italian regions sensitivity to soil desealing, Pileri's (2018) approach was used: a terminological research was employed with the aim to analyse the legislative and strategic instruments in a simple way. Figure I.19 encompasses the results of this research, which involved the urban planning laws of the 20 Italian regions[57] [58].

[57] Piedmont (Draft Regional Law No. 302/2018; Bill No. 74/2020); Lombardy (Regional Law No. 12/2005; No. 24/2006; No. 31/2014 and No. 18/2019; Regional Council Resolution 5135/XI); Veneto (Regional Law No. 14/2017 and No. 14/2019); Autonomous Provinces of Trento and Bolzano (Trento: Provincial Law No. 11/2007; Bolzano: Provincial President Decree 31/2018); Liguria (Regional Law No. 23/2018); Emilia-Romagna (Regional Law No. 24/2017); Tuscany (Regulation No. 2/2007; Regional Law No. 65/2014); Marche (Regional Law No. 22/2011); Lazio (Regional Law No. 7/2017); Abruzzo (Bill No. 252/2022; Bill 4 dec. 2017); Campania (Resolution No. 527/2019); Calabria (Regional Law No. 19/2002); Sicily (Regional Law No. 19/2020).

[58] Regional sustainable development strategies have been considered as well. These strategical instruments, include sometimes direct or indirect references to soil desealing. Specifically, the Lazio Region directly references the word '*desigillazione*' (desealing) (Regione Lazio, 2021), while the Lombardy and the Sardinia Regions cite the decrease of the urban soil sealing (Regione Lombardia, 2023; Regione Sardegna, 2021).

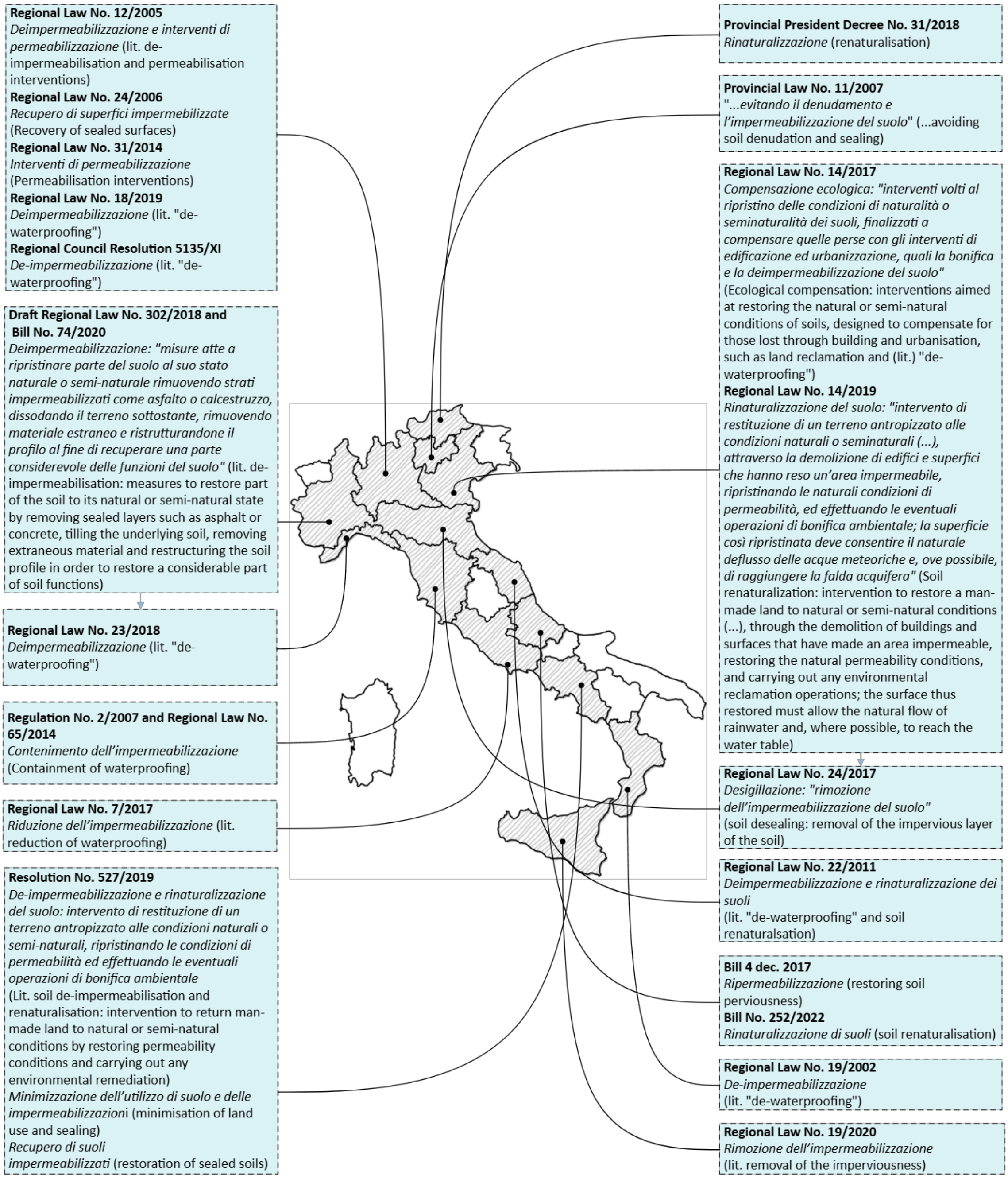

Figure I.19 | Soil desealing in the Italian regional urban planning laws. Source: result of a joint collaboration between the author and Marianna Ceci.

For what concerns the regional laws, soil desealing is not considered/mentioned in seven regions, i.e., Aosta Valley, Friuli-Venezia Giulia, Umbria, Molise, Apulia, Basilicata and Sardinia. In the remaining ones, soil desealing is referenced with a variety of terms, for instance '*deimpermeabilizzazione*' (lit. *dewaterproofing*), '*rinaturalizzazione*' (lit. renaturalising), '*rimozione dell'impermeabilizzazione*' (lit. removing the imperviousness), through which Italian regions explicit their intention of increasing the urban soil permeability.

The Regional Law No. 24/2017 of the Emilia-Romagna Region is the only one that uses the term '*desigillazione*' (desealing), while '*deimpermeabilizzazione*' (lit. de-waterproofing) is generally more widespread. Piedmont, for instance, in the Draft Regional Law No. 302/2018, defines '*deimpermeabilizzazione*' as a measure to restore a natural or semi-natural state of the soil (or a part of it). Furthermore, it explains that the sealed soil layers such as asphalt or concrete must be removed, the underlying soil must be tilled, and foreign material must be removed to restore a considerable part of the soil functions. The Regional Law No. 14/2017 of the Veneto Region, on the other hand, intends soil desealing as a compensation measure.

The terminological fragmentation and different consideration (or lack) of the concept of soil desealing observed in the Italian regions may depend on the different geomorphological and political characteristics of the Italian peninsula. Furthermore, this emphasises that, despite the efforts made at the local scale, considerable efforts still need to be made to integrate soil desealing at all Italian legislative and strategic levels.

4 On the steps of a new consideration of soil in the urban regeneration practices of medium-sized Italian cities

The relevance addressing soil consumption in urban areas has been acknowledged, especially in the framework of urban climate change adaptation and mitigation of the urban pluvial flood and urban heat island risk (see Chapter §1). The necessity of switching the perspective, integrating an increase of soil permeability in the urban transformation processes finds an answer in soil desealing. The existing literature highlights a growing recognition about its relevance in the climate change adaptation processes of European and Italian cities, opening new discussion scenarios and implementation chances. However, a specific framework for soil desealing has started to emerge only in recent years, highlighting the limitations of the working and research context surrounding this concept. Among all of them, one of the main critical themes is the absence of a clear and structured lexical and normative framework (see Chapters §2 and §3). For instance, it can be argued that the absence of a clear terminology reflects and results in the fragility of the applicative and theoretical spheres. An example is represented by the difficulties that can be encountered in building a structured and exhaustive state of the art review. However, despite these issues, the restoration of the soil permeability has been overall agreed to provide benefits in the urban journey towards climate change resilience. Among them, the positive outcomes of soil desealing are represented by the increase in quality, safety and liveability of the urban open spaces, as well as in the environmental benefits such as those on the hydrological cycle (see Chapter §2). The need of identifying the appropriate tools and methods to ensure the effectiveness of soil desealing becomes fundamental.

Within this context, involving the city users (thus the citizens and stakeholders) appears indispensable in climate change adaptation processes. In addition to the traditional top-down practices, bottom-up processes have been recognised and investigated as possible effective strategies for fostering soil desealing and positive impacts on all the sustainability spheres. Furthermore, it has been argued that citizens' involvement and empowerment in the urban transformation processes may be enhanced by the integration of top-down and bottom-up approaches. Integrated approaches may entail the necessary conditions for 'levelling the playground' and establishing a constant dialogue between citizens and the public decision- and policy-makers, recognising the vital role of communication and constant exchange of information, opinions and knowledge for shared processes. Furthermore, they may be able to allow citizens to feel heard, and the administration to intervene effectively (see Section §2.3 and Pissourios, 2014; Caselli, Ceci, et al., 2024).

On these steps, the definition of appropriate localisation and intervention criteria, as well as the identification of the relevant tools for the implementation of soil desealing gain importance. This research tries to contribute to find an answer to these challenges and to the unavoidably linked matters, in the specific framework of reducing the urban pluvial flood risk. *What are the most critical urban areas, and are desealing interventions feasible in those locations? What are the priority intervention areas?* These questions open topics such as the definition of the urban transformation potential, in all its declinations (e.g., public/private; used/unused; ...). Furthermore, the relationship between the city and the urban soil is associated with the definition of the appropriate tools to intervene, in a context that lacks a structured national framework that relies on more or less effective local initiatives and approaches (see Chapters §1 and §3). The German approach, with its set of country level policies for the limitation, compensation and mitigation of soil consumption reflected in municipal actions (see Subsection §2.2.2), suggests that a national direction towards soil desealing may be relevant for systematising these interventions.

The realisation of the necessity of a new welfare able to provide the community with the right of health, education, public mobility, housing and cities in the framework of the city being the hotspot of the manifestation of the adverse effects of climate change poses particular attention on urban regeneration and territorial rebalancing as the setting for these transformations (Ricci & Mariano, 2022), also in the context of soil desealing.

4.1 The role of Italian medium-sized cities

In this context, the framework of medium-sized Italian cities constitutes an ideal test-field to rethink the relationship between soil and city, thus understanding its transformation potential in association with the urban planning tools and climate change scenarios such as the mitigation of the urban pluvial flood risk.

4.1.1 Definition[59]

One of the first definitions of medium-sized cities comes from the United Nations Centre for Human Settlements (Habitat) (1996), which defined them as cities capable of hosting a population ranging from 100,000 to 500,000 inhabitants at a given time, according to Kingsley Davis's classification (Davis, 1955). However, the concept of the 'medium-sized city' does not have a precise definition, as its categorisation varies depending on the urban and territorial context, the state it belongs to, and the governing body involved (ANCI-IFEL, 2013). This ambiguity was also highlighted by Santamaria (2000).

Table I.12 encompasses an overview of the results of the literature review concerning the definition of medium-sized city, which has highlighted the existence of different terms for referring to this concept as well (i.a., 'medium city', 'secondary city', 'medium-sized town', 'medium-size urban areas', 'medium-size urban centre', 'medium-sized entity', 'mid-size city', 'mid-size urbanity', and the Italian composite words '*città media*', '*città di media dimensione*', '*centro urbano medio*', '*realtà media*').

[59] This subsection is partially based on Giulia Pedilarco's work, who, in the framework of her Ph.D. research within the Urban and regional planning research group of the University of Parma, has collaborated to the study of medium-sized cities. Specifically, Table I.1 was elaborated by the author, while the text of the subsection is a translation and partial elaboration of a text written by Giulia Pedilarco.

MEDIUM-SIZED CITY	***Author, year***	***Criteria for the definition or identification of medium-sized cities***
GLOBAL LEVEL	Angel et al., 2016	Ranking the cities in increasing order of their population and then dividing them in four ranges - small, medium, large, and very large cities - so that each of the four ranges contained approximately the same total population.
	OECD - Organization for Economic Co-operation and Development, 2014	Population: 200.000-500.000
	United Nations Centre for Human Settlements (Habitat), 1996	Population: 100.000-500.000 (based on Kingsley Davis)
EUROPEAN LEVEL	Eurotowns, n.d.	Population: 50.000-250.000
	Servillo et al., 2014	Population and density: the basic morphological classification defines Small and Medium-Sized Towns as continuous urban clusters with a population above 5.000 and a density above 300 inh/sqkm.
	ESPON, 2006	Location: a small or medium-sized town could be a town or urban area that is located outside of the metropolitan or large city regions (basic definition)
	UE & CE, 2003	Population: 50.000-250.000
ITALIAN LEVEL	Clerici, 2017	Presentation of various sources and concepts: - specific territorial capitals; - "real unidentified object" (Brunet, 1997); - vague concept, population 20.000-200.000 (Kunzmann, 2010); - localisation of present functions, relationship texture, urban cluster (ESPON, 2014); - role in the relational networks (Carriére, 2008); - division into three subcategories in the context of the relational networks (Nadou, 2010); - localisation (Kunzmann, 2010); - population: 30.000-500.000 (DATAR, 2012); - ambiguous concept (Accordo di partenariato 2014-2020); - ambiguous concept (Cori et al., 1978); - >45,000 and no metropolitan cities, services offered, role of urban authorities, indeterminate concept (Accordo di partenariato 2014-2020); - >45,000 and no metropolitan cities, administrative role, services offered (IFEL, 2013); - metropolitan cities; provincial capitals or individual municipalities; similar to FUAs (Italian regions); - ambiguous concept.
	ANCI-IFEL, 2013	Presentation of various sources and concepts: - population: 50.000-250.000, qualitative criteria (ESPON, 2006); - population: 50.000-250.000 (INTELI, 2011); - population: 50.000-250.000 (EC, 2002); - population: 50.000-250.000 (Eurotowns);

MEDIUM-SIZED CITY	***Author, year***	***Criteria for the definition or identification of medium-sized cities***
		- population: 50.000-250.000 (Tocci, 2010); - population: 20.000-200.000 (Kunzman, 2009); - population: 80.000-200.000 (Legambiente); - functional equipment (Lemmi, 2007) - qualitative classification based on the essential functions (Germany, *Bundesministerium für Verkehr, Bau- und Wohnungswesen*, 2004); - population; 25.000-120.000, dimensional and functional criterion (Santamaria, 2000); - >50,000, potential housing hardship, socioeconomic hardship (Campania Region, 2008); - provincial capitals (Consiglio italiano per le Scienze Sociali, 2011); - population: ~290.000 (EC, 2010); - increased quality of life, role of "decompression".
	Donaldson et al., 2020	Non-standard concept; localisation; additional role for functions.
	Escudero Gómez et al., 2019	Services, well-defined territorial structure (infrastructure, administrative units...), role as intermediaries; non-standard concept.
LITERATURE	Roberts, 2014	Presentation of various sources and concepts: - population, localisation, role, history, economy, non-standard concept. - population: 100.000-500.000 (UN-Habitat, 1996); - non-standard concept; - system of functions (Christaller, 1933); Christaller, 1966; Hall, 2005; Abdel-Rahman and Anas, 2012); - satellite cities (Angel et al., 2012); - smaller and more specialised than first rank cities with reference to developed countries (Freidman, 1986); - non-standard concept, functional role, >100,000 to...? (Song, 2013 and scholars); - functional role; - >100,000 but < of big cities (Rondinelli, 1982); - vague concept (UN, 2012); - smaller than primary cities (South African Cities Network); - function and scope in addition to size and hierarchy (World Bank, 2011); - hierarchy (Christaller, 1933); - further classification based on Christaller (Hall, 2005); - structural position in the urban network in addition to population sizes, surface areas or other statistical measures (Song, 2013) - scope, scale, functions, networks and market/business orientation - localisation, global business, services, population: 100.000-5.000.000, capitals or provinces, etc... (link to Hall work);

MEDIUM-SIZED CITY	***Author, year***	***Criteria for the definition or identification of medium-sized cities***
		- dimension, function, role, subcategories. 10-50% of the inhabitants of the largest cities, population: 100.000-5.000.000, administrative role, services, network.
	Roberts & Hohmann, 2014	Presentation of various sources and concepts: - population: 150.000-5.000.000, functions, services, non-standard concept, >100,000 but not the largest city in the country. - population: 100.000-500.000 (UN-Habitat) - part of a functional system (Other authors) - satellite cities, subcategories (Angel et al.) - population, dimension, functions, economy, 10-50% inhabitants of larger cities, poles of a network.
	Hohmann & Roberts, 2014	Population: 100.000-750.000; division in subcategories.
	Bolton & Hildreth, 2013	Population: 250.000-500.000
	INTELI – Inteligência em Inovação, Centro de Inovação, 2011	Population: 50.000-250.000; development poles (ESPON, 2006; RePUS, 2007).
	Kunzmann, 2009	Non-standard concept; population: 20.000-200.000 depending on the population density and the respective urban system in a country (Rivkin/Rivkin 1982, Rondonelli 1993; European Foundation 1994); functions; services.
	Hildreth, 2007	Offer of localised economies; characterised by a dynamic economic role change.
	Vey & Forman, 2002	Rank of cities based on their population

Table I.12 | Review of the definitions of medium-sized cities. Search keywords, in both Italian and English: '*centro medio*'; '*città media*'; 'medium sized city', 'mid-sized city', 'secondary town/city', 'intermediate city', 'second-order city'. Source: author's elaboration.

At the international level, the concept of 'medium-sized city' varies significantly, primarily based on the population residing within it. Cities in Asia tend to have a much higher population density compared to European cities, which, in turn, far exceed the population density of cities in the United States (United Nations Centre for Human Settlements (Habitat), 1996). Therefore, the geographical location is one of the main factors that must be accounted for.

For what concerns the European context, a high percentage of the population is distributed between small and medium-sized cities rather than large cities and metropolises. The number of European medium-sized cities is significant, to the point that they can be considered the typical city (Dehaene et al., 2013). Furthermore, these are characterised by a historical-geographical heritage, and they function both independently within an archipelago of European cities or as part of a network (Dehaene et al., 2013).

In the Italian peninsula, the medium-sized city is considerably smaller when compared to the European context. With the aim of finding a final definition for medium-sized cities, the foundation Institution for Finance and Local Economy (*Istituto per la Finanza e l'Economia Locale*) founded by the National Association of Italian Municipalities (*Associazione Nazionale dei Comuni Italiani*) ANCI-IFEL (2013), assessed all Italian municipalities based on demographic, economic, and productive criteria, as well as on the administrative and functional roles they perform. Urban hubs that were not metropolitan cities but had at least 45,000 inhabitants and specialised in the secondary or tertiary sectors were identified. These characteristics allowed for the identification of 94 administrations across Italy.

It is interesting to note that in the Emilia-Romagna region, all the provincial capitals, except Bologna, are considered medium-sized cities. This becomes particularly evident when comparing the region to others in Italy. For example, in regions like Sicily and Sardinia, some provincial capitals do not meet the criteria of medium-sized cities. On the contrary, in regions such as Piedmont and Lombardy, some towns within larger urban agglomerations are classified as medium-sized cities (ANCI-IFEL, 2013). Consequently, it is not always true that evaluating functions and demographics alone is sufficient.

4.1.2 Relevance

Medium-sized European and Italian cities constitute a peculiar and significative case to investigate the role of soil desealing in urban regeneration practices, for a multiplicity of reasons.

First of all, their importance is highlighted by the fact that 20% of the European population lives in such cities (Selada et al., 2013)[60]. European medium-sized cities have been the object of programmes such as URBAN II (EC, 2000), and of research and studies (ESPON, 2006; Servillo et al., 2014), in order to foster their sustainable development. If metropolitan urban areas can activate plans, programmes and attract international funding for their climate transition policies, as well as easily joining networks for the diffusion of knowledge, medium-sized cities can provide an essential contribution in territorial polycentric and balanced development (Clerici, 2017; Tedeschi, 2023), responding to challenges similar to those that bigger cities are asked to address. An additional advantage of medium-sized cities lies in their capacity to implement statutory plans with a more comprehensive approach. Unlike metropolitan cities, where the scale is often too broad to achieve exhaustiveness, medium-sized cities provide a manageable context for policies and projects (Mazza, 2013).

4.2 Soil desealing in Italian urban regeneration practices

When addressing urban areas transformability, it is essential to explore the concept of urban regeneration, which encompasses various approaches aimed at improving the liveability of degraded areas. The approaches vary depending on local goals, practices, and political agendas, reflecting the diverse ways in which communities and governments aim or have aimed to revitalise urban spaces over the years.

[60] In Italy, due to the growing relevance of medium-sized cities, it was considered appropriate to draft a dedicated programme for medium-sized cities (Comitato Interministeriale per le politiche urbane, 2013). This footnote is based on Giulia Pedilarco's work, who, in the framework of her Ph.D. research within the Urban and regional planning research group of the University of Parma, has collaborated to the study of medium-sized cities.

Historically, post-war 'urban renewal' emerged first, focusing on public health and wellbeing to address Europe affordable housing shortage. In the 1970s and 1980s, urban redevelopment expanded this scope, prioritising socioeconomic issues like unemployment and education over physical planning (Neto et al., 2014). The term 'urban regeneration' was first introduced in English urban planning during the 1970s. More recently, the 'New Urban Agenda' has included this concept in point No. 97 of its implementation plan, highlighting the multifaceted nature of urban regeneration: "We will promote planned urban extensions and infill, prioritizing renewal, regeneration, and retrofitting of urban areas, as appropriate, including the upgrading of slums and informal settlements, providing high-quality buildings and public spaces, promoting integrated and participatory approaches involving all relevant stakeholders and inhabitants, and avoiding spatial and socioeconomic segregation and gentrification, while preserving cultural heritage and preventing and containing urban sprawl" (United Nations, 2016). Within the context of the 'Agenda 2030' (United Nations, 2015), the promotion of an integrated and interscalar public government for fostering the resilience of cities through urban regeneration is encompassed by European Union policies (e.g., State Aid Control and Regeneration of Deprived Urban Areas, 2007; Territorial Agenda of the European Union, 2020; Towards an Inclusive, Smart and Sustainable Europe of Diverse Regions, 2011). Furthermore, urban regeneration finds further operational reference in the 'New Green Deal' (2019), the 'Just Transition Fund' (2021) and the 'Horizon Europe Programme' (2021/2027).

The European Commission reports that "regeneration typically designates a renewal process, i.e. some form of repair or improvement. In the context of public policy, the term is used to describe courses of action to transform some set of physical and socioeconomic variables. A regeneration process is therefore commonly targeted at revitalising problem areas – namely by addressing shortcomings in natural and built environments, heritage conservation, social integration and employment and economic activities – in cities and their surroundings, but also in rural settings" (EC, 2006b). Therefore, it can be said that **urban regeneration** aims to pursue cohesive, just and sustainable urban environments, with its dual focus on material improvements and the empowerment of citizens and communities (Palazzo & Cappuccitti, 2024).

In Italy, the term '*rigenerazione urbana*' has been used since the 2000s - i.a., by the Associazione Aree Urbane Dismesse (Associazione Aree Urbane Dismesse (AUDIS), 2008) - following a variety of other terms such as '*recupero', 'riqualificazione', riuso*' used to refer to the pursue of adaptation and renovation of urban heritage for the protection of the weakest groups rights (Palazzo & Cappuccitti, 2024). Indeed, Italian experimentations with urban regeneration started in the 1990s[61], contextually to the application of European Union policies. Among them, a focus on the social dimension, both for what regards socioeconomic aspects and public participation can be observed.

Within the close connection between urban regeneration and urban policies and planning, Palazzo & Cappuccitti (2024) identified two main features in recent literature concerning urban regeneration processes, namely:

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[61] However, the attention to the built environment had been already emphasised by Law No. 457/1978, the 'Residential Standards' (*Norme per l'edilizia residenziale*) which envisioned the identification by the municipalities (in urban general plans) "of areas where, due to their deteriorated conditions, it is appropriate to recover the existing building and town-planning heritage by means of interventions aimed at the conservation, rehabilitation, reconstruction and better use of the heritage itself. These areas may include individual buildings, building complexes, blocks and areas, as well as buildings to be used for equipment".

- public commissioning: strategic provisions aiming for a specific vision of cities, including low-carbon development;
- governance systems: these address decision-making quality, policy effectiveness, and inclusivity in public participation (Palazzo & Cappuccitti, 2024).

Urban regeneration - with its diverse and non-standardised applications[62] - often, and even more in the framework of climate change adaptation and mitigation, pursues the restoration of the relationship between the built and natural environment through specific projects that physically (and/or functionally) enhance the urban area without contributing to soil or resource consumption (Palazzo & Cappuccitti, 2024). The importance of urban regeneration in limiting soil consumption and addressing climate change challenges has been stressed also by Munafò (2023), who, with the last 'Report on Soil consumption, territorial dynamics and ecosystem services' (*Consumo di suolo, dinamiche territoriali e servizi ecosistemici*) emphasised that interventions should focus exclusively on the existing built environment, thereby avoiding additional land consumption. Furthermore, the report draws attention to the concept of no net land take and the necessity of national and regional coordination to define targets for reducing soil consumption and promoting soil desealing (Consumo di suolo, dinamiche territoriali e servizi ecosistemici, 2023).

However, urban regeneration has not been regulated by the Italian national legislation [2024]. It has also been argued that the traditional Italian tools for the construction of the city (i.e., the municipal urban plans, the expropriation processes and the urbanisation costs) are inadequate for dealing with the new social-economic and environmental issues posed by climate change, requiring changes in urban planning (Ricci & Mariano, 2022). These ideas are reflected in the 'Decalogue for urban regeneration' (*Decalogo per la rigenerazione urbana*), published by the Italian *Associazione Nazionale Costruttori Edili ANCE* in 2022 which aims to provide guidance in these regard (ANCE, 2022). At the national level, attempts have been made to provide a superordinate regulation on both urban regeneration and soil consumption (e.g, with the Chamber Act No. 2039/XVII (2016), the Draft Law 'Containment of soil consumption and reuse of built-up land' (*Contenimento del consumo del suolo e riuso del suolo edificato*) and the Senate Act No. 1028/XIX (2024), the Draft Law 'Urban regeneration and sustainable land use' (*Rigenerazione urbana e uso sostenibile del suolo*) which follow the group of Draft Laws that started with the Senate Act No. 1131/XVIII (2019), the Draft Law 'measures for urban regeneration' (*Misure per la rigenerazione urbana*)).

At the regional level, however, Italian regions have developed laws that deal with urban regeneration, referring to the reform of Title V of the Italian Constitution which sees territorial governance as a concurrent State-Regions matter (Table I.13[63]). Among them, the Regional Law No. 24/2017 of the Emilia-Romagna Region (see also Subsection §1.1.4) has the aim of switching the urban development model for one that promotes a growth that keeps into account the urban care and protection rather than soil consumption, promoting soil desealing interventions and specifying their role in the 'no net land take' context (see '*Capo I*' of the Law).

[62] For instance, Palazzo & Cappuccitti (2024) have underlined the connection between urban regeneration and placemaking, which considers the unique characteristics of locations and prioritises the interests of local communities.

[63] This table is based on Gloria Pellicelli's and Silvia Vitelli's research which was carried out within the Urban and regional planning research group of the University of Parma. Their research examined the regional legislative framework for urban regeneration and is updated to May 2023.

Italian region	*References to urban regeneration in the regional legislation*
Abruzzo	• **New Regional Law** TITLE II 'General provisions for territorial protection' (*TITOLO II - Disposizioni generali per la tutela del territorio*), CHAPTER I 'Zero net land consumption and promotion of urban regeneration and redevelopment' (*Consumo del suolo a saldo zero e promozione della rigenerazione e riqualificazione urbana*), Articles 8–20
Basilicata	-
Calabria	• **Regional Law No. 25/2022** 'Amendments and additions to Regional Law No. 19/2002 'Rules for the protection, governance, and use of the territory – Urban Planning Law of Calabria' (*Modifiche e integrazioni alla Legge regionale n. 19/2002 'Norme per la tutela, governo ed uso del territorio – Legge urbanistica della Calabria'*)
Campania	• **Regional Law No. 13/2022** 'Provisions on building simplification, urban regeneration, and redevelopment of existing building stock' (*Disposizioni in materia di semplificazione edilizia, di rigenerazione urbana e per la riqualificazione del patrimonio edilizio esistente*)
Emilia-Romagna	• **Regional Law No. 24/2017** 'Regional discipline on soil protection and land use' (*Disciplina regionale sulla tutela e l'uso del suolo*), which repeals and replaces the previous **Regional Law No. 20/2000** 'General discipline on territorial protection and use' - *Disciplina generale sulla tutela e l'uso del territorio'* and subsequent amendments, including part of Regional Law No. 6/2009 'Governance and socially responsible redevelopment of the territory' (*Governo e riqualificazione solidale del territorio*), Titles I and II
Friuli-Venezia Giulia	• **Regional Law No. 21/2015** 'Disposizioni in materia di varianti urbanistiche di livello comunale e contenimento del consumo di suolo' (Provisions on urban planning variants and limiting land consumption)
Lazio	• **Regional Law No. 7/2017** 'Provisions for urban regeneration and building recovery' (*Disposizioni per la rigenerazione urbana ed il recupero edilizio*)
Liguria	• **Regional Law No. 23/2018** 'Provisions for urban regeneration and the recovery of agricultural territory' (*Disposizioni per la rigenerazione urbana e il recupero del territorio agricolo*)
Lombardy	• **Regional Law No. 18/2019** 'Measures for simplification and incentives for urban and territorial regeneration, as well as for the recovery of existing building stock. Amendments and additions to Regional Law No. 12/2005 'Law on territorial governance' and other regional laws' (*Misure di semplificazione e incentivazione per la rigenerazione urbana e territoriale, nonché per il recupero del patrimonio edilizio esistente. Modifiche e integrazioni alla Legge regionale n. 12/2005 'Legge per il governo del territorio' e ad altre leggi regionali*)
Marche	• **Regional Law No. 22/2011** 'Rules on sustainable urban redevelopment' (*Norme in materia di riqualificazione urbana sostenibile*), as amended by Regional Laws No. 44/2013, 16/2015, 28/2015, and 8/2018) **Regional Law 14/2021** 'Provisions on urban regeneration and building activities. Amendments to Regional Law No. 22/2011, and Regional Law No. 22/2009' (*Disposizioni in materia di rigenerazione urbana e attività edilizia. Modifiche alla Legge regionale n. 22/2011 2011 e alla Legge regionale n. 22/2009*)
Molise	• **Regional Law No. 17/2012** 'Amendments to Regional Law No. 31/2008 'Interventions in favor of urban redevelopment'' (*Modifiche alla Legge regionale n. 31/2088 'Interventi a favore della riqualificazione urbana'*)
Piedmont	• **Regional Law No. 16/2018** 'Measures for the reuse, redevelopment of buildings, and urban regeneration'

Italian region	*References to urban regeneration in the regional legislation*
	(*Misure per il riuso, la riqualificazione dell'edificato e la rigenerazione urbana*) **Regional Law No. 7/2022** 'Rules on simplification in urban planning and constructions (*Norme di semplificazione in materia urbanistica ed edilizia*)
Autonomous Province of Bolzano	• **Provincial Law No. 9/2018** 'Territory and landscape' (*Territorio e paesaggio*), coordinated with amendments introduced (updated as of August 19, 2022)
Autonomous Province of Trento	• **Provincial Law No. 5/2021** 'Urgent simplification measures in building, urban planning, and local authorities' (*Misure urgenti di semplificazione in materia di edilizia, urbanistica ed enti locali*)
Apulia	• **Regional Law No. 21/2008** 'Rules for urban regeneration' (*Norme per la rigenerazione urbana*). **Regional Law of No. 20/2022** 'Rules for reuse and building redevelopment and amendments to Regional Law No. 33/2007 'Recovery of attics, porches, semi-basements, existing interventions, and unauthorized public areas' (*Norme per il riuso e la riqualificazione edilizia e modifiche alla Legge regionale n. 33/2007 'Recupero dei sottotetti, dei porticati, di locali seminterrati e interventi esistenti e di aree pubbliche non autorizzate'*)
Sardinia	• **Law No. 1 of January 18, 2021** 'Provisions for the reuse, redevelopment, and recovery of existing building stock and in territorial governance. Extraordinary urgent measures and amendments to Regional Laws No. 8/2015, No. 23/1985, No. 24/2016, and No. 16/2017' (*Disposizioni per il riuso, la riqualificazione ed il recupero del patrimonio edilizio esistente ed in materia di governo del territorio. Misure straordinarie urgenti e modifiche alle leggi regionali n. 8/2015, n. 23/1985, n. 24/2016 e n. 16/2017*)
Sicily	• **Law of August 13, 2020, No. 19** 'Rules for territorial governance – Coordinated text' (*Norme per il governo del territorio - TESTO COORDINATO*) (Regional Laws No. 36/2020 and No. 2/2021)
Tuscany	• **Regional Law No. 65/2014** 'Rules for territorial governance' (*Norme per il governo del territorio*), as amended by Regional Laws No. 43/2016, 91/2016, and 50/2017, replacing the previous Regional Law No. 1/2005 (*Norme per il governo del territorio*).
Umbria	• **Regional Law No. 15/2021** 'Further modifications and integrations to Regional Law No. 23 of November 28, 2003 (Reorganization rules in social housing)' (*Ulteriori modificazioni ed integrazioni alla Legge regionale n. 23/2003 - Norme di riordino in materia di edilizia residenziale sociale*)
Aosta Valley	-
Veneto	• **Regional Law No. 14/2019** 'Veneto 2050: Policies for urban redevelopment and renaturalisation of the territory and amendments to Regional Law No. 11/2004' (*Veneto 2050: politiche per la riqualificazione urbana e la rinaturalizzazione del territorio e modifiche alla Legge regionale 11/2004*) **Regional Law No. 19 of June 30, 2021** 'Simplifications in urban and building matters for the revival of the construction sector and the promotion of urban regeneration and containment of land consumption – Veneto Fast Construction' (*Semplificazioni in materia urbanistica ed edilizia per il rilancio del settore delle costruzioni e la promozione della rigenerazione urbana e del contenimento del consumo di suolo - Veneto cantiere veloce*)

Table I.13 | Italian regional legislation that references urban regeneration urban regeneration. Source: translation based on Gloria Pellicelli's and Silvia Vitelli's research. Last updated in May 2023.

Within this framework, the next paragraphs present an overview on the strategic and legislative instruments that have promoted soil desealing in the framework of addressing climate change and the increasing soil consumption.

Strategic and legislative instruments[64]

Among the strategic instruments, sustainable energy and climate action plans consist of voluntary tools that, in alignment with the traditional planning tools, guide cities that joined the Covenant of Mayors' climate network towards a resilient transition and help raising awareness of climate change and its related countermeasures[65] (Neves et al., 2016).

These plans constitute an interesting case study in the framework of climate change adaptation and soil desealing, as they integrate climate strategies and their practical implementation. Furthermore, the investigation of both their role in the urban planning scenario and their relationship with the traditional urban planning tools appears to be in the first phases and therefore relevant matters to discuss may emerge (Caselli et al., 2023; Tedeschi, 2023). Furthermore, the Covenant of Mayors played a crucial role in its early years, when it helped to develop climate strategies in European cities (Tedeschi, 2023). However, its current role is debatable (Tedeschi, 2023) due to the spread of tools to address climate change that may have gained greater importance than the sustainable energy and climate action plans.

Within the research framework of the current doctoral research, several sustainable energy and climate action plans of medium-sized Italian cities have been analysed, to unveil their references and relations with soil desealing and, additionally, analyse the role of this strategic tool in this context. The sustainable energy and climate action plans of the medium-sized Italian cities of Padua, Parma, Forlì, Piacenza, Mantua and Modena have been considered. The cities were chosen according to their pertinence to the 'Po Valley Megalopolis' (*Megalopoli Padana*) which, as recalled in the first chapter of this thesis, is one of the Italian areas where the municipal soil consumption percentages are higher (Figure I.4 and Figure I.5).

The analysis showed that despite sharing - on a general level - similar structures and contents, the sustainable energy and climate action plans express different sensitivity levels and approaches for increasing urban resilience. For instance, sections involving adaptation and mitigation measures are sometimes merged, while some other times they

[64] The following paragraphs have been partially adapted by the author based on 'Caselli, B., Ceci, M., De Noia, I., Garda, E., Tedeschi, G., & Zazzi, M. (2023). Achieving adaptation in medium sized cities: The contribution of urban climate transition strategies in increasing soil permeability. *Integrated Planning in a World of Turbolence* (*Book of Proceedings*), *2*, 620–664.' in which she is co-author (the published article encompasses the full attributions of the work) and on Marianna Ceci's research 'Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana.* [Doctoral thesis (submitted), University of Parma. Department of Engineering and Architecture]'.

[65] The 'Covenant of Mayors for climate and energy' was launched in Europe in 2008 and at a global level in 2015. The goals are reducing the greenhouse gases emissions and improving the urban energy management, based on the principles of transparency, flexibility, data evaluation and exchange of knowledge. Aligning with the 'Green Deal' and '2030 Agenda' context, as well as with the Paris Agreement, the signatories of the Covenant of Mayors committed to keep the global temperature rise below 1.5°C. Among the Covenant of Mayors goals, emerge the creation of a network of cities (the Covenant of Mayors supports bottom-up initiative, multilevel cooperation), as well as an increase of the awareness of the population about climate change adaptation and mitigation. In practical terms, cities that joined the climate network adopt a context-driven local action plan. The first generation of plans – the sustainable energy action plans - focused mainly on mitigation, while the second – the sustainable energy and climate action plans - includes both adaptation and mitigation actions with the aim of reducing the CO_2 emissions by at least 40% by 2030.

are separated into different chapters. This may express the awareness (or lack) of the need to adopt an integrated approach when dealing with climate change.

For what concerns soil desealing, some municipalities directly reference it, while others indirectly mention this concept in the framework of increasing the urban soil permeability, implementing green and blue infrastructure or nature-based solutions, in alignment with what was observed in literature. Among the factors that may have promoted the definition of soil desealing as a proper action, local projects such as the 'SOS4LIFE' project (see also Subsection §2.2.2) or the legislative context (e.g., the Regional Law No. 24/2017 of the Emilia-Romagna Region) have contributed to raise awareness of the topic, as reflected in the plans of the corresponding areas. Furthermore, different approaches to soil desealing interventions have been observed. Some sustainable energy and climate action plans included them as targeted actions (citing specific locations and projects), while other municipalities have mentioned them as a blanket-action for the whole municipality.

This difference is reflected also by the planning instruments that cities put in relation with soil desealing, which range from the most traditional to the most innovative ones. The search for an increased urban permeability is expressed in tools such as the climate transition strategies (Comune di Brescia, 2021b; Comune di Mantova et al., 2021) or the green regulations and plans (*regolamenti e piani del verde*) (Comune di Forlì, 2019; Comune di Padova, 2022; Comune di Parma, 2022). Finally, sustainable energy and climate action plans reference general urban plans (*piani regolatori generali*) and territorial governance plans (*piani di governo del territorio*), such as general urban plans of the Emilia-Romagna cases (Comune di Modena, 2023; Comune di Parma, 2023b; Comune di Piacenza, 2024b) and the intervention plan of Padua (Comune di Padova, 2023). Furthermore, some municipalities envision a revision of their instruments following the work that they conducted in the sustainable energy and climate action plans.

A potentially critical point that has emerged is the confusion caused by the multiplication of the instruments cited in these plans, which are a reflection of the intricated Italian legislative and strategic urban planning scenario. In this regard, sustainable energy and climate action plans play a valuable role, as they can serve - intentionally or not - as an organising framework, acting as a 'container' for both planned and past actions. The role of sustainable energy and climate action plans could therefore have started to develop as a supporting instrument to the other urban planning tools, rather than a proper strategic instrument.

In summary, sustainable energy and climate action plans acknowledge the municipalities efforts and make the steps taken towards sustainability explicit, even though their strategic perspective appears not to be fully developed yet (Caselli et al., 2023).

The next subsections include an overview on the selected case studies, including – without the aim of being exhaustive - the relationship of the sustainable energy and climate action plans with the traditional urban planning instruments for what concerns soil desealing. Despite not being regulatory instruments, sustainable energy and climate action plans can be considered as a strong signal of the city to achieve not only the carbon and climate neutrality objectives set at the various governance levels, but also those objectives of other regional and municipal plans and programmes.

4.2.1 Padua

In 2021, Padua developed a sustainable energy and climate action plan during its journey towards 'no net land take' and climate neutrality, committing to reducing its greenhouse gases emissions and adopting climate change adaptation actions (Regione Veneto, 2017, 2019). The Sustainable energy and climate action plan was developed following the guidelines 'Resilient Padua: guidelines for the construction of a local climate change adaptation plan' (*Padova Resiliente: Linee guida per la construzione del piano di adattamento al cambiamento climatico*) which cited the need of increasing the permeable urban area by replacing the urban paved surfaces (Musco et al., 2016). Among the actions of the Sustainable energy and climate action plan, soil desealing emerges as a voluntary action (Comune di Padova & VenetoADAPT, 2021).

The guidelines 'Resilient Padua' (Padova Resiliente)

Before developing its Sustainable energy and climate action plan, Padua collaborated with the IUAV University of Venice to investigate the urban heat island effect. In 2016, the guidelines 'Resilient Padua: guidelines for the construction of a local climate change adaptation plan' (*Padova Resiliente: Linee guida per la construzione del piano di adattamento al cambiamento climatico*) were published (Musco et al., 2016). The urban environmental criticalities were studied, as well as their short-, medium- and long- term impacts. Vulnerabilities related to urban floods (and surface runoff) and to the urban heat island effect were identified, as well as their appropriate countermeasures, such as the increase of permeable surfaces and green areas to replace the impervious ones.

The Building regulation (Regolamento edilizio)

References to soil desealing are also included in the last Padua Building regulation, which envisions parking lots to be implemented with permeable materials and trees to favour shade during the summer (Comune di Padova, 2020).

The new Interventions Plan (Piano degli interventi)

Two years after the Sustainable energy and climate action plan, the new Intervention plan (*Piano degli interventi*) of Padua was approved as the implementation instrument of the General urban plan (*piano regolatore generale*) (Comune di Padova, 2023). Soil desealing can be found among its measures, as well as the promotion of green and blue infrastructure (Comune di Padova, 2023). Soil desealing is envisioned to be applied in specific areas of the city, such as degraded or brownfields (C1 zones according to the urban zoning) where the urban regeneration of built-up areas is favoured. In this context, soil desealing is also promoted in the context of the ecological 'green road network'.

4.2.2 Parma

Parma developed a sustainable energy and climate action plan that describes - in a series of "cards" - the adaptation and mitigation objectives that the city aims to achieve by 2030 (Comune di Parma, 2021b). Parma does not treat soil desealing as an individual action, but it considers it an instrument to reduce soil imperviousness. For this reason, soil desealing is referenced throughout the document both with different direct references (using, however, different terms, e.g., '*deimpermeabilizzazione*') and indirect mentions (e.g., sustainable urban drainage systems or green roofs). Furthermore, the Sustainable energy and climate action plan mentions two existing tools that are related to soil desealing in Parma: the 'Hydraulic risk management regulation' (*Regolamento di gestione del rischio idraulico*) aims to limit soil imperviousness and promotes permeable surfaces, while the Green plan (*Piano del verde*) fosters soil desealing, reforestation and urban regeneration processes (Subsection §9.1.4 provides further insight on these instruments).

The new General urban plan (Piano urbanistico generale) 'PUG PR050'

In July 2023, the new General urban plan (*Piano urbanistico generale*) 'PUG PR050' of Parma was assumed as a regulatory and strategic instrument (Comune di Parma, 2023b), on the steps of the Regional Law No. 24/2017. The Plan defines the municipal responsibility for land use and transformation, with specific attention to regeneration processes and sustainability. References to soil desealing are included, both as a generic good practice for each intervention and for specific cases such as parking lots, addressing what foreseen by the Green plan (*Piano del verde*). The 'PUG PR050' also includes a map that identifies the desealable parking lots within the municipal borders.

The Green plan (Piano del verde)

The Green plan (*Piano del verde*) of Parma is a sector plan that considers urban green as a strategic asset for urban development. Despite not being a regulatory instrument, the Green plan may help towards a valorisation of the public and private urban green. The Green plan proposes soil desealing interventions and the implementation of trees, mainly in road infrastructure and parking lots, while contextually providing an assessment of streets that lack trees (Comune di Parma, 2022).

4.2.3 Forlì

The Sustainable energy and climate action plan of Forlì was adopted in 2022 and encompasses soil desealing as one of the actions identified for the urban adaptation to climate change, with a clear reference to the 'SOS4LIFE' project[66]. The Plan promotes soil desealing as a tool to face various climate risks, such as heat waves, cold waves, intense precipitation, flood, sea rise and droughts (Comune di Forlì, 2022). Soil desealing was mentioned with different terms and in different forms, such as 'desealing' (both with the Italian word '*desigillazione*' and in English), 'green restoration' and 'depaving'. Soil desealing can be found again in the Plan actions, being referenced both directly and indirectly. For instance, green roofs and walls are promoted, as well as green and blue infrastructure and nature-based solutions. Furthermore, the Sustainable energy and climate action plan encompasses desealing also among the awareness-raising actions.

Forlì Sustainable energy and climate action plan references the Operational municipal plan (*Piano operativo comunale*) and the Structural municipal plan (*Piano strutturale comunale*) while waiting [2024] for the new General Urban Plan adoption in accordance with the Regional Law No. 24/2017. Furthermore, the Sustainable energy and climate

[66] The Municipality of Forlì took part in the 'SOS4LIFE' project, funded by the European 'Life2014-2020 Programme' and activated in 2016. A whole knowledge and diagnostic process was carried out preceding direct and demonstrative soil desealing interventions. The areas feasible to be desealed (both in urban and agricultural contexts) were registered based on the urban planning instruments that identified them and on the citizens' reports (SOS4LIFE, 2018). Among these areas, the area in front of the San Domenico Museums was chosen to be regenerated. In March 2022, the area was transformed from car park to 'Museum Garden' (SOS4LIFE, 2022) and the permeable surface of the intervention area increased from 6% to about 70% (SOS4LIFE, 2022).

action plan mentions the 'Labour and climate pact' (*Piano per il lavoro e per il clima*), the Regional energy plan (*Piano energetico regionale*) and the Public and private green regulation (*Regolamento del verde pubblico e privato*).

The Public and private green regulation (Regolamento del verde pubblico e privato)

The Forlì Public and private green regulation (*Regolamento del verde pubblico e privato*), foresees any future intervention in parking areas to favour the use of permeable pavements over the entire surface (Comune di Forlì, 2019). Although not explicitly mentioned, soil desealing appears as an unavoidable action to implement this regulation.

4.2.4 Piacenza

Piacenza joined the Covenant of Mayors in 2019 and committed to develop, in two years, the necessary documentation for the sustainable energy and climate action plan (Comune di Piacenza, 2024c). Subsequently, Piacenza started a process of evaluation, monitoring and verification of actions aimed at reducing greenhouse gases emissions and climate change adaptation.

Piacenza Sustainable energy and climate action plan identifies general and sectorial objectives, among which soil desealing reoccurs. This concept is mentioned in the objectives that involve:

- people and health: in order to reduce the heat island effect, impermeable surfaces are envisioned to be reduced by replacing impervious pavements and increasing greenery;
- tourism: summer cooling and the improvement of the outdoor comfort of hospitality facilities are to be pursued with reflective materials or with materials with a lower absorption of solar radiation, green roofs and walls, and greenery;
- buildings and urban settlements: a census all the impermeable areas that can be transformed with nature-based solutions is envisaged to foster a sustainable urban drainage management; furthermore the revision of territorial government plans (*piani di governo del territorio*) is promoted to include hydraulic invariance criteria (see Footnote 22) aiming at greater soil permeability; for what regards the implementation of green and blue infrastructure, the Sustainable energy and climate action plan promotes the integration of the Green plan (*Piano del verde*) with information about the benefits and functions of green areas, and with the identification of locations where to implement or improve them;
- infrastructure and services: when maintaining these locations, the replacement of materials with draining and temperature-resistant asphalts is promoted (Comune di Piacenza, 2021).

The new General Urban Plan (Piano Urbanistico Generale)

Direct references to desealing can be found in the first documents of the new General urban plan (*Piano urbanistico generale*), which is currently [2024] being drafted. The new General urban plan also intends to address socio-environmental issues, among which soil desealing (and the limitation of soil sealing) emerge recurrently, with the aim to increase the retention and reuse of rainwater towards a higher resilience to intense meteorological events (Comune di Piacenza, 2024b). Interestingly, soil desealing is proposed for urban districts with varying historical-morphological characteristics, ranging from the residential districts to the sports centre, from the '*Via Emilia*' axis to the more ancient historic centre. All these areas are characterised by presence of paved surfaces, which often correspond to parking lots. As a matter of fact, wide open areas and roadside stalls are explicitly identified as feasible locations for soil desealing. While these areas have not been mapped yet [2024], the Municipality has identified the areas characterised by high imperviousness. Furthermore, the ownership of the areas is kept into account (e.g., the desealing of private areas is encouraged), as well as their use, functions and location. On a general level, the Municipality promotes the gradual desealing of the consolidated urban texture, and the protection of the porosity of non-transformed lands, regulating the construction activities in those areas (Comune di Piacenza, 2024a).

4.2.5 Mantua

A constant interest in climate-related issues characterises the city of Mantua. Plans, strategies and projects have been outlined and undertaken in recent years to develop a path of resilient transformation of the city and territory (Città di Mantova, 2017; Comune di Mantova, 2020; Comune di Mantova et al., 2021; Lucertini et al., 2018; Urban Green UP, 2017). The guidelines prepared by the IUAV University of Venice (co-ordinated by Professor Musco) in collaboration with the Municipality of Mantua, 'Mantova resiliente: towards the Climate Adaptation Plan - Guidelines' (*Mantova resiliente: verso il piano di adattamento climatico - Linee Guida*), anticipate the drafting of the Sustainable energy and climate action plan. The guidelines provide examples of good practices mainly focused on the use of nature-based solutions to increase soil permeability that are foreseen to be adopted especially on the most vulnerable areas.

The Sustainable energy and climate action plan was approved in 2020 (Comune di Mantova, 2020) and incorporated some suggestions of the aforementioned guidelines among its mitigation and adaptation actions. Furthermore, the Sustainable energy and climate action plan addresses soil desealing in various ways, also from a terminological point of view. Despite lacking a direct reference to this concept, various actions involve an increase in soil permeability. These actions range from blanket-intervention strategies (e.g. infiltration trenches, rain gardens, permeable pavements) to specific actions associated with a precise spatial location (such as green roofs on public and commercial buildings), to traditional and innovative planning tools or strategies. In the Plan, soil desealing can be associated with more traditional tools such as the River contracts, plans that deal with the urban hydraulic aspects, and the Municipal emergency plan (*Piano di emergenza comunale*), but also in more innovative tools, such as reforestation or urban renaturation plans. The Sustainable energy and climate action plan envisages a revision of the urban planning tools – i.e., the Territorial governance plan (*Piano di governo del territorio*) and the Building regulations (*Regolamento edilizio*) with new rules to regulate the use and conservation of green areas, encouraging the actions described in 'Mantova resiliente: towards the Climate Adaptation Plan - Guidelines' (*Mantova resiliente: verso il piano di adattamento climatico - Linee Guida*).

It is interesting to observe how the Sustainable energy and climate action plan of Mantua promotes, through participation or involvement actions such as web platforms, the awareness and dissemination of issues relating to public green areas, to foster the citizens' understanding of the municipality actions.

The document 'ACE3T-CLIMA Water, Heat and Energy: 3 Pillars for the Mantuan Climatic Transition (ACE3T-CLIMA Acqua, Calore ed Energia: 3 pilastri per la Transizione CLImatica del Mantovano)

In the broader reference frame of the Mincio Valley, Mantua appears as a partner in the drafting of the 'ACE3T-CLIMA Water, Heat and Energy: 3 Pillars for the Mantuan CLImatic Transition', a document that contributes to the urban and environmental regeneration processes in the territory (Comune di Mantova et al., 2021). Also in this case, a series of objectives and examples is aimed at increasing the permeability of soils: with respect to water drainage two paths are identified: reducing the impermeable surface area at urban level and increasing the green connection with the peri-urban belt (Comune di Mantova et al., 2021).

4.2.6 Modena

The Sustainable energy and climate action plan of Modena proposes various actions to cope with extra-ordinary climatic events that are increasingly affecting the city, such as heat waves, intense rainfall, floods, whirlwinds and droughts (Comune di Modena, 2020). Among them, emerges the promotion of desealing of, for instance, squares and car parks. The goal of increasing the permeable surfaces percentage encompasses both public spaces and industrial areas.

The importance given to this particular action, even if not explicitly mentioned, is reflected also in other actions that promote the increase of permeability in the urban area. For instance, the plan cites the new Urban planning and building regulation (*Regolamento urbanistico ed edilizio*) - developed in alignment with the Regional Law No. 24/2017 together with the new General urban plan (*Piano urbanistico generale*) - foreseeing it to focus on urban regeneration processes and include a permeability index for new constructions and renovations, as well as specific regulations on ecological-environmental endowments. The definition of urban planning guidelines that integrate nature-based solutions can be considered another indirect reference to soil desealing, as the removal of asphalt or concrete layers and the implementation of trees and green areas entails a more sustainable surface runoff management, a preservation of the soil ecosystem services, and an improvement of bioclimatic comfort and urban healthiness.

The 'Climate-energy info point' mentioned in the Plan - i.e., the reference office of the industry clusters on climate change mitigation and adaptation issues (involving, hopefully, also soil desealing) - is considered as an integral part of participatory, awareness-raising and capacity-building actions, also in the framework of the working tables with other competent entities.

The new General urban plan (Piano urbanistico generale)

Soil desealing and the implementation of nature-based solutions in paved squares and parking lots are envisioned by the new Modena General urban plan (*Piano urbanistico generale*). The location of these areas is registered (even though not for the whole municipal territory) in the documents of the 'Strategy for urban and ecological-environmental quality' (*Strategia per la qualità urbana ed ecologico-ambientale*) of the Municipality (Comune di Modena, 2023).

4.3 Concluding remarks

The growing recognition of soil desealing in the strategic and legislative instruments that promote climate change adaptation and urban resilience underscores the effort and the importance of its integration within urban regeneration practices. However, while significant progress has been made in acknowledging the benefits of soil desealing, challenges remain, particularly the lack of a standardised lexical and regulatory framework that can comprehensively guide these efforts. The Italian case, with its evolving regulatory and strategic landscape, illustrates the need for coordinated national and regional policies that support these interventions.

Medium-sized cities offer a unique opportunity to rethink the relationship between soil and both the urban environment and development - addressing the increasing soil consumption and promoting urban pluvial flood (and heat island) risk mitigation also by fostering citizens' involvement. Actively involving citizens and stakeholders in the urban climate transition processes appears to be an effective path forward to ensure that urban transformation is inclusive, equitable, and effective in addressing both environmental and socio-economic issues, also in relation to climate change.

The path forward lies in fostering the promising collective effort observed towards soil desealing and climate change adaptation and continuing to embrace these challenges. By promoting a closer relationship between urban areas and their natural environments, Italian cities, citizens and stakeholders can meaningfully contribute to the broader goals of sustainability and climate resilience.

II | Methodology for the definition of soil desealing intervention priorities and criteria

Building on the soil desealing and urban climate change adaptation theoretical framework that was outlined in Part I, Part II presents the methodology developed to identify priority areas and tools for implementing soil desealing interventions in urban regeneration practices, with the aim of reducing the urban pluvial flood risk[67]. The methodology is divided into three focus topics:

i) the urban pluvial flood risk and damage assessments that - based on the evaluation of the risk components (i.e., hazard, exposure, and vulnerability) allow to draft urban pluvial flood risk and damage maps, both for physical assets and the population (Chapter §5);

ii) the urban transformation potential assessment that - through the evaluation of the desealing potential and opportunities offered by the urban planning tools - allows for a qualitative and quantitative assessment of the urban transformability (Chapter §6);

iii) the investigation of the role of public participation and citizens' involvement in impacting the decision-making process (Chapter §7).

The methodology envisions associating the outcomes of these three phases to define the priorities and opportunities offered by urban areas and their transformation processes for implementing soil desealing criteria, taking into account the environmental, social, and economic factors that characterise both cities and their users.

[67] See Footnote 21.

5 Assessing the urban pluvial flood risk and damage to identify local critical areas

The review of the literature emphasised that scholars who addressed the urban pluvial flood risk assessments have proposed various approaches, each adjusted to the specific research aim, scope, scale, and context (Othmer et al., 2020). Building on them, Chapter §5 presents a methodology that, based on the determination of the urban pluvial risk and damage components (i.e., hazard, exposure and vulnerability), focused on their relevance for the population and physical assets in the framework of soil desealing.

Similarly to what proposed by Kim et al. (2022) and Mabrouk & Haoying (2023), the determination of the risk components is rooted on the identification and classification of the indicators used in literature aimed at assessing the urban pluvial flood risk in urban planning (Section §5.1). This allows to highlight the relevant factors considered the assessments. Furthermore, their selection constitutes the basis for drafting an approach tailored for specific scales and contexts, such as those of medium-sized Italian cities (Section §5.2).

The results of the methodology allow the creation of urban pluvial flood risk and damage maps. Figure II.20 summarises the steps of the proposed approach.

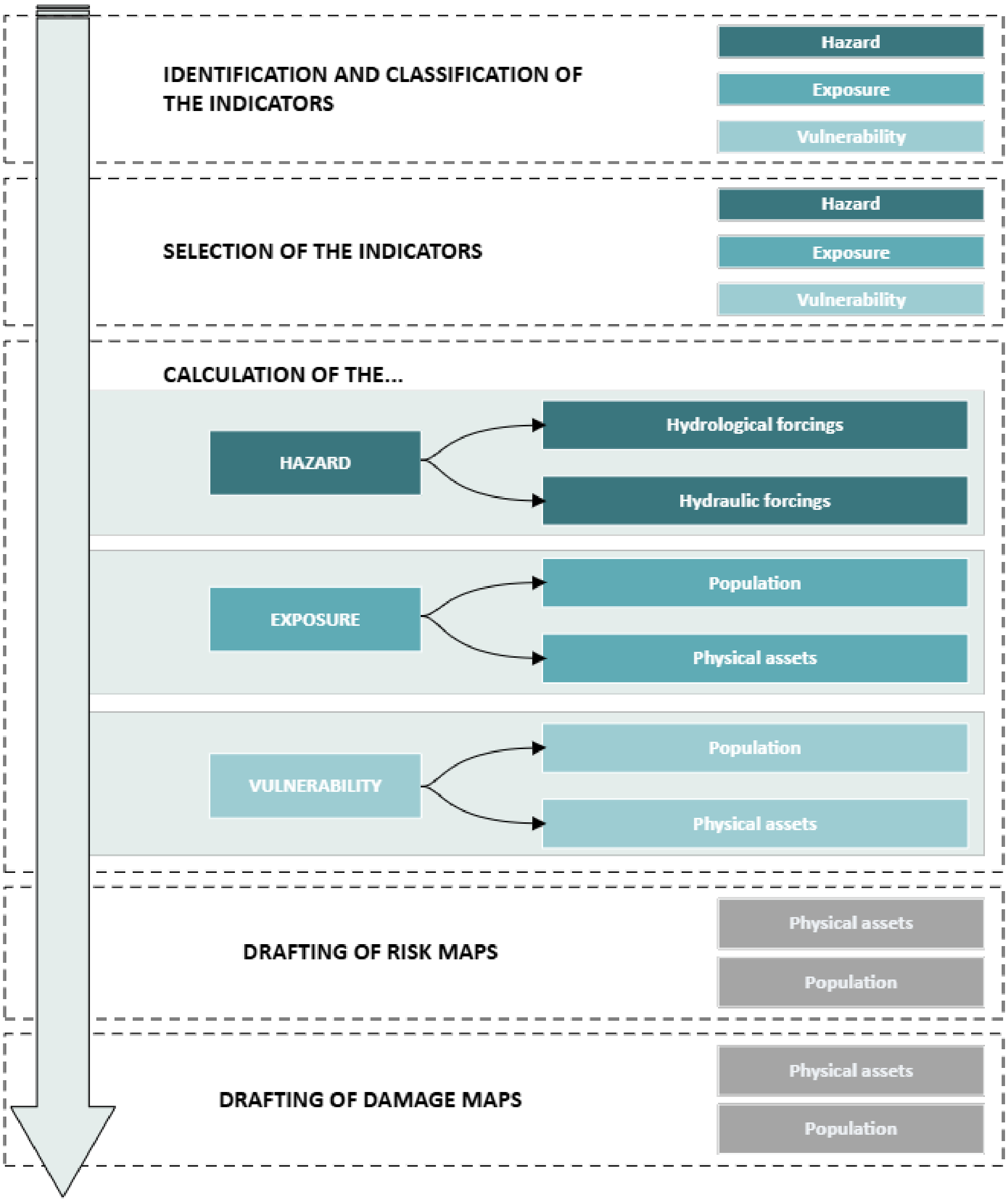

Figure II.20 | Proposed steps for the urban pluvial flood risk and damage assessment. Source: author's elaboration.

5.1 Identification and classification of the indicators

A broad range of indicators has been employed within urban pluvial flood risk assessments, each linked to diverse approaches, scales, and methods. The following subsections aim to provide a representative, though not exhaustive, overview on the indicators used in this context, based on the studies[68] identified in Subsection §1.2.2[69].

[68] From this point forward, the studies identified in Subsection §1.2.2 are referred to as the 'reviewed' studies or assessments.

[69] I.e., Hu, 2016; Elboshy et al., 2019; Marta et al., 2020; Essenfelder et al., 2022; Loli et al., 2022; Mabrouk & Haoying, 2023; Sambo et al., 2023; De Risi et al., 2020; Sperotto et al., 2016; Bibi et al., 2018; Othmer et al., 2020; Weerasinghe et al., 2018; K. Park et al., 2021; Kassem et al., 2022; Rincón et al., 2022; Kim et al., 2022; Ceragene et al., 2023.

In this research, indicators were initially classified and organised into tables according to the risk component specified in their respective reference study. Each indicator was also assigned a category (e.g., environmental characteristics) and a sustainability sphere. With the exception of hazard indicators, the indicators were subsequently reclassified based on the risk components as defined in Subsection §1.2.2.

The following subsections describe this process and its outcomes.

5.1.1 Hazard indicators

This subsection presents the hazard-related indicators that authors have used or identified in the reviewed pluvial flood risk assessments.

Within this analysis, indicators were first grouped into four categories, namely: i) environmental characteristics of the territory (e.g., slope elevation, permeability, land use); ii) flood characteristics (e.g., flood depth, flood extent); iii) precipitation characteristics (e.g., precipitation intensity, annual average precipitation); and iv) composite data (e.g., indexes). Additionally, they were classified as either input (I) or output (O) information and attributed a sustainability sphere. All hazard-related indicators belong to the environmental one.

Table II.14 lists the identified indicators, ordered according to both their category and reference study, to highlight their (potential) combined use in the comprehensive characterisation of the flood phenomenon.

Classification of the hazard indicators

Author, year	***Category***	***Indicator***	***I***	***O***	***Sustainability sphere***
Loli et al, 2022	Environmental characteristics	Elevation	•		Environmental
		Drainage	•		
		Slope	•		
		Permeability	•		
		Land use/Land cover			
Weerasinghe et al., 2017		Geology (rock/soil type)	•		
		Land use			
		Slope	•		
		Elevation	•		
		Distance from river network			
Kassem et al., 2022		Slope	•		
		Elevation	•		
		Land use			
		Peak discharge		•	
Li et al., 2023		Digital elevation model	•		
		Slope	•		
		River network density			
		Runoff coefficient		•	
Ellena et al., 2020	Flood characteristics	Floods		•	Environmental
Essenfelder et al., 2022		Water depth		•	
		Flood extent		•	

Classification of the hazard indicators					
Author, year	***Category***	***Indicator***	***I***	***O***	***Sustainability sphere***
Loli et al, 2022		Flow accumulation		•	
De Risi et al., 2019		Flood depth		•	
Sperotto et al., 2016		Maximum pluvial emergency thresholds		•	
Bibi et al., 2018		Total inundated area		•	
Othmer et al., 2020		Average spreading volume (m^3) per m2 building block		•	
		Pluvial impoundment depth		•	
		Flow velocity		•	
Weerasinghe et al., 2017		Flow accumulation		•	
Park et al., 2021		Flood depth		•	
		Flood range		•	
Kassem et al., 2022		Flow accumulation		•	
Rincón et al., 2022		Water depth		•	
		Flood extent		•	
		Water velocity		•	
Kim et al., 2022		Flood damage - historical damage		•	
		Scale of flood damage		•	
		Frequency of flood damage		•	
		Flooded areas		•	
Ceragene et al., 2023		Water velocity		•	
		Water depth		•	
Ellena et al., 2020	Precipitation characteristics	Annual total precipitation in wet days	•		Environmental
		Annual count of days when precipitation is equal or higher than 10 mm	•		
		Annual count of days when precipitation is equal or higher than 20 mm	•		
		Number of wet days	•		
		Annual maximum 1-day precipitation	•		
		Annual maximum consecutive 5-days precipitation	•		
Loli et al, 2022		Rainfall	•		
Sperotto et al., 2016		Intensity of precipitation	•		
Weerasinghe et al., 2017		Rainfall intensity	•		
Kim et al., 2022		Probable rainfall	•		
		Number of days of rainfall of 80 mm	•		
		Maximum rainfall per day	•		
		Maximum rainfall during the duration (24 h)	•		
		Annual average rainfall	•		

Classification of the hazard indicators					
Author, year	***Category***	***Indicator***	***I***	***O***	***Sustainability sphere***
Li et al., 2023		Average annual precipitation	•		
		Total number of days with annual daily precipitation ≥ 50 mm	•		
		Total number of days with annual daily precipitation ≥ 20 mm	•		
Hu, 2016	Composite	Rainstorm hazard index value (Frequency of intense rainfall events)			Environmental
Elboshy et al., 2018		Pluvial flood hazard			
Sambo et al., 2023		Very wet days*soil permeability*slope*urbanization degree			

Table II.14 | Classification of the hazard indicators identified in the reviewed pluvial flood risk assessments.

The process of classifying the indicators showed that their use and selection depends on the aim, scope, scale, and context of the research, as well as, in some cases, data availability. The classification shows that not all authors consider factors such as slope, permeability, drainage systems, or river network density as relevant to pluvial flood hazard assessments. Furthermore, precipitation is characterised differently across the studies: some view it in terms of intensity, while others consider average or maximum values over time. Despite these variations, flood depth and flood extent are commonly considered the primary indicators, while data such as the water velocity and flow accumulation are included selectively, based on study-specific needs.

Overall, it can be said that factors that are most frequently considered in urban pluvial flood risk assessments within the urban planning context generally aim to characterise the territory, flood, and precipitation. Furthermore, in the context of soil desealing it appears relevant to:

i) describe the territory using factors that influence precipitation infiltration and surface runoff;

ii) characterise precipitation according to what soil desealing can address, i.e., precipitation and water volumes within the maximum soil infiltration capacity, beyond which another scale of intervention becomes necessary. Thus, while describing extreme weather phenomena is essential for flood risk assessment and soil desealing can undoubtedly help reducing surface runoff (see also Chapter §4), this research framework is intended to address only meteorological events with smaller return times;

iii) characterise floods with their depth and area. With a similar reasoning to the previous point, flood velocity appears less relevant in the context of increasing soil perviousness.

5.1.2 Exposure indicators

Similarly to the pluvial flood hazard indicators, each exposure indicator (as identified by the reviewed studies) can be assigned to a category, namely:

- buildings location and type;

- built-environment characteristics and conditions;
- commercial/industrial infrastructure location;
- protected areas;
- land and economic productivity;
- educational infrastructure location;
- energy infrastructure location;
- land characteristics and use;
- health infrastructure location;
- historical, cultural and environmental assets location;
- infrastructure location;
- mobility infrastructure location and characteristics;
- population location;
- residential buildings location;
- services location;
- proximity;
- urbanisation;
- wealth.

Table II.15 encompasses the classification of the indicators identified through the literature review. In this case indicators are primarily ordered according to their category and are associated with all the sustainability spheres.

First classification of the exposure indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
Mabrouk & Han, 2023	Buildings - location	Building setbacks	Environmental
Essenfelder et al., 2022		Building footprint	
De Risi et al., 2019			
Bibi et al., 2018		Buildings	
Park et al., 2021		Location	
Kim et al., 2022		Number of buildings	
De Risi et al., 2019	Buildings - type	Types of building	Environmental
Rincón et al., 2022		Building category	
Mabrouk & Han, 2023	Built-environment - characteristics	Lot and block size	Environmental
		Lot, block and patch shape	
		Fraction of green space	
		Percent of landscape	
		Access to open space	
		Figure-ground diagram	Environmental
		Harmony with nature	Environmental
		Polyvalency	
		Homogeneous	
		Patch density	Environmental
	Built-environment - conditions	Worn-out urban texture	Environmental
Ellena et al., 2020	Commercial/industrial infrastructure - location	Industrial and commercial areas	Environmental
Sperotto et al., 2016		Commercial-industrial buildings	

First classification of the exposure indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
Sambo et al., 2023	Protected areas	Degree of protection of forests and semi-natural areas	Environmental
		Degree of protection of beaches	
		Degree of protection of wetlands and water bodies	
	Land and economic productivity	Gross value added of agricultural areas	Economic
		Gross value added of industrial areas	
		Gross value added of areas with the presence of population	
Rincón et al., 2022		Economic value of the building category	
Kim et al., 2022		Gross regional domestic product	
		Average official land price	
Loli et al, 2022	Educational infrastructure - location	Schools	Socio-environmental
Bibi et al., 2018			
Ellena et al., 2020	Energy infrastructure-location	Energy distribution infrastructure	Environmental
		Energy production infrastructure	
Mabrouk & Han, 2023	Land - characteristics and use	Sky view factor	Environmental
		Runoff coefficients	
		Rain falls volume	
Kim et al., 2022		Slope	
Ellena et al., 2020		Other areas	
Essenfelder et al., 2022		Land cover	
Ellena et al., 2020		Agricultural areas	
Mabrouk & Han, 2023		River valleys	
		Topographic parameters (slope exceeding 5%)	
Bibi et al., 2018		Crops/Vegetation	
Kim et al., 2022		River density	
Loli et al, 2022	Health infrastructure - location	Hospitals	Environmental
Bibi et al., 2018			
Ellena et al., 2020	Historical, cultural and environmental assets - location	Historical, cultural and environmental assets	Environmental
Sambo et al., 2023		Presence of UNESCO cultural sites	
Sperotto et al., 2016	Infrastructure - location	Infrastructure	Environmental
Ellena et al., 2020	Mobility infrastructure - location	Cycle infrastructure	Environmental
		Railway infrastructure	
		Road infrastructure	
Loli et al, 2022		Roads	
Bibi et al., 2018			
Kim et al., 2022			
Mabrouk & Han, 2023		Street connectivity	Environmental

First classification of the exposure indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
	Mobility infrastructure - characteristics	Street integration	
		Street depth	
Ellena et al., 2020	Population - location	Presence of the population	Socio-environmental
Loli et al, 2022			
De Risi et al., 2019			
Bibi et al., 2018			
Weerasinghe et al., 2017			
Kim et al., 2022			
Rincón et al., 2022		Population per building category	
Kim et al., 2022		Population density	
Mabrouk & Han, 2023			
Sambo et al., 2023			
Rivosecchi & Singh, 2023			
Ellena et al., 2020	Residential buildings - location	Residential areas	Environmental
Sperotto et al., 2016		Residential buildings	
Weerasinghe et al., 2017		Housing	
Ellena et al., 2020	Services - location	Centre for public service supply	Socio-environmental
Bibi et al., 2018		Hand Pumps	Environmental
		Latrines	
Mabrouk & Han, 2023	Proximity	Distance from the coast	Environmental
		Proximity to floodplains	
	Urbanisation	Urban growth	Environmental
Sambo et al., 2023		Urbanisation degree - Housing	Environmental
		Urbanisation degree - Road network	
		Urbanisation degree - Train-airports-ports	
		Urbanisation degree of green urban areas	
Kim et al., 2022	Wealth	Per capita income	Socio-economic

Table II.15 | Classification of the indicators that have been attributed the risk component 'exposure' in their reference study.

The review of urban pluvial flood exposure indicators shows that authors generally focused on the presence or absence of population and physical assets, thus addressing what is 'literally' exposed to risk, while sometimes characteristics that may influence exposure (e.g., building conditions) are specified. These characteristics are, however, often covered also by vulnerability indicators within these studies (Subsection §5.1.3). This confirms that the indicators choice varies depending on the context and aim of the studies.

Following the Intergovernmental Panel on Climate Change approach, exposed assets can be intended as those assets that may be adversely affected by the hazard (IPCC, 2018). In the context of urban pluvial flood risk assessments, the present research considers urban physical assets (e.g., roads and buildings) and population as the primary exposed assets. Consequently, indicators describing the characteristics of the population and physical asset are treated as vulnerability indicators. The following indicators' categories were therefore reclassified as vulnerability indicators, despite their original classification: i) building type; ii) built-environment characteristics and conditions; iii) protected areas; iv) economic aspects; v) mobility infrastructure characteristics; vi) proximity; vii) urbanisation; and viii) wealth. Table II.16 lists these indicators' categories and their corresponding indicators. It should be noted that the previously identified category 'land characteristics and use' encompasses both indicators that have been previously classified as hazard indicators (e.g., precipitation characteristics such as its volume), as well as indicators that include data that influences vulnerability (i.e., building uses). As a result, these indicators have not been considered among the exposure indicators.

Author, year	***Category***	***Indicator***
De Risi et al., 2019	Buildings - type	Types of building
Rincón et al., 2022		Building category
Mabrouk & Han, 2023	Built-environment - characteristics	Lot and block size
		Lot, block and patch shape
		Fraction of green space
		Percent of landscape
		Access to open space
		Figure-ground diagram
		Harmony with nature
		Polyvalency
		Homogeneous
		Patch density
	Built-environment - conditions	Worn-out urban texture
Sambo et al., 2023	Protected areas	Degree of protection of forests and semi-natural areas
		Degree of protection of beaches
		Degree of protection of wetlands and water bodies
	Land and economic productivity	Gross value added of agricultural areas
		Gross value added of industrial areas
		Gross value added of areas with the presence of population
Rincón et al., 2022		Economic value of the building category
Kim et al., 2022		Gross regional domestic product
		Average official land price
Mabrouk & Han, 2023	Mobility infrastructure - characteristics	Street connectivity
		Street integration
		Street depth
Mabrouk & Han, 2023	Proximity	Distance from the coast
		Proximity to floodplains
	Urbanisation	Urban growth
		Urbanisation degree - Housing
Sambo et al., 2023		Urbanisation degree - Road network

Author, year	*Category*	*Indicator*
		Urbanisation degree - Train-airports-ports
		Urbanisation degree of green urban areas
Kim et al., 2022	Wealth	Per capita income

Table II.16 | Indicators that have been reclassified from exposure to vulnerability indicators.

Furthermore, some authors considered building or land use categories (e.g., the location of commercial/industrial infrastructure; educational infrastructure; energy infrastructure; health infrastructure; historical, cultural, and environmental assets; mobility infrastructure; residential buildings; and services) when assessing exposure. These categories were reclassified as vulnerability features in this research, as they do not influence the exposure in the considered theoretical framework. The indicators and their categories are listed in Table II.17.

Author, year	*Category*	*Indicator*
Ellena et al., 2020	Commercial/industrial infrastructure - location	Industrial and commercial areas
Sperotto et al., 2016		Commercial-industrial buildings
Loli et al, 2022	Educational infrastructure - location	Schools
Bibi et al., 2018		
Ellena et al., 2020	Energy infrastructure - location	Energy distribution infrastructure
		Energy production infrastructure
Loli et al, 2022	Health infrastructure - location	Hospitals
Bibi et al., 2018		
Ellena et al., 2020	Historical, cultural and environmental assets - location	Historical, cultural and environmental assets
Sambo et al., 2023		Presence of UNESCO cultural sites
Sperotto et al., 2016	Infrastructure - location	Infrastructure
Ellena et al., 2020	Mobility infrastructure - location	Cycle infrastructure
		Railway infrastructure
		Road infrastructure
Loli et al, 2022		
Bibi et al., 2018		
Kim et al., 2022		
Ellena et al., 2020	Residential buildings - location	Residential areas
Sperotto et al., 2016		Residential buildings
Weerasinghe et al., 2017		Housing
Ellena et al., 2020	Services - location	Centre for public service supply
Bibi et al., 2018		Hand Pumps
		Latrines

Table II.17 | Indicators representing categories of physical assets that have been reclassified from exposure to vulnerability indicators.

Table II.18 encompasses the final classification of the exposure indicators.

Final classification of the exposure indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
Mabrouk & Han, 2023	Buildings - location	Building setbacks	Environmental
Essenfelder et al., 2022		Building footprint	
De Risi et al., 2019			
Bibi et al., 2018		Buildings	
Park et al., 2021		Location	
Kim et al., 2022		Number of buildings	
Ellena et al., 2020	Population - location	Presence of the population	Socio-environmental
Loli et al, 2022			
De Risi et al., 2019			
Bibi et al., 2018			
Weerasinghe et al., 2017			
Kim et al., 2022			
Rincón et al., 2022		Population per building category	
Kim et al., 2022		Population density	
Mabrouk & Han, 2023			
Sambo et al., 2023			
Rivosecchi & Singh, 2023			

Table II.18 | Final classification of the identified exposure indicators.

5.1.3 Vulnerability indicators

Authors who dealt with identifying indicators that characterise the pluvial flood vulnerability have considered all the spheres of sustainability. Each of the identified indicators can be assigned to one of the following categories:

- population age; education; ethnicity; gender; independence/health conditions; employment; location;
- public awareness level;
- civil and social advocacy organisations;
- voluntarism;
- health services capacity;
- housing capacity;
- digital services capacity;
- emergency services capacity;
- built-environment characteristics;
- services - location;
- technological services capacity;
- buildings: age; conditions; type;
- built-environment conditions;
- land characteristics and soil consumption;

- land use;
- mobility and mobility infrastructure type and characteristics;
- protection infrastructure;
- commercial/industrial infrastructure;
- land and economic productivity;
- damage potential;
- composite indicators.

Table II.19 encompasses the classification of the indicators that have been identified through the literature review. Also in this case, indicators have been ordered according to their category.

First classification of the vulnerability indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
Kim et al., 2022	Composite	Vulnerable population	Multiple
		Runoff curve index	
		Disaster-prone districts	
Elboshy et al., 2018		Vulnerability of buildings	Environmental
Ellena et al., 2020	Population - age	Elderly population	Social
		Young population	
Loli et al, 2022		Children	
Sambo et al., 2023		Population age (<5 and >65 years old)	
Mabrouk & Han, 2023		Age	
Bibi et al., 2018			
Othmer et al., 2020			
Weerasinghe et al., 2017			
Mabrouk & Han, 2023	Population - education	Educational attainment equality	Social
Bibi et al., 2018		Education	
Othmer et al., 2020		(Level of) education/qualification	
Ceragene et al., 2023		Illiteracy rate	
		Average level of education	
Othmer et al., 2020	Population - ethnicity	Ethnicity/ethnic minorities	Social
Elboshy et al., 2018	Population - gender	Women ratio	Social
Mabrouk & Han, 2023		Gender	
Bibi et al., 2018			
Elboshy et al., 2018	Population - independence/health conditions	Incapability ratio	Socio-economic
Loli et al, 2022		Health conditions	
Mabrouk & Han, 2023		Special needs	
		Independent population	
Bibi et al., 2018		Ability	
Othmer et al., 2020		People with illnesses/disabled people	
		Lone parent households with dependent children	
		(Single) pensioner households	

First classification of the vulnerability indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
Ceragene et al., 2023		Dependency ratio (% of dependent population, in relation to the percentage of the economically active population)	
Kim et al., 2022		Infant mortality	Social
Ceragene et al., 2023			
Mabrouk & Han, 2023	Population - employment	Employment status	Socio-economic
Othmer et al., 2020		Unemployment	
Weerasinghe et al., 2017		Employment	
Mabrouk & Han, 2023		Unemployment/employment rate	
Elboshy et al., 2018	Population - location	Population density	Socio-environmental
Othmer et al., 2020			
Ceragene et al., 2023			
Li et al., 2023			
Kim et al., 2022		Population in flooded areas	
Elboshy et al., 2018	Public awareness level	Risk	Social
Ellena et al., 2020		Local openness and awareness about environmental sustainability topic	
		Initiatives for adapting to climate change	
Mabrouk & Han, 2023	Civic and social advocacy organisations	Civic and social advocacy organizations	Social
Ellena et al., 2020	Voluntarism	Voluntarism	Social
Mabrouk & Han, 2023	Health services capacity	Medical care capacity	Socio-environmental
Ceragene et al., 2023		Doctors/1000 inhabitants	
		Percentage of population that does not rely on public health service	
Mabrouk & Han, 2023	Housing capacity	Homeownership	Socio-economic
Ceragene et al., 2023		Housing deficit	Socio-environmental
Ellena et al., 2020	Digital services capacity	Ultra-wideband technology coverage	Socio-environmental
Kim et al., 2022		TV distribution rate	
Mabrouk & Han, 2023	Emergency services capacity	Evacuation access	Socio-environmental
		Temporary shelter availability	
		Redundancy of emergency services	
Ceragene et al., 2023	Built-environment - characteristics	Percentage of population living in towns with fewer than 2500 inhabitants	Socio-environmental
Mabrouk & Han, 2023	Services - location	Public recreational facilities	Socio-environmental
Kim et al., 2022	Technological services capacity	Number of households not supplied with electricity	Socio-environmental
Ceragene et al., 2023		Percentage of homes without piped water	

First classification of the vulnerability indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
		Percentage of houses without drainage	
Mabrouk & Han, 2023	Buildings - age	Housing age	Environmental
Othmer et al., 2020		Construction year	
Kim et al., 2022		Old buildings	
Elboshy et al., 2018	Buildings - conditions	Building's condition	Environmental
Ellena et al., 2020		Presence of households in bad conditions	
Park et al., 2021		Decline of building	
Elboshy et al., 2018	Buildings - type	Building's material	Environmental
Park et al., 2021			
Mabrouk & Han, 2023		Sturdy housing type	
Bibi et al., 2018		Construction type categories	
Othmer et al., 2020		Number of floors	
Weerasinghe et al., 2017		Housing type (permanent or not)	
Park et al., 2021		Floor area ratio	
		Underground area	
Kim et al., 2022		Number of semi-basement households	
Ceragene et al., 2023		Percentage of houses with adobe floors	
Othmer et al., 2020	Buildings - type/condition	Building structure/resistance/condition	Environmental
Mabrouk & Han, 2023	Built-environment - conditions	Worn-out urban texture	Environmental
Sperotto et al., 2016	Land characteristics and soil consumption	Slope	Environmental
Kim et al., 2022		Lowland area	
		Slope	
Sperotto et al., 2016		Permeability	Environmental
		Recently flooded areas	
Ellena et al., 2020		Soil consumption	Environmental
Hu, 2016	Land - use	River shore areas	Environmental
Ellena et al., 2020		Ecosystem services reduction in forests	
Sambo et al., 2023		Forests and semi-natural areas extension	
		Vegetation typology in forests and semi-natural areas	
		Dune vegetation in forests and semi-natural areas	
		Wetland extension	
		Pastures and permanent spontaneous grass	
Othmer et al., 2020		Land use	
		Land use change	

First classification of the vulnerability indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
Hu, 2016	Mobility and mobility infrastructure type and characteristics	Highways	Environmental
		Roads	
		Thoroughfares	
		Crossroads	
		Junctions	
Ellena et al., 2020		Bridges/overpassess	
		Daily average traffics	
		Private mobility	
		Public mobility	
		Slow mobility in city centres	
Li et al., 2023		Road network density	
Ellena et al., 2020	Protection infrastructure	Hydraulic works	Environmental
		Slope stability works	
Mabrouk & Han, 2023	Commercial/industrial infrastructure	Commercial infrastructure exposed to hazards	Economic
Sambo et al., 2023		Industries with relevant accidents	
Park et al., 2021	Land and economic productivity	Land price	Economic
Li et al., 2023		Gross domestic product per unit area	
Li et al., 2023		Gross domestic product per capita	
Rincón et al., 2022	Damage potential	Social damage potential	Socio/ Environmental/ Economic
Essenfelder et al., 2022		Depth-damage functions	
De Risi et al., 2019		Fragility curves	
Othmer et al., 2020		Damage potential	
Othmer et al., 2020		Damages to infrastructures, structures and contents/loss - economic	
Essenfelder et al., 2022		Reconstruction costs	
Rincón et al., 2022		Economic damage potential	

Table II.19 | Classification of the indicators that have been attributed the risk component 'vulnerability' in their reference study.

The identified pluvial flood vulnerability indicators describe both the location of physical assets or population and the characteristics of the exposed assets that - according to the authors of the analysed studies - may influence their vulnerability. Not all authors incorporate indicators within the same categories, and notable differences are evident even among studies examining similar dimensions. For example, regarding population characteristics, some researchers highlight factors such as gender (specifically, female populations) and affiliation with an ethnic minority as elements that increase vulnerability. These indicators are selected based on the authors' understanding that certain demographic or socio-economic traits can intensify exposure and sensitivity to flood risks.

Following a similar approach to that of the exposure indicators, the vulnerability indicators were reclassified according to the theoretical framework of this research. This reclassification excludes certain categories that, by the same rationale, relate more directly to hazard or exposure rather than vulnerability, namely: i) population location; ii) land characteristics and soil consumption; and iii) the indicator 'commercial infrastructure exposed to hazards'. Additionally, some categories have not been included due to their relevance to urban contexts that differ significantly from the European setting, such as 'technological services capacity', which accounts for the absence of drainage or piped water infrastructure in buildings - factors less pertinent to the European urban areas. 'Composite' and 'land use' indicators have also been omitted, as they represent outcomes of the interaction between various factors that are already captured by other indicators considered within the analysis. The category 'damage potential' was also excluded from the final classification, as damage is conceptualised here as distinct from both risk and its components. Table II.20 presents the final classification of indicators, which, as previously anticipated, incorporates indicators which were initially categorised as exposure indicators by the authors of the reviewed studies.

