Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

multi-Risk sciEnce for resilienT commUnities undeR a changiNgclimate

Codice progetto MUR: **PE00000005** – E63C22002000002

Governance guidelines and policy recommendations for multi-scale integration of DRR and CCA

DV 5.4.2

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1. Technical References

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1. Technical References

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Contents

2. From the Catalogue to the Application

2.1 Introduction

2.1.1 Measuring Urban Resilience

In the ongoing process of integrating the concepts of sustainability and resilience into urban and territorial planning and design — where resilience is often considered a subsystem or operational component of sustainability (Folke et al., 2006, 2021) — there is a growing need to combine conceptual paradigms with interpretative and evaluative tools and methodologies capable of translating them into territorial innovation. In this regard, Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) emerge as key operational domains through which resilience and sustainability are institutionalised and enacted, offering normative guidance and practical mechanisms to reduce exposure, mitigate risks, and enhance adaptive capacity in the face of growing environmental uncertainties. This integration must consider the inherently multiscalar nature of both sustainability and resilience, which operate simultaneously across local, regional, and global levels, and whose interdependencies shape both vulnerabilities and adaptive capacities of territorial systems. In particular, the concept of resilience, especially in its transformative dimension of "bouncing forward" (Holling, 1987; Gunderson & Holling, 2002; Brunetta et al., 2019), implies not only the ability to absorb shocks and stresses, but also the ability to reconfigure socioeconomic systems on new, more robust and adaptive foundations. These processes of adaptation and transformation are rarely confined to a single spatial or institutional scale; instead, they require coordinated interventions that span multiple governance levels and territorial contexts. DRR and CCA, as institutionalised and internationally recognised frameworks (e.g., the Sendai Framework for DRR and the Paris Agreement on climate), play a pivotal role in structuring these multilevel responses, providing both policy coherence and technical approaches for mainstreaming resilience into planning practices.

At the global level, the push towards these paradigms has been driven by heightened awareness of the environmental impacts of human activity. Evidence of the damage caused by local pollutants, alongside scientific observations of anthropogenic climate change, has prompted an extended process of renewal. Within this process, research has played a key role, albeit with results that are not always straightforward, in guiding the evolution of regulatory frameworks, governance models, and urban and regional planning tools. It has also contributed to the generation of increasingly detailed, robust, and reliable datasets capable of informing decisions across diverse scales of action. From this perspective, our analysis focuses on resilience capacities understood as the abilities of communities to effectively mitigate risks, prepare for hazards, and respond to adverse events. This includes timely and efficient recovery, the restoration of essential functions and structures, and, where possible, the enhancement of systems to withstand future challenges better (Villagra et al., 2024). These capacities are deeply interwoven with DRR strategies aimed at reducing hazard exposure and vulnerability before a disaster occurs, and with CCA strategies that enable systems to adjust to the anticipated impacts of climate change over time.

Building on the shift from traditional concepts to a more dynamic understanding of resilience, this research aims to advance this understanding within urban and regional studies and planning (Davoudi et al., 2012). The method for evaluating resilience capacity requires an integrated approach starting from a catalogue of indicators that can be used to assess the capacity of a territorial system to absorb or adapt to diverse crisis of transformation events. According to Chmutina et al. (2023), evaluation should be understood not merely as a technical exercise, but as a strategic act that frames how resilience is conceptualised, prioritised, and enacted in planning and governance. In doing so, it becomes evident that there is a need to offer not only risk-specific instruments but also broader planning paradigms that support the transition towards more just, inclusive, and anticipatory urban and territorial development pathways.

2.1.2 The Catalogue of Resilience Indicators

The necessity to select indicators that can truly represent the resilience capacity of a determined territorial area leads to a shift from analysing a large set of data to summarising the findings. This shift becomes necessary to move from a wide and complex territorial analysis to a simpler formula to interpret the territorial and environmental situation over time easily. The simplicity of the evaluation activity by diverse kinds of disciplinary experts should not limit the catalogue's ability to fully describe the multifaceted aspects of the territory from the perspective of resilience capacity, leaving out the insights from literature analyses. Likewise, the simplification stems from the need to represent the indicators on a map using a Geographic Information System (GIS) and possibly using open data.

The application of the resilience indicator catalogue, presented in Deliverable 5.4.1[1], presents the challenge of ensuring adaptability to diverse contexts. Urban settings exhibit different features in terms of socio-economic, institutional and territorial conditions, risk exposure, governance structures, and the availability and quality of data. Consequently, it is crucial to combine context- and site-specific indicators to define a tailored set for measuring resilience in each city. Applying the catalogue to a specific case study aims to monitor resilience progress over time (Figueiredo et al., 2018) and enables the testing of both standardised indicators and customised indicators shaped by the distinctive features of the urban environment in question.

[1] Deliverable 5.4.1 is a product of the RETURN project, led by the Politecnico di Torino/DIST, entitled "Multisectoral Comprehensive Planning and Design along the Disaster Risk Management Cycle". Scientific supervisor: Angioletta Voghera; coordinator: Benedetta Giudice; with Grazia Brunetta and Manuela Rebaudengo. Research group: Giosuè Bronzino, Ilaria Cazzola, Valeria Vitulano.

3. Application of Indicators in a Case Study: Turin

3.1 Context Introduction

The strategic guidelines of the European Union towards neighbourhood-scale redevelopment strategies aimed at adaptation and mitigation, employing innovative technologies, smart infrastructure, and renewable energies to create sustainable, resilient, and inclusive neighbourhoods. This leads to an elevation of standards for sustainable development that, starting from the neighbourhood, can be extended to the entire city. The responses are also provided regarding the issue of the relationship between city-centre and periphery, where the issue of peripheral marginality can present a large repertoire of morphological and material elements: in the past decade, urban and spatial planning in the territorial context of Turin have undergone significant changes to adapt to unexpected crises. In fact, one of the testbeds for this purpose it can be the case city of Turin (Italy) and its planning tools: the complex topography of Turin, with hills in the east, a densely built-up city centre, and floodplains of the Po River and its tributaries (firstly Sangone creek, then Dora River and finally Stura creeks) makes it an optimal case study, also in the perspective of managing different types of hazards that come from environmental events and social challenges. The city's specific territorial morphology creates a complex mosaic of microclimates (Ellena et al., 2023), contributing to elevated air pollution levels and placing Turin among the most polluted cities in Italy and Europe (EEA, 2024), a situation further intensified by a high rate of private car ownership.

To develop new strategies in this challenge, since 2017 Regional plans (*Piano Territoriale Regionale* and *Piano Paesaggistico Regionale*) are being revised to align with regional strategies for sustainable development and climate change adaptation and to upgrade their operational effectiveness with the aim of offering a solid structural and legislative framework for local plans. The Province of Turin, until 2015, and now the Metropolitan City of Turin, is carrying out a process of constant review of its planning tool (firstly the *Piano Territoriale Generale Metropolitano* - PTGM) with a focus on controlling land take, improving slow mobility, and enhancing green and blue infrastructure. More recently, the institution of *Parco Naturale del Po Piemontese* started a review of its plan in order to upgrade the local planning with territorial scenarios including the challenge that come from ecological reticularity and arise from strategic and landscape perspective. Furthermore, a new tool that nowadays can provide a contribution to the planning, especially with special reference to area near rivers, is *River Agreement*, used to improve a voluntary planning aimed at developing the themes of resilience and sustainability of river stages (both in terms of water quality and social awareness).

In line with international objectives to mitigate climate change and its impacts, the Municipality of Turin joined the Mayors Adapt initiative in 2015 and signed the new Covenant of Mayors for Climate and Energy in 2019, leading to the drafting of its Climate City Contract in 2022. These commitments are increasingly reflected in urban planning tools. In 2020, the city started the updating of *Piano Regolatore Generale* - PRGC with a shared vision that, just in the *Proposta Tecnica del Progetto Preliminare* - PTPP, tries to involve feedback from multiple stakeholders.

Simultaneously, the sensitivity of the issue of *eco-districts* represents new models to face the current multi-risk conditions using a holistic approach to urban development, where environmental, social, and economic issues contribute to increasing the importance of creating resilient communities. The study is conducted in the current situation, but the historical maps, very numerous and detailed for the city of Turin, reveal that these challenges have already been faced by the city in past centuries and their effects can still be read today through historical cartography and sometimes from the numerous collections of photographs that testify in the past some critical events, first of all hydrogeological disasters. Considering environmental hazards, in fact, the percentage of over 65% of artificial Turin’s surface limits natural drainage significantly (Munafò, 2024). The combination of this high percentage with the extension of the city settled in floodplains makes the city vulnerable to both prolonged rainfall and intense downpours leading to flooding. The extensive built-up area also exacerbates the Urban Heath Island effect, thereby intensifying the impacts of heat waves.

Recently, Turin also faces socio-economic challenges due to an ageing population, with a strong ratio of people over 65. The city has experienced significant economic restructuring following the decline of the manufacturing and automotive sectors (Armano et al., 2016), creating complex socio-economic vulnerabilities. At the same time the city is interest by a strong growth of the student population, attracted in this place from the presence of certified university, especially renowned in technical experimentation. These factors make the city more fragile against critical situations while the population increases the need of targeted interventions in case of hazardous events and socio-economic crises. The presence of a very specialized services network (often aided by the assistance of voluntary organizations) still brilliantly attempts to minimize the effects of unexpected events.

The guiding concept of this testbed, realized on the case of Turin, can transform this experimentation in a multifaceted socio-ecological analysis aided by the disciplines that study multiple assets at the different scale: environmental, ecological, natural, anthropical, social and finally historical. The combination of green and blue infrastructure, settlements, grey infrastructures, pipe network (hydraulic and water supply networks, sewers, etc.) elaborates a special class of problems connected not only with urban planning but also with a complex system related to different dimensions (natural, anthropic and a combination of both). The riverside maximizes these aspects, combining the previous challenge with environmental problems related to the presence of the park also allows for the development of practical design solutions. This concept also addresses natural and social vulnerabilities, ensures the participation of local communities, and promotes integrated landscape enhancement.