Final classification of the vulnerability indicators

Author, year	***Category***	***Indicator***	***Sustainability sphere***
Ellena et al., 2020	Population - age	Elderly population	Social
		Young population	
Loli et al, 2022		Children	
Sambo et al., 2023		Population age (<5 and >65 years old)	
Mabrouk & Han, 2023		Age	
Bibi et al., 2018			
Othmer et al., 2020			
Weerasinghe et al., 2017			
Mabrouk & Han, 2023	Population - education	Educational attainment equality	Social
Bibi et al., 2018		Education	
Othmer et al., 2020		(Level of) education/qualification	
Ceragene et al., 2023		Illiteracy rate	
		Average level of education	
Othmer et al., 2020	Population - ethnicity	Ethnicity/ethnic minorities	Social
Elboshy et al., 2018	Population - gender	Women ratio	Social
Mabrouk & Han, 2023		Gender	
Bibi et al., 2018			
Elboshy et al., 2018	Population - independence/health conditions	Incapability ratio	Socio-economic
Loli et al, 2022		Health conditions	
Mabrouk & Han, 2023		Special needs	
		Independent population	
Bibi et al., 2018		Ability	
Othmer et al., 2020		People with illnesses/disabled people	
		Lone parent households with dependent children	
		(Single) pensioner households	
Ceragene et al., 2023		Dependency ratio (% of dependent population, in relation to the	

Final classification of the vulnerability indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
		percentage of the economically active population)	
Kim et al., 2022		Infant mortality	Social
Ceragene et al., 2023			
Mabrouk & Han, 2023	Population - employment	Employment status	Socio-economic
Othmer et al., 2020		Unemployment	
Weerasinghe et al., 2017		Employment	
Mabrouk & Han, 2023		Unemployment/employment rate	
Elboshy et al., 2018	Public awareness level	Risk	Social
Ellena et al., 2020		Local openness and awareness about environmental sustainability topic	
		Initiatives for adapting to climate change	
Mabrouk & Han, 2023	Civic and social advocacy organisations	Civic and social advocacy organisations	Social
Ellena et al., 2020	Voluntarism	Voluntarism	Social
Mabrouk & Han, 2023	Health services capacity	Medical care capacity	Socio-environmental
Ceragene et al., 2023		Doctors/1000 inhabitants	
		Percentage of population that does not rely on public health service	
Mabrouk & Han, 2023	Housing capacity	Homeownership	Socio-economic
Ceragene et al., 2023		Housing deficit	Socio-environmental
Ellena et al., 2020	Digital services capacity	Ultra-wideband technology coverage	Socio-environmental
Kim et al., 2022		TV distribution rate	
Mabrouk & Han, 2023	Emergency services capacity	Evacuation access	Socio-environmental
		Temporary shelter availability	
		Redundancy of emergency services	
Mabrouk & Han, 2023	Services - location	Public recreational facilities	Socio-environmental
Mabrouk & Han, 2023	Buildings - age	Housing age	Environmental
Othmer et al., 2020		Construction year	
Kim et al., 2022		Old buildings	
Elboshy et al., 2018	Buildings - conditions	Building's condition	Environmental
Ellena et al., 2020		Presence of households in bad conditions	
Park et al., 2021		Decline of building	
Elboshy et al., 2018	Buildings - type	Building's material	Environmental
Park et al., 2021			
Mabrouk & Han, 2023		Sturdy housing type	
Bibi et al., 2018		Construction type categories	
Othmer et al., 2020		Number of floors	

Final classification of the vulnerability indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
Weerasinghe et al., 2017		Housing type (permanent or not)	
Park et al., 2021		Floor area ratio	
		Underground area	
Kim et al., 2022		Number of semi-basement households	
Ceragene et al., 2023		Percentage of houses with adobe floors	
De Risi et al., 2019		Types of building	
Rincón et al., 2022		Building category	
Othmer et al., 2020	Buildings - type/condition	Building structure/resistance/condition	Environmental
Mabrouk & Han, 2023	Built-environment - characteristics	Lot and block size	Environmental
		Lot, block and patch shape	
		Fraction of green space	
		Percent of landscape	
		Access to open space	
		Figure-ground diagram	
		Harmony with nature	
		Polyvalency	
		Homogeneous	
		Patch density	
Mabrouk & Han, 2023	Built-environment - conditions	Worn-out urban texture	Environmental
Hu, 2016	Mobility and mobility infrastructure type and characteristics	Highways	Environmental
		Roads	
		Thoroughfares	
		Crossroads	
		Junctions	
Ellena et al., 2020		Bridges/overpasses	
		Daily average traffics	
		Private mobility	
		Public mobility	
		Slow mobility in city centres	
Li et al., 2023		Road network density	
Mabrouk & Han, 2023		Street connectivity	Environmental
		Street integration	
		Street depth	
Ellena et al., 2020	Protection infrastructure	Hydraulic works	Environmental
		Slope stability works	
Sambo et al., 2023	Protected areas	Degree of protection of forests and semi-natural areas	Environmental
		Degree of protection of beaches	

Final classification of the vulnerability indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
		Degree of protection of wetlands and water bodies	
Park et al., 2021	Land and economic productivity	Land price	Economic
Li et al., 2023		Gross domestic product per unit area	
Li et al., 2023		Gross domestic product per capita	
Sambo et al., 2023		Gross value added of agricultural areas	
		Gross value added of industrial areas	
		Gross value added of areas with the presence of population	
Rincón et al., 2022		Economic value of the building category	
Kim et al., 2022		Gross regional domestic product	
Kim et al., 2022		Average official land price	
Mabrouk & Han, 2023	Proximity	Distance from the coast	Environmental
		Proximity to floodplains	
Mabrouk & Han, 2023	Urbanisation	Urban growth	Environmental
Sambo et al., 2023		Urbanisation degree - Housing	
		Urbanisation degree - Road network	
		Urbanisation degree - Train-airports-ports	
		Urbanisation degree of green urban areas	
Kim et al., 2022	Wealth	Per capita income	Socio-economic
Buildings or land use categories indicators			
Ellena et al., 2020	Commercial/industrial infrastructure - location	Industrial and commercial areas	Environmental
Sperotto et al., 2016		Commercial-industrial buildings and industries with relevant accidents	
Loli et al, 2022	Educational infrastructure - location	Schools	Environmental
Bibi et al., 2018			
Ellena et al., 2020	Energy infrastructure - location	Energy distribution infrastructure	Environmental
		Energy production infrastructure	
Loli et al, 2022	Health infrastructure - location	Hospitals	Environmental
Bibi et al., 2018			
Ellena et al., 2020	Historical, cultural and environmental assets - location	Historical, cultural and environmental assets	Environmental
Sambo et al., 2023		Presence of UNESCO cultural sites	
Sperotto et al., 2016	Infrastructure - location	Infrastructure	Environmental
Ellena et al., 2020	Mobility infrastructure - location	Cycle infrastructure	Environmental
		Railway infrastructure	
		Road infrastructure	

Final classification of the vulnerability indicators			
Author, year	***Category***	***Indicator***	***Sustainability sphere***
Loli et al, 2022			
Bibi et al., 2018			
Kim et al., 2022			
Ellena et al., 2020	Residential buildings - location	Residential areas	Environmental
Sperotto et al., 2016		Residential buildings	
Weerasinghe et al., 2017		Housing	
Ellena et al., 2020	Services - location	Centre for public service supply	Environmental
Bibi et al., 2018		Hand Pumps	
		Latrines	

Table II.20 | Final classification of the identified vulnerability indicators.

It appears important to note that data availability and the selected sensitivity level chosen for a study can significantly influence the choice of indicators for evaluating the urban pluvial flood vulnerability, both for the population and physical assets. Researchers aiming for thorough assessments may include a broader range of indicators, to capture as many dimensions of vulnerability as possible. In contrast, studies with specific constraints or lower sensitivity might prioritise only the most relevant or accessible indicators. By refining the indicator selection, this thesis focuses on metrics that are closely connected to the soil desealing context.

5.1.4 Damage indicators

In the framework of the indicators review, those aimed at assessing the (potential) damage of both physical assets and population have emerged[70]. Even if not being considered proper indicators by some researchers, depth-damage curves represent an interesting case as they allow to aggregate more indicators based on statistical or empirical data (Essenfelder et al., 2022) and describe the damage to physical assets as a function of the flood depth (Huizinga et al., 2017). Flood depth-mortality (or flood depth-population affected) curves represent a similar approach in the sphere of assessing the social damage (Essenfelder et al., 2022; Rincón et al., 2022).

5.2 Methodology

Building on the previous section, Section §5.2 presents the steps for the definition of a methodology to assess the urban pluvial flood risk and damage.

A preliminary step (Subsection §5.2.1) involved further selecting and reorganising the indicators into categories from the classification developed in the previous section, according to i) this thesis theoretical framework; ii) its intended scale of analysis; and iii) its objectives. The following step (Subsection §5.2.2) defined the calculation of the risk components using (and, if necessary, adapting) the chosen indicators' categories. The final steps define the calculation of the urban pluvial flood risk and damage (Subsections §5.2.3

[70] The category 'damage potential' of Table II.19 provides an overview of the studies that considered damage in the flood risk assessment.

and §5.2.4) for drafting maps that offer their spatial representation. Subsection §5.2.5 summarises the methodology proposed for the calculation of the urban pluvial flood risks and provides final considerations.

5.2.1 Selection and reorganisation of the indicators

This subsection presents the selection and reorganisation of indicators into categories relevant for representing urban pluvial flood risk within the framework of this thesis. Specifically, the theoretical foundation for the risk components, which has guided the reorganisation of these indicators, aligns with the definitions outlined in Section §1.2.

The selected indicators were classified into:

- i) hazard-related categories aim to describe the potential occurrence of an urban pluvial flood event;
- ii) exposure-related indicators or indicators' categories describe the presence of people and assets that could be adversely affected by an urban pluvial flood;
- iii) vulnerability-related categories address the propensity or predisposition of these elements to be potentially affected by such an event.

Each category is relevant to the urban scale, either directly or by influencing it.

Hazard indicators' categories

Hazard-related indicators were selected on the basis of Table II.14. Keeping their classification into input and output categories (input indicators allow to determine output indicators such as the flood volume and flood depth), they were further divided into hydrological and hydraulic categories to distinguish between those linked to precipitation and those associated with the urban drainage system.

Exposure indicators

As previously mentioned, the selected exposure indicators represent the population and physical assets (i.e., buildings, rail and road infrastructure) located in the urban area, following the theoretical framework and aim of this research.

Vulnerability indicators' categories

The selected vulnerability indicators have been divided into two categories, namely adaptive capacity and sensitivity (Ellena et al., 2020; IPCC, 2018), as shown in Table II.21. **Adaptive capacity** categories allow to represent the ability of the population and of physical assets to adjust to damage, to take advantage of opportunities, or to respond to consequences of the urban pluvial floods. Among these factors there are the public awareness level, the presence of civic and social advocacy organizations, and voluntarism. Furthermore, **sensitivity** categories include indicators that describe the population or physical assets susceptible to harm.

Proximity and urbanisation categories have been excluded from the analysis. The first was excluded because it relates to the distance to floodplains and the coast in the literature, while this methodology adopts a different approach. The second is redundant, as the current analysis considers buildings and infrastructure networks on an entity-by-entity basis and including it would add unnecessary information.

Categories are given general names that do not imply any inherent positive or negative connotation. For instance, the ‘employment’ category aims to represent all indicators that describe the sensitivity of individuals based on their employment conditions, just as the ‘age’ category, which in its name does not suggest any particular value or bias, but aims to describe how certain age groups may be more sensitive. This process will be further explored in Part III, where the specific indicators and their measurements will be defined through an applied case study.

Results

Table II.21 provides the outcomes of the selection and reorganisation described in the previous paragraphs.

		Indicators or indicators' categories		
		INPUT	***OUTPUT***	
Hazard		Geology;	Flood volume and flood depth	Hydrological
		precipitation data;	Water velocity	Hydrological
		drainage basins;	Flood extent	Hydrological
		soil imperviousness;	Surface runoff/runoff retention values	Hydrological
		drainage network;	Critical areas of the drainage network	Hydraulic
		elevation;	Flow accumulation	Hydrological
		historical data.		
Exposure		Location of the population		
		Location of physical assets (buildings and infrastructure)		
Vulnerability - population & physical assets	*Sensitivity*	Population age; education; ethnicity; gender; independence; health conditions; employment; and wealth; housing capacity; buildings: age; conditions; type; built-environment characteristics and conditions; mobility and mobility infrastructure type and characteristics; land and economic productivity; presence of protected areas; land use: location of commercial/industrial; educational; energy; health; mobility; residential infrastructure and services; presence of historical, cultural and environmental assets.		
	Adaptive capacity	Public awareness level; civic and social advocacy organisations; voluntarism; presence of protection infrastructure; emergency services capacity; health services capacity; digital services capacity.		

Table II.21 | Selected indicators or indicators' categories.

5.2.2 Identification and calculation of the components

Based on the identification, classification and selection of the indicators, this subsection describes the approach chosen for the calculation of the urban flood risk components (Figure II.21), as well as the available data sources.

The calculation of the urban pluvial flood hazard has been divided into hydrological and hydraulic forcings, to account for both the precipitation-related and urban drainage network components. The calculation of the urban pluvial flood exposure assesses the presence or absence of the population and physical assets. The calculation of the urban pluvial flood vulnerability proposes an assessment of the sensitivity and adaptive capacity of – again - both the population and physical assets.

Following the considerations of the next paragraphs, thus accounting for the chosen approaches, choices and adjustments made to the identified indicators and indicators' categories, Table II.27 (Subsection §5.2.5) provides a final comprehensive overview on them and on the methods, reference studies and/or data sources, and software programs that were considered for their calculation.

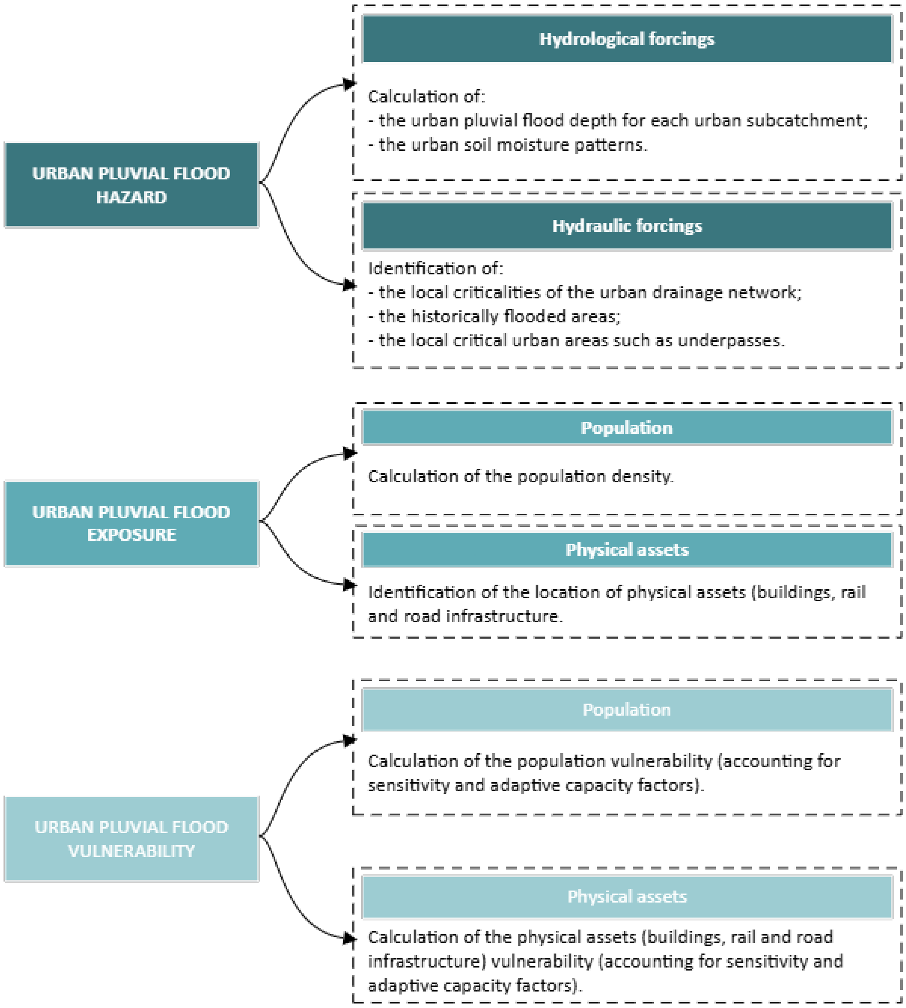

Figure II.21 | Approach for the calculation of the urban pluvial flood risk components. Source: author's elaboration.

Hydrological forcings

The urban pluvial flood depth can be calculated based on the description of infiltration phenomenon (and its complementary part, surface runoff) over time. In order to do so, literature encompasses:

i) theoretical models based on the theoretical interpretation of the infiltration phenomenon through Richards' equation, which represents the movement of water in unsaturated soils by combining the Darcy expression and a mass balance formulation[71];

ii) empirical models based on the empirical representation of the infiltration phenomenon, such as the Horton model, the Green-Ampt model and the Soil Conservation Service model.

Among the empirical methods, the Soil Conservation Service method (also called Curve Number method) allows to determine the surface runoff through the hydrological balance equation, namely:

$$R_s = P - Ip_a - F \qquad \text{(II.1)}$$

where R_s is the surface runoff; P is the precipitation; Ip_a is the initial absorption; F is the water volume infiltrated into the soil. Being Ip_a proportional to the maximum infiltration capacity S, Ip_a can be described as $Ip_a = \lambda S$, where λ is a proportionality factor usually assumed as 0.2. Therefore, the surface runoff R_s can be expressed as:

$$R_s = \frac{(P-0.2S)^2}{P+0.8S} \qquad \text{(II.2)}$$

The maximum infiltration capacity S depends on land use and on the soil characteristics such as the hydrologic soil group[72], and is approximated by a dimensionless parameter that indicates the runoff response characteristic of a drainage basin, the Curve Number (CN), according to this formula:

$$\mathrm{S} = \left(\frac{100}{CN} - 10\right) \cdot 25.4\ [mm] \qquad \text{(II.3)}$$

Calculating the surface runoff for the drainage basins (or subcatchments) allows to determine the flood volume and flood depth.

The water velocity and flood extent - despite representing useful indicators - require the setup of two-dimensional hydrologic models which account for the morphology of the territory and underground built areas but are time and resource consuming. For the purpose of this thesis, namely the identification of priority areas for the implementation of soil desealing, the altimetry of the urban area has been accounted for through the

[71] See 'https://www.sciencedirect.com/topics/earth-and-planetary-sciences/richards-equation' for further information.

[72] The Hydrologic Group classification, denoted as A, B, C, or D, represents the expected runoff from saturated soils. Group A soils are highly permeable and absorb water quickly, producing minimal runoff as they can infiltrate water at rates equal to or faster than typical rainfall. In contrast, Group D soils absorb water very slowly and generate substantial runoff due to their low permeability. Group B and C soils exhibit runoff levels between those of Groups A and D. Poorly drained soils are often classified under Group D, as their high water table impedes water movement through the soil (USDA, n.d.)

calculation of the Topographic Wetness Index (TWI). The Topographic Wetness Index is a dimensionless parameter that puts into relationship the slope and the upslope contributing area per unit width orthogonal to the flow directions, thus calculating the area draining to a single cell within a digital elevation model and the slope at that location, according to the following equation:

$$TWI = \ln\left(\frac{a}{tan\beta}\right) \quad \text{(II.4)}$$

where a is the upslope area and $tan\beta$ is the local slope (Allende-Prieto et al., 2024; Kelleher & McPhillips, 2020).

As emphasised by Kelleher & McPhillips (2020) the Topographic Wetness Index approach has been widely used in literature to study the soil moisture patterns, due to its so-called "parsimony". While it should be noted that this approach is less frequently used in urban landscapes due to the high influence of the drainage networks characteristics, the Topographic Wetness Index is still increasingly being applied in urban settings with the 'blue spots' approach, which focuses on the identification of depressions prone to filling during high intensity meteorological events when there are limited resources to employ complex hydrologic and hydraulic models (Kelleher & McPhillips, 2020). In this research, this index is employed in parallel to the map of the critical areas of the urban drainage network (see the following paragraph).

The underground urban built areas represent critical areas that are not accounted in the calculation of the Topographic Wetness Index. Therefore, gathering additional information about their location and characteristics appears relevant. In Italy, surveys of such data can be found in local level instruments, such as the local Civil protection plans (*Piani comunali di protezione civile*) that register - for instance - the location of underpasses.

Hydraulic forcings

The local critical areas of the urban drainage networks can be determined through hydraulic models, which simulate the stormwater flow through the system, allowing to identify critical nodes and conduits during precipitation events[73]. These models usually require information about the physical components of the drainage system, such as their material, dimension, planimetric and altimetric location, as well as an input precipitation depth. The data obtained for the models can be associated with historical flood data (Loli et al., 2022; Sperotto et al., 2016) for a comprehensive assessment. In Italy, this information can be usually found in the local level tools or databases of the administrations.

Exposed assets

As previously recalled, the exposed assets considered in this study consist of the population and physical assets, namely buildings and infrastructure (road and rail infrastructure). The Italian open data databases (at national, regional or provincial, and municipal level) the Italian national statistics institute (*Istituto nazionale di statistica*) and

[73] EPA SWMM (www.epa.gov/water-research/storm-water-management-model-swmm) - for instance - is a software developed by the United States Environmental Protection Agency and designed for planning, analysing, and designing tasks involving stormwater runoff, as well as combined and sanitary sewers and various drainage systems.

the urban planning instruments such as municipal urban plans (*piani regolatori generali*), aggregate information such as the location of buildings, infrastructure, and statistics on the population that, directly or with a degree of manipulation, allow to describe the location and some characteristics of the population and physical assets in urban areas.

Vulnerability

The vulnerability of physical assets and the population can be assessed using adaptive capacity and sensitivity indicators. Indicators can be then normalised to facilitate their comparison and then aggregated with a linear method (Ellena et al., 2020; Melis et al., 2023). In the case of this study, their sum with equal weights is proposed.

The literature review conducted led to the identification, classification, and selection of the following sensitivity indicators' categories:

- population age, education, ethnicity, gender, independence, health conditions, employment, and wealth;
- housing capacity;
- building age, condition, and type;
- built-environment characteristics and conditions;
- mobility and mobility infrastructure type and characteristics;
- land and economic productivity;
- presence of protected areas;
- land use: location of commercial/industrial, educational, energy, health, mobility, residential infrastructure and services;
- presence of historical, cultural, and environmental assets.

Similarly, the identified adaptive capacity indicators' categories include:

- public awareness level;
- civic and social advocacy organisations;
- voluntarism;
- presence of protection infrastructure;
- emergency services capacity;
- health services capacity;
- digital services capacity.

Data regarding the indicators can generally be gathered, similarly to the exposure data, from Italian open databases, urban planning instruments, and the Italian National Statistics Institute (*Istituto Nazionale di Statistica*)[74]. For what concerns the population, surveys are also valuable tools for gathering information directly from the population, particularly in assessing factors such as climate change awareness and attitudes toward soil desealing[75] [76].

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[74] Given that data formats and sources vary widely, software programs like QGIS (www.qgis.org) are useful for managing and integrating these datasets effectively.

[75] *Ut supra.*

[76] In the framework of employing surveys, useful instruments are the EUsurvey (https://ec.europa.eu/eusurvey/) platform for setting up surveys and data analysis software programs (e.g., PSPP, R, NLogit…).

5.2.3 Calculation of the risk

After the calculation of the urban flood risk components, normalising them to fixed value ranges facilitates their comparability and aggregation with linear methods (Ellena et al., 2020; Melis et al., 2023). In the framework of this thesis, the traditional formula

$$Risk = Hazard \cdot Exposure \cdot Vulnerability \tag{II.5}$$

is employed for the calculation of the risk (as an example, see Dipartimento della Protezione Civile, n.d.), by multiplying (with equal weights) its components for the chosen unit of analysis.

Figure II.22 summarises the steps of the proposed approach.

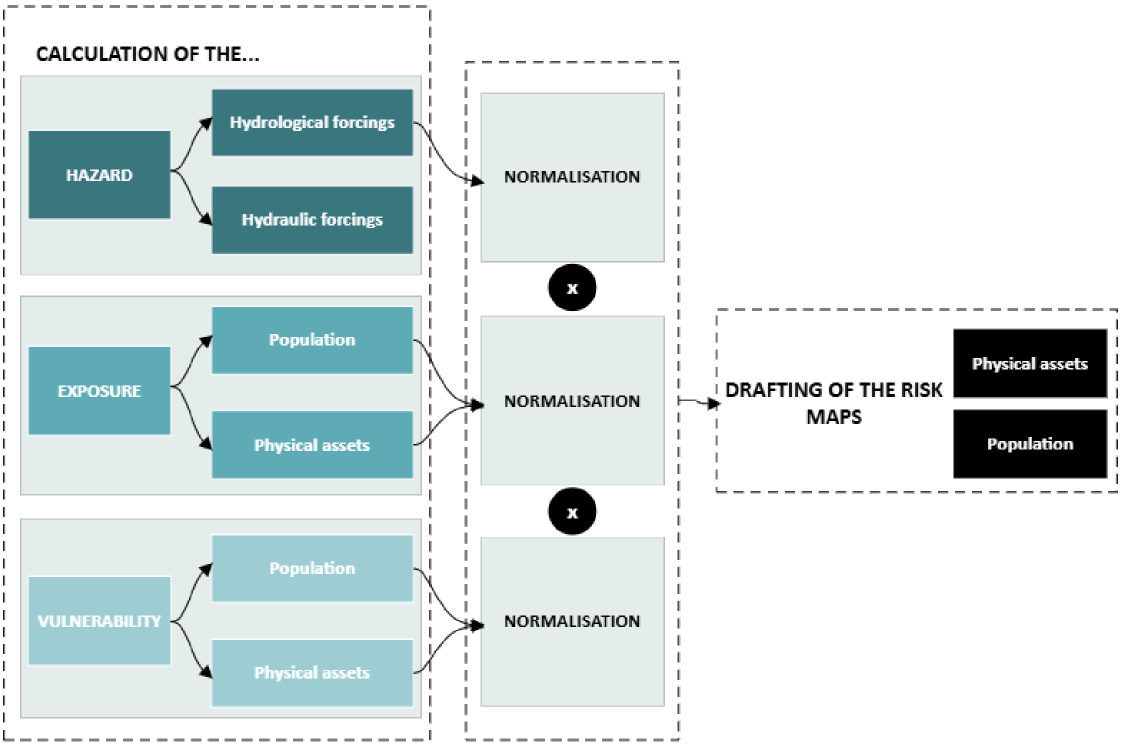

Figure II.22 | Overview of the approach for drafting the urban pluvial flood risk maps. Source: author's elaboration.

5.2.4 Calculation of the damage

The (potential) damage to physical assets and the population is also assessed. Traditionally, damage is understood as the interaction of the exposure and vulnerability for a given event, as expressed by the formula

$$Damage = Exposure \cdot Vulnerability \tag{II.6}$$

(as an example, see Regione Emilia-Romagna, n.d.).

However, in addition to the aforementioned formula (hereafter identified as approach A), damage has been assessed with various methods, including flood depth-damage curves and flood depth-mortality or population-affected curves (hereafter identified as approach B).

Figure II.23 summarises the steps of the approaches that have been employed within this thesis for calculating the urban pluvial flood damage, which can then be compared. The steps for the employment of the flood depth-damage curves are described in the following paragraphs.

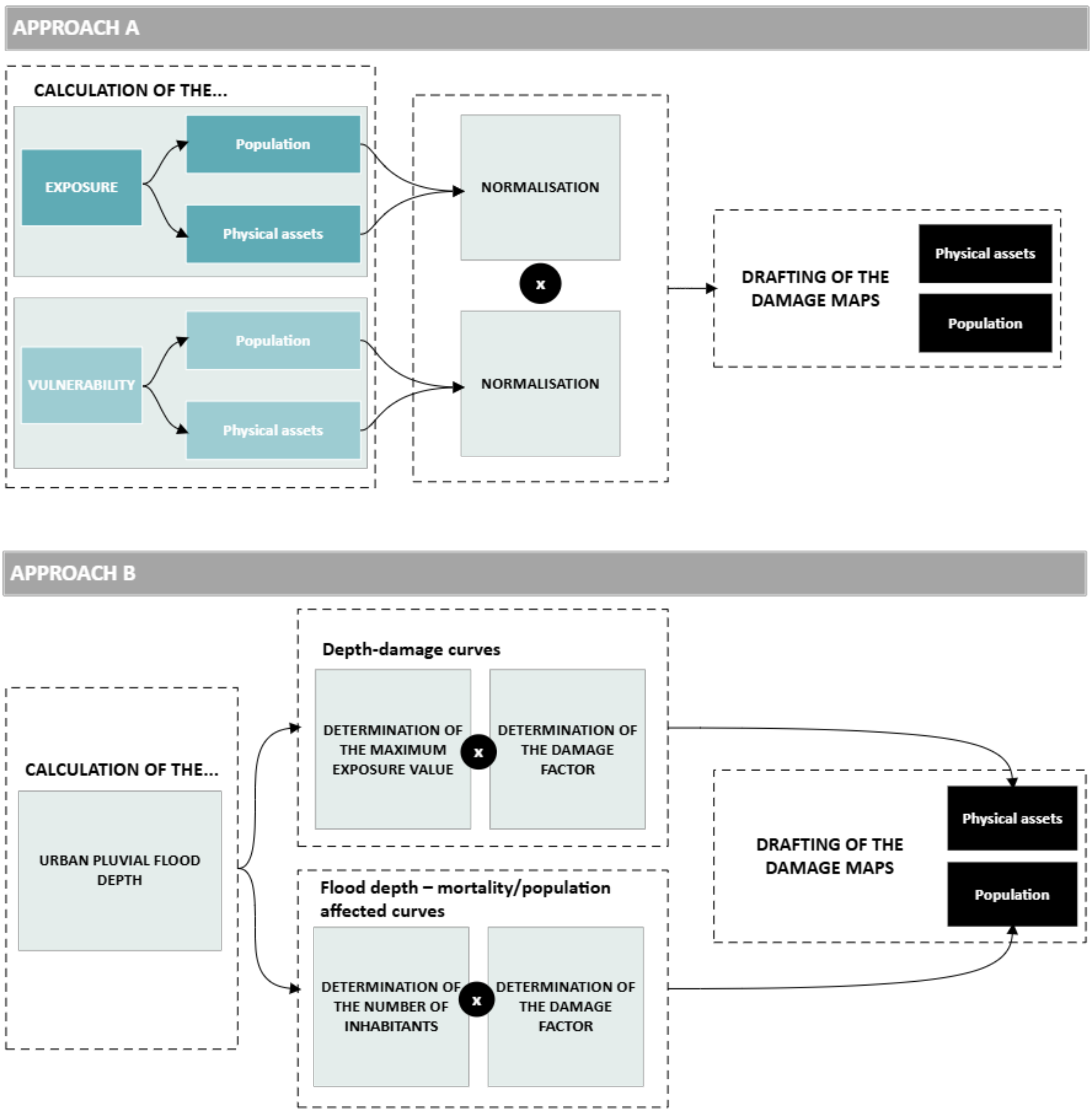

Figure II.23 | Overview of the approaches (A and B) employed for drafting the urban pluvial flood damage maps. Source: author's elaboration.

Damage to the physical assets

The damage to physical assets and land use classes caused by generic floods can be calculated by using depth-damage curves. For this purpose, Huizinga et al. (2017) have developed global depth-damage curves for the five continents. Based on extensive literature reviews, the researchers have put into relationship fractional damage as a function of the water depth. Figure II.24 shows the damage factor-water depth curves for Europe.

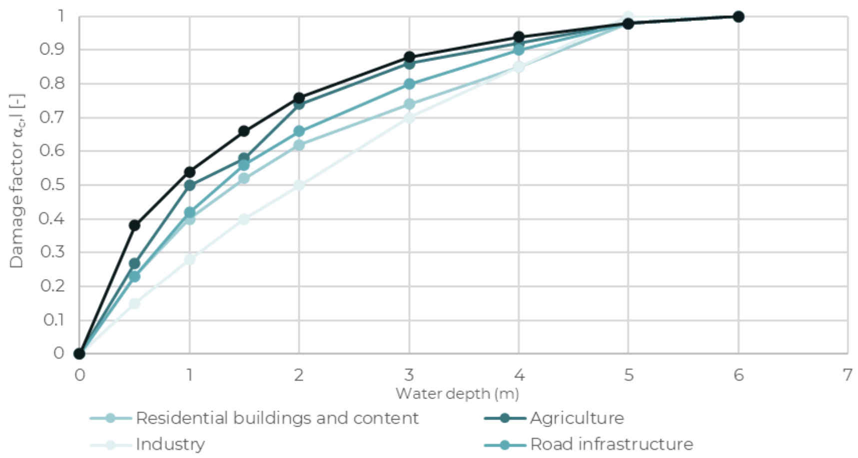

Figure II.24 | Damage factor-water depth curves for Europe according to Huizinga et al. (2017). Source: author's elaboration.

Damage factor-water depth curves, when associated with the maximum damage values[77], allow to calculate the damage for each square meter of built infrastructure (Huizinga et al., 2017), according to the formula

$$Damage = \alpha_c, l \cdot E_{max}, l \quad \text{(II.7)}$$

where α_c, l [-] is the damage factor, function of the water depth and E_{max}, l [€/m^2] is the maximum exposure value.

The damage values for each physical asset and land use category have been calculated for Italy according to Huizinga et al. (2017). The resulting values are encompassed by Table II.22.

Maximum exposure value E_{max},l for Italy [€/m²]							
Residential		***Agriculture***	***Industry***		***Road and rail infra-structure***	***Commerce***	
Buildings and content	***Land use***		***Buildings and content***	***Land use***		***Buildings and content***	***Land use***
739	148	0.22	838	251	21	1028	308

Table II.22 | Maximum exposure value determined based on Huizinga et al. (2017).

[77] The maximum damage values are based on construction costs surveys from multinational construction companies. These values are calculated through statistical regression with the socio-economic World Development Indicators, and allow to determine the urban pluvial flood damage in different continents and countries (Huizinga et al., 2017).

Damage to the population

The damage to the population can be calculated by using flood depth-mortality or population affected curves. The specification of these curves varies in literature (i.a., Jonkman et al., 2008; Jonkman & Asselman, 2003; Rincón et al., 2022; Russo & Parisani, 2019)[78]. Without the intention of being exhaustive, Table II.23 encompasses some of the functions that have been used or identified by researchers for the calculation of the social damage.

Author, year	*Description*	*Damage factor*	*Curve*
Jonkman & Asselman, 2003	Fast rising flood depth - mortality curve; slow rising flood depth - mortality curve	$f(d)_{fast} = 9.18 \cdot 10^{-4} * e^{1.52 \cdot flood\ depth}$ $f(d)_{slow} = 1.41 \cdot 10^{-3} * e^{0.59 \cdot flood\ depth}$	$Mortality = f(d) \cdot number\ of\ inhabitants$
Russo & Parisani, 2019	Flood depth - mortality curve	(d; mortality coefficient) = (0-2; 0), (3; 0.10), (4; 0.50), (5; 1.0), (6; 1.0)	$Mortality = mortality\ coefficient \cdot number\ of\ inhabitants$
Rincón et al., 2022	Flood depth - population affected curve	(d; affected population coefficient) = (0; 0%), (0.1; 100%), … , (2.5; 100%)	$Affected\ population = affected\ population\ coefficient \cdot number\ of\ inhabitants$
The flood depth (d) is expressed in meters.			

Table II.23 | Functions that have been identified for the calculation of social damage.

In the context of the calculation of damage to the population, and specifically the mortality, some considerations need to be made for the European and Italian cases.

In middle-and high-middle-income countries, the mortality fraction per event has decreased over time, while – on the contrary – it has been increasing for low-income countries (Jonkman et al., 2024). In Italy, the Italian national research council (*Consiglio Nazionale delle Ricerche*) reports account for one death as a consequence of pluvial floods in 2024 (Bianchi & Salvati, 2024a). As shown in Table II.24, previous years show similar data.

Year	*Number of deaths*
2023	1
2022	0
2021	1
2020	0
2019	0
2018-2014	2

[78] Among the applications, Chen (2007) employed Jonkman & Asselman's (2003) curves for case study of the Huong River Basin, considering a flood resulting from a historical precipitation. Russo & Parisani (2019) employed flood-depth mortality curves for an Italian case study, while Rincón et al. (2022) calculated the affected population for the case study of a flood risk assessment in Canada.

Table II.24 | Number of deaths resulting from pluvial floods between 2014 and 2023. Source: elaboration based on data from Bianchi & Salvati (2019, 2020, 2021, 2022, 2024b).

In this framework, Jonkman et al. (2024) emphasised that adaptation efforts such as enhancing warning systems and providing shelters are essential in reducing the population vulnerability to floods. The low number of fatalities in the Italian scenario – which is often linked to underpasses - suggests that the education of the population plays a critical role in mitigating flood-related mortality. In the framework of raising awareness, participatory processes acquire therefore a relevant role in involving the population and the communities.

5.2.5 Summary and final considerations

The following paragraphs summarise the proposed methodology for the urban pluvial flood risk and damage assessments. Table II.25 lists the chosen indicators or indicators' categories, reference studies for the assessment and/or data sources, as well as the proposed software programs for the calculation the risk components[79]. Table II.26 and Table II.27 encompass the proposed calculation methods for the risk and the damage.

As previously mentioned in Subsections §5.2.2 and §5.2.3, the urban pluvial flood vulnerability and risk assessments involve the use of normalisation. In the first case, the vulnerability indicators are normalised and then summed, while in the second, the risk components are normalised, multiplied, and then normalised again.

It appears interesting to emphasise that - while exposure and vulnerability are treated as separate components in the risk assessment - they are combined in the damage calculated with Approach B, which proposes the employment of maximum exposure values and damage factors.

Risk component	*Indicators or indicators' categories*		*Reference study for the assessment/ data sources*	*Software programs needed/proposed*
	INPUT	**OUTPUT**		
Hazard	- Geology (hydrological soil type); - pluvial data (precipitation depth); - drainage basins; - Curve Number (imperviousness); - elevation	Flood volume or depth	Hydrological model (Soil Conservation Service method)	- InVEST (naturalcapitalproject.stanford.edu/software/invest); - QGIS (www.qgis.org); - a spreadsheet software programs
		Runoff/runoff retention values		
		Topographic wetness index	Hydrological model (Allende-Prieto et al., 2024; Kelleher & McPhillips, 2020)	- QGIS/GRASS (www.qgis.org/ with SAGA and GRASS implementation); - a spreadsheet software program

[79] Opensource software programs have been preferred.

Risk component		Indicators or indicators' categories	Reference study for the assessment/ data sources	Software programs needed/proposed
		- Underground built areas; - historically flooded areas	Literature (e.g., local Civil Protection Plans)	- QGIS (www.qgis.org); - a spreadsheet software program
		- Local critical areas of the drainage network	Literature and/or hydraulic model	- EPA SWMM (www.epa.gov/water-research/storm-water-management-model-swmm); - QGIS (www.qgis.org); - a spreadsheet software program
Exposure		- Location of the population	Data collection (e.g., Municipal urban plan boards, open databases of the administrations)	- QGIS (www.qgis.org); - a spreadsheet software program
		- Location of physical assets (buildings and infrastructure)		
Vulnerability– population (P) & physical assets (PA	Sensitivity	- Population age; education; ethnicity; gender; independence; health conditions; employment; and wealth (P); - housing capacity (P); - buildings: age; conditions; type (P/PA); - built-environment characteristics and conditions (P/PA); - mobility and mobility infrastructure type and characteristics (P/PA); - land and economic productivity (PA); - presence of protected areas (PA); - land use: location of commercial/industrial; educational; energy; health; mobility; residential infrastructure and services (P/PA); - presence of historical, cultural and environmental assets (PA)	Data collection (e.g., Municipal urban plan boards, open databases of the administrations)	- QGIS (www.qgis.org); - a spreadsheet software program
	Adaptive capacity	- Public awareness level (P); - civic and social advocacy organisations (P); - voluntarism (P) - presence of protection infrastructure (P/PA); - emergency services capacity (P); - digital services capacity (P); - health services capacity (P)	Data collection (e.g., Municipal urban plan boards, open databases of the administrations; surveys)	- QGIS (www.qgis.org); - a spreadsheet software program - EUsurvey platform (ec.europa.eu/eusurvey/) - data analysis software programs (e.g., PSPP, R, NLogit…)

Table II.25 | Indicators and indicators' category, methods, reference studies, data sources and software programs for the calculation of the urban pluvial flood risk components.

Risk calculation
$Risk = Hazard \cdot Exposure \cdot Vulnerability$

Table II.26 | Formula for the calculation of the urban pluvial flood risk.

Damage	***Method/reference studies***	***Software programs needed/proposed***
Physical assets	Flood depth-damage curves (Huizinga et al., 2017)	- QGIS (www.qgis.org); - a spreadsheet software program
Population	Flood depth – mortality or flood depth - affected population curves (Jonkman et al., 2008; Jonkman & Asselman, 2003; Rincón et al., 2022; Russo & Parisani, 2019)	- QGIS (www.qgis.org); - a spreadsheet software program
Calculation	$Damage = \alpha_c, l \cdot E_{max}, l$ where α_c, l [-] is the damage factor, function of the water depth and E_{max}, l [€/m^2] is the maximum exposure value	

Table II.27 | Methods, reference studies and software programs for the calculation of the urban pluvial flood damage.

6 Investigating the transformation potential of urban areas

This chapter discusses the transformation potential of urban areas with the aim of identifying opportunities to implement soil desealing in urban regeneration practices and planning instruments. For this purpose, both the urban 'desealing potential' and the Italian legislative and strategic and legislative tools are considered as relevant scenarios to investigate. Supported by the literature review of Part I, this chapter is connected to the previous with the aim of comparing their outcomes for the definition of desealing priority areas. Practically, the results of the urban flood risk and damage assessments help to identify critical areas within the urban environment, which can then be compared to urban regions with high transformation potential[80].

The investigation of the urban transformability is structured around three main matters, which have been specifically identified for the Italian context in relation to soil desealing and climate change adaptation: public vs. private ownership of areas, programmatic vs. regulatory and strategic planning instruments, and location-based vs. generalised or index-based approaches. These dualities pertain both to the urban landscape itself and to its transformation processes. Figure II.25 illustrates these factors, which have guided the discussion in this chapter.

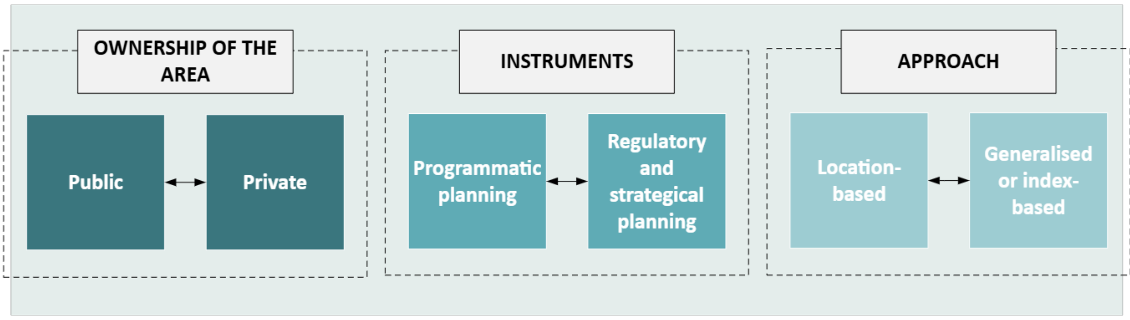

Figure II.25 | Factors influencing urban transformability. Source: author's elaboration.

With regard to the ownership of the areas, while public and private spaces coexist within cities and are subject to the same legislative systems (with overlapping or interrelated regulatory instruments), they are governed by profoundly different processes. In Italy, private property is traditionally highly valued, leading to a particular sensitivity among citizens regarding its management. Consequently, any transformations initiated by public authorities must be especially attentive to (and respectful of) the citizens' opinion[81]. In this context, public areas tend to be comparatively more straightforward to transform, also in the context of the assumption of a strong climate change adaptation-related public initiative.

Two main groups of planning instruments can be identified: programmatic and regulatory or strategic planning tools. Programmatic planning, which includes instruments such as the three-year public works programmes (*programmi triennali dei lavori pubblici*), is

[80] The terms 'transformation potential' and 'transformability' will be considered synonyms in the framework of this thesis.

[81] An example is the complex regulatory system of the expropriation procedures which resulted from decades (if not centuries) of debate regarding this topic (Zanon, 2008).

generally associated with public areas, while regulatory planning is more often linked to private areas. For example, the municipal urban plans (*piani urbanistici comunali*), although covering also public spaces, are primarily applied to guide the transformation of private spaces. Additionally, programmatic planning provides a relatively higher degree of certainty regarding the timing of interventions, while regulatory or strategic planning tends to offer a lower confidence level about when interventions will be implemented[82].

Furthermore, the literature (and case studies) review in Part I has identified several strategies for enhancing urban permeability. Two primary approaches have emerged: location-based and generalised or index-based approaches, which are sometimes combined (see Section §2.2). This chapter discusses these them, with a focus on their potential applications within the urban planning instruments.

Building on these initial considerations, the assessment of urban transformability is understood as linking an area desealing potential[83] - hence the practical possibilities a physical area presents for soil desealing, based on various social, economic, and environmental factors (Section §6.1) - with the opportunities provided by urban planning instruments (Section §6.2).

6.1 Evaluating the desealing potential

On a general level, researchers have explored the relationship between soil and the urban environment, identifying – also from a climate change adaptation perspective – the factors for assessing urban transformability.

As an example, some authors have studied the technical and environmental characteristics of urban areas, such as runoff retention and density, linking these aspects to their formation and transformation processes. Recognising them as relevant factors for planning, they propose intervention strategies aligned with urban characteristics. Observations such as these, reflected in municipal instruments such as general urban plans (*piani regolatori generali*), can impact zoning and reveal transformative opportunities within cities (Giaimo et al., 2020), thereby contributing to the mitigation of issues like urban flood risk.

Focusing on urban morphology, researchers have examined the negative spaces resulting from the chaotic, discontinuous and unplanned growth of contemporary cities as valuable sites for enhancing resources like air, water, and soil (Tommasoli, 2018). The marginal urban spaces where the city slowly becomes extra-urban land, industrial brownfields, domestic voids in the proximity of infrastructure, and unused road and rail infrastructure have been identified as relevant ecological spaces by Gilles Clément (2005) in his 'Manifesto of the Third Landscape'. These areas can be interpreted in a multiplicity of ways by the actors of the urban transformations, and the restoration of their ecological worth can contaminate also the surrounding areas by transforming them into 'green voids' (Gabbianelli, 2017). This concept of ecological contamination has been pursued also by scholars who promoted the identification of regenerable areas in the urban peripheries – through urban planning instruments such as municipal urban plans (*piani urbanistici*

[82] However, both instruments allow for interventions on already established or planned transformations through the implementation of new indices or requirements (e.g., in public works maintenance plans - *piani di manutenzione delle opere pubbliche*). Alternatively, they can propose new transformations, such as initiatives targeting the desealing of specific areas or types of areas.

[83] The terms 'desealing potential' and 'desealability' will be considered synonyms in the framework of this thesis.

comunali). Furthermore, they investigated their effect on the city and pursued a 'city to regenerate' as opposed to urban expansion (Barbarossa et al., 2014).

In the context of soil desealing, a practical example of the investigation of an urban area transformability (and desealing potential), was explored within the 'Green in Parma' project (see also Subsections §2.2.2 and §9.4.1), in which an initial approach to identify desealable or greenable areas was developed. This approach introduced the concept of '*piccolo verde mancato*' (literally, 'missed small green'), which emphasises the practical utility - or lack thereof - of certain paved urban spaces.

The diverse social, economic, and environmental processes shaping cities make it challenging to systematically assess the transformability of urban areas, also because the purpose of this assessment can vary. The following paragraphs outline a method (summarised in Subsection §6.1.3) for assessing the desealing potential of urban outdoor surfaces[84] by examining two groups of factors: those related to the context of the area (Subsection §6.1.1) and those pertaining to its intrinsic characteristics (Subsection §6.1.2).

6.1.1 Contextual factors

The first group of factors - the contextual factors – includes:

- the ownership of the area, which identifies whether areas are privately or publicly owned, influencing the processes associated with interventions;
- the characterisation of the area, which accounts for site-specific factors, including their development status, their phase within the urban lifecycle and their primary use.

These first contextual factors, while not being determinant for the desealability of an area, require evaluation according to the specificities of local urban planning instruments and the broader urban characteristics. However, given the assumption of the existence of a strong public initiative for soil desealing or the increase of soil permeability, the ownership of the area acquires relevance and makes the transformation easier.

Furthermore, there are contextual parameters that inherently positively or negatively influence the desealing potential. Among the positive contextual factors there are:

- the promotion of soil permeability in the area by the urban planning tools, for instance in accordance with zoning regulations (e.g., building and permeability parameters for interventions on the consolidated city);
- the local cultural/economic/social benefits that soil desealing might entail, i.e., soil desealing has a strong benefit not only on the environment, but also on the other spheres of sustainability. For instance, the implementation of green areas creates a place for social gatherings which is proven to be needed by the population. This was the case of some of the 'Depave' project actions (see Subsection §2.2.2);
- the existence of a favourable opinion or sensitivity of the local population, which may help to implement soil desealing from a political point of view;
- the existence of plans and projects for the area, which may ease the implementation of a soil desealing intervention, for instance public areas that are foreseen to be transformed (e.g., the renovation of a public square).

[84] While roofs can be included in the assessment as potentially desealable surfaces, the assessments in the present thesis focus specifically on ground-level surfaces.

A negative contextual factor is represented by the existence of technical/geomorphological constraints that hinder the implementation of soil desealing interventions, such as the presence of contaminated areas (i.a., Boglietti, 2024; Tobias et al., 2018).

The proximity to green areas may ease, from the practical point of view, maintenance works, while the proximity of services entails an increased need for a better urban performance with respect to flood risk management[85]. These factors, even though not directly influencing the transformability of the area, may "boost" it from the decision-makers' perspective.

6.1.2 Intrinsic factors

The second group of factors - the intrinsic factors – describes the characteristics of the paving recognised as influencing the feasibility of soil desealing interventions, namely:

- the usefulness of the paving, as there are areas that cannot be desealed due the paving function, e.g., road paving performs a logistic function;
- the cultural/historic/economic/social value of the paving, e.g., interventions on a historical paving may be prohibited by law to preserve their cultural and historic value;
- the date of installation/last maintenance of the paving is a further indicator of the ease in the implementation of soil desealing interventions. Citizens and decision-makers may be reluctant to allocate additional resources for replacing paving that has just undergone improvements, as it could be seen as wasteful or unnecessary;
- the condition of the paving, as interventions on a degraded paving may be more accepted by citizens and promoted by decision-makers.

6.1.3 Methodology

The following tables encompass the identified contextual and intrinsic factors (Table II.28 and Table II.29). These factors were structured as a 'classification sheet' for surveying urban areas, where each factor is linked to two or more possible cases that describe the conditions under which the area may fall. Each case is associated with either a positive or negative influence, except for the 'ownership of the area' and 'characteristics of the area' factors. Additionally, certain conditions may make desealing impossible, such as in cases of paving with a fundamental use; these conditions are marked with an asterisk.

From a practical standpoint, data collection for the identified factors may sometimes pose challenges. For example, information regarding the installation or last maintenance date of paving may not even be readily available to the local administration. However, this factors review is to be intended as an ideal working setting or recommendation for public entities, which can be then adapted to real-world situations. Strategies will need to be adjusted depending on the context and the available workforce, especially when certain data are not accessible and available.

[85] For instance, streets in the proximity of schools may benefit from an improved stormwater management, as well as from the implementation of green areas.

Contextual factors	*Positive (+)*	*Negative (-)*	*Method/Data sources*
Existence of plans and projects for the area	Plans or projects that encompass soil desealing have been envisioned for the area	Plans or projects in contrast with soil desealing have been envisioned for the area	Urban planning instruments, boards and reports (e.g., Municipal urban plans, Implementation plans), open databases of the administrations, and related resources
Promotion of soil permeability in the area by the urban planning tools	Soil permeability is promoted in the area	Soil permeability is not promoted in the area	
Local cultural/economic/social benefits of soil desealing	Soil desealing interventions result in relevant cultural, economic or social benefits	Soil desealing interventions do not result in relevant cultural, economic or social benefits	*Ad hoc* analysis (e.g., newspapers, surveys...)
Favour or sensitivity of the local population	The local population has been involved in processes that promote soil desealing or is very sustainability-oriented	The local population has not been involved in processes that promote soil desealing and does not show an orientation towards sustainability	*Ad hoc* analysis (e.g., newspapers, surveys...)
Constraints (technical/geomorphological) for soil desealing	There are no constraints that hinder soil desealing	There are constraints that hinder soil desealing*	Urban planning instruments boards and reports (e.g., Municipal urban plans, Implementation plans), open databases of the administrations, and related resources
Ownership of the area	Public/Private		Urban planning instruments boards and reports (e.g., Municipal urban plans, Implementation plans), open databases of the administrations, and related resources
Characterisation of the area (e.g., by the Municipal urban plan)	Development status, e.g., abandoned area or area identified for regeneration		Municipal urban plan boards and reports
	Phase within the city's development lifecycle, e.g., historic centres, consolidated city, or new expansions		
	Primary use of the area, e.g., industrial, commercial, or residential		
*Proximity to green areas***	Presence of parks and green areas in the surroundings	Absence of parks and green areas in the surroundings	Urban planning instruments boards and reports (e.g., Municipal urban plans, Implementation plans), open databases of the administrations, and related resources
*Proximity to services***	Presence of schools, hospitals and other relevant public infrastructure in the surroundings	Absence of schools, hospitals and other relevant public infrastructure in the surroundings	

*soil desealing is not possible, ** "boosting" factors

Table II.28 | Contextual factors of the desealing potential and possible method/data source for their assessment.

Intrinsic factors	Very positive (++)	Positive (+)	Negative (-)	Method/Data sources
Usefulness of the paving	Paving is useless	Paving is partially useless	Paving is fundamental *	Urban planning instruments boards and reports (e.g., Municipal urban plans, Implementation plans), open databases of the administrations, and related resources
Cultural/historic/economic/social value of the paving	Paving has no cultural, historic, economic or social value	Paving has a negligible cultural, historic, economic or social value	The cultural, historic, economic value of the paving is not negligible (e.g., protected area)*	
Date of installation/last maintenance of the paving	Installation of the paving in the distant past (e.g., >10 years)	Installation of the paving in the medium past (e.g., < 10 years e > 2 years)	Recent installation or maintenance of the paving (e.g., < 2 years)	Databases of the administrations, direct survey
Condition of the paving	The paving is not functional	The paving is functional but damaged	The paving is functional and not damaged	Databases of the administrations, direct survey

*soil desealing is not possible

Table II.29 | Intrinsic factors of the desealing potential and possible method/data source for their assessment. See the glossary for the Italian translations.

6.2 Identifying the urban planning instruments

As emphasised in Chapter §4, the absence of a national Italian framework for urban regeneration creates a gap in the legislative and normative landscape, hence concerning also the implementation of soil desealing. As a result, urban planning practices are currently shaped by the initiatives of progressive local administrations and private actors, who must navigate this process without formalised legislation or clear implementation guidelines. For example, some regions, such as Emilia-Romagna, have developed regional laws and certain cities have proactively created sector-specific tools to incorporate soil desealing into their urban planning instruments (see Section §4.2). This highlights the potential role of a structured nationwide legislative framework that may guide and standardise these efforts across different regions. Without such framework, progress relies on local initiatives which, to this day [2024] have resulted in uneven – despite promising - outcomes.

The Italian landscape offers several opportunities for advancing and scaling up more sustainable practices in urban transformation. Rooted also in the European framework (see Section §3.1), the Italian strategic and legislative urban scenario may have the potential to support a nationwide shift towards sustainability.

As noted in the ‘Agenda 21’ document, developed during the Earth Summit in 1992, local communities are important agents for implementing and formulating sustainable development strategies (MASE, n.d.; United Nations, 1992). Accordingly, local communities are envisioned as stakeholders who can highlight pressing needs and identify the most effective strategies for implementing soil desealing, thereby facilitating the transition at higher levels.

Within this context, this section aims to explore potential legislative opportunities for soil desealing at the municipal level, while also investigating the technical parameters necessary for regulating these interventions. The goal is to establish a set of guidelines that will not only assist local administrations, but also provide a knowledge framework to inform policy- and decision-makers at higher levels. As a general reference, the Italian urban planning scenario was summarised in Figure II.26, which provides an overview its levels and corresponding instruments. This includes both the strictly urban planning aspects as well as the related legislative and strategic frameworks.

The following subsections are structured according to the previously mentioned duality represented by location-based and performance- or index-based approaches (Figure II.25). On one hand, location-based approaches have been identified in case studies that define a list or a catalogue of urban areas that can/need to be desealed. On the other hand, generalised or index-based approaches are independent from the identification of desealable areas, but define indexes and parameters to regulate the potential performance of the urban area. The analysis further distinguishes the processes for private and public areas, and considers programmatic, regulatory and strategic planning instruments.

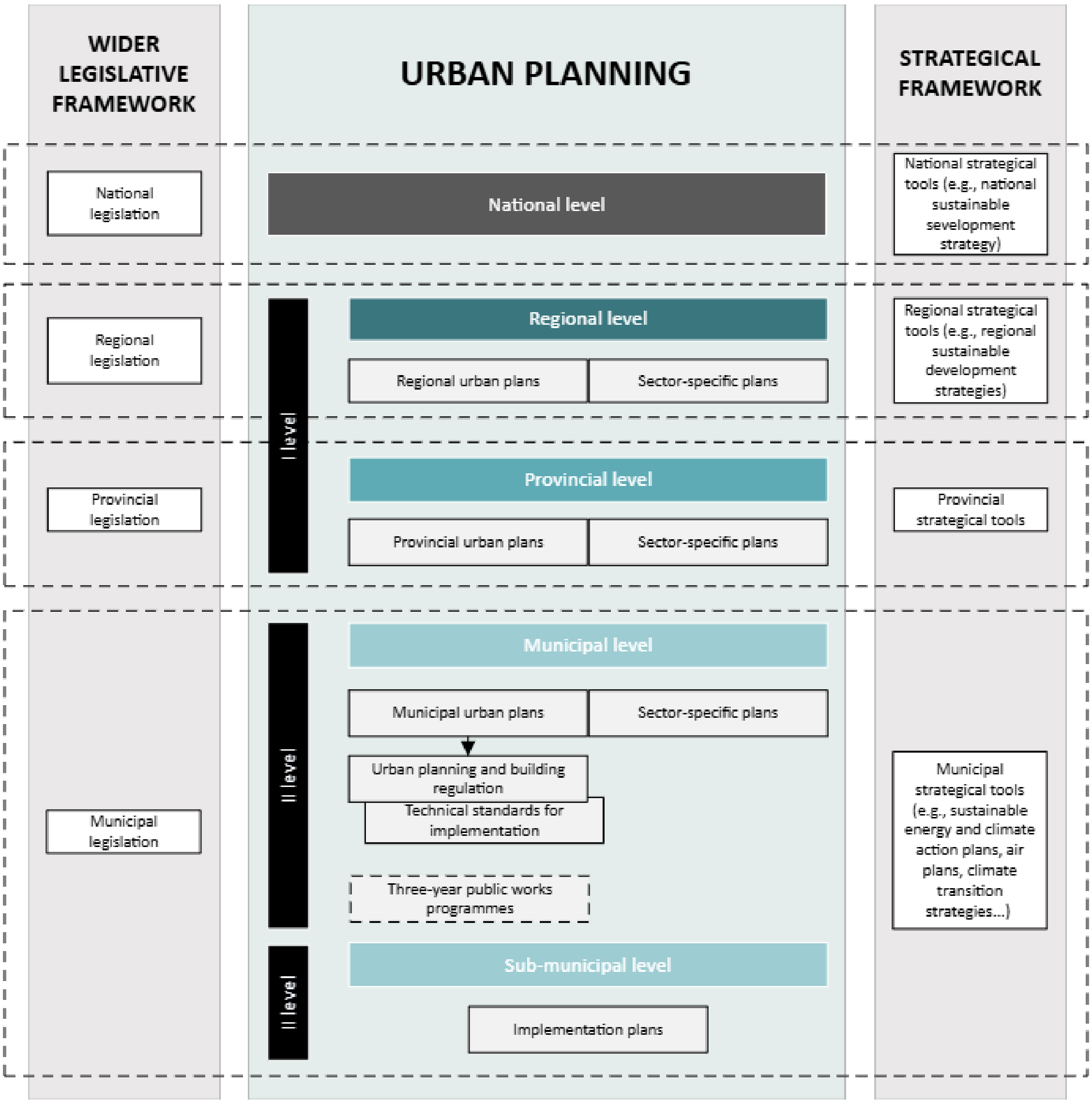

Figure II.26 | Levels and tools of the Italian urban planning framework. See the glossary for the Italian translations. Source: author's elaboration.

6.2.1 Location-based approaches

Location-based approaches typically involve identifying areas that are suitable for soil desealing, as was done in the German context (see Subsection §2.2.2). Whether based on transformability, technical factors, or both, these processes are generally guided by an urban planning instrument and may act on both public and private areas, and at various levels.

In Italian cities, the most suitable instruments may be represented by municipal urban plans (*piani urbanistici comunali*) or by sector-specific plans (*piani di settore*), such as the green plans (*piani del verde*) or a dedicated soil desealing plan (*piano di desigillazione*)[86]. Following the example of German cities, this could begin with creating a catalogue of areas

[86] The choice of the appropriate instrument depends on the specific context. In cases where a variety of urban planning instruments is already in place, introducing an ad-hoc, sector-specific plan for soil desealing may be redundant.

to deseal, followed by regulations to facilitate their transformation. For instance, they may be used to compensate soil consuming interventions such as new buildings. Furthermore, also three-year public works programmes (*programmi triennali dei lavori pubblici*) for what concerns public areas, and implementation plans (*piani attuativi*) for both public and private areas can refer to the identified areas and promote their desealing. Upper-level plans, such as regional and provincial urban plans (*piani urbanisitci regionali e provinciali*) may be relevant in the identification of areas of regional or provincial interest, that may be comprised by, for instance, more municipalities.

Considering the public and private property duality, desealing public areas may seem easier than private ones, as public initiatives can directly align with programmatic instruments such as the three-year public works programmes and their annual revisions[87]. In contrast, public intervention on private land is more complex due to the traditionally strong protection of private property in the Italian context, which complicates administrative actions on private grounds. Legislative instruments would need to enforce the transformation of private areas. In this context, a generalised or index-based approach could offer a less intrusive, low-imposition strategy that encourages compliance without placing excessive pressure on property owners. However, if the initiative comes from private individuals - such as citizens opting to deseal their property in exchange for financial or building incentives - the process may be more straightforward.

6.2.2 Generalised or index-based approaches

Approaches that are not based on the location of areas to deseal, but rather on the (past or potential) performance of the urban areas, may rely on various approaches to guide the transformation of the spaces. These may include:

- indexes;
- incentives;
- compensation measures or other related approaches.

The use of indexes, whether associated with municipal urban plans (*piani urbanistici comunali*) or sector-specific plans (*piani di settore*), can also be further detailed through urban planning and building regulations (*regolamenti urbanistici ed edilizi*) and technical standards for implementation (*norme tecniche di attuazione*), for instance according to the municipal land use. In the case of soil desealing, first and foremost, the municipal urban plans and sector-specific plans are relevant instruments which can pose limits on the city expansion[88]. Upper-level instruments, such as regional and provincial urban plans (*piani urbanistici regionali e provinciali*) may also specify, similarly to the local level plans, what encompassed by the regional laws according to land use or areas of supra-municipal competence. The urban planning tools may therefore pose more stringent parameters, fostering urban regeneration instead of expansions. However, acknowledging the difficulty in this kind of switch, relevant indexes could be oriented to include limits on impervious surfaces for new buildings or the requirement to maintain a minimum percentage of pervious surface. This can be achieved using percentage-based approaches

[87] In fact, when maintenance or urban transformation are planned, new opportunities arise. For instance, public works maintenance plans (*piani di manutenzione delle opere pubbliche*) for public buildings and infrastructure could be aligned with municipal urban plans, incorporating specifications related to permeability.

[88] For the case of the Emilia-Romagna Region, these instruments may specify what already envisioned by the Regional Law No. 24/2017 of the Emilia-Romagna Region, that imposes a 3% limit for new urban expansions.

or by calculating permeability indexes. An interesting case involves considering the 'hydrological and hydraulic invariances' (see Footnote 22 and Regione Lombardia, n.d.), which compares the performance of transformed areas to that of the natural environment. This approach is significant because, rather than imposing arbitrary limits, it involves a case-specific analysis. However, it is both time- and cost-intensive, and for the sake of efficiency, it may be replaced with simpler guidelines when necessary.

While indexes can be applied to both public and private transformations (thus being encompassed by programmatic, legislative and strategic instruments), incentives are primarily focused on private areas (and thus on legislative instruments). Although having a lower practical control on which areas will be desealed (also from a temporal perspective), they can be effective in reducing the urban impervious surface. For instance, volumetric incentives for desealing private land may encourage the transformation of spaces into more permeable areas. Similarly, discounts on urbanisation fees could lead to similar outcomes. This type of proposal is likely to be well-received by both the public and urban stakeholders, as it is less imposing than other strategies and is perceived as more respectful of private property, allowing private citizens the freedom to choose.

Compensation measures function similarly to incentives but take a more compulsory approach. Rather than viewing soil desealing as a mean to gain an advantage, they tie the transformation of an area to the mandatory desealing of another. This could be proposed by the party responsible for the transformation or selected from a catalogue of desealable areas developed by the municipality. This strategy could apply to both public and private spaces, as it may involve financing soil desealing interventions on public land as compensation for transformations on private properties.

A further option may involve asking the actors of the transformation, whether public or private, to justify the sealing of the areas that the project entails during the process of submitting building permits (*titoli abilitativi*). This strategy could offer several advantages, as it is not imposing and encourages stakeholders to become more sensitive to the issue, prompting them to reflect on their decisions. However, this type of request would need to be supported by a guiding document that outlines the most common scenarios to support the involved stakeholders and prevent any 'escape routes'.

A final remark is the need to differentiate the indexes and incentives based on urban zoning. As an example, industrial, commercial, and residential areas have distinct needs and specificities that arise from their intended uses. Tailoring these measures to the specific characteristics of each zone ensures more effective and appropriate interventions.

6.2.3 Overview of the available instruments and verification methods

The following table (Table II.30) summarises the available or potential instruments that could be used to foster the implementation of soil desealing within urban planning tools. In addition to their alignment with the identified approaches and suitability for public or private areas, the table includes a description of the opportunities offered by the tool.

Scale of the urban planning instrument	*Approach*		*Ownership of the areas*		*Description/Notes*
	Location-based	*Generalised or index-based*	*Private*	*Public*	
Regional and provincial urban plans	•	•	•	•	Regional and provincial urban plans can regulate the space from both legislative and strategic point of views. However, at this scale, location-based approaches seem suitable mainly for areas of supra-municipal interest.
Municipal urban plans	•	•	•	•**	Municipal urban plans can regulate the space both legislative and strategic point of views. **to a smaller extent
Sector-specific plans	•	•	•	•	Despite playing a similar legislative and strategic role to the municipal (and regional/provincial) urban plans, sector-specific plans may allow to focus on soil desealing with a designated instrument (e.g., with a soil desealing plan) or as a part of a broader topic (e.g., as a part of the green plan).
Urban planning and building regulations and *technical standards for implementation*	•	•	•	•**	These tools allow for the integration of practical measures - as their name says - and are therefore feasible instruments for the implementation of indexes, incentives, specifications on compensation measures and technical details of other nature. **to a smaller extent
Three-year public works programmes	•			•	This instrument collects the project envisioned by the municipalities for a duration of three years, being therefore suitable for expressing site-specific desealing public initiatives. They entail yearly revisions.
Implementation plans	•		•	•	These plans are those which, at the planning level, receive the prescriptions of the superordinate plans and translate them into practical projects or interventions. They can stem both from public and private initiative.
Sustainable energy and climate adaptation plans		•	•	•	Despite being an elective instrument, these plans allow to orient the urban transformation scenarios.

Table II.30 | Urban planning instruments and their role in the context of soil desealing in relation to the approach and the ownership of the areas. See the glossary for the Italian translations.

Table II.31 includes the practical opportunities offered by the instruments for the implementation of soil desealing.

Urban planning instrument	***Possible practical role for the implementation of soil desealing***
Regional and provincial urban plans	- Provide orientation and broad-spectrum quantitative and qualitative indications for the subordinate instruments, as well as fostering supra-municipal soil desealing interventions.
Municipal urban plans	- Specify the content of maintenance plans to include soil desealing; - specify limits for urban expansion, indexes, incentives and compensation measures for new interventions and the location of desealable areas.
Sector-specific plans	- Sector-specific plans may promote the same measures of Municipal urban plans by focusing on a theme, such as soil desealing, green areas, nature-based solutions. This can happen either through a dedicated plan or by a broader-scope plan (e.g., the Green plans).
Urban planning and building regulations and technical standards for implementation	- Provide further (technical) specification on what foreseen by the Municipal urban plan (e.g., specification on which indexes should be included in the maintenance plans).
Three-year public works programmes	- Envision projects and identify areas where to implement soil desealing in public areas.
Implementation plans	- Translate what foreseen by superordinate instruments in specific projects. Specify soil desealing interventions in planned maintenance works and renovations as well as new desealing projects.
Sustainable energy and climate adaptation plans	- Guide the other urban planning tools regarding new building and works, maintenance works and renovations; - identify opportunities for promoting new desealing projects and integrating soil desealing in the urban planning instruments.

Table II.31 | Urban planning instruments and their possible practical role for soil desealing.

As a final remark, Table II.32 outlines the available tools to verify compliance with the possible new permeability or soil desealing standards. In this regard, a distinction should be made regarding public and private areas. Private areas offer simpler verification opportunities concerning compliance with legislation. The issuance of building permits, regulated by the municipal urban plans (*piani urbanistici comunali*), allows for control and oversight of the interventions carried out within municipal boundaries. In contrast, public areas fall under administrative jurisdiction and are, counterintuitively, subject to less control. Nonetheless, public interventions must still comply with the municipal urban plans and related regulations to obtain some form of approval from the Municipality itself, for instance for what regards the compliance to the urban planning standards (*standard urbanistici*) at the urban scale. However, it can be argued that the initiative taken by the administration inherently suffices as a reliability indicator of its intent.

Ownership of the areas	***Verification method***
Private	Building permits
Public	Internal authorisation by the administration; verification of the compliance to urban planning standards at the urban scale

Table II.32 | Possible verification methods on interventions on private and public grounds.

7 Impacting the decision-making process through public participation[89]

The relevance of a strong public and private initiative has been discussed in the previous chapter, as well as the role of the citizens' opinion, as they allow for an increased ease in the implementation of soil desealing, which appears fundamental also in the framework of the methodology of this thesis.

On one hand, it appears relevant to investigate ways to foster the citizens' and the stakeholders' sensitiveness about the importance of both climate change adaptation and soil desealing, on the other hand, also citizens' and stakeholders' knowledge and opinion, such as their perception and preferences, acquire importance. The role of the localised (and specialised) knowledge of the urban users and communities has been recognised as opposed to the more traditional 'expert' knowledge of scholars and decision-makers.

The 'SOS4LIFE' project has emphasised the importance of soil desealing interventions within both bottom-up and top-down processes, referencing several international initiatives and movements, also led by associations and volunteers who are particularly sensitive to this issue. Further examples include the American 'Depave' and the Canadian 'Depave Paradise' (see Subsection §2.2.2). Since soil desealing affects local neighbourhoods and communities involving both public and private spaces, it entails challenges concerning social and environmental sustainability, public approval, and the potential engagement of citizens and stakeholders in decision-making and urban transformation design (Lafortezza & Sanesi, 2019).

In this context, citizens' involvement and public participation have emerged as relevant strategies for fostering collaboration among various stakeholders to achieve shared decision-making. A growing body of research explores methods and approaches for engaging stakeholders and citizens in spatial planning and urban design, with a particular focus on climate adaptation (i.a., Amenta & Arena, 2020; Uittenbroek et al., 2019). Therefore, it is crucial to further investigate these research areas in order to enhance the integration of different knowledge domains towards greater consensus on adaptation strategies (Burton & Mustelin, 2013; Conway et al., 2019) that may be beneficial also from a political point of view.

In this perspective, Section §7.1 investigates the role and the strategies for citizens' involvement, while Section §7.2 proposes a theoretical framework for gathering localised insight from the city users, represented by their perception and preferences.

[89] With the exception of Subsection §7.1.2, this chapter and its sections have been adapted by the author based on 'De Noia, I., Caselli, B., Kemperman, A., Rossetti, S., & van der Waerden, P. (2024). Towards participatory urban planning: insights from citizens. Results of a public questionnaire on climate change and its local effects in Parma. *TeMA - Journal of Land Use, Mobility and Environment, 17*(2), 193-212. https://doi.org/10.6093/1970-9870/10836' and the manuscript 'De Noia, I., van der Waerden, P., Kemperman, A. D. A. M. & Zazzi, M., Investigating preferences for soil desealing: insights from citizens for sustainable urban planning in Parma, Italy' in which she is co-author. The published article encompasses the full attributions of the work; attributions of the manuscript are pasted hereafter. Conceptualization: A.K., P.W., I.D.N.; Data curation: I.D.N.; Formal analysis: A.K., P.W., I.D.N.; Investigation: A.K., P.W., I.D.N.; Methodology: A.K., P.W., I.D.N.; Supervision: A.K., P.W., M.Z.; Validation; A.K., P.W., M.Z.; Visualization: I.D.N.; Roles/Writing - original draft: I.D.N.; and Writing - review & editing: I.D.N., A.K., P.W., M.Z..

7.1 Investigating the role and strategies for citizens' involvement

Citizens' involvement in urban transition processes has increasingly gained recognition among both scholars and practical urban transformation initiatives. This underscores the importance of meaningful citizens' participation in fostering healthier and more resilient cities, aligning with the third and eleventh goals of the '2030 Agenda for Sustainable Development' (Mouratidis, 2021; United Nations, 2015).

Researchers have been examining the role of public participation and the knowledge held by citizens and communities since the last century (Paez, 2003), also in the context of urban planning and climate change adaptation (Few et al., 2007). Smith (1983) defined **public participation** as an inclusive process that allows those impacted by a decision to contribute with their perspectives. In the context of urban transformations, public participation is crucial as it helps to capture the aspirations of stakeholders, encourages the generation of ideas, and fosters empowerment and awareness. Consequently, it is regarded as a key factor in ensuring the effectiveness and quality of urban planning (Semeraro et al., 2020). Nonetheless, participatory processes can encounter various challenges that need careful consideration. Important questions arise, such as *who is participating and to what extent?*, as well as *what constitutes a genuinely participatory process?* Both research and practice highlight the necessity of examining the purpose and significance of participation to prevent its exploitation and to acknowledge the emotions of participants. This vigilance helps to avoid creating false expectations of power within the decision-making process, which can lead to feelings of dissatisfaction (Arnstein, 1969). This concern is particularly relevant due to the uncertainties entailed by climate change (Few et al., 2007) and in today's digital age (Tang & Waters, 2005).

As already mentioned in Part I of the present thesis, the effectiveness of bottom-up initiatives in addressing citizens' needs is becoming increasingly apparent (Pissourios, 2014). Furthermore, the integration of these initiatives with top-down practices adds significant value (Girard et al., 2015). The next paragraphs investigate the role and the specificities of bottom-up processes and the contribution of young people in the urban planning and climate change adaptation framework.

7.1.1 Bottom-up processes

The relevance of bottom-up participatory processes in urban planning has been explored in scientific literature from multiple perspectives, aiming to address various socio-economic and environmental challenges linked to climate change. Some researchers have examined these processes through case studies (i.a., Geropanta et al., 2022; Nicolini & Pinto, 2013; Vogt, 2002), while others have developed taxonomies and reviews of existing approaches (i.a., Seve, Redondo, et al., 2023; Meroni & Selloni, 2022).

On a broader scale, bottom-up participatory processes have been widely recognised as effective strategies for enhancing urban resilience to climate change (i.a., Strange et al., 2022; Vaňo et al., 2021; D'Ascanio & Palazzo, 2023). Additionally, their importance in the context of urban development and regeneration has been highlighted (i.a., Canesi et al., 2022; Mayrhofer, 2018), with a focus on their political and socio-economic roles (i.a., Manojlovic et al., 2013; García de Jalón et al., 2020; Kuokkanen & Palonen, 2018; Eizenberg, 2019). Other scholars have concentrated on identifying tools that can facilitate and promote bottom-up participatory processes, such as art (Seve, Domínguez, et al., 2023) and video games (Delaney, 2022). Among these, digital technologies have emerged as an important tool (Sharifi et al., 2017; Stelzle et al., 2017), offering the potential to overcome spatial and temporal limitations. Overall, the contributions of citizens' and stakeholders' knowledge, expertise, and perceptions play a critical role in improving urban transformation processes. Furthermore, approaches that integrate bottom-up methods with traditional top-down practices have also been positively evaluated by researchers (i.a., De Lange et al., 2020; Semeraro et al., 2020), offering an alternative to conventional top-down strategies.

Two distinct perspectives have emerged in the research on fostering citizens' and stakeholders' participation, empowerment, and bottom-up contributions in addressing the effects of climate change. The first group of authors identifies a grassroots demand for urban space transformation and explores how to meet these needs. For instance, Santoro et al. (2020) highlighted a bottom-up call for environmental improvement, using the case of Bari, Italy, where the development of a new master plan relied on civic walks, community interviews, and both qualitative and quantitative knowledge-building approaches. Similarly, Zagare (2018) explored self-organising processes that link climate adaptation and urban development, examining local participatory methodologies. In this context, co-design and co-planning emerge as essential strategies and tools, whether physical or digital (Sharifi et al., 2017; Stelzle et al., 2017), allowing stakeholders to collaborate in shaping the future of cities through both top-down and bottom-up transformation processes.

The second group of researchers focuses on strategies that actively encourage the emergence of bottom-up processes. For example, Charli-Joseph et al. (2018) proposed 'transformation laboratories' as a methodological approach, designed to create a safe space that fosters dialogue and interaction among participants, thus switching the perceptions of individual roles and promoting agency for socio-environmental change. In terms of tools, Ranjbar Nooshery et al. (2017) examined public participation geographic information systems as a mean to tackle urban environmental issues, as well as data mining tools to gather citizens' insights and support bottom-up planning processes. Vaňo et al. (2021) introduced a model involving mediatory agencies to bridge lower and higher planning levels, addressing procedural barriers and demonstrating how bottom-up actions can inspire green infrastructure planning on a broader scale. In the context of flood risk management, Manojlovic et al. (2013) presented a four-step cycle – awareness-raising, understanding, experimenting, and evaluation - that promotes early public involvement in planning, allowing citizens and professionals to collaboratively develop strategies.

7.1.2 The contribution of young people[90]

The growing integration of community involvement into traditional top-down planning processes, alongside bottom-up approaches, reflects an increasing recognition of the need to prioritise people's wellbeing in the creation of more resilient and happier cities, aligning, again, with goals of the '2030 Agenda for Sustainable Development' (United

[90] This subsection has been adapted by the author based on 'De Noia, I., & Rossetti, S. (2024). Participation for Everyone: Young People's Involvement in the Shift Towards Happier and More Resilient Cities. In A. Marucci, F. Zullo, L. Fiorini, & L. Saganeiti (Eds.), Innovation in Urban and Regional Planning (pp. 515–525). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54096-7_45' in which she is co-author. The published article encompasses the full attributions of the work.

Nations, 2015)[91]. Urban areas, in particular, play a relevant role in enhancing the wellbeing of citizens and communities, a benefit that has been shown to increase through their involvement in public participation processes (i.a., Garau & Pavan, 2018; Mouratidis, 2021).

Despite this, the engagement of young people in participatory planning is still in its initial phases, with most initiatives focused on the adult population (Berrang-Ford et al., 2011; Haynes & Tanner, 2015). This is especially concerning given that, alongside the elderly, children and young people are among the most vulnerable to the impacts of climate change (Xu et al., 2012). Therefore, it is increasingly important to incorporate the voices, needs, and vulnerabilities of young people into urban planning strategies and legislative frameworks, as highlighted by Winge & Lamm (2019).

Oliver et al. (2014) have emphasised that youth participation can vary widely, from non-participation (e.g., manipulation) to full participation, where young people actively share decision-making responsibilities with adults. While researchers have explored the role of co-planning and co-design in promoting active citizenship and greater community engagement in urban space transformation (Carra et al., 2018; Ceci, De Noia, et al., 2023; Petrella, 2017), approaches involving participatory laboratories for young people must be carefully structured to ensure that the processes are meaningful. This means fostering a sense of purpose, control, and connectedness, elements which are essential for building resilience (Oliver et al., 2014). Laboratories and activities should be seen not only as platforms for communication, awareness-raising, and education, but also as opportunities for mutual knowledge exchange. It is crucial to value the experiences and perspectives of participants, framing the workshops as collaborative spaces rather than one-directional teaching sessions. For this thesis, the focus would be on gathering insights and feedback from participants concerning climate change and adaptation processes, while also encouraging the sharing of ideas and fostering connections among participants through interactive activities.

7.2 Investigating citizens' and stakeholders' perception and preferences

Among the various tools and strategies available to foster dialogue between citizens and stakeholders, digital instruments and surveys have proven to be useful in soliciting citizens' input in participatory processes (see Subsection §2.3.2). Surveys not only gather valuable data but also facilitate citizens' engagement and participation in urban planning and regeneration processes, for instance in assessing their perception of climate change and its (local) effects, as well as their preferences regarding adaptation strategies. Recognising the population as bearer of knowledge, this allows to gather data and insights from the citizens at different scales in addition to that collected from, for instance, technical analyses.

Individuals' choice-behaviour

Among the various methods to engage citizens and understand their preferences, discrete choice modelling provides a valuable framework for analysing individual choice behaviour (McFadden, 1973). The assessment of environmental preferences can be

[91] The connection between the built environment and quality of life is well-documented and is often evaluated through metrics such as Subjective Well-Being (SWB).

performed qualitatively or quantitatively. Quantitative methods such as rating, ranking, and choice tasks have been widely utilised in this framework. Based on random utility theory, researchers predict choices by calculating the overall utility of alternatives while accounting for the inherent uncertainty in human behaviour[92].

In this theoretical framework, stated-choice experiments have long been employed both in theory and practice, and have gained widespread recognition in various applied economics fields (Hess & Daly, 2024). In a stated-choice experiment respondents are presented with hypothetical alternatives that are described by a number of attributes. The alternatives are created based on an experimental design that supports the estimation of the independent effects of each attribute on the choice (although complete alternatives are presented).

In the context of urban climate adaptation, Tiellemans et al. (2022) used a stated-choice experiment to explore residents' preferences for sustainable energy measures, generating policy insights. Similarly, Verboven (2021) applied this method to investigate urban residents' preferences for green infrastructure solutions aimed at heat adaptation. Stated-choice experiments represent therefore an established approach to citizens' preferences also in the context of soil desealing. For instance, policy and practice attributes, such as the procedural, formal and technical characteristics can be evaluated presenting the citizens with stated-choice tasks.

[92] Choice behaviour can be measured and characterised based on the assumption that individuals compare available choice alternatives on relevant attributes and choose the alternative that maximizes the utility score, which is calculated as the sum of the utility of the alternatives (McFadden, 1973).

8 Identifying priority areas and intervention criteria

The previous chapters have examined methodologies for gathering and generating the layers of a knowledge framework to support the integration of soil desealing into urban planning and regeneration practices. Within this scenario, when identifying priority areas and corresponding intervention criteria, urban planners must adopt a comprehensive vision, integrating both quantitative and qualitative data, as well as objective and subjective factors.

In the context of the present research, the information that must be carefully integrated includes:

- the urban pluvial flood risk, its components (i.e., hazard, exposure, and vulnerability) and the urban pluvial flood damage;
- the transformation potential of urban areas, considering both the areas desealabilty and the suitable urban planning instruments;
- the insights and the role of citizens' involvement, thus acknowledging their knowledge, perceptions, and preferences.

The urban pluvial flood risk and damage maps can be overlaid and/or compared – also by identifying risk and damage levels - with the desealing potential map, highlighting their differences and common points, such as areas that exhibit high levels of both factors.

Citizens' insight is relevant for the assessment of the urban pluvial flood risk, particularly as part of the vulnerability indicators' categories (e.g., public awareness level). Furthermore, it also plays a similar role in fostering the desealing potential of urban areas by, for instance, enhancing the acceptance or the need of the interventions. Ensuring citizens' participation in the planning, implementation, and management of the intervention appears therefore crucial, and it allows also to support the definition of priority areas and intervention criteria

Finally, urban planning instruments and tools serve a dual role: they must be considered in assessing opportunities, while also acting as potential recipients of the proposed changes for fostering urban resilience, as they can be incorporated into their revisions.

III | Applicative case studies on Italian medium-sized cities

Part III focuses on two applicative case studies located in the Po Valley, specifically the medium-sized Italian cities of Parma (located in Emilia-Romagna) and Brescia (located in Lombardy).

The methodology developed in Part II was first employed in Parma (Chapter §9), with the aim of identifying soil desealing interventions priorities and criteria. Parma constitutes an interesting scenario, having demonstrated a strong sensitivity and awareness of climate change-related issues. The city has engaged with climate neutrality initiatives giving birth to the 'Territorial alliance climate neutrality Parma', has joined the Covenant of Mayors in 2013, has adopted a sustainable energy action plan in 2014 and then a sustainable energy and climate action plan in 2021 (Comune di Parma, n.d.). Furthermore, it is home to numerous environmental associations, such as the Centre for Environmental Ethics (*Centro Etica Ambientale*) of Parma[93] and the consortium KilometroVerde Parma[94], as well as to the University of Parma, which departments actively research on climate-related topics. In the framework of this thesis, the Department of Engineering and Architecture has provided valuable opportunities for data collection and (applied) research experiences thanks to its connections with local stakeholders and the broader community (e.g., in the context of the 'Green in Parma' community project). An additional research experience about citizens' perception and preferences was carried out in collaboration with Eindhoven University of Technology, where the author spent a visiting semester in 2023 within the Department of the Built Environment[95].

In Chapter §10, the case of Parma is put in comparison with Brescia, where a number of urban planning instruments and practical projects involving climate change adaptation, soil desealing and citizens' involvement have been developed in recent years. Examples are the Climate transition strategy and the '*Un filo naturale*' project and the IV Variant of the Territorial governance plan (*Variante del Piano di governo del territorio*). The Climate transition strategy was investigated also in the context of the collaboration with the science centre 'AmbienteParco', where the author of the current research joined the employees to provide scientifical and technical support for the setup of climate change adaptation-related workshops in the framework of the Climate transition strategy[96].

Part III ends with some final consideration encompassed by Chapter §11, which traces the outcomes and the conclusions of the applicative case studies and their comparison.

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93 https://www.centroeticambientale.org/
94 www.kilometroverdeparma.org
95 The visiting research period was conducted under the supervision of Prof. A. Kemperman and Dr. Ir. Peter van der Waerden.
96 The University of Parma was involved within the National Operational Programme on Research and Innovation 2014-2020, which promotes an integration between universities and enterprises. In the case of Ph.D. programmes, this concretises in a six-month long stage for Ph.D. students.

9 Climate change adaptation in Parma: defining priorities and tools for soil desealing

This chapter focuses on the Parma applicative case study. Section §9.1 provides the description of its territorial context and the existing knowledge framework, identifying relevant information and tools necessary for the development of the practical application of the methodology\. The following sections include the urban pluvial flood risk and damage assessments (Section §9.2), the transformation potential assessment (Section §9.3) and the investigation of citizens' involvement processes that were carried out within the city (Section §9.4).

9.1 Territorial context and knowledge framework

Parma (Map III.1) is located along the historic Via Emilia in the western part of the Emilia-Romagna region, within the aforementioned 'Po Valley Megalopolis' (*Megalopoli Padana*). The city is divided into 13 neighbourhoods[97] and has an increasing population - an uncommon trend in Italy, observed only in six cities. With approximately 200,000 inhabitants, Parma covers an area of 260.77 km^2, resulting in a population density of 769.2 inhabitants per km^2. This figure is lower than the average density of other provincial capitals[98] (Comune di Parma, 2023a).

Within the regional context, the province of Parma has the highest percentage of mountainous terrain (43.5%) and the lowest percentage of lowland areas (25%) in Emilia-Romagna (Comune di Parma, 2023a). The municipal area is predominantly located in the lowlands and comprises a denser centre where the inhabitants are concentrated[99], surrounded by minor fractions. All the urbanised areas have showed a rapid development from the 1950s - both from the residential and industrial point of view - which contributed to the growth of the population (Studio Zanzucchi Srl & Comune di Parma, 2015). After a period of depolarisation affecting cities like Bologna, Parma, Piacenza, and Ferrara since the 1970s, Parma has observed a reversal of this trend since the early 2000s (Comune di Parma, 2023a). According to the 'Study for the analysis of hydraulic risk in the municipal territory' (*Studio per l'analisi del rischio idraulico sul territorio comunale*) urbanised areas in Parma increased significantly, from 301 hectares in 1950 to 4,489 hectares in 2015.

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[97] The neighbourhoods are: Oltretorrente; Parma Centro; Pablo; Molinetto; Montanara; San Leonardo; Vigatto; Cittadella; Lubiana; San Lazzaro; Cortile San Martino; Golese and San Pancrazio (Comune di Parma, 2021a).

[98] E.g., Piacenza (881.9 inhabitants/km^2) and Modena (1,031.9 inhabitants/km^2).

[99] The demographic density is higher in the central neighbourhoods compared to the peripheral ones. E.g., Parma Centro (8,376.1 inhabitants/km^2), Pablo (7,799.0 inhabitants/km^2) and Oltretorrente (7,7470.8 inhabitants/km^2).

9.1.1 Land use and land cover

The following tables (Table III.33 and Table III.34) encompass the land use[100] and land cover[101] categories of Parma and its neighbourhoods, as well as their quantification.

Agricultural areas cover roughly 66.44% of the municipal territory and are predominantly dedicated to intensive farming models. The region is known for its traditional agri-food products, several of which hold certifications such as the 'Protected designation of origin' (PDO) or 'Protected geographical indication' (PGI). Parma industrial activity is closely tied to the agro-food sector, particularly focusing on the production of machinery and equipment for food processing, packaging and preservation (Comune di Parma, 2023a; Parma Food Valley, n.d.).

Residential areas constitute 10.26% of the municipal territory, most of which comprise sparse residential fabric (4.91% of the urban area).

Land use [%]															
CODE	***Category***	***Neighbourhood***													
		Cortile San Martino	*Cittadella*	*Golese*	*Lubiana*	*Molinetto*	*Montanara*	*Oltretorrente*	*Pablo*	*Parma Centro*	*San Leonardo*	*San Lazzaro*	*San Pancrazio*	*Vigatto*	*PARMA*
1411	*Parks*	0.22	2.24	0.33	1.13	3.09	5.05	19.96	1.81	5.23	2.22	0.48	0.41	0.08	**0.85**
1412	*Villas*	0.15	1.84	0.23	1.32	1.24	0.00	0.00	0.00	0.00	0.00	0.17	1.20	1.36	**0.79**
1413	*Urban wastelands*	3.01	0.33	0.44	0.57	2.16	2.74	0.00	1.04	0.00	1.79	0.42	1.29	0.30	**0.97**
1422	*Sports areas*	0.83	1.39	0.32	0.61	2.70	4.52	0.00	3.76	1.16	1.07	0.46	0.95	0.39	**0.77**
1424	*Golf courses*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	**0.03**
1425	*Racecourses and annexed spaces*	0.00	0.20	0.05	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	**0.09**
1426	*Car racing tracks and annexed spaces*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	**0.01**
1430	*Cemeteries*	0.07	0.00	0.04	0.16	1.77	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.04	**0.11**
1223	*Green areas associated with road infrastructure*	0.48	0.11	0.58	0.11	0.16	0.46	0.21	0.15	0.00	1.43	0.62	0.17	0.07	**0.33**
2121	*Simple irrigated arable land*	63.02	55.42	72.39	60.90	32.74	7.65	0.00	0.46	0.23	14.32	68.57	65.01	73.43	**63.01**
2122	*Nurseries*	0.00	0.09	0.03	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	**0.05**
2123	*Vegetable crops in open field, greenhouse and under plastic*	0.32	0.00	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.57	0.01	**0.11**
2210	*Vineyards*	0.28	0.30	0.22	0.30	0.06	0.00	0.00	0.00	0.00	0.00	0.34	0.31	0.19	**0.24**
2220	*Orchards*	0.18	0.08	0.17	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.14	0.05	**0.12**
2241	*Poplar plantations*	0.80	0.01	0.74	0.02	0.27	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.12	**0.31**
2242	*Other timber crops*	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	**0.01**
2310	*Meadows*	0.67	2.79	1.06	6.56	0.99	0.00	0.00	0.00	0.00	0.04	4.51	2.95	1.62	**2.26**
2410	*Temporary crops associated with permanent crops*	0.23	0.05	0.06	0.03	0.82	0.48	0.00	0.00	0.00	0.08	0.11	0.23	0.21	**0.16**

[100] Data was obtained from the Emilia-Romagna Region land use, which encompasses a four-level hierarchical legend derived from the specifications of the European Corine Land Cover (CLC) project (Regione Emilia-Romagna, 2018).
[101] Data was obtained from the '2021 land cover map' developed by the Institute for Environmental Protection and Research (Istituto Superiore per la Protezione e la Ricerca Ambientale, 2021).

Land use [%]															
CODE	***Category***	***Neighbourhood***													
		Cortile San Martino	***Cittadella***	***Golese***	***Lubiana***	***Molinetto***	***Montanara***	***Oltretorrente***	***Pablo***	***Parma Centro***	***San Leonardo***	***San Lazzaro***	***San Pancrazio***	***Vigatto***	***PARMA***
2420	*Complex cropping and parcel systems*	0.06	0.15	0.13	0.03	0.09	1.25	0.00	0.30	1.19	0.85	0.20	0.18	0.03	**0.14**
2430	*Areas with agricultural crops and important natural spaces*	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
3112	*Oak, hornbeam, and chestnut dominant forests*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	**0.03**
3113	*Willow and poplar dominant forests*	0.04	0.39	0.22	0.26	0.61	0.00	0.00	0.00	0.00	0.00	0.38	0.57	0.36	**0.29**
3114	*Floodplain forests predominantly with oaks and ashes*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	**0.01**
3116	*Shrubby thickets*	0.02	0.09	0.14	0.17	0.54	0.00	0.22	0.00	0.00	0.01	0.24	0.09	0.07	**0.12**
3231	*Evolving shrub and tree vegetation*	0.39	0.96	0.51	0.07	1.29	3.30	0.00	0.00	0.00	0.77	0.56	0.71	1.52	**0.77**
3232	*Recent afforestation*	1.07	0.00	0.05	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.02	0.12	0.05	**0.21**
4110	*Internal wetlands*	0.13	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.33	**0.28**
1111	*Compact and dense residential fabric*	0.00	0.00	0.00	0.00	0.00	0.00	29.64	0.00	33.68	0.00	0.00	0.00	0.00	**0.45**
1112	*Sparse residential fabric*	0.89	7.18	1.71	8.44	15.80	33.63	16.13	41.64	18.65	32.23	2.34	3.72	2.32	**4.91**
1121	*Urban residential fabric*	1.03	4.65	0.74	2.29	4.98	6.88	0.00	2.22	0.08	3.20	1.55	1.25	1.32	**1.78**
1122	*Isolated residential structures*	3.59	3.52	2.67	3.40	2.58	0.38	0.00	0.00	0.00	1.23	4.40	3.69	2.63	**3.12**
1211	*Productive settlements with annexed spaces*	9.24	1.50	2.21	2.00	7.29	2.26	0.00	10.20	3.12	11.20	3.05	3.81	1.98	**3.74**
1212	*Agricultural and livestock settlements with annexed spaces*	1.29	1.83	1.95	1.44	0.16	0.00	0.00	0.00	0.00	0.00	1.55	1.42	2.08	**1.58**
1213	*Commercial settlements*	0.89	0.38	0.06	0.56	1.31	0.39	0.00	1.35	0.99	3.49	0.42	0.49	0.13	**0.47**
1214	*Public and private service settlements*	0.65	0.92	1.73	1.27	2.31	6.59	10.90	3.81	15.89	5.96	0.66	1.05	0.89	**1.43**
1215	*Hospital settlements*	0.00	0.00	0.00	0.00	0.64	0.76	0.95	13.67	0.00	0.00	0.00	0.00	0.00	**0.14**
1216	*Big technological plants*	0.55	0.00	0.21	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	**0.15**
1221	*Highways and expressways*	1.06	0.35	1.04	0.55	0.91	1.71	0.00	0.00	0.00	2.37	1.11	0.68	0.08	**0.72**
1222	*Road networks and annexed spaces*	3.03	3.40	1.67	3.40	6.89	11.01	12.94	12.03	9.96	9.98	2.12	2.63	1.22	**2.85**
1224	*Railway networks and annexed spaces*	1.06	0.00	0.64	0.00	0.33	0.00	0.00	6.02	4.87	1.46	1.47	0.72	0.00	**0.64**
1227	*Networks for energy distribution and production*	0.05	0.08	0.00	0.00	1.68	0.00	0.00	0.02	0.78	0.63	0.04	0.01	0.08	**0.12**
1228	*Photovoltaic plants*	0.79	0.00	0.00	0.45	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.15**
1229	*Water distribution networks and areas*	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	**0.01**

Land use [%]															
CODE	**Category**	**Neighbourhood**													
		Cortile San Martino	*Cittadella*	*Golese*	*Lubiana*	*Molinetto*	*Montanara*	*Oltretorrente*	*Pablo*	*Parma Centro*	*San Leonardo*	*San Lazzaro*	*San Pancrazio*	*Vigatto*	*PARMA*
1241	*Commercial airports*	0.00	0.00	2.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.40**
1242	*Sports and recreational flight airports and heliports*	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
1311	*Active extraction areas*	0.00	0.14	0.53	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.29	0.00	**0.16**
1312	*Inactive extraction areas*	0.00	0.17	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.73	0.25	**0.18**
1322	*Urban solid waste landfills*	0.16	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.04**
1323	*Scrap and vehicle deposits*	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.38	0.00	**0.04**
1331	*Construction sites and excavations*	0.33	0.59	0.17	0.59	1.88	0.14	0.44	0.00	0.00	0.08	0.00	0.48	0.36	**0.37**
1332	*Remediated and artefact soils*	1.08	2.02	0.54	0.27	0.79	1.41	0.88	0.20	0.00	3.48	0.63	0.65	0.43	**0.79**
5111	*Riverbeds and streams with sparse vegetation*	0.08	2.61	0.84	0.48	2.69	5.25	7.74	0.83	4.18	0.97	0.21	1.25	3.56	**1.56**
5112	*Riverbeds and streams with abundant vegetation*	0.84	0.55	1.86	1.10	0.60	4.15	0.00	0.00	0.00	0.78	1.00	0.82	1.23	**1.13**
5113	*Embankments*	0.44	0.51	0.53	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.09	0.04	0.26	**0.28**
5114	*Canals and waterways*	0.57	0.21	0.48	0.56	0.00	0.00	0.00	0.00	0.00	0.37	1.12	0.60	0.27	**0.49**
5123	*Artificial basins*	0.26	0.70	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.02	0.03	**0.17**

Table III.33 | Land use categories from Parma and its neighbourhoods. Source: author's elaboration based on data from the Emilia-Romagna Region (Regione Emilia-Romagna, 2018).

Furthermore, with reference to Table III.34, 78.49% of the municipal territory is classified as consumed by the Italian Institute for Environmental Protection and Research (*Istituto Superiore per la Protezione e la Ricerca Ambientale*). Figure I.3 represents the borader context of the Italian territory, within which the increasing rates of soil consumption and the high percentage of consumed soil highlight significant opportunities for soil desealing to improve the local conditions.

The predominance of a sparse residential fabric emphasises the potential for optimising sealed surfaces and improving land use. For instance, densification - guided by regulations aimed at limiting new soil consumption while preserving agricultural lands - could represent a relevant strategy. Volumetric incentives and their association with soil desealing for this case study will be further explored in Section §9.3.

Land Cover [%]															
CODE	***Category***	***Neighbourhood***													
		Oltretorrente	***Parma Centro***	***Pablo***	***Molinetto***	***Montanara***	***San Leonardo***	***Vigatto***	***Cittadella***	***Lubiana***	***San Lazzaro***	***Cortile San Martino***	***Golese***	***San Pancrazio***	***PARMA***
1	*Consumed soil*	20.32	18.39	27.52	16.30	21.58	25.07	4.61	7.69	7.57	5.61	7.14	4.62	6.59	**7.11**
2	*Non-consumed soil*	28.43	17.59	14.54	55.95	40.96	30.27	87.38	78.88	78.56	83.37	76.12	83.51	80.03	**78.36**
111	*Buildings, constructions, warehouses*	37.66	47.94	37.01	12.77	21.08	25.40	3.44	6.32	6.69	4.06	6.32	3.39	5.62	**6.36**
112	*Asphalted roads*	12.07	9.69	11.77	7.81	11.49	11.06	2.09	4.37	4.13	3.61	4.29	3.54	3.96	**4.04**
113	*Railway tracks*	0.00	4.06	5.18	0.21	0.00	1.36	0.00	0.00	0.00	1.17	0.66	0.42	0.44	**0.46**
114	*Airports*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	**0.16**
116	*Other impermeable/paved areas not built upon*	0.00	2.13	1.71	5.27	2.53	3.89	0.95	1.14	1.42	0.63	2.63	1.18	1.23	**1.52**
117	*Permanent paved greenhouses*	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.06	**0.01**
118	*Landfills*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.00	0.00	**0.04**
121	*Unpaved roads*	0.00	0.00	0.00	0.18	0.20	0.04	1.10	0.60	0.44	0.56	0.54	0.82	0.39	**0.66**
122	*Construction sites and other dirt areas*	1.52	0.19	2.18	1.48	1.95	2.26	0.30	0.57	0.70	0.80	1.08	0.78	0.97	**0.79**
123	*Non-renaturalised extraction areas*	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.24	0.01	0.19	0.00	0.71	0.24	**0.22**
125	*Ground-mounted photovoltaic fields*	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.45	0.00	0.77	0.00	0.00	**0.15**
126	*Other artificial coverings whose removal restores the initial soil conditions*	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
202	*Roundabouts and junctions (permeable areas)*	0.00	0.00	0.09	0.01	0.21	0.65	0.00	0.02	0.03	0.00	0.15	0.13	0.01	**0.07**
203	*Unpaved greenhouses*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.13	0.00	0.45	**0.06**
	Not consumed	28.43	17.59	14.62	55.96	41.17	30.92	87.38	78.91	78.59	83.38	76.40	83.65	80.49	21.51
	Consumed	71.57	82.41	85.38	44.04	58.83	69.08	12.62	21.09	21.41	16.62	23.60	16.35	19.51	78.49

Table III.34 | Land cover categories of Parma and its neighbourhoods. Source: author's elaboration based on data from the Italian Institute for Environmental Protection and Research (Istituto Superiore per la Protezione e la Ricerca Ambientale, 2021).

9.1.2 Climate data

Parma is characterised by a temperate continental climate with a wide annual temperature range, with cold winters and hot summers. Rainfall is mainly concentrated in autumn and spring, while the summer heat often leads to thunderstorms in the lowlands. The region is generally not very windy, which contributes to winter fog and summer humidity. These conditions foster the build-up of pollutants like PM_{10} in the winter and ozone in the summer, negatively affecting air quality. Climate change is evident in Parma temperature patterns, with both maximum and minimum temperatures showing an upward trend in average and extreme values, especially during the summer. Precipitation data also indicate increasing rainfall during autumn, while a growing frequency of dry years over the past decade and longer drought periods in summer are being observed, with a possible emphasis on the extremes between these phenomena (Comune di Parma, 2021b). Significant flood events have affected Parma in autumn, most notably the October 2014 flood, which had severe consequences on the city southern neighbourhoods, e.g., Molinetto and Montanara ('13 ottobre 2014, Parma color fango', 2016). More recently, in October 2024, pluvial events have also caused flooding, such as 120 mm of precipitation recorded over 18 hours, which led to heavy impacts on the city ('Un'altra alluvione travolge l'Emilia-Romagna. A Parma allagamenti, situazione più pesante in provincia', 2024).

The impacts of soil sealing on stormwater management are evident also during more "ordinary" rainfall events, as shown in Figure III.27 that highlights the situation in the Montanara neighbourhood following a pluvial event in spring 2024.

Figure III.27 | The situation in the Montanara neighbourhood following a pluvial event in spring 2024. Source: photo taken by the author (2024).

Pluviometric data

The 'Study for the analysis of hydraulic risk in the municipal territory' (*Studio per l'analisi del rischio idraulico sul territorio comunale*), based on data from the 'Parma Università' rain gauge station (located 55 meters above the sea level) provides the intensity-duration-frequency curves for duration greater or less than an hour (Table III.35, Figure III.28 and Figure III.29).

More specifically, intensity-duration-frequency curves are a mathematical representation that connects the intensity of an event (such as rainfall) to its duration and the frequency of its occurrence.

Frequency is defined as the inverse of the probability of that event happening. In Italy and other European countries, intensity-duration-frequency curves are expressed by the following formula:

$$h(t_p, T_R) = a(T_R) \cdot t_p^n \qquad \text{(III.8)}$$

where h is the precipitation depth, t_p is the duration, T_R is the considered return period, n is the characteristic parameter of the function[102] (and is independent from T_R), and a is a characteristic parameter of the function that depends on the return period T_R.

Intensity-duration-frequency curves parameters. Duration < 1 hour						
Return period T_R [years]	10	25	50	100	200	500
a [mm/h]	38.36	46.51	52.56	58.57	64.55	72.44
n [-]	0.372	0.369	0.368	0.366	0.365	0.364
Intensity-duration-frequency curves parameters. Duration > 1 hour						
Return period T_R [years]	10	25	50	100	200	500
a [mm/h]	37.14	44.34	49.67	54.97	60.24	67.20
n [-]	0.320	0.324	0.326	0.328	0.329	0.331

Table III.35 | Parameters of the Intensity-duration-frequency curves. Source: elaboration from Studio Zanzucchi Srl & Comune di Parma (2015).

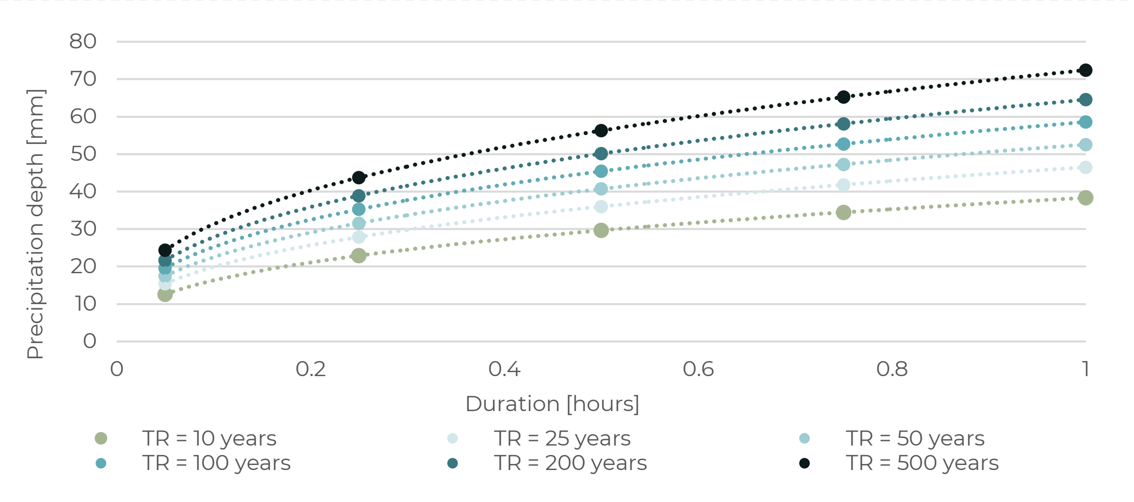

Figure III.28 | Intensity-duration-frequency curves for durations shorter than 1 hour. Source: elaboration based on Studio Zanzucchi Srl & Comune di Parma (2015).

[102] The conditions n<1 and n>0 apply, as the height of precipitation is an increasing function (n>0), and the average intensity of precipitation decreases with increasing duration (n<1).

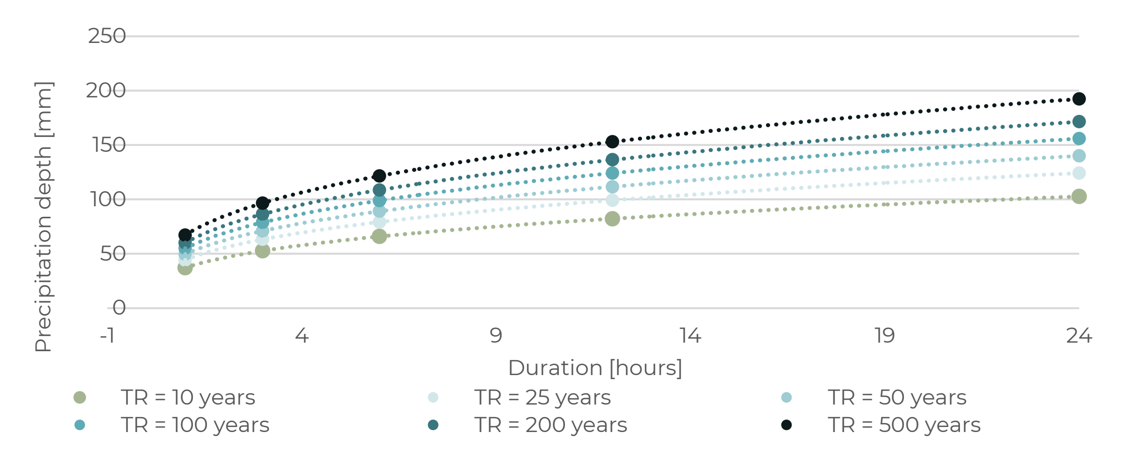

Figure III.29 | Intensity-duration-frequency curves for durations longer than 1 hour. Source: elaboration based on Studio Zanzucchi Srl & Comune di Parma (2015).

9.1.3 Urban water systems and floods

This subsection presents the main elements of Parma water system, addressing the hydrological characteristics of the region, the design and function of urban drainage systems, and the hydrogeological conditions of the territory. Additionally, the existing tools and literature that have dealt with flood assessment and mapping are discussed.

Hydrology and drainage systems

The municipal territory of Parma is entirely flat, with the Taro River marking its western boundary and the Enza stream the eastern. The city is further divided by two watercourses: the Parma and Baganza streams. The first is a tributary of the Po River and converges with the Baganza stream before flowing through the urban historic centre. In addition to the main streams, a network of minor (covered and uncovered) canals flows in the territory, and, especially in the main urban area, serves also the role of combined drainage canals. For what concerns the drainage network, the system is mainly combined (68%), and collects therefore sanitary wastewater and stormwater together (Studio Zanzucchi Srl & Comune di Parma, 2015).

Hydrogeology

The Municipality of Parma is located on a high plain between the ending of the Apennine chain, which is characterised by the presence of i) alluvial fans[103] and thus by soil with a gravel and sand matrix, and ii) a flood plain characterised by silty and clay soils[104] (Studio Zanzucchi Srl & Comune di Parma, 2015). Considering the region that goes from the Apennines to the Po Plain, a hard-rock mountain aquifers, a flat heterogeneous alluvial

[103] Alluvial fans form where a river carrying a significant sediment load emerges from a confined channel into a low-gradient area. The surface of these fans is usually inclined between 1° and 15°, with the slope depending on the grain size of the sediment and the processes involved in its deposition.

[104] The hydrological characteristics of the context entail the necessity of some considerations regarding the presence of clay, that may partially hinder the infiltration of rainwater into the soil. In addition to considering the local Hydrogeological Soil Groups (see Subsection §9.2.1), this research accounts for the expected heterogeneity in the area (thus the presence of gravel other than clay) which is visible in Figure III.30. Furthermore, it should be noted that the implementation of soil desealing interventions is always foreseen to entail a project assessing its impacts on the urban drainage.

aquifer and a losing river can be identified. Despite the alluvial aquifer being hydrogeologically located downstream of the hard-rock aquifers, there is no direct groundwater inflow from the latter to the first, due the presence of the clay sediments. The alluvial aquifer is recharged through the infiltration of local precipitation and indirectly through the Taro river. From the lithological point of view, the alluvial aquifer is characterised by an alternance of gravels, sands, silts, and silty clays. An alluvial fan of gravel–sand–silt opens on the north of the study area (Pinardi et al., 2023). Pinardi et al. (2023) developed a hydrogeological map with the aim of serving multiple purposes such as the development of vulnerability maps for planners and administrators that deal with water resources (Pinardi et al., 2023). The resulting section is shown in Figure III.30. Furthermore, Cortesi & Segadelli (2014) depicted the regular pattern of the water table, that flows from the southwest from the northeast (Figure III.31).

These considerations open the discussion about the unavoidability of considering also the underground space when dealing with soil desealing. This means understanding and assessing for each intervention if soil desealing should be intended as a “full” desealing intervention, thus envisioning the rainwater absorption into the soil as the main process, or if storage systems or drainage devices should be designed (see Section §2.4). This is, incidentally, the case of parking lots, that must deal carefully with the collection of rainwater, as it contains oils and other pollutants deriving from cars and traffic. In the wider framework of managing the surface runoff, also the design of detention ponds (Figure III.32) where the infiltration capacity of the soil is higher may constitute a relevant strategy in Parma.

As already mentioned at the beginning of this thesis, soil desealing can change shape according to the necessities of the urban spaces. It could be indeed argued that - even more than merely increasing the urban areas permeability - soil desealing helps mimicking the natural environment, employing green areas as a strategy to restore the traditional water cycle, with the additional “technocratic” aid of technical and human made solutions.

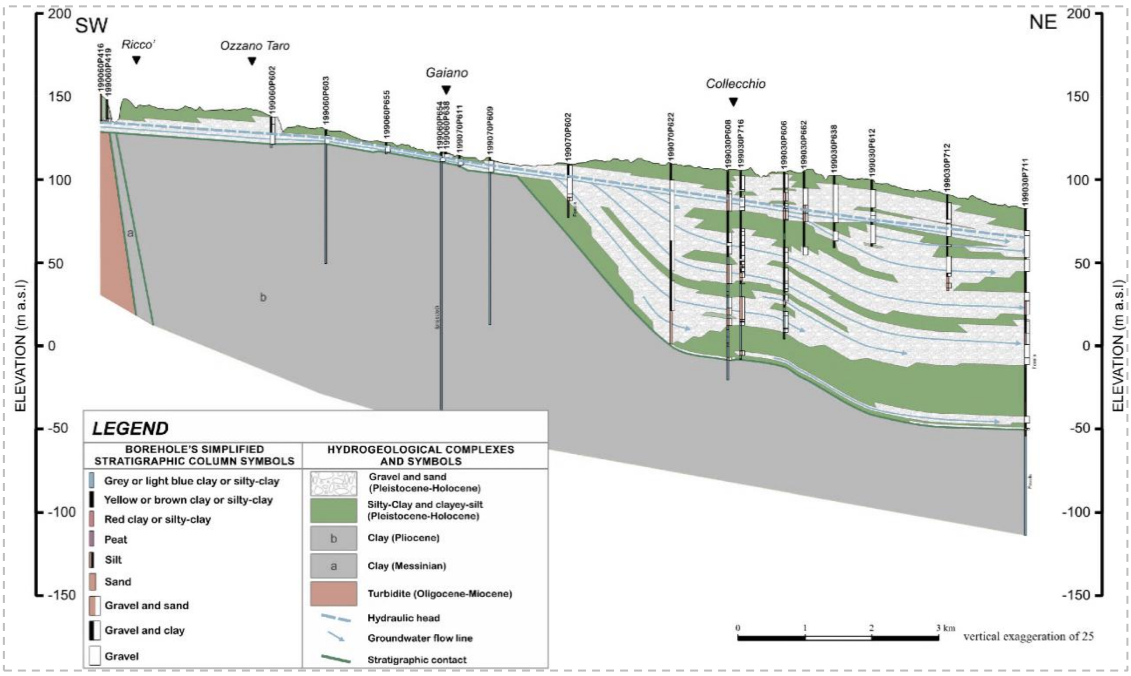

Figure III.30 | Hydrogeological section illustrating the configuration of subsystems where the Apennines meet the Parma plain. Source: Pinardi et al., 2023.

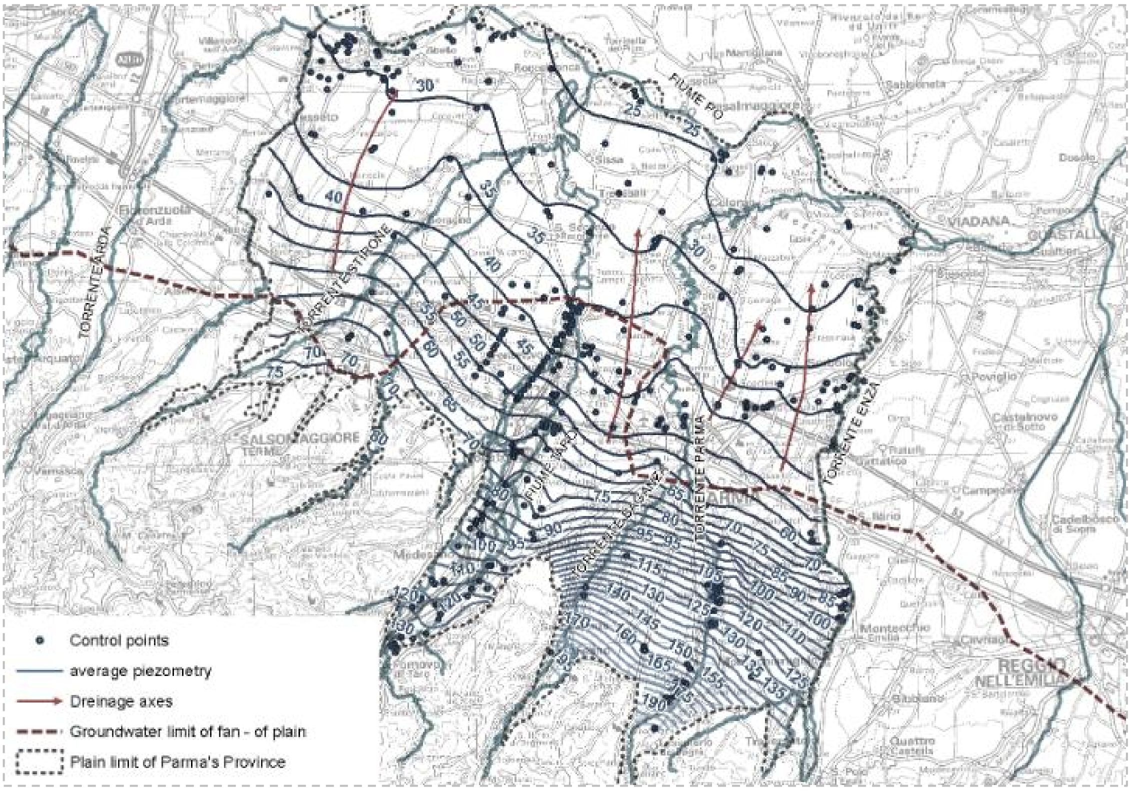

Figure III.31 | Map of the average water table in the Parma region. Source: Cortesi & Segadelli, 2014.

Figure III.32 | An example of a detention pond located in the southern neighbourhoods of Parma. Source: photo taken by the author (2024).

Flood maps

The Po River Basin authority (*Autorità di bacino del fiume Po*) and the Emilia-Romagna Region developed flood maps[105] in accordance with the 'Directive 2007/60/EC on the assessment and management of flood risks' and to the Legislative Decree No. 49/2010 'Implementation of Directive 2007/60/EC on the assessment and management of flood risks' (*Attuazione della direttiva 2007/60/CE relativa alla valutazione e alla gestione dei rischi di alluvioni*) (see Subsection §1.2.1)[106].

The Municipality of Parma has further detailed these maps at the municipal scale, implementing them with the historical and theoretical floods that concern the urban canals and the drainage network. In this regard, the records of historical floods, the damage claims of public and private entities, previous studies and Iren (an Italian energy multiutility) records have been considered (Studio Zanzucchi Srl & Comune di Parma, 2015).

9.1.4 Soil desealing and the existing tools

Parma is characterised by several legislative and strategic instruments that are connected or deal with soil desealing and/or the urban pluvial flood risk. The following subsections provide an overview of these tools and their content, which are in line with the already cited Regional Law No. 24/2017 of the Emilia-Romagna Region (i.a., Subsection §1.1.4 and Section §3.2).

Legislative instruments

As recalled in Section §3.2, the new General urban plan (*Piano urbanistico generale*) 'PUG PR050' of Parma defines the municipal responsibility for land use and transformation, with specific attention to urban regeneration processes and sustainability. References to soil desealing are included in this instrument, both as a generic good practice for each intervention and for specific cases such as parking lots. The new 'PUG PR050' includes a map that identifies the desealable parking lots within the municipal borders, in accordance with what foreseen by the Green plan (*Piano del verde*). Furthermore, it includes an index – the 'RIFO index' – which sets building footprint reduction goals. The current[107] Building regulation (*Regolamento edilizio*) - which will be updated with the new General urban plan - includes minimum permeability standards and maximum coverage indexes (*indici di copertura*) for various zoning classes.

Despite not being a regulatory instrument, the Green plan fosters the valorisation of the public and private urban green, while proposing soil desealing interventions and the implementation of trees, mainly in road infrastructure and parking lots while providing also an assessment of streets that lack trees (see also §4.2.2).

The three documents i) 'Study for hydraulic and flood risk analysis on municipal territory' (*Studio per l'analisi del rischio idraulico e alluvionale sul territorio comunale*); ii) 'Municipal

[105] The flood maps, with reference to the three probability levels defined by the European Commission (low, medium and high) have been defined by the Po River basin authority for what concerns the principal hydrographic network (Po River and principal tributaries) and by the Emilia-Romagna Region for what concerns the secondary hydrographic lowland network (Studio Zanzucchi Srl & Comune di Parma, 2015).
[106] For the sake of completeness, it is important to highlight that both the Hydrogeological structure plan (*Piano di assetto idrogeologico*) and the Provincial coordination territorial plan (*Piano territoriale di coordinamento provinciale*) have delineated the river belts with reference to floods, based on multiple scenarios.
[107] The PR050 new General urban plan has yet to be enforced [2024].

hydraulic risk plan' (*Piano del rischio idraulico comunale*); iii) 'Hydraulic risk management regulation' (*Regolamento di gestione del rischio idraulico*) constitute further instruments developed by the Municipality that, in the context of mitigating the urban flood risk, emphasise its sensitiveness for this theme and soil desealing (Studio Zanzucchi Srl & Comune di Parma, 2015, 2016, 2021). In addition to a deeper understanding of the flood phenomena in the urban territory, these instruments encompass also management strategies. The 'Hydraulic risk management regulation' – which is attached to the Building regulation (*Regolamento edilizio*) – mentions that new urban- and building-level interventions are required to improve (or not to worsen) the stormwater drainage. In Title V of the document, devices such as permeable pavements, green roofs, and more in general devices that increase the infiltration of rainfall into the soil are mentioned and encouraged.

Finally, also the Municipal civil protection plan (*Piano comunale di protezione civile*) - specifically the Board 2.6 of the Emergency plan (*Piano di emergenza*) - identifies and maps the critical points that need to be monitored and considered during flood events, such as underpasses. These points are also put into relation with the flood maps developed by the Emilia-Romagna Region and the Po River basin authority.

Strategic instruments

For what concerns strategic instruments, the Sustainable energy and climate action plan of Parma (Section §4.2.2), in accordance with what was generally assessed for the sustainable energy and climate action plans (Caselli et al., 2023), serves as a container of actions and guidelines. Divided into "cards" that recall specific adaptation and mitigation strategies and actions, the Plan recalls the intention of the Municipality to deseal parking lots, including commercial areas. The Plan refers to the Green plan (*Piano del verde*) for what concerns the promotion of soil desealing and mentions desealing (or on a more general level, the intention of increasing the urban permeable surfaces) in the framework of various projects, highlighting, once again the interest of the administration for this topic

As a concluding remark, it is interesting to observe that in Parma, differently to other urban contexts within the 'Po Valley Megalopolis' (*Megalopoli Padana*), the Sustainable energy and climate action plan dedicates a special action to soil desealing (Caselli et al., 2023; Comune di Parma, 2021b).

9.2 Urban pluvial flood risk and damage assessment

Following the theoretical framework presented in Chapter §5, the next subsections present the urban pluvial flood risk and damage assessments for the city of Parma in the context of soil desealing. Based on the existing literature, hydrological and hydraulic forcings are identified as a part of the urban pluvial flood hazard. Specifically, hydrological forcings were modelled and determined by employing the Soil Conservation Service (or Curve Number) method, which allowed to calculate the urban pluvial flood depths for the urban subcatchments (i.e., the urban drainage basins). The hydraulic forcings, on the other hand, were gathered from the existing literature[108]. The exposed

[108] The existing studies in Parma (Studio Zanzucchi Srl & Comune di Parma, 2015, 2016, 2021) employ a similar methodology for determining hydrological forcings as the foundation of hydraulic forcings assessment. For the purposes of this thesis, the hydrological forcings were calculated from anew, allowing for a full control over the

assets were then identified and mapped, and finally the vulnerability of the physical assets and the population was assessed. The assessment is focused on the inner urban area, namely the area comprised by the ring roads, which is outlined in all the drafted maps presented in this thesis.

9.2.1 Hydrological forcings

Hydrological forcings were calculated by employing the Soil Conservation Service method on the whole municipal territory (see Subsections §5.2.2 and §5.2.3 for the theoretical references). The flood depth and volume, as well as runoff retention and infiltration rates were obtained by employing the InVEST Urban Flood Risk Mitigation Model which - in accordance to the Soil Conservation Service method - compares the pluvial flood volume to the retained flood volume for each pixel (The Natural Capital Project, n.d.).

Furthermore, the Topographic Wetness Index was calculated with the SAGA module of QGIS (www.qgis.org/) to account for the altimetry of the municipal territory, allowing therefore to identify the soil moisture patterns following the guidelines of Hans van der Kwast (2019) and Mattivi et al. (2019).

Data and materials

Data required for employing the Soil Conservation Service method (and thus the InVEST Urban Flood Risk Mitigation Model) to obtain flood volume and infiltration rates (and therefore the urban pluvial flood depth) are:

- the precipitation depth;
- the hydrologic group of the soils;
- the land use/land cover;
- the Curve Numbers associated with each land use and land cover category;
- the urban drainage basins or subcatchments (i.e., the areas of interest or units of analysis).

Table III.36 encompasses the sources that were used for gathering or calculating the information, which are available for the whole Emilia-Romagna region, and are generally accessible in the regional opendata databases of the Italian territory.

Required data	***Source***
Precipitation depth	Intensity-duration-frequency curves (Studio Zanzucchi Srl & Comune di Parma, 2015)
Land use/land cover (base map)	Land use map – vector (Regione Emilia-Romagna, 2018); Land cover map – raster/10 m resolution (Istituto Superiore per la Protezione e la Ricerca Ambientale, 2021); Imperviousness map – raster/10 m resolution (Copernicus Land Monitoring Service, 2018); Imperviousness map – raster/10 m resolution (Regione Emilia-Romagna, 2011)
Curve Numbers	Land use/land cover categories and their corresponding Curve Number (NRCSUSDA, 1986, 2004; The Natural Capital Project, n.d.)

base data (e.g., land use). This was particularly relevant also in the context of soil desealing, as it allowed for experimentation in the assessment of hydrological forcings using different input datasets (e.g., soil imperviousness or land cover) and to simulate soil desealing interventions.

Required data	*Source*
Soil Hydrologic Groups	Map of hydrologic groups of the Emilia-Romagna Region (Regione Emilia-Romagna, 2014a)
Urban subcatchments	Map of the subcatchments (Studio Zanzucchi Srl & Comune di Parma, 2015)

Table III.36 | Data and sources used for the calculation of the urban pluvial flood depth.

Furthermore, the Topographic Wetness Index can be calculated based on the altimetry of the territory, which is described, for example, by the Digital Terrain Model maps of the Emilia-Romagna Region (Regione Emilia-Romagna, 2014b).

Urban pluvial flood depth

The InVEST Urban Flood Risk Mitigation Model was set up by inputting the data listed in the previous subsections. The following paragraphs describe the calculation of the urban pluvial flood depth, based on the sources encompassed by Table III.36.

Precipitation depth

The precipitation depth $h(t_p, T_R)$ was calculated for return periods of ten and 25 years, which are chosen for two main reasons. First, the ten years return period characterises the oldest part of the urban drainage network, and 25 years is the commonly design return period used for urban drainage networks (Studio Zanzucchi Srl & Comune di Parma, 2015) in Parma. This choice is motivated also by the willingness to assess the urban flood risk for "ordinary management conditions", which correspond also to the condition in which soil desealing may play the most impactful role. Furthermore, this choice possibly allows the outcome to be related the 'Study for hydraulic and flood risk analysis on municipal territory' (*Studio per l'analisi del rischio idraulico e alluvionale sul territorio comunale*). For similar reasons, the considered precipitation duration t_p is one hour. Therefore, taking into account a duration of one hour and return periods of ten and 25 years, precipitation depths are calculated according to the formulas considered in Subsection §9.2.1, as shown in Table III.37.

Return period (T_R) ***= 10 years***	***Return period*** (T_R) ***= 25 years***
a = 37.14, n = 0.320	a = 44.34, n = 0.324
Duration (t_p) = 1 hour	Duration (t_p) = 1 hour
$h(t_p, T_R) = 37.14$	$h(t_p, T_R) = 44.34$

Table III.37 | Calculated precipitation depths for the duration of one hour and return periods of ten and 25 years.

Soil Hydrologic Groups

The soil hydrologic groups of the territory were then defined. The municipal area is characterised by the predominant presence of the soil hydrologic group D, followed by some areas belonging to group C along the Parma and Baganza streams.

Land use, land cover and Curve Number

Base maps were then gathered, specifically:

- the '2018 land use map' developed by the Emilia-Romagna Region (Regione Emilia-Romagna, 2018);
- the '2021 land cover map' developed by the Institute for Environmental Protection and Research (Istituto Superiore per la Protezione e la Ricerca Ambientale, 2021);
- the '2018 high resolution layer imperviousness' from the Copernicus Land Monitoring Service (Copernicus Land Monitoring Service, 2018);
- the '2011 lowland imperviousness map' of the Emilia-Romagna Region (Regione Emilia-Romagna, 2011).

Each base map category (identified by a code) was associated with a Curve Number, determined according to the Soil Hydrologic Group and literature. Specifically, reference was made to the United States Department of Agriculture agency 'Natural Resources Conservation Service' (the former 'Soil Conservation Service' agency) that developed i) the Hydrology National Engineering Handbook (210-VI-NEH) and ii) the technical release 'Urban Hydrology for Small Watersheds' (210-VI-TR-55). These documents present simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs (NRCSUSDA, 1986, 2004). Furthermore, the InVEST user guide constituted an additional data source (The Natural Capital Project, n.d.)[109].

Different land cover, land use and impervious maps were used also with the purpose of addressing the uncertainties associated with the Soil Conservation Service method, which inherently involves some degree of approximation when estimating impervious surface percentages according to the land use categories. For what concerns soil imperviousness map, the corresponding Curve Number for each imperviousness percentage was determined by interpolating the known values of the graphs and tables provided by the United States Department of Agriculture Natural Resources Conservation Service.

Table III.38, Table III.39, Table III.40, and Table III.41 present the results of this procedure according to the soil hydrologic groups of the study area.

CODE	***Description***	***Source for the definition of the Curve Number***		***Curve Number***	
				Soil hydrogeological group	
		Source code	***Description***	***C***	***D***
1	*Consumed soil*	210-VI-NEH	Impervious areas (lots, roofs, driveways, etc.)	98	98
2	*Non-consumed soil*	210-VI-NEH	Open space (lawns, parks, golf courses, cemeteries, etc.) - Fair condition (grass cover 50% to 75%)	79	84
11	*Permanent consumed soil*	-	-	-	-
111	*Buildings, constructions, warehouses*	210-VI-NEH	Impervious areas (lots, roofs, driveways, etc.)	98	98
112	*Asphalted roads*	210-VI-NEH		98	98
113	*Railway tracks*	210-VI-NEH		98	98
114	*Airports*	210-VI-NEH		98	98
115	*Ports*	210-VI-NEH		98	98

[109] While suggesting also the use of United States Department of Agriculture agency 'Natural Resources Conservation Service' information.

CODE	Description	Source for the definition of the Curve Number		Curve Number Soil hydrogeological group	
		Source code	Description	C	D
116	*Other impermeable/paved areas not built upon*	210-VI-NEH		98	98
117	*Permanent paved greenhouses*	210-VI-NEH		98	98
118	*Landfills*	210-VI-NEH		98	98
12	*Reversible consumed soil*	-	-	-	-
121	*Unpaved roads*	210-VI-NEH	Streets and roads - Gravel (including right-of-way)	89	91
122	*Construction sites and other dirt areas*	210-VI-NEH	Gravel	89	91
123	*Non-renaturalised extraction areas*	210-VI-NEH	Gravel	89	91
124	*Quarries in the aquifer*	210-VI-NEH	Gravel	89	91
125	*Ground-mounted photovoltaic fields*	210-VI-NEH	Industrial	91	93
126	*Other artificial coverings which removal restores the initial soil conditions*	210-VI-NEH	Impervious areas (lots, roofs, driveways, etc.)	98	98
201	*Artificial water bodies*	InVEST user guide	Water bodies	99	99
202	*Roundabouts and junctions (permeable areas)*	210-VI-NEH	Open space (grass cover > 75%)	74	80
203	*Unpaved greenhouses*	210-VI-NEH	Row crops SR - Good	85	89
204	*Bridges and viaducts on non-artificial ground*	210-VI-NEH	Streets and roads: Paved; curbs and storm sewers	98	98

Table III.38 | Curve Numbers associated with the categories of the '2018 land use map' developed by the Emilia-Romagna region.

CODE	Description	Source for the definition of the Curve Number		Curve Number Soil hydrogeological group	
		Source code	Description	C	D
0	*Not classified*	-	-	99	99
1111	*Compact and dense residential fabric*	210-VI-NEH	Residential districts - imp 65%	90	92
1112	*Sparse residential fabric*	210-VI-NEH	Residential districts - imp 38%	83	87
1121	*Urban residential fabric*	210-VI-NEH	Residential districts - imp 65%	90	92
1122	*Isolated residential structures*	210-VI-NEH	Residential districts - imp 12%	77	82
1211	*Productive settlements with annexed spaces*	210-VI-NEH	Industrial	91	93
1212	*Agricultural and livestock settlements with annexed spaces*	210-VI-NEH	Farmsteads - buildings, lanes, driveways, and surrounding lots	82	86
1213	*Commercial settlements*	210-VI-NEH	Commercial and business	94	95
1214	*Public and private service settlements*	210-VI-NEH	Commercial and business	94	95
1215	*Hospital settlements*	210-VI-NEH	Commercial and business	94	95
1216	*Big technological plants*	210-VI-NEH	Industrial	91	93
1221	*Highways and expressways*	210-VI-NEH	Streets and roads: Paved; curbs and storm sewers	98	98
1222	*Road networks and annexed spaces*	210-VI-NEH	Streets and roads: Paved; curbs and storm sewers	98	98

CODE	Description	Source for the definition of the Curve Number		Curve Number Soil hydrogeological group	
		Source code	Description	C	D
1223	*Green areas associated with road infrastructure*	210-VI-NEH	Open space (grass cover > 75%)	74	80
1224	*Railway networks and annexed spaces*	210-VI-NEH	Streets and roads: Paved; curbs and storm sewers	98	98
1227	*Networks for energy distribution and production*	210-VI-NEH	Industrial	91	93
1228	*Photovoltaic plants*	210-VI-NEH	Industrial	91	93
1229	*Water distribution networks and areas*	210-VI-NEH	Industrial	91	93
1241	*Commercial airports*	210-VI-NEH	Streets and roads: Paved; curbs and storm sewers	98	98
1242	*Sports and recreational flight airports and heliports*	210-VI-NEH	Streets and roads - Paved; open ditches (including right-of-way)	92	93
1311	*Active extraction areas*	210-VI-NEH / 210-VI-TR-55, Second Ed.	Gravel	89	91
1312	*Inactive extraction areas*	210-VI-NEH / 210-VI-TR-55, Second Ed.	Gravel	89	91
1321	*Landfills and deposits of quarries, mines and industries*	210-VI-NEH	Impervious areas (lots, roofs, driveways, etc.) – in favour of safety	98	98
1322	*Urban solid waste landfills*	210-VI-NEH / 210-VI-TR-55, Second Ed.		98	98
1323	*Scrap and vehicle deposits*	210-VI-NEH / 210-VI-TR-55, Second Ed.		98	98
1331	*Construction sites and excavations*	210-VI-NEH / 210-VI-TR-55, Second Ed.	Gravel	89	91
1332	*Remediated and artefact soils*	210-VI-NEH / 210-VI-TR-55, Second Ed.	Gravel	89	91
1411	*Parks*	210-VI-NEH / 210-VI-TR-55, Second Ed.	Open space (lawns, parks, golf courses, cemeteries, etc.) - Good condition (grass cover > 75%)	74	80
1412	*Villas*	210-VI-NEH	Residential districts - imp 12%	77	82
1413	*Urban wastelands*	210-VI-NEH	Fallow – in favour of safety	91	94
1422	*Sports areas*	210-VI-NEH	Open space (lawns, parks, golf courses, cemeteries, etc.) - Fair condition (grass cover 50% to 75%)	79	84
1423	*Amusement parks and equipped areas (aquaparks, zoos and similar)*	210-VI-NEH	Open space (lawns, parks, golf courses, cemeteries, etc.) - Fair condition (grass cover 50% to 75%)	79	84
1424	*Golf courses*	210-VI-NEH	Open space (lawns, parks, golf courses, cemeteries, etc.) - Good condition (grass cover > 75%)	74	80
1425	*Racecourses and annexed spaces*	210-VI-NEH	Open space (lawns, parks, golf courses, cemeteries, etc.) - Good condition (grass cover > 75%)	74	80
1426	*Car racing tracks and annexed spaces*	210-VI-NEH	Streets and roads - Paved; open ditches (including right-of-way)	92	93
1430	*Cemeteries*	210-VI-NEH	Open space (lawns, parks, golf courses, cemeteries, etc.) - Poor condition (grass cover < 50%)	86	89
2110	*Not irrigated arable land*	210-VI-NEH	Row crops SR - Good	85	89
2121	*Simple irrigated arable land*	210-VI-NEH	Row crops SR - Good	85	89
2122	*Nurseries*	210-VI-NEH	Woods-grass combination (orchard or tree farm)	72	79

CODE	Description	Source for the definition of the Curve Number		Curve Number Soil hydrogeological group	
		Source code	Description	C	D
2123	*Vegetable crops in open field, greenhouse and under plastic*	210-VI-NEH	Row crops SR - Good	85	89
2210	*Vineyards*	210-VI-NEH	Woods-grass combination (orchard or tree farm)	72	79
2220	*Orchards*	210-VI-NEH	Woods-grass combination (orchard or tree farm)	72	79
2241	*Poplar plantations*	210-VI-NEH	Woods-grass combination (orchard or tree farm)	72	79
2242	*Other timber crops*	210-VI-NEH	Woods—grass combination (orchard or tree farm)	72	79
2310	*Meadows*	210-VI-NEH	Meadow-continuous grass, protected from grazing and generally mowed for hay	71	78
2410	*Temporary crops associated with permanent crops*	210-VI-NEH	Fallow – in favour of safety	91	94
2420	*Complex cropping and parcel systems*	210-VI-NEH	Fallow – in favour of safety	91	94
2430	*Areas with agricultural crops and important natural spaces*	210-VI-NEH	Farmsteads—buildings, lanes, driveways, and surrounding lots	82	86
3112	*Oak, hornbeam, and chestnut dominant forests*	210-VI-NEH	Woods - Good	70	77
3113	*Willow and poplar dominant forests*	210-VI-NEH	Woods - Good	70	77
3114	*Floodplain forests predominantly with oaks and ashes*	210-VI-NEH	Woods - Good	70	77
3116	*Shrubby thickets*	210-VI-NEH	Woods - Poor	77	83
3231	*Evolving shrub and tree vegetation*	210-VI-NEH	Brush-brush-forbs-grass mixture with brush the major element	65	73
3232	*Recent afforestation*	210-VI-NEH	Woods—grass combination (orchard or tree farm)	72	79
4110	*Internal wetlands*	InVEST user guide	Water bodies	99	99
5111	*Riverbeds and streams with sparse vegetation*	InVEST user guide	Water bodies	99	99
5112	*Riverbeds and streams with abundant vegetation*	InVEST user guide	Water bodies	99	99
5113	*Embankments*	InVEST user guide	Water bodies	99	99
5114	*Canals and waterways*	InVEST user guide	Water bodies	99	99
5123	*Artificial basins*	InVEST user guide	Water bodies	99	99

Table III.39 | Curve Numbers associated with the categories of the '2021 Land cover map' developed by the Institute for Environmental Protection and Research (*Istituto Superiore per la Protezione e la Ricerca Ambientale*).

Impervious percentage	Curve Number for Soil Hydrological Group C	Curve Number for Soil Hydrological Group D
0	77	82
1	77	82
10	77	82
20	74	84
30	82	86

Impervious percentage	*Curve Number for Soil Hydrological Group C*	*Curve Number for Soil Hydrological Group D*
40	84	87
50	86	89
60	89	91
70	91	93
80	93	94
90	95	96
100	98	98

Table III.40 | Curve Numbers associated with the categories of the '2018 High Resolution Layer Imperviousness' from the Copernicus Land Monitoring Service.

Impervious percentage	*CODE*	*Curve Number for Soil Hydrological Group C*	*Curve Number for Soil Hydrological Group D*
0	593	77	82
25	719	81	85
50	657	86	89
75	582	92	93
90	456	95	96
100	301	98	98

Table III.41 | Curve Numbers associated with the '2011 Lowland Imperviousness map' of the Emilia-Romagna Region.

Results

The model was run for a total of eight times, associating the chosen base maps to the return periods of ten and 25 years (Table III.42).

Simulation		
Base map	***Return period***	
	10 years	***25 years***
Land use map – vector (Regione Emilia-Romagna, 2018);	•	•
Land cover map – raster/10 m resolution (Istituto Superiore per la Protezione e la Ricerca Ambientale, 2021);	•	•
Imperviousness map – raster/10 m resolution (Copernicus Land Monitoring Service, 2018);	•	•
Imperviousness map – raster/10 m resolution (Regione Emilia-Romagna, 2011)	•	•

Table III.42 | Summary of the test model runs.

Map III.2 and Map III.3 illustrate the outcomes of the analyses, showing the urban pluvial flood depths for various return periods (ten and 25 years) and base maps. The urban pluvial flood depth was derived by dividing the flood volume calculated by the software for each subcatchment by its corresponding area. Overall, despite the use of different base maps, significant differences were not observed among them. For its practical advantages in analysing the territory from an urban planning perspective, the flood depth based on the land use map of the Emilia-Romagna Region was used in the following steps of this assessment, as it allowed for a good control on the information - especially for the purpose of the implementation and simulation of soil desealing interventions.

Topographic Wetness Index

The Topographic Wetness Index was then calculated employing the opensource software QGIS (www.qgis.org/) according to the theoretical framework presented in Subsection §5.2.2. The following steps were taken (Hans van der Kwast, 2019):

i) the Digital Terrain Model map of the municipal territory was used as a basis to calculate the local slope $tan\beta$. Contextually, the voids of the maps were corrected (i.e., filled);
ii) the contributing upslope area a was calculated with the flow accumulation tool from SAGA implementation of QGIS;
iii) the Topographic Wetness Index was then calculated with Formula II.4.

Map III.4 encompasses the results of the calculations.

Overlay of the urban pluvial flood depths and Topographic Wetness Index

The urban pluvial flood depth and the Topographic Wetness Index where then normalised for each point i to scale them to the [0-1] range, according to the formula

$$x_{norm}^{i} = \frac{x^{i} - x_{min}}{x_{max} - x_{min}} \tag{III.9}$$

where x_{norm}^{i} is the normalised value, x^{i} is the raster pixel to normalise and x_{max} and x_{min} represent the maximum and minimum values of the raster pixels.

These values were then summed using the raster calculator in QGIS and normalised once again (for the return times of both ten and 25 years). The results are displayed in Map III.5 and Map III.6 - which present the hydrological forcings.

9.2.2 Hydraulic forcings

The aforementioned documents ‘Study for Hydraulic and Flood Risk Analysis on Municipal Territory’ (*Studio per l’analisi del rischio idraulico e alluvionale sul territorio comunale*), ‘Municipal Hydraulic Risk Plan’ (*Piano del rischio idraulico comunale*), and ‘Hydraulic Risk Management Regulation’ (*Regolamento di gestione del rischio idraulico*) were utilised for the determination of the hydraulic forcings. These documents specifically provide the analysis of the urban drainage network of Parma, conducted using a SWMM model (see Footnote 73), to identify critical nodes and conduits of the urban drainage system for return periods of ten and 25 years considering a one-hour rainfall duration (Studio Zanzucchi Srl & Comune di Parma, 2015, 2016, 2021). Additionally, the ‘Study for hydraulic and flood risk analysis on municipal territory’ includes data on historically flooded areas (see Tables 06 and 06.1 of the document).

The Municipal civil protection plan (*Piano comunale di protezione civile*) also offers insights on critical areas and locations during meteorological events, based on their intrinsic characteristics (e.g., underpasses) and prior analyses. Specifically, Boards 2.5 and 2.6 map these data (Comune di Parma & Protezione Civile - Comune di Parma, 2024).

All the gathered information concerning hydraulic forcings is presented in Map III.7 and Map III.8, which can be related with the hydrological forcings (Map III.2 and Map III.3) and urban pluvial flood risk maps (Map III.13, Map III.14, Map III.15 and 15a, and Map III.16 and 16.a).

9.2.3 Exposed assets

The exposed assets consist of the population and physical assets, specifically buildings and road and rail infrastructure (Map III.9)[110]. The population density was calculated for each subcatchment and census section using data from the open database provided by the Municipality of Parma and updated to 2024 (Comune di Parma, 2024). This was because subcatchments exhibit significant variations in area, whereas census sections are generally more consistent in terms of surface size[111]. The results are presented in Map III.10 and Map III.10a.

For the purposes of the urban pluvial flood risk assessment, data normalisation was carried out as follows:

- physical assets: a value of 1 indicates their presence, while 0 indicates their absence;
- population: values were normalised on a continuous scale.

9.2.4 Vulnerability

The vulnerability of the physical assets and the population was then assessed based on the methodology identified in Subsection §5.2.2. The considered indicators' categories reflect those identified in the reference studies, and corresponding indicators were identified for Parma in accordance with the environmental, social and economic characteristics of the urban area.

For what concerns the sensitivity indicators' categories, their following metrics were identified based on the review of the indicators used in literature (Subsections §5.2.1 and §5.2.2):

- age: sensitivity related to age is expressed through the percentage of people younger than 5 and older than 65, as proposed in literature (e.g., Sambo et al., 2023) and similarly reflected in analyses by the Municipality of Parma (Comune di Parma, 2021a);
- education: sensitivity is linked to the educational level of the population and can be expressed through the percentage of illiterate people (i.a., Ceragene et al., 2023). This serves as a proxy for identifying those who might be less likely to understand, receive, or act on flood alerts from institutions. It should be noted that this is a general-level indicator, as other factors also influence this phenomenon;
- ethnicity: sensitivity related to ethnicity is expressed by the percentage of foreigners (Othmer et al., 2020), who may not be fully familiar with the specificities

[110] In Map III.9, buildings have been represented according to the use categories identified by the Geoportale of the Emilia-Romagna Region.
[111] In the following subchapters, if not specified, the exposed population density considered in the analyses refers to that calculated on the census section.

of the territory or alert systems, or who may face linguistic barriers that prevent understanding;

- gender: literature identifies women as more vulnerable to floods (Elboshy et al., 2019). Therefore, gender-related vulnerability is represented by the percentage of females in the population;
- independence: vulnerability associated with independence is expressed through the dependency ratio (i.a., Ceragene et al., 2023; Loli et al., 2022; Othmer et al., 2020), which measures the proportion of the inactive population (individuals aged 0–14 and those over 64) relative to the potentially active population (individuals aged 15–64);
- health conditions: while health is a crucial factor in assessing vulnerability, such data are often unavailable due to privacy concerns. The age indicator may serve as a partial substitute, as, for instance, older individuals are more likely to experience health-related vulnerabilities;
- housing capacity: this indicator was excluded due to the lack of reliable data at the appropriate scale for analysis;
- buildings: age; conditions; type; and built-environment characteristics and conditions: sensitivity related to the built-environment is expressed through the percentage of residential buildings in poor condition (Elboshy et al., 2019; Ellena et al., 2020; K. Park et al., 2021) per unit of analysis. This reflects the general state of the analysed area, assuming that a higher number of poorly maintained buildings indicates greater vulnerability. While this indicator is relevant for low-intensity floods, more significant floods might require additional data, such as construction materials or structural characteristics;

- mobility and infrastructure characteristics: vulnerability concerning mobility infrastructure is represented by the presence of underpasses, which, as identified in previous chapters, are critical points for both population safety and physical assets (Comune di Parma & Protezione Civile - Comune di Parma, 2024; Studio Zanzucchi Srl & Comune di Parma, 2015);

- land and economic productivity: due to limited data availability, this indicator is represented by the location of infrastructure and services, such as commercial, industrial, educational, energy, health, mobility, and residential facilities;

- protected areas and cultural/environmental assets: sensitivity in this category is expressed by the location of protected paved areas and significant architectural or landscape assets, which are particularly sensitive to climate change impacts (Ellena et al., 2020; Sambo et al., 2023).

For what concerns the adaptive capacity indicators related to vulnerability, the following metrics have been identified:

- public awareness level: this indicator category is measured by people’s perception of the relevance of climate change and the observed effects in their neighbourhoods, reflecting their awareness of this issue;

- civic and social advocacy organisations and voluntarism: this indicator category is expressed through the number of associations per area, highlighting their potential role in emergency forecast and prevention, response, and recovery phases;

- presence of protection infrastructure: the presence of hydraulic protection works (Ellena et al., 2020) serves as an indicator of adaptive capacity;

- emergency services capacity: proximity to designated emergency gathering areas, as identified by Civil Protection, represents this indicator category (Mabrouk & Haoying, 2023);

- digital services capacity: initially considered as an indicator of adaptive capacity due to its role in disseminating alerts and emergency information, digital services were reassessed. While Parma is well-covered by digital networks, the 2014 flood exposed their vulnerability when the Telecom telephonic station located in the street '*Via Po*' was damaged, causing city-wide connection failures ('13 ottobre 2014, Parma color fango', 2016; 'L'alluvione a Parma', 2014). Antennas were initially marked as sensitive points but were ultimately excluded due to insufficient data on their function and network interdependence;

- health services capacity: this indicator is represented by proximity to hospitals, reflecting the population access to health care in emergencies (Bibi et al., 2018; Loli et al., 2022).

For each indicator category, the reference exposed assets (physical assets or population) were identified both from the theoretical perspective and from the current assessment point of view, as well as according to their subcategory (sensitivity/adaptive capacity[112]). Table III.43 shows the results of this step, and encompasses a description containing information such as the indicator calculation method or, in certain cases, information about why it was excluded from the analysis. Furthermore, for each indicator, its scale, measure, format, year and source were specified in Table III.44 and Table III.45.

After elaborating and normalising each of them, indicators were summed to obtain the physical assets and population vulnerability. Results are encompassed by Map III.11 and Map III.12.

Indicator category	***Indicator***	***Exposed assets***	***Exposed assets considered in the assessment***		***Vulnerability subcategory***
			Pop.	***Phy. Assets***	
Age	Percentage of people younger than 5 years and older than 65 years	Population	•		Sensitivity
Education	Percentage of illiterate people	Population	•		Sensitivity

[112] From a practical perspective, each indicator category was normalised on a scale ranging from 0 to 1, where 0 represents the lowest sensitivity and 1 the highest. Indicators that were originally formulated on an opposite scale have been marked as 'inverted' in the measure field (Table III.44).

Indicator category	*Indicator*	*Exposed assets*	*Exposed assets considered in the assessment*		*Vulnerability subcategory*
			Pop.	*Phy. Assets*	
Ethnicity	Percentage of foreigners	Population	•		Sensitivity
Gender	Percentage of females	Population	•		Sensitivity
Independence	Dependency ratio	Population	•		Sensitivity
Health conditions	N/A[113]	Population	N/A		Sensitivity
Employment	= Independence	Population	N/A		Sensitivity
Wealth	Residential building values for square meter	Population	•		Sensitivity
Housing capacity	N/A[114]	Population	N/A		Sensitivity
Buildings: age; conditions; type	Residential buildings in poor condition per census section	Population/ Physical assets		•	Sensitivity
Built-environment characteristics and conditions;		Population/ Physical assets		•	Sensitivity
Mobility and mobility infrastructure type and characteristics	Critical nodes of the road network	Population/ Physical assets	•	•	Sensitivity
Land and economic productivity	= Location of commercial/industrial; educational; energy; health; mobility; residential infrastructure and services	Physical assets	N/A		Sensitivity
Location of commercial/industrial; educational; energy; health; mobility; residential infrastructure and services	Percentage of: commercial areas; industrial areas; residential areas	Population/ Physical assets		•	Sensitivity
	Presence of services	Physical assets		•	Sensitivity
Presence of protected areas	Location of protected (*vincolate*) paved areas and landscape and architectural assets	Physical assets		•	Sensitivity
Presence of historical, cultural and environmental assets					
Public awareness level	Relevance of climate change	Population	•		Adaptive capacity
	Observed effects of climate change in the neighbourhood	Population	•		Adaptive capacity
Civic and social advocacy organisations	Number of associations	Population	•		Adaptive capacity
Voluntarism					

[113] Difficulties have been encountered in gathering data with a significant detail with respect to the considered scale (e.g., availability only at the municipal scale). In this case, also the privacy component must be considered when dealing with this information.

[114] Difficulties have been encountered in gathering data with a significant detail with respect to the considered scale (e.g., availability only at the municipal scale).

Indicator category	*Indicator*	*Exposed assets*	*Exposed assets considered in the assessment*		*Vulnerability subcategory*
			Pop.	*Phy. Assets*	
Presence of protection infrastructure	Presence of hydraulic protection works	Population/ Physical assets	•	•	Adaptive capacity
Emergency services capacity	Proximity to emergency areas	Population	•		Adaptive capacity
Digital services (capacity)	N/A	Population/ Physical assets	N/A		Adaptive capacity/ Sensitivity
Health services capacity	Proximity to hospitals	Population	•		Adaptive capacity

Table III.43 | Specifications about the identified indicators categories.

Indicator	*Description*	*Measure*	*Scale*
Percentage of people younger than 5 years and older than 65 years	Ratio between the population aged <5 and ≥65 years and the total population	Normalised value/ subcatchment	Subcatchment
Percentage of illiterate people	Ratio between the illiterate population and the total population	Normalised value/ census section	Census section
Percentage of foreigners	Ratio between the population with a foreign citizenship and the total population	Normalised value/ subcatchment	Subcatchment
Percentage of females	Ratio between the female and the total population	Normalised value/ subcatchment	Subcatchment
Dependency ratio	Ratio between the inactive population, comprising young people aged between 0 and 14 and the elderly over 64, and the potentially active population aged between 15 and 64)	Normalised value/ neighbourhood	Neighbourhood
Residential building values for square meter	Residential building values for square meter	Normalised value/ the cadastral micro-zones (*microzone catastali*) - inverted	Cadastral micro-zones (*microzone catastali*)
Residential buildings in poor condition per census section	Number of residential buildings in poor condition	Normalised value/ census section	Census section
Critical nodes of the road network	Location of the underpasses	1 if present 0 if absent considering a 15 m buffer	Entity
Percentage of: *commercial areas;* *industrial areas;* *residential areas.*	Commercial areas; industrial areas; residential areas; road and rain infrastructure	Normalised value	Entity
Presence of services	Location of services	1 if present 0 if absent	Entity

Indicator	*Description*	*Measure*	*Scale*
Location of protected (vincolate) paved areas and landscape and architectural assets	Protected (*vincolate*) paved areas Location of landscape and architectural assets (Legislative Decree No. 42/2004)	1 if present 0 if absent. If point elements, a 5 m buffer was considered	Entity
Relevance of climate change	Percentage of people who have a clear idea about the relevance of climate change	Normalised value/ Neighbourhood - inverted	Neigh.
Observed effects of climate change in the neighbourhood	Percentage of people that observed a high number of effects of climate change in their neighbourhood	Normalised value/ Neighbourhood - inverted	Neigh.
Number of associations	Number of associations	Normalised value/ subcatchment - inverted	Subcatchment
Presence of hydraulic protection works	Location of hydraulic protection works[115]; detention basins	0 if present 1 if absent in the subcatchment	Subcatchment
Proximity to emergency areas	Proximity of a point to emergency areas	Normalised value/subcatchment of the proximity of the subcatchment centroid to emergency areas centroid - inverted	Subcatchment
Proximity to hospitals	Proximity of a point to hospitals	Normalised value per subcatchment of the proximity of the subcatchment centroid to hospitals centroid - inverted	Subcatchment

Table III.44 | Specifications about the identified indicators – part I.

Indicator	*Format*	*Year*	*Source*
Percentage of people younger than 5 years and older than 65 years	Shapefile (point)	2024	Opendata - Municipality of Parma/Italian national statistics institute (*Istituto nazionale di statistica*)
Percentage of illiterate people	Shapefile (area)	2011	Italian national statistics institute (*Istituto nazionale di statistica*)
Percentage of foreigners	Shapefile (point)	2024	Opendata - Municipality of Parma/Italian national statistics institute (*Istituto nazionale di statistica*)
Percentage of females	Shapefile (point)	2024	Opendata - Municipality of Parma/Italian national statistics institute (*Istituto nazionale di statistica*)
Dependency ratio	Shapefile (area)	2020	General urban plan PR050
Residential building values for square meter	Shapefile (area)	1 semester - 2024	Italian Revenue Agency (Agenzia delle Entrate) - Real Estate Market Observatory (*Osservatorio del mercato immobiliare*)

[115] Retaining and retaining walls, embankments, drainage and irrigation channels, dams, hydraulic regulating works.

Indicator	*Format*	*Year*	*Source*
Residential buildings in poor condition per census section	Shapefile (area)	2011	Italian National Statistics Institute (*Istituto Nazionale di Statistica*)
Critical nodes of the road network	Shapefile (point)	2018	Municipal civil protection plan
Percentage of: commercial areas; industrial areas; residential areas	Shapefile (area)	2018	IV level land use map of the Emilia-Romagna Region
Presence of services	Shapefile (area)	2018 and 2010 (Schools)	IV level land use map of the Emilia-Romagna Region and own data (schools)
Location of protected (*vincolate*) paved areas and landscape and architectural assets	Shapefile (area and point)	2023	General urban plan PR050 and MiC Regional Secretariat for the Emilia-Romagna Region (*Segretariato Regionale del MiC per l'Emilia-Romagna*)
Relevance of climate change	Shapefile (area)	2023	Survey on climate change and its local effects in Parma (see Subsection §9.4.1)
Observed effects of climate change in the neighbourhood	Shapefile (area)	2023	Survey on climate change and its local effects in Parma (see Subsection §9.4.1)
Number of associations	Shapefile (point)	2023	General urban plan PR050
Presence of hydraulic protection works	Shapefile (area or linear)	Downloaded in 2024	Geoportale - Emilia-Romagna Region General urban plan PR050
Proximity to emergency areas	Shapefile (area)	2024	Municipal civil protection plan
Proximity to hospitals	Shapefile (area)	2018	IV level land use map of the Emilia-Romagna Region

Table III.45 | Specifications about the identified indicators – Part II.

9.2.5 Risk maps

The urban pluvial flood risk was then calculated with the traditional formula

$$Risk = Hazard \cdot Exposure \cdot Vulnerability \tag{II.5}$$

In order to do so, the previously assessed (and normalised) risk components were rasterised and then multiplied with the QGIS raster calculator, for both the physical assets and the population.

Results are encompassed by the following maps (Map III.13, Map III.14, Map III.15 and 15a, and Map III.16 and 16.a), which represent:

- the urban pluvial flood risk map for physical assets and a return time of 10 years;
- the urban pluvial flood risk map for physical assets and a return time of 25 years;
- the urban pluvial flood risk map for the population and a return time of 10 years;
- the urban pluvial flood risk map for the population and a return time of 25 years.

The assessment for the urban pluvial flood risk for the population was performed considering both the population density per census section and subcatchment.

9.2.6 Damage maps

The following paragraphs describe the calculation of the urban pluvial flood damage according to the theoretical framework identified in Subsection §5.2.4, which is then represented through maps, both for the population and physical assets.

Physical assets

The damage of the physical assets was first determined with Formula II.6, i.e.,

$$Damage = Exposure \cdot Vulnerability \quad \text{(II.6)}$$

which was defined as Approach A within this thesis. Results are encompassed by Map III.17.

Depth-damage curves based on Huizinga et al. (2017) were then employed to calculate the maximum damage of the physical assets (Approach B).

Therefore, following the methodology presented in the Joint Research Centre of the European Commission report, the following steps were taken, with the help of the software programs QGIS and Microsoft Excel[116].

Based on the calculated flood depth for the return periods of ten and 25 years (Subsection §9.2.1), the associated damage factor α_c, l was calculated based on the interpolation of the values of the curves (Figure II.24 and Subsection §5.2.4) for each considered physical asset, namely buildings and road and rail infrastructure elements (Table III.46).

For each building, the damage factor α_c, l was multiplied by the maximum exposure value E_{max}, l, obtained by associating the building categories of the 'buildings' shapefile of the Emilia-Romagna Region with those proposed by the Joint Research Centre of the European Commission report[117] (see Table III.47). The calculated damage values per unit of area are represented in Map III.18 and Map III.19. A similar procedure was employed for road and rail infrastructure (Map III.20 and Map III.21).

By multiplying these values for the area of the element, it was also possible to calculate the maximum damage for each building.

Damage factors α_c, l [-]					
Water depth [m]	***Residential buildings and content***	***Agriculture***	***Industry***	***Road and rail infrastructure***	***Commerce***
0	0	0	0	0	0
0.5	0.23	0.27	0.15	0.23	0.38
1	0.4	0.5	0.28	0.42	0.54

[116] Microsoft Excel was licensed by the University of Parma in the framework of the Ph.D. Programme.
[117] When the Emilia-Romagna Region categories did not have a direct correspondence, choices were made in favour of safety.

Damage factors α_c, l [-]					
Water depth [m]	**Residential buildings and content**	**Agriculture**	**Industry**	**Road and rail infrastructure**	**Commerce**
1.5	0.52	0.58	0.4	0.56	0.66
2	0.62	0.74	0.5	0.66	0.76
3	0.74	0.86	0.7	0.8	0.88
4	0.85	0.92	0.85	0.9	0.94
5	0.98	0.98	1	0.98	0.98
6	1	1	1	1	1

Maximum exposure value E_{max}, l for Italy [€/m^2]							
Residential		**Agriculture**	**Industry**		**Road and rail infrastructure**	**Commerce**	
Buildings and content	**Land use**		**Buildings and content**	**Land use**		**Buildings and content**	**Land use**
739	148	0.22	838	251	21	1028	308

Table III.46 | Damage factors and maximum exposure values for Italian physical assets according to Huizinga et al. (2017).

Building categories identified by the Emilia-Romagna Region	*Corresponding category of the Joint Research Centre of the European Commission report*
Residential	Residential buildings and content
Religious buildings	Commercial buildings and content
N/A	
Sports venues	
Industrial buildings	Industrial buildings and content

Table III.47 | Correspondence between the building categories identified by the Emilia-Romagna Region and the Joint Research Centre of the European Commission.

Population

The damage of the population was first determined with Formula II.6 (Approach A)[118]. Results are encompassed by Map III.22.

The mortality and the affected population were then calculated for each subcatchment (Approach B), as outlined in Subsection §5.2.4 - using three different approaches to compare their results. The calculations are presented in Map III.23, Map III.24, Map III.25 and Map III.26. The affected population was assessed according to Rincón et al. (2022) for both a ten- and 25 year return period. Similarly, the approaches proposed by Jonkman & Asselman (2003) and Russo & Parisani (2019) were applied to evaluate population mortality. However, no differences in mortality rates were observed between the two return periods in these latter approaches.

Notably, the Russo & Parisani (2019) method reported no fatalities, which aligns with the historically low mortality rates associated with urban pluvial flooding in Italy (see Subsection §5.2.4). Given this context, the methods focusing on the affected population rather than its mortality appears more relevant within this assessment and its implications for soil desealing.

[118] With the aim of comparing the results with the other methodologies, the population density per subcatchment was employed.

Comparison of the approaches

The two approaches for calculating urban pluvial flood damage to physical assets and the population yielded varying results.

Approach B incorporates flood depth into the damage calculation (as well as a maximum exposure value E_{max}, l in the case of physical assets). In contrast, Approach A involves multiplying exposure and vulnerability, but – within the framework of this research – does not account for variables such as the flood depth, which is treated as a hazard indicator. This highlights the inherent variability of the assessment through Approach A, as the calculation relies on the consideration of the two risk components (exposure and vulnerability), which, as previously addressed, can differ.

On one hand, Approach A allows for case-specific assessments, better reflecting the unique characteristics of the area under study. On the other hand, Approach B provides a more standardised methodology, with values tailored to either Italy or Europe. This standardisation is advantageous because it allows for straightforward assessments that are easily comparable across different case studies, as it relies less on the availability of local data.

The outcomes of the two methodologies are worth analysing. Regarding damage to the population, Map III.22 (Approach A) and Map III.23, Map III.24, Map III.25 and Map III.26 (Approach B) exhibit comparable results terms of the distribution of lower and higher damage values. However, for damage to physical assets, the results differ. For example, Approach A (Map III.17) considers all physical assets simultaneously. Conversely, Approach B distinguishes between buildings and rail and road infrastructure, assigning distinct damage factors α_c, l and maximum exposure values E_{max}, l to each category (Map III.18, Map III.19, Map III.20 and Map III.21), making the results overall less comparable.

9.3 The transformation potential

In parallel to the urban pluvial flood risk assessment for physical assets and the population, the transformation potential was investigated, with respect both to the desealability of the urban area surfaces and to the urban planning legislative and strategic tools.

9.3.1 Evaluation of the desealing potential at the urban scale

Based on the methodology identified in Subsection §6.1.3, the contextual and intrinsic factors were associated with an indicator. Table III.48 and Table III.50 specify the indicator description, measure, scale, as well as their format, year and source for Parma. Table III.49 and Table III.51 present the same information for the intrinsic factors.

Among them, it makes sense to motivate some of the choices that were made, which build on Section §6.1. Regarding the local cultural, economic, and social benefits of soil desealing, inspiration was drawn from initiatives such as ‘Depave’ and ‘Depave Paradise’ (Subsection §2.2.2), where citizens identified degraded areas in need of transformation into community spaces. Indicators for urban degradation include therefore the percentage of residential buildings in poor conditions, the location of abandoned or unused buildings, and residential building values per square meter. While these indicators provide a solid starting point for an initial assessment, they could benefit from being complemented by additional analyses and more refined indicators.

Proximity to services was also considered as an indicator of areas with potential for significant improvement in the urban environment, particularly in contexts like school streets.

For what concerns the information on the date and condition of the paving, municipalities may possess relevant databases. In this analysis, a historical assessment of the urban area was used, considering 1950 as a benchmark year for identifying most suitable areas for soil desealing. Surfaces paved prior to this year may have been updated or are likely to be protected, whereas those paved after this year may still be in good condition and less suitable for intervention. This hypothesis should, however, be adapted based on the specific contexts.

The ownership of the area by the Municipality is considered as a positive factor, under the assumption of a strong public initiative for soil desealing, as inferable form Parma efforts in this regard (see Subsection §4.2.2 and §9.1.4).

The usefulness of paving was evaluated according to land use. The lowest value was attributed to road and rail infrastructure (and landfills), where paving is essential for functionality. Higher values were assigned to industrial, commercial, productive, and residential areas, as well as services and hospitals, where not all impervious surfaces are strictly necessary for their function. The highest values were attributed to all other land uses.

The identified normalised indicators were summed, with the exception of protected (*vincolate*) paved areas, landscape and architectural assets, and constraints for soil desealing which have been attributed the lowest desealability value (0) *ex-post*. The result was normalised again[119], and the urban desealing potential was assessed. Map III.27 and Map III.28 show the results of this analysis. Map III.28 includes also the identified transformation "boosters" indicators, which emphasise further opportunities for soil desealing.

Contextual factor	***Indicator***	***Description***	***Measure***	***Scale***
Existence of plans and projects for the area	Location of areas/buildings for which renovation plans or projects have been envisioned	Specifically, areas identified as: - commercial, directional and hospitality areas to be qualified; - buildings to be developed; - production areas to be qualified; - residential or mixed residential areas to be qualified	1 if present 0 if absent	Entity
		Buildings subject to building renovation	1 if present 0 if absent	Entity

[119] The extent on which the final normalisation was performed corresponds to a smaller portion of municipal area.

Contextual factor	***Indicator***	***Description***	***Measure***	***Scale***
Promotion of soil permeability in the area by the urban planning tools	Location of areas to be subject to footprint reduction (RIFO index)	Areas to be subject to footprint reduction (RIFO index)	1 if present 0 if absent	Entity
	Location of parking lots which have been identified as suitable for soil desealing interventions	Parking lots which have been identified as suitable for soil desealing interventions	1 if present 0 if absent	Entity
Local cultural/economic/ social benefits of soil desealing	Residential buildings in poor condition per census section	Number of residential buildings in poor condition	Normalised value	Census section
	Location of abandoned/unused buildings	Abandoned/unused buildings	1 if present 0 if absent	Entity
			1 if present 0 if absent considering a 5 m buffer	Entity
	Residential building values for square meter	Residential building values for square meter	Normalised value	Cadastral micro-zones (*Microzone catastali*)
Favour or sensitivity of the local population	Percentage of the population that observed a high number of effects in their neighbourhood	Sensitivity to the impacts of climate change	Normalised value	Neighbour-hood
	Percentage of the population that perceives the necessity of soil desealing in their neighbourhood	Perceived necessity of soil desealing	Normalised value	Neighbour-hood
Constraints for soil desealing	Location of contaminated areas	Contaminated sites	0 if present 1 if absent considering a 50 buffer Their presence determines the unfeasibility of the transformation	Entity
Ownership of the area	Location of the areas owned by the Municipality	Areas owned by the Municipality	1 if present 0 if absent	Entity
Transformation "boosters"	***Indicator***	***Description***	***Measure***	***Scale***
Proximity to green areas	Urban green areas with a 50 meters buffer	Urban green areas with a 50 meters buffer	1 if present 0 if absent	Entity
Proximity to services	Urban services with a 50 meters buffer	Services (land use maps), schools, hospitals and libraries with a 50 meters buffer	1 if present 0 if absent	Entity

Table III.48 | Contextual factors and transformation "boosters" of the desealing potential – part I.