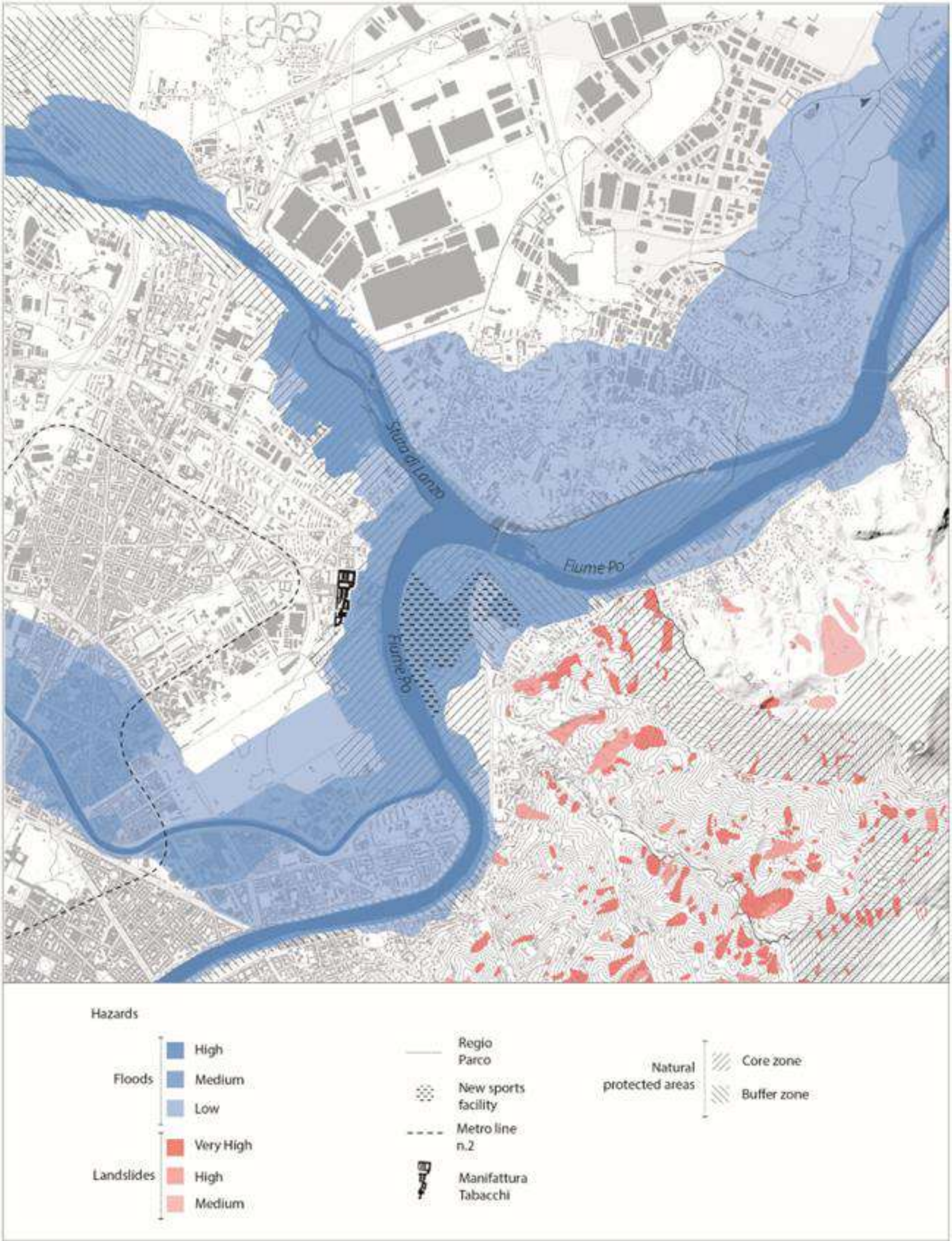

Figure 1*: the territory taken into consideration in this study.*

The specific area under analysis where the indicators were tested, corresponds to the neighbourhoods of “Regio Parco”, “Vanchiglia”, and “Madonna del Pilone”. These neighbourhoods belong to districts (*Circoscrizioni*, the administrative zones into which the municipal territory is divided) No. 6 and 7. This territory represents a complex socio-ecological system where urban, natural, and social elements intersect, making it particularly suitable for testing resilience indicators. Moreover, several urban transformations planned for the coming years make it particularly valuable to monitor resilience over time. Metro Line 2 is expected to reach this part of the city, improving accessibility in areas historically underserved by public transport. Brownfield regeneration projects, such as the redevelopment of the Manifattura Tabacchi into cultural hubs and university facilities, are underway. Additionally, a sports centre within Meisino Park will contribute to reshaping the area’s image. These large-scale transformations are complemented by several smaller-scale interventions financed through the National Recovery and Resilience Plan (NRRP).

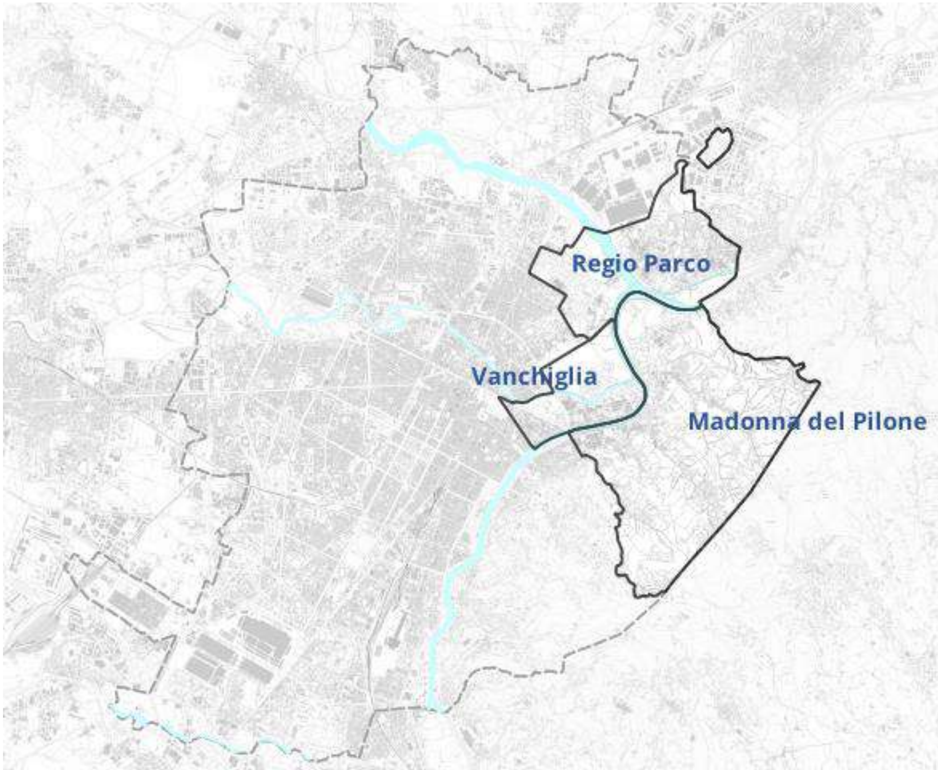

Figure 2: The three neighbourhoods of Turin selected for the application and spatialization of the indicators.

3.2 Selecting a Targeted, Context-Specific Set of Indicators

This study began, in Deliverable 5.4.1, with a search of SCOPUS bibliographic sources, using specific keywords related to resilience. The search produced 213 articles related to the topic of resilience, addressed from multiple aspect. The articles highlight the trans-disciplinarity of the topic of resilience which often clashes and sometimes meets with the topic of resistance.

The indicators reported in the reviewed articles encompass various dimensions of urban systems and resilience. In this study, these indicators were associated with five dimensions: Built Environment, Environmental, Social, Economic, and Institutional. Moreover, to simplify the selection and subsequent use of the indicators, they were grouped by thematic categories.

This thematic grouping made it possible to organize the wide variety of topics covered in the literature into a set of concepts that summarize the breadth of the field. Although the research is carried out within a wide range of scientific articles, some aspects still need to be explored further: for example, the matter related to the importance of heritage in disaster scenarios, secondly, the specific question related to the chemical pollution and chemical hazard.

Unfortunately, it is very clear to the authors of this contribution that this study cannot collect all aspects of the application of the theme of resilience in a generic territory. The authors acknowledge that this study cannot encompass all aspects of applying resilience concepts to a generic territory. Furthermore, the large number of indicators in the initial dataset is not suitable for defining resilience within a GIS platform, especially given that the study's goal is to describe resilience components in a spatial and graphic form for urban spaces, with a strong analytical orientation.

Building on the indicator catalogue developed in Deliverable 5.4.1, a subset of 28 indicators was selected for application to the case study. This selection is not intended to be exhaustive, but rather illustrative, providing a representative sample through which to explore multiple dimensions of urban resilience at different scales. Moving beyond the purely analytical function of indicators, the broader objective is to establish an operational foundation for the development of integrated governance guidelines.

Table 1, based on the indicator catalogue presented in Deliverable 4.1, outlines the specific dimensions of resilience addressed by each indicator—namely, the built environment, environmental, social, economic, and institutional dimensions. Each indicator is assigned a progressive ID number (*Number* column) to facilitate its indication and to link it with the corresponding sheets and maps in the following section. The table includes also the *Indicator Name*, its *Topic* — such as buildings, collaboration, demography, ecosystem services, emergency, income, heritage, pollution, infrastructures and network, landscape, land use, natural/green space, planning and programming, resources/resources consumption, services — and a concise *Definition*. The *Direction* column indicates whether the indicator contributes positively (+), negatively (−), or in a context-dependent manner (in this case it is marked as *not defined* (n.d.)) to resilience. The final column lists the *Data Sources* used to construct each indicator.

It is worth noting that, although the indicators are derived from the original framework in Deliverable 4.1, many were adapted during testing in a real-word case study to improve their relevance and practical effectiveness. While they continue to reflect the same key elements (e.g., public educational facilities), their operationalization and calculation methods may differ. For example, an indicator originally defined as the proportion of area occupied by educational facilities may be reformulated to express proximity to such facilities.

Additionally, three indicators specifically related to the ecological network — *Fragility, Naturality and Relevance for the Conservation* — were newly introduced, as they were not included in the original catalogue. Two further indicators — *Green shaded pathways* (developed from *Public urban trees*) and *Public services* — were also newly formulated, although they remain conceptually coherent with the original framework.

Table 1: List of indicators selected for the Turin applicative case

Built Enviroment	*Environmental*	*Social*	*Economic*	*Institutional*	*Number*	*Resilience indicators*	*Topic*	*Definition*	*Direction*	*Data Source*
x					1	**Building density**	Buildings	Density of buildings within a selected area expressed with the Floor area ratio (ratio of a building's total floor area to the size of land upon which it is built).	(-)	CTC 2024 - layer "Volumetric Unit" ("Unità Volumetrica"); CTC 2024 - layer "Settlement Unit" ("Unità insediativa")
x				x	2	**Brownfield Sites***	Buildings	Percentage of surface occupied by unused, abandoned, or underutilized areas — typically former industrial or commercial sites (brownfields) with potential for redevelopment — over the total surface of the census section.	n.d.	Carta Tecnica Comunale (Comune di Torino), 2024; Piano Regolatore Generale (Comune di Torino), update 2024; Torino Atlas (Urban Lab), 2017; Comune di Torino, Census sections (2024)
x			x		3	**Industrial Area**	Buildings	Proportion of industrial areas within the census section.	n.d.	Land Cover Piemonte (Regione Piemonte) 2023, field "lcp", classes "12110", "12100"; Comune di Torino, Census sections (2024)
		x			4	**Local Associations**	Collaboration	The concentration of local associations within a 300-meter radius.	(+)	Registro delle Associazioni (Città di Torino), 2025; Comune di Torino, Census sections (2024)
		x			5	**Aging Index**	Demography	The number of the elderly aged 65 years and over, per 100 individuals younger than 14 years old in the specific population of a selected area.	n.d.	Comune di Torino, Census sections (2024)
x		x			6	**Population Density**	Demography	Number of residents per census section.	(-)	Comune di Torino, Census sections (2024)
x	x		x		7	**Carbon Storage and Sequestration**	Ecosystem services	The amount of carbon stored in a landscape and amount of carbon sequestered over time.	(+)	Città metropolitana di Torino, Simulsoil, 2018
x		x		x	8	**Emergency Shelters***	Emergency	Distance of the census section centroid to the nearest temporary shelters established to provide refuge and support for individuals and families during emergencies	(-)	Piano Comunale di Protezione Civile (Comune di Torino), 2020 – layers "Aree di ricovero – Accoglienza"; Comune di Torino, Census sections (2024)
		x	x		9	**Real Estate Values***	Income	Average rental value of the predominant residential typology within the census section, based on the OMI (Osservatorio del Mercato Immobiliare) zoning.	n.d.	Zone OMI, Osservatorio del Mercato Immobiliare (Agenzia delle Entrate), 2024

Built Enviroment	*Environmental*	*Social*	*Economic*	*Institutional*	*Number*	*Resilience indicators*	*Topic*	*Definition*	*Direction*	*Data Source*
x					10	**Cycling Infrastructure***	Infrastructures and network	Percentage of the total area of the census section within a 300-meter radius buffer around cycling paths.	(+)	Piano Territoriale di Coordinamento, 2011; Comune di Torino, Census sections (2024)
x				x	11	**Public Transportation**	Infrastructures and network	The concentration of tram and bus stops within a 300-meter radius.	(+)	Regione Piemonte, “Linee di trasporto pubblico locale”, 2024
x				x	12	**Public Water Fountains**	Infrastructures and network	Percentage of the total area of the census section within a 300-meter radius of one or more public water fountains.	(+)	I Love Toret, 2022, https://ilovetoret.it/it/; Comune di Torino, Census sections (2024)
x	x				13	**Land Take**	Land Use	Percentage of the land take area within the census section.	(-)	Land Cover Piemonte (Regione Piemonte), 2023; Comune di Torino, Census sections (2024)
	x				14	**Ecological Network: Fragility**	Natural/ Green spaces	Sensitivity to pressures such as pollution, exotic and invasive species, and anthropogenic disturbance in general.	(-)	Land Cover Piemonte (Regione Piemonte) 2023
	x				15	**Ecological Network: Naturality**	Natural/ Green spaces	Relevance/suitability of land uses for biodiversity conservation, simultaneously assessing their importance for both habitats and species.	(+)	Land Cover Piemonte (Regione Piemonte) 2023
	x				16	**Ecological Network: Relevance**	Natural/ Green spaces	Importance of the area for biodiversity conservation.	(+)	Land Cover Piemonte (Regione Piemonte) 2023
	x			*x*	*17*	**Forest Cover**	Natural/ Green spaces	Proportion of forest coverage within the census section.	(+)	Land Cover Piemonte (Regione Piemonte) 2023, field “lcp”, all classes included within CLC-level I “3. Forest and semi natural areas”; Comune di Torino, Census sections (2024)
	x				*18*	**Green Shaded Pathways**	Natural/ Green spaces	Percentage of pedestrian circulation area within a 10-meter buffer from at least one tree, over the total pedestrian circulation area of the census section.	(+)	Carta Tecnica Comunale (Comune di Torino), 2024; Alberate (Comune di Torino), 2025; Comune di Torino, Census sections (2024)
x	*x*				*19*	**Imperviousness**	Natural/ Green spaces	Proportion of impermeable surfaces that prevents the infiltration of water into the ground, over the total area.	(-)	LCP 2023, field “imp_2022_perc” (% imperviousness, polygon average based on 10m pixels, from REMOTE SENSING Consumo di suolo ISPRA2022, Sentinel2 - NDVI2023)
	x				*20*	**NDVI**	Natural/ Green spaces	Normalized difference vegetation Index. It provides information on the presence and condition of vegetation on the Earth's surface.	(+)	Land Cover Piemonte (Regione Piemonte) 2023, field “ndvi_2023_perc”
x	*x*				*21*	**Public Urban Trees***	Natural/ Green spaces	Number of public urban trees.	(+)	Alberate (Comune di Torino), 2025; Comune di Torino, Census sections (2024)

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Built Enviroment	***Environmental***	***Social***	***Economic***	***Institutional***	***Number***	***Resilience indicators***	***Topic***	***Definition***	***Direction***	***Data Source***
	x				*22*	**Tree Cover**	Natural/ Green spaces	Extent of land area covered by the canopy of trees.	(+)	Copernicus Dataset, Tree Cover Density 2018 (raster 10 m), Europe, 3-yearly (2018). DOI (raster 10 m): https://doi.org/10.2909/486f77da-d605-423e-93a9-680760ab6791
	x	*x*			*23*	**Green Urban Spaces**	Services	Number of inhabitants within the census section with access to a green urban area less than 300m away.	(+)	Città di Torino, Piano strategico dell'infrastruttura verde, 2021; CTC 2024 - layer "Urban greenspace"; Comune di Torino, Census sections (2024)
				x	*24*	**General Practitioners***	Services	Distance of the census section centroid to the nearest general practitioner.	(-)	Medici di Medicina Generale (Azienda Sanitaria Locale Città di Torino), 2025; Comune di Torino, Census sections (2024)
x				*x*	*25*	**Hospitals***	Services	Distance of the census section centroid to the nearest hospital.	(-)	Comune di Torino (AperTO), layer "Ospedali" (2011); Comune di Torino, Census sections (2024)
x		*x*			*26*	**Public Educational facilities***	Services	Distance of the census section centroid to the nearest public educational facility.	(-)	Comune di Torino (AperTO), layer "scuole_aree_geo" (2012) CTC 2024, layer "Settlement Unit" Comune di Torino, Census sections (2024)
		x		*x*	*27*	**Public Services***	Services	Percentage of surface occupied by public service facilities over the total surface of the census section. Public green areas are excluded and addressed through separate indicators.	(+)	Piano Regolatore Generale (Comune di Torino), update 2024; Comune di Torino, Census sections (2024)
x		*x*			*28*	**Public or affiliated sports facilities***	Services	Distance of the census section centroid to the nearest public sport facility.	(-)	AperTO (Comune di Torino), 2011; Comune di Torino, Census sections (2024)

** The indicator has been modified from its original formulation found in the literature to facilitate its application and to ensure greater relevance and usefulness within the specific case study context.*

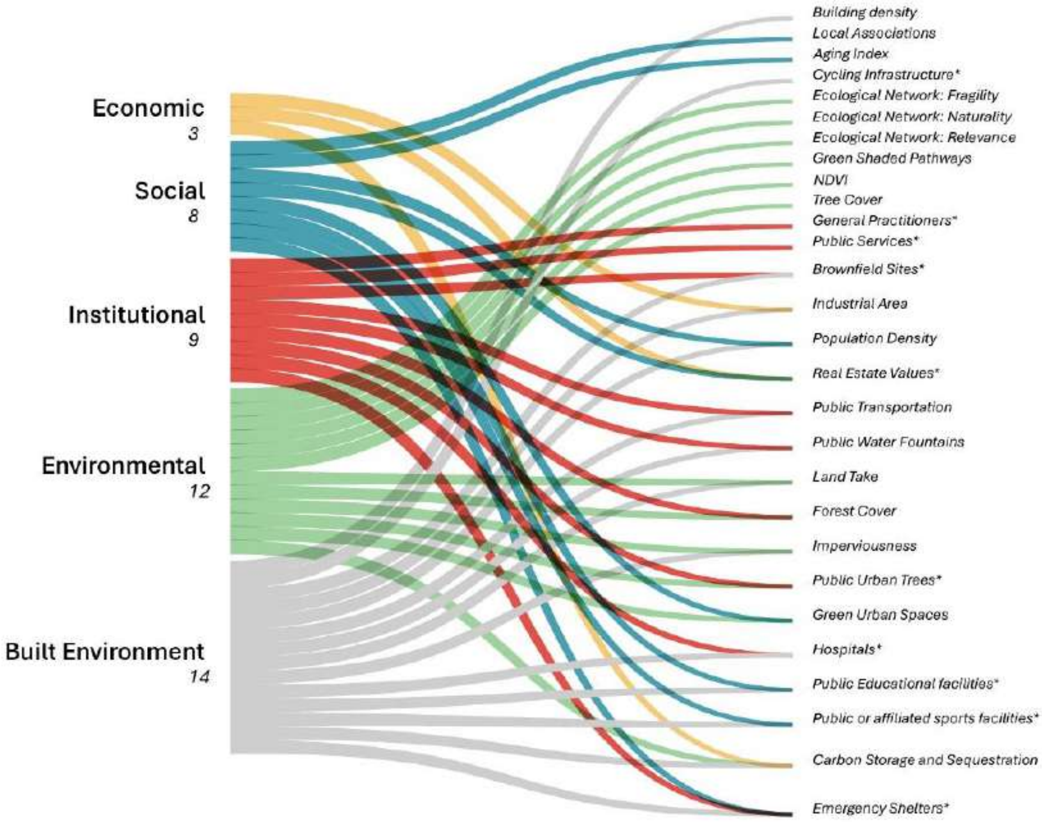

Figure 3: Applied indicators in the case study, grouped by topic.