Intrinsic factors	Indicator	Description	Measure	Scale
Cultural/historic/economic/social value of the paving	Location of protected (*vincolate*) paved areas	Protected (*vincolate*) paved areas	0 if present. Their presence determines the unfeasibility of the transformation	Entity
	Location of landscape and architectural assets	Landscape and architectural assets (Legislative Decree No. 42/2004)	0 if present. Their presence determines the unfeasibility of the transformation. If point elements, a 5 m buffer was considered	Entity
Date of installation/last maintenance of the paving	Historical thresholds of the urban area	Analysis of the historical thresholds of the urban area development phases	1 if 1950, 0 if else	Entity
Condition of the paving				
Usefulness of the paving	Usefulness of the paving	Attribution of a usefulness value to the land use categories	0 for road and rail, infrastructure and landfills 0.5 for industrial, commercial, productive and residential areas, services, hospitals [...] 1 if else	Entity

Table III.49 | Intrinsic factors of the desealing potential – part I.

Contextual factors	Format	Year	Source
Location of areas/buildings for which renovation plans or projects have been envisioned	Shapefile (area)	2023	General urban plan PR050
	Shapefile (area)	2023	General urban plan PR050
Location of areas to be subject to footprint reduction (RIFO index)	Shapefile (area)	2023	General urban plan PR050
Location of parking lots which have been identified as suitable for soil desealing interventions	Shapefile (area)	2023	General urban plan PR050
Residential buildings in poor condition per census section	Shapefile (area)	2011	Italian National Statistics Institute (*Istituto Nazionale di Statistica*)
Location of abandoned/unused buildings	Shapefile (area)	Downloaded in 2024	Geoportale - Emilia-Romagna Region
	Shapefile (point)	2023	General urban plan PR050
Residential building values for square meter	Shapefile (area)	1 semester - 2024	Italian Revenue Agency (*Agenzia delle Entrate*) - Real Estate Market Observatory (*Osservatorio del mercato immobiliare*)

Contextual factors	*Format*	*Year*	*Source*
Percentage of the population that observed a high number of effects in their neighbourhood	Shapefile (area)	2023	Survey on climate change and its local effects in Parma (see Subsection §9.4.1)
Percentage of the population that perceives the necessity of soil desealing in their neighbourhood	Shapefile (area)	2023	Survey on climate change and its local effects in Parma (see Subsection §9.4.1)
Location of contaminated areas	Shapefile (point)	2023	General urban plan PR050
Location of the areas owned by the Municipality	Shapefile (area)	N/A	Municipality of Parma
Transformation "boosters"			
Indicator	***Format***	***Year***	***Source***
Urban green areas with a 50 meters buffer	Shapefile (area)	N/A	Municipality of Parma
Urban services with a 50 meters buffer	Shapefile (area)	2018 and 2010 (schools)	Land use - Emilia-Romagna Region; Municipality of Parma

Table III.50 | Contextual factors and transformation "boosters" of the desealing potential – part II.

Intrinsic factors	*Format*	*Year*	*Source*
Location of protected (vincolate) paved areas	Shapefile (area)	2023	General urban plan PR050
Location of landscape and architectural assets	Shapefile (point) (area)	2024	MiC Regional Secretariat for the Emilia-Romagna Region (*Segretariato Regionale del MiC per l'Emilia-Romagna*)
Historical thresholds of the urban area	Shapefile (area)	2023	General urban plan PR050
Usefulness of the paving	Shapefile (area)	2018	IV level land use map of the Emilia-Romagna Region.

Table III.51 | Intrinsic factors of the desealing potential – part II.

9.3.2 Which urban planning instruments?

As emphasised, the context of Parma reflects a growing recognition of the necessity of implementing soil desealing, as evidenced by the various legislative and strategic tools that address this issue (see Subsections §4.2.2 and §9.1.4). While these frameworks create significant opportunities, they also introduce complexities in navigating existing tools and determining where to focus interventions.

Strategic instruments, such as the Sustainable energy and climate action plan, can serve as overarching collectors of initiatives, providing valuable guidance (Caselli et al., 2023). More practical and specific measures are outlined in the urban planning legislative tools such as the General urban plan (*Piano urbanistico generale),* which includes initial area identification (the desealable parking lots) and considerations for permeability requirements in the related instruments such as the Building regulation (*Regolamento edilizio*).

While sector-specific plans (*piani di settore*) such as the Green plan (*Piano del verde)* could be developed or enriched, implementing further legislative fragmentation may not be practical. Instead, it may be more effective to expand and refine the existing instruments like the General urban plan. For example, leveraging the opportunities provided by the intention of the Municipality to deseal parking lots, as well as the promotion of the 'RIFO index', and implementing further specifications and information about desealable surfaces and desealing priorities could help prioritise desealing efforts, especially in the context of an existing regional law that promotes soil desealing. In this framework, also the three-year public works programmes (*programmi triennali dei lavori pubblici*) appear as a useful tool for putting in action soil desealing and the public initiative.

As the analysis results demonstrate, most paved areas are transformable to some degree and can play a meaningful role in mitigating urban pluvial flood risks. This supports the adoption of diffuse approaches for both public and private areas, such as the German compensation measures, without forgetting collaborative and integrative processes like the Dutch '*Steenbreek*' programme, which encourage citizens' and stakeholders' involvement in the desealing of both public and private areas that could be integrated also in the more strategic instruments. Overall, the General urban plan emerges as a suitable framework for implementing such measures, enabling a more coordinated and impactful approach to soil desealing.

9.4 Insights for decision-makers from public participation

This chapter focuses on the insights and contribution that public participation processes can provide in relation to soil desealing, in the theoretical framework outlined in Section §2.3 and Chapter §7. The experiences that were developed and explored within the doctoral research provided valuable insights from both an academic and a practical perspective, and they allowed to gauge (localised) citizens' sensitivity, preferences, opinions and responsiveness the investigated topics, recognising and valuing localised knowledge from citizens. The insights gathered through these participatory processes allow to shape proposals that reflect and, hopefully, align with public opinion, thereby enhancing the likelihood of support and successful implementation.

The survey developed as part of the 'Green in Parma' project (Subsection §9.4.1) served as the foundation for creating a second survey, advancing the research by investigating public preferences for soil desealing (Subsection §9.4.3). The overall positive feedback regarding the importance of addressing urban resilience and soil desealing - as well as the insights on the perceived value of engaging in climate transition processes observed in these experiences - inspired the inclusion of small interactive activities during independent dissemination events. These activities provided opportunities to gather additional insights and opinions from the citizens of all ages.

Section §9.4 describes the main phases and activities of the 'Green in Parma' community project (Subsection §9.4.1); the role of young people's involvement in climate change adaptation processes (Subsection §9.4.2); and the setup, distribution, analysis and outcomes of a survey about soil desealing preferences in Parma inspired by the 'Green in Parma' experiences (Subsection §9.4.3).

9.4.1 The 'Green in Parma' community project[120]

As previously addressed, the soil consumption rates of the city of Parma have been increasing, leading to a number of challenges for the urban area, such as the climate-related impacts like heat waves, the urban heat island effect and flooding, all of which have caused substantial damage in recent years. The growing public awareness of these issues has resulted in initiatives like the grassroot project 'Green in Parma'. This project is one of the first in Parma to focus on community participation, promoting urban resilience by enhancing soil desealing and green areas (Caselli et al., 2022; Ceci, De Noia, et al., 2023). Furthermore, it is particularly relevant in the framework of this research as it allowed for an applicative scenario for both soil desealing and citizens' involvement and participation.

'Green in Parma' is promoted by the Centre for Environmental Ethics (*Centro Etica Ambientale*) of Parma[121], a third-sector organisation that is part of the National network of centres for environmental ethics (*Rete nazionale dei centri per l'etica ambientale*). The Centre for Environmental Ethics of Parma promotes activities aligned with the Sustainable Development Goals of the 2030 Agenda, coordinating a diverse network of local partners, including various social and economic stakeholders.

In early 2021, the Centre for Environmental Ethics, in collaboration with local organisations and institutions including the University of Parma organised a series of open science webinars focusing on the urban impacts of climate change. The emerged dialogue highlighted the need for knowledge transfer to active citizens, aimed at fostering and supporting urban transformations to address the challenges posed by climate change. It was within this context that the 'Green in Parma' community project was developed to meet the need for a participatory approach in implementing more effective greening interventions aligning with the community's needs. In April 2021, the project obtained co-funding by winning a call for proposals from the IREN Territorial Committee[122] and 'Green in Parma' was officially launched in the autumn of the same year. As illustrated in Figure III.33, the 'Green in Parma' project was initially structured around three main modules.

The first module (A) focused on information dissemination and awareness-raising, aiming to educate citizens and stakeholders about local climate change impacts. This effort also fostered the creation of a network of partners and contacts to facilitate the identification of potential areas for desealing interventions through a bottom-up approach. Starting in late October 2021, a series of public and partner meetings took place to raise awareness of climate change and present the project vision to urban stakeholders.

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[120] Subsection §9.4.1 has been adapted by the author based on 'Ceci, M., De Noia, I., Tedeschi, G., Caselli, B., & Zazzi, M. (2023). Soil de-sealing and participatory urban resilience actions: The "Green in Parma" case study. UPLanD - Journal of Urban Planning, Landscape & Environmental Design, 7(2), Article 2. https://doi.org/10.6093/2531-9906/10116' and 'De Noia, I., Caselli, B., Kemperman, A., Rossetti, S., & van der Waerden, P. (2024). Towards participatory urban planning: insights from citizens. Results of a public survey on climate change and its local effects in Parma. *TeMA - Journal of Land Use, Mobility and Environment, 17*(2), 193-212. https://doi.org/10.6093/1970-9870/10836' in which she is co-author. The published article encompasses the full attributions of the work.

[121] The Centre for Environmental Ethics (*Centro Etica Ambientale*) of Parma is a third-sector organisation that coordinates and develops projects in alignment with the Sustainable Development Goals of the 2030 Agenda, as well as the values and themes outlined in Pope Francis' Encyclical *'Laudato Si'* (https://www.centroeticambientale.org/).

[122] I.e., Organisations that connect the Iren Group, an energy multiutility, with local stakeholders in relation to the company services and sustainability initiatives (www.gruppoiren.it/it/sostenibilita/coinvolgimento-degli-stakeholder/comitati-territoriali.html and www.irencollabora.it/projects/6017c061257f5792056d520e/green-in-parma/6017c061257f5792056d520d).

The second module (B) mainly involved participation and co-design activities, encouraging citizens and stakeholders to engage in the promotion of urban resilience and co-design green urban spaces. This module includes the development of strategies for soil desealing interventions in areas selected through a participatory process that involved project partners, stakeholders, and the community. This module resulted in a soil desealing experiment at the San Bernardo Parish, which – located in the San Leonardo neighbourhood in Northern Parma – involved the local Neighbourhood Committee, the parish community, and other local groups. During this phase, the project team developed a public survey, 'Parma wonders about the local effects of climate change', launched at the end of 2022 via an online platform and presented within this subsection.

The third module (C) outlined the executive phase, focusing on the actual implementation of desealing or greening interventions.

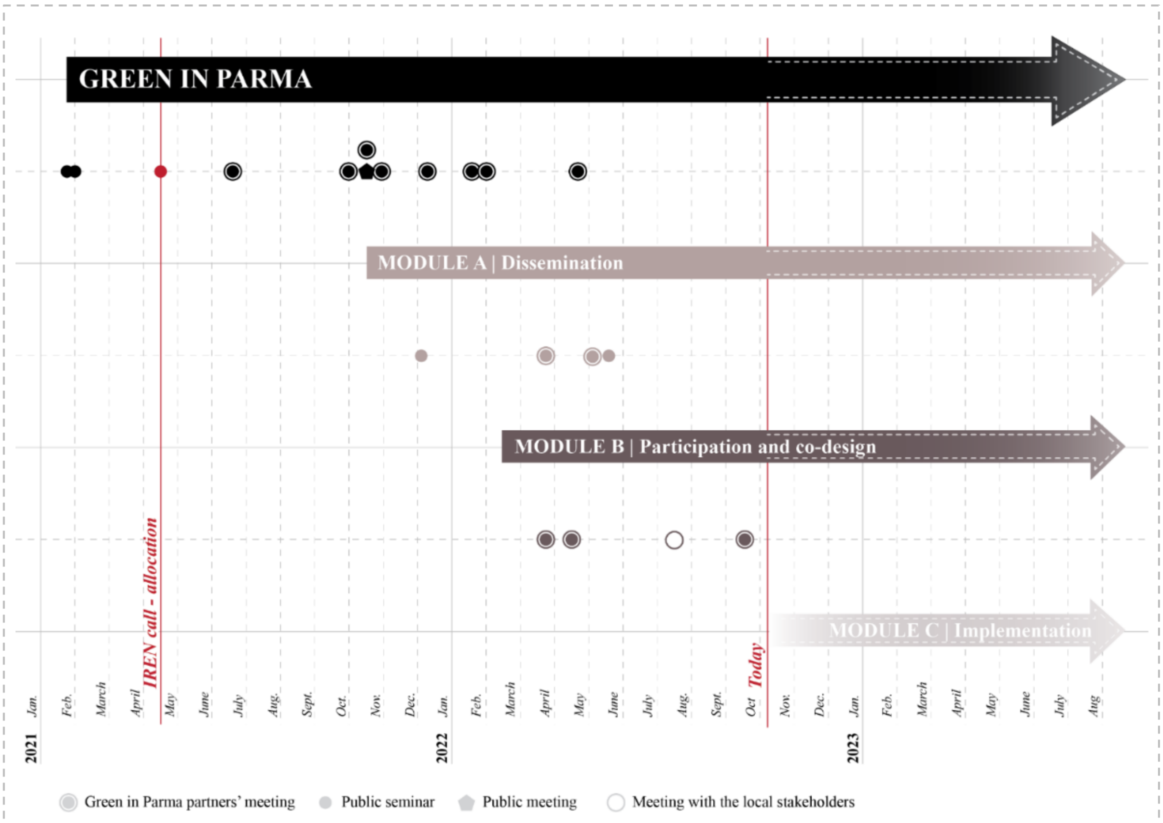


Figure III.33 | Timeline of the 'Green in Parma' project phases. Source: author's elaboration.

A desealing practical experience: the San Bernardo Parish courtyard

In February 2022, the co-design initiative focused on soil desealing began in the San Leonardo neighbourhood. Separated from the historical centre by a railway, the district is known for its high population density and multicultural population. Over the years, this area has seen significant redevelopment by the municipal government to improve urban and territorial quality, and to address safety and degradation issues to enhance local wellbeing.

The initiative, promoted by the members of the 'Green in Parma' project, aimed at developing - together with the members of the San Bernardo Parish and the local neighbourhood group 'Manifesto di San Leonardo' - a co-design process aimed at desealing the courtyard of the parish. This area had been highlighted in previous public discussions as highly impermeable and particularly problematic during summer due to the urban heat island effect. Additionally, the space, while privately owned, serves also a public use, making it a suitable candidate for a quicker intervention process compared to exclusively public or private spaces. It also benefited from an already established, engaged community.

The research group in Urban and regional planning of the University of Parma provided an initial analysis of the site, focusing on its low ecological value and high level of impervious surfaces. Following this, representatives from the parish joined a meeting where the research group shared preliminary design ideas to kickstart the community-driven co-design process. The team used representative photos of the site and citizen-friendly imagery to present potential nature-based solutions, avoiding overly technical language to ensure accessibility for non-experts. The discussion that followed identified several issues, including i) lack of shade in the courtyard; ii) extreme summer temperatures, and iii) the small size of an existing tree-lined flowerbed. One proposed solution involved the gradual removal of asphalt and interlocking concrete blocks, following a 3x3 meter grid (Figure III.34), in an incremental perspective. The role of the University in this initiative was to communicate the environmental benefits of soil desealing and to suggest methodological approaches, such as exploratory surveys and interviews. The idea was to begin with temporary interventions, inspired by tactical urbanism (Greco, 2012; Zazzi et al., 2020), before proceeding with permanent desealing, possibly through self-construction with financial support from 'Green in Parma' funds and technical assistance from local voluntary associations.

However, although the area presented significant opportunities for improvement through soil desealing, the project encountered resistance. One major challenge was the tension between the environmental benefits of desealing and the community's concerns about altering established uses of the space including ensuring vehicle access for the elderly and emergency services, and maintenance costs. Following some discussions, the availability of the area was retracted, resulting in the unsuccessfulness of the project.

Hence, a step backwards was taken and an exploratory survey was developed to gauge sensitivities and interest of the urban population (and therefore stakeholders) concerning climate change and its local effects, as well as for adaptation interventions (and soil desealing) (Centro Etica Ambientale, 2021; Caselli et al., 2022; Ceci, De Noia, et al., 2023). The outcomes of the survey (presented in the next paragraphs) led to a second desealing project, namely the desealing of the square '*Piazza Bassano del Grappa*', located in the San Leonardo neighbourhood, which is currently [2024] being carried out with the involvement of the local community and of the local administration ('Per Riqualificare Il Quartiere Seminiamo Nuove Piante', 2024).

Figure III.34 | Hypothesis of a 'temporary to permanent' intervention in the San Bernardo Parish: overlapping of a 3mx3m grid identifying regular guiding sectors for a co-designed process of progressive desealing of the courtyard. Source: author's elaboration.

The survey 'Parma wonders about the local effects of climate change'

As previously mentioned, an online survey was created in late 2022 following the unsuccessful desealing project at San Bernardo Parish. Its primary aim was to gather insights into citizens' perceptions of climate change and its localised effects on the urban area, as the community perspective is considered a relevant component of the broader knowledge framework of the urban context. This can serve as a foundation for guiding urban planning and transformation scenarios that address social and environmental needs and vulnerabilities (Ceci et al., 2023). Additionally, the survey aimed to increase citizens' understanding and empower them regarding their role and the importance of greening in local strategies for climate change adaptation (see Section §2.3 and Chapter §7).

The survey, titled 'Parma wonders about the local effects of climate change', was promoted by the Centre for Environmental Ethics (*Centro Etica Ambientale*) of Parma, the Emilia-Romagna regional Agency for Prevention, Environment and Energy (*Agenzia regionale per la prevenzione, l'ambiente e l'energia dell'Emilia-Romagna*), and the research group in Urban and regional planning of the University of Parma.

The development of the survey took place during several meetings that involved the University's research group, the Centre for Environmental Ethics members, the Emilia-Romagna regional Agency for Prevention, Environment and Energy, and additional project partners. The survey was also endorsed by local organisations, including the ecologist association Associazione Donne Ambientaliste (ADA Onlus), the Doctors for the Environment Association of Parma (*Associazione Medici per l'Ambiente di Parma*), the Parma Local Health Unit (*Azienda Unità Sanitaria Locale di Parma*), the National Confederation of Craftsmen of Parma (*Confederazione Nazionale dell'Artigianato di Parma*), the high school *Liceo Gian Domenico Romagnosi*, and media partner *La Repubblica Parma*. The structure and the contents of the survey were carefully defined over the course of the meetings, in a reciprocal exchange of ideas that allowed for an iterative design of the survey.

Designed to be accessible to all population groups, the survey featured 13 questions (Figure III.35) which were divided into three main sections. The first section gathered demographic information about the respondents; the second explored climatic risks and their effects at regional, urban, and local levels; and the final section examined citizens' preferences for climate change adaptation interventions. Figure III.36 illustrates the conceptual model of the survey, which aimed to investigate potential relationships between the demographic characteristics of the sample and the perceived importance of climate change, observed local effects, and the urgency of interventions. Although the questions were shaped in collaboration with stakeholders and not directly linked to a literature review, the subsequent bivariate analyses drew on existing literature that suggests a connection between demographic factors and perceptions of climate change (Poortinga et al., 2019; Weber, 2016).

Among the various options available for conducting a survey, an online survey was chosen for its ability to reach a wider audience and for its technical and economic accessibility. It also provided an opportunity to gather opinions from citizens who are generally less involved in community or public life, offering them a mean to express their views. The survey was set up using the EUSurvey platform (www.ec.europa.eu/eusurvey) and was made available online, in Italian, during December 2022. Figure III.35 outlines the questions and the respective single or multiple-choice answers. These served as the foundation for defining the analysis variables, based on the conceptual model. For the sake of brevity, some sections of the answers have been excluded and are indicated with the symbol '[…]' or A/A (as above).

	Question		Choice answers	Variable denomination and characteristics	
Q1	Age	SINGLE CHOICE	<15; 15-20; 21-30; 31-50; 51-70; >70	Age	DEMOGRAPHIC/STRING/INDEPENDENT
Q2	Sex	SINGLE CHOICE	Single choice: F; M; Other	Sex	DEMOGRAPHIC/STRING/INDEPENDENT
Q3	Neighbourhood where you live/that you most frequently visit	SINGLE CHOICE	Parma Centro; Oltretorrente; Molinetto; Pablo; Golese ; San Pancrazio; San Leonardo; Cortile San Martino; Lubiana; San Lazzaro; Cittadella; Montanara; Vigatto	Neighbourhood	DEMOGRAPHIC/STRING/INDEPENDENT
Q4	Activities	SINGLE CHOICE	Unpaid domestic worker; Student; Freelancer; Employee in the public sector; Employee in the private sector; Entrepreneur (industry-agriculture); Entrepreneur (services-trade); Retired; Other	Activities	DEMOGRAPHIC/STRING/INDEPENDENT
Q5	Social activities [...]	SINGLE CHOICE	Regular; Saltuary/occasional; None	Social activities	DEMOGRAPHIC/STRING/INDEPENDENT
Q6	With reference to western Emilia, from the Apennines to the Po River, how relevant do you consider the role of climate change on the increasing trend of dry spring-winter and large summer droughts, heavy rains, hailstorms and tornadoes?	SINGLE CHOICE	Very relevant; Somewhat relevant; Irrelevant	Relevance of climate change	CLIMATE CHANGE RISK AND EFFECTS/STRING/DEPENDENT
Q7	With reference to western Emilia, from the Apennines to the Po, how relevant do you consider the role of climate change on the trend of increasing temperatures and frequency of heat waves?	SINGLE CHOICE	Very relevant; Somewhat relevant; Irrelevant	Relevance of climate change	CLIMATE CHANGE RISK AND EFFECTS/STRING/DEPENDENT
Q8	With reference to the city of Parma, what do you think could be the main effects (impacts) of dry springs and winters and major summer droughts, heat waves, heavy rains, hailstorms and tornadoes?	MULTIPLE-CHOICE	Degradation of green areas and street greenery; Reduced usability/liveability of the outdoor environment for people and animals; Negative effects on the safety and well-being of workers in the outdoor environment; Adverse effects on health and well-being within homes and workplaces; Adverse health effects from poor air quality [...]; Increased deaths among the elderly and frail people; Damage to public/private outdoor properties; Restrictions on drinking water supply; Flooding; Non-significant impacts; I do not know	Effects of climate change_City of Parma_1 A/A_2 ... A/A_11	CLIMATE CHANGE RISK AND EFFECTS/STRING/DEPENDENT
Q9	In the neighbourhood that you have selected in question D3, as a result of the heat waves and prolonged summer droughts of the past two decades, have there been any cases of people becoming/feeling seriously ill?	SINGLE CHOICE	Several; Some; None; I do not know	Observed effects of climate change_Neighbourhood	CLIMATE CHANGE RISK AND EFFECTS/STRING/DEPENDENT
Q10	In the neighbourhood that you have selected in question Q3, as a result of the heat waves and prolonged summer drought periods of the past two decades, have there been any instances of major green losses?	SINGLE CHOICE	Several; Some; None; I do not know	Observed effects of climate change_Neighbourhood	CLIMATE CHANGE RISK AND EFFECTS/STRING/DEPENDENT
Q11	In the neighbourhood that you have selected in question D3, as a result of heavy rainfall/hail/high winds/thunderstorms in the past two decades, have there been any instances of flooding or damage to public/private properties?	SINGLE CHOICE	Several; Some; None; I do not know	Observed effects of climate change_Neighbourhood	CLIMATE CHANGE RISK AND EFFECTS/STRING/DEPENDENT
Q12	Considering the neighbourhood and the parts of the city of Parma that you frequent, and referring to the state of the built-up areas (cemented/paved/asphalted), what interventions do you think are most urgent in order to reduce climate risk?	MULTIPLE-CHOICE	Replacement of dark flooring/asphalts with light-coloured flooring/asphalts [...]*; Implementation of greenery on buildings [...]; Removal of excess concrete/asphalt [...]; Refurbishing manholes and street drains [...]; Wastewater network refurbishment [...] ; Aqueduct network refurbishment [...]; Build rainwater storage tanks [...]; I am not sufficiently informed to answer. *each answer included the purpose of the intervention	Perceived urgency of interventions_Built-up areas_1 A/A_2 ... A/A_8	ADAPTATION INTERVENTIONS/STRING/DEPENDENT
Q13	Considering the neighbourhood and the parts of the city of Parma that you frequent, and referring to the state of the unbuilt and green areas (but also of the strips, often built up, on the side of roads/sidewalks/sidewalks), what interventions do you think are most urgent in order to reduce climate risk?	MULTIPLE-CHOICE	Implementation of trees/shrubs on green areas to be redeveloped and on unbuilt areas, including partly cemented areas [...]*; Implementation of new greenery connected to existing greenery [...]; Redevelopment/rehabilitation of aquatic ecosystems [...]; Construction of [infiltration] trenches/pits [...]; Implementation of trees/hedges in roadside/sidewalk strips [...]; I am not sufficiently informed to answer. *each answer included the purpose of the intervention	Perceived urgency of interventions_1 A/A_2 ... A/A_6	ADAPTATION INTERVENTIONS/STRING/DEPENDENT

Figure III.35 | The questions and the choice answers of the survey. 'A/A' stands for as above. Source: author's elaboration.

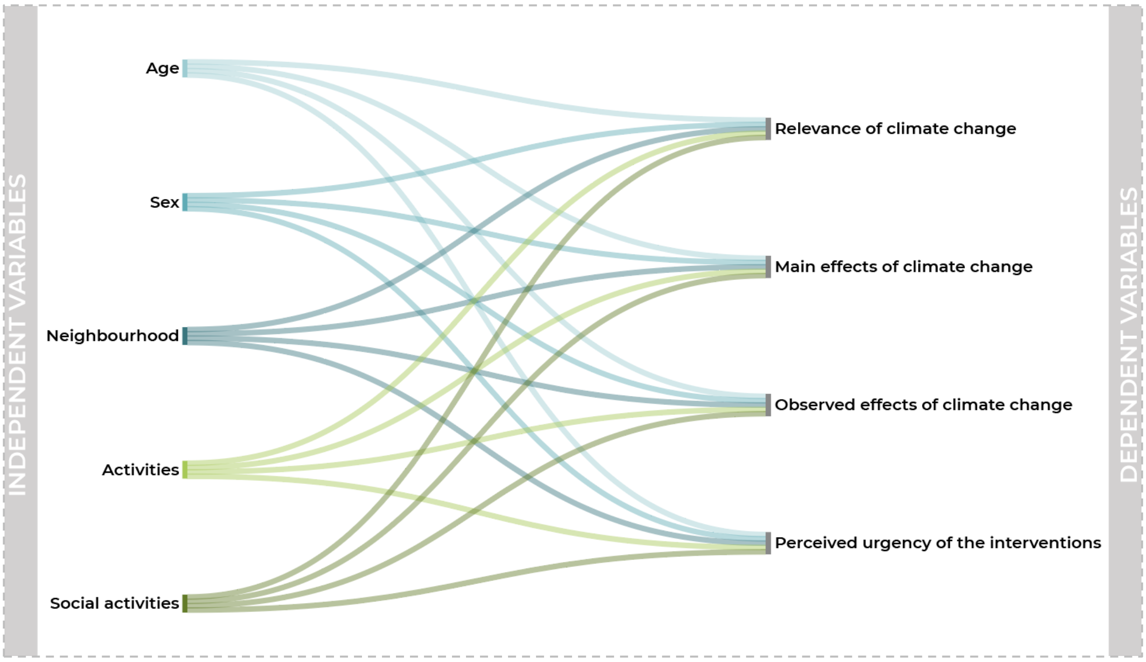


Figure III.36 | Conceptual model behind the survey setup. Source: author's elaboration.

The survey was promoted through multiple channels, including the mailing lists of the University of Parma and the Centre for Environmental Ethics, and local newspapers. A total of 1,352 responses were collected between 27 December 2022 and 28 February 2023. The initial descriptive analyses were shared with the public during a press conference on 4 March 2023, followed by presentations at conferences and publications.

In-depth statistical analyses were conducted [123], using Chi-square tests to assess the statistical significance of the results, as well as factor analyses to identify response patterns. Microsoft Excel and IBM SPSS [124] software programs were used for these analyses, while the open-source software QGIS (www.qgis.org) was employed to explore the relationship between the survey data and the socio-environmental characteristics of the city, such as land use and the population's mean age.

Methodology for the analysis of the survey data

This section outlines the methodology used to perform both univariate descriptive analyses and bivariate analyses on the survey results.

The first step involved defining the variables for the univariate descriptive analysis, which explored each variable in the dataset separately. For multiple-choice questions, a variable was created for each possible answer. Additionally, each of them was assigned to one of three groups: i) demographic; ii) climate change risk and effects; and iii) adaptation interventions. These groups correspond to the three main sections of the survey. Figure III.35 summarises the variables created for each question, along with their characteristics, such as their category (demographic/climate change risk and effects/adaptation

[123] The results of the survey were analysed by the author within the research group of Urban and regional planning of the University of Parma in collaboration with Eindhoven University of Technology. The already mentioned published article (see Footnote 120) encompasses the full attributions of the work.
[124] IBM SPSS was licensed in the framework of the visiting research semester carried out at Eindhoven University of Technology.

interventions), value type (which was ‘string’ in all cases), and variable type (independent/dependent). Simple histograms were then generated using IBM SPSS, with the variables choice answers on the x-axis and the count of respondents who selected them on the y-axis. In some cases, categories needed to be grouped to make them more suitable for further analysis. For example, the age categories ‘<15’ and ‘15-20’ were combined, as well as ‘51-70’ and ‘>70’, to ensure a significant and comparable number of respondents in each category.

A critical step in the univariate analysis involved evaluating the participation of different population groups to assess the sample representativeness of the urban population (Gobo, 2004). To achieve this, the demographic characteristics of the urban population (in percentages) were compared with those of the sample using available open data. The demographic variables considered were ‘age’, ‘sex’, and ‘neighbourhood’. Data were sourced from the Municipality of Parma website (www.comune.parma.it/) and ISTAT (esploradati.istat.it/), referencing data as of January 1, 2023.

To understand the relationship between citizens’ classes (demographic variables – Q1 to Q5) and their perception of climate change and its local effects (climate change risk and effects variables – Q6 to Q11, and adaptation interventions variables – Q12 to Q13), bivariate analyses were conducted. Specifically, demographic variables were compared with other variables using Chi-square tests (Voinov et al., 2013) and factor analyses (Adelman, 1990).

Specifically, a Chi-square χ^2 test examines the association between two variables of nominal or ordinal measurement levels, testing a null hypothesis (H_0 – no difference between groups) and an alternative hypothesis (H_1 – a difference exists between groups). This is typically done using a cross-table, which shows the observed frequencies in a sample. The Chi-square χ^2 observes the difference between the observed and expected frequencies, using the formula

$$\chi^2 = \sum_{i=1}^{k} \frac{(o_i - e_i)^2}{e_i} \qquad \text{(III.10)}$$

where o_i is the observed frequency in cell *i* and e_i is the expected frequency in cell *i*.

In other words, Chi-square tests allow to test whether a difference found in the sample can be generalised to the population, based on the comparison of the Chi-square with a critical value determined by the degrees of freedom and significance level (this study assumes a significance level of 5%). If the Chi-square value exceeds the critical value, the null hypothesis H_0 is rejected, indicating a significant difference between the groups.

Additionally, factor analyses were performed, and the rotated component matrix generated by IBM SPSS was defined and interpreted. Factor analyses helped identify patterns in the responses to the multiple-choice questions.

Similarly to univariate analyses, the first step necessary to proceed with the bivariate analyses was defining the variables. The same variables used in the univariate analyses were retained, with the exception of questions Q8, Q12, and Q13, for which new variables were created corresponding to one or more choices from the multiple-choice questions (Table III.52).

Question	*Corresponding variable(s) name(s)*	*Variable group*
Q8	Physical_Effects of climate change_City of Parma	Climate change risk and effects
	Drinking water_*A/A*	
	Flooding_*A/A*	
	Health_ Effects of climate change_City of Parma	
	None_*A/A*	
Q12	NBSs*_Perceived urgency of interventions_Built-up areas	Adaptation interventions
	Grey measures__*A/A*	
	Desealing__*A/A*	
	None__*A/A*	
Q13	Perceived urgency of interventions_Green areas	
* NBSs stands for nature-based solutions.		

Table III.52 | Multiple-chioice questions and corresponding variables. A/A stands for as above.

The bivariate analyses were performed between all independent and dependent variables. However, for the purpose of this thesis, only the Chi-square tests and factor analyses conducted between the 'Neighbourhood' variable and the dependent variables will be discussed. The statistically significant Chi-square tests were qualitatively compared to the socio-environmental characteristics of the neighbourhoods, aiming to explore how factors such as the soil consumption rates in the neighbourhoods influenced the respondents' answers.

Results

The following paragraphs present the results of the analyses that were carried out, namely:

i) the demographic characteristics of the sample;
ii) the univariate analyses concerning the climate change risk and effects variables and the adaptation interventions variables;
iii) the results of the Chi-square tests;
iv) the results of the factor analyses.

Sample characteristics

The univariate analysis of the dataset revealed the following age distribution: 215 individuals aged 0-20, 298 aged 21-30, 350 in the 31-50 age range, and 489 in the 51-70 or over 70 category. Regarding gender, 819 respondents identified as female, while 533 identified as male or other. As illustrated in Figure III.37, the most commonly selected neighbourhoods were 'Parma Centro' (344), 'Cittadella' (181), and 'Oltretorrente' (166). The least represented neighbourhood [125] was Cortile San Martino which, situated in the northern part of the city, presented only 13 respondents.

Regarding participants' activities, the majority were students (481), followed by public sector employees (391), private sector employees (192), and freelancers or entrepreneurs (120). The last demographic variable reflects participants' involvement in volunteering or social activities: most respondents (631) indicated that they are not active in such

[125] To improve the readability, from this point onwards, the neighbourhood chosen by the participants in Question 3 will be referred to as 'their' neighbourhood, and the individuals responding will be designated as 'participants from' that neighbourhood or similar expressions.

activities, while 302 are regularly engaged, and 419 participate only occasionally. Available open data enabled a comparison of the demographic (independent) variables with the population of Parma. However, no open data regarding the activities or social engagement of the citizens were found online. The results of this analysis, focusing on the variables of age, sex, and neighbourhood, are illustrated in the following image (Figure III.38) and indicate that, overall, the urban population is well represented.

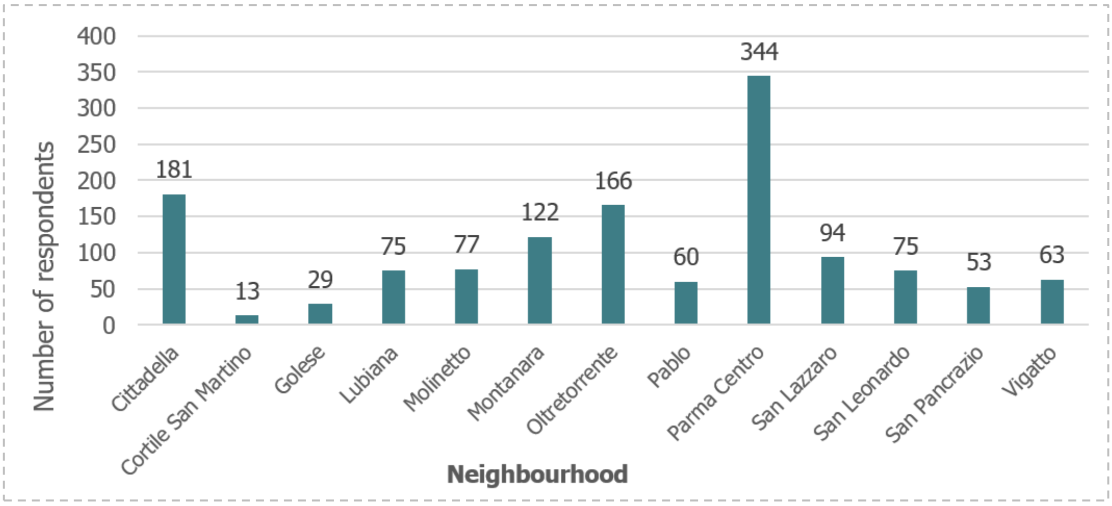


Figure III.37 | Distribution of the sample among the neighbourhoods. Source: author's elaboration.

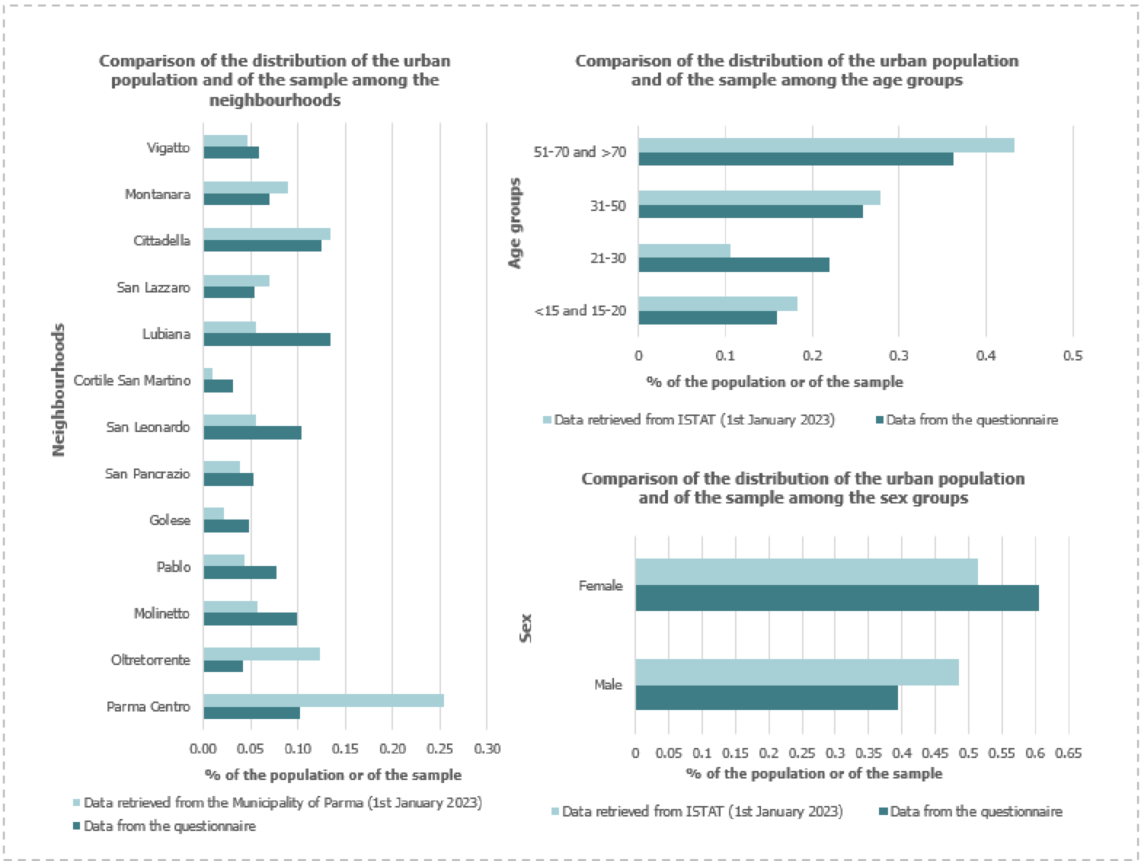


Figure III.38 | Comparison of the sample characteristics with those of the urban area.
Source: author's elaboration.

Climate change risks and effects variables

Regarding the participants' perception of climate change relevance to the regional territory, a significant majority (85.9%) clearly recognise its importance, while the remaining 14.1% express some uncertainty.

As detailed in Table III.52, Question 8 was divided into five distinct variables for separate analysis about the observed effects of climate change on the urban area, namely: effects on physical assets and/or properties; effects on drinking water; floods; effects on health; and no observed effect.

The results show that, concerning the city of Parma, 81.8% of participants have observed climate change impacts on physical assets and/or properties, while 59.7% noted effects on drinking water. Additionally, 62.2% reported observing flooding, and 90% acknowledged health-related impacts. Overall, 98.3% of participants selected at least one response other than 'Non-significant impacts/I do not know' (None_Effects of climate change_City of Parma).

When it comes to the observed effects of climate change in their neighbourhood (Observed effects of climate change_Neighbourhood), most participants (66.7%) expressed doubt regarding whether heat waves and prolonged droughts have led to increased illness among residents. Consequently, this variable was not included in the subsequent analysis.

The analysis of the variable 'Observed effects of climate change_Neighbourhood', which examines participants' observations of climate change effects in their neighbourhood, revealed that 16.1% of respondents noted a high number of impacts, 30.3% a medium number, and more than half (53.1%) observed few or no impacts. The analysis of the variable 'Observed effects of climate change_Neighbourhood', thus the one that investigates the respondents' answer about their observation of climate change effects in their neighbourhood, showed that 16.1% of the participants observed a high number of impacts, 30.3% a medium one and more than half (53.1%) low or none.

Adaptation interventions variables

As illustrated in Table III.52, Question 12 was divided into four separate variables for analysis for what concerns the perceived urgency on interventions on built-up areas, namely: nature-based solutions; grey measures; soil desealing; and no perceived urgency for interventions.

The majority of respondents (87.3%) believe that nature-based solutions are needed in built-up areas of their neighbourhood, while 79.1% advocate for the implementation of grey measures, such as constructing rainwater storage tanks or refurbishing the aqueduct network. Additionally, 60.6% of participants support soil desealing initiatives. Overall, 92.5% of respondents indicated a preference for at least one type of intervention.

Regarding the final variable (Perceived urgency of interventions_Green areas), 92.1% of participants expressed a desire to take action on green areas as well.

Outcomes of the Chi-square tests

Chi-square tests were conducted between the independent and dependent variables outlined in Table III.53, in line with the conceptual model depicted in Figure III.36. Table 3 summarises the fulfilment of the Chi-square test conditions, which are:

i) condition 1 – fewer than 20% of expected counts are less than 5;

ii) condition 2 – there are no zero expected counts.

With the exception of one test, all others met these conditions. The table also indicates whether the differences between the groups are statistically significant at a 5% significance level, with four tests yielding statistically significant results.

Independent variable	***Dependent variable***	***Are the conditions for the Chi-square test met?***	***Is the difference between the two groups statistically significant at a 5% significance level?***
Relevance of climate change	Neighbourhood	✓	✗
Physical_Effects of climate change_City of Parma		✓	✗
Drinking water_Effects of climate change_City of Parma		✓	✗
Flooding_Effects of climate change_City of Parma		✓	✗
Health_Effects of climate change_City of Parma		✓	✗
None_Effects of climate change_City of Parma		✗	✗
Observed effects of climate change_Neighbourhood		✓	✓
NBSs_Perceived urgency of interventions_Built-up areas		✓	✗
Grey measures__Perceived urgency of interventions_Built-up areas		✓	✓
Desealing__Perceived urgency of interventions_Built-up areas		✓	✓
None__Perceived urgency of interventions_Built-up areas		✓	✓
Perceived urgency of interventions_Green areas		✓	✗

Table III.53 | Overview of the conducted Chi-square tests and their fulfilment of the chosen conditions.

Figure III.39 and Figure III.40 provide a summary of the results from the Chi-square tests. The following paragraphs will focus on describing the statistically significant tests and comparing them with the socio-environmental data of each neighbourhood (see Figure III.41[126]). The aim is to explore whether and how residing in or frequenting a particular neighbourhood impacts the responses given by participants.

[126] The legend of Figure III.41h is available on the website ssl.comune.parma.it with the query 'Delibera di Giunta No.172 26/04/2017 ('Approvazione della proposta di Piano di Rischio Idraulico (PRI) del Comune di Parma')'. Figure III.41g refers to Rota (2017) and, for what concerns the land surface temperature map, to Aster/CNR-IBIMET Florence data surveyed in June 2015. The perimeter of the neighbourhoods was retrieved from the Municipality of Parma open data website.

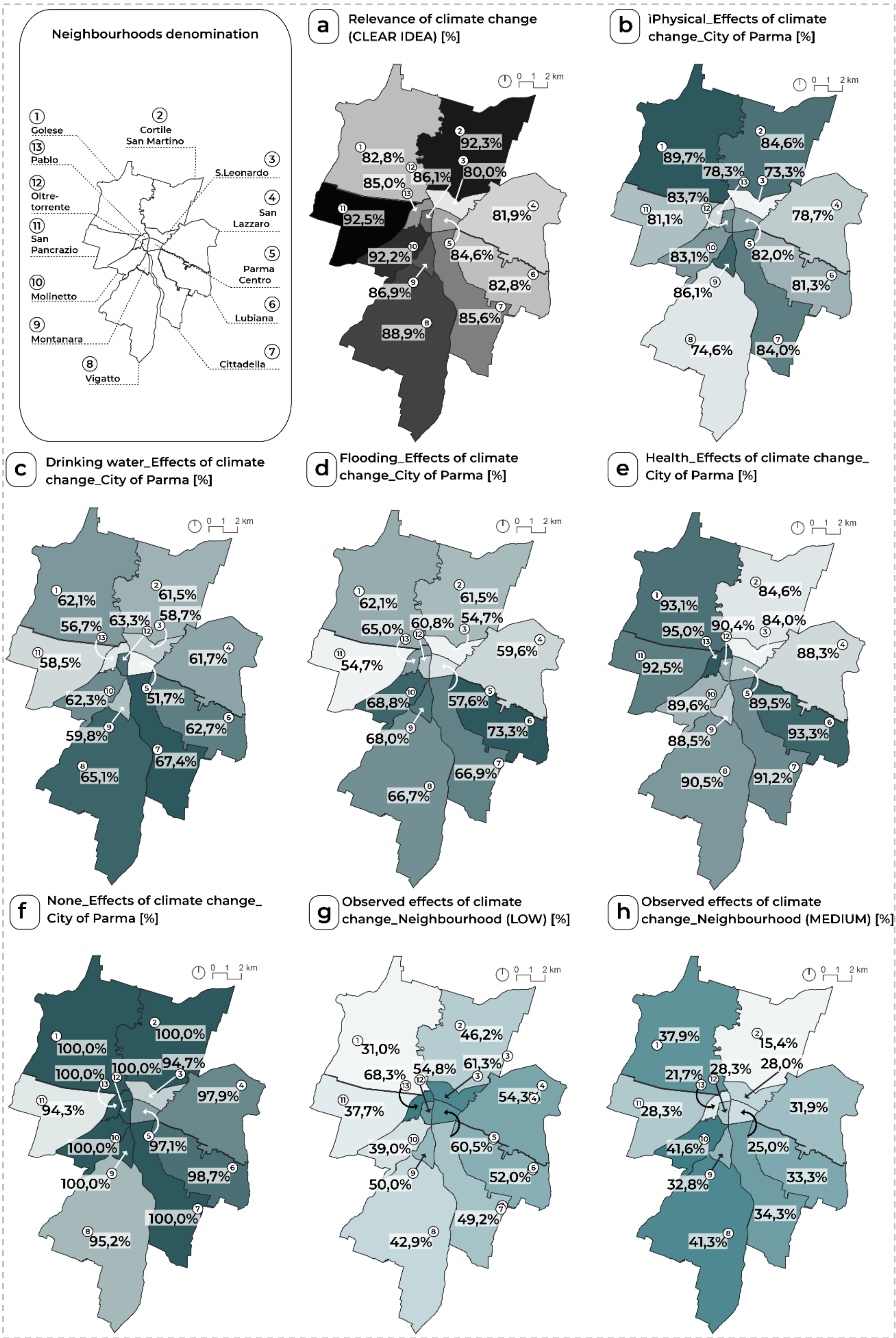


Figure III.39 | Results of the Chi-square tests between the Neighbourhood and the dependent variables - Part 1. Source: author's elaboration.

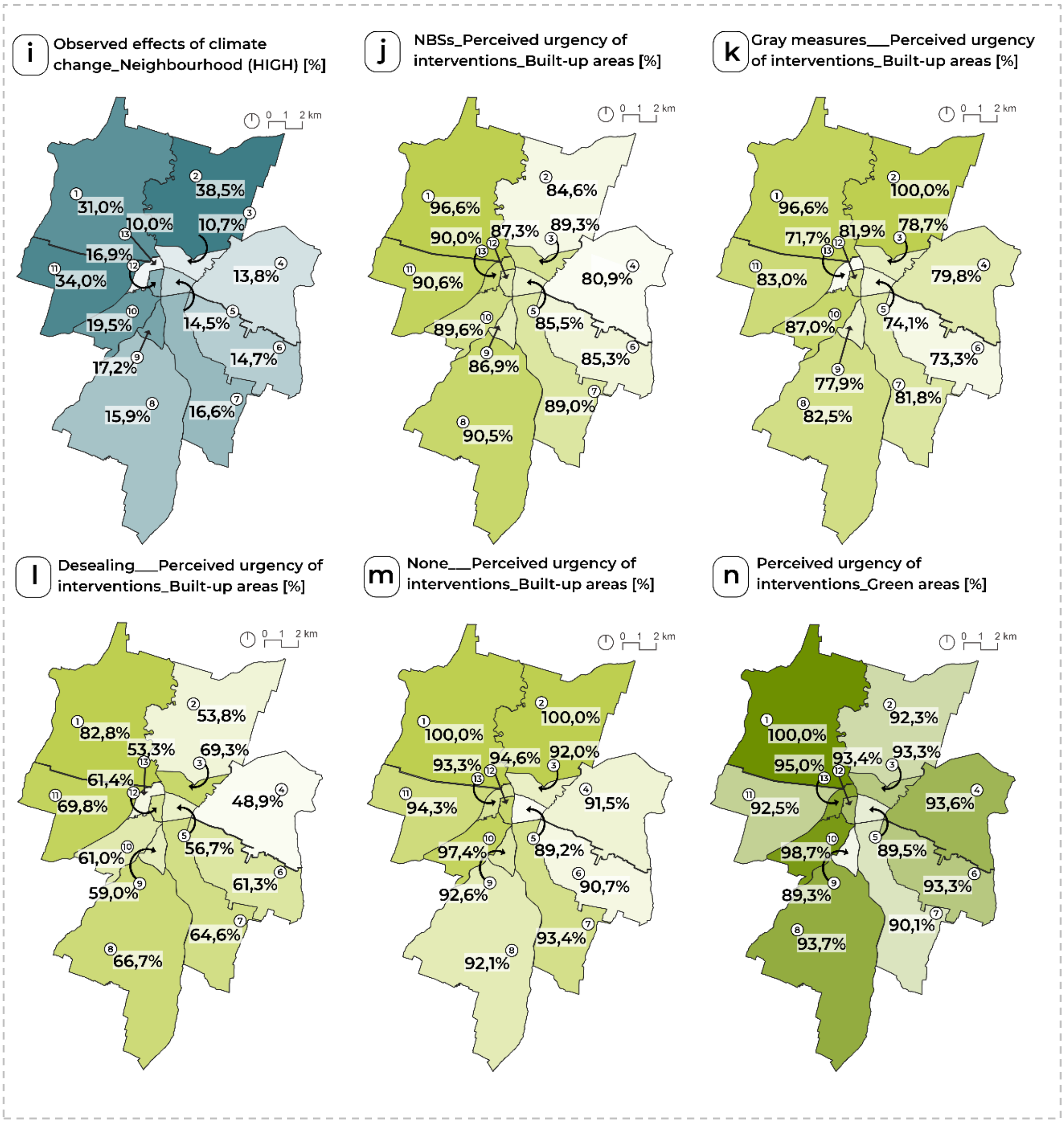


Figure III.40 | Results of the Chi-square tests between the Neighbourhood and the dependent variables - Part II. Source: author’s elaboration.

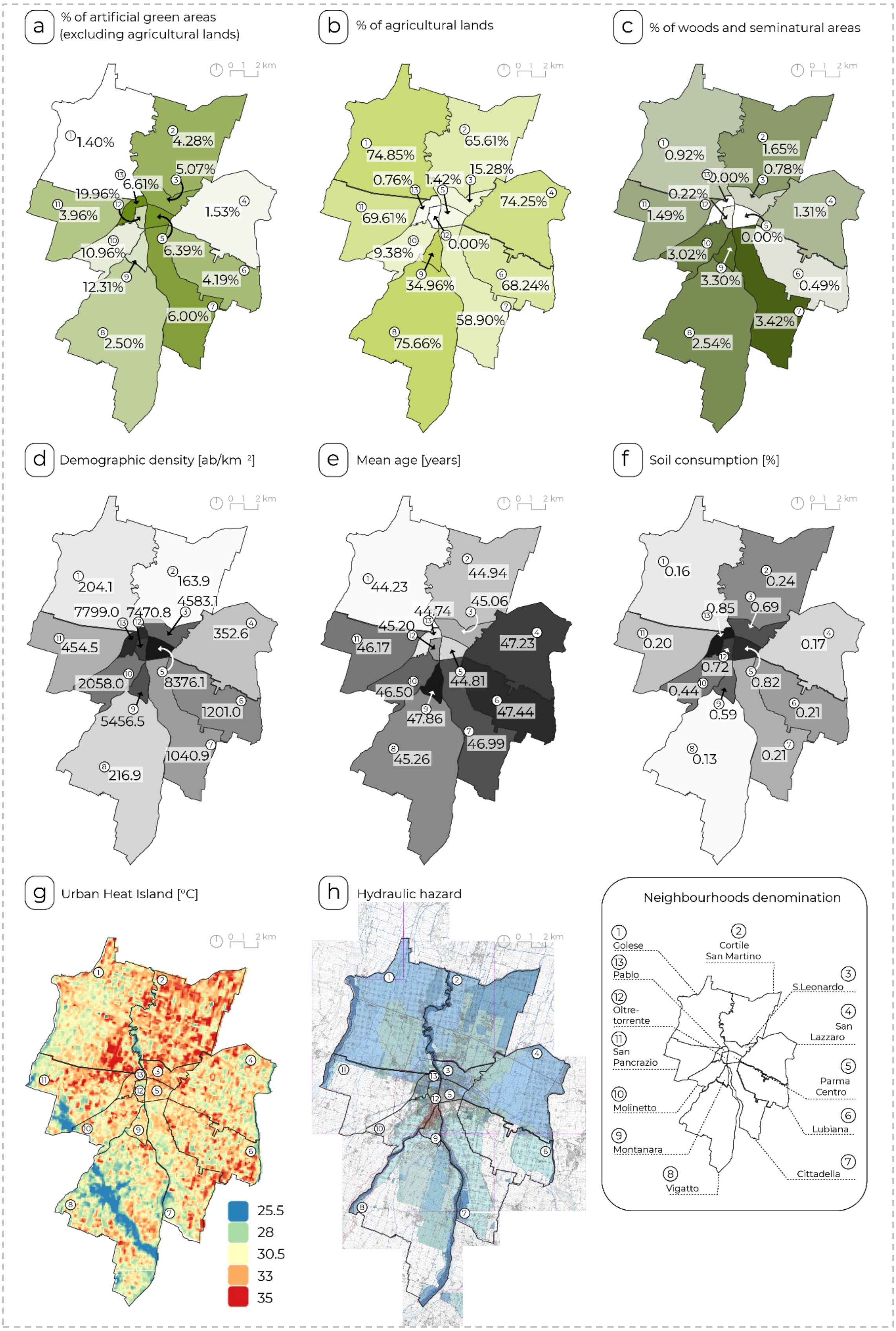


Figure III.41 | Socio-environmental characteristics of the neighbourhoods. Source: author's elaboration, see Footnote 126 for more information for the data sources and legend.

Observed effects of climate change_Neighbourhood - Neighbourhood

The Chi-square test results examining the relationship between the variables 'Observed Effects of Climate Change in Neighbourhoods' and 'Neighbourhood' indicate that participants who reported experiencing the most significant effects of climate change were predominantly from Cortile San Martino (38.5%) and San Pancrazio (34.0%) (Figure III.39i). In contrast, respondents from Molinetto (41.6%) and Vigatto (41.3%) noted a medium level of effects (Figure III.39h), while the lowest levels were reported by participants from Pablo (68.3%) and San Leonardo (61.3%) (Figure III.39g). The neighbourhoods that demonstrated the least sensitivity to climate change effects were primarily located in the central and eastern parts of the city, which also correspond to areas with higher population densities (Figure III.41d). These central neighbourhoods are characterised by higher soil consumption (Figure III.41f). In contrast, medium to high levels of climate change effects were more frequently reported in peripheral neighbourhoods, which typically feature a higher percentage of agricultural and semi-natural land, as well as lower demographic densities and soil consumption (Figure III.41a, Figure III.41b and Figure III.41c). The local administration heightened focus on maintaining central areas may contribute to the reduced perception among residents regarding the impacts of climate change in these neighbourhoods.

Grey measures___Perceived urgency of interventions_Built-up areas - Neighbourhood

The need for grey measures to address the effects of climate change in built-up areas (Figure III.40k) is most pronounced among residents of Cortile San Martino (100%) and Golese (96.6%). In contrast, the demand for such measures is significantly lower among participants from Pablo (28.3%) and Lubiana (26.7%).

Figure III.42 illustrates the distribution of residents across neighbourhoods based on the number of choices they selected regarding the urgency of grey measures in built-up areas to address climate change effects. The categories include those who chose zero, one, two, three, or four options.

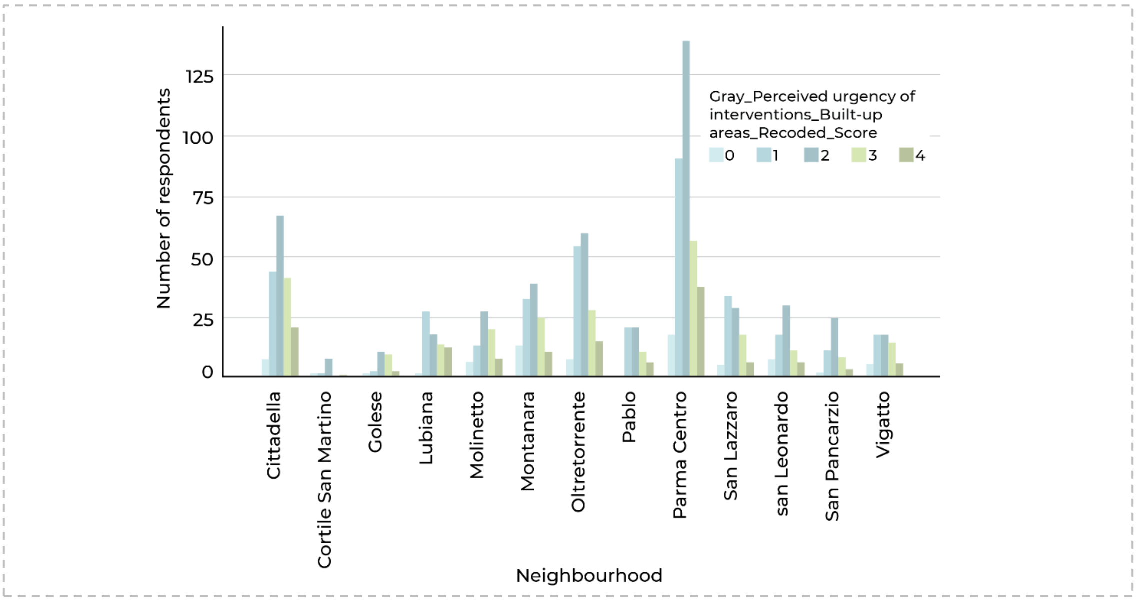


Figure III.42 | Distribution among the neighbourhoods of people who selected zero, one, two or three choices related to the urgency of NBSs on built-up spaces to face the effects of climate change. Source: author's elaboration.

Desealing___Perceived urgency of interventions_Built-up areas - Neighbourhood

The perceived urgency for desealing interventions (Figure III.40l) is higher in the Golese (82.8%) and San Pancrazio (69.8%) neighbourhoods, both of which show low levels of urban greenery (Figure III.41a). Interestingly, these areas do not have particularly high demographic densities or soil consumption percentages (Figure III.41d and Figure III.41f). However, they are significantly impacted by the urban heat island effect (Figure III.41g). In contrast, more than half of the respondents from San Lazzaro (51.1%) and 46.7% from Pablo do not perceive a strong need for desealing. San Lazzaro, while showing low percentages of urban greenery, also has lower urban heat island effect and soil consumption percentages. On the other hand, Pablo is characterised by high soil consumption and urban greenery, and not by a very high urban heat island effect. Overall, the percentage of participants from each neighbourhood who recognise an urgency for desealing is lower than that for the other proposed interventions. This could be attributed to a lack of widespread awareness of soil desealing and its associated benefits, as it is a relatively new concept for the general public: the introduction of soil desealing into the regional legislative framework occurred in 2017 with the Emilia-Romagna Region Regional Law No. 24/2017.

None___Perceived urgency of interventions_Built-up areas - Neighbourhood

Regarding the perceived urgency for interventions in grey areas (Figure III.40j, Figure III.40k, Figure III.40l and Figure III.40m), all neighbourhoods exhibit a notable sensitivity towards this issue. The Chi-square test results indicate that every respondent from the Cortile San Martino and Golese neighbourhoods believes that at least one type of intervention is necessary to address climate change effects. This percentage decreases to 89.2% in Parma Centro, where 10.8% of participants do not perceive a need for interventions in built-up areas.

Overall, more than 80% of respondents in each neighbourhood acknowledge the urgency for nature-based solutions. The highest percentage is found in Golese, which has also the lowest amount of urban greenery (Figure III.41a). Conversely, the central and eastern neighbourhoods show a lower perceived urgency for interventions, despite having high soil consumption and demographic density (Figure III.41d and Figure III.41f).

Outcomes of the factor analyses

Following the Chi-square tests, factor analyses were performed on three questions. The subsequent paragraphs and tables describe the analysed survey questions, the identified factors, and the multiple-choice options that participants frequently selected together, thereby revealing the underlying factors.

The factor analysis of the 11 potential responses for Question 8 revealed four distinct factors, which are detailed in Table III.54.

Question	*Factor number*	*Factor description*	*Associated multiple-choices*
Question 8	1	Health and wellbeing concerns	The negative effects on the safety and wellbeing of workers in the outdoor environment; the adverse effects on health and wellbeing within homes and workplaces; the increased deaths among the elderly and frail people; the reduced usability/livability of the outdoor environment for people and animals.
	2	Concerns about quality outdoor environment	Adverse health effects from poor air quality (secondary pollutants such as ozone); reduced usability/livability of the outdoor environment for people and animals; degradation of green areas and street greenery.
	3	Concerns about water	Flooding; restrictions on drinking water supply.
	4	Degradation of public and private outdoor properties	The damage to public/private outdoor properties; the degradation of green areas and street greenery.

Table III.54 | Factors that emerged from the analysis of Question 8.

Furthermore, three factors were identified for Question 12 and its 8 possible choices, which are described in Table III.55.

Question	*Factor number*	*Factor description*	*Associated multiple-choices*
Question 12	1	Perceived urgency for water and rainwater related interventions	The removal of excess concrete/asphalt to increase the green area and rain infiltration into the soil; the aqueduct network refurbishment to cut down water losses.
	2	Perceived urgency for rainwater drainage-related interventions	The aqueduct network refurbishment to cut down water losses; refurbishing manholes and street drains to improve their operation and enhance stormwater drainage; the wastewater network refurbishment improve rainwater.
	3	Perceived urgency for improving thermal comfort	The replacement of dark flooring/asphalts with light-coloured flooring/asphalts reflecting solar radiation to improve thermal comfort; the inclusion of greenery on buildings (green walls and roofs) to improve thermal comfort and retain rain.

Table III.55 | Factors that emerged from the analysis of Question 12.

Finally, two factors were identified for Question 13 and its six possible choices, described in Table III.56.

Question	*Factor number*	*Factor description*	*Associated multiple-choices*
Question 13	1	Perceived urgency for the implementation of green-related interventions on green areas	The inclusion of trees/hedges in roadside/sidewalk strips for improving thermal comfort and outdoor living; the insertion of trees/shrubs on green areas to be redeveloped and on unbuilt areas, including partly cemented areas, for improved thermal comfort and outdoor living; the insertion of new greenery connected to existing greenery for biodiversity growth.
	2	Perceived urgency for water and rainwater-related interventions on green areas	The redevelopment/rehabilitation of aquatic ecosystems, e.g., canals, which are now dry or the site of drains or culverts, to restore their ecological functions; construction of trenches/pits in unbuilt and green areas and road/trail/sidewalk strips for rain retention and infiltration into the soil.

Table III.56 | Factors that emerged from the analysis of Question 13.

Discussion

The analysis of the survey provided valuable insights into citizens' perceptions of climate change and its local effects. Several considerations regarding the survey design, distribution, and analysis of results are noteworthy. Regarding its design, the survey it was initially intended as an exploratory experiment for qualitative analysis. Therefore, shifting then to quantitative methods necessitated adjustments to the variables, which could have been avoided with a different initial setup. The composition of the sample resulting from the survey distribution arises further matters to discuss. The sample predominantly includes students and public sector employees, likely due to the effectiveness of the University of Parma's mailing list compared to other distribution channels. This composition may have significantly affected the results, as – for instance - students may have relocated to Parma only for their studies, hence lacking an in-depth knowledge of the urban area. In retrospect, tracking the means of access to the survey (such as mailing lists or newspapers) could have provided insights into this kind of influences. Furthermore, considering the voluntary nature of the survey, it is likely that participants that were more interested in climate change issues were more prone to take part to the survey.

While some basic comparisons with the demographic characteristics of the population were conducted and yielded generally positive results (see Figure III.38), enhancing the representativeness of the urban population would be beneficial for future research developments. For example, focusing on engaging the less represented neighbourhoods such as Cortile San Martino in future phases of the bottom-up project could be valuable.

Several factors should also be taken into account for what regards the analysis of the survey. As indicated by the soil consumption and demographic density maps (see Figure III.41d and Figure III.41f), central neighbourhoods exhibit higher soil consumption and demographic density. However, the peripheral neighbourhoods of Parma display heterogeneity in their level of urbanisation, potentially leading to inaccurate interpretations of the results. Furthermore, the administrative neighbourhood boundaries of the Municipality of Parma were used for analysis, which include agricultural land. Future analyses or surveys may benefit from focus on urbanised areas, tailoring demographic questions accordingly.

The initial qualitative examination of the link between Chi-square test results and socio-environmental data for the neighbourhoods could be expanded. More structured statistical analyses could be beneficial, as well as in-depth considerations of the combined influence of various neighbourhood features. For instance, as observed regarding the perceived urgency of desealing interventions, a high percentage of soil consumption in a neighbourhood combined with a high percentage of urban green areas may reduce citizens' perceived need for soil desealing.

Ultimately, the exploratory and general nature of this survey serves as a preliminary step toward more in-depth analyses of the neighbourhoods. Acknowledging the importance of adapting to climate change, future developments have involved experiments that explore citizens' preferences for various interventions, i.e., stated-choice experiments (see Subsection §9.4.3).

Outcomes of the desealing practical experience and of the survey

The research group in Urban and regional planning engagement in specific research activities within the 'Green in Parma' project provided insights into the role of desealing interventions as tools for fostering public engagement (and *vice versa*). The first outcomes of the initiative showed widespread interest among the public and stakeholders, for what concerns both urban climate change adaptation and soil desealing.

Module A, through its presentation of concrete case studies, successfully stimulated citizens' participation and helped to expand the network of the involved local actors. The coordination among partners with different expertise fostered the creation of an environment where constructive discussions took place. At the same time, differences in backgrounds and agendas ended in occasional limitations. An additional positive outcome was the identification of community members willing to collaborate on open-space greening interventions. The existence of a network of stakeholders committed to these issues appears relevant both for the 'Green in Parma' project and from an academic perspective, helping – for instance - the establishment of Third Mission activities.

Given the small scale of the proposed intervention, the project primary aim was to have a local impact, with the hope of spreading awareness in the surrounding neighbourhood and in the city. Achieving a broader environmental impact at the city level, however, would require a larger economic and planning effort. Despite the community's general agreement with the project ideals, they were hesitant to discuss significant changes to the spaces functions. This raised questions about whether (semi)private areas are more (or less) suitable for such initiatives compared to public spaces, given the trade-offs between speed and the likelihood of success. The experience highlighted the need to carefully balance competing community needs and expectations when proposing resilience-enhancing interventions.

It is evident that a lack of knowledge and awareness of climate change and soil consumption-related issues among citizens and stakeholders can hinder successful interventions. In the case of the 'Green in Parma' project, the parish community placed limitations on the proposed interventions when the environmental benefits were not perceived to outweigh the social benefits of current space use. However, despite the initial challenges, this "unsuccessful" attempt to implement a co-designed desealing process in a semi-public space provided valuable lessons. It suggested the need to recalibrate activities, focusing on public spaces in collaboration with the administration to continue raising citizens' awareness.

Further steps of the project 'Green in Parma' would need to involve the neighbourhoods communities with in-person meetings and workshops. Acknowledging the survey results, urban transformation processes cannot do without the direct contact with the population, which allows to deepen the level of knowledge about the citizens' perception about climate change, understand if the gathered insight needs to be further investigated and/or corrected, and capture feelings and emotions that cannot be translated into words. Therefore, the information obtained through the survey analysis are to be intended as a piece of the knowledge framework which is necessary to orient the future scenarios and empower the population.

An important lesson from this experience was the need to be cautious when presenting pre-planning ideas, as even preliminary concepts might be perceived as final, imposed solutions. The Dutch '*Steenbreek*' programme (see Subsection §2.2.2) offers valuable inspiration for future developments of the project, as it involves municipalities, provinces, water boards, non-governmental organisations, ecologists, and universities in a collaborative effort to address the paving of private and public areas. Namely, it highlighted the importance of providing economic incentives like funding the removal of impermeable surfaces and offering low-maintenance greenery as replacements. In this regard, economic resources played a crucial role within the 'Green in Parma' project initiative in the San Bernardo Parish. While third-party funding was clearly explained to citizens and stakeholders during the early planning stages, resistance emerged when preliminary budget estimates were shared. In this regard, a thorough budget analysis requires some design guidelines and choices, but these must be carefully communicated to stakeholders as tools for discussion, rather than finalised plans.

Finally, keeping in mind the aim of promoting soil desealing, the results of the survey analysis can lead to a few practical conclusions. Within the bottom-up project 'Green in Parma', it would make sense to, for instance, plan pilot 'demonstrative' desealing projects in neighbourhoods that appeared to be sensitive to climate change, its effects and its counteractions. Furthermore, it appears appropriate to propose participatory processes aiming at sharing and co-learning in neighbourhoods where citizens appear to be less sensitive to the issues related to urban greenery and climate change-related matters, in a mutual knowledge exchange with the communities.

9.4.2 Young people's involvement in climate change adaptation

This subsection presents two small-scale projects developed or investigated as part of this research within the 'Transversal and Orientation Skills Pathways' (*Percorsi per le Competenze Trasversali e per l'Orientamento*) programme at the University of Parma, which involves high school students from the city. Among the aims of these experiences, there was the aim to engage young people in climate change adaptation activities, including soil desealing, recognising them as stakeholders and bearers of knowledge equally as the adult population (see the theoretical framework outlined in Subsection §7.1.2).

The first project emerged from the co-design process at the San Bernardo Parish (Subsection 9.4.1), which led to a collaboration between stakeholders and residents that extended beyond a single initiative. In March 2022, an additional project within the 'Green in Parma' was proposed by one of the collaborators, i.e., a Parma-based agronomist specialising in small-scale urban greening. This project aimed to create a booklet of solutions for enhancing green spaces identified by the public through a community voluntary survey[127]. The survey was based on a 'catalogue of typical cases' where soil sealing is unnecessary in urban areas. The initial testing of this project took place in April 2022. Organised by the research group in Urban and regional planning of the University of Parma, the event involved students in a collaborative data collection exercise using the Mergin Map (www.merginmaps.com) geographical information system platform. Students were asked to map unnecessary sealed areas along their typical daily routes. The outcomes of this pilot initiative helped refine the structure of the official community voluntary survey developed within the 'Green in Parma' project. They highlighted the students' willingness and interest in engaging in such activities, despite some difficulties in handling maps and urban-scale data.

In addition, in April 2022, another session of the Transversal and Orientation Skills Pathways programme was held, where students were introduced to the concept of soil desealing, followed by a practical exercise. Based on what they had learned, students were given the task of drafting a project for a soil desealing intervention in the northern part of Parma, specifically in the square '*Piazza Bassano del Grappa*', located in the San Leonardo neighbourhood (see Figure III.43 and Subsection §9.4.1). This project, linked to the 'Green in Parma' initiative, aims to involve young people in providing input on a potential soil desealing intervention for the square in the near future.

During the event, students were asked to respond to a series of questions before and after the teaching and practical activities to assess their sensitivity and understanding of the experiences. The outcomes demonstrate a positive result from these activities, with (anonymous) comments such as: "I believe that desealing is important to give back life to areas that are sometimes abandoned, I'm glad to have learned about this technique" and "I believe to have learned not only that soil desealing is important to give again value to areas that are nowadays full of buildings, and that nature should live together with men".

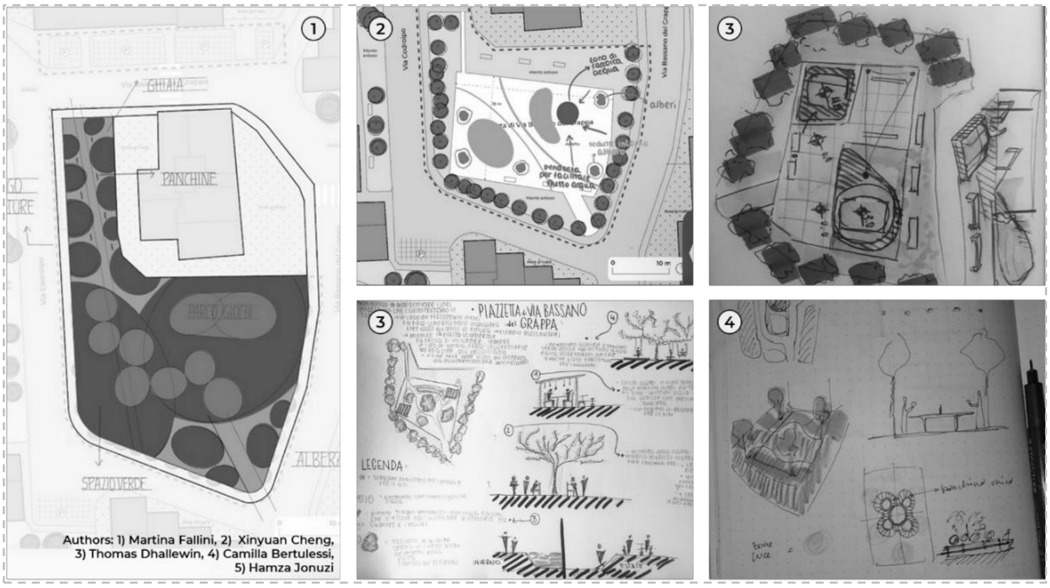


Figure III.43 | Outcomes of the exercise that involved drafting a project for a soil desealing intervention in the square '*Piazza Bassano del Grappa*' in Parma. Source: author's elaboration.

[127] Community voluntary surveys were intended within the project as a form of citizen science, namely using a collaborative geographical information system platform to collect citizens' (students') reports about cases where urban paving is not necessary.

9.4.3 Citizens' preferences and activities for soil desealing[128]

This subsection explores citizens' preferences regarding soil desealing by examining how the attributes of such interventions influence their choices through a stated-choice experiment, which was developed and analysed at the Department of the Built Environment of Eindhoven University of Technology, under the supervision of Prof. Astrid Kemperman and Dr. Ir. Peter van der Waerden. The stated-choice experiment considered both policy-related elements (procedural attributes) and practical aspects (technical and formal attributes). The findings provided both broad and context-specific insights into residents' preferences, offering valuable guidance for scholars and public administrations. These insights can support the integration of soil desealing measures into urban planning tools that govern transformations in both public and private spaces.

Methodology for the analysis of the survey data

The next paragraphs outline the methodology used to design, distribute, and analyse the stated-choice experiment conducted to explore the preferences of Parma residents regarding soil desealing.

Design of the questionnaire and structure of the analyses

The survey began with an introduction, which included an overview of the stated-choice experiment and its supplementary questions. Furthermore, it encompassed the consent form for participation alongside: i) general information about the research and survey; ii) additional informative links; iii) the survey scenario, represented by the Municipality of Parma deciding to implement soil desealing interventions to mitigate urban heat island effect and reduce pluvial flood risk; and iv) an outline of the questionnaire structure.

The survey was divided into several parts. Part 1 contained socio-demographic questions, followed by the stated-choice tasks - i.e., the hypothetical choice scenarios - in Part 2. In Part 3, participants were asked to answer questions based on the New Ecological Paradigm scale (Dunlap et al., 2000) to assess their environmental attitude. To prevent bias, this section was positioned after the stated-choice tasks. Part 4 included questions about participants' willingness to accept specific soil desealing interventions, their involvement in soil desealing activities, and their preferences for areas to be desealed under a scenario where the Municipality planned such interventions.

The survey ended with a comment box allowing participants to share feedback. The questionnaire structure, summarised in Figure III.44, was refined through iterative testing with university students, academic staff, and members of the public to improve clarity and comprehensibility.

Figure III.45 illustrates the questionnaire structure and the corresponding analyses, which are elaborated in the following sections. To examine and predict respondents' choice behaviours while accounting for heterogeneity, Multinomial Logit (MNL) and Latent Class (LC) models were employed. Additionally, Chi-square χ^2 tests were conducted to associate

[128] Subsection §9.4.3 has been adapted and partially implemented by the author based on the manuscript 'De Noia, I., van der Waerden, P., Kemperman, A. D. A. M. & Zazzi, M., Citizens' Preferences for Soil Desealing: Results from a Stated-Choice Experiment in Parma, Italy'. Attributions of the manuscripts are pasted hereafter. Conceptualisation: A.K., P.W., I.D.N.; Data curation: I.D.N.; Formal analysis: A.K., P.W., I.D.N.; Investigation: A.K., P.W., I.D.N.; Methodology: A.K., P.W., I.D.N.; Supervision: A.K., P.W., M.Z.; Validation; A.K., P.W., M.Z.; Visualization: I.D.N.; Roles/Writing - original draft: I.D.N.; and Writing - review & editing: I.D.N., A.K., P.W., M.Z..

model outcomes with participants' socio-demographic characteristics, and McFadden's Rho-square ρ^2 was used to evaluate the models' goodness-of-fit.

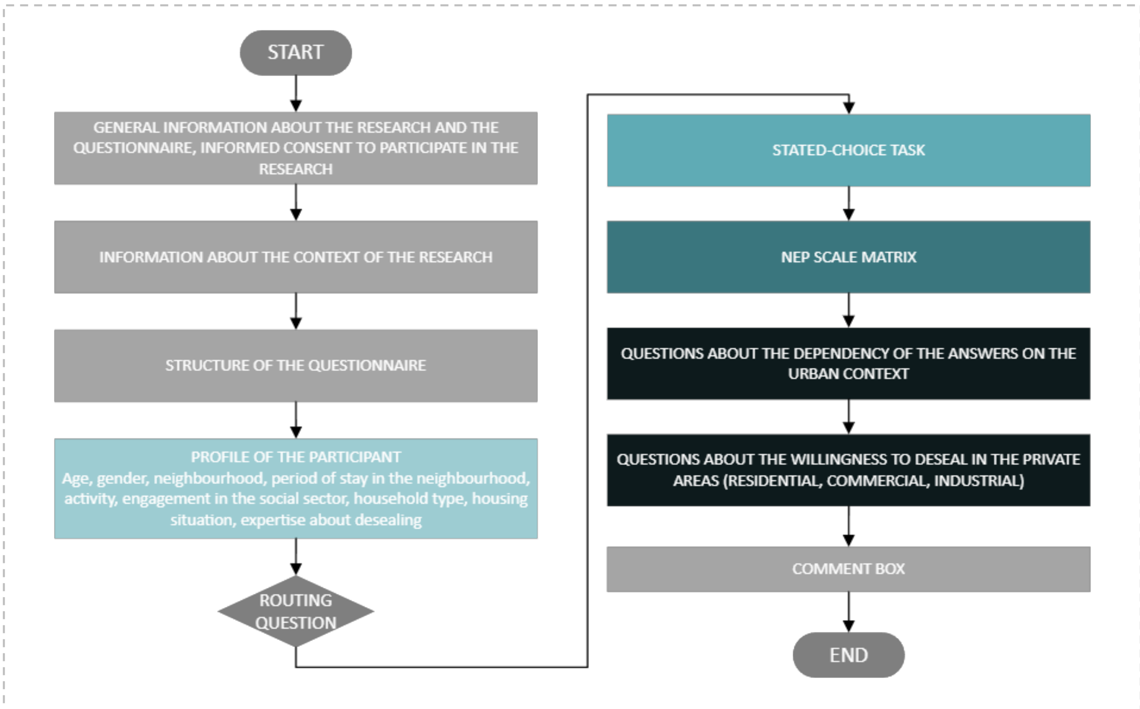


Figure III.44 | Structure of the questionnaire. Source: author's elaboration.

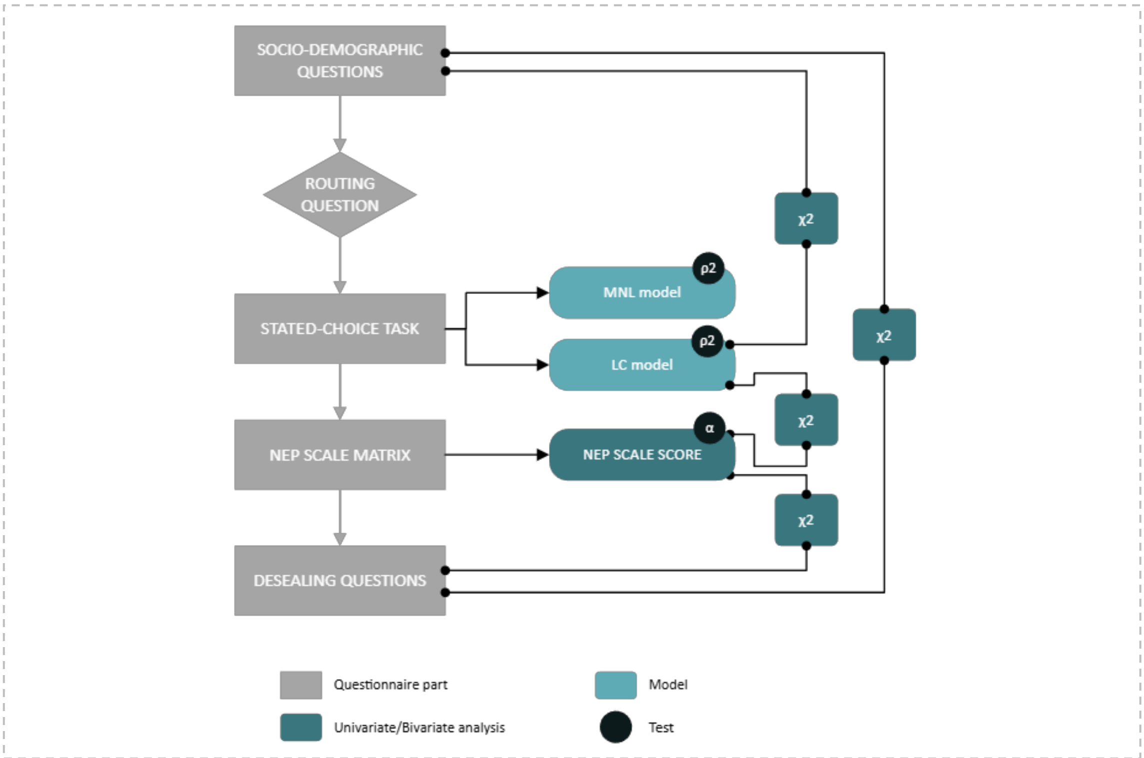


Figure III.45 | Structure of the analysis methodology. Source: author's elaboration.

Design of the stated-choice experiment

The stated-choice experiment was structured to present participants with hypothetical choice scenarios involving soil desealing interventions (referred thereafter mainly as stated-choice tasks). Participants were asked to imagine that such an intervention would occur in the neighbourhood they had selected in the initial part of the survey and to indicate their preferred scenario. These scenarios were defined by independent attributes spanning both policy and practical domains, enabling a quantitative assessment of the attributes significance. Each participant completed multiple stated-choice tasks, facilitating the calculation of the alternatives utility using the following formula:

$$U_{iq} = V_{iq} + \varepsilon_{iq} = \sum_n \beta_n X_{inq} + \varepsilon_{iq} \qquad \text{(III.11)}$$

where U_{iq} is the utility of alternative i for individual q; V_{iq} is the structural utility of alternative i for individual q; ε_{iq} is the random utility of alternative i for individual q; β_n represents (generic) weight of attribute n; X_{inq} represents the score of alternative i on attribute n for individual q.

The following sections detail the methodology used to design the attributes and structure of the stated-choice tasks.

Attributes and levels

The attributes for the hypothetical choice scenarios were carefully selected to ensure they were limited in number, mutually independent, essential for addressing the problem, relevant to planning and policymaking, and easily comprehensible for participants. Before engaging in the stated-choice tasks, participants were provided with a clear explanation of the attributes and their respective levels.

Table III.57 lists the ten selected attributes and their levels, following the guidelines proposed by Adamowicz et al. (1998). These attributes were identified through a comprehensive literature review of previous studies (Caselli, De Noia, et al., 2024; De Noia et al., 2022) and the gained experience on the field with the bottom-up soil desealing projects involved in the 'Green in Parma' experience (Caselli et al., 2022; Ceci, De Noia, et al., 2023). The sources used to identify these attributes are also included in Table III.57. The levels for each attribute were chosen based on the literature to reflect real-world scenarios and the range within which trade-offs might realistically occur.