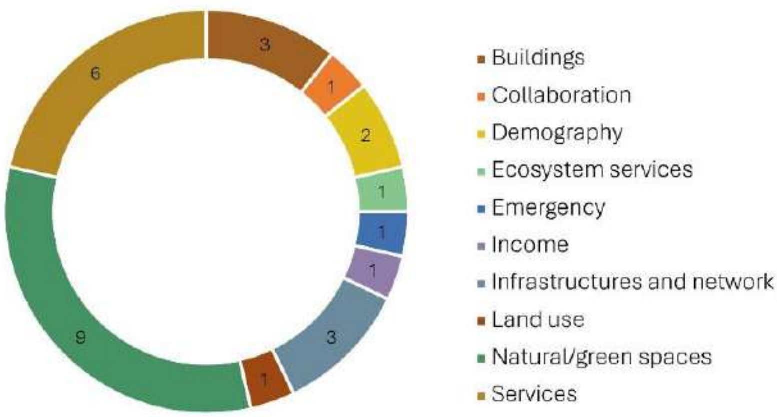

Figure 4: Applied indicators in the case study, grouped by topic.

3.3 Operational Applications of Indicators

The following analyses were carried out in a GIS environment (QGIS version 3.34.6-Prizren) to spatialize and measure the various selected indicators based on the characteristics listed in the Table 1 and adapted to the specific case study. This operation has been also influenced by the type of available spatial and territorial databases, which are sometimes not open-source or lack sufficient detail to reach the considered analysis scale. In this regard, it is necessary to list some of the main sources used for the application of the indicators in the case of Turin, available to the research group:

- The main topographic mapping base of the municipal territory is represented by the Technical Municipal Map (*Carta Tecnica Comunale*, CTC) of the City of Turin, updated to 2024. This spatial database is more detailed and updated than the Regional Technical Map (BDTRE Piemonte).
- Demographic data find a greater level of spatial detail in the Census Sections (*Sezioni di censimento*), with data updated to 2024 (http://geoportale.comune.torino.it/geocatalogocoto/?sezione=catalogo).
- The land cover and land use classes in the case of Turin are based on the Land Cover Piemonte (LCP) 2023 dataset of Piedmont Region as their primary reference (https://www.geoportale.piemonte.it/geonetwork/srv/ita/catalog.search#/metadata/r_piemon:35df8a16-5d89-461f-a0f2-abc2180713d2).

For each indicator, a detailed sheet has been compiled, including the information listed in Table 2 and the corresponding map.

Table 2: Description of the information reported for each selected indicator.

Name	**Name of the indicator**
Source indicator ID	Indicates the source indicator from the Catalogue in the Deliverable 5.4.1 (*Multisectoral Comprehensive Planning and Design along the Disaster Risk Management Cycle*), used as the basis for the case study application
Dimension	The dimensions of resilience addressed by the indicator. These include environmental, built environment, social, economic and institutional dimensions. A single indicator can cover one or more dimensions
Topic	Thematic categories including buildings, cooperation, demography, ecosystem services, emergency, heritage, income, infrastructure and networks, land use, landscape, natural/green spaces, planning and programming, pollution, resources/resource consumption, and services
Definition	Short explanation of the indicator
Direction	Whether the indicator has a positive or negative effect on resilience. In addition, the direction can be expressed as "not defined" when the effect varies depending on the specific context and requires further interpretation
Formula	The mathematical representation, when possible, of the indicator
Unit of measure	The unit in which the indicator is measured

Data source	The dataset, institutional repository or platform that supplies the information used to build the indicator
Territorial scale	The geographic resolution of the dataset used for the indicator
Timescale	The year or time frame that the dataset used to calculate the indicator covers

1_BUILDING DENSITY

Name	**Building density**
Source indicator ID	1
Dimension	☒Built ☐Environmental ☐Social ☐Economic ☐Institutional
Topic	Buildings
Definition	Density of buildings within a selected area expressed with the Floor area ratio (ratio of a building's total floor area to the size of land upon which it is built)
Direction	☐positive ☒negative ☐not defined
Formula	$N = A_r/A_t$ N = floor area ratio (building density) A_r= building's total floor area A_t= building's lot area
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	CTC 2024 - layer "Volumetric Unit" ("Unità Volumetrica") CTC 2024 - layer "Settlement Unit" ("Unità insediativa")
Timescale of reference	2024

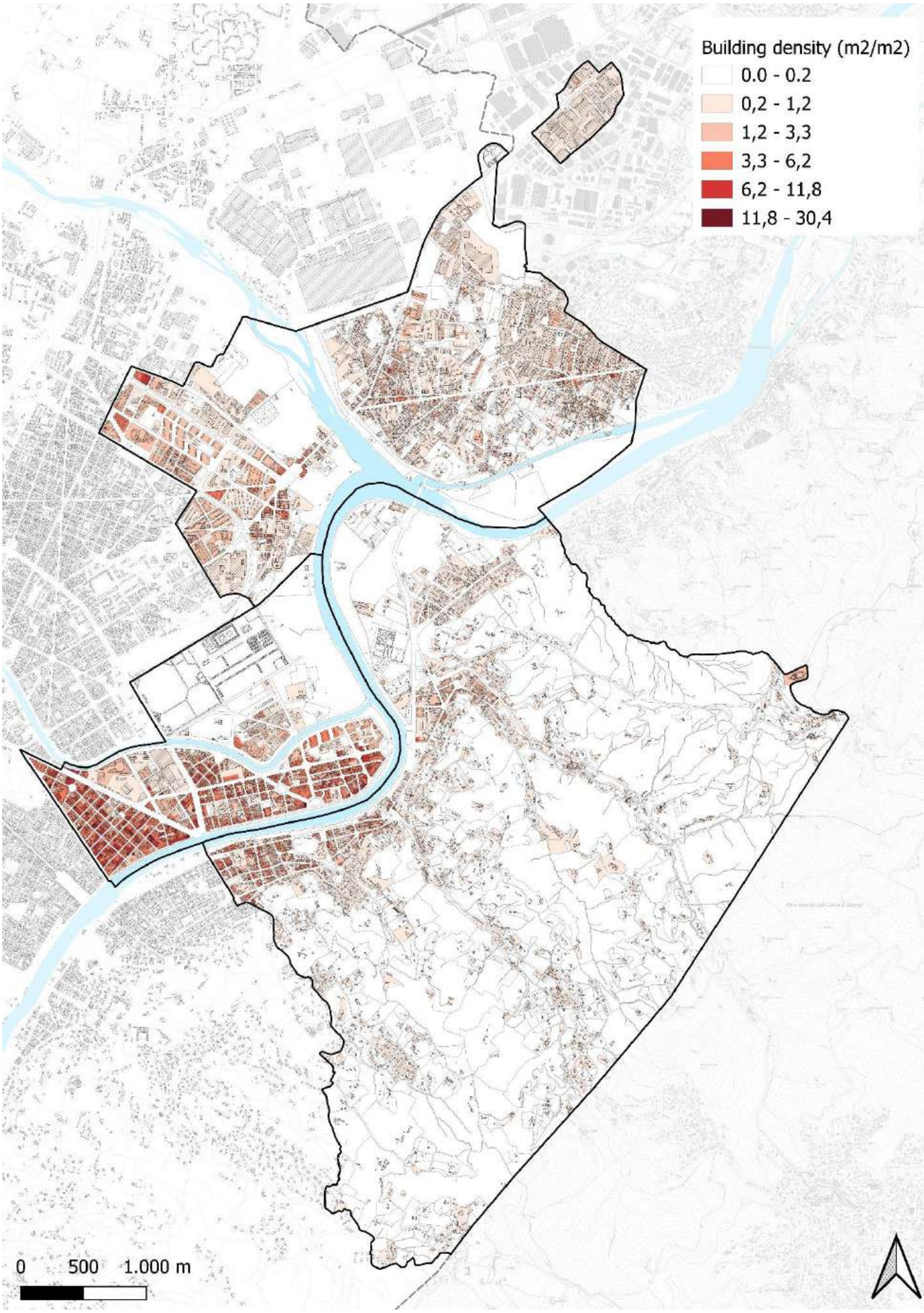

Figure 5: Spatial representation of the 'Building Density' indicator.