Attribute	***Level 1***	***Level 2***	***Level 3***	***Sources***
Main areas of intervention	Paved road infrastructure and paved public parking lots	Paved squares and paved areas of public parks	Public services paved areas (like hospitals, schools)	(Aimar, 2023; Caselli et al., 2022; Ceci, Caselli, et al., 2023; SOS4LIFE, 2020)
Proposal of the areas	Public	Private	Public-private	(Caselli et al., 2022; Ceci, De Noia, et al., 2023; De Noia et al., 2022; Pissourios, 2014)
Main purpose of the desealing intervention	Improving environmental	Restoring water and soil functions	Enhancing biodiversity	Climate-ADAPT, n.d

Attribute	Level 1	Level 2	Level 3	Sources
	and urban quality			
Design of the desealing intervention	Top-down	Bottom-up	Co-design	Caselli et al., 2022b; Pissourios, 2014; SOS4LIFE, 2020
Percentage of desealed area	100%	75%	50%	De Noia et al., 2022; Gibelli et al., 2015
New vegetation	Trees, shrubs and grass	Shrubs and grass	Grass	Caselli et al., 2022b; Dierkes, 2015
Post-intervention perception of the temperature benefits in summer	Strong	Average	Weak	Ceci, Caselli, et al., 2023; Gibelli et al., 2015
Post-intervention surfaces after rainfall	Wet	Wet with small ponds	Wet with medium and large ponds	De Noia et al., 2022; Gibelli et al., 2015
Citizens' involvement in the construction	In all phases	In some phases	With guided tours	Caselli et al., 2022b
Citizens' involvement in monitoring and maintenance	In all phases	In some phases	With guided tours	Caselli et al., 2022b

Table III.57 | Attributes and levels of the stated-choice alternatives.

The stated-choice tasks

Following the selection of attributes and their levels, 27 profiles were generated using an orthogonal fractional factorial design. This approach created an orthogonal subset of attribute level combinations to represent potential soil desealing interventions as hypothetical choice scenarios (the stated-choice tasks). The 27 profiles were then duplicated, resulting in three sets of nine tasks, each comprising three alternatives, including a 'neither' option. These alternatives were randomly created based on the recommended number of tasks (Adamowicz et al., 1998).

To reduce participant fatigue, each respondent was assigned to one of the three groups through a routing question. As illustrated in Figure III.46, participants completed nine tasks corresponding to the group they were assigned.

Figure III.47 illustrates an example of a stated-choice task presented to participants. The task was designed with graphical elements including icons and colours to improve clarity and facilitate understanding (Adamowicz et al., 1998).

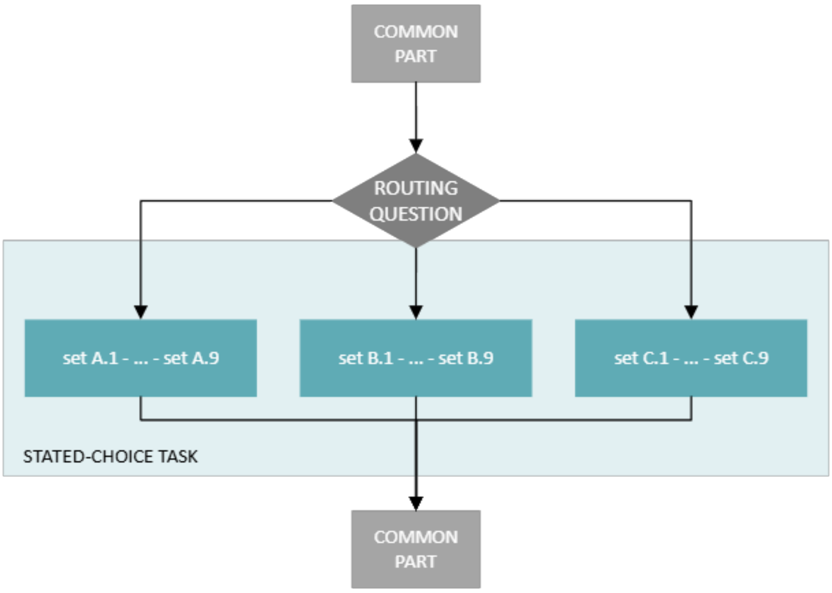


Figure III.46 | The structure of the stated-choice experiment in the context of the questionnaire.
Source: author's elaboration.

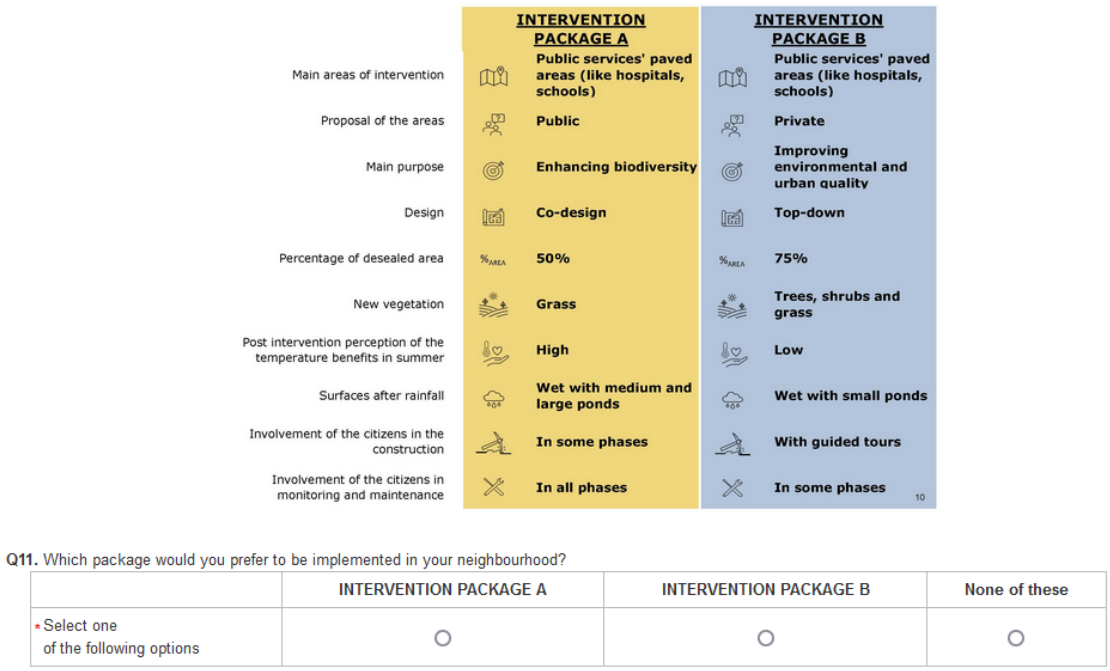


Figure III.47 | One of the choice tasks that was presented to the participants.
Source: author's elaboration.

Data collection and participants

The questionnaire was approved by the Research Ethics Board of the University of Parma (Prot. 280945 31/10). The survey was conducted between November 2023 and January 2024, and was made available in both Italian and English through the University of Parma institutional mailing lists and through social media platforms. To participate, individuals were required to either reside in or be familiar with the city of Parma. The survey was hosted on the EUSurvey platform (ec.europa.eu/eusurvey), with separate links created for each language and distribution method, referencing to the outcomes of the previously developed survey about citizens' perception (see Subsection §9.4.1). A total of 357 individuals participated in the survey: three accessed the English version via social media, 22 through the University of Parma mailing lists, while the Italian version was accessed 22 times through social media and 310 times via the mailing lists.

Analysis of the stated-choice experiment

To numerically represent the categorical data, the responses from the stated-choice tasks were effect-coded. These data were then analysed using the NLOGIT software (limdep.com/products/nlogit/), employing two models: i) a multinomial logit model (MNL) to predict participants' choice behaviours (Kjær, 2005) and ii) a latent class model (LC) to capture heterogeneity in preferences. The LC model specifically allows for the identification of groups (or classes) of individuals with similar preferences (Swait, 1994). Additionally, McFadden's Rho-square ρ^2 was used to assess the goodness-of-fit for the MNL model, with values exceeding 0.2 indicating a good model fit[129] (Louviere et al., 2000; McFadden, 1973).

The multinomial logit model (MNL)

The MNL model, grounded in utility theory, is the most commonly used approach for analysing discrete choice data. Assuming no correlation between alternatives or choices, the MNL model calculates the probability of individual q choosing alternative i using the following equation:

$$p_{iq} = \frac{\exp(V_{iq})}{\sum_{i'} \exp(V_{i'q})}, i, i' \in A_q \qquad \text{(III.12)}$$

where A_q is the set of alternatives for individual q; V_{iq} is the structural utility of alternative i for individual q. This model is based on the assumption that the random utility is independently and identically distributed according to a double exponential (Gumbel) distribution (Adamowicz et al., 1998; Hensher et al., 2015).

The latent class model (LC)

The LC model is a special case of random parameters specification, where a discrete number of support points are hypothesised (Swait, 1994). It operates within a theoretical framework where an individual's behaviour is influenced by observable attributes and latent heterogeneity, which varies according to unobservable factors.

[129] McFadden's ρ^2 can be calculated according to the following formula: $\rho^2 = 1.0 - [LL(\beta)/LL(0)]$, where $LL(\beta)$ is the log-likelihood function using the estimated parameters and $LL(0)$ is the log-likelihood function using the null-model (Hensher et al., 2015).

This relationship is represented by the following formula:

$$P_{q|c}(j) = \frac{exp\left(x'_{q,j}\beta_c\right)}{\sum_{j-1}^{Jq} exp\ (x'_{q,j}\beta_c)} \tag{III.13}$$

where $P_{q|c}$ is the probability of choice j by individual q, in class (or cluster) c (Hensher et al., 2015).

The New Ecological Paradigm scale

The New Ecological Paradigm scale was used to assess respondents’ environmental attitudes (Dunlap et al., 2000). It consists of 15 items, with participants rating each on a scale from ‘strongly disagree’ to ‘strongly agree’. The total score ranges from a minimum of 15 (indicating a low pro-environmental attitude) to a maximum of 75 (indicating a high pro-environmental attitude). The results can be classified into different categories, and Cronbach's alpha α can be calculated to evaluate the internal consistency of the responses (Cronbach, 1951), with values greater than 0.70 considered acceptable.

The Chi-square tests

Chi-square χ^2 tests were used to examine the relationship between the categorical variables of the survey, similarly to what was done in Subsection §9.4.1.

Results

The results of the analyses exploring citizens' preferences for soil desealing - specifically regarding its procedural, technical, and formal attributes - are presented in the following paragraphs.

The sample

First, the categories of the socio-demographic variables were recoded. The characteristics of the sample are presented in the following table (Table III.58). The available open data, retrieved from the Municipality of Parma and Italian national statistics institute (*Istituto nazionale di statistica*) (updated as of January 1, 2023), facilitated a comparison of the socio-demographic characteristics of the sample with the overall population of Parma. Specifically, as shown in Table III.58, the age, gender, and neighbourhood distribution of the respondents generally align with the urban population, indicating a representative sample.

Variable	*Category*	*Percentage of the sample [%]*	*Percentage of the population [%]*
Age	18-30 years	35.9	43.3
	31-50 years	31.7	27.9
	51->70 years	32.5	28.8
Gender	Female	54.1	51.5

Variable	*Category*	*Percentage of the sample [%]*	*Percentage of the population [%]*
	Male or other	45.9	48.5
Neighbourhood	Cittadella/Lubiana/San Lazzaro	19.0	25.9
	Cortile San Martino/Golese/San Pancrazio/Pablo/San Leonardo	16.0	17.0
	Molinetto/Vigatto/Montanara	24.9	19.4
	Parma Centro/Oltretorrente	40.1	37.7
Period of stay in the neighbourhood	Less than one year	16.0	N/A
	More than one year but less than five	21.0	N/A
	More than five years but less than ten	13.2	N/A
	More than ten years	49.9	N/A
Activity	Employee	28.3	N/A
	Entrepreneur/Freelancer/Academic	34.5	N/A
	Student/Other	37.3	N/A
Engagement in the social sector	None	41.2	N/A
	Saltuary/occasional	36.7	N/A
	Regular	22.1	N/A
Household type	I live alone/Other	18.5	N/A
	I live with a partner	20.2	N/A
	I live with a partner and one or more children	26.6	N/A
	I live with one or more housemates	15.1	N/A
	I live with one or more members of my family	19.6	N/A
Housing situation	I am renting/Other	35.9	N/A
	I own my house	64.1	N/A
Expertise about desealing	I've heard about it for personal reasons	25.5	N/A
	I've heard/dealt with it at work or as a student/volunteer	19.3	N/A
	I've never heard about it	55.2	N/A

Table III.58 | Socio-demographic characteristics of the sample and the population. Source: data regarding the population are based on open data retrieved from the Municipality of Parma and Italian national statistics institute (*Istituto nazionale di statistica*).

The results of the multinomial logit model (MNL) *estimation*

The results of the MNL model estimation are presented in Table III.59, while Figure III.48 provides a graphical representation of the part-worth utilities for each parameter. The figure includes error bars to show the standard error (SE) above and below the mean, as well as the significance of the parameters. McFadden's ρ^2 value for the model is 0.23, which indicates a good fit of the model.

Attribute	*Attribute level*	*Part-worth utility*	*Standard Error (SE)*	*Significance*
Constant		1.93	0.07	0.000
Main areas of intervention	Paved road infrastructure and paved public parking lots	-0.01	0.03	0.764

Attribute	*Attribute level*	*Part-worth utility*	*Standard Error (SE)*	*Significance*
	Paved squares and paved areas of public parks	0.01	0.05	0.842
	Public services' paved areas (like hospitals, schools)	0.00		
Proposal of the areas	Public	0.04	0.05	0.433
	Private	-0.15	0.04	0.000
	Public-private	0.11		
Main purpose	Improving environmental and urban quality	0.08	0.05	0.106
	Restoring water and soil functions	-0.02	0.06	0.773
	Enhancing biodiversity	-0.06		
Design	Top-down	-0.03	0.06	0.638
	Bottom-up	-0.06	0.05	0.244
	Co-design	0.09		
Percentage of desealed area	100%	0.20	0.06	0.001
	75%	0.06	0.05	0.189
	50%	-0.26		
New vegetation	Trees, shrubs and grass	0.24	0.05	0.000
	Shrubs and grass	-0.06	0.06	0.288
	Grass	-0.18		
Post-intervention perception of the temperature benefits in summer	Strong	0.28	0.05	0.000
	Average	0.01	0.06	0.930
	Weak	-0.28		
Surfaces after rainfall	Wet	0.11	0.05	0.022
	Wet with small ponds	0.08	0.04	0.060
	Wet with medium and large ponds	-0.18		
Involvement of the citizens in the construction	In all phases	-0.05	0.08	0.567
	In some phases	0.02	0.06	0.714
	With guided tours	0.03		
Involvement of the citizen in monitoring and maintenance	In all phases	0.01	0.04	0.787
	In some phases	-0.04	0.06	0.435
	With guided tours	0.03		

Table III.59 | Estimation of the parameters of the MNL model.

The constant parameter is significant and positive, indicating that citizens are generally inclined to prefer a soil desealing intervention over no intervention at all. Among the significant positive parameters - listed from most to least influential - are: i) a ‘strong post-intervention perception of temperature benefits in summer’; ii) the presence of ‘trees, shrubs, and grass’ as new vegetation; iii) a ‘100%’ desealed area; and iv) the absence of ponds after rainfall (‘wet’ surfaces); followed by v) ‘wet surfaces with small ponds’.

Regarding the parameters that negatively affect participants' preferences, the only significant one is the proposal of areas for desealing through ‘private’ initiative. The parameters related to i) citizens' involvement in construction, ii) monitoring and maintenance, iii) the design of the interventions, iv) their main purpose, and v) the main intervention areas do not show statistical significance. Similarly, the following parameters lack statistically significant influence: i) the 'public' and 'public-private' proposals for the areas to be desealed; ii) percentages of desealed areas lower than 100%; iii) the inclusion of 'shrubs and grass' and 'grass' as new vegetation; iv) the 'average' and 'weak' post-intervention perception of temperature benefits in summer; and the presence of medium and large ponds on surfaces after rainfall.

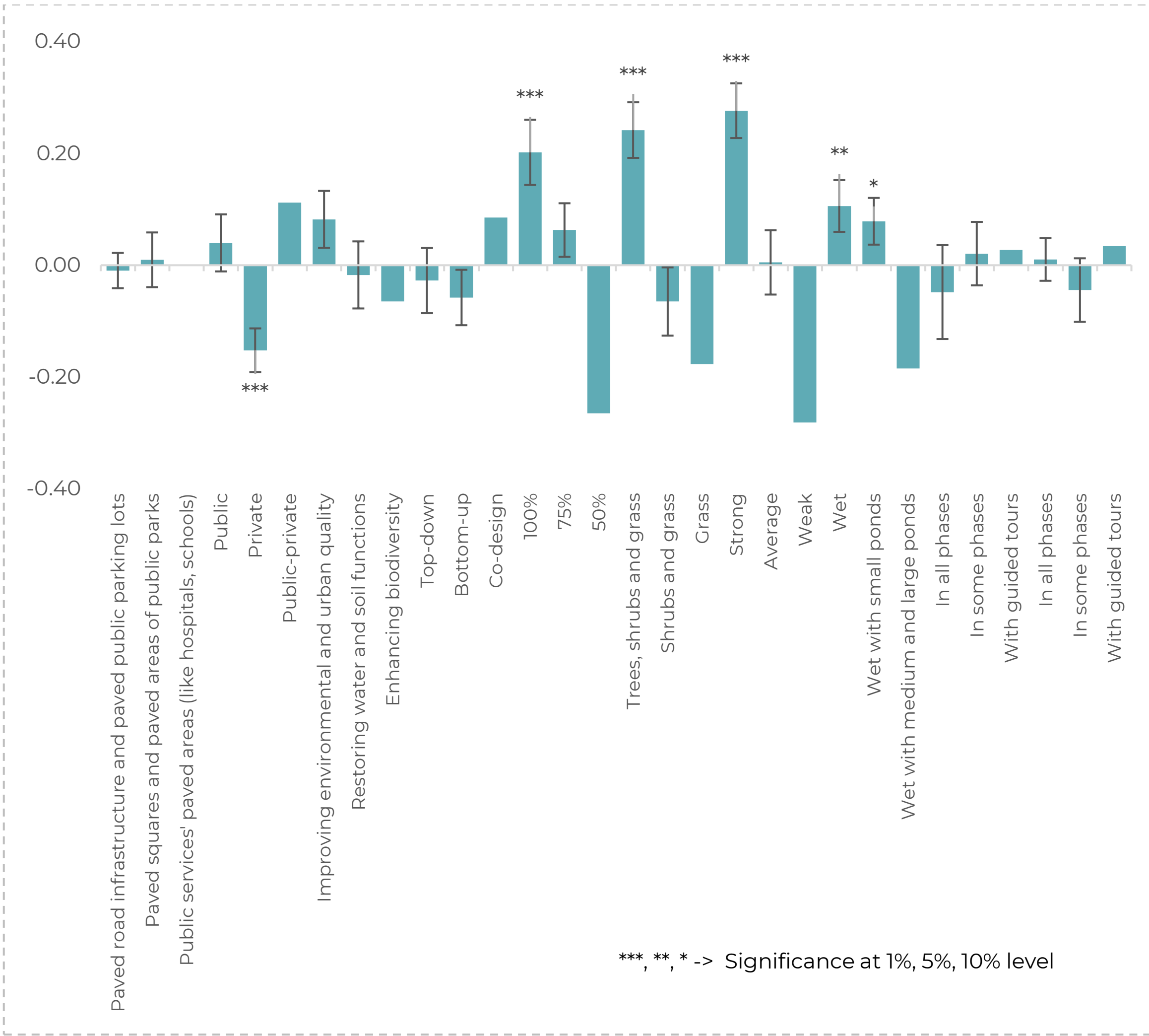


Figure III.48 | Diagram of the influence of the parameters on the desealing intervention preferences. Source: author's elaboration.

The results of the latent class model (LC) estimation

The LC model was estimated for two classes: Class I and Class II. The probability of respondents belonging to Class I is 89.7%, while Class II has a probability of 10.3%. Table III.60 presents the results of the LC model for both classes, and Figure III.49 visually shows the influence of the parameters on respondents' preferences.

Class I is characterised by a significant and positive weight of the constant parameter, suggesting that respondents in this class are generally inclined to choose a soil desealing intervention over no intervention. In contrast, Class II displays a significant negative weight for the constant parameter, indicating that participants in this class are generally not inclined to opt for a soil desealing intervention.

For Class I, the significant attributes that positively influence respondents' preferences are, in order of influence: i) a 'strong' post-intervention perception of the temperature benefits in summer, ii) the inclusion of 'trees, shrubs, and grass' as new vegetation, iii) a '100%' desealed area, and iv) the absence of ponds after rainfall ('wet' surfaces). As with the MNL model, the only negative influencing factor is the 'private' proposal for the areas to be desealed.

		Class I		*Class II*	
Attribute	***Attribute level***	***Part-worth utility***	***Significance***	***Part-worth utility***	***Significance***
Constant		4.00	***	-1.04	***
Main areas of intervention	Paved road infrastructure and paved public parking lots	-0.01		0.02	
	Paved squares and paved areas of public parks	0.03		-0.11	
	Public services' paved areas (like hospitals and schools)	-0.02		0.09	
Proposal of the areas	Public	-0.02		0.09	
	Private	-0.20	***	-0.20	
	Public-private	0.22		0.11	
Main purpose	Improving environmental and urban quality	-0.01		0.12	
	Restoring water and soil functions	0.06		0.00	
	Enhancing biodiversity	-0.05		-0.12	
Design	Top-down	0.07		0.09	
	Bottom-up	-0.06		-0.27	
	Co-design	-0.01		0.18	
Percentage of desealed area	100%	0.28	*	-0.03	
	75%	0.02		0.08	
	50%	-0.29		-0.05	
New vegetation	Trees, shrubs and grass	0.32	***	0.09	
	Shrubs and grass	-0.16		0.25	
	Grass	-0.16		-0.34	
Post-intervention perception of the	Strong	0.36	***	0.43	***
	Average	0.01		0.05	
	Weak	-0.37		-0.48	

Attribute	*Attribute level*	*Class I* Part-worth utility	*Class I* Significance	*Class II* Part-worth utility	*Class II* Significance
temperature benefits in summer					
Surfaces after rainfall	Wet	0.21	***	0.07	
	Wet with small ponds	0.04		0.45	***
	Wet with medium and large ponds	-0.25		-0.53	
Involvement of the citizens in the construction	In all phases	-0.21		-0.19	
	In some phases	0.07		0.13	
	With guided tours	0.14		0.06	
Involvement of the citizen in monitoring and maintenance	In all phases	0.04		-0.26	*
	In some phases	-0.09		0.17	
	With guided tours	0.06		0.09	
***, **, * -> Significance at 1%, 5%, 10% level.					

Table III.60 | Estimation of the LC model – Classes I and II.

The second class of respondents (Class II) is generally not inclined to choose a soil desealing intervention, as indicated by the negative constant parameter. However, there are two attributes that significantly and positively influence their preferences: i) a 'strong' post-intervention perception of the temperature benefits in summer, and ii) 'wet surfaces with small ponds' after rainfall. The only parameter that significantly and negatively influences their preferences is the involvement of citizens in all the monitoring and maintenance phases of the soil desealing interventions.

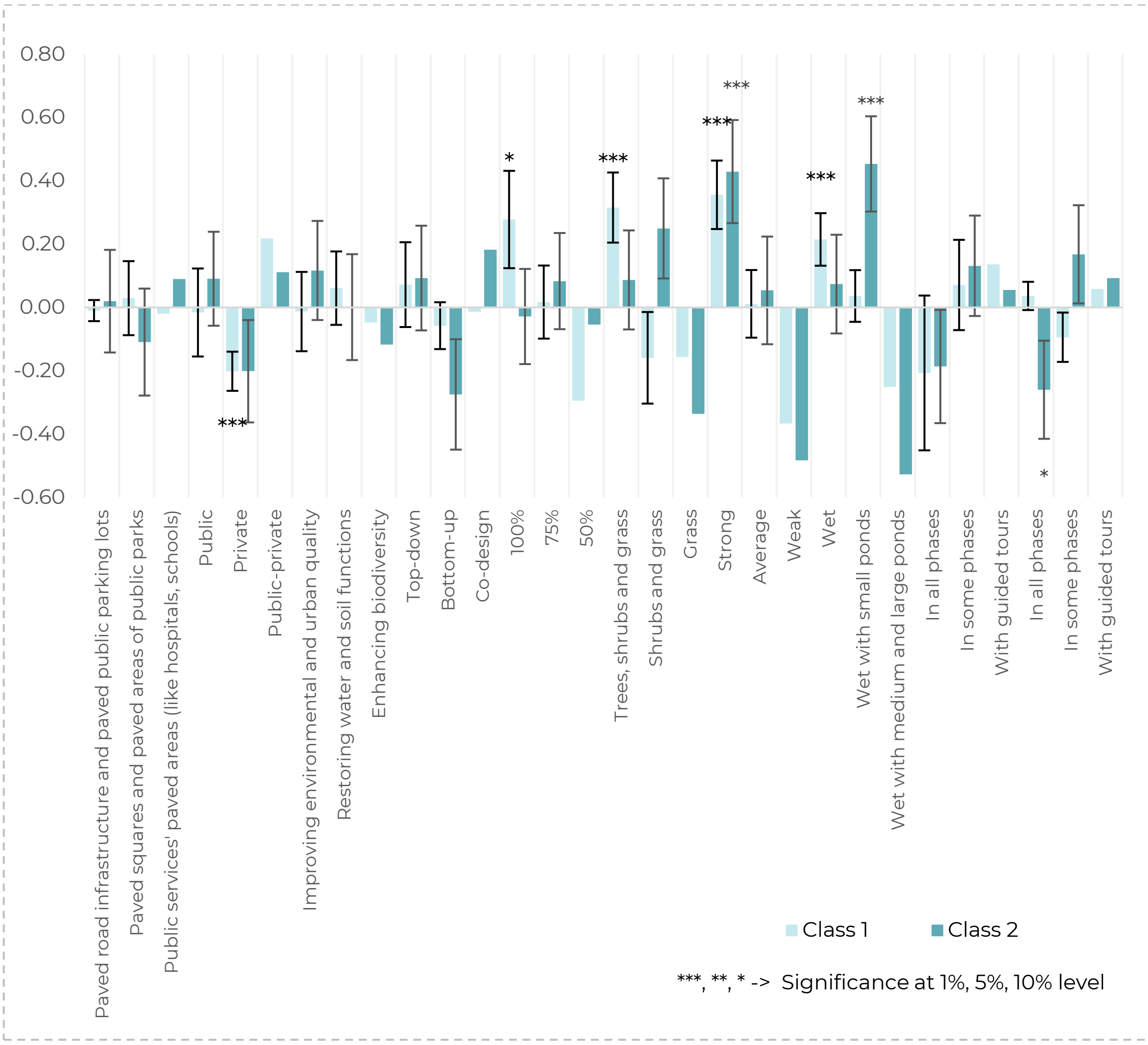


Figure III.49 | Diagram of the influence of the parameters on the desealing intervention preferences for Class 1 and 2. Source: author's elaboration.

Chi-square tests were conducted to study the relationship between the socio-demographic characteristics of the respondents and their class membership. Among the analysed variables - such as those involving age, gender, neighbourhood, length of stay in the neighbourhood, activity, engagement in the social sector, household type, housing situation, and expertise about soil desealing - only the variable ‘activity’ showed statistically significant results. Specifically, the analysis revealed that the category ‘Students/other’ is the most likely to belong to Class I, with 93.2% of individuals in this category in the first class. In contrast, the category ‘Entrepreneurs/Freelancers/Academics’ is more likely to belong to Class II, with 15.4% of this group in the second class. Among ‘Employees’, 92.1% belong to Class I, while the remaining 7.9% are in Class II. The following subsections will examine the relationship between the LC model classes and the respondents' environmental attitudes.

The New Ecological Paradigm scale results

The New Ecological Paradigm scale was analysed, and participants’ scores were categorised into five ranges. The minimum score was 15 (indicating that participants selected the least pro-environmental answer on all 15 questions), while the maximum score was 75 (indicating that participants chose the most pro-environmental answer for all questions). The majority of participants (51.8%) fell into the 52-63 range, which is the second-highest category, as shown in Table III.61. Overall, 82.6% of the participants were in the two highest classes, corresponding to the 52-63 and 64-75 score ranges.

	New Ecological Paradigm score				
	Low pro-environmental attitude ↔ High pro-environmental attitude				
Range	15-27	28-39	40-51	52-63	64-75
Respondents' percentage	0.3%	1.1%	16.0%	51.8%	30.8%

Table III.61 | The scores of the participants in the New Ecological Paradigm scale.

Class II are those with a lower pro-environmental attitude (i.e., New Ecological Paradigm score: 15-52). More specifically, 81.1% of respondents with scores in this range belong to Class II. This finding suggests a clear connection between participants' environmental attitudes and their preferences for soil desealing interventions, with individuals who have a more pro-environmental mindset more likely to favour such interventions.

The internal consistency of the responses provided by participants was evaluated using the Cronbach's alpha α coefficient, which yielded a value of 0.8, indicating an acceptable level of internal consistency. Socio-demographic characteristics of respondents were compared to their results on the New Ecological Paradigm scale using Chi-square tests. A statistically significant relationship was observed between respondents New Ecological Paradigm scores and their class membership. Notably, 93.6% of individuals with a strong pro-environmental attitude (i.e., New Ecological Paradigm score: 64-75) were categorised as Class I and showed the highest likelihood of belonging to this group. Conversely, those most likely to be in Class II exhibited the lowest pro-environmental attitudes (i.e., New Ecological Paradigm score: 15-51).

Soil desealing activities in private areas

The analysis of the results of the last questions of the survey show that most participants (68.1%) would have answered the survey the same way if they considered a different neighbourhood, or the whole city of Parma (71.7%). Furthermore, while 65.0% of the respondents would be willing to deseal a private residential area of his property, 26.6% believe that their house or building does not have a suitable area for this type of intervention. Furthermore, regarding their engagement in soil desealing activities, 21.6% of the respondents answered that they already put in action soil desealing interventions; 28.0% responded that, while they would do so, their house or building does not have suitable areas; and 23.5% answered that, while their house/building has suitable areas, they do not have the opportunity to act.

For what concerns residential areas, the respondents' preferred way to introduce soil desealing is through measures proposed by the Municipality (39.8%), followed by areas proposed by the citizens (29.4%), by areas proposed by the Municipality (20.7%) and by areas proposed by private entities or associations (10.1%).

Finally, for what regards industrial and commercial areas, 83.8% of the respondents would be in favour of the implementation of soil desealing interventions, with - similarly to residential areas - a preference for measures proposed by the Municipality (35.3%).

However, the first preference is followed by the proposal of the areas by the Municipality (29.4%) and then by the citizens (19.6%) and private entities or associations (15.7%).

Discussion

The results of this study suggest that the citizens of Parma generally exhibit a pro-environmental attitude and are inclined toward soil desealing interventions, reflecting a broader environmental awareness. The high pro-environmental attitudes, as measured by the New Ecological Paradigm scale, suggest that those with less interest in environmental issues may have opted not to participate in the survey. This could explain the generally high environmental scores and the potential biases in the sample, where individuals with less concern for environmental issues may have been underrepresented.

Furthermore, the focus on temperature benefits, vegetation types, and rainfall absorption benefits aligns with the urban challenges faced in Parma, such as the urban heat island effect and flooding issues. These are tangible, real-world problems that participants are likely to have directly experienced, leading to a higher prioritisation of these aspects. The connection between local environmental problems and the survey responses suggests that citizens are more inclined to support interventions that they perceive as addressing immediate and visible concerns, like temperature regulation and water absorption.

On the other hand, the lack of significant preference for certain intervention attributes, such as the purpose of the interventions or the design and location of areas to be desealed, could reflect a sense of disconnection or uncertainty regarding these more abstract aspects. Respondents may not feel adequately informed about the broader goals of soil desealing, leading them to safer, more familiar choices like the idea of a 100% desealed area. The lack of influence of certain variables, like citizens' involvement and intervention design, may suggest a preference for authorities to make decisions without requiring extensive public involvement. This aligns with the tendency for Italian citizens to trust institutions to handle complex matters (Merler, 2021).

Additionally, the fact that most respondents would not have altered their answers based on different neighbourhoods or the entire city suggests a lack of localised knowledge on the impact of desealing in different urban contexts. This highlights a potential information gap that may affect citizens' ability to connect their own local experiences with broader urban interventions.

In summary, while the findings indicate a positive disposition towards soil desealing, they also underline the importance of providing clear, targeted information to the public, especially when it comes to the broader goals and implications of such interventions. Tailoring communication efforts to address these gaps in understanding and increasing citizens' engagement appears, once again, as extremely relevant for fostering greater acceptance and participation in urban environmental initiatives.

Outcomes of the survey

The findings indicate an interest from citizens in the topic of soil desealing and urban transformation, as reflected in their participation, final comments, and follow-up emails. This suggests that citizens are open to expanding their knowledge about environmental issues, and therefore public entities, universities, and associations interested in soil desealing should prioritise educational and outreach initiatives. These efforts should focus on providing clear information and promote citizens' empowerment, avoiding impositions that might lead to resistance, as emphasised by Arnstein's (1969) ladder of participation.

Citizens, being valuable stakeholders in urban transformation processes, can offer important insights, including the more technical aspects of soil desealing.

Based on the preferences revealed in the study, the following points should be prioritised in the implementation of soil desealing interventions within urban planning processes to better align with citizens' expectations:

- providing temperature benefits;
- providing rain absorption benefits;
- implementing new high- and medium-rise vegetation;
- maximising the desealed surface area.

Furthermore, while most citizens appear to be favourable in putting in action soil desealing interventions, it seems that they prefer indirect measures proposed by the Municipality. There is, however, a difference in preferences for private residential and commercial/industrial areas, probably as a reflection of the private property relevance in the Italian traditional relationship with the urban space (Zazzi, 2019). The private initiative in proposing the areas to deseal is preferred for private residential spaces as opposed to commercial/industrial ones, where the proposal of the areas by the Municipality is favoured. In both cases, however, the intervention of the associations is the least favourite option.

9.5 Priorities and criteria for soil desealing

The priorities and criteria for soil desealing in Parma were defined based on the assessments and experiences described in the previous chapters. These criteria account for i) the urban pluvial flood risk and its components (hazard, exposure, and vulnerability), ii) the urban pluvial flood damage to both physical assets and the population [130], iii) the transformation potential of urban areas (considering both desealability and suitable urban planning instruments), as well as iv) the insights from/the role of citizens' involvement.

Based on these considerations, the urban pluvial flood risk maps for two return periods - ten and 25 years - were overlaid with data regarding desealability. A similar procedure was applied also with respect to the damage assessments. The outcomes consist of the maps of the entire urban area that depict the interaction between these factors on a graduated scale. Higher values indicate an overlap of high values for both factors, while values approaching zero mean that both are low. Intermediate values require comparison with the base maps to provide further insight.

The maps that were drafted are:

- Map III.29 | Overlay of the desealing potential and risk maps (physical assets) – Return period = 10 years;
- Map III.30| Overlay of the desealing potential and risk maps (physical assets) – Return period = 25 years;
- Map III.31 and III.31a | Overlay of the desealing potential and risk maps (population) – Return period = 10 years (per census section and subcatchment);

[130] For the sake of brevity, the word 'damage' is used to refer to the affected population and to the mortality identified in Subsection §9.2.6.

- Map III.32 and III.32a | Overlay of the desealing potential and risk maps (population) – Return period = 25 years (per census section and subcatchment);
- Map III.33| Overlay of the desealing potential and damage maps (physical assets) - Approach A;
- Map III.34| Overlay of the desealing potential and damage maps (physical assets) - Approach B (Buildings) – Return period = 10 years;
- Map III.35| Overlay of the desealing potential and damage maps (physical assets) - Approach B (Buildings) – Return period = 25 years;
- Map III.36| Overlay of the desealing potential and damage maps (physical assets) - Approach B (Rail and road infrastructure) – Return period = 10 years;
- Map III.37| Overlay of the desealing potential and damage maps (physical assets) - Approach B (Rail and road infrastructure) – Return period = 25 years;
- Map III.38| Overlay of the desealing potential and damage maps (population) - Approach A;
- Map III.39| Overlay of the desealing potential and damage maps (population) - Approach B (Rincón et al., 2022) – Return period = 10 years;
- Map III.40| Overlay of the desealing potential and damage maps (population) - Approach B (Rincón et al., 2022) – Return period = 25 years;
- Map III.41| Overlay of the desealing potential and damage maps (population) - Approach B (Jonkman & Asselman, 2003);
- Map III.42| Overlay of the desealing potential and damage maps (population) - Approach B (Russo & Parisani, 2019).

From an operative (and demonstrative) perspective aimed at developing practical data for identifying the priorities for soil desealing within the urban planning scenario, maps classifying both the risk (for the return periods of ten and 25 years) and the desealability according to levels were developed. The five classes allow for the comparative identification of priorities across the urban area through the comparison of the higher risk and desealibility levels. Considerations should also be weighed against the hydraulic forcings, which provide a broader understanding of how the urban drainage network performs.

These drafted maps are:

- Map III.43 | Three-level risk maps - physical assets - Return period = 10 years;
- Map III.44 | Three-level risk maps - physical assets - Return period = 25 years;
- Map III.45 | Three-level risk maps - population - Return period = 10 years;
- Map III.46 | Three-level risk maps - population - Return period = 25 years;
- Map III.47 | Three-level desealing potential.

Within the framework of this thesis, data were classified into five-level maps. However, the number of classes (and hence the level ranges) can be changed accordingly to the desired working setting.

Regarding the available urban planning tools, while not aiming to frame a rigid scenario within this research - the General urban plan (*piano urbanistico generale*) of Parma has been identified as an effective instrument for integrating the findings of these analyses. This includes incorporating generalised and index-based approaches such as compensation measures, which may appear less invasive to the citizens, and specifying desealable areas within both the new General urban plan and the Green plan (*Piano del verde*) according to the identified priorities. For what concerns public areas, in addition to considering them also within the desealable areas envisioned by – for instance -

compensation measures, three-year public works programmes (*programmi triennali dei lavori pubblici*) represent a further relevant instrument for acting on the priorities.

Additionally, areas presenting a high risk but a low desealability due to their protection - such as the boulevard '*Viale Martiri della Libertà*' - may be subjected to specific management strategies, requiring clear decisions regarding their protection and use.

Finally, the experiences in Parma that dealt with citizens' involvement highlighted a notable awareness of climate change and the importance of soil desealing, though this consciousness varies depending on their location. Even more in this context, the selection of intervention areas, in addition to considering the urban pluvial flood risk and damage, should account for the population perspective – also for a merely temporal management of the interventions. Examples are actions and campaigns tailored to the perception or preferences of the residents, such as the perceived need for soil desealing interventions in the neighbourhoods, thus locating or designing pilot projects or structuring awareness-raising initiative accordingly. As these observations stem from the surveys analysed in Subsections §9.4.1 and §9.4.3, further investigation involving direct engagement with communities and stakeholders could provide deeper insights or potentially redirect the findings, especially in the Italian context.

9.5.1 Simulation of soil desealing in two urban subcatchments

At the end of the analysis, it appears useful and insightful to employ the methodology on a more detailed scale, to observe its performance on the subcatchment scale. This subchapter describes the outcomes of this application on two subcatchments, which are also represented in Map III.48, which outlines the performed analyses.

The subcatchments were selected as they present both high desealing potential and elevated risk, considering a return period of 25 years[131]. This is also observable in the Map III.44, Map III.46 and Map III.47. As previously mentioned, the hydraulic forcings were also accounted for, highlighting critical nodes and conduits within the subcatchment areas (see Map III.3).

The first subcatchment (the western) represents a predominantly residential area with limited desealing opportunities, while the second (the eastern) features mixed land uses and a higher percentage of impervious surfaces, offering greater potential for desealing interventions. This diversity provided valuable insights into the scalability and applicability of the method.

As a first step, suitable areas for soil desealing were identified and mapped at the subcatchment scale, based on a preliminary assessment of the opportunities offered by urban planning instruments (e.g., the presence of parking lots identified as desealable in the General urban plan, or areas identified for the application of the 'RIFO index'). Additionally, private parking lots and impervious service areas were considered, mapping them as suitable desealing locations alongside other unused or abandoned sealed areas and paved spaces without car traffic.

After mapping the areas to be desealed (corresponding to 3% of the total area for the western subcatchment and 11% for the eastern), they were reclassified as green spaces in the '2018 land use map' of the Emilia-Romagna Region used for calculating hydrological forcings (Subsection §9.2.1). The simulation was then run again to calculate the urban

[131] This return period was chosen because it is assumed to corresponds to the design return period of the drainage network, as mentioned in Subsection §9.2.1.

pluvial flood depth under the new conditions. Following the same steps outlined in this chapter, the urban pluvial flood risk was then reassessed, and the results of the 'after scenario' were compared to those of the 'before scenario'.

The results of the simulation, encompassed by Map III.48, show that soil desealing is effective in reducing urban pluvial flood hazard (specifically, the flood depth decreases in the eastern subcatchment) and, consequently, the risk to both the population and physical assets, provided that a sufficient amount of desealable surface is available. As a matter of fact, one of the subcatchments (the western) showed no significant change due to the limited percentage of desealable - and thus virtually desealed – area. The lower desealability of this subcatchment is also consistent with what was observed from the desealing potential map, thereby validating it for this instance.

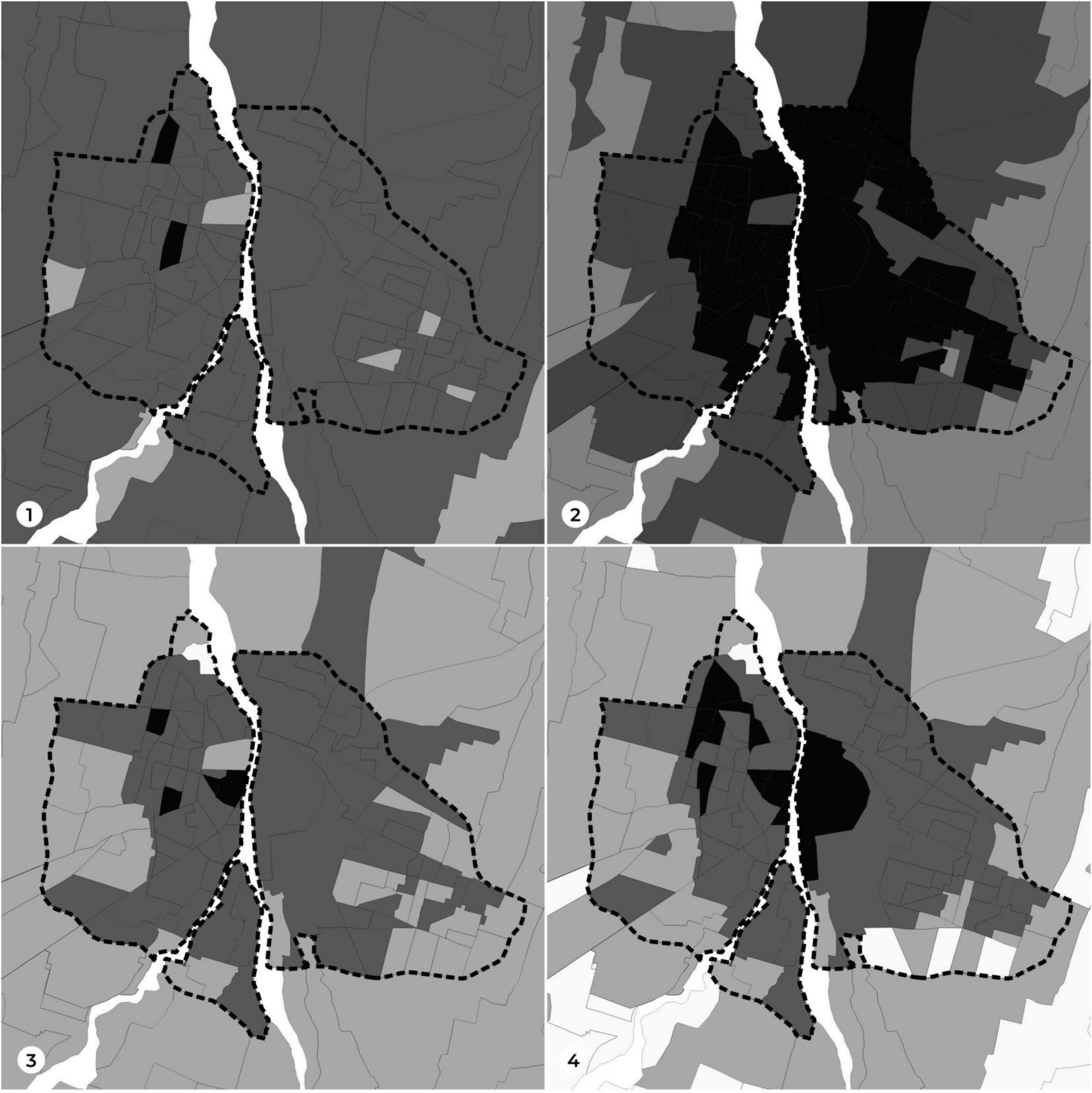
On a less promising note, it should be noted that variability in the permeability percentages of the same land uses was observed across the two subcatchments. This highlights the mentioned approximation entailed by the Curve Number method, which, despite being widely employed in literature and practice (Agenzia Regionale per la Protezione dell'Ambiente della Sardegna & Regione Sardegna, 2019; Ibrahim et al., 2022; Jahan et al., 2021; Studio Zanzucchi Srl & Comune di Parma, 2015; The Natural Capital Project, n.d.), is acknowledged not fully reflect real-world conditions (Salata et al., 2022).

Map III.1 | Urban context and administrative boundaries

Perimeter of the inner urban area (area inside the ring road)
Neighbourhoods

Basemap: Google Satellite (accessed 2024). Google Maps.

0 0.5 1 1.5 km



Map III.2 | Hydrological forcings - Flood depth - Return period = 10 years

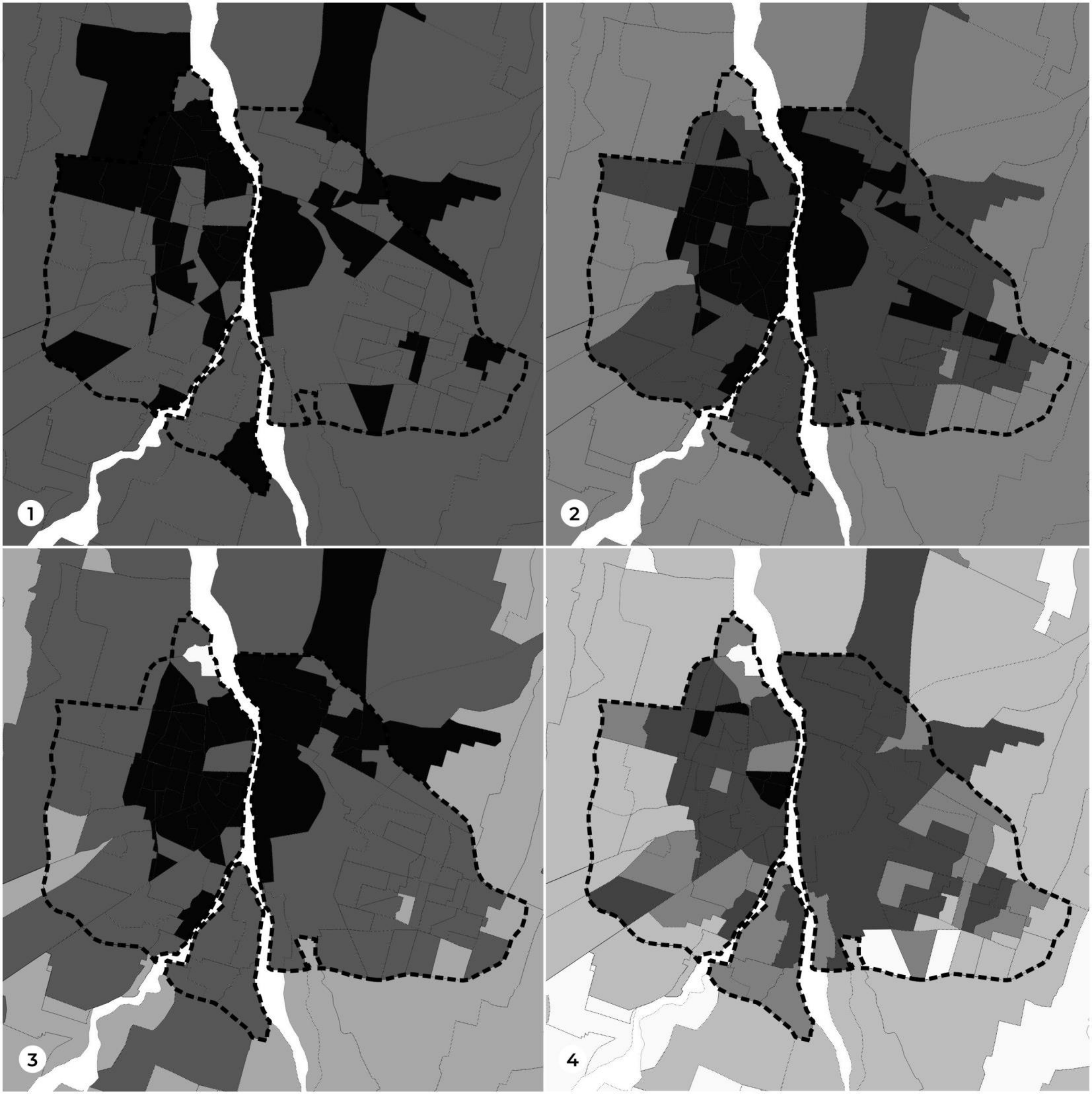
Flood depth [m]
- 0
- 0.01
- 0.02
- 0.03
- 0.04

Perimeter of the inner urban area (area inside the ring road)

Subcatchments

Base maps used for the calculation
1: Land use (Regione Emilia-Romagna, 2018)
2: Land cover (ISPRA, 2021)
3: Imperviousness (Copernicus Land Monitoring Service, 2018)
4: Imperviousness (Regione Emilia-Romagna, 2011)

0 1 2 3 km



Map III.3 | Hydrological forcings - Flood depth - Return period = 25 years

Flood depth [m]

- 0
- 0.01
- 0.02
- 0.03
- 0.04

Perimeter of the inner urban area (area inside the ring road)

Subcatchments

Base maps used for the calculation
1: Land use (Regione Emilia-Romagna, 2018)
2: Land cover (ISPRA, 2021)
3: Imperviousness (Copernicus Land Monitoring Service, 2018)
4: Imperviousness (Regione Emilia-Romagna, 2011)

0 1 2 3 km

Map III.4 | Hydrological forcings - Topographic Wetness Index

Normalised values

1

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

0 0.5 1 1.5 km

Map III.5 | Hydrological forcings - Flood depth (land use) and Topographic Wetness Index
Return period = 10 years

Normalised values
1
0

Group
Perimeter of the inner urban area
(area inside the ring road)
Subcatchments

Map III.6 | Hydrological forcings - Flood depth (land use) and Topographic Wetness Index
Return period = 25 years

Normalised values

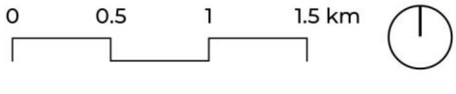
1

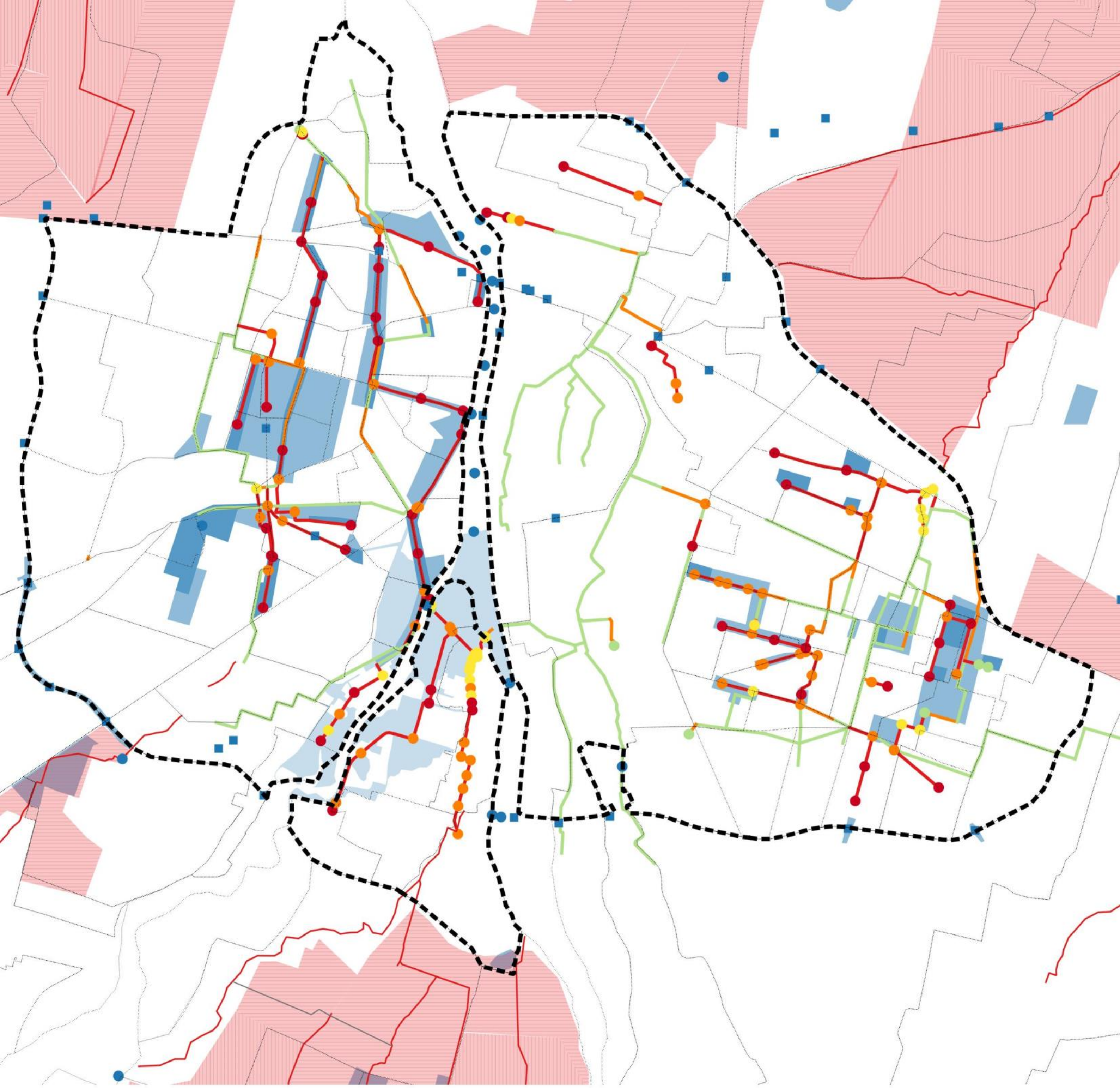
0

Group

Perimeter of the inner urban area (area inside the ring road)

Subcatchments





Map III.7 | Hydraulic forcings - Criticalities of the drainage network- Return time = 10 years

Inner urban area

Critical nodes
of the urban drainage network

- High criticality
- Medium criticality
- Very high criticality
- Low criticality

Conduits of the urban drainage network

- Free surface flow operation
- Operation under pressure
- Operation at full capacity and elimination of the air gap

Outer urban area

Linear criticalities

- Inadequate hydraulic functionality

Critical areas

- Channel overflow (excessive soil sealing)
- Minor channel overflow (inadequate cross sections)

Intrinsic critical points

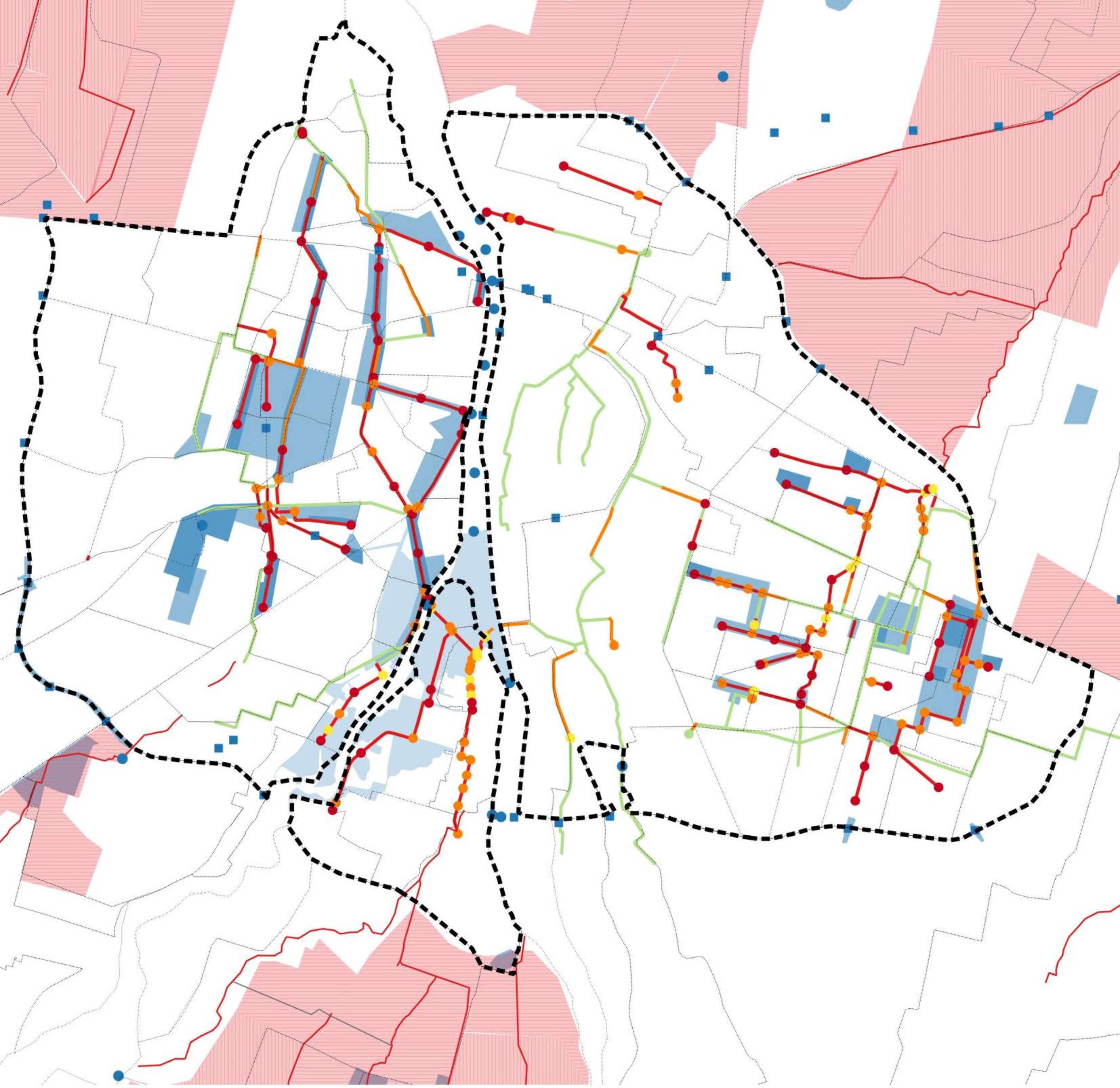
- Monitoring points
- Underpasses

Historically flooded areas

Urban drainage systems and canals

- Frequent floods
20 years < Reurn time < 50 years
- Infrequent floods
100 years < Reurn time < 200 years
- Very frequent floods
5 years < Reurn time < 20 years
- Perimeter of the inner urban area (area inside the ring road)
- Perimeter of the subcatchments

0 0.5 1 1.5 km



Map III.8 | Hydraulic forcings - Criticalities of the drainage network- Return time = 25 years

Inner urban area

Critical nodes of the urban drainage network

- High criticality
- Medium criticality
- Very high criticality
- Low criticality

Conduits of the urban drainage network

- Free surface flow operation
- Operation under pressure
- Operation at full capacity and elimination of the air gap

Outer urban area

Linear criticalities

- Inadequate hydraulic functionality

Critical areas

- Channel overflow (excessive soil sealing)
- Minor channel overflow (inadequate cross sections)

Intrinsic critical points

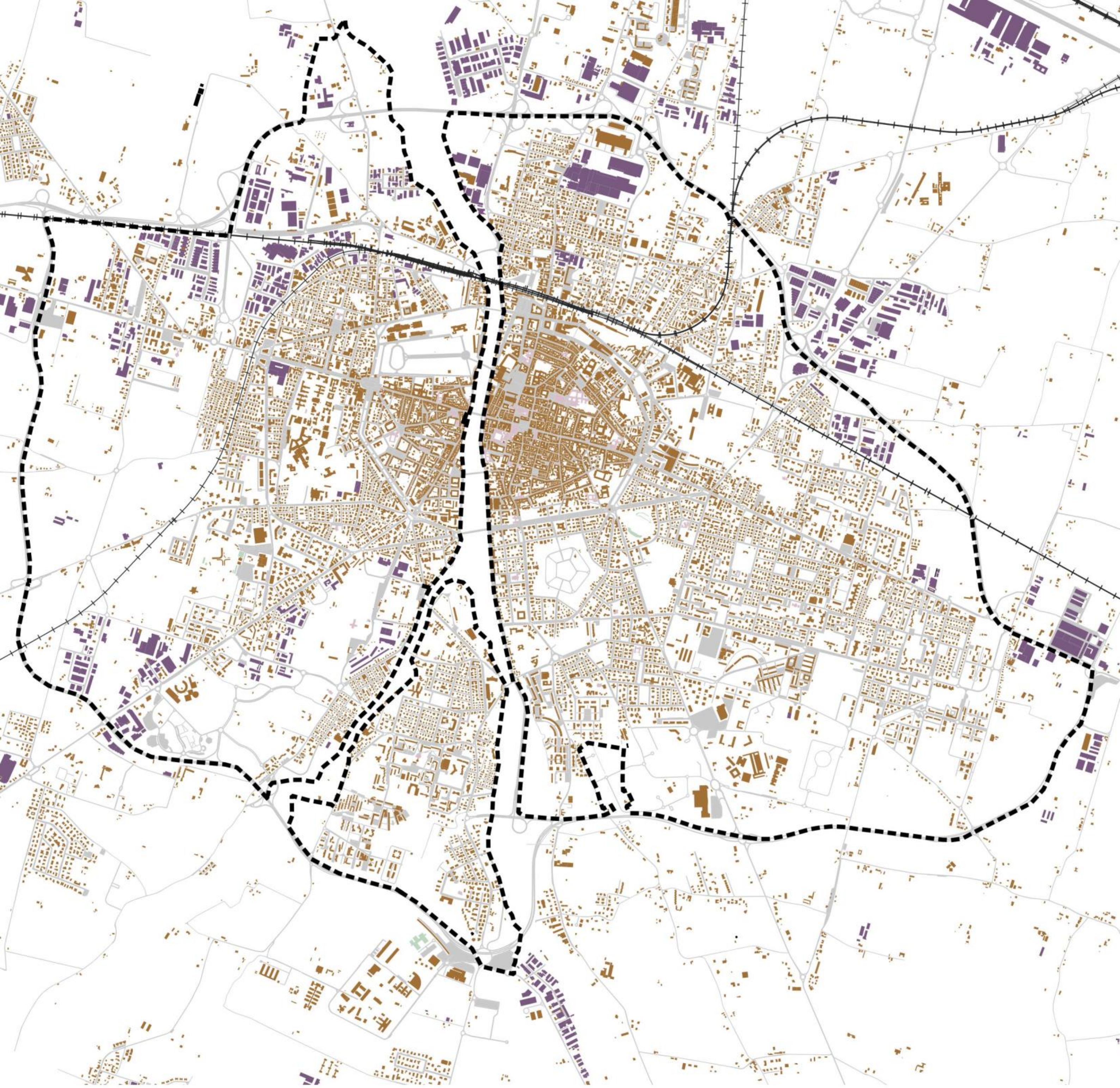
- Monitoring points
- Underpasses

Historically flooded areas

Urban drainage systems and canals

- Frequent floods 20 years < Reurn time < 50 years
- Infrequent floods 100 years < Reurn time < 200 years
- Very frequent floods 5 years < Reurn time < 20 years
- Perimeter of the inner urban area (area inside the ring road)
- Perimeter of the subcatchments

0 0.5 1 1.5 km



Map III.9 | Exposed physical assets

Buildings (classified according to the building use categories from the Emilia-Romagna Region Geoportale data)

- Residential
- Industrial
- Religious building
- Sports venues
- N/A

- Rail infrastructure
- Road infrastructure

- Perimeter of the inner urban area (area inside the ring road)

0 0.5 1 1.5 km

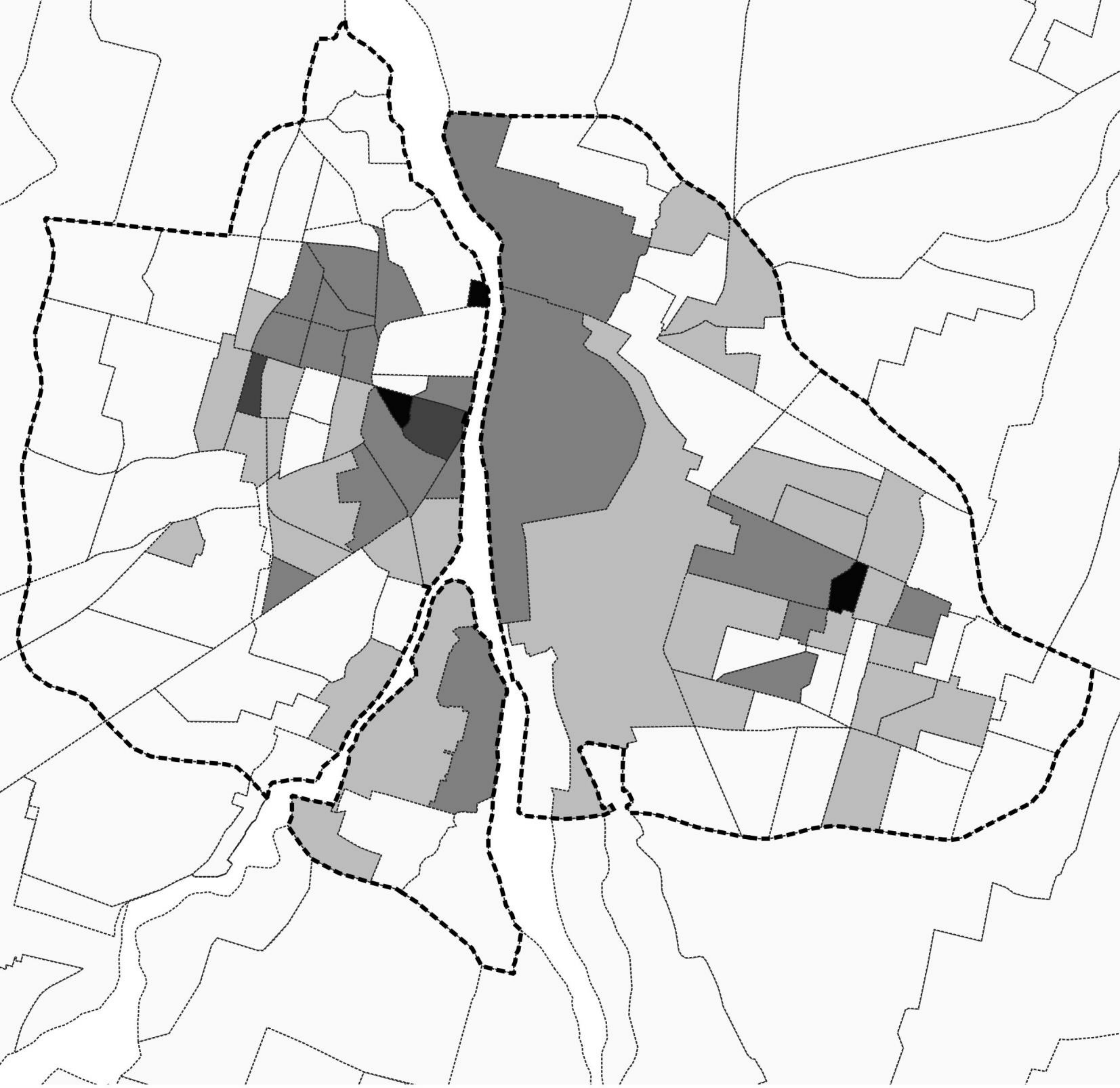
Map III.10 | Exposed population

Population density per census section
[inhabitants/hectare]

- 0 - 75
- 75 - 150
- 150 - 225
- 225 - 300
- 300 - 375
- 375 - 450
- 450 - 525
- 975 - 1050

Perimeter of the inner urban area
(area inside the ring road)

0 0.5 1 1.5 km



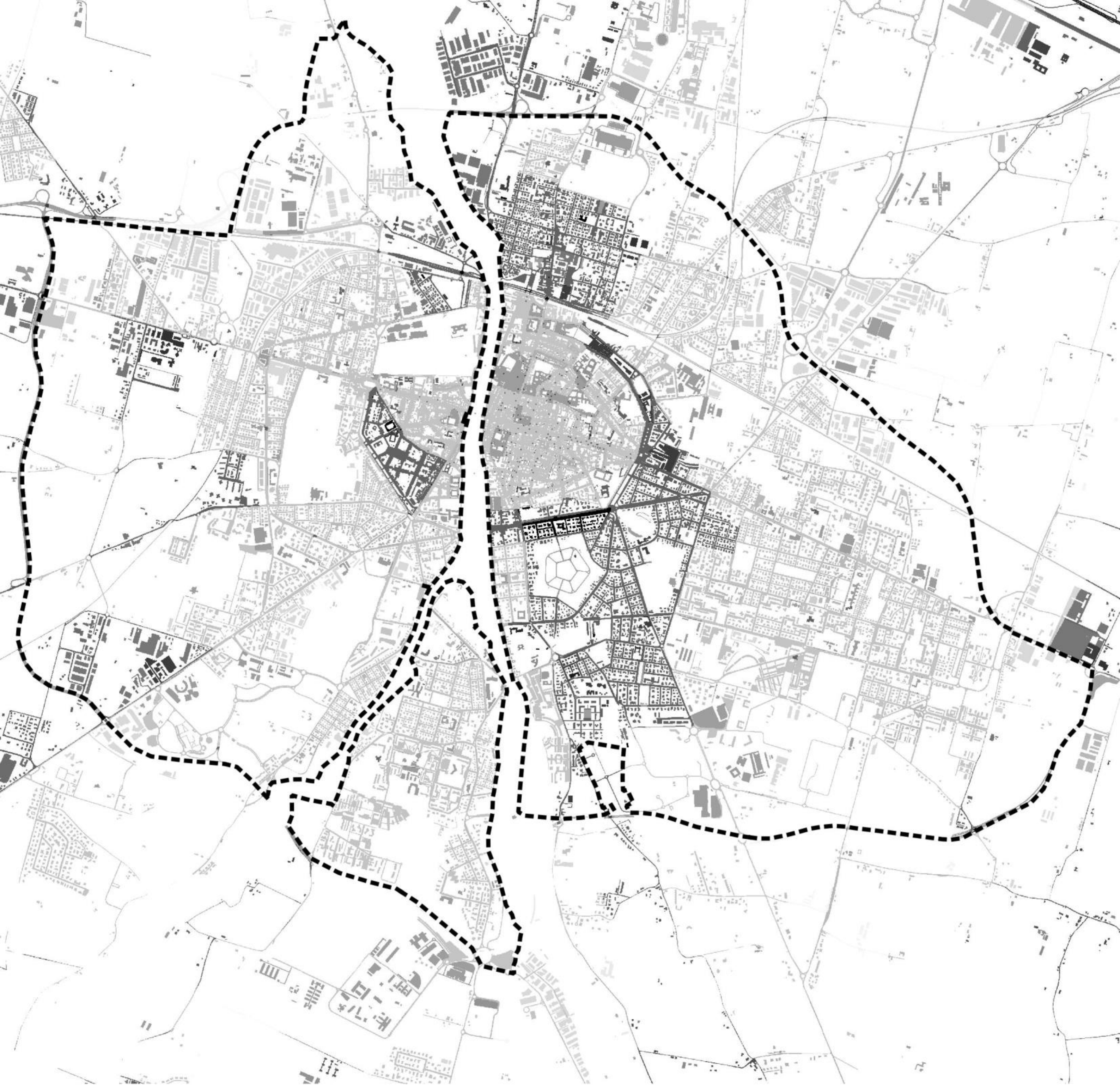
Map III.10a | Exposed population

Population density per subcatchment
[inhabitants/hectare]

- 0 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250

Perimeter of the inner urban area
(area inside the ring road)

0 0.5 1 1.5 km



Map III.11 | Vulnerability of the physical assets

Normalised values

1

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

0 0.5 1 1.5 km

Map III.12 | Vulnerability of the population

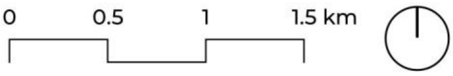
Normalised values

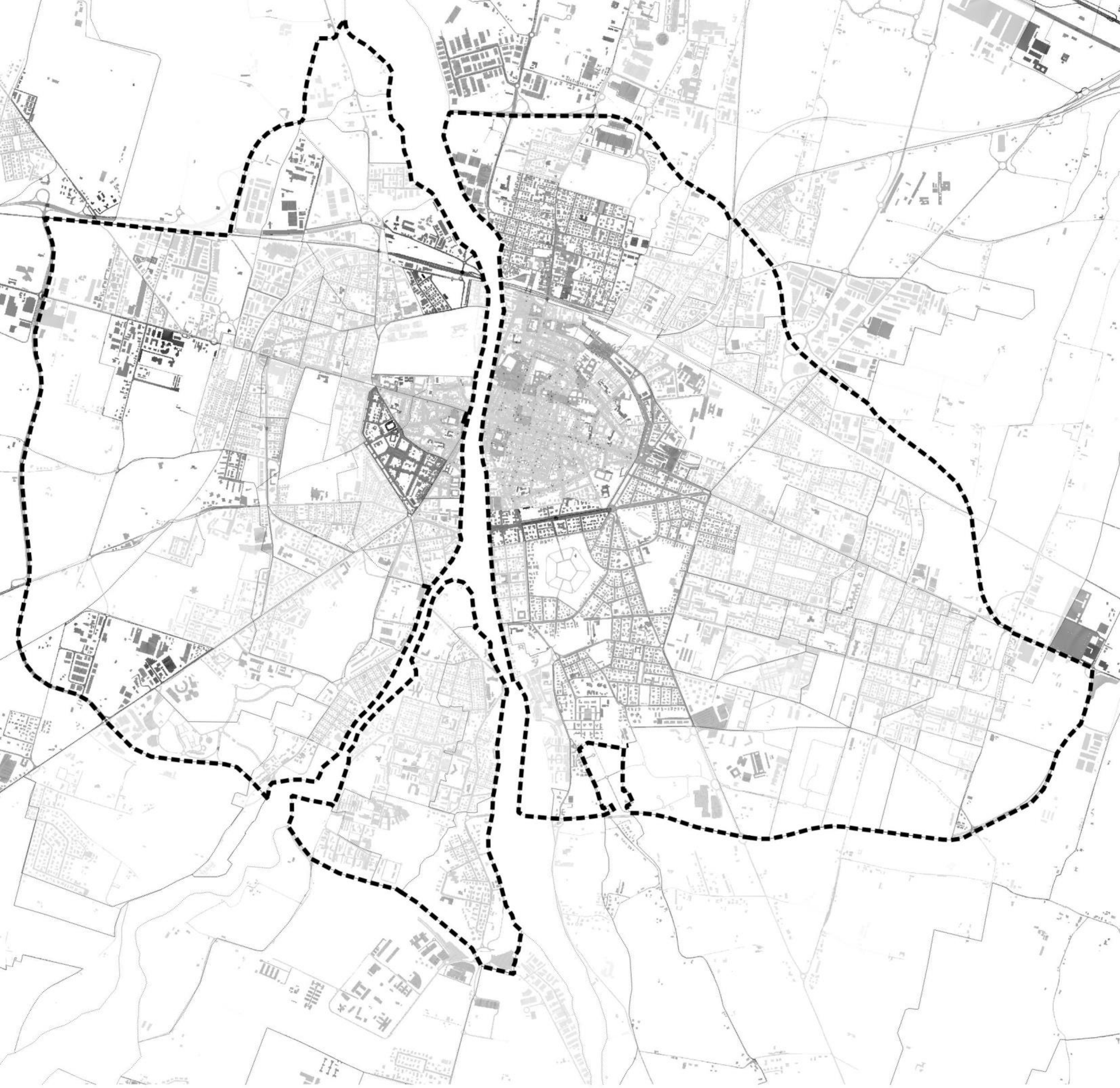
1

0

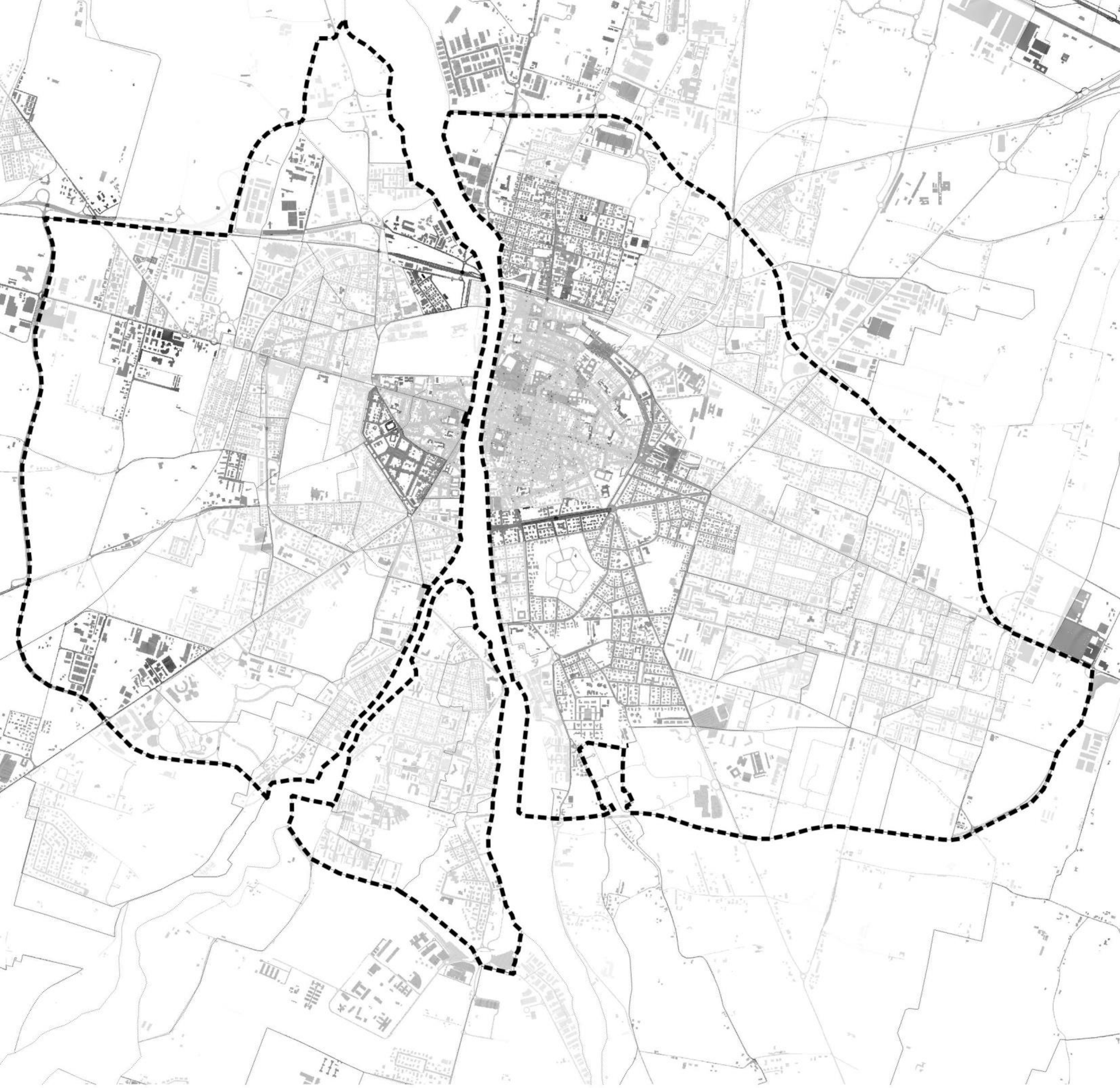
Perimeter of the inner urban area
(area inside the ring road)

Subactchments





Map III.13 | Risk map - physical assets - Return period = 10 years

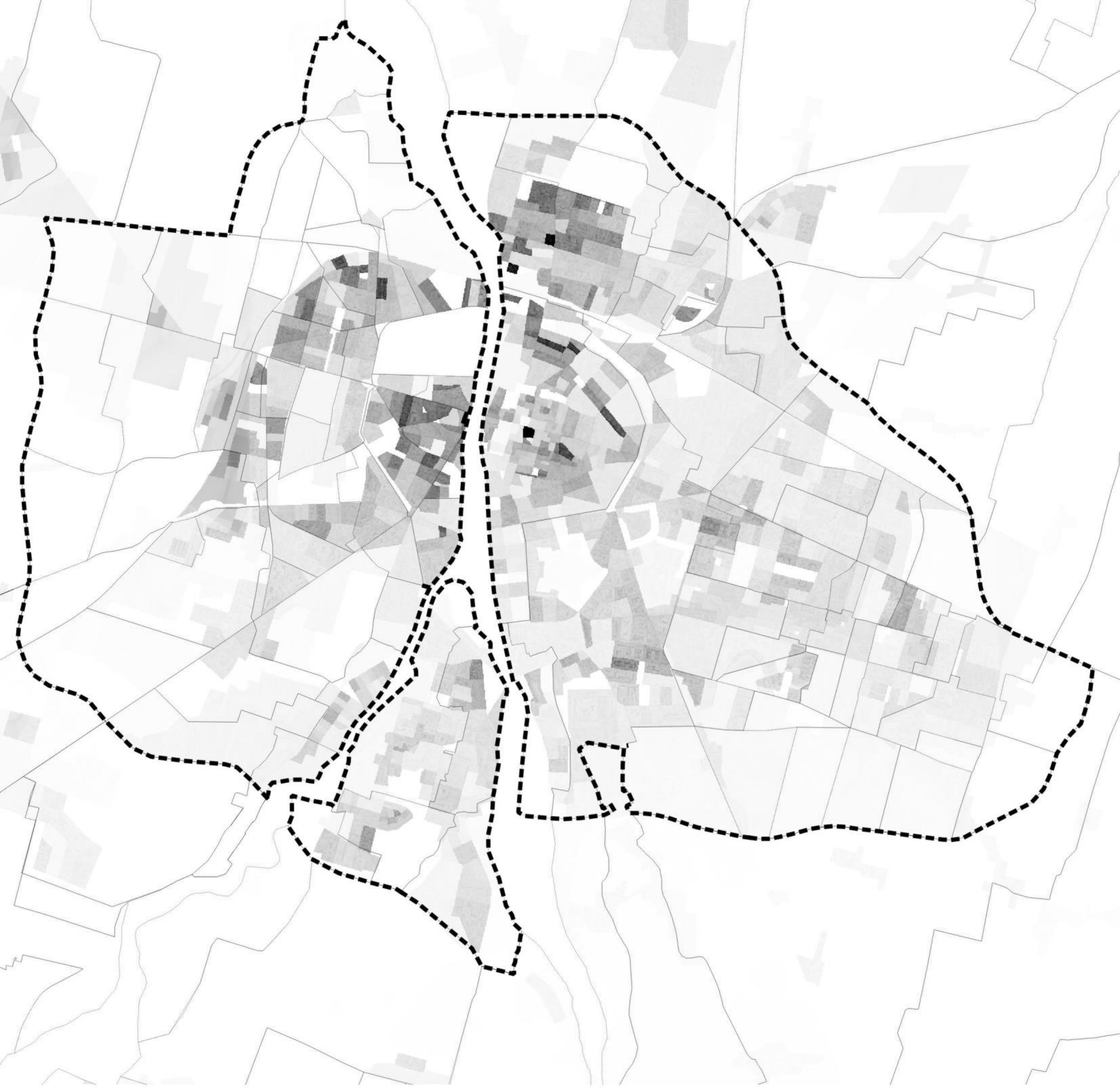


Map III.14 | Risk map - physical assets - Return period = 25 years

Normalised values
1
0

Perimeter of the inner urban area
(area inside the ring road)
Subcatchments

0 0.5 1 1.5 km



Map III.15 | Risk map - population - Return period = 10 years

Based on the population exposure calculated per census section

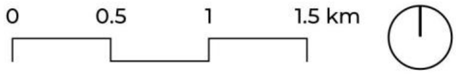
Normalised values

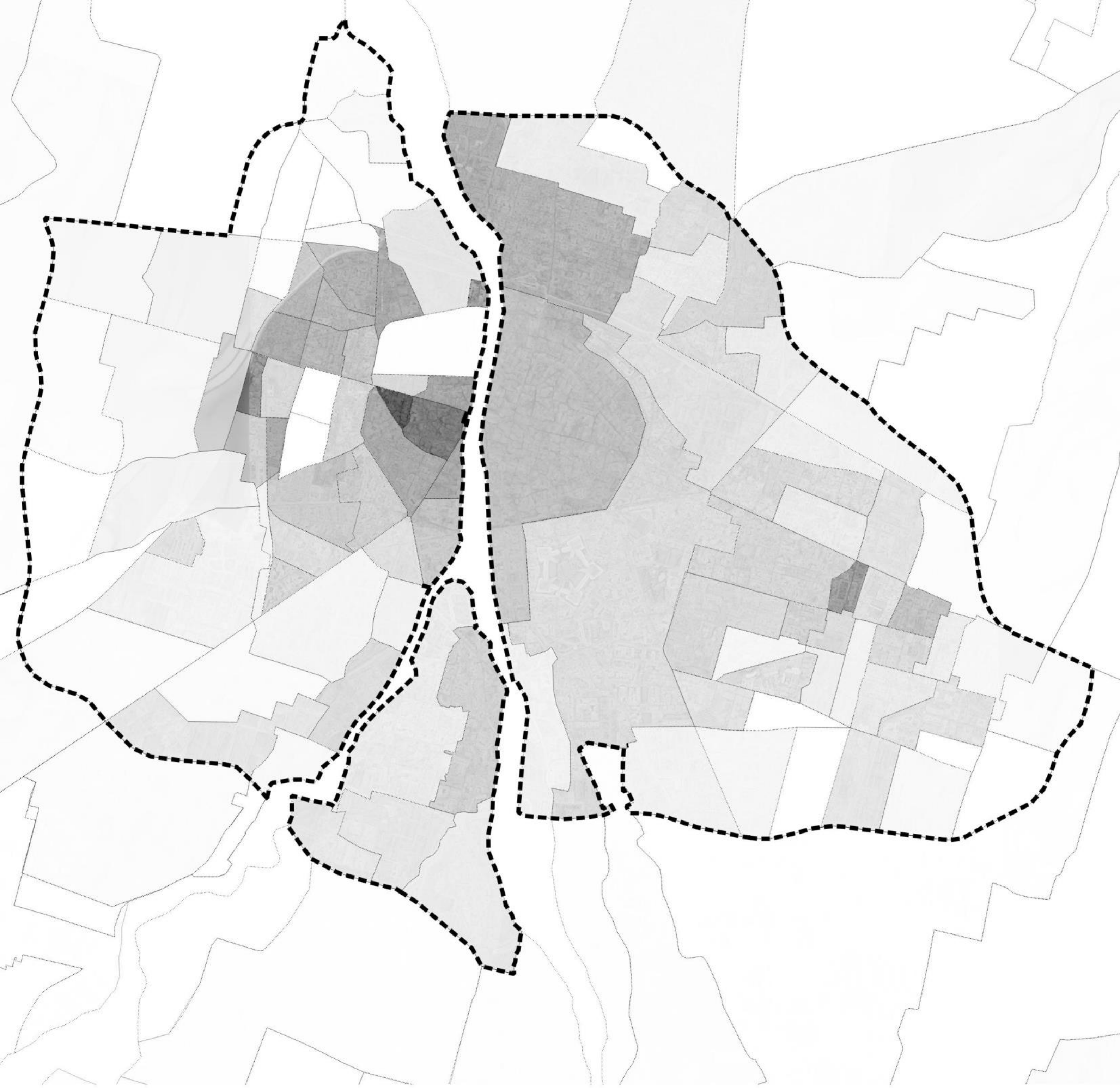
1

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments





Map III.15a | Risk map - population - Return period = 10 years

Based on the population exposure calculated per subcatchment

Normalised values

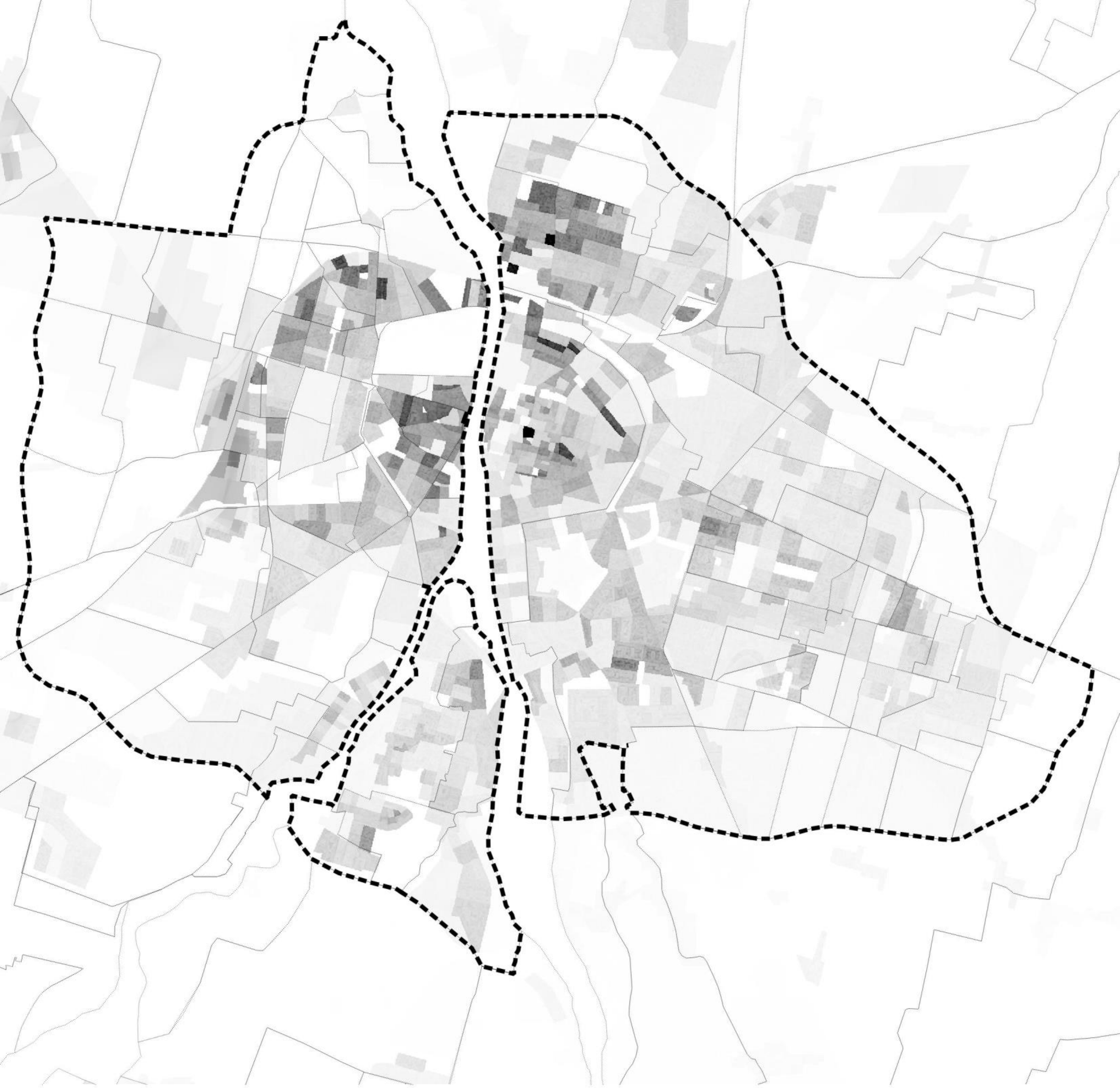
1

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

0 0.5 1 1.5 km



Map III.16 | Risk map - population - Return period = 25 years

Based on the population exposure calculated per census section

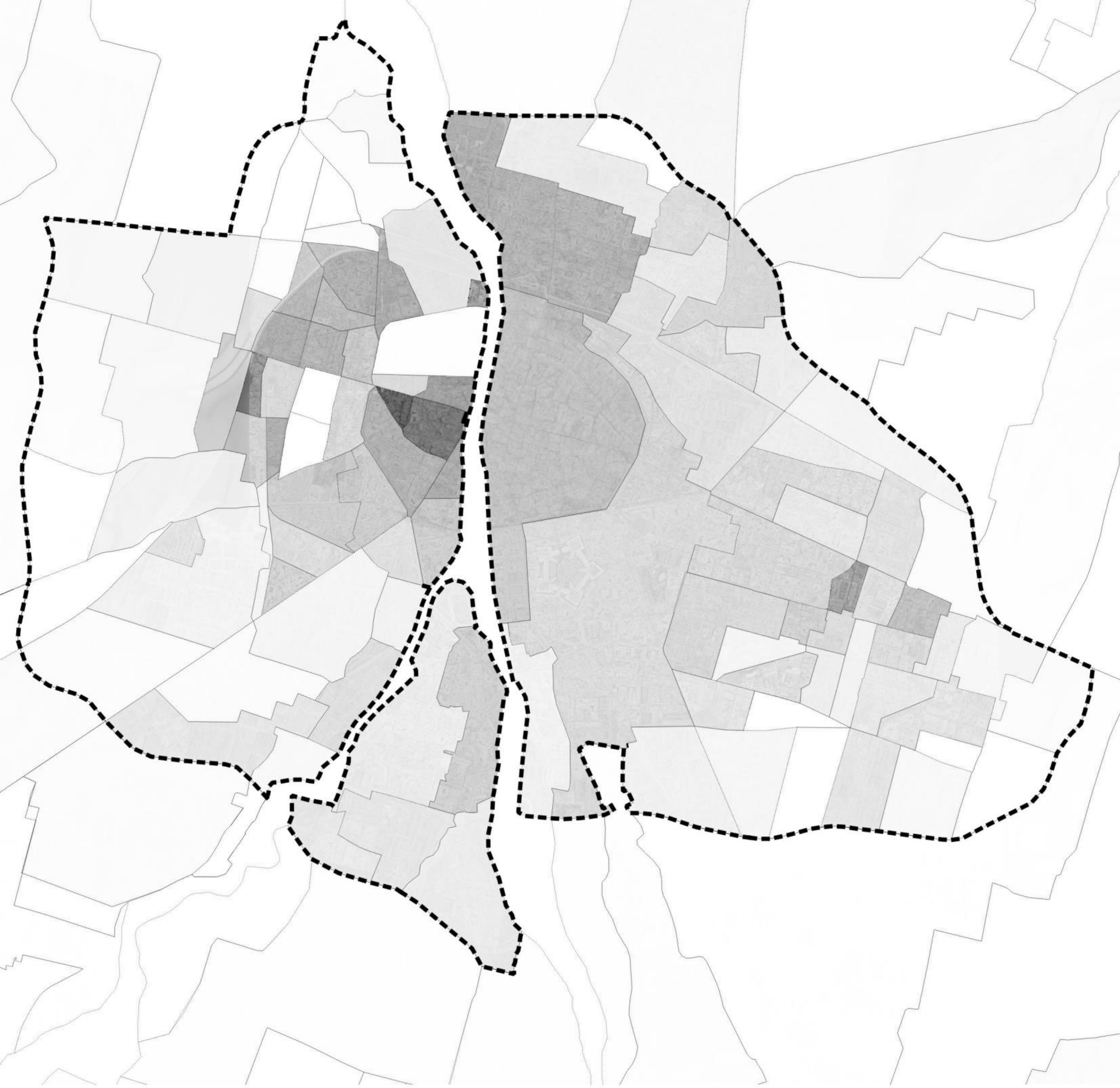
Normalised values

1

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments



Map III.16a | Risk map - population - Return period = 25 years

Based on the population exposure calculated per subcatchment

Normalised values

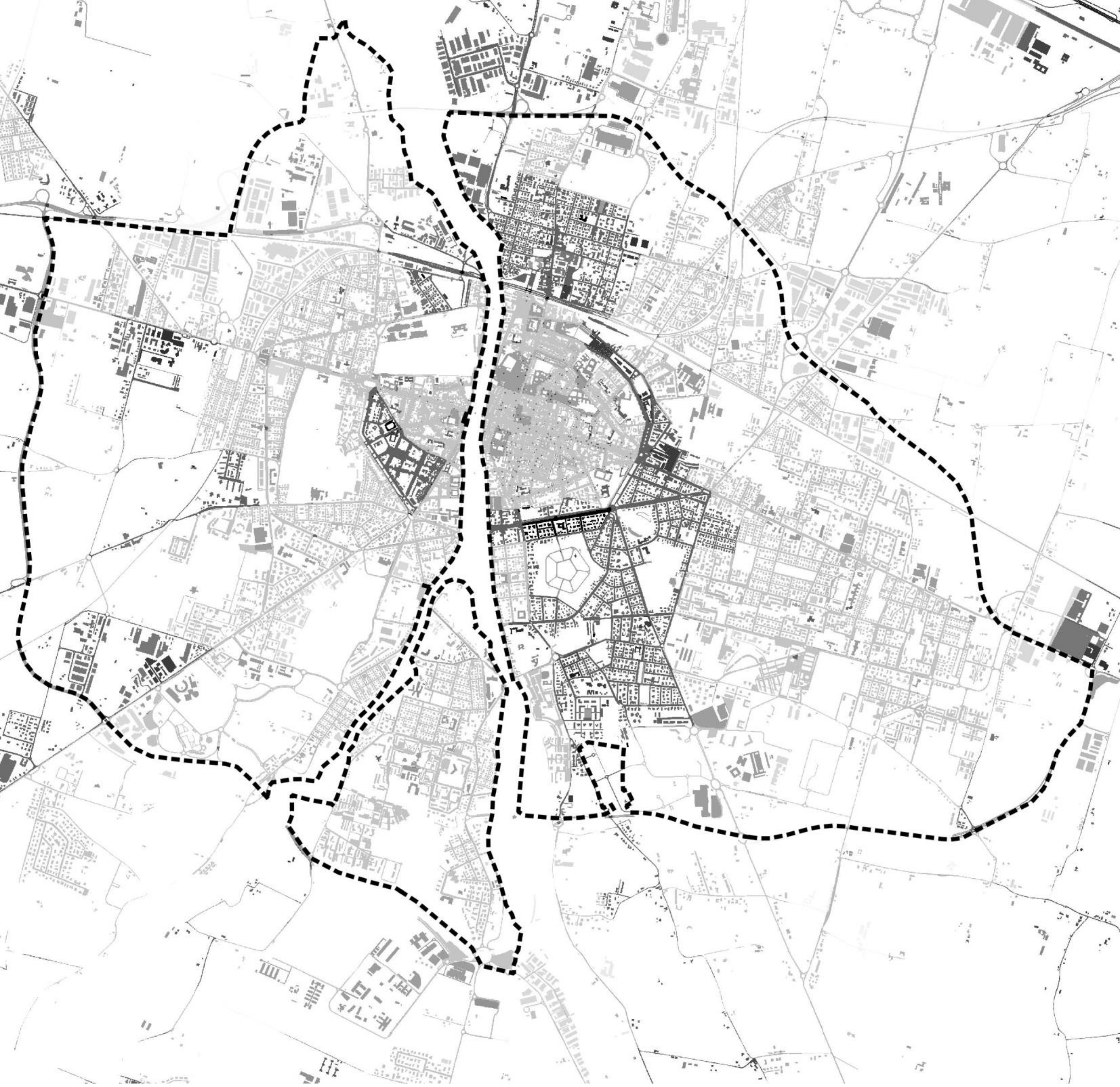
1

0

Perimeter of the inner urban area (area inside the ring road)

Subcatchments

0 0.5 1 1.5 km



Map III.17 | Damage to physical assets – Approach A

Normalised values

1

0

Perimeter of the inner urban area
(area inside the ring road)

0 0.5 1 1.5 km

Map III.18 | Damage to physical assets - Approach B – Buildings – Return period = 10 years

Damage [€/m²]
- 0
- 2.51
- 3.40
- 5.03
- 6.80
- 7.54
- 7.81
- 10.20
- 15.63
- 23.44

Inner urban area
(area inside the ring roads)

0 0.5 1 1.5 km

Map III.19 | Damage to physical assets - Approach B – Buildings – Return period = 25 years

Damage [€/m²]

- 0
- 5.03
- 6.80
- 7.54
- 10.20
- 15.63
- 23.44

Inner urban area
(area inside the ring roads)

0 0.5 1 1.5 km

Map III.20 | Damage to physical assets - Approach B – Rail and road infrastructure – Return period = 10 years

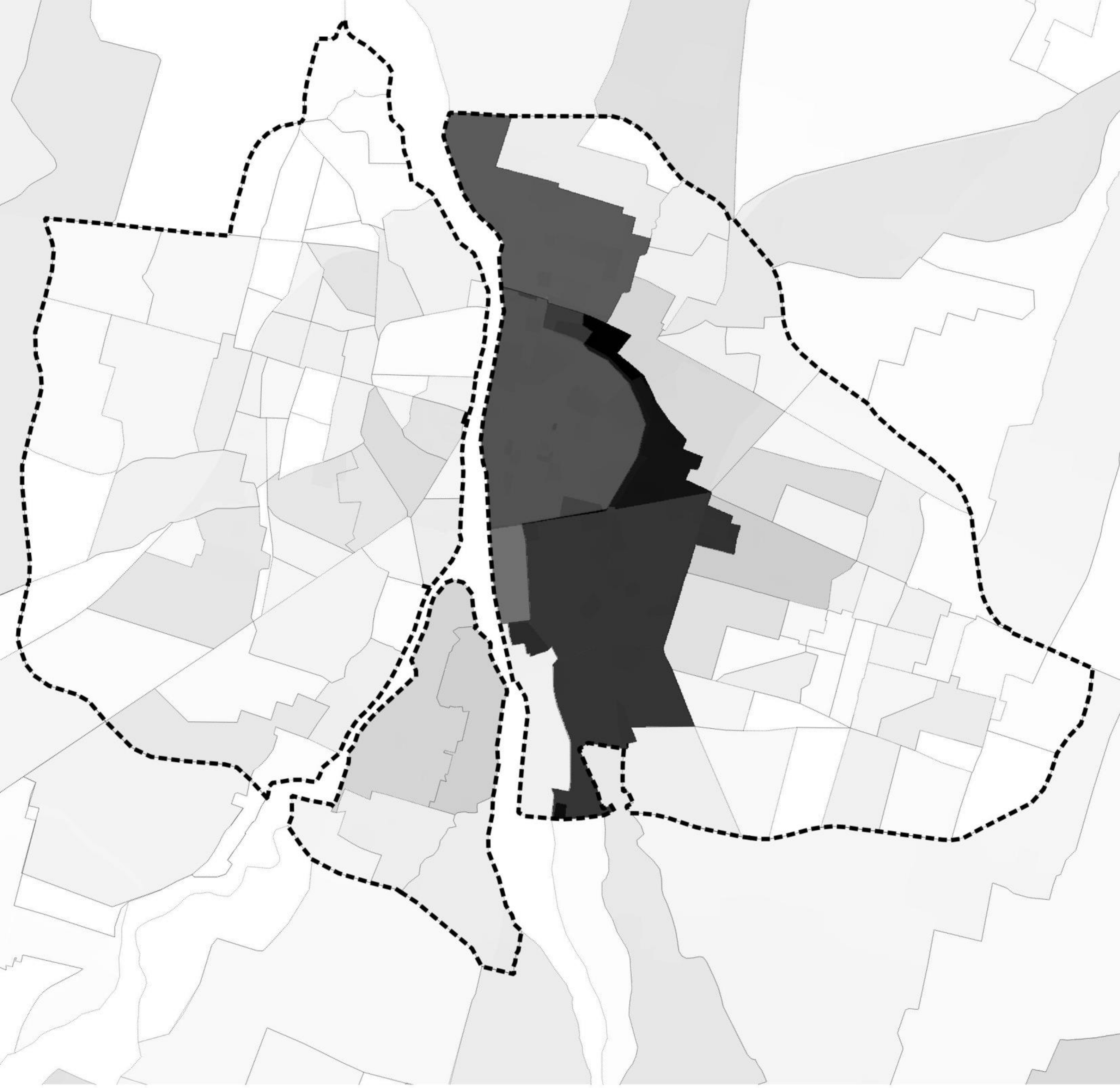
Map III.21 | Damage to physical assets - Approach B – Rail and road infrastructure – Return period = 25 years

Road infrastructure
Damage [€/m²]
0.00
0.19
0.29

Rail infrastructure
Damage [€/m²]
0.00
0.19
0.29

Inner urban area
(area inside the ring roads)

0 0.5 1 1.5 km



Map III.22 | Damage to the population - Approach A

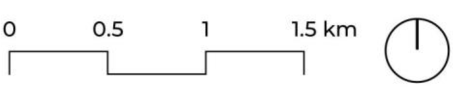
Normalised values

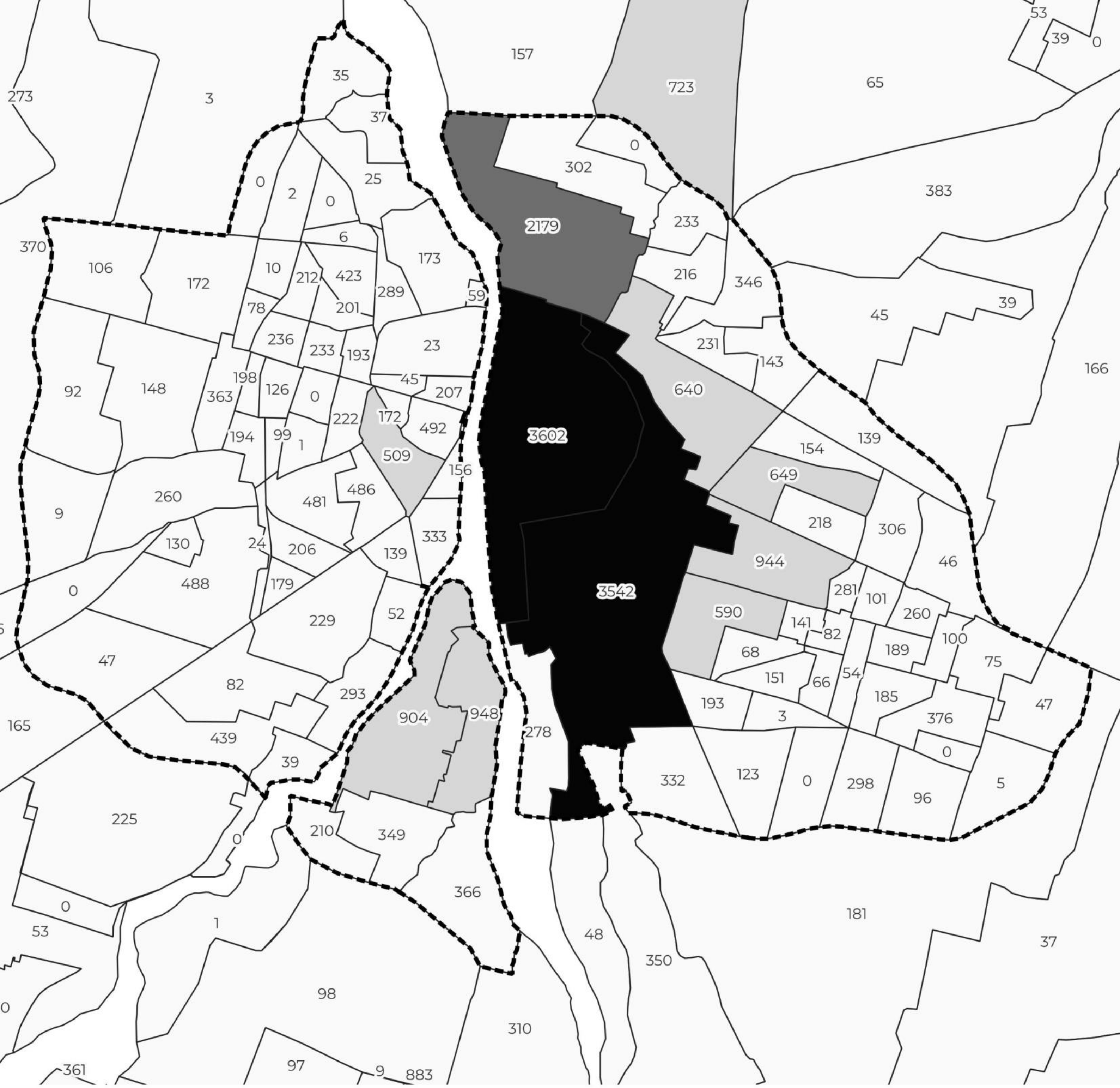
1

0

Perimeter of the inner urban area
(area inside the ring road)

Subactchments





Map III.23 | Damage to the population - Approach B (Rincón et al., 2022) – Return period = 10 years

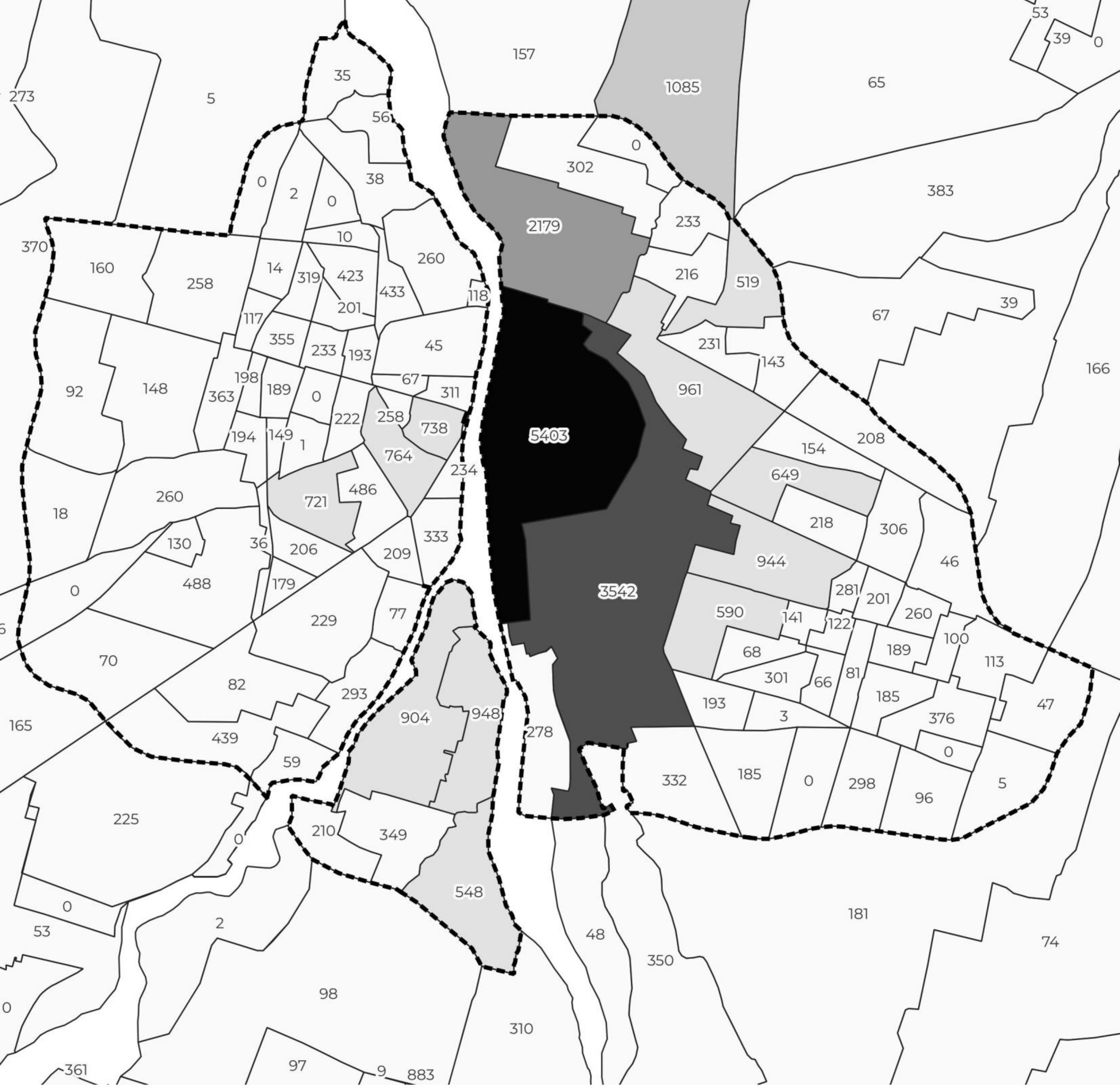
Affected population [n. of people]

- 0 - 500
- 500 - 1000
- 1000 - 1500
- 1500 - 2000
- 2000 - 2500
- 2500 - 3000
- 3000 - 3500
- 3500 - 4000

Inner urban area
(area inside the ring roads)

Historical centre

0 0.5 1 1.5 km



Map III.24 | Damage to the population - Approach B (Rincón et al., 2022) – Return period = 25 years

Population affected [n. of people]

- 0 - 500
- 500 - 1000
- 1000 - 1500
- 1500 - 2000
- 2000 - 2500
- 2500 - 3000
- 3000 - 3500
- 3500 - 4000
- 4000 - 4500
- 4500 - 5000
- 5000 - 5500

Inner urban area (area inside the ring roads)

Historical centre

0 0.5 1 1.5 km

Map III.25 | Damage to the population - Approach B (Jonkman & Asselman, 2003)

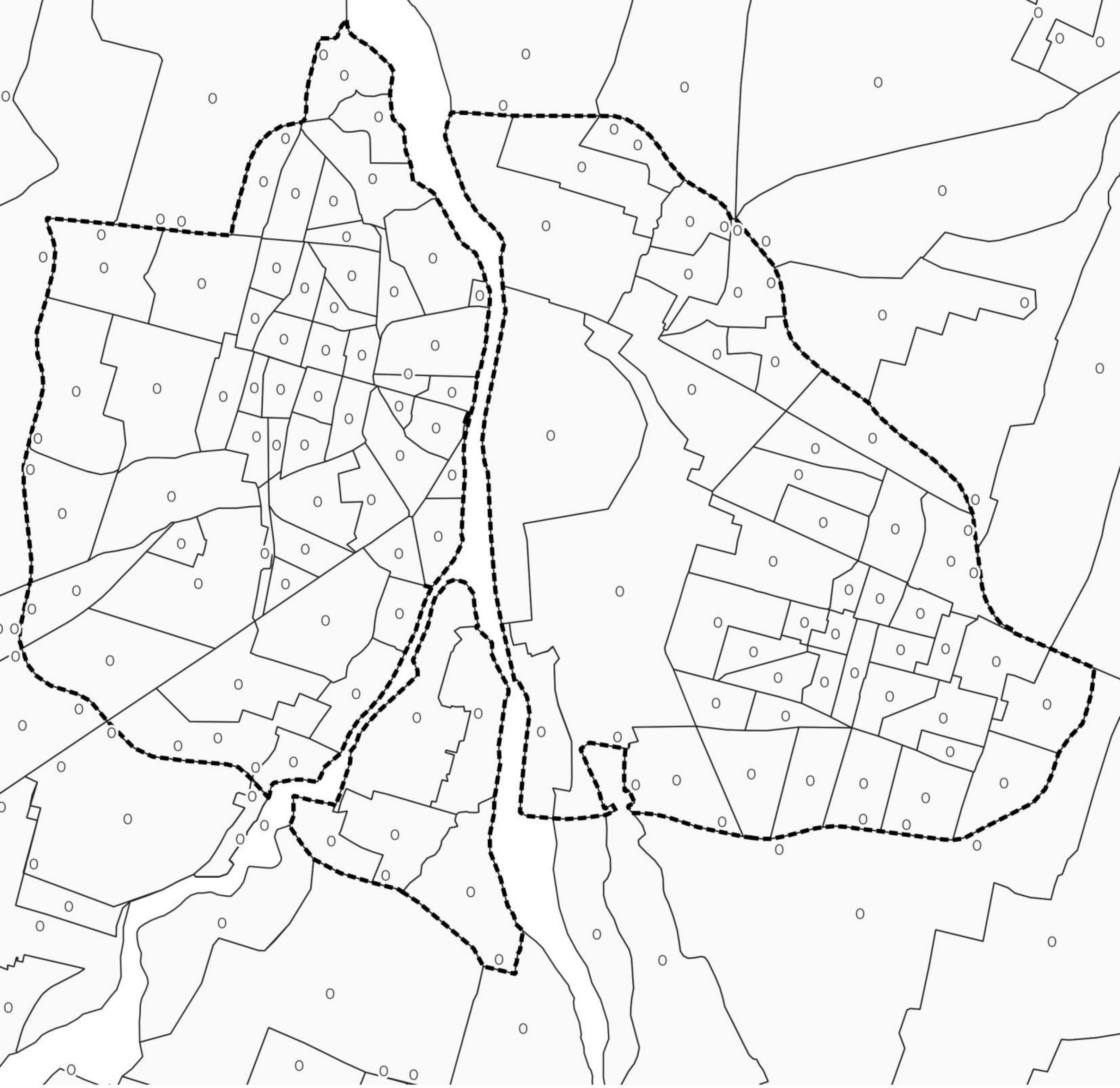
Mortality [n. of people]

- 0
- 1
- 2
- 3
- 4
- 5
- 11
- 18

Inner urban area
(area inside the ring roads)

Historical centre

0 0.5 1 1.5 km



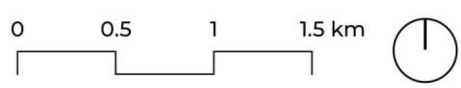
Map III.26 | Damage to the population - Approach B (Russo & Parisani, 2019)

Mortality [n. of people]

0

Inner urban area
(area inside the ring roads)

Historical centre



Map III.27 | Desealing potential

Normalised values

1

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

0 0.5 1 1.5 km

Map III.28 | Desealing potential and opportunities

Normalised values

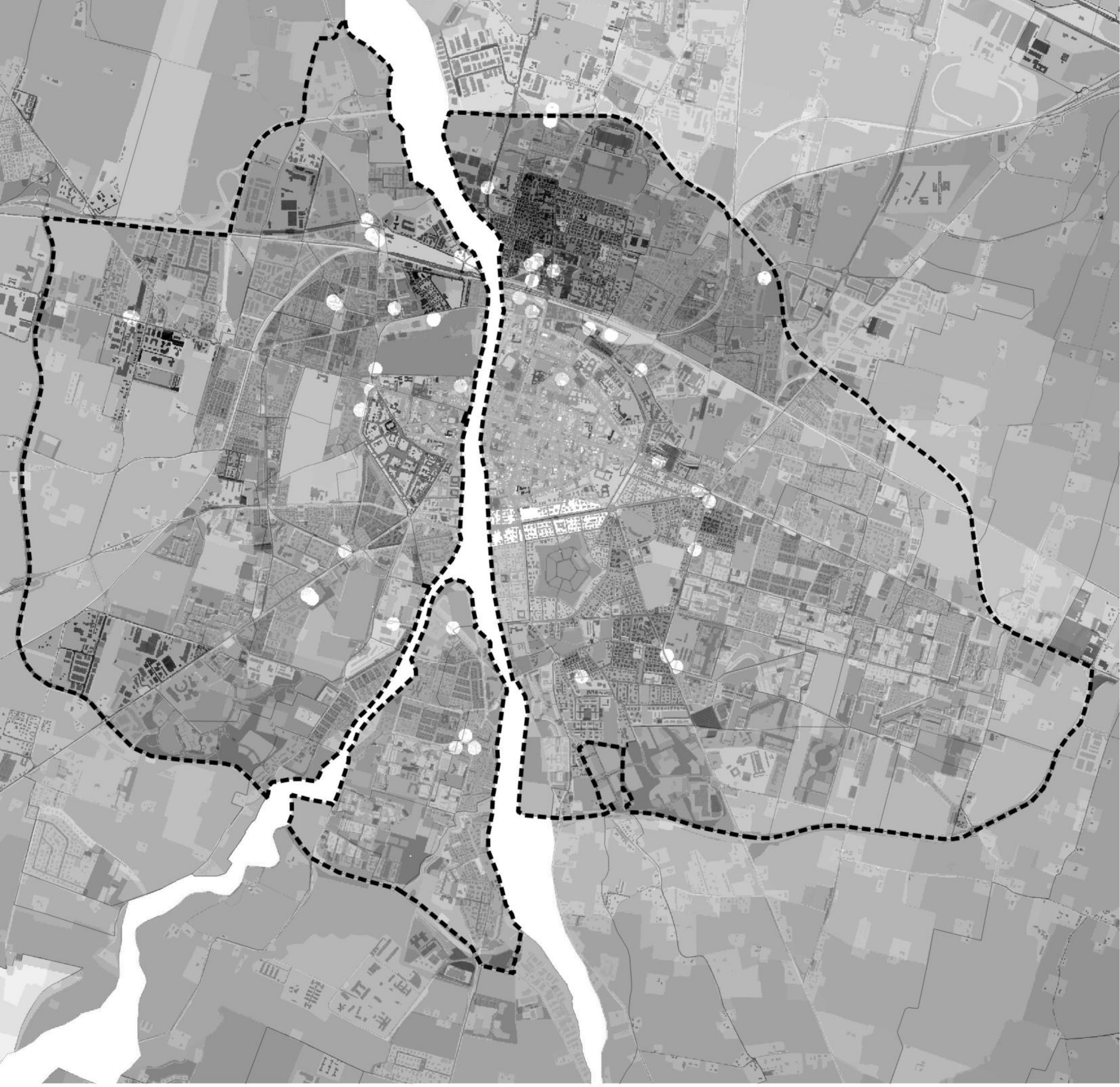
1

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

0 0.5 1 1.5 km



Map III.29 | Overlay of the desealing potential and risk maps - physical assets - Return period = 10 years

Values

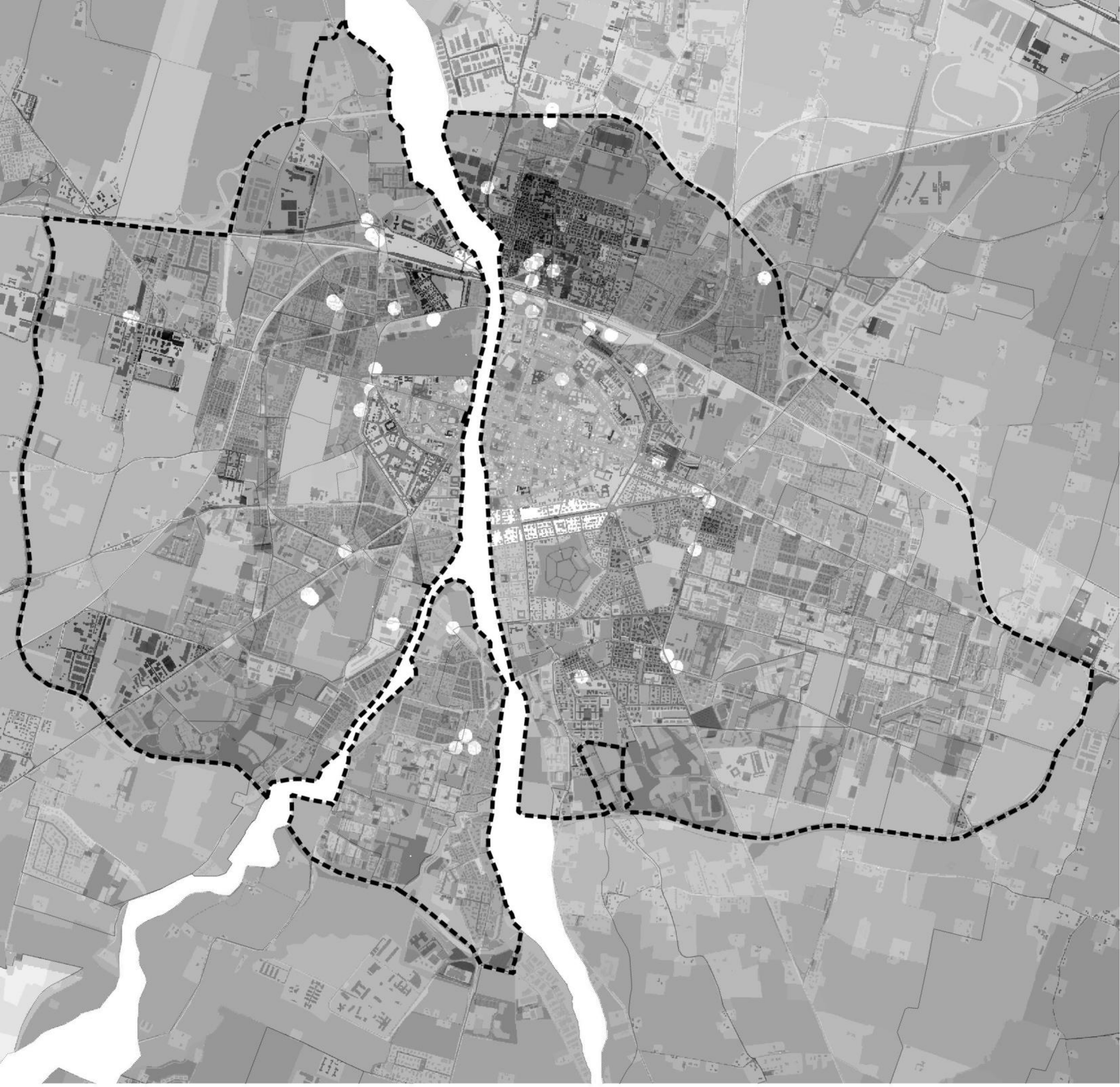
1.48

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

0 0.5 1 1.5 km

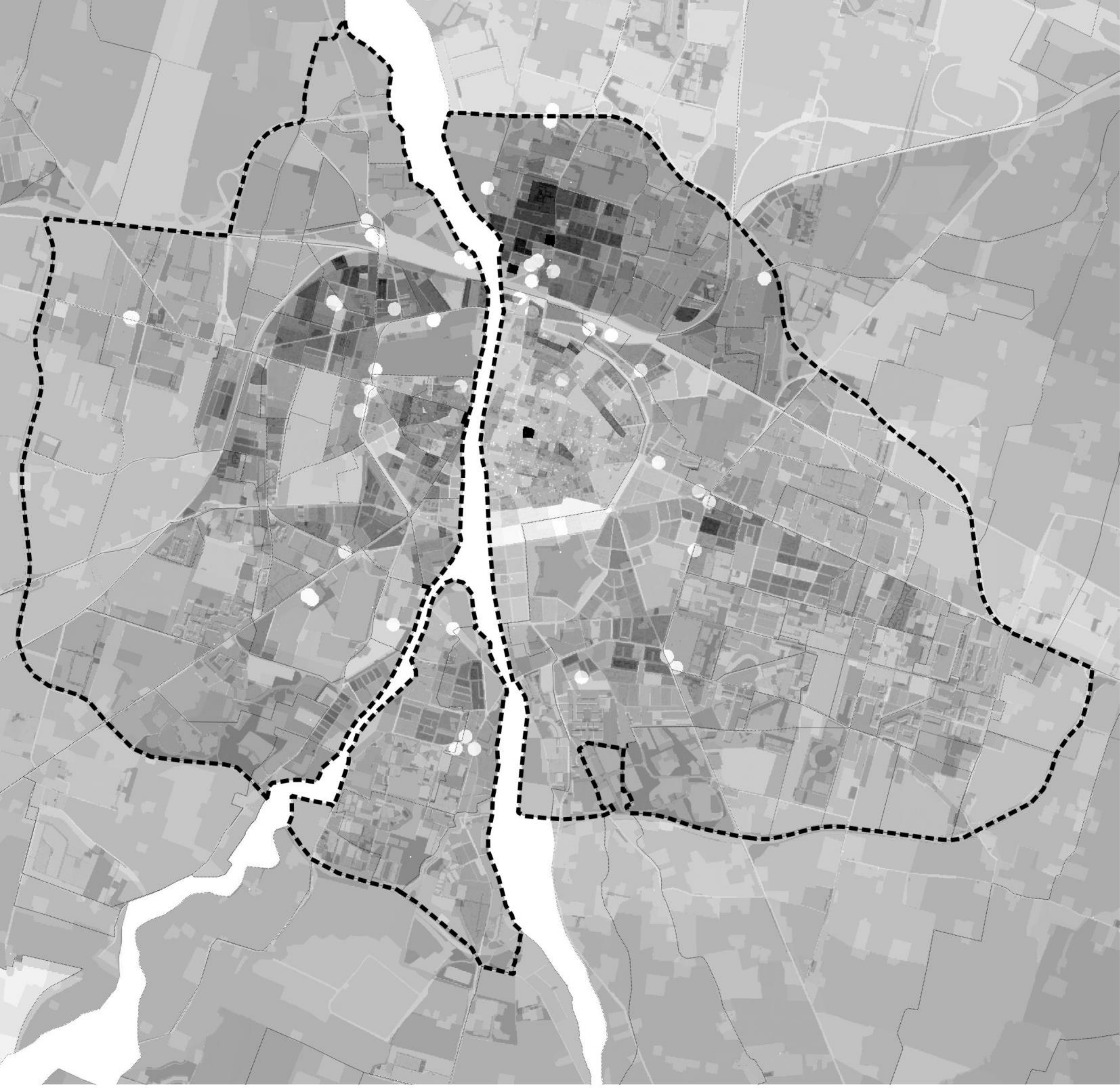


Map III.30 | Overlay of the desealing potential and risk maps - physical assets - Return period = 25 years

Values
1.48
0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments



Map III.31 | Overlay of the desealing potential and risk maps - population - Return period = 10 years

Based on the population exposure calculated per census section

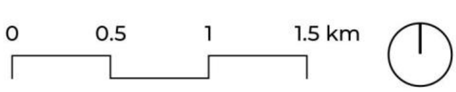
Values

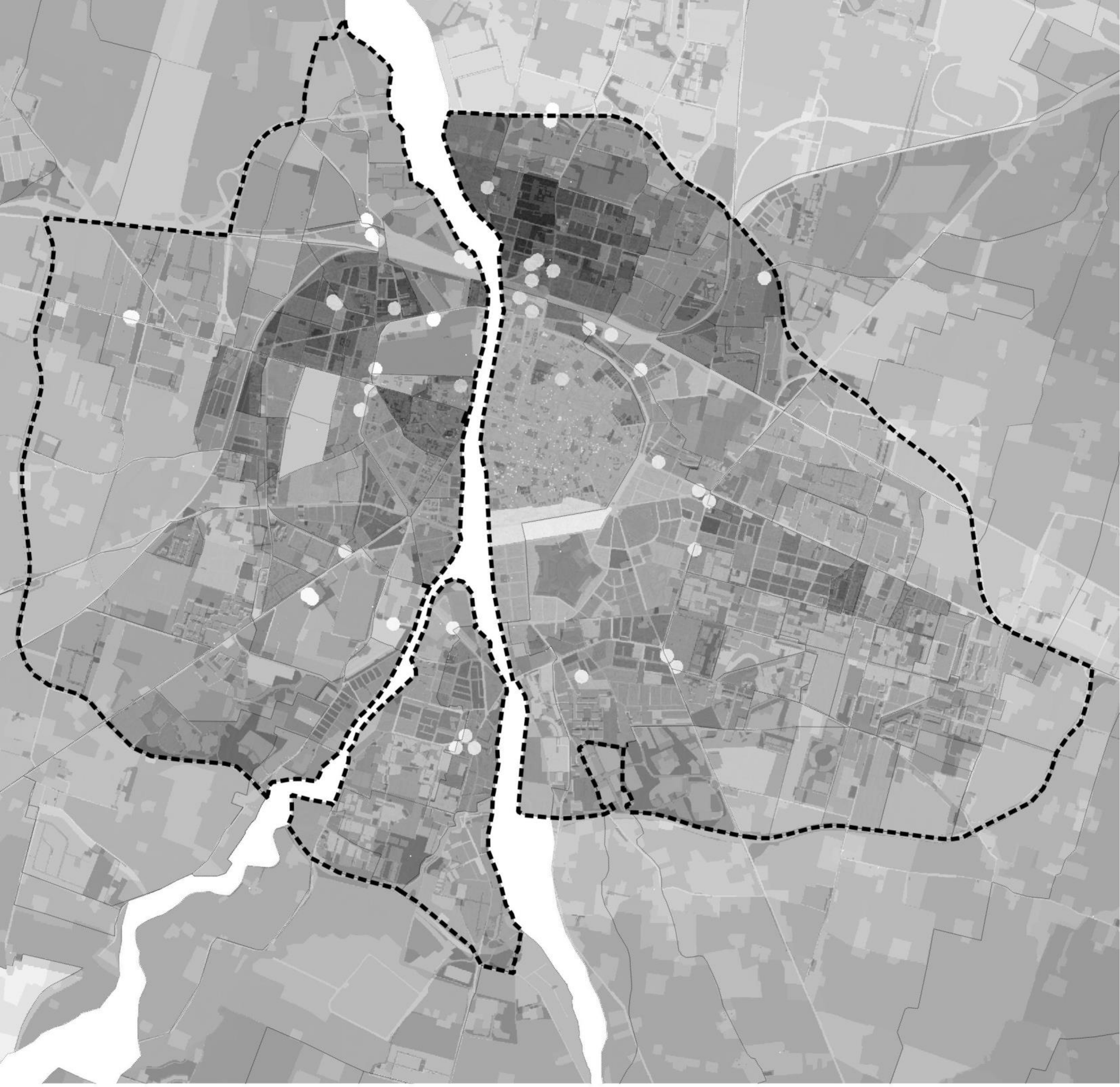
1.69

0

Perimeter of the inner urban area (area inside the ring road)

Subcatchments





Map III.31a | Overlay of the desealing potential and risk maps – population – Return period = 10 years

Based on the population exposure calculated per subcatchment

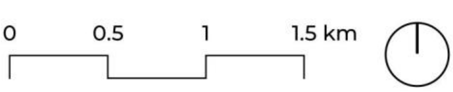
Values

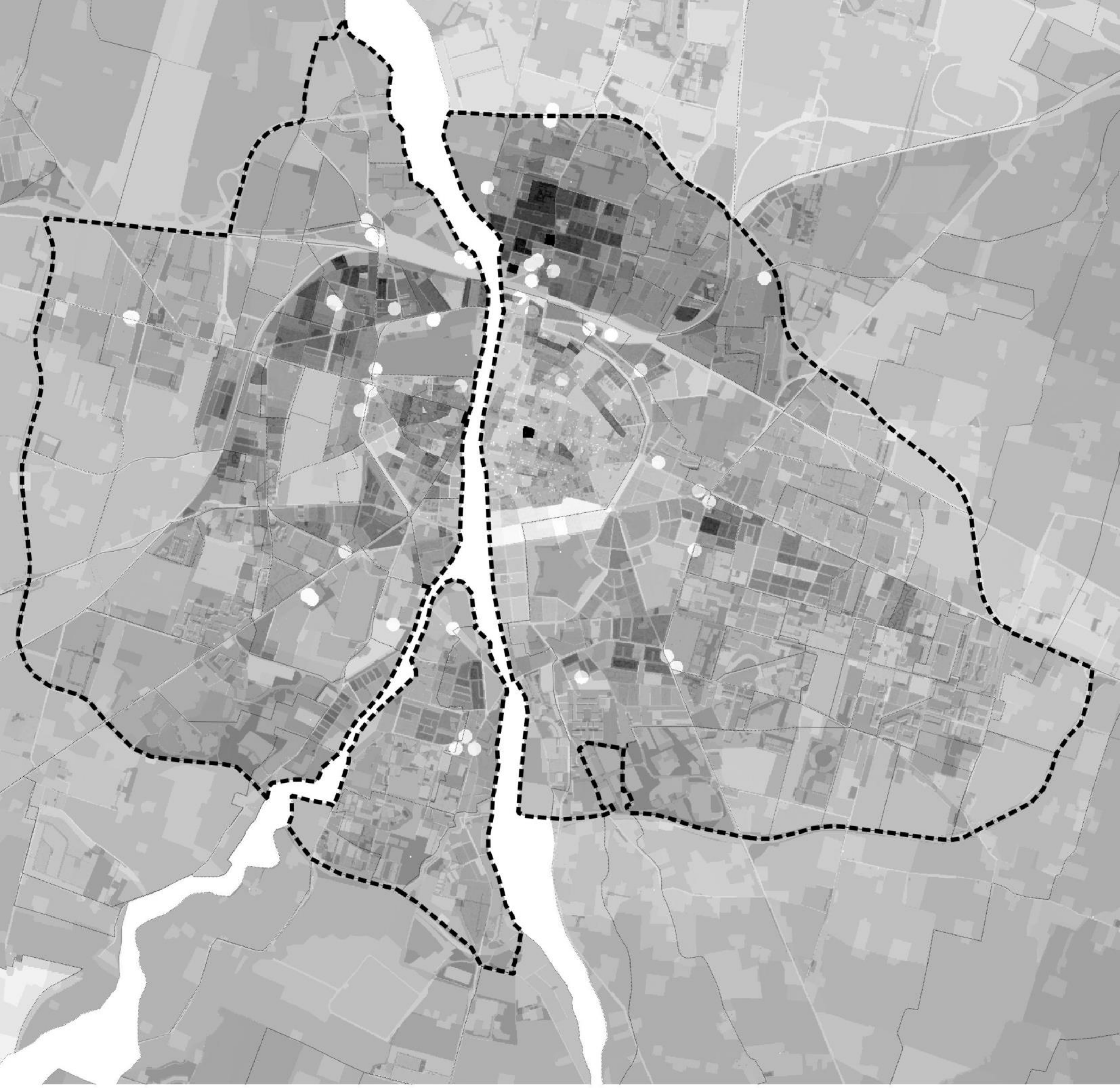
1.58

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments





Map III.32 | Overlay of the desealing potential and risk maps – population – Return period = 25 years

Based on the population exposure calculated per census section

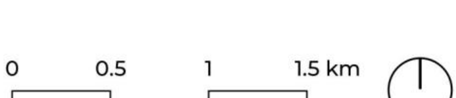
Values

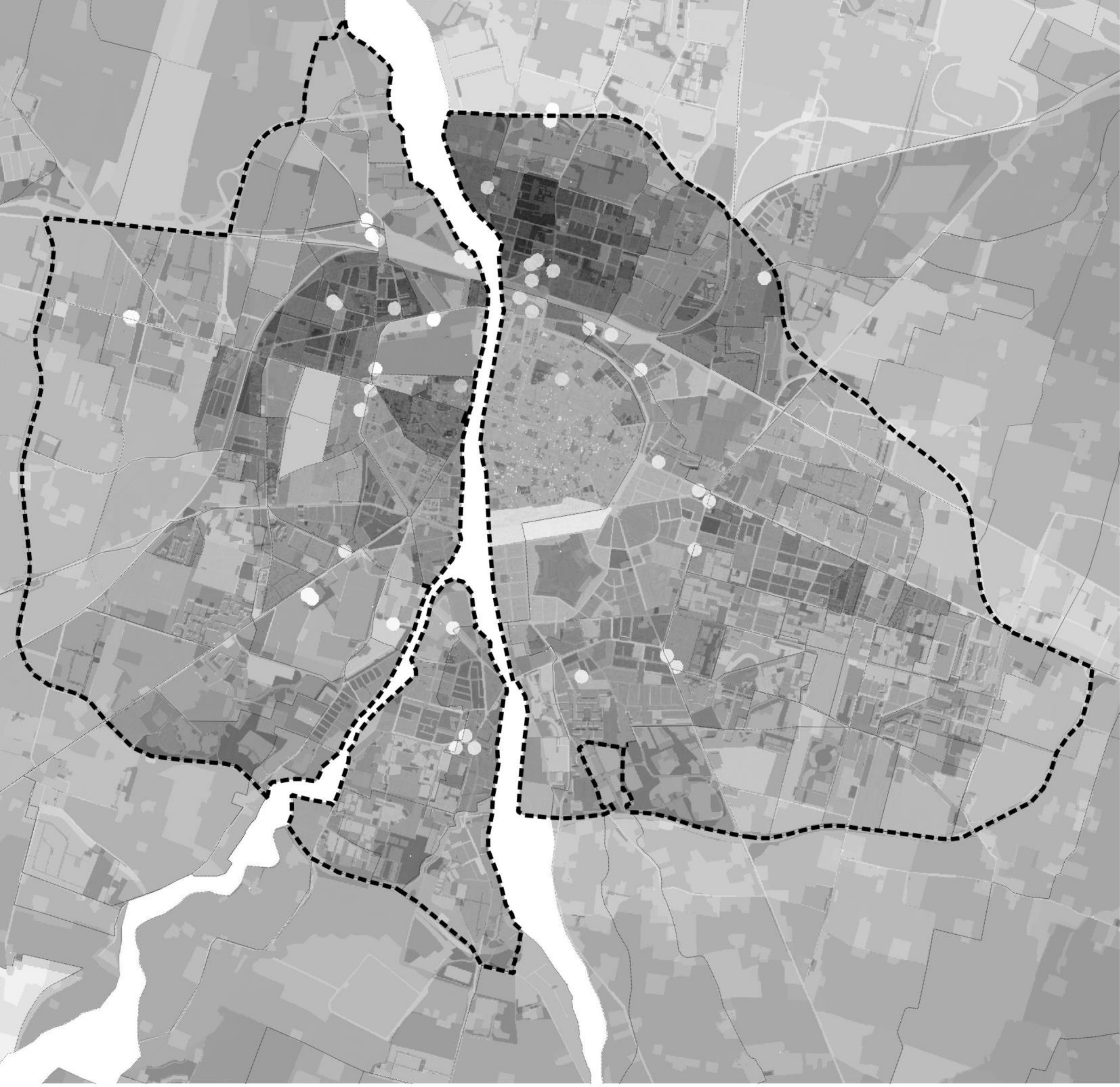
1.71

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments





Map III.32a | Overlay of the desealing potential and risk maps – population – Return period = 25 years

Based on the population exposure calculated per subcatchment

Values

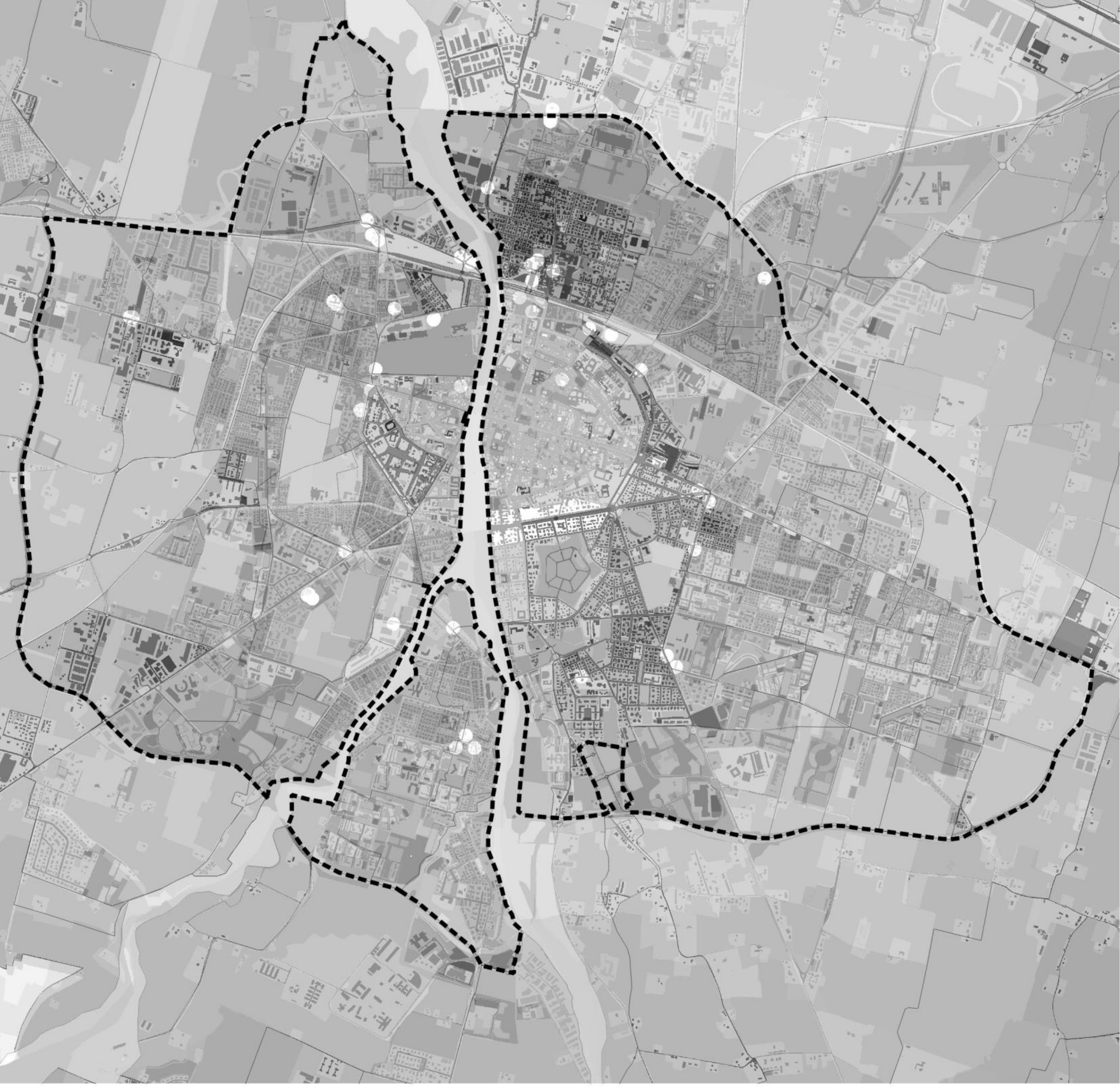
1.58

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

0 0.5 1 1.5 km



Map III.33 | Overlay of the desealing potential and damage maps - physical assets – Approach A

Values

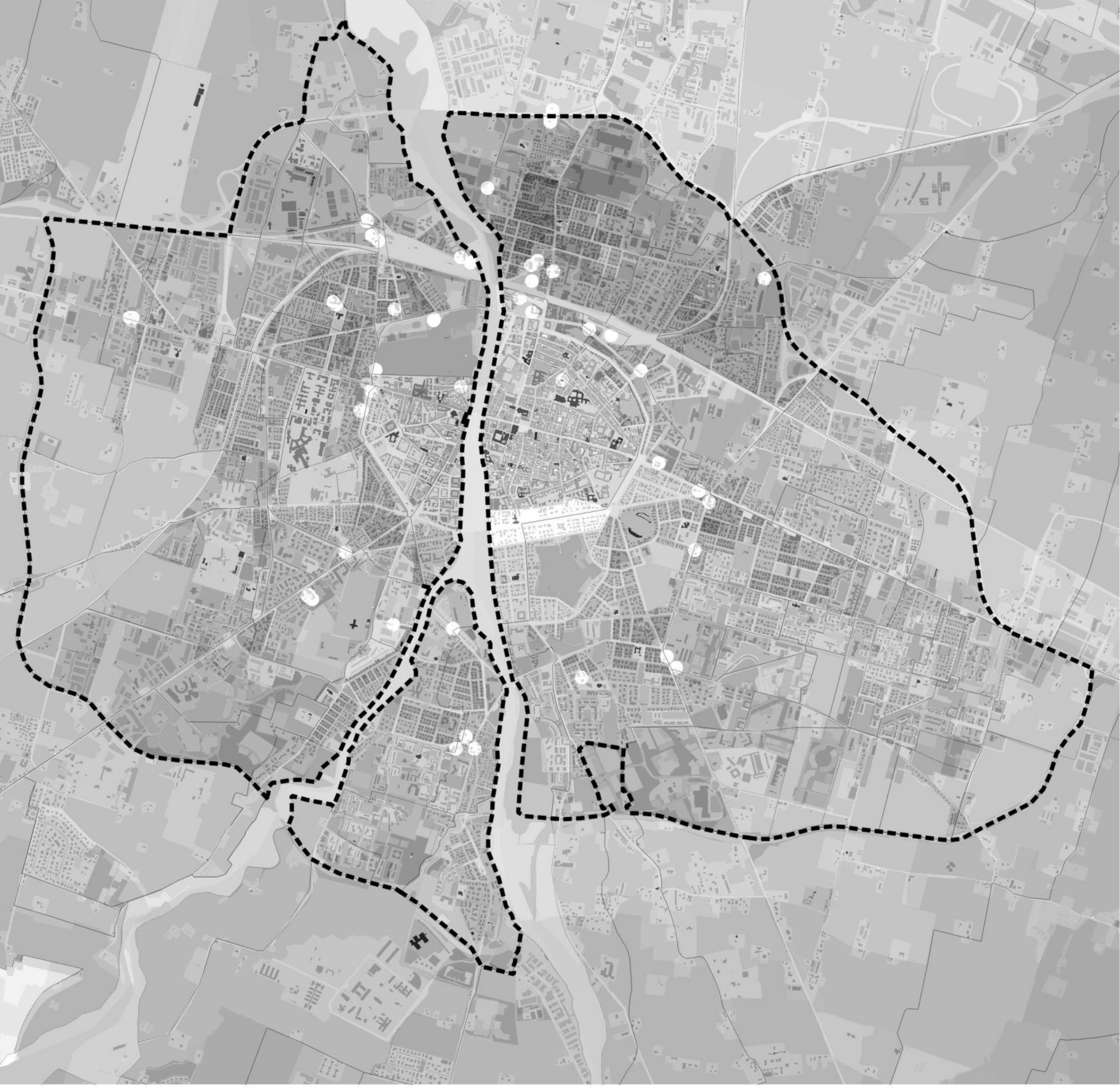
1.86

0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

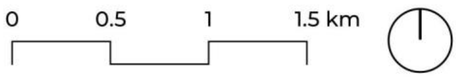
0 0.5 1 1.5 km



Map III.34 | Overlay of the desealing potential and damage maps - physical assets - Approach B
Buildings – Return period = 10 years

Values
1.85
0

Perimeter of the inner urban area
(area inside the ring road)
Subcatchments

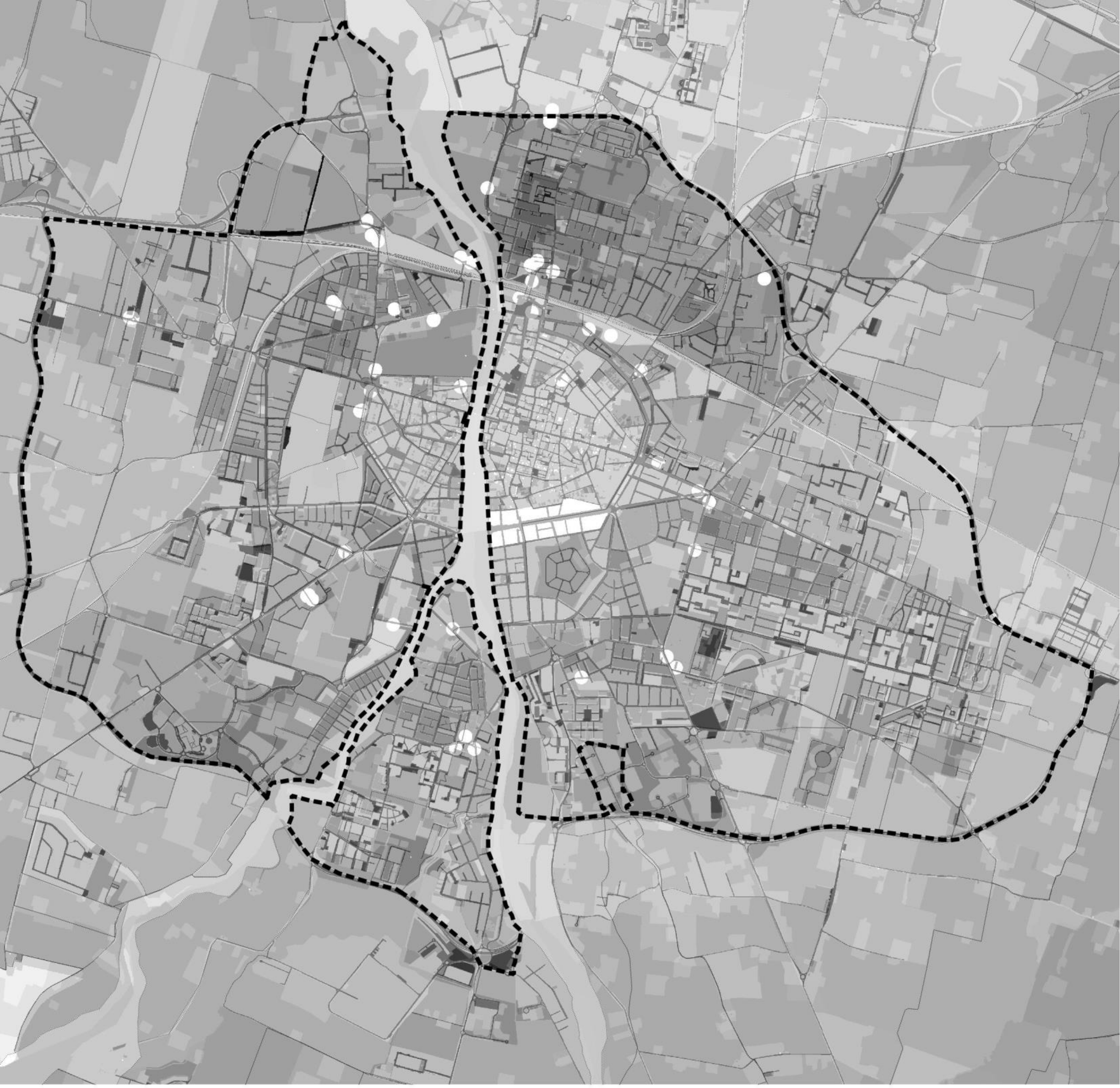


Map III.35 | Overlay of the desealing potential and damage maps - physical assets - Approach B
Buildings – Return period = 25 years

Values
1.51
0

Perimeter of the inner urban area
(area inside the ring road)
Subcatchments

0 0.5 1 1.5 km



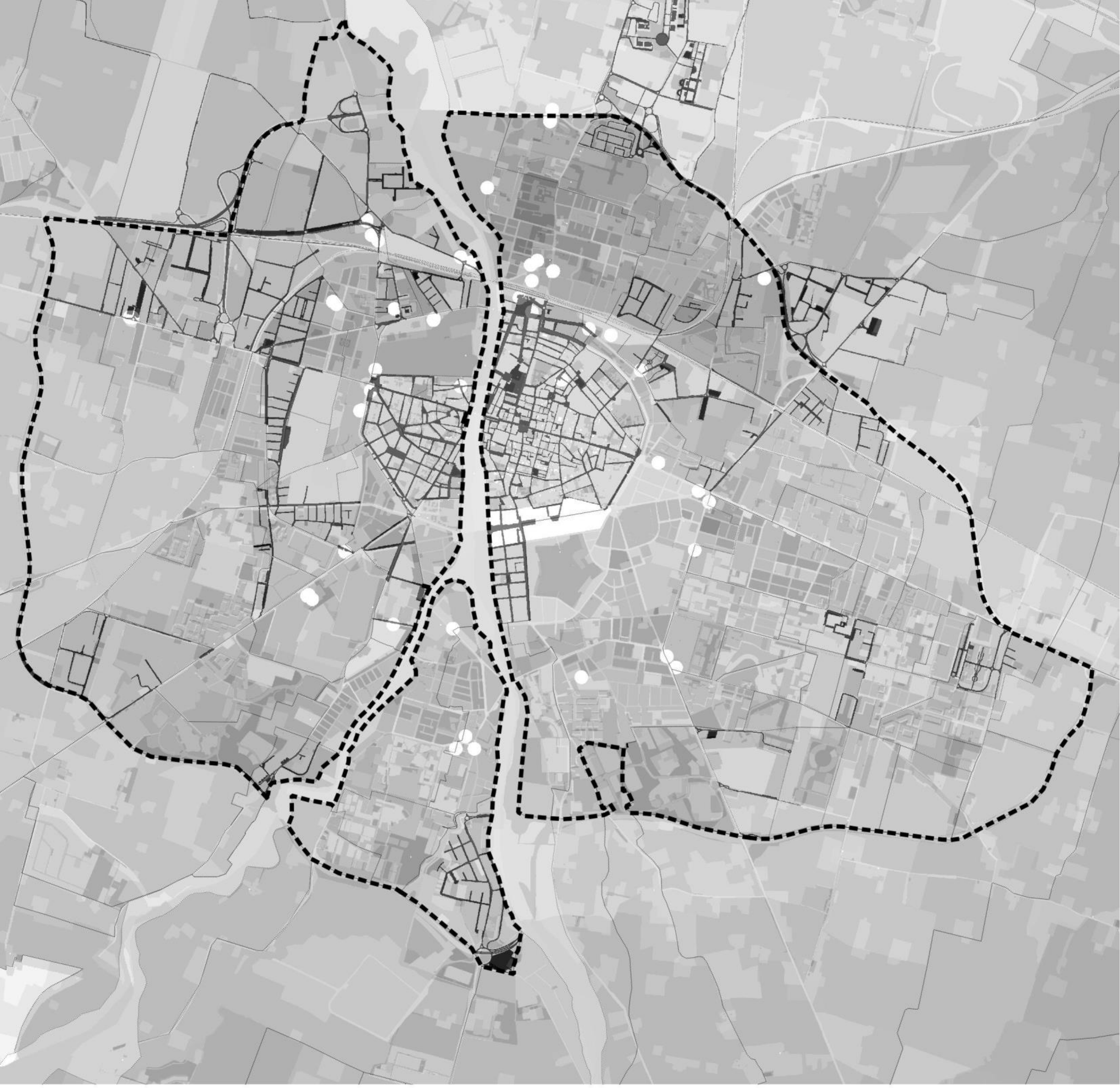
Map III.36 | Overlay of the desealing potential and damage maps - physical assets - Approach B
Rail and road infrastructure – Return period = 10 years

Values
1.61
0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

0 0.5 1 1.5 km



Map III.37 | Overlay of the desealing potential and damage maps - physical assets - Approach B
Rail and road infrastructure – Return period = 25 years

Values
1.96
0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments

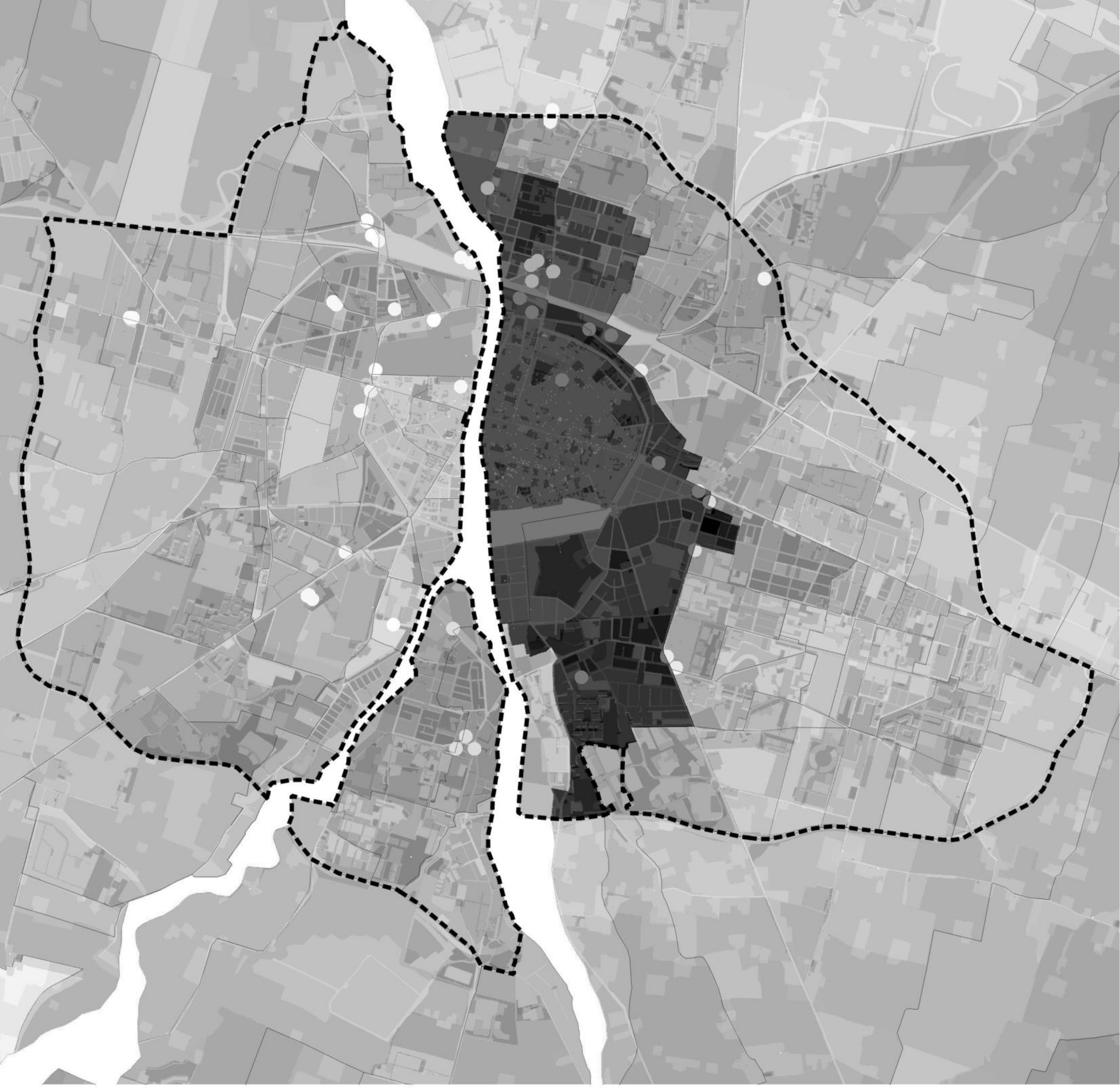
0 0.5 1 1.5 km

Map III.38 | Overlay of the desealing potential and damage maps - population - Approach A

Values
1.76
0

Perimeter of the inner urban area
(area inside the ring road)
Subcatchments

0 0.5 1 1.5 km



Map III.39 | Overlay of the desealing potential and damage maps - population - Approach B (Rincón et al., 2022)
Return period = 10 years

Values
1.84
0

Perimeter of the inner urban area
(area inside the ring road)
Subcatchments

0 0.5 1 1.5 km

Map III.40 | Overlay of the desealing potential and damage maps - population - Approach B (Rincón et al., 2022)
Return period = 25 years

Values
1.72
0

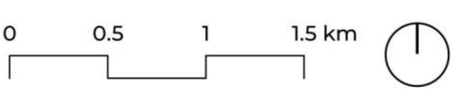
Perimeter of the inner urban area
(area inside the ring road)
Subcatchments

0 0.5 1 1.5 km

Map III.41 | Overlay of the desealing potential and damage maps - population - Approach B (Jonkman & Asselman, 2003)

Values
1.86
0

Perimeter of the inner urban area
(area inside the ring road)
Subcatchments

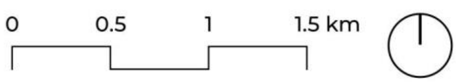


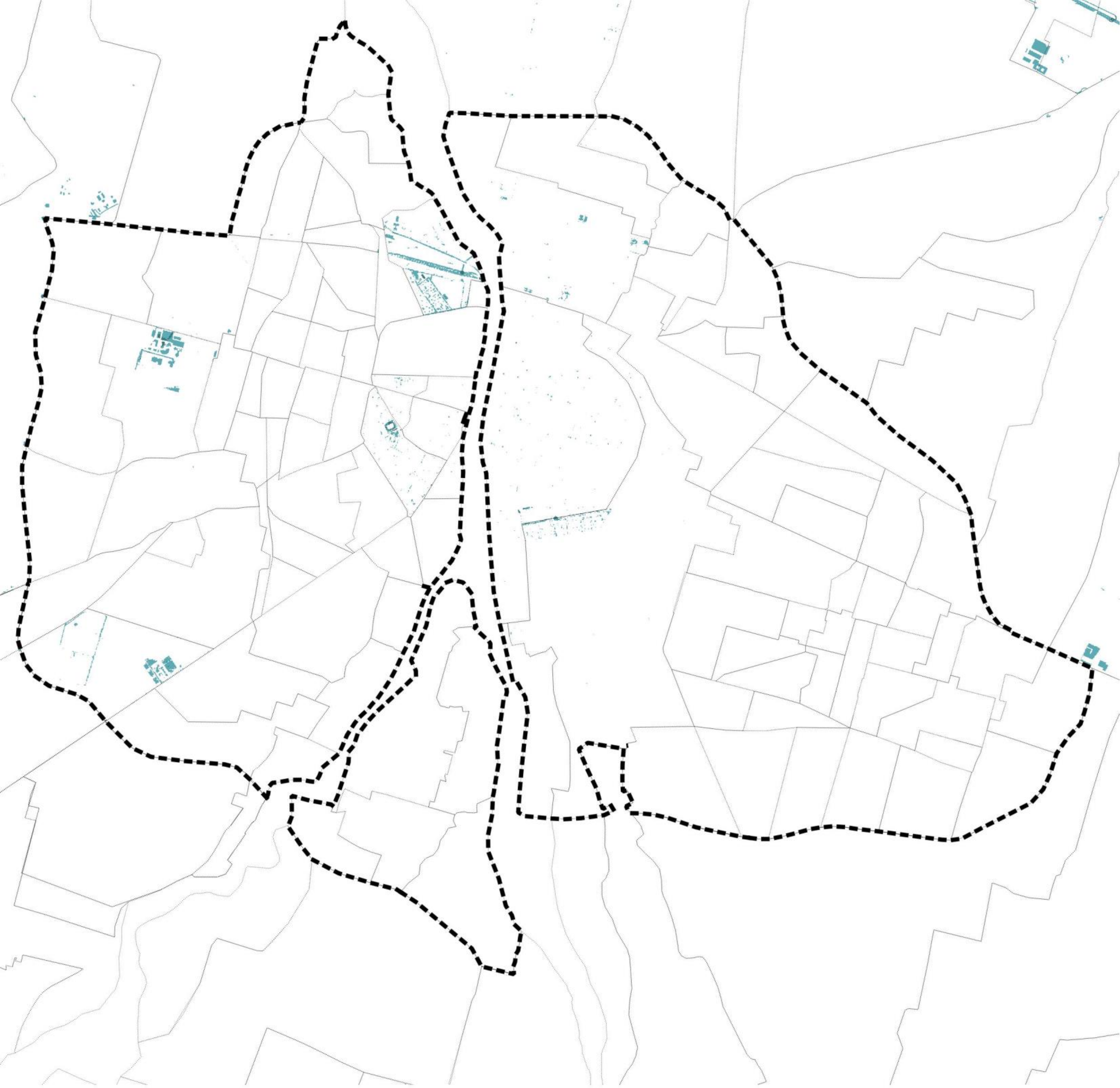
Map III.42 | Overlay of the desealing potential and damage maps - population - Approach B (Russo & Parisani, 2019)

Values
1
0

Perimeter of the inner urban area
(area inside the ring road)

Subcatchments





Map III.43 | Five-level risk maps - physical assets - Return period = 10 years

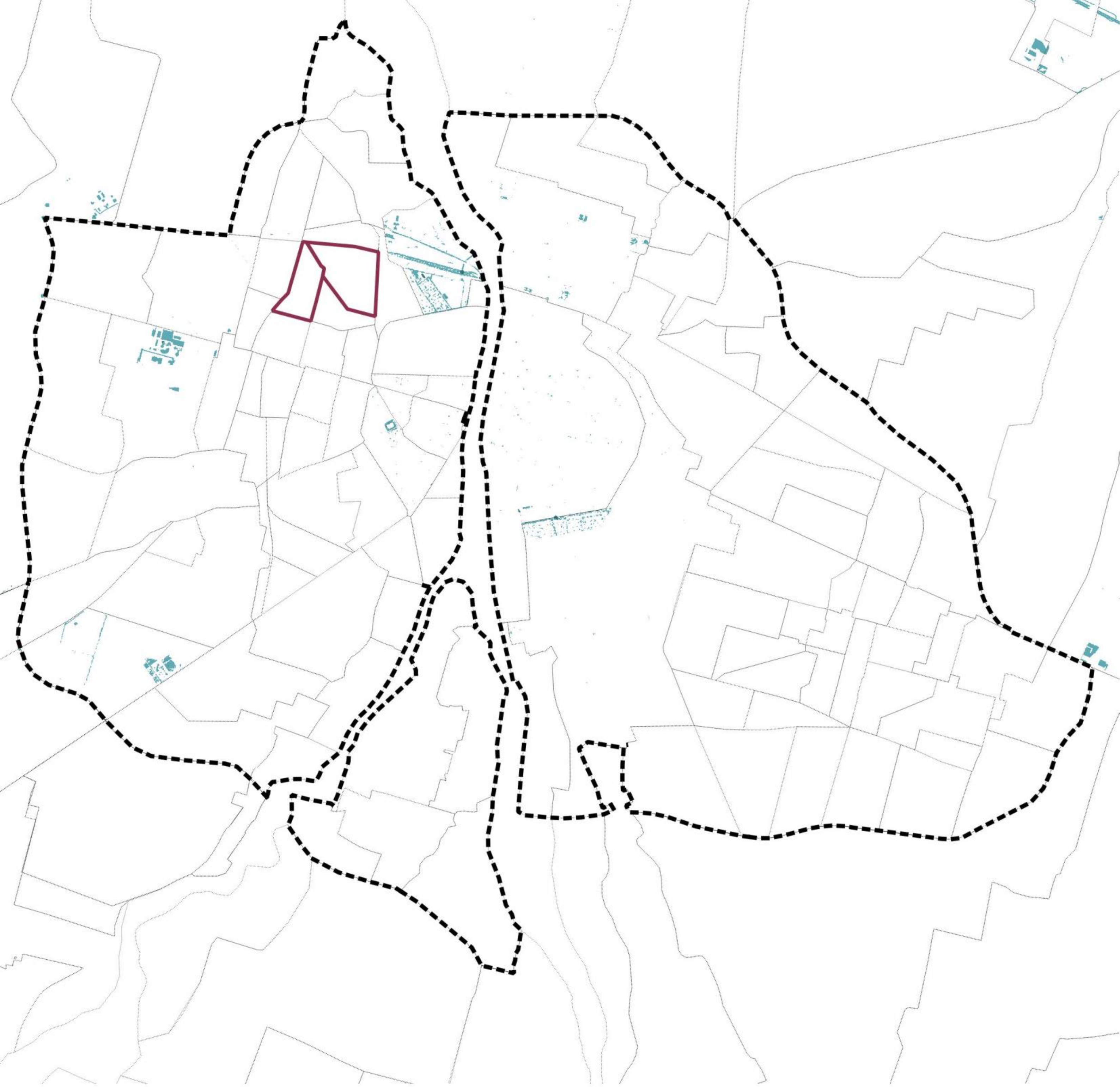
Normalised values ranges

- <= 0.20
- 0.20 - 0.40
- 0.40 - 0.60
- 0.60 - 0.80
- > 0.80

Perimeter of the inner urban area (area inside the ring road)