2_BROWNFIELD SITES

Name	**Brownfields Sites**
Source indicator ID	88
Dimension	☒Built ☐Environmental ☐Social ☐Economic ☒Institutional
Topic	Buildings
Definition	Percentage of surface occupied by unused, abandoned, or underutilized areas — typically former industrial or commercial sites (brownfields) with potential for redevelopment — over the total surface of the census section.
Direction	☐positive ☐negative ☒not defined
Formula	$N = B/A \times 100$ N = Brownfield Sites B = Brownfield Area A= Total surface of the census section
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	Carta Tecnica Comunale (Comune di Torino), 2024; Piano Regolatore Generale (Comune di Torino), update 2024; Torino Atlas (Urban Lab), 2017; Comune di Torino, Census sections (2024)
Timescale of reference	2024

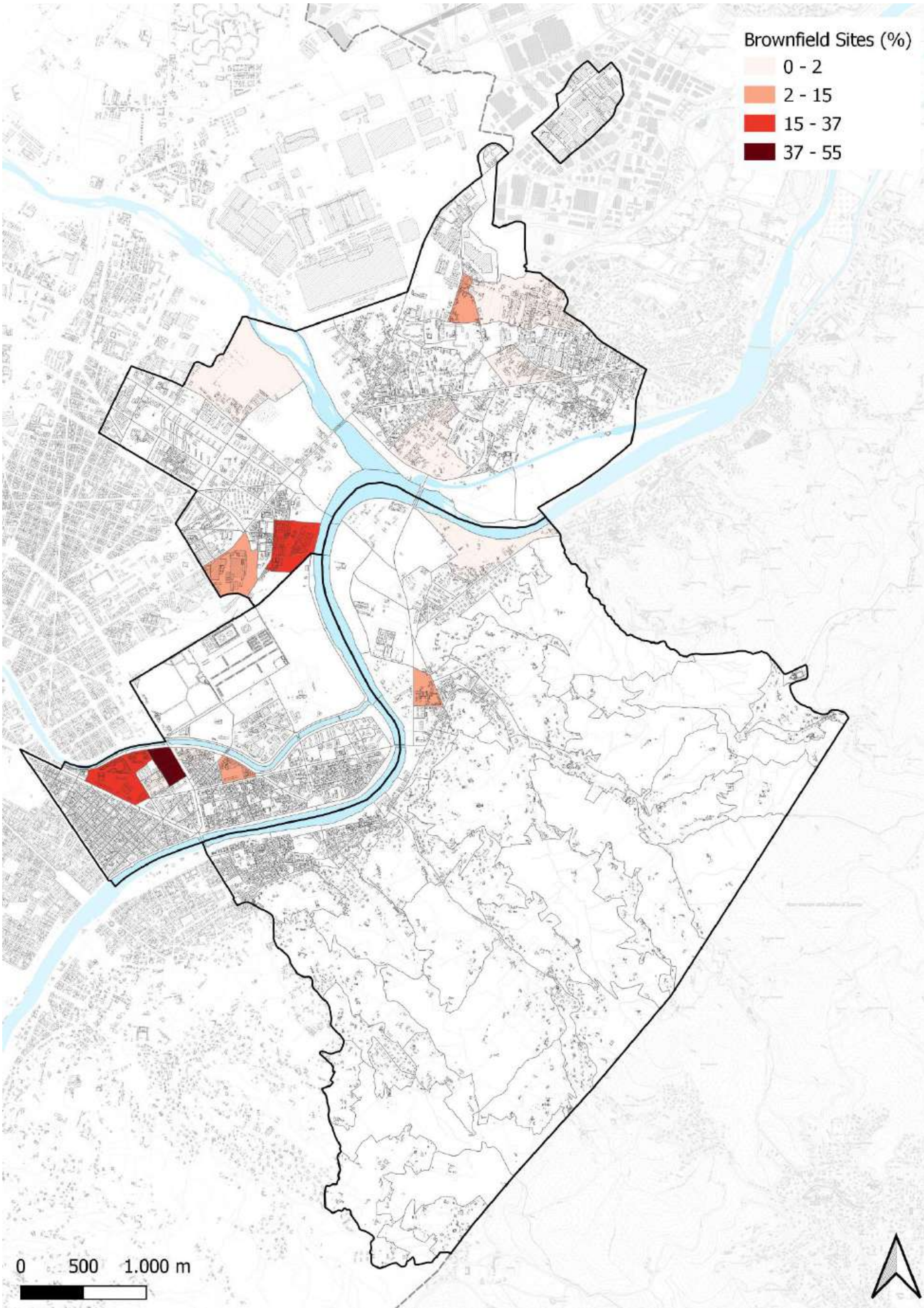

Figure 6: Spatial representation of the 'Brownfield Sites' indicator.

3_INDUSTRIAL AREA

Name	**Industrial area**
Source indicator ID	7
Dimension	☒Built ☐Environmental ☐Social ☒Economic ☐Institutional
Topic	Buildings
Definition	Proportion of industrial areas within the census section.
Direction	☐positive ☐negative ☒not defined
Formula	$N = F_t / A_t$ N = proportion of industrial area F_t = sum of surface of factories in the census section A_t = total surface of the census section
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	Land Cover Piemonte (Regione Piemonte) 2023, field “lcp”, classes “12110”, “12100”; Comune di Torino, Census sections (2024)
Timescale of reference	2023

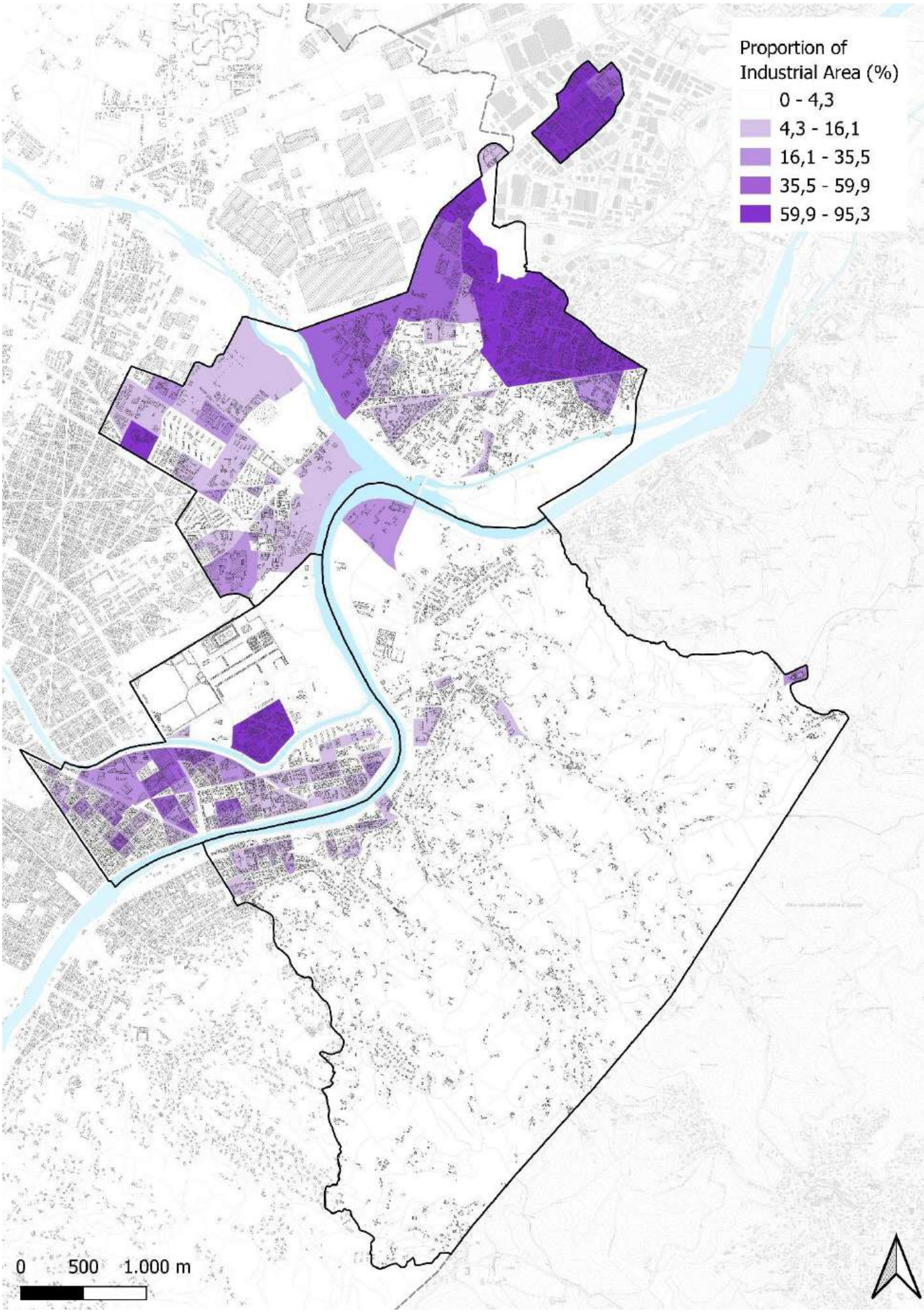

Figure 7: Spatial representation of the 'Industrial Area' indicator.

4_LOCAL ASSOCIATIONS

Name	**Local Associations**
Source indicator ID	8
Dimension	☐Built ☐Environmental ☒Social ☐Economic ☐Institutional
Topic	Collaboration
Definition	The concentration of local associations within a 300-meter radius.
Direction	☒positive ☐negative ☐not defined
Formula	Kernel Density Estimation
Unit of measure	unit/m2
Territorial scale of reference	Sub-district
Data source	Registro delle Associazioni (Città di Torino), 2025; Comune di Torino, Census sections (2024)
Timescale of reference	2025