Subcatchments

0 0.5 1 1.5 km

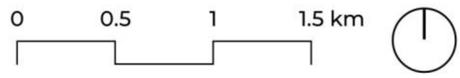


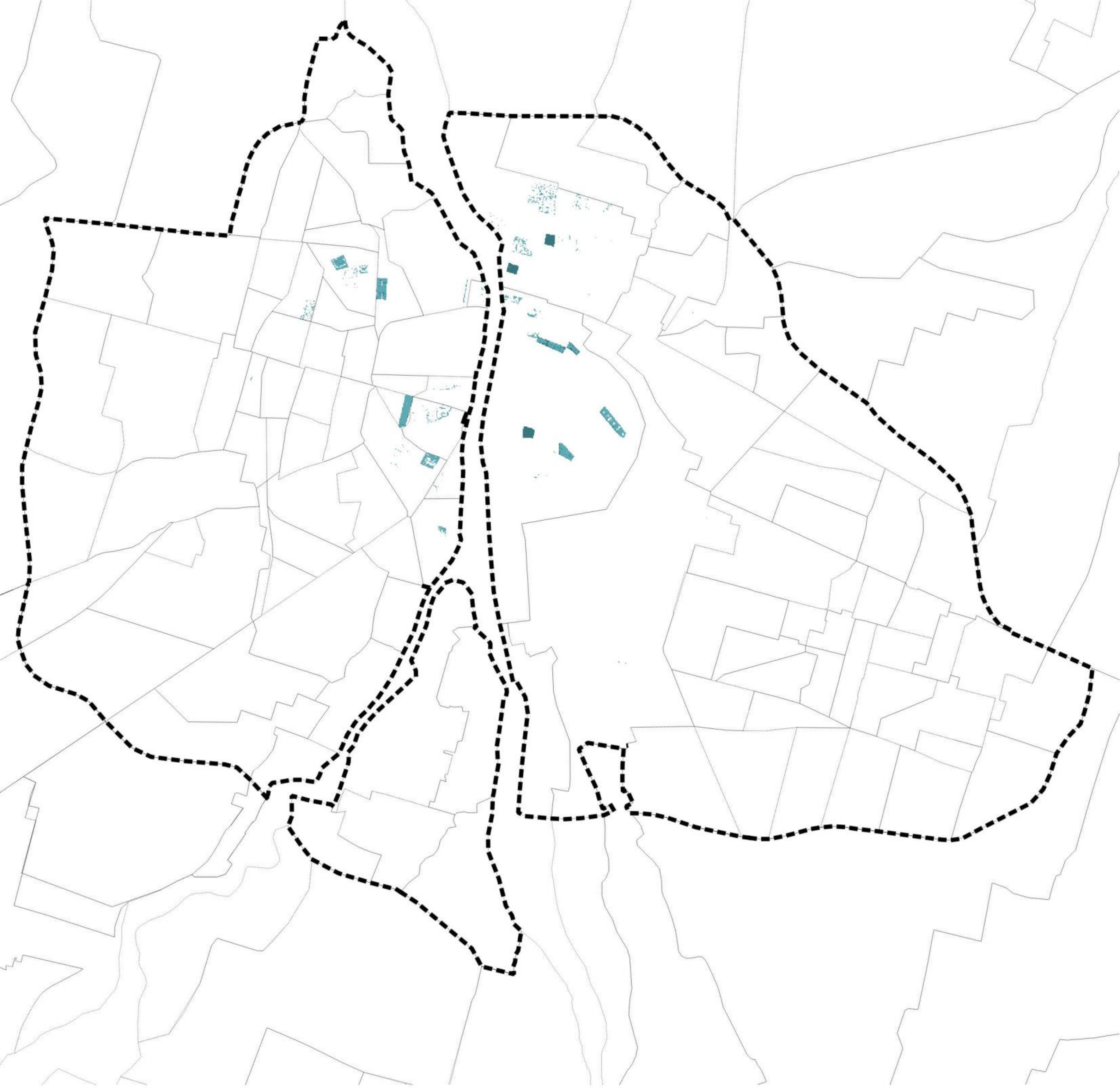
Map III.44 | Five-level risk maps - physical assets - Return period = 25 years

Normalised values ranges

- <= 0.20
- 0.20 - 0.40
- 0.40 - 0.60
- 0.60 - 0.80
- > 0.80

- Perimeter of the inner urban area (area inside the ring road)
- Subcatchments
- Study area





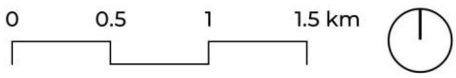
Map III.45 | Five-level risk maps - population - Return period = 10 years

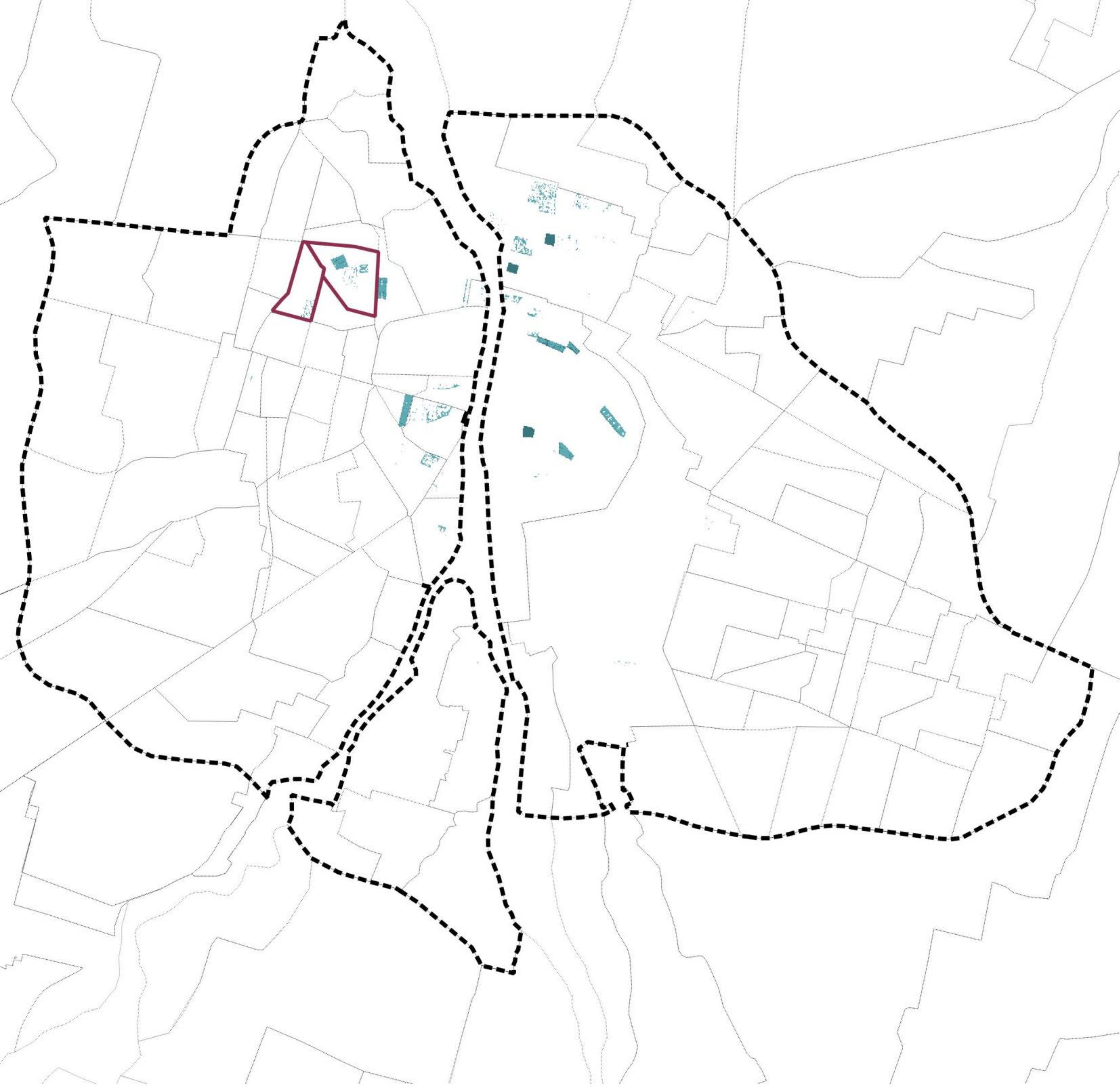
Normalised values ranges

- <= 0.20
- 0.20 - 0.40
- 0.40 - 0.60
- 0.60 - 0.80
- > 0.80

Perimeter of the inner urban area (area inside the ring road)

Subcatchments





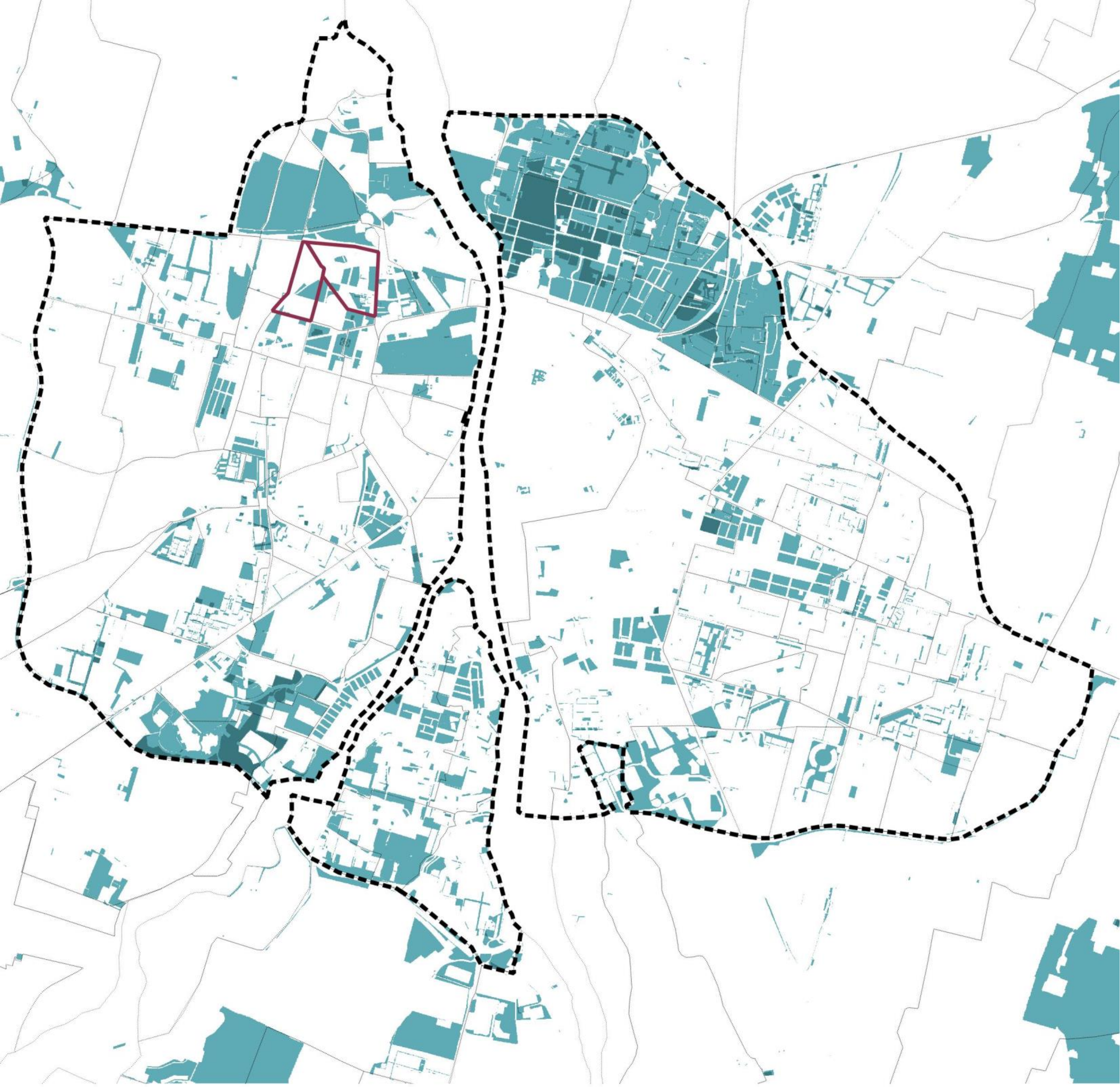
Map III.46 | Five-level risk maps - population - Return period = 25 years

Normalised values ranges

- <= 0.20
- 0.20 - 0.40
- 0.40 - 0.60
- 0.60 - 0.80
- > 0.80

- Perimeter of the inner urban area (area inside the ring road)
- Subcatchments
- Study area

0 0.5 1 1.5 km



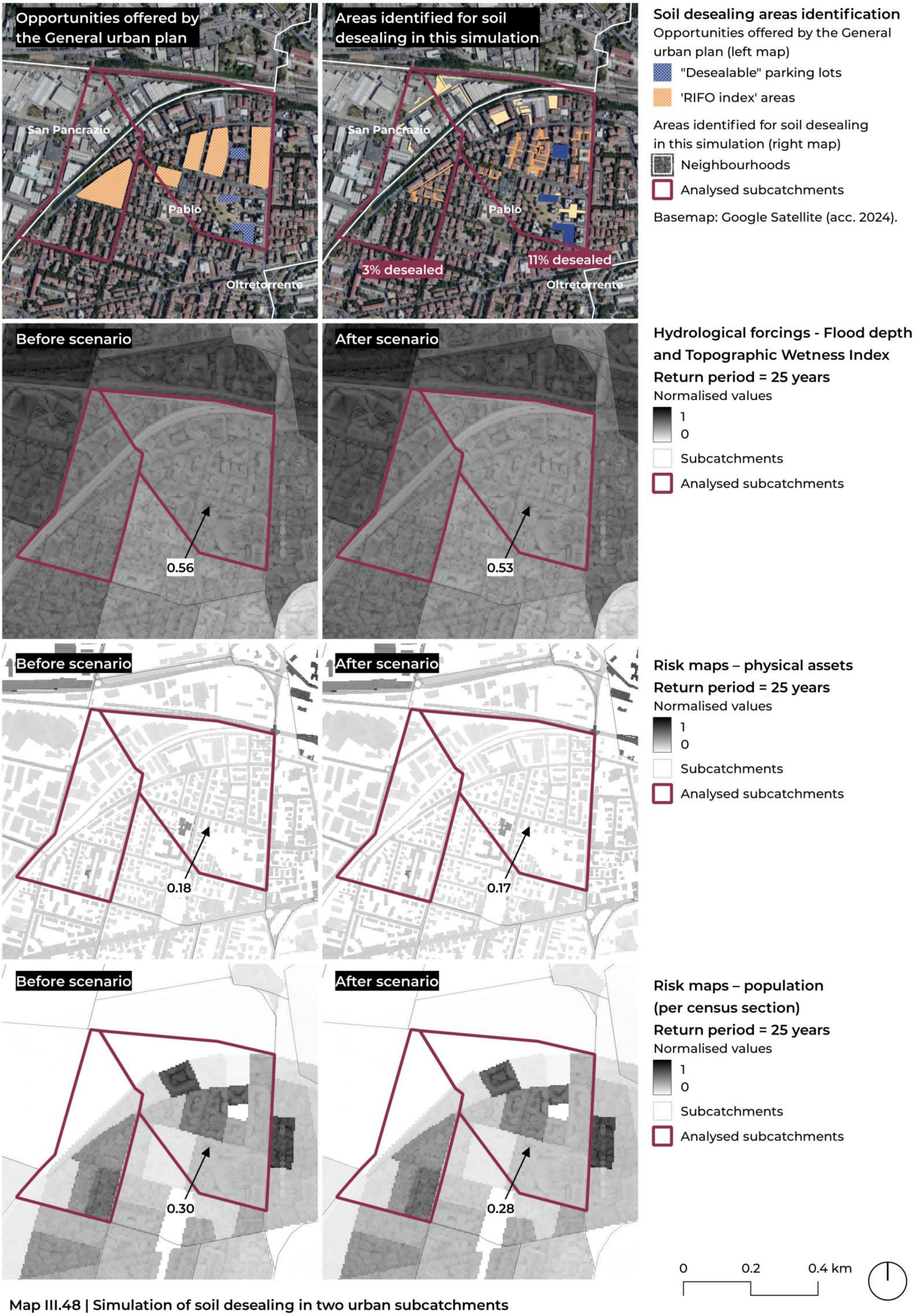
Map III.47 | Five-level desealing potential

Normalised values ranges

- <= 0.20
- 0.20 - 0.40
- 0.40 - 0.60
- 0.60 - 0.80
- > 0.80

- Perimeter of the inner urban area (area inside the ring road)
- Study area

0 0.5 1 1.5 km



Map III.48 | Simulation of soil desealing in two urban subcatchments

10 Climate change adaptation in Brescia: experiences and tools for soil desealing

The next sections and subsections describe, without the aim of being exhaustive, some of the experiences that have been put in action in Brescia for what regards climate change adaptation and, more specifically, soil desealing. First, Section §10.1 describes the city territorial context and knowledge framework, while Section §10.2 investigates the urban flood risk assessments that have been carried out in the city, as well as the opportunities that have been identified for the urban transformation. Section §10.3 describes the experiences put in action for involving the citizens with regard to soil desealing.

10.1 Territorial context and knowledge framework

The Municipality of Brescia covers an area of 90.34 km^2 and is situated in the upper Po Valley, where the Trompia Valley opens. While it lies at the base of Mount Maddalena and Cidneo Hill, the urban area is predominantly flat, bordered to the north by the Brescia Pre-Alps, to the east by the Garda Pre-Alps, and to the west by the Franciacorta region. The Pre-Alpine mountain range surrounds the city, with the entire southern slope of Mount Maddalena (including its summit), falling within the municipal area. This gives the municipal territory a total elevation range of 770 meters. The historic centre is located within the Venetian-era city walls, which were demolished during the late 19th century and early 20th century. Over the past two decades, the city population has grown gradually, approaching 200,000 residents in 2021 (Comune di Brescia, 2021b).

10.1.1 Land use and land cover

The municipal territory is predominantly composed of urbanised areas, which account for 56% of the total, followed by agricultural zones (24%) and forested and semi-natural areas (19%). The urbanised area primarily consists of residential areas (48%), which are followed by productive areas (21%). Other land uses include green spaces (13%) and services, representing 3% of the territory (Comune di Brescia, 2021b).

10.1.2 Climate data

The municipality of Brescia lies within a region that experiences a continental climate, which characterises most of Lombardy. The highest levels of precipitation occur primarily during the spring and autumn months. Data from the Brescia Ghedi weather station show an upward temperature trend, as reflected by the projections form the International Panel on Climate Change, indicating an increase in heatwave risk. In addition, the Brescia Ghedi station data allows for an examination of maximum daily precipitation patterns over the historical period 1951–2005. The projections from the Intergovernmental Panel on Climate Change models suggest that while precipitation will likely increase in the future, this rise is not as pronounced as the expected rise in maximum temperatures (Comune di Brescia, 2021a).

10.1.3 Urban water systems and floods

The western part of the municipal territory is crossed longitudinally by the Mella River, which originates in the Maniva area. After passing through the Trompia Valley, it enters the city from the north (Comune di Brescia, 2021b). The river is the primary element of the municipal water network, complemented by a dense system of canals and secondary rivers that originate in the hills surrounding the city, pass through the urban fabric, and contribute to irrigating the southern agricultural areas (Boglietti, 2024).

The city of Brescia is subject to meteorological risks (i.e., heatwaves and floods) that are increasingly relevant in the context of climate change (Comune di Brescia, 2021a). Also the Sustainable energy and climate action plan of Brescia has inferred the main meteoclimatic risks affecting Brescia based on data from the European Severe Weather Database covering the period 1997–2017. Over this timeframe, the most prevalent events include cloudbursts and heavy rain, windstorms and hailstorms (Comune di Brescia, 2021a).

The main critical conditions and flood risks have been associated with the following situations: i) concentrations of peak flows even during events with short return periods, due to the intense expansion of urbanised areas; ii) inadequate hydraulic works within the hydrographic network; and iii) interferences with crossing structures unsuitable for sustaining high flow rates (Comune di Brescia, 2021a, 2021b). Boglietti (2024) has expressed these conditions in two primary risks resulting from intense rainfall events identified for the city: i) overflowing of surface water bodies in the upstream basins of the urban area; ii) flooding in the urban areas due to the insufficient capacity of drainage systems to handle large volumes of water in a short time.

In this framework, the Municipal civil protection plan (*Piano comunale di protezione civile*) identifies macro areas presenting the highest criticalities for hydraulic risk referring to the four main zones outlined in the hydraulic monitoring system (Boglietti, 2024). Furthermore, the Municipal civil protection plan considers flood data in accordance with both the Flood risk management plan (*Piano di gestione del rischio di alluvioni*) and the Hydrogeological structure plan (*Piano di assetto idrogeologico*) (Comune di Brescia, 2021a). In addition to the flood areas, the Municipal civil protection plan identifies critical parts of the city such as underpasses (Comune di Brescia, 2017).

10.1.4 Soil desealing and the existing tools

In Brescia, several strategic and legislative instruments have been incorporated into the urban planning and building legislative frameworks to address soil desealing (both directly and indirectly) and climate change adaptation.

As previously recalled (Subsections §2.2 and §3.2), the Regional Law No. 31/2014 ‘Provisions for the reduction of soil consumption and the redevelopment of degraded soil’ (*Disposizioni per la riduzione del consumo di suolo e per la riqualificazione del suolo degradato*) of the Lombardy Region has addressed the importance of soil desealing, Furthermore, for what concerns the management of the surface runoff, the concepts of hydraulic and hydrologic invariance have been introduced for both new urban developments or urban regeneration projects (see Footnote 22 and Regione Lombardia, n.d.).

Strategic instruments

The Climate transition strategy (*Strategia di transizione climatica*) of Brescia has provided a framework for mitigating climate impacts, including initiatives to increase soil permeability in urban areas.

In 2020, in the context of addressing the causes and effects of climate change – thus promoting mitigation and adaptation actions, reducing vulnerability to extreme weather phenomena and raising public awareness – the Italian Cariplo Foundation, within the project 'F2C - Cariplo Climate Foundation' (*F2C - Fondazione Cariplo per il Clima*), launched the call for ideas 'Climate strategy' (*Strategia clima*). The call for ideas was aimed at medium and large municipalities and had the purpose of defining climate transition strategies for those cities. The objectives were: i) the implementation of adaptation and mitigation actions; ii) the revision of urban planning tools; iii) capacity building for municipal technicians; iv) citizens' involvement and v) climate monitoring[132]. In the first edition of the call, four territorial clusters were involved, namely Bergamo, Brescia, Brianza Ovest and Mantova. Among them, Brescia developed - within the project '*Un filo naturale*' (lit. a natural thread) - its Climate transition strategy. The Climate transition strategy was approved by the Municipal Council in 2021 and involves the Municipality of Brescia in partnership with other entities, i.e., the science centre 'AmbienteParco', the foundation *Centro Euro-Mediterraneo per i Cambiamenti Climatici*, and the park '*Parco delle Colline di Brescia*', with the contribution of the Cariplo Foundation and the Lombardy Region.

The strategy, which was intended as a flexible and programmatic instrument, was developed in accordance with the strategic and regulatory instruments and defines a vision and the objectives to – over the course of 30 years – achieve the climate transition of the territory. The objectives are i) the promotion of adaptation and mitigation to climate change in urban and peri-urban settings and ii) the increase of the citizens', stakeholders' and policy-makers' knowledge on climate change by activating participatory processes. The slogan of the strategy makes its goals explicit, transforming Brescia into:

- an 'oasis city', thus creating shade and cooler temperatures for people's wellbeing and improving the urban microclimate;
- a 'sponge city', thus restoring the water times and spaces, making soils permeable and welcoming life;
- a 'city for people', with beautiful and liveable spaces to guarantee the right to health, slow mobility, meeting and inclusion.

The Climate transition strategy envisions these goals to be achieved through actions that aim to i) cope with extreme heat, create shade, cool, improve the urban microclimate and foster biodiversity; ii) cope with extreme weather events, restore soil permeability and save water resources; iii) absorb and/or reduce emissions of CO_2 and other greenhouse gases; and iv) raise public awareness of climate change, involve people in the climate transition process and foster greater urban sociality (*Un Filo Naturale*, n.d.).

The Sustainable energy and climate action plan of Brescia, approved in 2021, is strictly connected with the Climate transition strategy and includes the recognition of the need to focus on reducing the effects of soil sealing by increasing permeable areas, taking into account the issues arising from climate change in urban planning instruments. Furthermore, it mentions that, with the adoption of an annex to the Building regulation, the Municipality will be able to establish energy standards for new construction or

[132] https://www.fondazionecariplo.it/it/progetti/ambiente/strategia-clima.html

building restoration, regulate public spaces and urban green areas, and encourage the redevelopment of abandoned buildings and areas in order to maintain or better increase the percentage of permeable land, thus enabling sustainable urban drainage. Directly referring to the Climate transition strategy, the Sustainable energy and action plan addresses the need to redevelop those urban areas sealed by various types of settlements, such as warehouses, yards, and parking lots, by creating green zones. In this context, it emphasises that the actions need to be part of participatory design practices with the citizens (Comune di Brescia, 2021a).

Legislative instruments[133]

The Brescia Municipal Council Resolution No. 10/2018 foresaw the adaptation of the city Territorial governance plan (*Piano di governo del territorio*) to the provisions of the Flood risk management plan (approved in 2016 by the Institutional Committee of the Po River Basin Authority). This update was carried out to verify the compatibility of the (foreseen) urban planning transformations with the territorial conditions, expanding the knowledge framework derived from the Flood risk management plan and two hydraulic studies that were carried out on the urban streams (Comune di Brescia, 2021a).

A first version of the IV Variant of the Territorial governance plan (*Variante del Piano di governo del territorio*) was developed in 2023, introducing a modification in the Services Plan (*Piano dei servizi*) that involved the implementation of a 'Soil desealing implementation plan' (*Piano attuativo di depavimentazione*), which was previously anticipated by both the Sustainable energy and climate action plan and the Climate transition strategy. This involved the development of a map of public areas suitable for soil desealing, categorised by levels. This map was accompanied by a study defining its contents and the associated regulations, with the aim of subsequently drafting an implementation plan for the desealing of public areas to achieve urban regeneration with a focus on climate resilience. In other words, an annex was planned to be introduced in the Service plan, containing the areas suitable for desealing, categorised by levels of suitability for desealing (Figure III.50).

However, in January 2023 the Variant was updated with respect to the outcomes of the Strategic environmental assessment (*Valutazione ambientale strategica*) and the proposed variant to the Services plan was deleted. However, evidence has not been found to explain why.

[133] The information entailed by these paragraphs have been gathered from the Municipality of Brescia website.

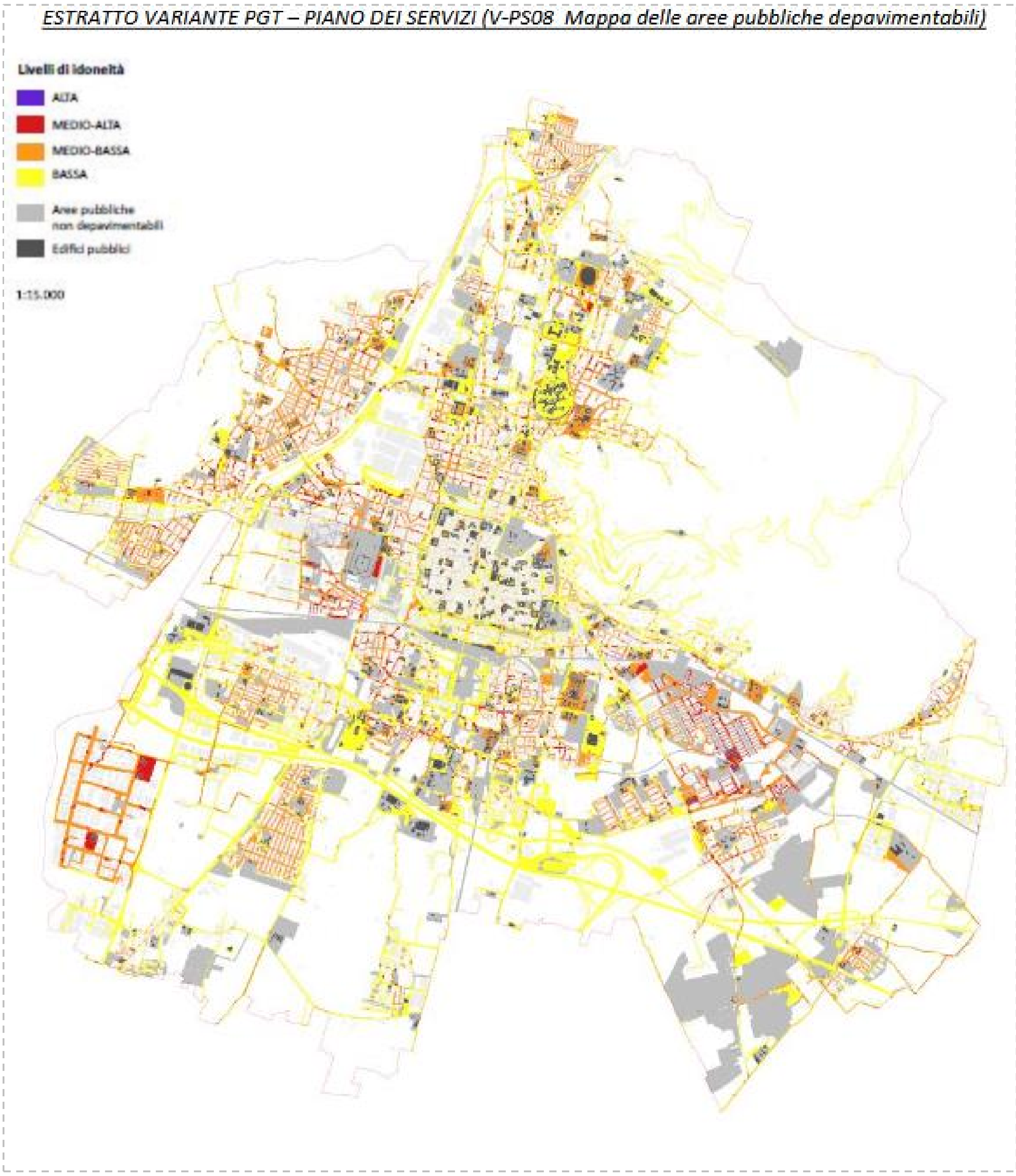


Figure III.50 | Extract from the Brescia IV Variant of the Territorial government plan of the Municipality of Brescia. Source: Brescia IV Variant of the Territorial government plan available on the Municipality website.

10.2 Urban flood risk assessments and opportunities for the urban transformation

In 2024, a research closely related to the urban planning scenario of Brescia was published, directly addressing climate change adaptation and soil desealing. Among the other aspects, this study investigated the critical issues related to the urban drainage system and the suitability for water infiltration into the soil, with the aim of defining priorities for desealing interventions.

Namely, Boglietti (2024) has identified critical areas connected to Brescia urban drainage network, focusing on identifying zones most impacted by extreme weather events, specifically heavy rainfall, in the framework of the IV Variant to the Territorial government plan (*Variante del piano di governo del territorio*). The analysis relied on data provided by A2A, the local territorial company managing stormwater drainage, which divided the area into hydraulic subcatchments and assigned priority levels to each zone. These priorities highlighted areas where the drainage infrastructure was problematic and causes flooding. Particularly urgent (high-priority) zones were considered those where direct structural upgrades to the drainage network were not feasible, making surface-level interventions essential to manage stormwater. Industrial areas represented a significant challenge, as they were largely impermeable and lacked sufficient public spaces for such interventions. On this basis, the author identified priority levels for intervention, which were reclassified into three categories:

- high priority: includes zones marked as high or very high priority and the industrial areas with critical issues;
- medium priority: covers zones previously identified with medium and low priority;
- low priority: encompasses the remaining areas, as all zones can benefit from surface-level interventions which positively impact the urban drainage system.

The researcher then evaluated the suitability for water infiltration into the soil based on the analyses previously conducted by the local administration. The work focused on identifying areas where the implementation of soil desealing might have been hindered by hydrogeological, technical, environmental or legal constraints. Areas with no limitations were classified as having maximum suitability, while those with potential constraints were categorised as having medium or low suitability. The latter classifications indicated that further specific investigations would have been necessary to determine whether such constraints could significantly complicate or impede infiltration. Overall, due to the absence of extensive quantitative data for the urban area in question, the researcher adopted a qualitative approach to assess soil suitability for water infiltration (Boglietti, 2024).

After the first two steps (i.e., the identification of the critical areas of the urban drainage network and the suitability for water infiltration into the soil), the author identified areas for prioritising desealing interventions by focusing on the urban zones with a residential population. Using a calculation matrix, Boglietti (2024) first combined the analysis of the urban drainage network criticalities with the soil infiltration suitability to create a 'hydraulic suitability map'. High hydraulic suitability was – for instance - assigned to areas where implementing soil desealing was not limited by territorial constraints and could benefit the existing drainage system. Subsequently, the 'hydraulic suitability map' was overlaid with a previously developed population health risk map using the same matrix (Boglietti, 2024).

Finally, Boglietti (2024) investigated the opportunities for the urban transformation by identifying several factors for guiding depaving interventions:

- citizens' proposals: areas suggested by the public for urban regeneration (see also Subsection §10.3.1);
- environmental islands: urban areas with high accessibility for public transport and safe conditions for pedestrians and cyclists;

- urban transformation areas: zones that were part of ongoing or planned urban transformations;
- landscape accessibility routes: areas with pathways promoting the use of green spaces, which could benefit from desealing to improve urban aesthetics and connectivity;
- services: locations near essential services, where depaving could improve the area quality and attractiveness, making it more appealing to both residents and visitors;
- mobility infrastructure: existing or planned transportation infrastructure that could be regenerated through depaving, enhancing pedestrian and cycling routes while revitalising the surrounding area.

10.3 Urban transformations and citizens' involvement

In the framework of the Climate transition strategy (*Strategia di transizione climatica*) of Brescia, two processes have been investigated aimed at involving the citizens - namely the participatory process '*SpaziAttivi*' and the laboratories set up at the science centre 'AmbienteParco'.

10.3.1 The participatory process '*SpaziAttivi*'

The participatory process '*SpaziAttivi*' (lit. active spaces) is carried out by the Urban Center Brescia of the Municipality of Brescia in the framework of its Climate transition strategy (*Strategia di transizione climatica*). Through citizens' involvement, degraded urban areas were identified with the aim of transforming them into spaces for social gathering where people can feel a sense of belonging, by means of urban regeneration and adaptation interventions (Comune di Brescia, 2024b). The project has been divided into phases, as shown in the following table (Table III.62). As of today [2024], the '*SpaziAttivi*' process is still being carried out.

Steps of the '*SpaziAttivi*' project		
Participatory exploration		
2022	Phase A	Exploration of the areas (56 areas were proposed)
	Phase B	Analysis of the areas
	Phase C	Choice of the areas (two areas were selected)
Co-design		
2023/2024	Phase D	Participatory planning (including public meeting, exploratory walks and idea laboratories)
Next steps		
2024/2025	Phase E	Co-implementation
	Phase F	Management

Table III.62 | Steps of the '*SpaziAttivi*' project. Source: information was gathered from Comune di Brescia (2024b).

10.3.2 Climate change adaptation laboratories[134]

The Climate transition strategy (*Strategia di transizione climatica*) of Brescia and the '*Un filo naturale*' (lit. a natural thread) project (Comune di Brescia, 2021b) offer an interesting case study about the participation of citizens of all ages.

Among the 'Citizens' involvement and communication' (*Coinvolgimento della cittadinanza e comunicazione*) actions, Action 7.2.5 – 'Experiential activities of AmbienteParco in cultural areas' (*Attività esperienziali di AmbienteParco nei luoghi culturali*) aims to communicate the Climate transition strategy through climate adaptation experiences organised by the science centre 'AmbienteParco'. The Urban and regional planning research group from the University of Parma collaborated on these workshops[135]. The following paragraphs summarise the initial outcomes of the first stage of the project, tested in the Afterschool Programme for middle-schoolers at AmbienteParco. These workshops were designed to assess their potential integration into the activities of the science centre and represent an opportunity for applied research on participatory processes aimed at young people. They also served to evaluate students' awareness of climate change through surveys and direct observation. These initial results contribute to the discussion on youth involvement in climate adaptation processes, shaping future urban planning and land use and recognising young people as knowledge holders and as the adults of tomorrow (Oliver et al., 2014).

As Oliver et al. (2014) note, youth participation ranges from 'non-participation' to full decision-sharing with adults. These workshops were designed as meaningful participatory processes that foster resilience by encouraging mutual knowledge exchange. Pre- and post-workshop surveys were used to gather feedback from participants, further informing climate change strategies.

Setup of the laboratories

The design process for the laboratories began in the summer of 2022, focusing on outlining the practical features of the workshops and analysing the Climate transition strategy and its actions to identify the most relevant themes for the laboratories. An 'informative and operative' approach was adopted, with workshops tailored for middle school students and their families. These sessions were designed to be engaging narratives with hands-on experiments, aiming to foster not only knowledge acquisition, but also the development of practical and social skills, including problem-solving and interpersonal relationships.

The selected themes related to climate change adaptation were chosen for their relevance to current climate challenges and associated urban planning practices and countermeasures, including the implementation of green roofs and resilient urban green.

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[134] Subsection §10.3.2 has been adapted by the author based on 'De Noia, I., & Rossetti, S. (2024). Participation for Everyone: Young People's Involvement in the Shift Towards Happier and More Resilient Cities. In A. Marucci, F. Zullo, L. Fiorini, & L. Saganeiti (Eds.), Innovation in Urban and Regional Planning (pp. 515–525). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54096-7_45' in which she is co-author. The published article encompasses the full attributions of the work.

[135] The University of Parma participated in the National Operational Programme on Research and Innovation 2014-2020, which fosters collaboration between universities and businesses. For Ph.D. programs, this involves a six-month internship for students. The author worked alongside AmbienteParco staff, offering scientific and technical support in developing and testing workshops related to climate change adaptation.

The themes included:

- climate change and greenhouse gases: to provide an overview of the Climate transition strategy;
- soil and water: to introduce Action 2.1 of the Strategy – 'Resilient urban regeneration interventions (desealing and oasis areas)' (*Interventi di riqualificazione urbana in chiave resiliente* (*de-pavimentazione e zone oasi*);
- green roofs and nature-based solutions: to address Action 2.2 – 'Implementation of pilot green roofs with production of knowledge tools for their implementation' (*Realizzazione di tetti verdi pilota con produzione di strumenti conoscitivi per la loro diffusione*);
- trees and ecosystem functions and services: to introduce Action 2.3 – 'Renovation of the urban trees located on road infrastructure with resilient plants' (*Rinnovo di alberature stradali cittadine con piante resilienti*);
- biodiversity: this additional transversal theme encompasses the overall framework of the Strategy.

To identify suitable climate change-related experiments for young people, a web-based research was conducted, focusing on the identified themes. Based on this preliminary research, five experiments were developed, as summarised in Table III.63.

Code	***Experiment theme***	***Description***	***Mode***
E1	*Climate change and greenhouse gases*	Introductory part that provides an overview of climate change and the Climate transition strategy, followed by an experiment designed to visualize CO_2 emissions. This experiment involves placing a balloon over the top of a glass jar to capture the carbon dioxide produced from the reaction between acetic acid (found in vinegar) and baking soda.	Fully interactive, individual
E2	*Soil and water*	In this experiment, students explore the percolation rate of water through various soil types. Using funnels crafted from recycled bottles filled with different soils, they can observe this process firsthand. Students are then organised into groups to physically simulate the interactions between water, sand, silt, and clay (Agriculture in the Classroom - Utah State University Cooperative Extension, n.d.).	Frontal interactive
E3	*Green roofs and nature-based solutions*	This experiment focuses on creating a model of a green roof. Using a shoebox as a base (National Building Museum, 2012), students can construct either a small extensive green roof by sowing seeds or a small intensive green roof by planting seedlings.	Fully interactive, individual
E4	*Trees and ecosystem functions and services*	Students explore the CO_2 absorption capacity of trees and capillary action through memory games and straightforward physical experiments.	Fully interactive, group
E5	*Biodiversity*	Students conduct surveys using specialised survey cards to identify various plant and animal species in a natural area (*Making Species Maps | Science Project*, n.d.). They are encouraged to discover as many species as possible.	Fully interactive, individual

Table III.63 | Characteristics of the experiments.

The experiments were conducted over three days during the Afterschool Programme at AmbienteParco (Figure III.51 and Figure III.52) - from November 2022 to January 2023. On the first test day (TD1), students participated in the 'Climate change and greenhouse gases' experiment (E1) and the 'Green roofs and nature-based solutions' experiment (E3). The second test day (TD2) focused on soil permeability and density (E2) and included various activities related to trees and their CO_2 absorption capacity (E4). In January 2023, a third test day (TD3) featured the 'Soil and water' experiment (E2) along with an additional experiment on biodiversity (E5).

Figure III.51 | The image on the left shows the 'Climate change and greenhouse gases' experiment (E1), while the outcomes of the 'Green roofs and nature-based solutions' experiment (E3) are displayed on the right. Source: AmbienteParco and personal photographs.

Setup of the surveys

To assess the students' perceptions of the first two test days, three surveys were developed: an initial survey at the start of each day (TD1_pre and TD2_pre) and a final survey to evaluate the results from TD2 (TD21_post). On TD3, students completed a survey both before (TD3_pre) and after (TD3_post) the laboratory session (Figure III.52). All surveys were distributed in printed form, were anonymous, and designed to be brief and easy to understand, ensuring they could be completed in a limited timeframe.

The initial structure of the surveys included a first question regarding the participants' age and, for TD1_pre and TD2_pre, about their knowledge of climate change. The main section of the surveys concentrated on the students' understanding of the workshop topics. The final questions aimed to determine whether the students were aware of the Climate transition strategy and the '*Un filo naturale*' project, as well as their expectations for the workshop. TD12_post and TD3_post required students to answer the same questions presented in TD1_pre, TD2_pre, and TD3_pre to assess the effectiveness of the workshops. Additionally, in TD12_post and TD3_post, students were asked whether they had learned something new during the laboratories, what aspects they enjoyed the most, and what improvements they would suggest.

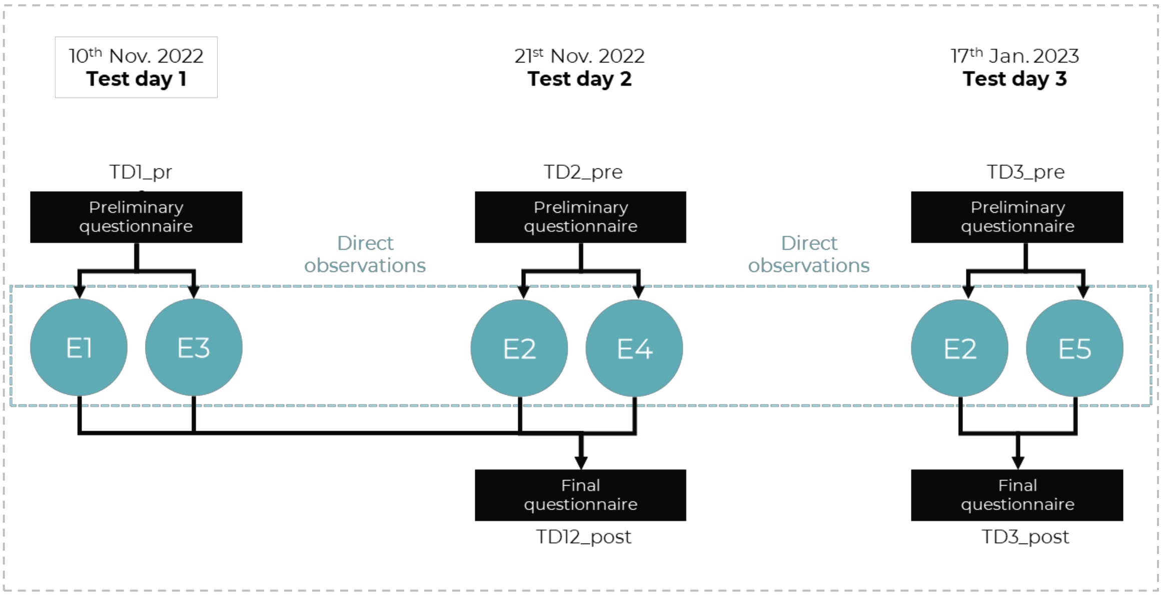

Figure III.52 | The figure summarises the schedule of the test days, for what concerns both the experiments and the surveys. Source: author's elaboration.

Outcomes of the laboratories

The outcomes of the workshops were evaluated through both surveys and direct observations. Among the direct observations, several practical challenges were noted. Some experiments proved to be quite time-consuming, and improvements were needed in the management of tools and materials. It was also observed that participants' attention decreased during lengthy and complex experiments (particularly during frontal ones), and they had a preference for clear and straightforward activities. On the contrary, interactive laboratories (e.g., E3) were more effective in engaging students, who showed greater sensitivity and responsiveness, leading to stimulating questions and positive competitiveness. Furthermore, students demonstrated awareness of the issues related to climate change and expressed a desire to share their experiences and learn more about adaptation strategies. They particularly valued practical explanations of processes and phenomena they encountered in their city or learned about in school, such as the demonstration of greenhouse gas production and green roofs.

The surveys were completed by students aged 10 to 17. Table III.64 and Table III.65 present some of the most significant findings. TD1_pre and TD12_post were filled out by ten students, TD2_pre by eleven, while TD3_pre and TD3_post had six respondents. It is important to note that the students in the Afterschool Programme were not the same across the three test days due to the non-compulsory nature of the Programme and the high variability in attendance. Additionally, the Programme is characterised by a multicultural participant pool, attracting students from diverse backgrounds. This analysis will provide a simple descriptive overview of the results, primarily due to the small number of respondents.

TD1_pre and TD2_pre indicated that participants had a good understanding of climate change, with only 11.1% and 20% of students stating they were unaware of it. In TD12_post, these results were nearly identical, with 10% of participants reporting no knowledge on the topic. In contrast, questions regarding the Climate transition strategy and the specific themes covered in the workshops showed an overall increase in participants' knowledge. For example, the percentage of students unaware of greenhouse gases decreased from 33.3% (TD1_pre) and 37.5% (TD2_pre) to just 10%. Before TD2, 77.8% of students were unfamiliar with green roofs, but this percentage decreased by 37.8% after the workshop. Furthermore, after TD2, the proportion of respondents with at least some understanding of soil permeability and filtration rates rose from 54.6% to 90%. The final questions in TD12_post revealed that nine out of the ten respondents felt they had learned something from the workshops conducted during TD1 and TD2. The same number of students responded to the question '*What did you like the most*?' by either naming their favourite experiment or expressing their appreciation for the workshop. TD3_pre and TD3_post produced results consistent with the previous surveys. Knowledge of biodiversity increased from 33.3% to 66.7%, with an additional 33.3% responding 'more or less'. In the final survey (TD3_post), more than half of the respondents indicated familiarity with the '*Un filo naturale*' project, and five out of six participants answered the question '*What did you like the most?*' by either naming their favourite experiment or expressing their enjoyment of the workshop.

	TD1_pre	***TD2_pre***	***TD12_post***
Number of respondents	10	11	10
Respondents that have at least some knowledge about climate change	88.9%	80%	90%
Respondents that have at least some knowledge about greenhouse gases	66.7%	62.5%	90%
Respondents that have at least some knowledge about green roofs	22.2%	N/A	60%
Respondents that have knowledge about soil permeability and filtration rate	N/A	54.6%	90%
Respondents that feel like they have learnt something from the workshops	N/A	N/A	90%
Respondents that have some knowledge about the project 'Un filo naturale'	0%	N/A	50%

Table III.64 | Highlights of the results of TD1_pre, TD2_pre, and TD12_post.

	TD3_pre	***TD3_post***
Number of respondents	6	6
Respondents that have knowledge about soil permeability and filtration rate	33.3%	80%
Respondents that have knowledge about biodiversity	33.3%	66.7%
Respondents that feel like they have learnt something from the workshops	N/A	60%
Respondents that have some knowledge about the project 'Un filo naturale'	N/A	60%

Table III.65 | Highlights of the results of TD3_pre and TD3_post.

Although the surveys involved a limited number of participants, they showed results that aligned with the direct observations made during the laboratories. Both the pre- and post-workshop surveys revealed similar findings regarding students' knowledge of climate change, highlighting that discussing very general topics without practical experiments may lead to less effective communication.

No negative feedback was reported by the students, likely because they may have perceived the surveys as tests and the workshop facilitators as teachers. Future surveys and laboratories may benefit from fostering a more friendly and informal atmosphere to help reduce the perceived hierarchical gap between students and organisers, a gap that cannot be entirely eliminated due to the participants' young age. On the contrary, the indirect feedback gathered - such as the students' interest and engagement during the workshops - provided valuable insights into the necessary improvements for the experiments and workshops. For example, better portioning of materials for E3 could enhance time management. Furthermore, observations regarding students' preferences (e.g., the duration and format of the laboratories) informed the decision to divide the experiments into three modules, which will be incorporated into AmbienteParco experience packages. The proposal outlined in Table III.66 aimed at achieving a better balance in the duration and format of the various activities, as well as to group similar topics together.

Module	*Experiment theme*	*Experiments*
1	Climate change and the Climate transition strategy of Brescia	E1
2	Nature-based solutions and ecosystem services	E3, E4
3	Soil and biodiversity	E2, E5

Table III.66 | The three modules proposed after the first test-stage of the laboratories.

Overall, the initial test-stage of the laboratories appears to have been effective in raising awareness of both the Climate transition strategy and climate adaptation measures, with students demonstrating sensitivity and responsiveness to these topics. The questions posed and the experiences shared during the workshops indicate that awareness of climate change-related issues is growing among the younger population, which is both engaged and active in this regard. The participants' engagement with these topics underscores the importance of involving them in the urban planning legislative and strategic scenarios - not only in single participatory experiences, but potentially in structured traditional top-down processes and bottom-up initiatives. For instance, organising participatory and co-design workshops where young people can identify and propose priority intervention areas could effectively enrich urban planning with the needs of young citizens. The experimental nature of this initiative was constrained by the limited number of students involved and the complexity of the tools used. Implementing the workshops in AmbienteParco experience packages may provide further insights from a larger participant sample.

Future research and application scenarios could involve improving the surveys. In this test phase, the forms were distributed in print, but transitioning to digital distribution would facilitate data collection on a larger scale and allow integration with other tools. For instance, recent developments in participatory methods emphasise the role of geographical information systems (Schröter et al., 2023), which could incorporate the virtual collection of geospatial data into co-design processes. Combining this technology with traditional survey methods could significantly enhance the effectiveness of participatory urban planning. The initial definition of sustainable development states that "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). *Thus, where better to start than with future generations themselves?*

11 Final considerations and comparison of the experiences

The applicative case studies on Parma and Brescia provided insightful results, allowing for several considerations regarding both the methodology and soil desealing efforts.

The methodology which was developed in the framework of this research and then applied in Parma resulted in the assessment of urban pluvial flood risk (and its components) and damage, as well as the transformation potential of the urban area. Citizens' involvement processes offered a valuable opportunity to bridge the "expert" knowledge with the local one, emphasising a shared interest in enhancing urban resilience through greening and soil desealing interventions.

The urban pluvial flood risk maps were classified into five levels and compared with the desealing potential map, defining an approach for the identification of priority areas which can be employed in urban planning within the framework of implementing soil desealing in urban regeneration practices. In this regard, this research provides a concrete and expeditive method to assemble layers of knowledge to identify – at the urban scale - priority areas and instruments for addressing soil consumption and the related urban pluvial flood risk. Additionally, damage maps allow to account for economic and further social aspects relevant in the framework of decision-making.

Furthermore, two example subcatchments were chosen for the simulation of the implementation of soil desealing interventions on a more detailed scale, yielding promising results. The simulation allowed to show the impact of soil desealing on reducing urban pluvial flood hazard and risks. However, these results highlighted the need for further localised studies to - for instance - identify the actual transformability of the urban spaces, as well as the importance of widespread and diffuse desealing interventions to achieve significant impacts. This underscores, once more, the relevance of the collaboration between citizens and the administration.

In this framework, even small-scale interventions are beneficial. Every step contributes incrementally to improving urban resilience, as reflected in the Chinese phrase from the philosopher Xunzi (荀子, 310 B.C. - 220 B.C.) cited at the beginning of the thesis. "积土成山，积水成渊" (*jī tǔ chéng shān, jī shuǐ chéng yuan* in pinyin) can be translated as "accumulated earth becomes a mountain, accumulated water becomes a deep abyss", conveying the idea that small, consistent efforts can lead to significant achievements or outcomes over time. In the context of minor interventions, future studies could consider developing additional indicators to capture the ability of soil desealing of reducing the urban pluvial flood vulnerability - as soil desealing promotes public awareness, helps disseminating knowledge and provides social spaces, thereby offering improvements across all dimensions of sustainability.

For what concerns the indicators, their precision, selection and the limitations posed by their availability highlight the context dependency of the assessment. Despite not being inherently negative, this means that administrations or other stakeholders must adapt the methodology by selecting and tailoring indicators to the specifics of their case study.

In this regard, the Brescia case study provided an opportunity to compare the methodology that was applied in Parma with a different scenario. The following paragraphs present observations on the case studies, focusing on priorities, opportunities, and the transformation potential, as well as the context of citizens' involvement and urban planning tools.

Determination of the soil desealing priorities, opportunities and transformation potential

In 2024, a thesis closely related to the urban planning scenario of Brescia was published, within the context of climate change adaptation and soil desealing. Developed by Boglietti (2024), the study shares similarities with the present work, but also differs in several aspects. One first distinction lies in the lexical choices: desealing/*desigillazione* in this study versus depaving/*depavimentazione* in the other. Furthermore, differences emerge in the consideration of urban flood risk, priority areas, and the transformation potential or opportunities offered by the urban space.

However, while these elements are approached differently, the general methodology remains comparable. More specifically, both studies adopt a similar structure for evaluating soil desealing priorities, namely:

i) defining the risk;
ii) assessing transformation potential;
iii) defining priorities.

However, the studies diverge in how these factors are addressed. In the present study, priorities were identified as the interaction of the highest classes of the urban pluvial flood risk with the transformation potential, which is defined by intrinsic and contextual factors, as well as with the definition of the opportunities offered by the suitable planning tools. Boglietti's (2024) study, on the other hand, determined priorities by combining the a suitability for water infiltration into the soil with the identified criticalities in the urban drainage network, which resulted in a 'hydraulic suitability' map. The latter, overlayed with the 'population health risk' map, was used for identifying the priorities. Furthermore, opportunities are understood in Boglietti's (2024) work as strategic and decisional possibilities offered by public urban spaces.

For what regards the urban flood risk, both studies take into account the urban pluvial flood risk, but the approaches differ. The present study distinguishes between hydraulic and hydrological forcings (proposing an expeditive methodology to assess the latter with generally easily accessible data), whereas Boglietti (2024) utilised the criticalities identified by the local territorial company managing stormwater drainage. While offering a quicker method, it entails potentially less control over the specific forcings and - as addressed in the study itself - requires further investigations in contexts where data are not available.

Furthermore, also the employment of the risk concept and formula varies. While in the current study the integration of the risk components – hazard, exposure and vulnerability – occurs through the risk formula, these components are incorporated into priority maps by overlaying a health risk map with a 'hydraulic suitability' map in Boglietti's (2024) research. This emphasises, once more, the various approaches that exist and have been used in literature for addressing the flood risk (see Subsection §1.2).

For what concerns the transformation potential and opportunities, the current approach includes contextual and intrinsic elements, such as citizens' perception, potential advantages of desealing and the existence of planned municipal interventions. Boglietti (2024) includes this kind of indicator in the opportunity maps. While similar indicators are used in both studies, their selection varies, likely reflecting differences in data availability and contextual considerations that may also depend on the objective and framework of the research. Overall, fewer indicators may simplify the process, but the trade-off should be further investigated.

Citizens' involvement and urban planning context and tools

The public participation case studies in Brescia and Parma constitute interesting experiences. The initiatives held in Parma (e.g., the 'Green in Parma' project) focus on greening efforts and soil desealing interventions on public and semi-public areas, while Brescia highlights projects like '*SpaziAttivi*' and educational workshops for children in the context of the Climate transition strategy. These examples demonstrate a growing interest in increasing the urban resilience and soil desealing. It has been observed that, while citizens show a willingness to participate in surveys and a generally favourable opinion with regard to soil desealing, they seem to accept interventions more easily on public areas, while private and semi-public areas often face more resistance. Thus, more delicate intervention criteria may be more effective for the latter.

In terms of available planning instruments, notable differences exist. Parma, through the revision of its General urban plan (*Piano urbanistico generale*), has integrated elements from the Sustainable energy and climate action plan and the other urban planning tools, resulting in a certain degree of coherence. However, no dedicated instruments for soil desealing have been clearly identified, as well as a definite urban strategy in this regard. The efforts are represented by indexes such as the 'RIFO index' aimed at reducing the buildings footprint, permeability standards, and the identification of desealable parking lots. Similarly, Brescia has acted in accordance with its Climate transition strategy (*Strategia di transizione climatica*) to foster structured public participation and initiate top-down processes - sometimes coupled with bottom-up projects (e.g., the '*SpaziAttivi*' project). Despite these efforts, soil desealing was not implemented in the IV Variant to the Territorial government plan (*Variante del piano di governo del territorio*).

In line with the Italian scenario, the outcomes of the two urban experiences reveal that significant progress in soil desealing remains limited, but promising. Nonetheless, interest in the topic is growing, and ongoing efforts are opening the way for future advancements. Practical examples include the soil desealing interventions recently and successfully put in action in the '*Via Metastasio*' street in Brescia and the '*Piazza Bassano del Grappa*' square in Parma (Comune di Brescia, 2024a; 'Per Riqualificare Il Quartiere Seminiamo Nuove Piante', 2024).

In this framework, this thesis contributes to this dialogue by experimenting, collecting experiences, and providing insights for decision-makers, citizens, and stakeholders with both practical and theoretical experiences. By defining a urban level methodology for identifying soil desealing priorities and proposing associated intervention criteria, this research will hopefully support the successful implementation of soil desealing interventions in the urban planning and regeneration scenario of Italian medium-sized cities.

IV | Conclusions

This final section presents the conclusions drawn from this research experience, building also on the considerations made in the final chapter of Part III (Chapter §11).

First, by referencing the research carried out by the fellow Ph.D. student Marianna Ceci, it attempts to synthesise shared insights and differences by focusing on soil desealing and the research process itself (Chapter §12).

Additionally, it offers a set of guidelines and criteria formulated in the perspective of a collaborative effort between local administrations and citizens (Chapter §13). These guidelines, derived from both the referenced (applied) research within this thesis and other experiences undertaken during this Ph.D. programme, aim to qualitatively summarise the lessons learned for effectively integrating soil desealing in the urban planning and regeneration scenario of the medium-sized Italian cities.

The last chapter (Chapter §14) reflects on the research limitations and explores potential avenues for its developments.

12 Urban heat island and pluvial flood risk mitigation in the context of soil desealing

As highlighted throughout this research, the fellow Ph.D. student Marianna Ceci investigated the role of soil desealing in mitigating the urban heat island risk (Ceci, 2025). Comparing the two studies appears relevant, as soil sealing and desealing play a similar role in simultaneously influencing the urban heat island and urban pluvial flood risks. This comparison reveals both divergences and common points.

Both analyses proposed a methodology for the definition of the risk based on its traditional formula, thus evaluating the components, and subsequently proposing a methodology to assess the transformability of the urban area. Both analyses employed the traditional formula for risk evaluation, assessing its components (i.e., hazard, exposure and vulnerability). However, the methodologies diverge in their selected indicators, reflecting the distinct objectives of each study. In Ceci's (2025) work, exposure focused on a specific population segment (the elderly), whereas the current research considered the entire urban population and physical assets, including buildings and transportation infrastructure. Furthermore, given the nature of the studies, hazard was represented by surface temperature maps in Ceci's (2025) thesis, while hydrological and hydraulic forcings were considered in the current research.

For assessing the vulnerability, Ceci (2025) incorporated sensitivity and adaptive capacity indicators. Sensitivity indicators included demographic factors such as population density; elderly women; individuals living alone; and those aged over 85, along with morphological factors such as building conservation state; building density; proximity to watercourses; sealed areas; albedo; and the sky view factor. Adaptive capacity indicators encompassed green area availability; the normalised difference vegetation index; proximity to socio-assistential buildings; and access to cool areas. While the current research also assesses the urban pluvial flood risk with both sensitivity and adaptive capacity indicators, it considers those referring to the population and physical assets separately.

The overlapping causes and effects of soil sealing and desealing within the two doctoral studies suggest the existence of a potential for multi-risk and transformability analyses, accounting for both the urban pluvial and heat island risks. However, when considering these studies, an important difference that must be considered lies in the scales of analysis: urban for pluvial flood risk, and sub-neighbourhood for the urban heat island risk. This disparity makes the direct comparison of their outcomes challenging. Future research could benefit from applying Ceci's (2025) methodology at the urban scale (or *vice versa*) to further explore these commonalities and differences. Preliminary insights can still be drawn from Ceci's (2024) case study that investigated a critical census section of the San Leonardo neighbourhood. Notably, this census section does not emerge as significant in the risk and transformability maps of the current study, suggesting potential discrepancies in urban-scale assessments.

A closer examination of the two approaches allows for further considerations on the nature of the spatial impacts of soil desealing. For the urban pluvial flood risk assessment, the city was divided into independent subcatchments, where individual surface contributions are difficult to isolate due collective effects. Conversely, the urban heat island effect demonstrates a more direct, location-specific relationship observable by users. As a very practical example, standing on a paved asphalt surface in summer produces an immediate sensation of heat, while the role of specific surfaces during flooding is less apparent due to the influence of, for instance, the urban drainage system itself.

The comparison of the two studies emphasises also the importance of the presence of diverse green spaces. In the context of urban heat island mitigation, trees provide shade that directly cools the environment. A more diverse and thoughtfully designed approach to greenery - beyond simply increasing its area - offers additional benefits also in the framework of the mitigation of the urban pluvial flood risk by acting on the hydrological cycle components (e.g., improving infiltration and evapotranspiration). This underscores the importance of detailed and thoughtful design in desealing interventions from both landscape architecture and ecological perspectives.

13 Guidelines and criteria for soil desealing to reduce the urban pluvial flood risk

This chapter aims to provide a set of guidelines and criteria for promoting effective soil desealing in the urban planning and regeneration practices of Italian-medium-sized cities, building on the previous parts of the current research.

The guidelines, drafted in the framework of the mitigation of the urban pluvial flood risk, are aimed at administrations and citizens with virtuous intents and initiatives.

Guidelines for the administration

Location of priority areas

1. Review (or draft) the maps of the desealable areas and higher urban pluvial flood risk areas.
2. Prioritise urban-scale areas where desealability and risk overlap by using maps classified according to levels.
3. Employ public participation processes (such as survey results) to identify, at a preliminary level, locations where interventions are more likely to be accepted and/or beneficial.
4. Take into account existing studies on other risks, such as the urban heat island risk, setting up the selection of the priority areas.
5. Keep into account that even small-scale interventions play a role in mitigating the urban pluvial flood risk.

Procedural aspects

6. When dealing with urban planning instruments, ensure consistency in goals, actions, and terminology.
7. Use strategic instruments for setting overarching goals and guidelines.
8. Consider acting in the framework of the existing legislative municipal tools, i.e., general urban plans (*piani regolatori generali*) and sector-specific plans (*piani di settore*).
9. Adopt an especially sensitive approach for private ownership.
10. When addressing urban regeneration or building renovations, consider requiring a justification for any sealed surface.
11. Develop measures to control urban expansion. Without such controls, the aim of reducing soil consumption cannot be achieved (e.g., Regional Law No. 24/2017 of the Emilia-Romagna Region).

Disaster risk prevention and citizens' involvement

12. Raise awareness among the citizens of actions they can take during and after urban pluvial flood events. This promotes risk preparedness and response behaviour, reducing vulnerability while fostering dialogue and shared knowledge. Strengthen also the warning systems.

13. Involve citizens throughout all intervention phases. Engaging local communities helps integrate local knowledge with expert insights and fosters awareness and knowledge sharing.

14. Participation can be both enjoyable and meaningful for citizens, fostering dialogue and shared knowledge. Promote initiatives like the tile removal competitions set up among Dutch municipalities[136].

Citizens' preferences and communication strategy

15. Investigate citizens' preferences and focus the interventions and their communication accordingly. E.g., for the case of Parma, citizens seem to value temperature regulation and rain absorption benefits, medium- and high-rise vegetation as well as the dimension of the desealed surface area in each intervention.

[136] https://www.nk-tegelwippen.nl/

Guidelines for the citizens

Engage

1. Ask questions and express your concerns about soil sealing and desealing.
2. Be open to the ideas and plans presented by the administration.
3. Stay informed by following updates and announcements related to urban projects.
4. Reach out to the administration for clarification or to share feedback.
5. Attend community meetings and workshops organised by the administration or communities.

Learn

6. Educate yourself on the impact of urban planning and environmental issues, as well as on the solutions to address urban challenges.
7. Take the time to stay informed about potential solutions and how they can benefit your community.

Wonder

8. Do you have unnecessary paving on your property? Consider how it might be affecting the environment.
9. Take the opportunity to reflect on what actions you can take to contribute to the community's wellbeing.

Share

10. Share the knowledge you gain with others to promote collective awareness and action.
11. Propose ideas for improvement. If you have suggestions on how to enhance the urban environment or reduce the impact of sealing, share them with your community or the administration.

Act

12. Take any opportunity you have to make the urban environment more permeable!

14 Limitations and future developments of the research

In conducting this research, encountering areas for improvement was inevitable. While specific limitations of the proposed methodology are addressed in the text, this chapter highlights broader relevant points and potential future developments.

Among these, the selection of indicators, as well as the methods for assessing urban pluvial flood risk and desealing potential are worth discussing. This is not due to inherent flaws in the used approaches, but rather due to the lack of a standardised methodology in literature regarding how to consider risk, its components, and the desealability of urban areas. This variability in concepts was reflected in the identification and selection of indicators, allowing - however - their adaptation to different theoretical and physical contexts. With reference to the lack of a unique methodology, this research attempts to order concepts and indicators, specifically in investigating the role of soil desealing in mitigating urban pluvial flood risk.

Furthermore, the analyses conducted in this research primarily focused on overlay techniques and spatial indicators, including buffer zones and minimum distance calculations. However, more advanced spatial analysis methods could be incorporated in future research. For instance, isochrone maps could be used to evaluate whether all residents can access green or desealed areas within a given travel time from their homes, workplaces, or essential services. Similarly, space syntax analysis could help identify urban paths with greater predicted pedestrian flows, allowing interventions to prioritise accessibility and usability in relation to urban pluvial flood or other climate-related risks. These directions are currently being explored within a research fellowship titled 'Planning guidelines for climate sensitive street space transformations', in which the author of this thesis is involved at the University of Parma, within the Urban and regional planning research group. The research project addresses the role of public outdoor mobility spaces in climate change adaptation. In this framework, further analysis may consider minimum safe paths and priority areas to ensure the protection of vulnerable citizens. With specific reference to soil desealing and the current research, these developments would enable a more refined prioritisation of intervention areas, building upon the overlay and classification of urban pluvial flood risk and desealability maps.

Another relevant topic to discuss and potential issue is data availability, which has sometimes hindered the precision of the analyses. To address this, indicators' categories have been selected with an emphasis on information generally available as open data within the Italian context - but there is still space for improvement. However, when envisioning the employment of this methodology by the administration, data availability should not represent a concern.

Regarding the analyses scale, the methodology presented here has proposed a city-wide approach for assessing both urban pluvial flood risk and damage, and the desealing potential. An interesting - even though resource-dependent - insight may be represented by the validation of the methodology with city-wide field investigations.

Another interesting area for future research would be simulating the desealing of all potentially desealable urban surfaces and assess their performance in urban pluvial flood risk and damage mitigation. While it may seem overly optimistic, the encouraging progress in cities like Brescia and Parma in soil desealing and public participation suggests the potential to see these simulations applied, at least partially, to real-world scenarios.

List of figures

List of maps

All the maps have been drafted by the author, with data sources mentioned within either their legend or the text.

List of tables

All the tables have been elaborated by the author, with data sources mentioned within either their caption or the text.

References

13 ottobre 2014, Parma color fango: Speciale alluvione. (2016, October 13). *Gazzetta di Parma*. https://www.gazzettadiparma.it/archivio-bozze/2021/12/06/news/13-ottobre-2014-parma-color-fango-speciale-alluvione-509619/

Adamowicz, W., Louviere, J., & Swait, J. (1998). *Introduction to Attribute-Based Stated Choice Methods*.

Adelman, I. (1990). Factor Analysis. In J. Eatwell, M. Milgate, & P. Newman (Eds.), *Time Series and Statistics* (pp. 90–94). Palgrave Macmillan UK. https://doi.org/10.1007/978-1-349-20865-4_9

Adobati, F., & Garda, E. (2018). Recuperare terra: Cinque contesti applicativi di politiche di de-sealing. *Urbanistica Informazioni 278 s.i.*, 160–164.

Adobati, F., & Garda, E. (2019a). Land return: Le azioni di de-sealing per il recupero del suolo nei contesti urbani. *TERRITORIO*, *90*, 154–162. https://doi.org/10.3280/TR2019-090017

Adobati, F., & Garda, E. (2019b). Space to water. Le azioni di de-sealing per la resilienza dei sistemi urbani. *Planum_Atti della Conferenza Internazionale - Urbanpromo XV Edizione Progetto Paese | Triennale di Milano, 23 novembre 2018*, 95–102. https://www.academia.edu/39020237/Space_to_water_Le_azioni_di_de_sealing_per_la_resilienza_dei_sistemi_urbani

Adobati, F., & Garda, E. (2020). Soil releasing as key to rethink water spaces in urban planning. *City, Territory and Architecture*, *7*(1), 9. https://doi.org/10.1186/s40410-020-00117-8

Agenzia Regionale per la Protezione dell'Ambiente della Sardegna, & Regione Sardegna. (2019). *Carta del Curve Number Regionale*. https://www.sardegnageoportale.it/documenti/40_615_20190329081206.pdf

Agriculture in the Classroom - Utah State University Cooperative Extension. (n.d.). *Perkin' Through the Pores—Slip Slidin' Away*. Retrieved 19 June 2023, from https://www.soils4kids.org/files/s4k/perkin.pdf

Aimar, F. (2023). Limiting Soil Sealing and Depaving: Local Actions for Regenerating Public Spaces to Build Green Infrastructures. *Urban Book Series*, 127–137. Scopus. https://doi.org/10.1007/978-3-031-28772-5_11

Alleanza Italiana per lo Sviluppo Sostenibile. (2019). *L'Italia e gli Obiettivi di Sviluppo Sostenibile—Rapporto ASviS 2019*. https://asvis.it/public/asvis2/files/Rapporto_ASviS/REPORT_ASviS_2019.pdf

Allende-Prieto, C., Roces-García, J., & Sañudo-Fontaneda, L. Á. (2024). The High-Resolution Calibration of the Topographic Wetness Index Using PAZ Satellite Radar Data to Determine the Optimal Positions for the Placement of Smart Sustainable Drainage Systems (SuDS) in Urban Environments. *Sustainability*, *16*(2), Article 2. https://doi.org/10.3390/su16020598

Almeida, C. R. de, Teodoro, A. C., & Gonçalves, A. (2021). Study of the Urban Heat Island (UHI) Using Remote Sensing Data/Techniques: A Systematic Review. *Environments*, *8*(10), Article 10. https://doi.org/10.3390/environments8100105

Amenta, L., & Arena, A. (2020). Climate resilient cities. Introducing two complementary projects' approaches to mitigate the negative impacts of climate change. *UPLanD - Journal of Urban Planning, Landscape & Environmental Design*, *5*(2), Article 2. https://doi.org/10.6093/2531-9906/7036

ANCE. (2022). *Decalogo per la rigenerazione urbana*. https://ance.it/wp-content/uploads/allegati/Decalogo.pdf

ANCI-IFEL. (2013). *L'Italia delle città medie* (4; i Comuni - Quaderni di Analisi ANCI-IFEL). Centro Documentazione e Studi dei Comuni italiani ANCI-IFEL. https://www.fondazioneifel.it/documenti-e-pubblicazioni/item/4674-l-italia-delle-citta-medie-iv-quaderno-della-collana-i-comuni

Angel, S., Blei, A. M., Parent, J., Lamson-Hall, P., & Galarza Sánchez, N. (2016). *Atlas of Urban Expansion: The 2016 Edition: Vol. Volume 1: Areas and Densities*. New York University, UN-Habitat, Lincoln Institute of Land Policy.

Arnstein, S. R. (1969). A Ladder Of Citizen Participation. *Journal of the American Institute of Planners*, *35*(4), 216–224. https://doi.org/10.1080/01944366908977225

Artmann, M. (2014). Assessment of Soil Sealing Management Responses, Strategies, and Targets Toward Ecologically Sustainable Urban Land Use

Management. *AMBIO*, *43*(4), 530–541. https://doi.org/10.1007/s13280-014-0511-1

Arunab, K. S., & Mathew, A. (2024). Quantifying urban heat island and pollutant nexus: A novel geospatial approach. *Sustainable Cities and Society*, *101*, 105117. https://doi.org/10.1016/j.scs.2023.105117

Associazione Aree Urbane Dismesse (AUDIS). (2008). *Carta AUDIS della Rigenerazione Urbana*.

Balram, S., & Dragićević, S. (2005). Attitudes toward urban green spaces: Integrating questionnaire survey and collaborative GIS techniques to improve attitude measurements. *Landscape and Urban Planning*, *71*(2), 147–162. https://doi.org/10.1016/j.landurbplan.2004.02.007

Barbarossa, L., La Rosa, D., Martinico, F., & Privitera, R. (2014). La rigenerazione urbana come strumento per la costruzione della città sostenibile. *Atti della XVI conferenza nazionale SIU 'Urbanistica italiana nel mondo Prospettive internazionali contributi e debiti culturali'*. XVI conferenza nazionale SIU 'Urbanistica italiana nel mondo Prospettive internazionali contributi e debiti culturali'.

Bartolomeis, G. L. de. (1847). *Notizie topografiche e statistiche sugli stati Sardi ...: Opera preceduta dalle teorie generali sulle statistiche e speciali alle riconoscenze militari*.

Bayerisches Landesamt für Umwelt. (n.d.). *Ökokonto*. Retrieved 10 September 2022, from https://www.lfu.bayern.de/natur/oefka_oeko/oekokonto/index.htm

Bazan, G., & Adelfio, S. (2015). Telerilevamento e GIS per la valutazione e il monitoraggio delle isole di calore in ambiente urbano. *XIX Conferenza Nazionale ASITA*. https://www.academia.edu/26464179/Telerilevamento_e_GIS_per_la_valutazione_e_il_monitoraggio_delle_isole_di_calore_in_ambiente_urbano

Berrang-Ford, L., Ford, J. D., & Paterson, J. (2011). Are we adapting to climate change? *Global Environmental Change*, *21*(1), 25–33. https://doi.org/10.1016/j.gloenvcha.2010.09.012

Bianchi, C., & Salvati, P. (2019). *Rapporto sul Rischio posto alla Popolazione italiana da Frane e Inondazioni—Quinquiennio 2014-2018*. CNR-IRPI. https://www.polaris.irpi.cnr.it/wp-content/uploads/POLARIS-Rapporto-quinquennale-2014-2018.pdf

Bianchi, C., & Salvati, P. (2020). *Rapporto Periodico sul Rischio posto alla Popolazione italiana da Frane e Inondazioni—Anno 2019*. CNR-IRPI. https://www.polaris.irpi.cnr.it/wp-content/uploads/report_2019.pdf

Bianchi, C., & Salvati, P. (2021). *Rapporto Periodico sul Rischio posto alla Popolazione italiana da Frane e Inondazioni—Anno 2020*. CNR-IRPI. https://doi.org/10.30437/report2020

Bianchi, C., & Salvati, P. (2022). *Rapporto Periodico sul Rischio posto alla Popolazione italiana da Frane e Inondazioni—Anno 2021*. CNR-IRPI. https://doi.org/10.30437/report2021

Bianchi, C., & Salvati, P. (2024a). *Rapporto Periodico sul Rischio posto alla Popolazione Italiana da Frane e da Inondazioni—Anno 2023*. CNR-IRPI. https://doi.org/10.30437/report2023

Bianchi, C., & Salvati, P. (2024b). *Rapporto Periodico sul Rischio posto alla Popolazione italiana da Frane e Inondazioni—Anno 2022 (Seconda Edizione)*. CNR-IRPI. https://doi.org/10.30437/report2022-v2

Bibi, T., Nawaz, F., Rahman, A., Razak, K., & Latif, A. (2018). Flood Risk Assessment of River Kabul and Swat Catchment Area: District Charsadda, Pakistan. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-4/W9*, 105–113. https://doi.org/10.5194/isprs-archives-XLII-4-W9-105-2018

Biesbroek, R., Swart, R., & Van der Knaap, W. (2009). The mitigation-adaptation dichotomy and the role of spatial planning. *Habitat International*, *33*(3), 230–237. https://doi.org/10.1016/j.habitatint.2008.10.001

Blum, W. E. H. (2005). Functions of Soil for Society and the Environment. *Reviews in Environmental Science and Bio/Technology*, *4*(3), 75–79. https://doi.org/10.1007/s11157-005-2236-x

Boglietti, S. (2024). *Il contributo degli strumenti di governo del territorio per l'adattamento delle città ai cambiamenti climatici* [Università di Brescia]. https://iris.unibs.it/handle/11379/594345

Bolton, T., & Hildreth, P. (2013). *Mid-sized cities: Their role in England's economy*. Centre for Cities. https://www.centreforcities.org/wp-content/uploads/2014/08/13-06-18-Mid-Sized-Cities.pdf

Bundesministerium für Bildung und Forschung. (2013). *Risiken beherrschen, Chancen nutzen—Die Region Dresden stellt sich dem Klimawandel. Strategiekonzept zum Integrierten Regionalen Klimaanpassungsprogramm für die Region Dresden*. Förderkennzeichen FKZ 01LR0802. www.regklam.de

Burton, P., & Mustelin, J. (2013). Planning for Climate Change: Is Greater Public Participation the Key to Success? *Urban Policy and Research*, *31*(4), 399–415. https://doi.org/10.1080/08111146.2013.778196

Canesi, R., D'Alpaos, C., & Marella, G. (2022). A Case of Local Community Engagement for Urban Regeneration: The South Boston Area. In F. Abastante, M. Bottero, C. D'Alpaos, L. Ingaramo, A. Oppio, P. Rosato, & F. Salvo (Eds.), *Urban Regeneration Through Valuation Systems for Innovation* (pp. 217–228). Springer International Publishing. https://doi.org/10.1007/978-3-031-12814-1_13

Cardona, O.-D., Van Aalst, M. K., Birkmann, J., Fordham, M., McGregor, G., Perez, R., Pulwarty, R. S., Schipper, E. L. F., Sinh, B. T., Décamps, H., Keim, M., Davis, I., Ebi, K. L., Lavell, A., Mechler, R., Murray, V., Pelling, M., Pohl, J., Smith, A.-O., & Thomalla, F. (2012). Determinants of Risk: Exposure and Vulnerability. In C. B. Field, V. Barros, T. F. Stocker, & Q. Dahe (Eds.), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (1st ed., pp. 65–108). Cambridge University Press. https://doi.org/10.1017/CBO9781139177245.005

Carra, M., Levi, N., Sgarbi, G., & Testoni, C. (2018). From community participation to co-design: "Quartiere bene comune" case study. *Journal of Place Management and Development*, *11*(2), 242–258. https://doi.org/10.1108/JPMD-06-2017-0046

Carter, M. R., Gregorich, E. G., Anderson, D. W., Doran, J. W., Janzen, H. H., & Pierce, F. J. (1997). Concepts of soil quality and their significance—Chapter 1. In E. G. Gregorich & M. R. Carter (Eds.), *Developments in Soil Science* (Vol. 25, pp. 1–19). Elsevier. https://doi.org/10.1016/S0166-2481(97)80028-1

Caselli, B., Ceci, M., De Noia, I., Garda, E., Tedeschi, G., & Zazzi, M. (2023). Achieving adaptation in medium sized cities: The contribution of urban climate transition strategies in increasing soil permeability. *Integrated Planning in a World of Turbolence (Book of Proceedings)*, *2*, 620–664.

Caselli, B., Ceci, M., De Noia, I., Garda, E., & Zazzi, M. (2024). Towards the Integration of Soil Desealing in the Urban Areas' Transformation Processes. In A. Marucci, F. Zullo, L. Fiorini, & L. Saganeiti (Eds.), *Innovation in Urban and Regional Planning* (Vol. 1, pp. 286–298). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54118-6_27

Caselli, B., Ceci, M., De Noia, I., Tedeschi, G., & Zazzi, M. (2022). La desigillazione del suolo nelle azioni partecipate di resilienza urbana: Il caso "Green in Parma". *Oltre Il Futuro: Emergenze, Rischi, Sfide, Transizioni, Opportunità, 306 special issue*, 42–44. http://www.urbanisticainformazioni.it/IMG/pdf/ui306si_sessione_02.pdf

Caselli, B., De Noia, I., Garda, E., & Zazzi, M. (2024). Incrementare la permeabilità dei suoli nelle città medie: Il contributo dei Piani d'Azione per l'Energia Sostenibile e il Clima. In G. Brunetta, A. Casu, E. Conticelli, & S. Lai (Eds.), *Atti della XXV Conferenza Nazionale SIU Transizioni, giustizia spaziale e progetto di territorio* (Vol. 04, pp. 185–192). Planum Publisher e Società Italiana degli Urbanisti, Roma-Milano.

CE. (2021, November 17). *COM(2021) 699 final, Strategia dell'UE per il suolo per il 2030. Suoli sani a vantaggio delle persone, degli alimenti, della natura e del clima*. https://ec.europa.eu/environment/publications/eu-soil-strategy-2030_en

CE & DGA. (2013). *Superfici impermeabili, costi nascosti: Alla ricerca di alternative all'occupazione e all'impermeabilizzazione dei suoli*. Publications Office. https://data.europa.eu/doi/10.2779/21953

Ceci, M. (2025). *Adattamento al cambiamento climatico nelle pratiche di rigenerazione urbana: Il contributo della desigillazione del suolo per il contrasto all'isola di calore urbana*. [Doctoral thesis (submitted)]. University of Parma. Department of Enginering and Architecture.

Ceci, M., Caselli, B., & Zazzi, M. (2023). Soil de-sealing for cities' adaptation to climate change. Planning of priority interventions in urban public space. *TeMA - Journal of Land Use, Mobility and Environment*, *16*(1), 121–145. https://doi.org/10.6093/1970-9870/9395

Ceci, M., De Noia, I., Tedeschi, G., Caselli, B., & Zazzi, M. (2023). Soil de-sealing and participatory urban resilience actions: The "Green in Parma" case study. *UPLanD - Journal of Urban Planning, Landscape & Environmental Design*, *7*(2), Article 2. https://doi.org/10.6093/2531-9906/10116

Centro Etica Ambientale. (2021, October 29). *Presentazione del Progetto di Comunità Green in Parma—Orto Botanico dell'Università di Parma 29 ottobre 2021*. CEA-Parma edizioni digitali 2021.

Ceragene, M., Bonasia, R., Cea, L., & Cuevas-Cancino, M. de la O. (2023). A Risk-Based Approach for the Analysis of Flood Impact in Villahermosa (Tabasco, Mexico). *Water*, *15*(22), 3969. https://doi.org/10.3390/w15223969

Cervera, M., Bell, S., Muñoz, F., Mishra, H. S., Fleming, L. E., Grellier, J., Carrasco-Turigas, G., Nieuwenhuijsen, M. J., Vert, C., & Gascon, M. (2021). A Transdisciplinary Approach to Recovering Natural and Cultural Landscape and Place Identification: A Case Study of Can Moritz Spring (Rubí, Spain). *International Journal of Environmental Research and Public Health*, *18*(4), 1709. https://doi.org/10.3390/ijerph18041709

Chandler, T. J. (1970). *Selected Bibliography on Urban Climate*. Secretariat of the World Meteorological Organization.

Charli-Joseph, L., Siqueiros-García, J., Eakin, H., Manuel-Navarrete, D., & Shelton, R. (2018). Promoting agency for social-ecological transformation: A transformation-lab in the Xochimilco social-ecological system. *Ecology and Society*, *23*. https://doi.org/10.5751/ES-10214-230246

Chen, J. (2007). *Flood Damage Map for the Huong River Basin* [University of Twente]. https://essay.utwente.nl/68464/1/Chen-Jorik.pdf

Choudhury, K., & Jansen, L. J. M. (1998). *Terminology for Integrated Resources Planning and Management*. FAO. https://www.researchgate.net/publication/239539807_Terminology_for_Integrated_Resources_Planning_and_Management

Città di Mantova (Director). (2017, September 28). *MANTOVA HUB - Un progetto di riqualificazione urbana* [Video recording]. https://www.youtube.com/watch?v=JpT4Eaymn-s

Città metropolitana di Milano. (2022, March). *Spugna*. Spugna. https://www.cittametropolitana.mi.it/PNRR/Piani-Urbani-Integrati/Spugna/index.html

Città metropolitana di Milano, & CAP Holding spa. (2022, March 10). *Piano Urbano Integrato Citta metropolitana Spugna*.

City of New York. (2024a). *Green Infrastructure*. https://www.nyc.gov/site/dep/water/green-infrastructure.page

City of New York. (2024b). *Greenstreets Program*. https://portal.311.nyc.gov/article/?kanumber=KA-01554

City of Philadelphia. (2014). *Green Streets Design Manual*.