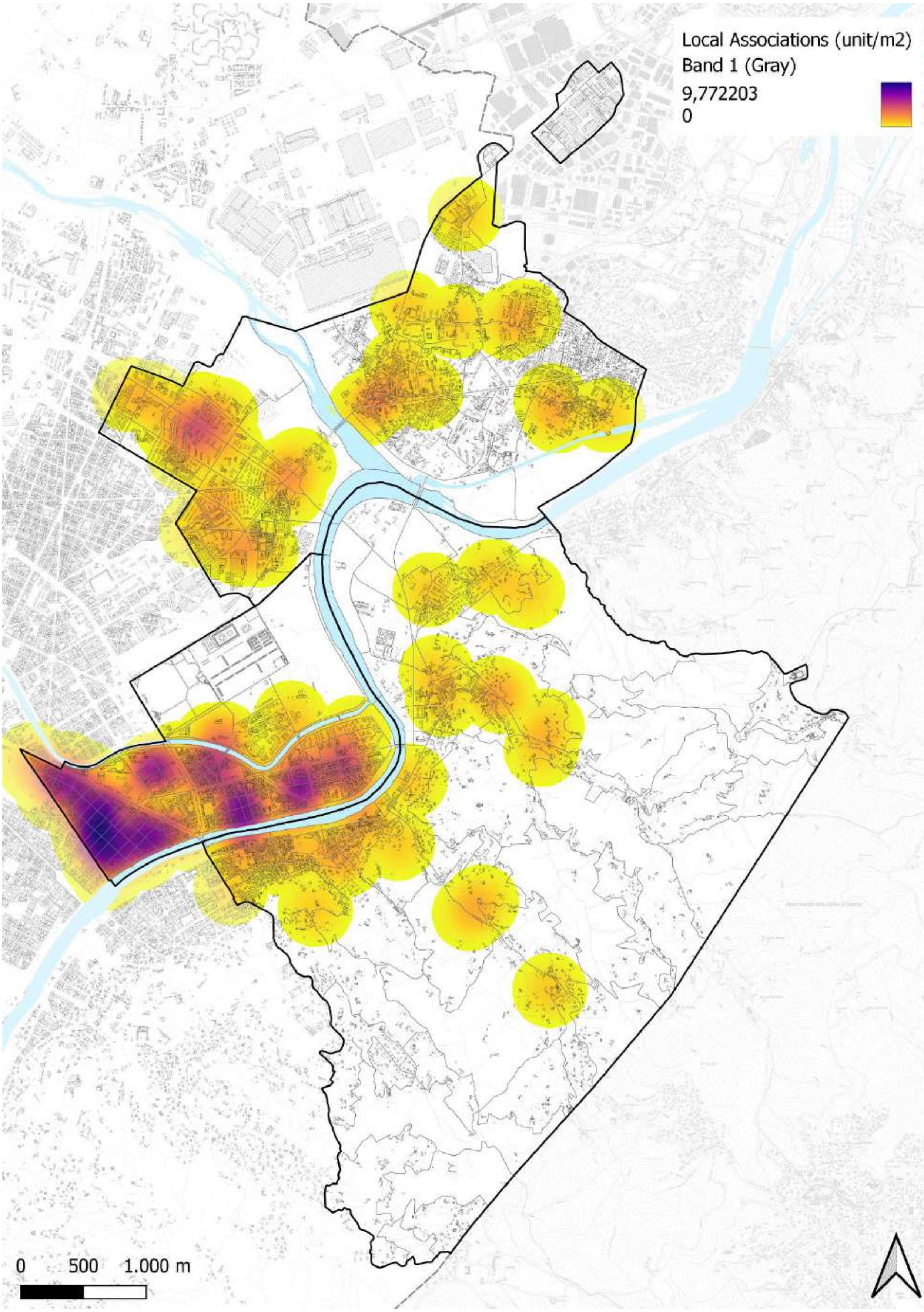

Figure 8: Spatial representation of the 'Local Associations' indicator.

5_AGING INDEX

Name	**Aging index**
Source indicator ID	91
Dimension	☐Built ☐Environmental ☒Social ☐Economic ☐Institutional
Topic	Demography
Definition	The number of the elderly aged 65 years and over, per 100 individuals younger than 14 years old in the specific population of a selected area.
Direction	Threshold value = 100 Aging index > 100 negative Aging index < 100 positive
Formula	N = Pe/Py *100 N = Aging index Pe = population aged 65 yrs old and over Py = population aged 15 yrs old and under
Unit of measure	Adimensional
Territorial scale of reference	Sub-district
Data source	Comune di Torino, Census sections (2024)
Timescale of reference	2024

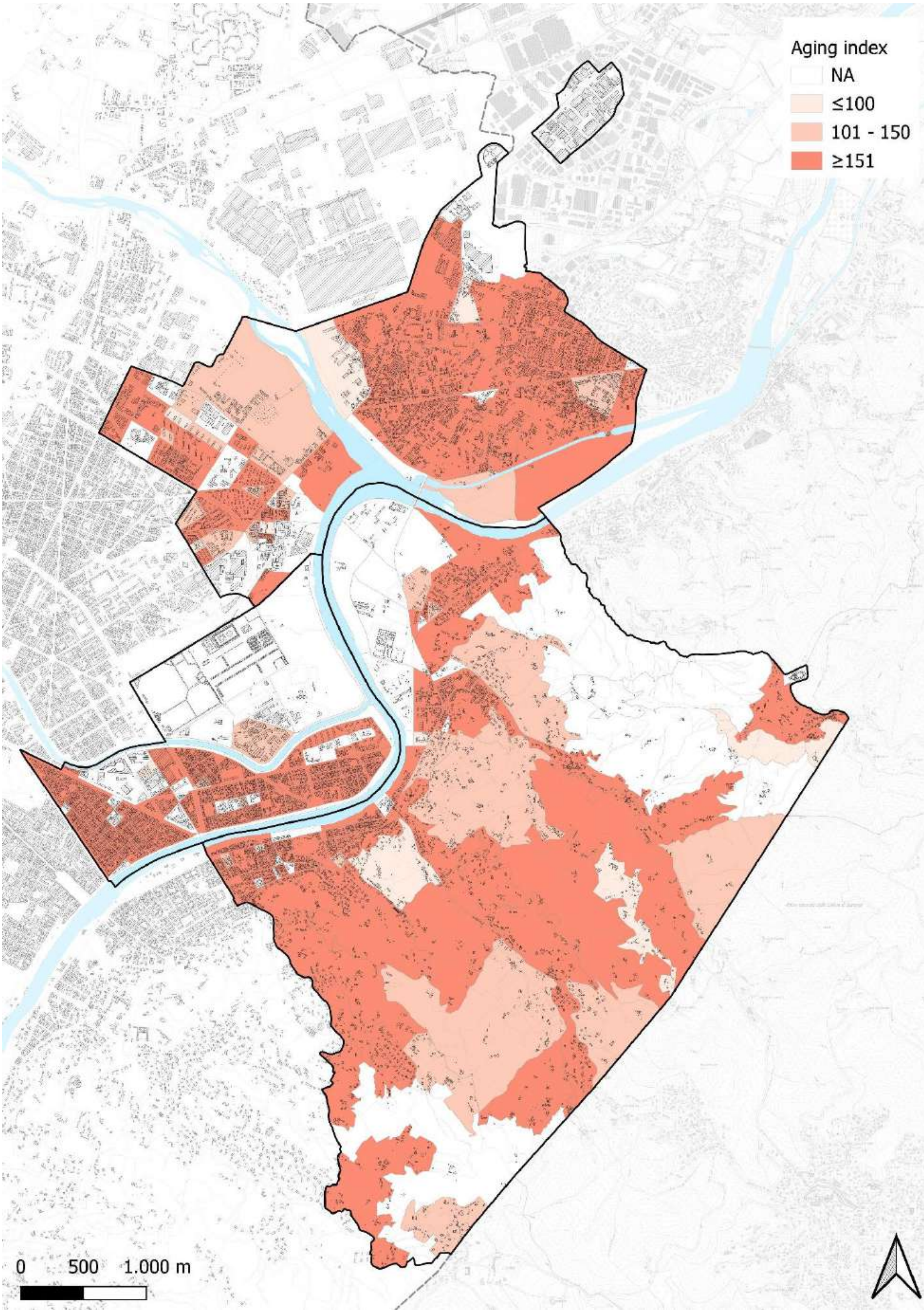

Figure 9: Spatial representation of the 'Aging Index' indicator.

6_POPULATION DENSITY

Name	**Population Density**
Source indicator ID	14
Dimension	☒Built ☐Environmental ☒Social ☐Economic ☐Institutional
Topic	Demography
Definition	Number of residents per census section.
Direction	☐positive ☒negative ☐not defined
Formula	$N = R/A$ N = population density R = number of residents A = total surface of the census section
Unit of measure	Inh/km^2
Territorial scale of reference	Sub-district
Data source	Comune di Torino, Census sections (2024)
Timescale of reference	2024

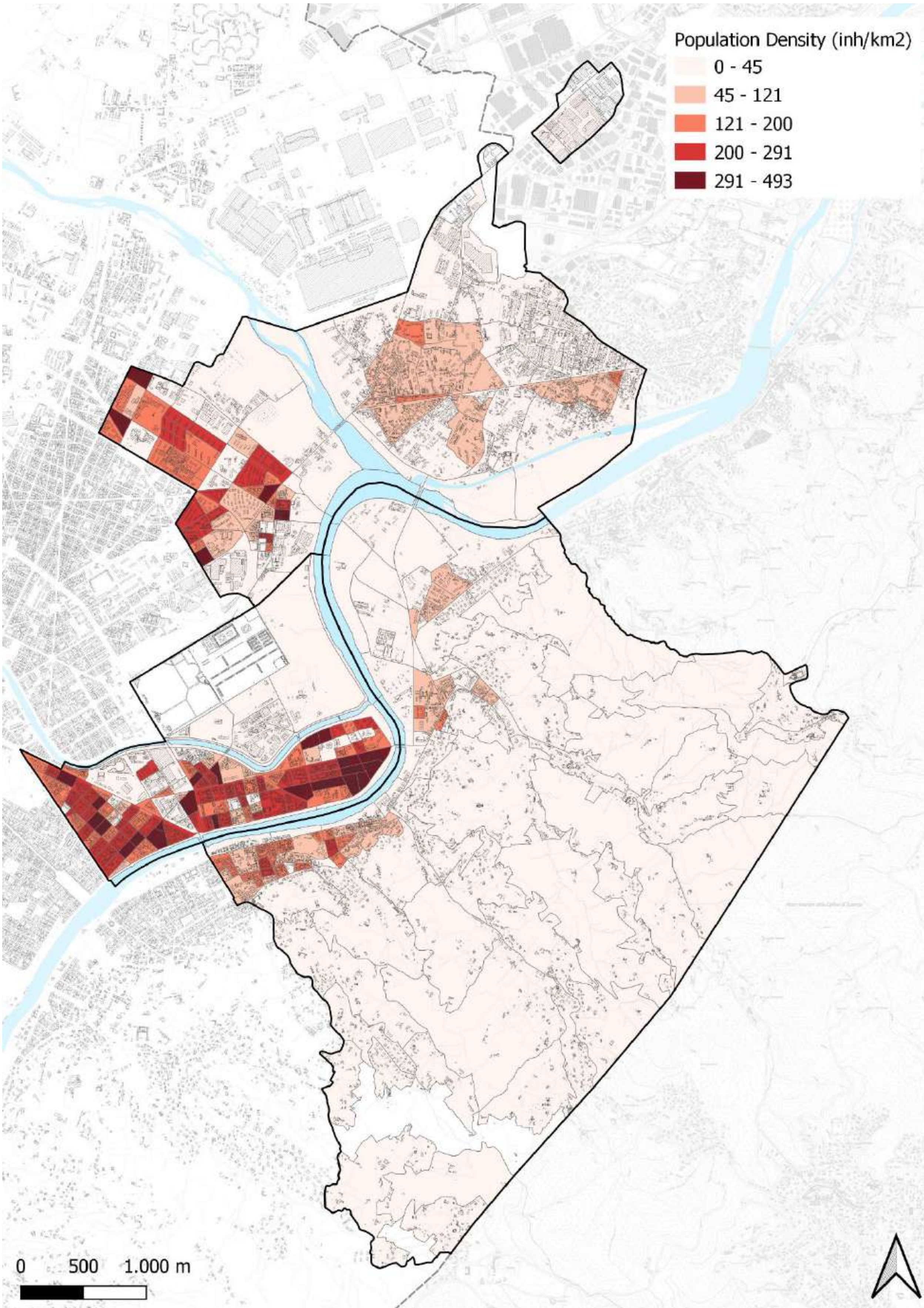

Figure 10: Spatial representation of the 'Population Density' indicator.

7_CARBON STORAGE AND SEQUESTRATION

Name	**Carbon Storage and Sequestration**
Source indicator ID	17
Dimension	☒Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Ecosystem services
Definition	The amount of carbon stored in a landscape and amount of carbon sequestered over time.
Direction	☒positive ☐negative ☐not defined
Formula	Based on Simulsoil evaluation model
Unit of measure	t/pixel
Territorial scale of reference	Sub-district
Data source	Città metropolitana di Torino, Simulsoil, 2018
Timescale of reference	2018

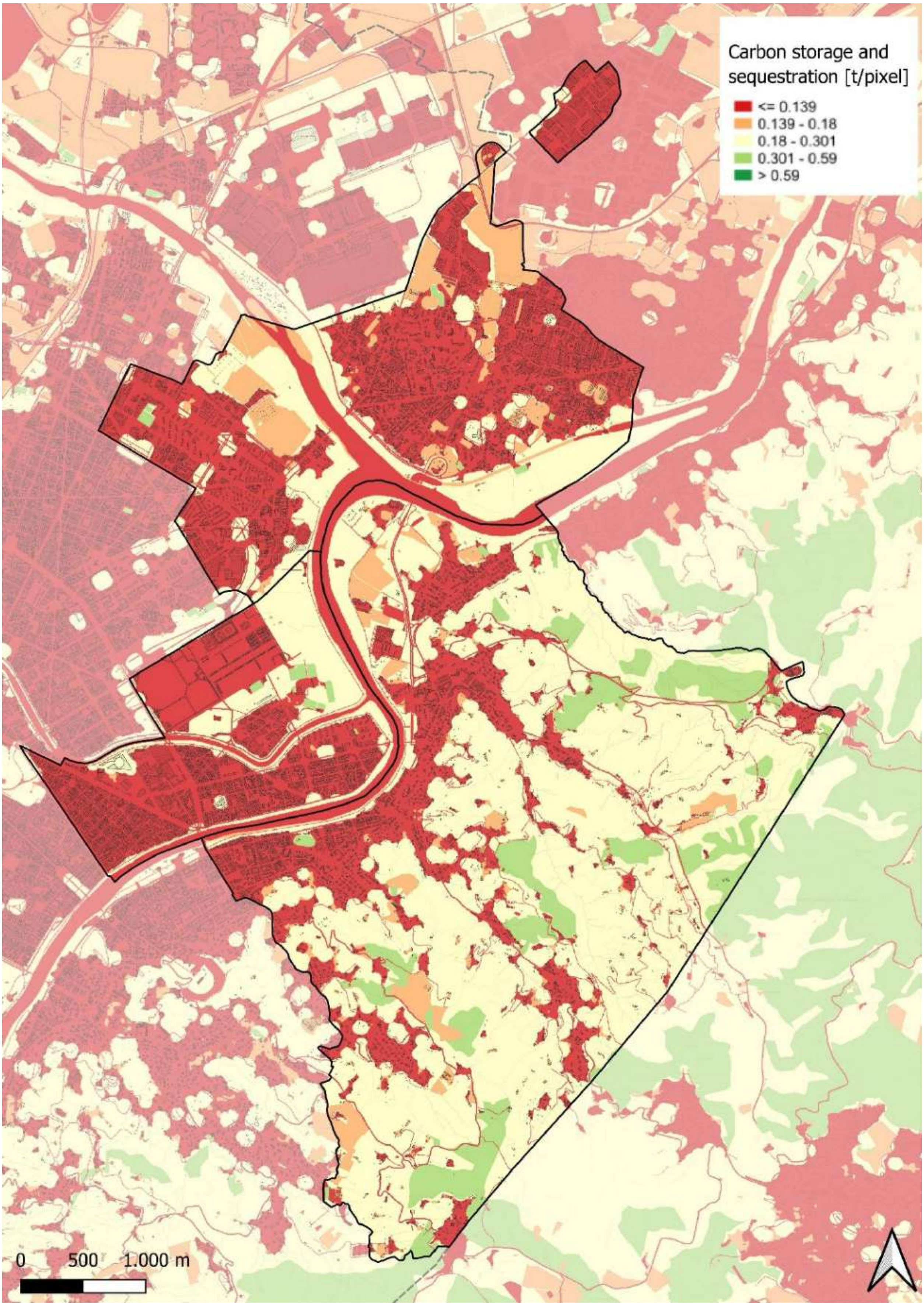

Figure 11: Spatial representation of the 'Carbon Storage and Sequestration' indicator.

8_EMERGENCY SHELTERS

Name	**Emergency Shelters**
Source indicator ID	**26**
Dimension	☒Built ☐Environmental ☒Social ☐Economic ☒Institutional
Topic	Emergency
Definition	Negative of the census section centroid to the nearest temporary shelters established to provide refuge and support for individuals and families during emergencies.
Direction	☐positive ☒negative ☐not defined
Formula	QGIS Algorithm provided by QGIS Distance to nearest hub (points) (qgis:distancetonearesthubpoints). Given an origin and a destination layers, this algorithm computes the distance between origin features and their closest destination one.
Unit of measure	m
Territorial scale of reference	Sub-district
Data source	Piano Comunale di Protezione Civile (Comune di Torino), 2020 – layers “Aree di ricovero – Accoglienza”; Comune di Torino, Census sections (2024)
Timescale of reference	2020

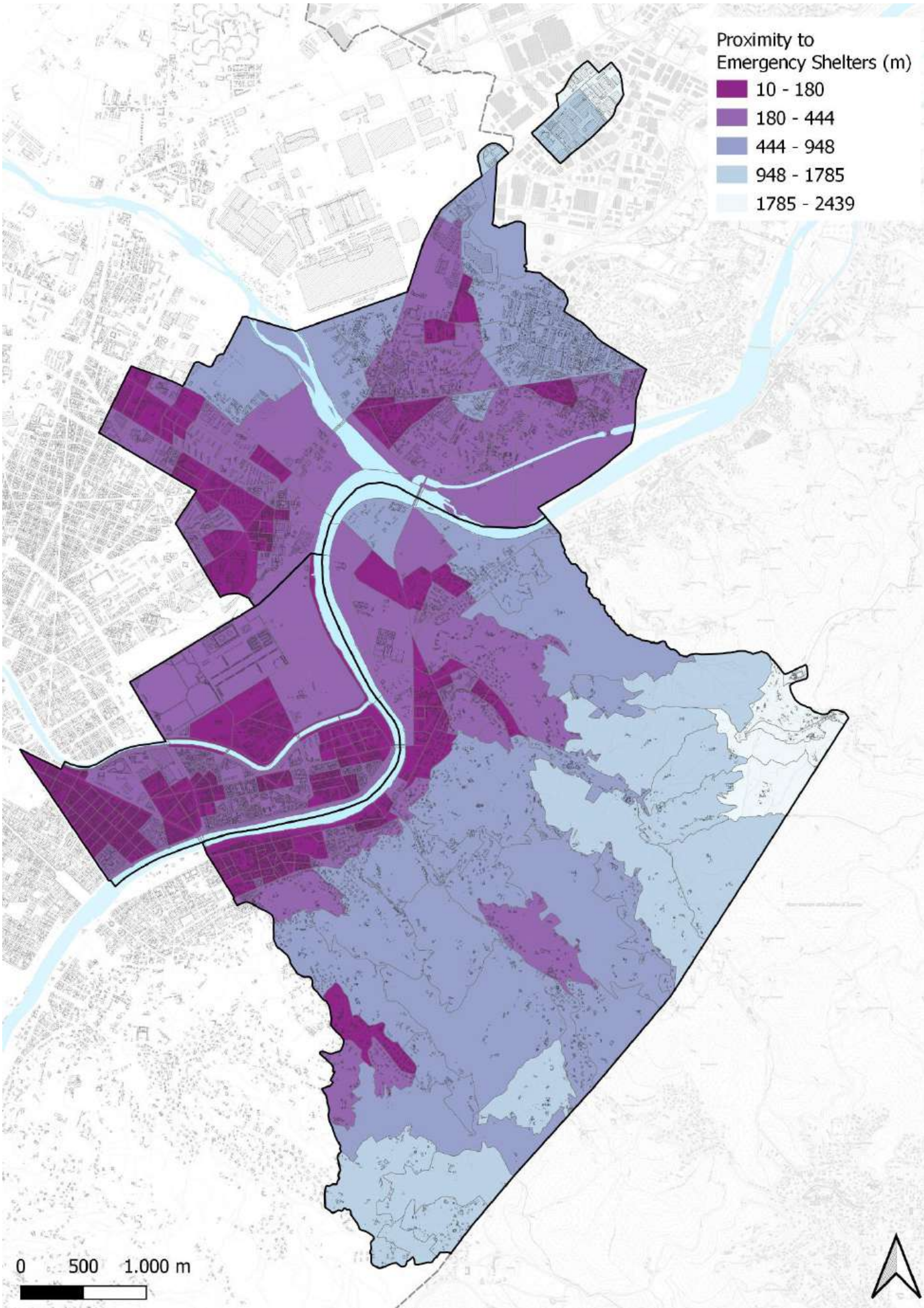

Figure 12: Spatial representation of the 'Emergency Shelter' indicator.