Clément, G. (2005). *Manifesto del Terzo paesaggio*. Quodlibet. https://www.quodlibet.it/libro/9788874620487

Clerici, M. A. (2017). Le città medie nelle politiche di coesione 2014-2020. In L. Viganoni (Ed.), *Commercio, consumo e città: Quaderno di lavoro* (pp. 71–98). Franco Angeli. http://digital.casalini.it/9788891767554

Climate-ADAPT. (n.d.). *Berlin Biotope Area Factor – Implementation of guidelines helping to control temperature and runoff*. Retrieved 6 September 2022, from https://climate-adapt.eea.europa.eu/en/metadata/case-studies/berlin-biotope-area-factor-2013-implementation-of-guidelines-helping-to-control-temperature-and-runoff

Cockx, K., Pieters, J., Vijver, E. V. D., Willems, P., & Vanacker, S. (2023). *Monitoring the evolution of sealed surfaces in Flanders (Belgium) with annual high-resolution soil sealing maps* (EGU23-9824). EGU23. Copernicus Meetings. https://doi.org/10.5194/egusphere-egu23-9824

Comitato Interministeriale per le politiche urbane. (2013). *Metodi e Contenuti sulle Priorità in tema di Agenda Urbana*. http://www.cngeologi.it/wp-content/uploads/2013/04/Linee-Guida-CIPE.pdf

Comune di Brescia. (2017). *Piano comunale di Protezione Civile*. https://www.comune.brescia.it/aree-tematiche/protezione-civile/piano-comunale-di-protezione-civile/piano-comunale-di-protezione-civile

Comune di Brescia. (2021a). *Piano d'Azione per l'Energia Sostenibile e il Clima*. https://www.comune.brescia.it/aree-tematiche/ambiente/progetti/patto-dei-sindaci-piani-dazione-lenergia

Comune di Brescia. (2021b). *Una comunità che partecipa per trasformare la sfida del cambiamento climatico in opportunità. Strategia di Transizione Climatica—Delibera di Consiglio Comunale n. 52 del 25.06.2021*. https://www.comune.brescia.it/servizi/urbancenter/unfilonaturale/Documents/210720_UC_AT_188-RELAZIONE_STC_BS_rev2.pdf

Comune di Brescia. (2024a). *Riqualificazione via Metastasio*. https://www.comune.brescia.it/news/riqualificazione-metastasio

Comune di Brescia. (2024b). *Spazi Attivi*. https://www.comune.brescia.it/aree-tematiche/urban-center/progetto-un-filo-naturale/spazi-attivi

Comune di Forlì. (2019, January). *Regolamento del Verde Pubblico e Privato del Comune di Forlì*.

Comune di Forlì. (2022). *PAESC - Piano di azione per l'energia sostenibile e il clima*.

Comune di Mantova. (2020, June). *PAESC DI MANTOVA. Piano d'Azione per l'Energia e il Clima 2005-2030*.

Comune di Mantova, Comune di Curtatone, Comune di Marmirolo, Comune di Porto Mantovano, Comune di San Giorgio Bigarello, Comune di Volta Mantovana, Unione Colli Mantovani, Parco Regionale del Mincio, & Alkémica. (2021, September 8). *Strategia di Transizione Climatica. ACE3T - CLIMA Acqua Calore ed Energia: 3 pilastri per la transizione Climatica del MAntovano*.

Comune di Milano. (2022, February 21). *Piano Aria Clima*.

Comune di Modena. (2020, January). *PAESC Modena*.

Comune di Modena. (2023, June 23). *ST - Strategia per la qualità urbana ed ecologico—Ambientale*. https://www.comune.modena.it/argomenti/pug/elaborati-2023/st-strategia-per-la-qualita-urbana-ed-ecologico-ambientale

Comune di Padova. (2020, February 17). *Regolamento Edilizio*.

Comune di Padova. (2022). *Piano del verde comunale*. https://www.padovanet.it/informazione/piano-del-verde-comunale

Comune di Padova. (2023). *Piano degli interventi_Relazione generale*.

Comune di Padova, & VenetoADAPT. (2021, June 15). *PAESC DI PADOVA*.

Comune di Parma. (n.d.). *Parma Climate Neutral 2030*. Retrieved 1 October 2024, from https://www.comune.parma.it/it/amministrazione/aree-amministrative/settore-staff-della-direzione-generale/struttura-operativa-finanziamenti-comunitari-e-strategici/missione-100-citta-intelligenti-e-ad-impatto-climatico-zero/parma-climate-neutral-2030

Comune di Parma. (2021a). *La realtà socio-demografica dei quartieri di Parma al 31.12.2020*. https://www.comune.parma.it/comune/Statistica/quartieri-1_m1067.aspx

Comune di Parma. (2021b, June). *PAESC - Piano d'Azione per Energia Sostenibile e il Clima*.

Comune di Parma. (2022, March). *Piano del Verde_DP_Relazione.pdf*. https://drive.google.com/file/d/1TashEnelI9og3NiCov7I3BPhYSDh84rn/view?usp=sharing&usp=embed_facebook

Comune di Parma. (2023a). *Indagine demografica e socio-economica* (QC-1.0.2; PR050 Temi 1). https://www.parma2050.eu/indagine-socio-economica-e-demografica/

Comune di Parma. (2023b, July). *PUG-PR050_Il nuovo Piano Urbanistico Generale*. https://www.parma2050.eu/

Comune di Parma. (2024). *Popolazione residente al 1 gennaio 2024* [Dataset]. Open Data Comune di Parma. https://opendata.comune.parma.it/dataset/popolazione-residente-al-1-gennaio-2024/resource/c57205af-6f35-46b8-af3c-a3e9e5e402d9#{}

Comune di Parma, & Protezione Civile - Comune di Parma. (2024). *Piano Comunale di Protezione Civile*. https://atti.comune.parma.it/AttiVisualizzatore/visualizza/delibera/1583722

Comune di Piacenza. (2021, March). *PAESC del Comune di Piacenza. Obiettivi e azioni per l'adattamento ai cambiamenti climatici*.

Comune di Piacenza. (2024a, February). *PUG_Documento preliminare di Valsat*.

Comune di Piacenza. (2024b, February). *PUG_Presentazione degli obiettivi strategici e delle scelte generali di assetto del territorio_Consultazione Preliminare*.

Comune di Piacenza. (2024c, April 29). *Patto dei sindaci per il clima e l'energia*. http://www.comune.piacenza.it/it/public_documents/1000

Conway, D., Nicholls, R. J., Brown, S., Tebboth, M. G. L., Adger, W. N., Ahmad, B., Biemans, H., Crick, F., Lutz, A. F., De Campos, R. S., Said, M., Singh, C., Zaroug, M. A. H., Ludi, E., New, M., & Wester, P. (2019). The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. *Nature Climate Change*, *9*(7), Article 7. https://doi.org/10.1038/s41558-019-0502-0

Copernicus Land Monitoring Service. (2018). *High Resolution Layer Imperviousness* [Dataset]. https://doi.org/10.2909/3bf542bd-eebd-4d73-b53c-a0243f2ed862

Cortesi, S., & Segadelli, S. (2014). *Hydrogeological analysis of Parma Province to support mining planning (Sustainable Aggregates Planning in South East Europe—SNAP-SEE - WP4)*. Unpublished. http://rgdoi.net/10.13140/RG.2.2.13143.68000

Couch, C., Fraser, C., & Percy, S. (Eds.). (2003). *Urban Regeneration in Europe*. John Wiley & Sons.

Couch, V. T., Salata, S., Saygin, N., Frary, A., & Arslan, B. (2023). De-Sealing Reverses Habitat Decay More Than Increasing Groundcover Vegetation. *Climate*, *11*(6), Article 6. https://doi.org/10.3390/cli11060116

Council Of Europe. (1973). European soil charter. *Biological Conservation*, *5*(2), 148–150. https://doi.org/10.1016/0006-3207(73)90103-1

Council of Europe. (2000). *Landscape Convention (ETS No. 176)*. https://www.coe.int/en/web/landscape/home/

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297–334. https://doi.org/10.1007/BF02310555

D'Ascanio, R., & Palazzo, A. L. (2023). Unfolding the Aniene River in Peri-Urban Rome. From Conflicts to Opportunities for a Sustainable Strategy. In B. Giudice, G. Novarina, & A. Voghera (Eds.), *Green Infrastructure: Planning Strategies and Environmental Design* (pp. 43–53). Springer International Publishing. https://doi.org/10.1007/978-3-031-28772-5_4

Davis, K. (1955). The Origin and Growth of Urbanization in the World. *American Journal of Sociology*, *60*(5), 429–437. https://doi.org/10.1086/221602

De Lange, M., De Waal, M., & Bouw, M. (2020). The hackable city. In K. S. Willis & A. Aurigi (Eds.), *The Routledge Companion to Smart Cities* (1st ed., pp. 351–366). Routledge. https://doi.org/10.4324/9781315178387-24

De Noia, I. (2021). *L'acqua come risorsa ed elemento per una progettazione territoriale sostenibile: Valorizzazione dell'area di Comano Terme tra paesaggi del benessere e produzione energetica* [Master's thesis]. University of Trento. Department of Civil, Environmental and Mechanical Engineering.

De Noia, I., Favargiotti, S., & Marzadri, A. (2022). *Renaturalising lands as an adaptation strategy. Towards an integrated water-based design approach. TeMA - Journal of Land Use, Mobility and Environment. 15 (2).* https://doi.org/10.6093/1970-9870/9074

De Risi, R., Jalayer, F., De Paola, F., Carozza, S., Yonas, N., Giugni, M., & Gasparini, P. (2020). From flood risk mapping toward reducing vulnerability: The case of Addis Ababa. *Natural Hazards*, *100*(1), 387–415. https://doi.org/10.1007/s11069-019-03817-8

Dehaene, M., Havik, K., & Notteboom, B. (2013). *The Mid-size City as a European Urban Condition and Strategy* (pp. 2–9).

Delaney, J. (2022). Minecraft and Playful Public Participation in Urban Design. *Urban Planning*, *7*(2), 330–342. https://doi.org/10.17645/up.v7i2.5229

Dessì, V., Farnè, E., Ravanello, L., & Salomoni, M. T. (2017). *RIGENERARE LA CITTÀ CON LA NATURA. Strumenti per la progettazione degli spazi pubblici tra mitigazione e adattamento ai cambiamenti climatici.* https://territorio.regione.emilia-romagna.it/paesaggio/pubblicazioni/rigenerare-la-citta-con-la-natura

DGE. (2013). *Hard surfaces, hidden costs: Searching for alternatives to land take and soil sealing*. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/16427

Dickinson, G. C., & Shaw, M. G. (1977). What is 'land use'? *Area*, *9*(1), 38–42. http://www.jstor.org/stable/20001161

Dierkes, C. (2015). Entsiegelung mit wasserdurchlässigen Flächenbelägen – zurück zum natürlichen Wasserkreislauf. *De- Und Semizentrale Niederschlagswasserbehandlungsanlagen: Tagungsband IKT-Forum: Niederschlagswasser, Vegetation & Infrastruktur - 22. & 23. April 2015, Gelsenkirchen*, 43–58.

Dipartimento della Protezione Civile. (n.d.). *Che cos'è il rischio?* Retrieved 13 November 2024, from https://www.protezionecivile.gov.it/it/approfondimento/che-cos---il-rischio-/

Dipartimento della Protezione Civile. (2016). *Pianificazione di protezione civile*. Media e comunicazione. https://servizio-nazionale.protezionecivile.gov.it/it/approfondimento/pianificazione-di-protezione-civile/

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the Assessment and Management of Flood Risks, 288 (2007). http://data.europa.eu/eli/dir/2007/60/oj/eng

Donaldson, R., Marais, L., & Nel, E. (2020). Secondary Cities in South Africa. In R. Massey & A. Gunter (Eds.), *Urban Geography in South Africa: Perspectives and Theory* (pp. 121–137). Springer International Publishing. https://doi.org/10.1007/978-3-030-25369-1_8

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *Journal of Social Issues*, *56*(3), 425–442.

EC. (2000). *COM(2000)1100, Guidelines for a Community initiative concerning economic and social regeneration of cities and of neighbourhoods in crisis in order to promote sustainable urban development Urban II*. https://eur-lex.europa.eu/EN/legal-content/summary/urban-ii.html

EC. (2002, April 16). *COM(2002)179 final, Towards a Thematic Strategy for Soil Protection*. https://eur-lex.europa.eu/legal-content/IT/ALL/?uri=CELEX%3A52002DC0179

EC. (2006a). *COM(2006)232 final, Proposal for a directive establishing a framework for the protection of soil and amending Directive 2004/35/EC*. https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=celex%3A52006PC0232

EC. (2006b). *State aid control and regeneraton of deprived urban areas—Vademecum*. http://store1.digitalcity.eu.com/store/clients/release/AAAAGNJH/doc/regeneration_deprived_urba_areas_2007.06.24-16.27.18.pdf

EC. (2006c, September 22). *COM(2006)231 final, Thematic Strategy for Soil Protection*. https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=celex%3A52006DC0231

EC. (2011a). *Mapping Guide v.6.2 for a European Urban Atlas*. European Union. https://www.eea.europa.eu/data-and-maps/data/urban-atlas/mapping-guide/urban_atlas_2006_mapping_guide_v2_final.pdf/download

EC. (2011b, September 20). *COM(2011)571 final, Roadmap to a Resource Efficient Europe*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52011DC0571

EC. (2012, March 12). *COM(2012)93 final, Proposal for a decision on accounting rules and action plans on greenhouse gas emissions and removals resulting from activities related to land use, land use change and forestry*. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0093:FIN:EN:PDF

EC. (2020). *COM(2020) 380 final, EU Biodiversity Strategy for 2030*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52020DC0380

EC. (2021, November 17). *COM(2021)699 final, EU Soil Strategy for 2030 Reaping the benefits of healthy soils for people, food, nature and climate*. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM%3A2021%3A699%3AFIN

EC. (2022a). *Urban-rural Europe—Introduction*. Eurostat Statistics Explained. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Urban-rural_Europe_-_introduction

EC. (2022b, June 22). *Nature restoration law*. Energy, Climate Change, Environment. https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en

EC. (2023). *COM(2023)416 final, Proposal for a Directive on Soil Monitoring and Resilience (Soil Monitoring Law)*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0416

EC & DGE. (2012a). *Guidelines on best practice to limit, mitigate or compensate soil sealing*. Publications Office. https://doi.org/10.2779/75498

EC, & DGE. (2012b). *Soil Sealing* [In-depth Report]. https://ec.europa.eu/environment/archives/soil/pdf/sealing/Soil%20Sealing%20In-depth%20Report%20March%20version_final.pdf

EC e DGE. (2022). *Nature restoration law: For people, climate, and planet*. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/86148

EEA. (n.d.). *Average annual increase of sealing*. Retrieved 9 November 2024, from https://www.eea.europa.eu/data-and-maps/figures/average-annual-increase-of-sealing-2/average-annual-increase-of-sealing/112569_MAP2-LSI002-Average-annual-change.eps.75dpi.png/download

EEA. (2004). Land Use. In *EEA Glossary*. https://www.eea.europa.eu/help/glossary/eea-glossary/land-use

EEA. (2012). *Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies* (EEA Report 2; p. 143). https://www.eea.europa.eu/publications/urban-adaptation-to-climate-change

EEA. (2019). *Land and soil in Europe: Why we need to use these vital and finite resources sustainably*. Publications Office of the European Union. https://data.europa.eu/doi/10.2800/779710

EEA. (2020, March 25). *Percentage soil sealing by country*. https://www.eea.europa.eu/en/analysis/maps-and-charts/percentage-sealing-by-country-1

EEA. (2021). *Imperviousness and imperviousness change in Europe* [Indicator Assessment]. Data and Maps. https://www.eea.europa.eu/data-and-maps/indicators/imperviousness-change-2/assessment

EEA. (2023a). *Countly profiles—Italy*. Climate ADAPT. https://climate-adapt.eea.europa.eu/en/countries-regions/countries/italy

EEA. (2023b). *Net land take in cities and commuting zones in Europe*. Analysis and Data. https://www.eea.europa.eu/en/analysis/indicators/net-land-take-in-cities

EEA. (2024). *Climate change impacts, risks and adaptation*. EEA Topics. https://www.eea.europa.eu/en/topics/in-depth/climate-change-impacts-risks-and-adaptation

Eizenberg, E. (2019). Patterns of self-organization in the context of urban planning: Reconsidering venues of participation. *Planning Theory*, *18*(1), 40–57.

Elboshy, B., Kanae, S., Gamaleldin, M., Ayad, H., Osaragi, T., & Elbarki, W. (2019). A framework for pluvial flood risk assessment in Alexandria considering the coping capacity. *Environment Systems and Decisions*, *39*(1), 77–94. https://doi.org/10.1007/s10669-018-9684-7

Ellena, M., Guglielmo, R., Giuliana, B., Alessandra, B., Veronica, V., & Paola, M. (2020). Past and future hydrogeological risk assessment under climate change conditions over urban settlements and infrastructure systems: The case of a sub-regional area of Piedmont, Italy. *Natural Hazards*, *102*(1), 275–305. https://doi.org/10.1007/s11069-020-03925-w

Ellena, M., Melis, G., Zengarini, N., Di Gangi, E., Ricciardi, G., Mercogliano, P., & Costa, G. (2023). Micro-scale UHI risk assessment on the heat-health nexus within cities by looking at socio-economic factors and built environment characteristics: The Turin case study (Italy). *Urban Climate*, *49*, 101514. https://doi.org/10.1016/j.uclim.2023.101514

Escudero Gómez, L. A., García González, J. A., & Martínez Navarro, J. M. (2019). Medium-sized Cities in Spain and Their Urban Areas within National Network. *Urban Science*, *3*(1), Article 1. https://doi.org/10.3390/urbansci3010005

ESPON. (2006). *The Role of Small and Medium-Sized Towns (SMESTO)* (Final Report 1.4.1). ESPON - European Spatial Planning Observation Network. https://www.espon.eu/sites/default/files/attachments/fr-1.4.1_revised-full.pdf

ESRI. (n.d.). *Data Model Definition*. GIS Dictionary. Retrieved 9 March 2023, from https://support.esri.com/en-us/gis-dictionary/data-model

Essenfelder, A. H., Bagli, S., Mysiak, J., Pal, J. S., Mercogliano, P., Reder, A., Rianna, G., Mazzoli, P., Broccoli, D., & Luzzi, V. (2022). Probabilistic Assessment of Pluvial Flood Risk Across 20 European Cities: A Demonstrator of the Copernicus Disaster Risk Reduction Service for Pluvial Flood Risk in Urban Areas. *Water Economics and Policy*, *08*(03), 2240007. https://doi.org/10.1142/S2382624X22400070

EU. (2013, December 28). *Decision No 1386/2013/EU, on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' Text with EEA relevance*. http://data.europa.eu/eli/dec/2013/1386/oj/ita

European Parliament. (2024). *Statistiche sul cambiamento climatico in Europa*. Tematiche | Parlamento europeo. https://www.europarl.europa.eu/topics/it/article/20180703STO07123/statistiche-sul-cambiamento-climatico-in-europa

Eurotowns. (n.d.). *Eurotowns network*. Eurotowns. Retrieved 17 May 2022, from https://www.eurotowns.org/network/

Fabbri, D., Pizzol, R., Calza, P., Malandrino, M., Gaggero, E., Padoan, E., & Ajmone-Marsan, F. (2021). Constructed Technosols: A Strategy toward a Circular Economy. *Applied Sciences*, *11*(8), Article 8. https://doi.org/10.3390/app11083432

FAO. (1997). *AFRICOVER: Land cover classification*. FAO. https://www.fao.org/publications/card/en/c/95946a89-1242-45fc-9b21-1b55a8d1b8ff/

Ferraioli, E., Appiotti, F., Magni, F., & Reho, M. (2020). *L'importanza degli strumenti partecipativi nella pianificazione paesaggistica per far fronte alle nuove dinamiche di trasformazione del territorio*. https://air.iuav.it/handle/11578/296887

Few, R., Brown, K., & Tompkins, E. L. (2007). Public participation and climate change adaptation: Avoiding the illusion of inclusion. *Climate Policy*, *7*(1), 46–59. https://doi.org/10.1080/14693062.2007.9685637

Fokaides, P., Kylili, A., Nicolaou, L., & Ioannou, B. (2016). The effect of soil sealing on the urban heat island phenomenon. *Indoor and Built Environment*, *25*(7), 1136–1147. https://doi.org/10.1177/1420326X16644495

Forum nazionale Salviamo il Paesaggio. (2018, January 31). *Proposta di legge di iniziativa popolare | Norme per l'arresto del consumo di suolo e per il riuso dei suoli urbanizzati*. http://www.salviamoilpaesaggio.it/blog/wp-content/uploads/2018/02/DEFINITIVO-Proposta-di-legge-iniziativa-popolare-Forum-SiP-agg.-31-1-2018.pdf

Franco, S., & Cappa, F. (2021). Citizen science: Involving citizens in research projects and urban planning. *TeMA - Journal of Land Use, Mobility and Environment*, *14*(1), 114–118. https://doi.org/10.6092/1970-9870/7892

Gabbianelli, A. (2017). *Spazi residuali. La vegetazione nei processi di rigenerazione urbana*. https://iris.polito.it/handle/11583/2721872

Gaglione, F. (2022). *Città e climate change. La vulnerabilità delle aree urbane alle isole di calore*. FedOA - Federico II University Press. https://doi.org/10.6093/978-88-6887-139-0

Garau, C., & Pavan, V. M. (2018). Evaluating Urban Quality: Indicators and Assessment Tools for Smart Sustainable Cities. *Sustainability*, *10*(3), Article 3. https://doi.org/10.3390/su10030575

García de Jalón, S., Chiabai, A., Tague, A., Artaza, N., Ayala, A., Quiroga, S., Kruize, H., Suárez, C., Bell, R., & Taylor, T. (2020). Providing Access to Urban Green Spaces: A Participatory Benefit-Cost Analysis in Spain. *International Journal of Environmental Research and Public Health*, *17*, 2818. https://doi.org/10.3390/ijerph17082818

Garda, E. (2019). Let's get dirty! Le azioni di depaving dei suoli urbani per la multifunzionalità degli spazi sottoutilizzati. *Altre Modernità*, 164–178. https://doi.org/10.13130/2035-7680/12150

Garda, E. (2020). Le azioni di depaving dei suoli urbani per una nuova multifunzionalità degli spazi sottoutilizzati. *La città contemporanea: un gigante dai piedi d'argilla. Atti della conferenza internazionale | Torino, 15 novembre 2019*, *LA CITTÀ CONTEMPORANEA: UN GIGANTE DAI PIEDI D'ARGILLA*, 225–231. https://aisberg.unibg.it/handle/10446/160720

Garda, E. (2022). Reasons, Concepts, and Methods for Soil De-sealing in the Regulatory Framework of the Italian Regions. *Italian Journal of Planning Practice*, *12*(1), 65–81. Scopus.

Gaßner, H., Willand, A., Fischer, J., Pippke, N., & Umweltbundesamt Deutschland. (2001).

Anforderungen an die Wiederherstellung von Bodenfunktionen nach Entsiegelung. https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/2027.pdf

Geropanta, V., Karagianni, A., Parthenios, P., Ampatzoglou, T., Fatouros, L., Simantiraki, V., Brokos-Melissaratos, O., & Eleftheriadis, D. (2022). *Digitalization of Participatory Greening—The case of UnionYouth in Chania*. 469–478. https://doi.org/10.52842/conf.ecaade.2022.1.469

Gerundo, C. (2018). *L'adattamento delle città ai cambiamenti climatici*. FedOA - Federico II University Press. https://doi.org/10.6093/978-88-6887-031-7

Gharbi, A., De Runz, C., & Akdag, H. (2017). Urban Development Modelling: A Survey. In S. Faiz & K. Mahmoudi (Eds.), *Handbook of Research on Geographic Information Systems Applications and Advancements* (pp. 96–124). IG Global. https://doi.org/10.4018/978-1-5225-0937-0.ch004

Giaimo, C., Salata, S., & Pantaloni, G. G. (2020). Pianificare la rigenerazione dei tessuti insediativi. Il caso dell'adattamento ai fenomeni di pioggia intensa a Settimo Torinese (To). *Atti Della Conferenza Nazionale UrbanPromo XVII Edizione*, 159–171. https://iris.polito.it/handle/11583/2853501

Gibelli, G., Gelmini, A., Pagnoni, E., & Natalucci, F. (2015). *GESTIONE SOSTENIBILE DELLE ACQUE URBANE. MANUALE DI DRENAGGIO 'URBANO'* (Perché, Cosa, Come Regione Lombardia, Ersaf). https://www.contrattidifiume.it/it/pubblicazioni/manuali-e-linee-guida/#/

GIZ, & EURAC. (2017). *Risk Supplement to the Vulnerability Sourcebook. Guidance on how to apply the Vulnerability Sourcebook's approach with the new IPCC AR5 concept of climate risk*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://mia.giz.de/cgi-bin/getfile/53616c7465645f5f310415fa5c203135e852ca01ddf63ca75cbc46be2f1eba4e49c8386d845c2643ba428490416d76b947421762e5f3ab5f81d72ddeacdb797e/giz2017-0552en-risk-supplement-vulnerability-sourcebook.pdf

Gobo, G. (2004). Sampling, Representativeness and Generalizability. In C. Seale, G. Gobo, J. Gubrium, & D. Silverman, *Qualitative Research Practice* (pp. 405–426). SAGE Publications Ltd. https://doi.org/10.4135/9781848608191.d34

Grashof, A. (2019). *Greening private gardens: A formative evaluation of the effectiveness of Steenbreek as a steering mechanism* [Bachelor's Thesis, University Utrecht]. https://studenttheses.uu.nl/bitstream/handle/20.500.12932/33247/Grashof_Thesis.pdf?sequence=1

Greco, J. (2012). *Small, nimble projects are adding value to public spaces.*

Guttenberg, A. Z. (1959). *A Multiple Land Use Classification System*. *25*(3), 143–150. https://doi.org/10.1080/01944365908978322

Hans van der Kwast (Director). (2019, November 16). *Calculate the Topographic Wetness Index in QGIS* [Video recording]. https://www.youtube.com/watch?v=aHCLCUwg3O0

Harlan, S. L., Declet-Barreto, J. H., Stefanov, W. L., & Petitti, D. B. (2013). Neighborhood Effects on Heat Deaths: Social and Environmental Predictors of Vulnerability in Maricopa County, Arizona. *Environmental Health Perspectives*, *121*(2), 197–204. https://doi.org/10.1289/ehp.1104625

Haughton, G., White, I., & Pinto, N. (2020). *Planning in the post-pandemic era*. https://researchcommons.waikato.ac.nz/bitstream/handle/10289/15757/Pandemic%20planning%20Apr20%20TCPA.pdf?sequence=2

Haynes, K., & Tanner, T. M. (2015). Empowering young people and strengthening resilience: Youth-centred participatory video as a tool for climate change adaptation and disaster risk reduction. *Children's Geographies*, *13*(3), 357–371. https://doi.org/10.1080/14733285.2013.848599

Henriques, C. D. (2021). Geoinformation Technologies in Land Use Monitoring of Fast-Growing Cities for Sustainable Urban Development: Maputo as a Laboratory for Research and Action. In *Methods and Applications of Geospatial Technology in Sustainable Urbanism* (pp. 34–56). IGI Global. https://doi.org/10.4018/978-1-7998-2249-3.ch002

Hensher, D. A., Rose, J. M., & Greene, W. H. (2015). *Applied Choice Analysis* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/CBO9781316136232

Hess, S., & Daly, A. (Eds.). (2024). Designing and conducting stated choice experiments. In M. C. J. Bliemer & J. M. Rose, *Handbook of Choice*

Modelling (pp. 172–205). Edward Elgar Publishing. https://doi.org/10.4337/9781800375635.00013

Hildreth, P. (2007, May). Understanding medium-sized cities. *Town and Country Planning*, 163–167.

Hohmann, R. P., & Roberts, B. (2014). *Secondary Cities: Managing Urban Land Governance Systems*. https://www.academia.edu/6796564/Secondary_Cities_Managing_Urban_Land_Governance_Systems

Horta, M. B., Cabral, M. I., Pires, I., Bachi, L. S., Luz, A., Fernandes, G. W., Drumond, M. A., & Carvalho-Ribeiro, S. (2020). Assessing Urban Ecosystem Services: Different Methodological Approaches Applied in Brazil, Germany, and Portugal. In *Developing Eco-Cities Through Policy, Planning, and Innovation: Can It Really Work?* (pp. 312–359). IGI Global. https://doi.org/10.4018/978-1-7998-0441-3.ch012

Howard, L. (1833a). *The Climate of London: Deduced from Meteorological Observations Made in the Metropolis and at Various Places Around it* (Vol. 1). Harvey and Darton, J. and A. Arch, Longman, Hatchard, S. Highley [and] R. Hunter.

Howard, L. (1833b). *The Climate of London: Deduced from Meteorological Observations Made in the Metropolis and at Various Places Around it* (Vol. 2). Harvey and Darton, J. and A. Arch, Longman, Hatchard, S. Highley [and] R. Hunter.

Hu, H. (2016). Rainstorm flash flood risk assessment using genetic programming: A case study of risk zoning in Beijing. *Natural Hazards*, *83*(1), 485–500. https://doi.org/10.1007/s11069-016-2325-x

Huizinga, J., De, M. H., & Szewczyk, W. (2017, April 12). *Global flood depth-damage functions: Methodology and the database with guidelines*. JRC Publications Repository. https://doi.org/10.2760/16510

Ibrahim, S., Brasi, B., Yu, Q., & Siddig, M. (2022). Curve number estimation using rainfall and runoff data from five catchments in Sudan. *Open Geosciences*, *14*(1), 294–303. https://doi.org/10.1515/geo-2022-0356

INTELI – Inteligência em Inovação, Centro de Inovação. (2011). *Creative-based Strategies in Small and Medium-sized Cities: Guidelines for Local Authorities*.

IPCC. (2018). Annex I: Glossary. In J. B. R. Matthews, (Ed.), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]* (pp. 541–562). Cambridge University Press. https://www.ipcc.ch/sr15/chapter/glossary/

IPCC. (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.).* Cambridge University Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

IPCC. (2023). *Annex I: Glossary [Reisinger, A., D. Cammarano, A. Fischlin, J.S. Fuglestvedt, G. Hansen, Y. Jung, C. Ludden, V. Masson-Delmotte, R. Matthews, J.B.K Mintenbeck, D.J. Orendain, A. Pirani, E. Poloczanska, and J. Romero (eds.)]. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]* (pp. 119–130). IPCC. doi:10.59327/IPCC/AR6-9789291691647.002

Irmak, M., Yilmaz, S., & Dursun, D. (2017). Effect of different pavements on human thermal comfort conditions. *Atmósfera, 30*, 355–366. https://doi.org/10.20937/ATM.2017.30.04.06

Isola di calore urbano. (n.d.). In *Treccani*. Retrieved 3 November 2023, from https://www.treccani.it/vocabolario/neo-isola-di-calore-urbano_%28Neologismi%29/

ISPRA. (n.d.). *Corine Land Cover*. ISPRA | Attività | Geologia, Suolo e Siti Contaminati. Retrieved 26 May 2022, from https://www.isprambiente.gov.it/it/attivita/suolo-e-territorio/copertura-del-suolo/corine-land-cover

ISPRA. (2021). *Libro Bianco sulla gestione sostenibile dei suoli* [Report Soil4Life Life GIE/IT/000477].

Istituto Superiore per la Protezione e la Ricerca Ambientale. (2021). *Carta nazionale di copertura del suolo 2021* [Dataset]. https://www.isprambiente.gov.it/it/attivita/suolo-e-territorio/suolo/copertura-del-suolo/carta-nazionale-di-copertura-del-suolo

Jahan, K., Pradhanang, S. M., & Bhuiyan, M. A. E. (2021). Surface Runoff Responses to Suburban Growth: An Integration of Remote Sensing, GIS, and Curve Number. *Land*, *10*(5), Article 5. https://doi.org/10.3390/land10050452

Jember, Y. (2019). Land Use Land Cover Dynamics in Ribb Watershed and Its Implication to the Sustainability of Ribb Dam: South Gondar, Ethiopia. In *Geospatial Technologies for Effective Land Governance* (M. El-Ayachi, L. El Mansouri (Eds.), p. 14). IGI Global. https://doi.org/10.4018/978-1-5225-5939-9.ch009

Jobstmann, H., Prokop, G., & Schönbauer, A. (2011a). *Overview of best practices for limiting soil sealing or mitigating its effects in EU-27: Final report*. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/15146

Jobstmann, H., Prokop, G., & Schönbauer, A. (with Direzione generale dell'Ambiente (Commissione europea)). (2011b). *Report on best practices for limiting soil sealing and mitigating its effects*. Ufficio delle pubblicazioni dell'Unione europea. https://data.europa.eu/doi/10.2779/15146

Jonkman, S. N., & Asselman, N. (2003). Method for the Estimation of Loss of Life Caused by Floods in the Netherlands. In Y. Chen (Ed.), *GIS and Remote Sensing in Hydrology, Water Resources and Environment* (Vol. 1). WL | Delft Hydraulics.

Jonkman, S. N., Curran, A., & Bouwer, L. M. (2024). Floods have become less deadly: An analysis of global flood fatalities 1975–2022. *Natural Hazards*, *120*(7), 6327–6342. https://doi.org/10.1007/s11069-024-06444-0

Jonkman, S. N., Vrijling, J., & Vrouwenvelder, A. C. W. M. (2008). Methods for the estimation of loss of life due to floods: A literature review and a proposal for a new method. *Natural Hazards*, *46*, 353–389. https://doi.org/10.1007/s11069-008-9227-5

Joye, R., & Notteboom, B. (2018). Learning to make space for demolition. *Eclas Conference 2018 'Landscapes of Conflict'*, *Eclas conference 2018 'Landscapes of conflict'*, 573–580.

Kalogeropoulos, G., Dimoudi, A., Toumboulidis, P., & Zoras, S. (2022). Urban Heat Island and Thermal Comfort Assessment in a Medium-Sized Mediterranean City. *Atmosphere*, *13*(7). Scopus. https://doi.org/10.3390/atmos13071102

Kang, T. (2017, June 1). *160 Years of Central Park: A Brief History*. Central Park Conservancy. https://www.centralparknyc.org/articles/central-park-history

Kassem, Y., Gökçekuş, H., & Alijl, N. (2022). Flash Flood Risk Assessment for Girne Region, Northern Cyprus. *Engineering, Technology & Applied Science Research*, *12*(3), Article 3. https://doi.org/10.48084/etasr.4939

Kelleher, C., & McPhillips, L. (2020). Exploring the application of topographic indices in urban areas as indicators of pluvial flooding locations. *Hydrological Processes*, *34*(3), 780–794. https://doi.org/10.1002/hyp.13628

Kemperman, A., & Timmermans, H. (2014). Green spaces in the direct living environment and social contacts of the aging population. *Landscape and Urban Planning*, *129*, 44–54. https://doi.org/10.1016/j.landurbplan.2014.05.003

Kibblewhite, M. g, Ritz, K., & Swift, M. j. (2008). Soil health in agricultural systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1492), 685–701. https://doi.org/10.1098/rstb.2007.2178

Kielce. (2018). *Plan Adaptacji do zmian klimatu*.

Kim, J., Kim, D., Lee, M., Han, H., & Kim, H. S. (2022). Determining the Risk Level of Heavy Rain Damage by Region in South Korea. *Water*, *14*(2), Article 2. https://doi.org/10.3390/w14020219

Kjær, T. (2005). A review of the discrete choice experiment—With emphasis on its application in health care. In *A review of the discrete choice experiment—With emphasis on its application in health care* [Report]. Syddansk Universitet.

Kunzmann, K. R. (2009). *Medium-sized Towns, Strategic Planning and Creative Governance in the South Baltic Arc*. IUFA Conference, Bologna. http://www.visible-cities.net/documents/KRK_MediumSized_Cities.pdf

Kuokkanen, K., & Palonen, Em. (2018). Post-Political Development and Emancipation: Urban

Participatory Projects in Helsinki. In *Public Space Unbound*. Routledge.

Lafortezza, R., & Sanesi, G. (2019). Nature-based solutions: Settling the issue of sustainable urbanization. *Environmental Research*, *172*, 394–398. https://doi.org/10.1016/j.envres.2018.12.063

L'alluvione a Parma. (2014, October 14). *Il Post*. https://www.ilpost.it/2014/10/14/alluvione-parma-esondazione-baganza/

Landsberg, H. E. (Ed.). (1981a). 5—The Urban Heat Island. In *International Geophysics* (Vol. 28, pp. 83–126). Academic Press. https://doi.org/10.1016/S0074-6142(08)60187-4

Landsberg, H. E. (1981b). *The Urban Climate*. Academic Press.

Lastoria, B., Bussettini, M., Mariani, S., Piva, F., & Braca, G. (2021). *Rapporto sulle condizioni di pericolosità da alluvione in Italia e indicatori di rischio associati* (353; Rapporti). ISPRA & SNPA. https://www.isprambiente.gov.it/files2021/pubblicazioni/rapporti/rapporto_alluvioni_ispra_353_16_11_2021_rev2.pdf

Le Guern, C., Prézeau, F., Clozel, B., Leduc, T., Musy, M., Rodler, A., Guernouti, S., Béchet, B., Dufrasnes, E., Stabile, O., Recknagel, C., Garnier, H., & Lefranc, A. (2022, September 5). *Soil properties and desealing strategies: Feedback from the DésiVille project (France)*. SUITMA 11 Conference on Soils of Urban, Industrial, Traffic and Mining Areas. https://hal.science/hal-03769990

Leinfelder, H. (2018). Making space for less. Towards de-sealing and de-construction in planning policy—KU Leuven. *Making Space for Hope*. AESOP Annual Congress - Making space for hope, 2018/07/10 - 2018/07/14, Gothenburg. https://kuleuven.limo.libis.be/discovery/fulldisplay/lirias1998770/32KUL_KUL:Lirias

Leone, F., Isola, F., & Pittau, R. (2023). Evaluating the urban heat island phenomenon from a spatial planning viewpoint. A systematic review. *TeMA - Journal of Land Use, Mobility and Environment*, 75–93. https://doi.org/10.6093/1970-9870/10306

Li, J., Zheng, A., Guo, W., Bandyopadhyay, N., Zhang, Y., & Wang, Q. (2023). Urban flood risk assessment based on DBSCAN and K-means clustering algorithm. *Geomatics, Natural Hazards and Risk*, *14*(1), 2250527. https://doi.org/10.1080/19475705.2023.2250527

Loli, M., Mitoulis, S., Kefalas, G., Bouzoni, E., Kapetas, L., Diaz-Fanas, G., & Arroyo, F. (2022, July 6). *Flood risk for urban mobility in Maputo, Mozambique: Regional-scale indexing based on earth observation and demographic data*. ICONHIC2022 3rd International Conference on Natural Hazards & Infrastructure. https://doi.org/10.5281/zenodo.7245484

Losco, S., & de Biase, C. (2021). Land Consumption Versus Urban Regeneration. In C. Bevilacqua, F. Calabrò, & L. Della Spina (Eds.), *New Metropolitan Perspectives. NMP 2020* (pp. 228–239). Springer International Publishing. https://doi.org/10.1007/978-3-030-48279-4_22

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). *Stated Choice Methods: Analysis and Applications*. Cambridge University Press. https://doi.org/10.1017/CBO9780511753831

Lucertini, G., Dall'Omo, C. F., Maragno, D., Negretto, V., & Musco, F. (2018). *Mantova Resiliente: Linee guida per un adattamento climatico local-based*. https://air.iuav.it/handle/11578/293616

Mabrouk, M., & Haoying, H. (2023). Urban resilience assessment: A multicriteria approach for identifying urban flood-exposed risky districts using multiple-criteria decision-making tools (MCDM). *International Journal of Disaster Risk Reduction*, *91*, 103684. https://doi.org/10.1016/j.ijdrr.2023.103684

Magni, F. (2023). Il clima cambia la città? Il paesaggio dell'adattamento urbano come nuova forma di trasformazione urbanistica contemporanea. In M. Reho, F. Magni, & F. Musco (Eds.), *Cambiamento climatico e paesaggio. Dalla definizione degli impatti alla costruzione di nuovi modelli di governance* (pp. 85–106). FrancoAngeli. https://air.iuav.it/bitstream/11578/333830/3/11862.1_%2BMAGNI%20%281%29_compressed.pdf

Maiellaro, G. F., & Costantino, P. (2023). Regole sul consumo di suolo come segno del progresso. E l'Italia? *Il Sole 24 Ore*. https://www.econopoly.ilsole24ore.com/2023/12/20/consumo-suolo-rigenerazione-italia-ddl/

Maienza, A., Ungaro, F., Baronti, S., Colzi, I., Giagnoni, L., Gonnelli, C., Renella, G., Ugolini, F., & Calzolari, C. (2021). Biological Restoration of Urban Soils after De-Sealing Interventions. *Agriculture*, *11*(3), 190.

Making Species Maps | Science Project. (n.d.). Science Buddies. Retrieved 19 June 2023, from https://www.sciencebuddies.org/science-fair-projects/project-ideas/EnvSci_p044/environmental-science/making-species-maps?from=Blog

Manik, T. K., & Syaukat, S. (2015). *The impact of urban heat islands: Assessing vulnerability in Indonesia*. https://www.iied.org/10721iied

Manley, G. (1958). On the frequency of snowfall in metropolitan England. *Quarterly Journal of the Royal Meteorological Society*, *84*(359), 70–72. https://doi.org/10.1002/qj.49708435910

Manojlovic, N., Behzadina, N., & Pasche, E. (2013). On the Way to a Flood Risk Management Plan. In W. Leal Filho (Ed.), *Climate Change and Disaster Risk Management* (pp. 379–397). Springer. https://doi.org/10.1007/978-3-642-31110-9_25

Maragno, D., Musco, F., & Patassini, D. (2017). La gestione del rischio di ondate di calore e allagamenti in ambiente urbano: Un modello applicativo. *Atti della XX Conferenza Nazionale SIU*, 131–140. https://www.academia.edu/36268203/Politiche_e_strategie_progettuali_innovative_per_laumento_della_resilienza_dei_sistemi_urbani_il_caso_delle_watersquares_in_Olanda

MASE. (n.d.). *L'Agenda 21*. Retrieved 17 October 2024, from https://www.mase.gov.it/pagina/lagenda-21

MASE. (2023a, February 27). *Piano Nazionale di Adattamento ai Cambiamenti Climatici_Allegato Database Azioni*.

MASE. (2023b, December). *Piano Nazionale di Adattamento ai Cambiamenti Climatici*.

Mattivi, P., Franci, F., Lambertini, A., & Bitelli, G. (2019). TWI computation: A comparison of different open source GISs. *Open Geospatial Data, Software and Standards*, *4*(1), 6. https://doi.org/10.1186/s40965-019-0066-y

MATTM. (2015). *Strategia Nazionale di Adattamento ai Cambiamenti Climatici*. https://pdc.mite.gov.it/it/norme/politicaenormativa/politica-ambientale/politica-nazionale/snac-strategia-nazionale-di

Mayor's Office of Sustainability and ICF International. (2015). *Growing stronger: Toward a climate-ready Philadelphia*.

Mayrhofer, R. (2018). Co-Creating community gardens on untapped terrain – lessons from a transdisciplinary planning and participation process in the context of municipal housing in Vienna. *Local Environment*, *23*(12), 1207–1224. https://doi.org/10.1080/13549839.2018.1541345

Mazza, L. (2013). If Strategic "Planning Is Everything, Maybe It's Nothing": Comments on Albrechts and Balduccis article: "Practicing Strategic Planning". *disP - The Planning Review*, *49*(3), 40–42. https://doi.org/10.1080/02513625.2013.859006

McFadden, D. (1973). Conditional logit analysis of qualitative choice behavior. In P. Zarembka (Ed.), *Frontiers in Econometrics* (pp. 105–142). Academic Press.

McHarg, I. L. (2007). *Progettare con la natura*. Franco Muzzio Editore.

Melis, G., Di Gangi, E., Ellena, M., Zengarini, N., Ricciardi, G., Mercogliano, P., & Costa, G. (2023). Urban Heat Island effect and social vulnerability in Turin: Prioritizing climate change mitigation action with an equity perspective. *Science Talks*, *8*, 100258. https://doi.org/10.1016/j.sctalk.2023.100258

Merler, S. (2021). Technocracy, Trust and Democracy: Evidence on Citizens' Attitudes from a Natural Experiment in Italy. *Government and Opposition*, *56*(2), 301–325. https://doi.org/10.1017/gov.2019.26

Meroni, A., & Selloni, D. (2022). The Rise of Co-design Processes for Urban Commons. In A. Meroni & D. Selloni (Eds.), *Service Design for Urban Commons* (pp. 11–22). Springer International Publishing. https://doi.org/10.1007/978-3-031-06035-9_2

Meuser, H. (2013). Rehabilitation of Soils in Urban Environments. In H. Meuser (Ed.), *Soil Remediation and Rehabilitation: Treatment of Contaminated and Disturbed Land* (pp. 5–36). Springer Netherlands. https://doi.org/10.1007/978-94-007-5751-6_2

Meyer, M. (2011). *Reduction of surface sealing in urban areas*. https://www.grin.com/document/183038

Meyfroidt, P., Roy Chowdhury, R., de Bremond, A., Ellis, E. C., Erb, K.-H., Filatova, T., Garrett, R. D., Grove, J. M., Heinimann, A., Kuemmerle, T., Kull, C. A., Lambin, E. F., Landon, Y., le Polain de

Waroux, Y., Messerli, P., Müller, D., Nielsen, J. Ø., Peterson, G. D., Rodriguez García, V., … Verburg, P. H. (2018). Middle-range theories of land system change. *Global Environmental Change*, *53*, 52–67. https://doi.org/10.1016/j.gloenvcha.2018.08.006

Mohajerani, A., Bakaric, J., & Jeffrey-Bailey, T. (2017). The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. *Journal of Environmental Management*, *197*, 522–538. https://doi.org/10.1016/j.jenvman.2017.03.095

Mohanty, S., Panda, J., & Rath, S. S. (2021). Geospatial Technology in Urban Sprawl Assessment: A Review. In *Methods and Applications of Geospatial Technology in Sustainable Urbanism* (pp. 1–33). IGI Global. https://doi.org/10.4018/978-1-7998-2249-3.ch001

Mohs, B., & Meiners, H.-G. (1994). *Kriterien des Bodenschutzes bei der Ver- und Entsiegelung von Böden: Untersuchungsprogramm Bodenver-/-entsiegelung, Forschungsbericht 107 03 007 16*. Umweltbundesamt.

Mott, M. (n.d.). *Green Streets in Philadelphia*. Retrieved 25 June 2024, from https://www.mottmac.com/article/11556/projects/green-streets-philadelphia

Mouratidis, K. (2021). Urban planning and quality of life: A review of pathways linking the built environment to subjective well-being. *Cities*, *115*, 103229. https://doi.org/10.1016/j.cities.2021.103229

Munafò, M. (Ed.). (2021). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici* (Report SNPA 22/21). https://www.snpambiente.it/pubblicazioni/report-snpa/consumo-di-suolo-dinamiche-territoriali-e-servizi-ecosistemici-edizione-2021/

Munafò, M. (Ed.). (2022). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici* (Report SNPA 32/22). https://www.snpambiente.it/pubblicazioni/report-snpa/consumo-di-suolo-dinamiche-territoriali-e-servizi-ecosistemici-edizione-2022/

Munafò, M. (Ed.). (2023). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici* (Report SNPA 37/23). https://www.snpambiente.it/snpa/consumo-di-suolo-dinamiche-territoriali-e-servizi-ecosistemici-edizione-2023/

Munafò, M., & Tombolini, I. (2014). *Il consumo di suolo in Italia. Edizione 2014* (Rapporti 195/2014). ISPRA. https://www.isprambiente.gov.it/it/pubblicazioni/rapporti/il-consumo-di-suolo-in-italia

Musco, F. (2014, January 24). La rigenerazione urbana e la resilienza al clima che cambia: Prime considerazioni dal progetto UHI. *La Città Si Rigenera. Riqualificazione Urbana e Clima Delle Città*. https://www.comune.modena.it/lecittasostenibili/documenti-cittasostenibili/pianificazione-e-partecipazione/conferenze-e-convegni/report-pubblicazioni/la-citta-si-rigenera-24-gennaio-2014-modena/abstractbook

Musco, F., & Fregolent, L. (2014). *Pianificazione urbanistica e clima urbano: Manuale per la riduzione dei fenomeni di isola di calore urbano*. Il Poligrafo.

Musco, F., Maragno, D., Magni, F., Innocenti, A., Negretto, V., Università IUAV di Venezia, Comune di Padova - Settore Ambiente e Territorio, Mazzetto, P., Luise, D., & Zuin, M. (2016). *Padova Resiliente. Linee guida per la costruzione del piano di adattamento al cambiamento climatico*. https://www.padovanet.it/notizia/20160713/padova-resiliente

Nakao, T. (2019). *Public Involvement in Green Infrastructure Maintenance on Local Streets* [Graduating Project, The University of British Columbia]. https://open.library.ubc.ca/media/stream/pdf/42591/1.0387212/4

Nardino, M., Fiorillo, E., Cremonini, L., Georgiadis, T., Morabito, M., Crisci, A., & Guerri, G. (2022). Mapping daytime thermal patterns of Bologna municipality (Italy) during a heatwave: A new methodology for cities adaptation to global climate change. *Urban Climate*, *46*, 101317. https://doi.org/10.1016/j.uclim.2022.101317

National Building Museum (Director). (2012, February 7). *How to Make a Green Roof* [Video recording]. https://www.youtube.com/watch?v=jUh6R1hs2Tw

Nestroy, O. (2006). Grundlegende Gedanken zur Wiedernutzbarmachung ehemaliger Bergbaue. *BHM Berg- und Hüttenmännische Monatshefte*, *151*(12), 487–491. https://doi.org/10.1007/BF03165217

Neto, L., Pinto, N., & Burns, M. (2014). Evaluating the Impacts of Urban Regeneration Companies in Portugal: The Case of Porto. *Planning Practice & Research*, *29*(5), 525–542. https://doi.org/10.1080/02697459.2014.973685

Neves, A. R., Blondel, L., Brand, K., Hendel-Blackford, S., Rivas Calvete, S., Iancu, A., Melica, G., Koffi, B., Zancanella, P., & Kona, A. (with Commissione europea, & Covenant of Mayors for Climate & Energy). (2016). *Linee guida del Patto dei Sindaci per il Clima e 'Energia per la presentazione dei rapporti di monitoraggio*. Ufficio delle pubblicazioni dell'Unione europea. https://op.europa.eu/en/publication-detail/-/publication/ac865f28-dedb-11e6-ad7c-01aa75ed71a1/language-it

Nicolini, E., & Pinto, M. R. (2013). Strategic Vision of a Euro-Mediterranean Port City: A Case Study of Palermo. *Sustainability*, *5*(9), Article 9. https://doi.org/10.3390/su5093941

Ningrum, W. (2018). Urban Heat Island towards Urban Climate. *IOP Conference Series: Earth and Environmental Science*, *118*, 012048. https://doi.org/10.1088/1755-1315/118/1/012048

Nortcliff, S., Hulpke, H., Bannick, C., Terytze, K., Knoop, G., Bredemeier, M., Schulte-Bisping, H., Auerswald, K., Litz, N., Mayer, R., Stoy, A., Alef, K., Kerndorff, H., Crössmann, G., Eikmann, T., Franzius, V., Grimsky, D., Möhlenbruch, N., Storm, P., & Dworshak, U. (2006). *Soil, Definition, Function, and Utilization of Soil* (Vol. 33, pp. 399–420). https://doi.org/10.1002/14356007.b07_613.pub2

NRCSUSDA. (1986). *Urban Hydrology for Small Watersheds* (Technical Release 55). https://www.hydrocad.net/pdf/TR-55%20Manual.pdf

NRCSUSDA. (2004). Estimation of Direct Runoff from Storm Rainfall. In *Hydrology National Engineering Handbook*.

Nuruzzaman, M. (2015). Urban Heat Island: Causes, Effects and Mitigation Measures - A Review. *International Journal of Environmental Monitoring and Analysis*, *3*(2), Article 2. https://doi.org/10.11648/j.ijema.20150302.15

OECD. (2014). *Population by region—Urban population by city size—OECD Data*. theOECD. http://data.oecd.org/popregion/urban-population-by-city-size.htm

Oke, T. R. (1982). The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society*, *108*(455), 1–24. https://doi.org/10.1002/qj.49710845502

Oliveira, E., Tobias, S., & Hersperger, A. M. (2018). Can Strategic Spatial Planning Contribute to Land Degradation Reduction in Urban Regions? State of the Art and Future Research. *Sustainability*, *10*(4), Article 4. https://doi.org/10.3390/su10040949

Oliver, K. G., Collin, P., Burns, J., & Nicholas, J. (2014). Building resilience in young people through meaningful participation. *Australian E-Journal for the Advancement of Mental Health*. https://doi.org/10.5172/jamh.5.1.34

Osservatorio del Paesaggio trentino. (2022). *Rapporto di ricognizione sul tema della gestione del fenomeno del consumo di suolo*.

Othmer, F. J., Becker, D., Schulte, L. M., & Greiving, S. (2020). A Methodological Approach to Municipal Pluvial Flood Risk Assessment Based on a Small City Case Study. *Sustainability*, *12*(24), Article 24. https://doi.org/10.3390/su122410487

Pachauri, R. K., Mayer, L., & Intergovernmental Panel on Climate Change (Eds.). (2014). *Climate change 2014: Synthesis report*. Intergovernmental Panel on Climate Change.

Paez, D. (2003). Spatial and Temporal Representation of Environmental Policy Outcomes Using Geo-Computation: A Case Study in Victoria, ... *San Diego, USA*. https://www.academia.edu/25147643/Spatial_and_Temporal_Representation_of_Environmental_Policy_Outcomes_Using_Geo_Computation_A_Case_Study_in_Victoria_

Palazzo, A. L., & Cappuccitti, A. (2024). *Rigenerazione urbana. Sfide e strategie*. Carocci.

Park, C. (2007). A Dictionary of Environment and Conservation. In *A Dictionary of Environment and Conservation*. Oxford University Press. https://www.oxfordreference.com/view/10.1093/acref/9780198609957.001.0001/acref-9780198609957

Park, K., Choi, S.-H., & Yu, I. (2021). Risk Type Analysis of Building on Urban Flood Damage. *Water*, *13*(18), Article 18. https://doi.org/10.3390/w13182505

Parma Food Valley. (n.d.). *Parma Food Valley—Dove il cibo è molto di più*. Retrieved 15 November 2024, from https://www.parmafoodvalley.net/

Pelorosso, R., Gobattoni, F., Lopez, N., & Leone, A. (2013). Verde urbano e processi ambientali: Per una progettazione di paesaggio multifunzionale. *TeMA - Journal of Land Use, Mobility and Environment*, *6*(1), 95–111. https://doi.org/10.6092/1970-9870/1418

Peng, Y., & Reilly, K. (2021). *Using Nature to Reshape Cities and Live with Water: An overview of the Chinese Sponge City Programme and Its Implementation in Wuhan*. IUCN European Regional Office. https://growgreenproject.eu/wp-content/uploads/2021/01/Sponge-City-Programme-in-Wuhan-China.pdf

Per riqualificare il quartiere seminiamo nuove piante. (2024, December 21). *Gazzetta Di Parma*.

Petrella, Vi. (2017). *Breve prontuario di co-progettazione. Idee e strumenti per avviare e gestire progetti condivisi*. https://www.pv.camcom.it/files/Paviasviluppo/PaviainRete2017/prontuario%20co-progettazione.pdf

Pileri, P. (2018). *100 parole per salvare il suolo. Piccolo dizionario urbanistico-italiano*. Altra Economia.

Pinardi, R., Feo, A., Ruffini, A., & Celico, F. (2023). Purpose-Designed Hydrogeological Maps for Wide Interconnected Surface–Groundwater Systems: The Test Example of Parma Alluvial Aquifer and Taro River Basin (Northern Italy). *Hydrology*, *10*(6), Article 6. https://doi.org/10.3390/hydrology10060127

Pissourios, I. (2014). Top-Down and Bottom-up Urban and Regional Planning: Towards a Framework for the Use of Planning Standards. *European Spatial Research and Policy*, *21*(1), 83–99.

Poortinga, W., Whitmarsh, L., Steg, L., Böhm, G., & Fisher, S. (2019). Climate change perceptions and their individual-level determinants: A cross-European analysis. *Global Environmental Change*, *55*, 25–35. https://doi.org/10.1016/j.gloenvcha.2019.01.007

Prokop, G., Jobstmann, H., & Schönbauer, A. (2011). *Report on best practices for limiting soil sealing and mitigating its effects*. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/15146

Puerari, E., Concilio, G., Longo, A., & Rizzo, F. (2013). *Innovating public services in urban environments: A SOC inspired strategy proposal*.

Ranjbar Nooshery, N., Taleai, M., Kazemi, R., & Ebadi, K. (2017). DEVELOPING A WEB-BASED PPGIS, AS AN ENVIRONMENTAL REPORTING SERVICE. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-2-W7*, 115–121. ISPRS Geospatial Week 2017 (Volume XLII-2/W7) - 18–22 September, Wuhan, China. https://doi.org/10.5194/isprs-archives-XLII-2-W7-115-2017

Rau, S. (2022). *Sponge Cities: Integrating Green and Gray Infrastructure to Build Climate Change Resilience in the People's Republic of China* (0 ed., ADB Briefs) [ADB Briefs]. Asian Development Bank. https://doi.org/10.22617/BRF220416-2

Ravanello, L. (2022, January 26). Riduzione del consumo di suolo e desigillazione delle superfici nelle aree urbane. *ADRIADAPT*. https://adriadapt.eu/it/adaptation-options/riduzione-del-consumo-di-suolo-e-desigillazione-delle-superfici-nelle-aree-urbane/

Regione Emilia-Romagna. (n.d.). *GLOSSARIO PGRA*. Retrieved 13 November 2024, from https://ambiente.regione.emilia-romagna.it/it/suolo-bacino/sezioni/piano-di-gestione-del-rischio-alluvioni/glossario-pgra

Regione Emilia-Romagna. (2011). *La carta delle aree impermeabilizzate della pianura* [Dataset]. https://ambiente.regione.emilia-romagna.it/it/geologia/suoli/suoli-pianificazione/carta-aree-impermeabilizate-pianura

Regione Emilia-Romagna. (2014a). *Carte Applicative—Carta dei Gruppi Idrologici della pianura emiliano-romagnola* [Dataset]. https://datacatalog.regione.emilia-romagna.it/catalogCTA/dataset/r_emiro_2016-04-18t100752

Regione Emilia-Romagna. (2014b). *DTM 5x5* [Dataset]. https://geoportale.regione.emilia-romagna.it/catalogo/dati-cartografici/altimetria/layer-2

Regione Emilia-Romagna. (2018). *2014—Coperture vettoriali uso del suolo di dettaglio—Edizione 2018*

[Dataset]. https://geoportale.regione.emilia-romagna.it/download/dati-e-prodotti-cartografici-preconfezionati/pianificazione-e-catasto/uso-del-suolo/2014-coperture-vettoriali-uso-del-suolo-di-dettaglio-edizione-2018

Regione Emilia-Romagna, & SOS4LIFE. (2020). *LIBERARE IL SUOLO - 1. Linee guida per migliorare la resilienza ai cambiamenti climatici negli interventi di rigenerazione urbana.*

Regione Lazio. (2021, March 30). *Strategia regionale per lo Sviluppo sostenibile 'Lazio, regione partecipata e sostenibile'.*

Regione Lombardia. (n.d.). *Invarianza idraulica e idrologica*. Retrieved 27 September 2024, from https://www.regione.lombardia.it/wps/portal/istituzionale/HP/DettaglioRedazionale/servizi-e-informazioni/Enti-e-Operatori/territorio/difesa-del-suolo/invarianza-idraulica-e-idrologica/invarianza-idraulica-e-idrologica

Regione Lombardia. (2023). *Strategia regionale per lo sviluppo sostenibile*. https://www.svilupposostenibile.regione.lombardia.it/it/strategia-regionale/la-strategia

Regione Sardegna. (2021, October 8). *Sardegna 2030 La Strategia della Regione Sardegna per lo Sviluppo Sostenibile*.

Regione Veneto. (2017, June 6). *LR 14/2017 Disposizioni per il contenimento del consumo di suolo e modifiche della legge regionale 23 aprile 2004, n. 11 'Norme per il governo del territorio e in materia di paesaggio'*. https://bur.regione.veneto.it/BurvServices/pubblica/DettaglioLegge.aspx?id=346720

Regione Veneto. (2019, April 4). *LR 14/2019 Veneto 2050: Politiche per la riqualificazione urbana e la rinaturalizzazione del territorio*. https://www.regione.veneto.it/web/ambiente-e-territorio/veneto-2050

Ricci, L., & Mariano, C. (2022). Urban regeneration, climate adaptation, and territorial governance. Experimentation and innovation in the Plan for an integrated strategy between urban planning and ecology. In *WORLD HERITAGE and ECOLOGICAL TRANSITION Le Vie dei Mercanti XX International Forum* (pp. 205–213). https://iris.uniroma1.it/handle/11573/1666080

Righini, S. (2016, December 7). *Consumo di suolo e strategie di adattamento climatico. Lombardia e Sassonia a confronto*. https://www.arcipelagomilano.org/archives/44955

Rincón, D., Velandia, J. F., Tsanis, I., & Khan, U. T. (2022). Stochastic Flood Risk Assessment under Climate Change Scenarios for Toronto, Canada Using CAPRA. *Water*, *14*(2), Article 2. https://doi.org/10.3390/w14020227

Rivosecchi, A., & Singh, M. (2023). Small Island City Flood Risk Assessment: The Case of Kingston, Jamaica. *Water*, *15*(22), Article 22. https://doi.org/10.3390/w15223936

Rizwan, A. M., Dennis, L. Y. C., & Liu, C. (2008). A review on the generation, determination and mitigation of Urban Heat Island. *Journal of Environmental Sciences*, *20*(1), 120–128. https://doi.org/10.1016/S1001-0742(08)60019-4

Roberts, B. (2014). *Managing Systems of Secondary Cities Book—Policy Responses in International Development*. Cities Alliance/UNOPS. https://www.citiesalliance.org/sites/default/files/1d%20%28i%29%20-%20Managing%20Systems%20of%20Secondary%20Cities%20Book_low_res.pdf

Roberts, B., & Hohmann, R. P. (2014). The Systems of Secondary Cities: The neglected drivers of urbanising economies. *CIVIS Sharing Knowledge and Learing from Cities*, *7*.

Rodrigues Tomás, L., Barbosa Jurema, M. C., Cassiano dos Santos, J., De Resende Londe, L., Tortorella Reani, R., De Albuquerque Linhares, C., & Santos, L. (2021). From Macro to Micro: Two Approaches to Study Urban Mobility in a Brazilian Municipality. In *Methods and Applications of Geospatial Technology in Sustainable Urbanism* (p. 35). IGI Global. https://doi.org/10.4018/978-1-7998-2249-3.ch005

Romano, B., & Zullo, F. (2020). *Deimpermeabilizzazione e densificazione urbana: Metodi e limiti* (pp. 27–31).

Rota, P. (2017). *Una fragilità adattabile. Mappe climatiche e indirizzi urbanistici per la resilienza dei quartieri residenziali della città media emiliana. An adaptable fragility. Urban climatic maps and guidelines to the resiliency of the residential neighbourghoods of the middle Emilian city.* [Tesi di dottorato, Università di Parma]. https://www.repository.unipr.it/handle/1889/3455

Russo, A., & Parisani, G. (2019). *Misurare la resilienza nella gestione del rischio inondazioni: Il caso di San Mauro Torinese (TO)*. Conferenza ESRI Italia 2019, Roma. https://www.esriitalia.it/media/sync/20190327_192948_AlessandraRusso_2019.pdf

Saber, A., Salehipour Bavarsad, F., Jihui, Y., & Tondelli, S. (2022). Nature-based solutions in different local climate zones of Bologna. *Oltre Il Futuro: Emergenze, Rischi, Sfide, Transizioni, Opportunità, 306 special issue*, 123–125. http://www.urbanisticainformazioni.it/IMG/pdf/ui306si_sessione_02.pdf

Salata, S., Velibeyoğlu, K., Baba, A., Saygın, N., Couch, V. T., & Uzelli, T. (2022). Adapting Cities to Pluvial Flooding: The Case of Izmir (Türkiye). *Sustainability*, *14*(24), Article 24. https://doi.org/10.3390/su142416418

Sambo, B., Bonato, M., Sperotto, A., Torresan, S., Furlan, E., Lambert, J. H., Linkov, I., & Critto, A. (2023). Framework for multirisk climate scenarios across system receptors with application to the Metropolitan City of Venice. *Risk Analysis*, *43*(11), 2241–2261. https://doi.org/10.1111/risa.14097

Santamaria, F. (2000). La notion de <<ville moyenne>> en France, en Espagne et au Royaume-Uni (The notion of <<medium-sized town>> in France, Spain and the United Kingdom. *Annales de Géographie*, *109*, 227–239.

Santoro, S., Balena, P., & Camarda, D. (2020). Knowledge Models for Spatial Planning: Ecosystem Services Awareness in the New Plan of Bari (Italy). *Sustainability*, *(4)*. https://doi.org/10.3390/su12041516

Santos, T., Silva, C., Tenedório, J. A., & Montenegro Góes, T. (2021). Remote Sensing and GIS for Modelling Green Roofs Potential at Different Urban Scales. In *Methods and Applications of Geospatial Technology in Sustainable Urbanism* (p. 43). IGI Global. https://doi.org/10.4018/978-1-7998-2249-3.ch009

Schröter, B., Gottwald, S., Castro-Arce, K., Hartkopf, E., Aguilar-González, B., & Albert, C. (2023). Virtual participatory mapping of nature-based solutions in the Grande de Tárcoles River basin, Costa Rica: Connecting diverse knowledge systems in a context of physical immobility. *Science of The Total Environment*, *872*, 162195. https://doi.org/10.1016/j.scitotenv.2023.162195

Science for Environment Policy. (2016). *No net land take by 2050? Science for Environment Policy Future Brief 14*. http://ec.europa.eu/environment/integration/research/newsalert/pdf/no_net_land_take_by_2050_FB14_en.pdf

Selada, C., Vilhena Da Cunha, I., & Tomaz, E. (2013). Creative-Based Strategies in Small and Medium-Sized Cities: Key Dimensions of Analysis. *Quaestiones Geographicae*, *31*(4), 43–51. https://doi.org/10.2478/v10117-012-0034-4

Semeraro, T., Nicola, Z., Lara, A., Sergi Cucinelli, F., & Aretano, R. (2020). A Bottom-Up and Top-Down Participatory Approach to Planning and Designing Local Urban Development: Evidence from an Urban University Center. *Land*, *9*(4), Article 4. https://doi.org/10.3390/land9040098

Senato della Repubblica. (2012, December 11). *AS 3601/XVI - Ddl Valorizzazione delle aree agricole e contenimento del consumo del suolo*. https://www.senato.it/japp/bgt/showdoc/16/DDLPRES/0/697201/index.html?part=ddlpres_ddlpres1-relpres_relazione

Senatsverwaltung für & Umwelt, Mobilität, Verbraucher und Klimaschutz. (2022, August 17). *Entsiegelungspotenziale in Berlin*. https://www.berlin.de/sen/uvk/umwelt/bodenschutz-und-altlasten/vorsorgender-bodenschutz/vorsorgender-bodenschutz-nichtstofflich/entsiegelungspotenziale/

Servillo, L., Atkinson, R., Smith, I., Russo, A., Sýkora, L., Demazière, C., & Hamdouch, A. (2014). *TOWN, small and medium sized towns in their functional territorial context* [Final Report]. ESPON - European Spatial Planning Observation Network. https://www.espon.eu/sites/default/files/attachments/TOWN_Final_Report_061114.pdf

Seve, B., Domínguez, E. R., & Martínez, Z. M. (2023). Urban notes. Conscious and participatory drawing. *EGA Expresión Gráfica Arquitectónica*, *28*(48), Article 48. https://doi.org/10.4995/ega.2023.16878

Seve, B., Redondo, E., & Sega, R. (2023). Facetas de la co-creación urbana. *ACE: Arquitectura, Ciudad y Entorno*. https://doi.org/10.5821/ace.17.51.11694

Sharifi, A., Chelleri, L., Fox-Lent, C., Grafakos, S., Pathak, M., Olazabal, M., Moloney, S., Yumagulova, L., & Yamagata, Y. (2017). Conceptualizing Dimensions and Characteristics of Urban Resilience: Insights from a Co-Design Process. *Sustainability*, *9*(6), 1–20.

Sibeud, E., Floriat, M., & Boulogne, E. (2018). La démarche Ville perméable de la Métropole de Lyon: Retours d'expérience et perspectives. *Techniques Sciences Méthodes*, 33–40. https://doi.org/10.1051/tsm/201804033

Smith, L. G. (1983). *Impact Assessment and Sustainable Resource Management*. Longman. https://doi.org/10.4324/9781315846187

Smith, P., House, J. I., Bustamante, M., Sobocká, J., Harper, R., Pan, G., West, P. C., Clark, J. M., Adhya, T., Rumpel, C., Paustian, K., Kuikman, P., Cotrufo, M. F., Elliott, J. A., McDowell, R., Griffiths, R. I., Asakawa, S., Bondeau, A., Jain, A. K., … Pugh, T. A. M. (2016). Global change pressures on soils from land use and management. *Global Change Biology*, *22*(3), 1008–1028. https://doi.org/10.1111/gcb.13068

SOS4LIFE. (n.d.). *SOS4LIFE - Save Our Soil for Life*. S.O.S. 4 LIFE. Retrieved 5 June 2023, from https://www.sos4life.it/

SOS4LIFE. (2017a). *Ricognizione a scala regionale/nazionale/europea di linee guida per rimozione, stoccaggio e ripristino dei suoli nei cantieri e valutazione dei servizi ecosistemici dei suoli urbani* (A.1.2).

SOS4LIFE. (2017b). *Sintesi di norme, linee guida, buone pratiche, casi studio in materia di limitazione di consumo di suolo e resilienza urbana al cambiamento climatico* (A.1.3).

SOS4LIFE. (2018). *Consumo di suolo, superfici impermeabilizzate, stato di attuazione aree edificabili e aree dismesse recuperabili a Forlì, Carpi e San Lazzaro di Savena* (B.1.1).

SOS4LIFE. (2020). *Final report*.

SOS4LIFE (Director). (2022, October 21). *Il desealing di Forlì* [Video recording]. https://www.youtube.com/watch?v=W4s7pNNjkSQ

Sperotto, A., Torresan, S., Gallina, V., Coppola, E., Critto, A., & Marcomini, A. (2016). A multi-disciplinary approach to evaluate pluvial floods risk under changing climate: The case study of the municipality of Venice (Italy). *Science of The Total Environment*, *562*, 1031–1043. https://doi.org/10.1016/j.scitotenv.2016.03.150

Stelzle, B., Jannack, A., & Rainer Noennig, J. (2017). Co-Design and Co-Decision: Decision Making on Collaborative Design Platforms. *Procedia Computer Science*, *112*, 2435–2444. https://doi.org/10.1016/j.procs.2017.08.095

Stewart, I. D. (2011). A systematic review and scientific critique of methodology in modern urban heat island literature. *International Journal of Climatology*, *31*(2), 200–217. https://doi.org/10.1002/joc.2141

Stichting Steenbreek I Samen van verstening naar vergroening. (n.d.). Stichting Steenbreek. Retrieved 13 March 2023, from https://steenbreek.nl/home/

Stobbelaar, D. J., van der Knaap, W., & Spijker, J. (2021). Greening the City: How to Get Rid of Garden Pavement! The 'Steenbreek' Program as a Dutch Example. *Sustainability*, *13*(6), Article 6. https://doi.org/10.3390/su13063117

Strange, K., Satorras, M., & March, H. (2022). Bridging Urban Climate Justice and Participatory Governance to Explore the Transformative Capacity of Climate Resilience. In I. Ruiz-Mallén, H. March, & M. Satorras (Eds.), *Urban Resilience to the Climate Emergency: Unravelling the transformative potential of institutional and grassroots initiatives* (pp. 21–42). Springer International Publishing. https://doi.org/10.1007/978-3-031-07301-4_2

Studio Zanzucchi Srl, & Comune di Parma. (2015). *Studio per l'analisi del rischio idraulico e alluvionale sul territorio comunale*.

Studio Zanzucchi Srl, & Comune di Parma. (2016). *Piano del Rischio Idraulico Comunale*.

Studio Zanzucchi Srl, & Comune di Parma. (2021). *Regolamento di gestione del rischio idraulico*.

Swait, J. (1994). A structural equation model of latent segmentation and product choice for cross-sectional revealed preference choice data. *Journal of Retailing and Consumer Services*, *1*(2), 77–89. https://doi.org/10.1016/0969-6989(94)90002-7

Syafitri, R. A. W. D., Pamungkas, A., & Santoso, E. B. (2021). Urban Form Factors that Play Important Roles on UHI Spatial-Temporal Pattern: A Case Study of East Surabaya, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *764*(1), 012030. https://doi.org/10.1088/1755-1315/764/1/012030

Tang, K., & Waters, N. (2005). The Internet, GIS and Public Participation in Transportation Planning. *Progress in Planning - PROG PLANN*, *64*, 7–62. https://doi.org/10.1016/j.progress.2005.03.004

Tedeschi, G. (2023). *Piani urbanistici e piani per il clima nella città media emiliana: Criteri per l'integrazione* [Doctoral thesis, University of Parma. Department of Enginering and Architecture]. https://www.repository.unipr.it/handle/1889/5329

The Natural Capital Project. (n.d.). *Urban Flood Risk Mitigation InVEST*. http://releases.naturalcapitalproject.org/invest-userguide/latest/en/urban_flood_mitigation.html#curve-number

Thermal Inertia. (n.d.). In *ScienceDirect Topics*. Retrieved 1 August 2024, from https://www.sciencedirect.com/topics/engineering/thermal-inertia

Tiellemans, N. H. M., Kemperman, A. D. A. M., Maussen, S. J. E., & Arentze, T. A. (2022). The influence of group decision making on residents' preferences for sustainable energy measures of dwellings. *Building Research & Information*, *50*(4), 410–423. https://doi.org/10.1080/09613218.2021.1992261

Tobias, S., Conen, F., Duss, A., Wenzel, L. M., Buser, C., & Alewell, C. (2018). Soil sealing and unsealing: State of the art and examples. *Land Degradation & Development*, *29*(6), 2015–2024. https://doi.org/10.1002/ldr.2919

Tommasoli, L. (2018). Tra il negativo e il positivo del tessuto urbano. Un dialogo con il potenziale rigenerativo delle città contemporanee. *URBANISTICA DOSSIER*, *015*, 150–154.

Torelli, G. (2017). La rigenerazione urbana nelle recenti leggi urbanistiche e del governo del territorio. *La rigenerazione urbana e le nuove sfide per il governo del territorio*, *3*, 651–679.

Trigila, A., Iadanza, C., Lastoria, B., Bussettini, M., & Barbano, A. (2021). *Dissesto idrogeologico in Italia: Pericolosità e indicatori di rischio* (Rapporti 356/2021). ISPRA. https://www.isprambiente.gov.it/files2022/pubblicazioni/rapporti/rapporto_dissesto_idrogeologico_italia_ispra_356_2021_finale_web.pdf

Turri, E. (2001). *La megalopoli padana*. Marsilio Editori. https://www.marsilioeditori.it/libri/scheda-libro/3177556/la-megalopoli-padana

UE & CE. (2003). *Il partenariato con le città: L'iniziativa comunitaria URBAN*. Ufficio delle pubblicazioni ufficiali delle Comunità Europee.

Uittenbroek, C. J., Mees, H. L. P., Hegger, D. L. T., & Driessen, P. P. J. (2019). The design of public participation: Who participates, when and how? Insights in climate adaptation planning from the Netherlands. *Journal of Environmental Planning and Management*, *62*(14), 2529–2547. https://doi.org/10.1080/09640568.2019.1569503

Un Filo Naturale. Una comunità che partecipa per trasformare la sfida del cambiamento climatico in opportunità. (n.d.). Museo Scienze Naturali Brescia. Il museo del futuro possibile. Retrieved 28 June 2024, from https://museoscienzebrescia.it/un-filo-naturale/

Un'altra alluvione travolge l'Emilia-Romagna. A Parma allagamenti, situazione più pesante in provincia. (2024, October 21). *La Repubblica Parma*. https://parma.repubblica.it/cronaca/2024/10/21/news/un_altra_alluvione_travolge_l_emilia-romagna_a_parma_allagamenti_situazione_piu_pesante_in_provincia-423567802/

United Nations. (1987). *Report of the World Commission on Environment and Development: Our Common Future*. United Nations. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

United Nations. (1992). *Agenda 21*. United Nations Conference on Environment & Development, Rio de Janerio, Brazil. https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf

United Nations. (2012). *The Future We Want*. UN Conference on Sustainable Development, Rio. https://www.eea.europa.eu/policy-documents/the-future-we-want-2013declaration

United Nations. (2015). *Agenda 2030*. https://unric.org/it/agenda-2030/

United Nations. (2016). *The New Urban Agenda*. https://habitat3.org/the-new-urban-agenda/

United Nations Centre for Human Settlements (Habitat). (1996). *The Management of Secondary Cities in Southeast Asia*. UN-HABITAT.

Urban Green UP. (2017, June 1). *Urba Green UP - Mantova*. https://www.urbangreenup.eu/mantova/mantova.kl

USDA. (n.d.). *Hydrologic Soil Group*. Retrieved 17 November 2024, from https://www.hec.usace.army.mil/confluence/hmsdocs/hmsguides/files/118099517/118099546/1/1665679165857/HydrologicSoilGroup_DominantCondition.pdf

USEPA. (2014, June). *Climate Change Adaptation Plan*.

USEPA. (2017, November 2). *Land Use* [Reports and Assessments]. https://www.epa.gov/report-environment/land-use

USEPA. (2024a, April 24). *EPA's Programs and Actions to Address Extreme Heat* [Collections and Lists]. https://www.epa.gov/climate-adaptation/epas-programs-and-actions-address-extreme-heat

USEPA. (2024b, June). *2024-2027 Climate Adaptation Plan*.

Vancouver, C. of. (n.d.). *The Green Streets Program: Volunteer gardening on traffic calming spaces*. Retrieved 25 June 2024, from https://vancouver.ca/home-property-development/green-streets-program.aspx

Vaňo, S., Stahl Olafsson, A., & Mederly, P. (2021). Advancing urban green infrastructure through participatory integrated planning: A case from Slovakia. *Urban Forestry & Urban Greening*, *58*, 126957. https://doi.org/10.1016/j.ufug.2020.126957

Vargas-Hernández, J. G., & Danish, M. S. S. (2021). System of Green Resilience Eco-Oriented Land Uses in Urban Socio-Ecosystems. In *Eco-Friendly Energy Processes and Technologies for Achieving Sustainable Development* (pp. 1–23). IGI Global. https://doi.org/10.4018/978-1-7998-4915-5.ch001

Vargas-Hernández, J. G., & Orozco-Quijano, E. P. (2022). Sustainable Resilience in Urban Land Use. In *Innovative Economic, Social, and Environmental Practices for Progressing Future Sustainability* (C. Goi, p. 24). IGI Global. https://doi.org/10.4018/978-1-7998-9590-9.ch013

Varlese, L. (2023, July 21). Stefano Boeri: 'Viviamo tra lamiere e cemento, il grande caldo imporrà di ripensare le città'. *HuffPost Italia*. https://www.huffingtonpost.it/life/2023/07/21/news/stefano_boeri-12932892/

VASWCD. (n.d.). *Impervious Surface Removal*. Retrieved 19 January 2023, from https://vaswcd.org/impervious-surface-removal

Verboven, R. (2021). *The preferences and willingness to pay of urban residents in the Netherlands regarding Green-Based Solutions for heat adaptation* [Master's thesis, Eindhoven University of Technology]. https://pure.tue.nl/ws/portalfiles/portal/170222368/Verboven_1368273_CME.pdf

Vey, J. S., & Forman, B. (2002). *Demographic Change in Medium-Sized Cities: Evidence from the 2000 Census*. Center on Urban & Metropolitan Policy In Collaboration with The National League of Cities. https://www.brookings.edu/wp-content/uploads/2016/06/veyformanmedcities.pdf

Vogt, S. (2002). Citizens' participation in urban planning in Tôkyô. *Geographische Rundschau*, *54*(6), 50–53.

Voinov, V., Balakrishnan, N., & Nikulin, M. S. (2013). *Chi-squared goodness of fit tests with applications*. Elsevier/AP.

Voogt, J. (2008). *How Researchers Measure Urban Heat Islands*.

Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment*, *86*(3), 370–384. https://doi.org/10.1016/S0034-4257(03)00079-8

Vujovic, S., Haddad, B., Karaky, H., Sebaibi, N., & Boutouil, M. (2021). Urban Heat Island: Causes, Consequences, and Mitigation Measures with Emphasis on Reflective and Permeable Pavements. *CivilEng*, *2*(2), Article 2. https://doi.org/10.3390/civileng2020026

Wallonie. (2024, April 23). *Schéma de Développement du Territoire. Vers une optimisation spatiale*.

Washington D.C. Department of Energy & Environment. (n.d.). *RiverSmart Homes*. Retrieved 25 June 2024, from https://doee.dc.gov/service/riversmart-homes

Washington State Department of Natural Resources. (n.d.). *Action 9: Reduce Impervious Surfaces and Increase Green Stormwater Infrastructure Solutions*. Retrieved 19 January

2023, from https://www.dnr.wa.gov/WRAP_Action_9

Weber, E. U. (2016). What shapes perceptions of climate change? New research since 2010. *WIREs Climate Change*, *7*(1), 125–134. https://doi.org/10.1002/wcc.377

Weerasinghe, K. M., Gehrels, H., Arambepola, N. M. S. I., Vajja, H. P., Herath, J. M. K., & Atapattu, K. B. (2018). Qualitative Flood Risk assessment for the Western Province of Sri Lanka. *Procedia Engineering*, *212*, 503–510. https://doi.org/10.1016/j.proeng.2018.01.065

Winge, L., & Lamm, B. (2019). Making the red dot on the map—Bringing children's perspectives to the city planning agenda through visible co-design actions in public spaces. *Cities & Health*, *3*(1–2), 99–110. https://doi.org/10.1080/23748834.2019.1604931

World Bank. (2010). *Cities and climate change: An urgent agenda* (Text/HTML 10). https://documents.worldbank.org/en/publication/documents-reports/documentdetail/194831468325262572/Cities-and-climate-change-an-urgent-agenda

World Health Organization. (2016). *Urban green spaces and health* (WHO/EURO:2016-3352-43111-60341). Article WHO/EURO:2016-3352-43111-60341. https://iris.who.int/handle/10665/345751

Xu, Z., Sheffield, P. E., Hu, W., Su, H., Yu, W., Qi, X., & Tong, S. (2012). Climate Change and Children's Health—A Call for Research on What Works to Protect Children. *International Journal of Environmental Research and Public Health*, *9*(9), Article 9. https://doi.org/10.3390/ijerph9093298

Yang, M., Wang, H., Yu, C. W., & Cao, S.-J. (2023). A global challenge of accurately predicting building energy consumption under urban heat island effect. *Indoor and Built Environment*, *32*(3), 455–459. https://doi.org/10.1177/1420326X221123222

Zagare, V. (2018). Towards a Method of Participatory Planning in an Emerging Metropolitan Delta in the Context of Climate Change: The Case of Lower Paraná Delta, Argentina. *A+BE | Architecture and the Built Environment*, *25*, Article 25. https://doi.org/10.7480/abe.2018.25.2660

Zanon, B. (2008). *Territorio, ambiente, città. Temi, esperienze e strumenti dell'urbanistica contemporanea*. Alinea.

Zardini, M. (2003). *(A) asfalto: Il carattere della città*. Electa.

Zazzi, M. (2019). Il fenomeno della diffusione urbana e dell'urbanizzazione delle campagne. In B. Caselli, P. Ventura, & M. Zazzi, *Città in contrazione* (pp. 39–58). Maggioli. https://www.maggiolieditore.it/citta-in-contrazione.html

Zazzi, M., Rossetti, S., & Caselli, B. (2020). Spazi e tempi dell'accessibilità urbana durante e dopo l'emergenza sanitaria. *PROBLEMI E STRUMENTI PER RIDURRE I RISCHI NELLE CITTÀ*, *1*. https://www.urbanit.it/wp-content/uploads/2020/07/BP_ZAZZI_ROSSETTI_CASELLI.pdf

Zingraff-Hamed, A., Hüesker, F., Albert, C., Brillinger, M., Huang, J., Lupp, G., Scheuer, S., Schlätel, M., & Schröter, B. (2021). Governance models for nature-based solutions: Seventeen cases from Germany. *Ambio*, *50*(8), 1610–1627. https://doi.org/10.1007/s13280-020-01412-x

Zluwa, I., & Pitha, U. (2021). The Combination of Building Greenery and Photovoltaic Energy Production—A Discussion of Challenges and Opportunities in Design. *Sustainability*, *13*(3), Article 3. https://doi.org/10.3390/su13031537

Attributions

This work was conducted in collaboration with the fellow Ph.D. student Marianna Ceci, with whom the author shared the research topic of soil desealing for urban climate change adaptation. While the current research focused on the role of soil desealing in mitigating urban pluvial flood risk, her work explored its relationship with the urban heat island phenomenon. Shared aspects of the research are indicated through footnotes, explicitly identifying whether they are the result of joint collaboration or her individual contributions.

Additionally, parts of this Ph.D. research were carried out at the Department of the Built Environment of Eindhoven University of Technology, under the supervision of Prof. Astrid Kemperman and Dr. Ir. Peter van der Waerden. These are explicitly delineated in the relevant sections, with references to jointly published articles. Specifically, these sections include the analysis of the survey 'Parma wonders about the local effects of climate change' and the setup, distribution, and analysis of the stated-choice experiment about citizens' preferences for soil desealing in Parma (i.a., Subsections §9.4.1 and §9.4.3).

Lastly, the practical exploration of young people's involvement in climate change laboratories was conducted at the science centre 'AmbienteParco' (Section §9.4.2).

Additional attributions are provided within the text.

Front and back covers

This thesis front cover was designed by the author, using one of her photographs that illustrates the coexistence of anthropic action and the natural environment in urban pavements. The back cover features a word cloud generated from the text of this work.

Disclaimer

Artificial Intelligence was employed to assist language refinement of this text. All content has been reviewed to ensure accuracy and alignment with the author's intentions.

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Ilaria De Noia

CLIMATE CHANGE ADAPTATION *in* URBAN REGENERATION PRACTICES

The contribution of soil desealing in reducing the urban pluvial flood risk


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