9_REAL ESTATE VALUES

Name	**Real Estate Values**
Source indicator ID	37
Dimension	☐Built ☐Environmental ☒Social ☒Economic ☐Institutional
Topic	Income
Definition	Average rental value of the predominant residential typology within the census section, based on the OMI (Osservatorio del Mercato Immobiliare) zoning.
Direction	☐positive ☐negative ☒not defined
Formula	N=E N= Real Estate Values E= Average rental value per square meter per month
Unit of measure	€/m^2/month
Territorial scale of reference	Sub-district
Data source	Zone OMI, Osservatorio del Mercato Immobiliare (Agenzia delle Entrate), 2024
Timescale of reference	2024

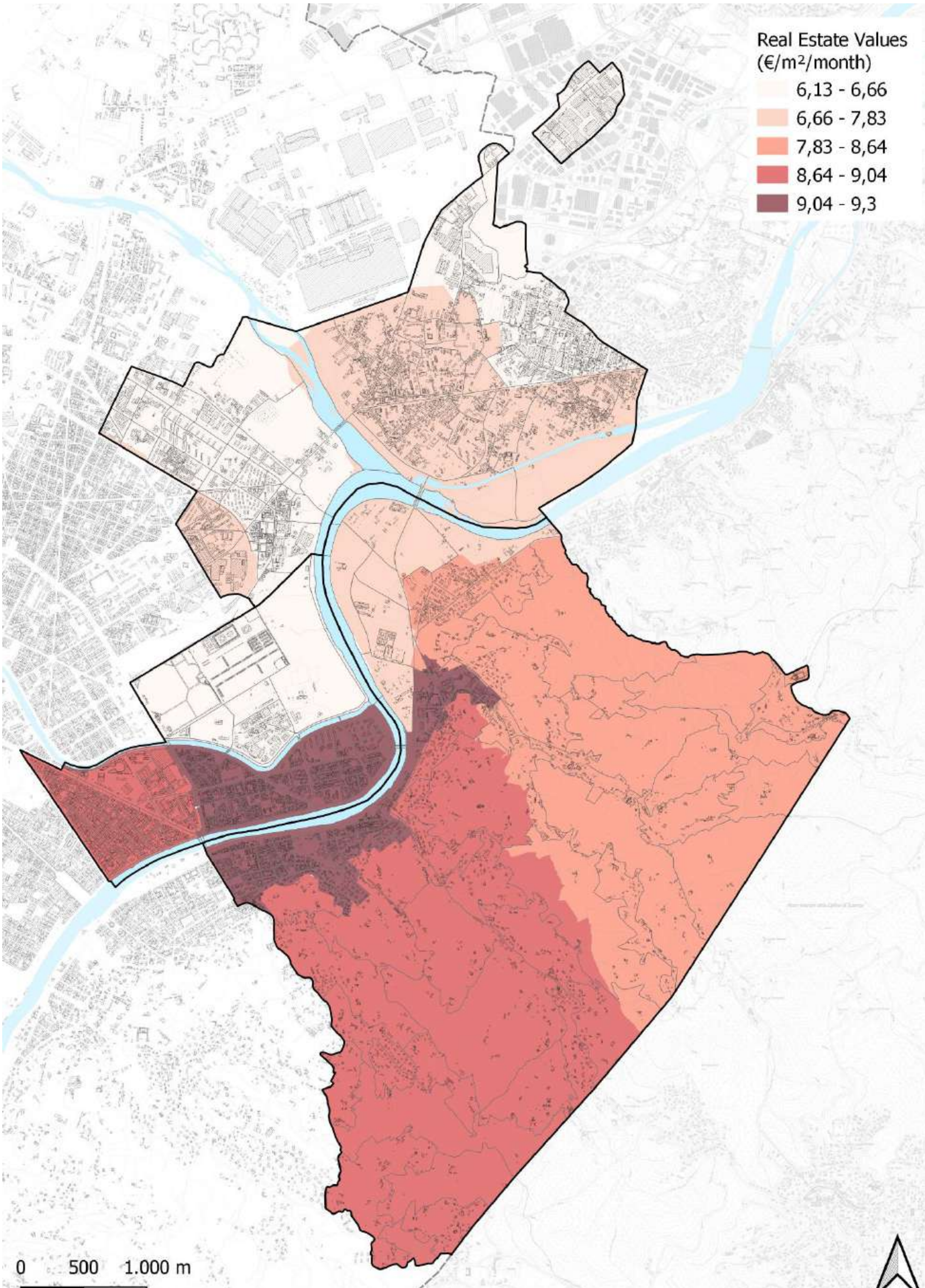

Figure 13: Spatial representation of the 'Real Estate Values' indicator.

10_CYCLING INFRASTRUCTURE

Name	**Cycling Infrastructure**
Source indicator ID	40
Dimension	☒Built ☐Environmental ☐Social ☐Economic ☐Institutional
Topic	Infrastructures and network
Definition	Percentage of the total area of the census section within a 300-meter radius buffer around cycling paths.
Direction	☒positive ☐negative ☐not defined
Formula	$N = C/A \times 100$ N = Brownfield Sites C = Area covered by the 300-meter buffers around cycling paths A= Total surface of the census section
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	Piano Territoriale di Coordinamento, 2011; Comune di Torino, Census sections (2024)
Timescale of reference	2011

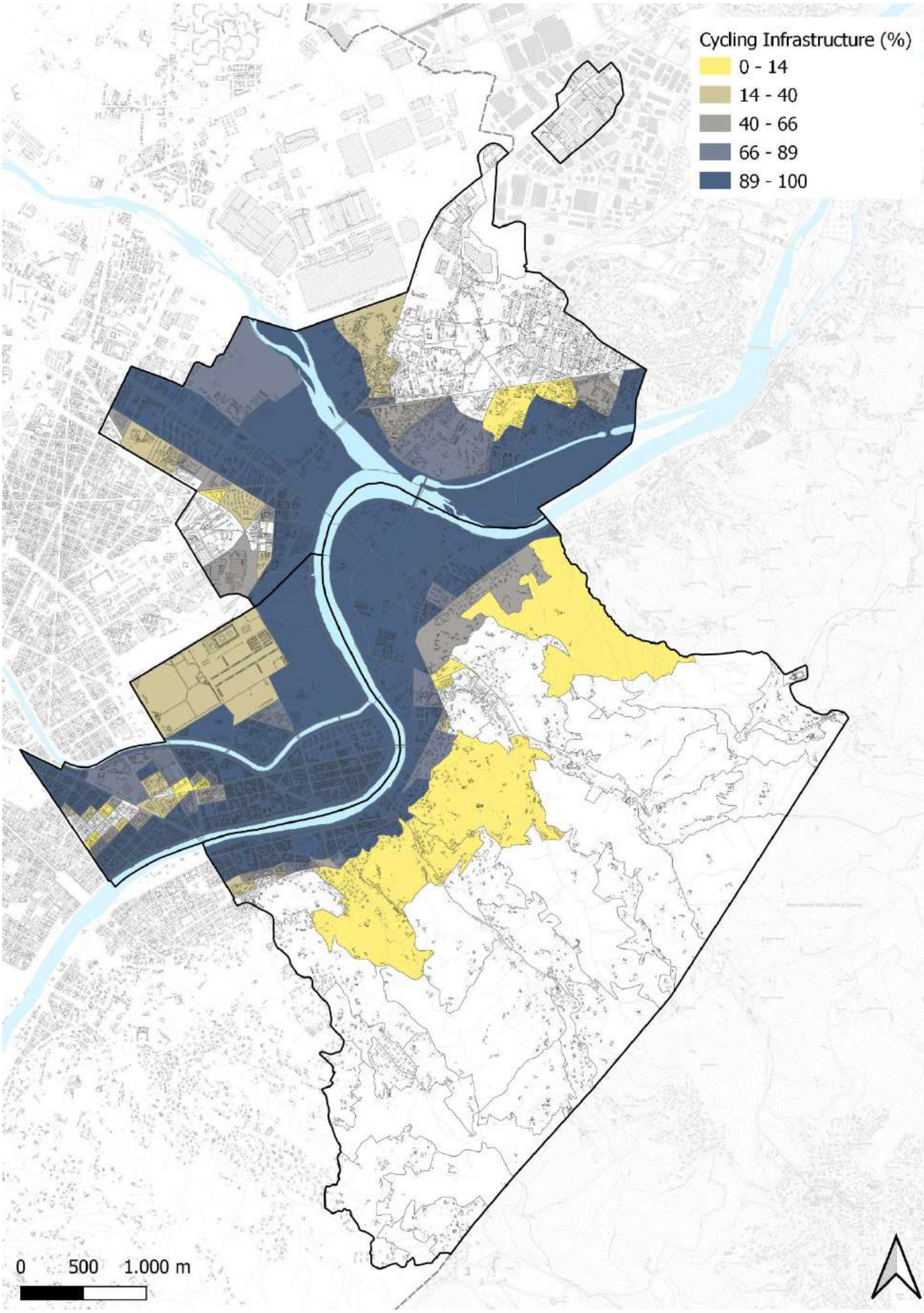

Figure 14: Spatial representation of the 'Cycling Infrastructure' indicator.

11_PUBLIC TRANSPORT

Name	**Public Transport**
Source indicator ID	48
Dimension	☒Built ☐Environmental ☐Social ☐Economic ☒Institutional
Topic	Infrastructures and network
Definition	The concentration of tram and bus stops within a 300-meter radius.
Direction	☒positive ☐negative ☐not defined
Formula	Kernel Density Estimation
Unit of measure	unit/m^2
Territorial scale of reference	Sub-district
Data source	Regione Piemonte, “Linee di trasporto pubblico locale”, 2024
Timescale of reference	2024

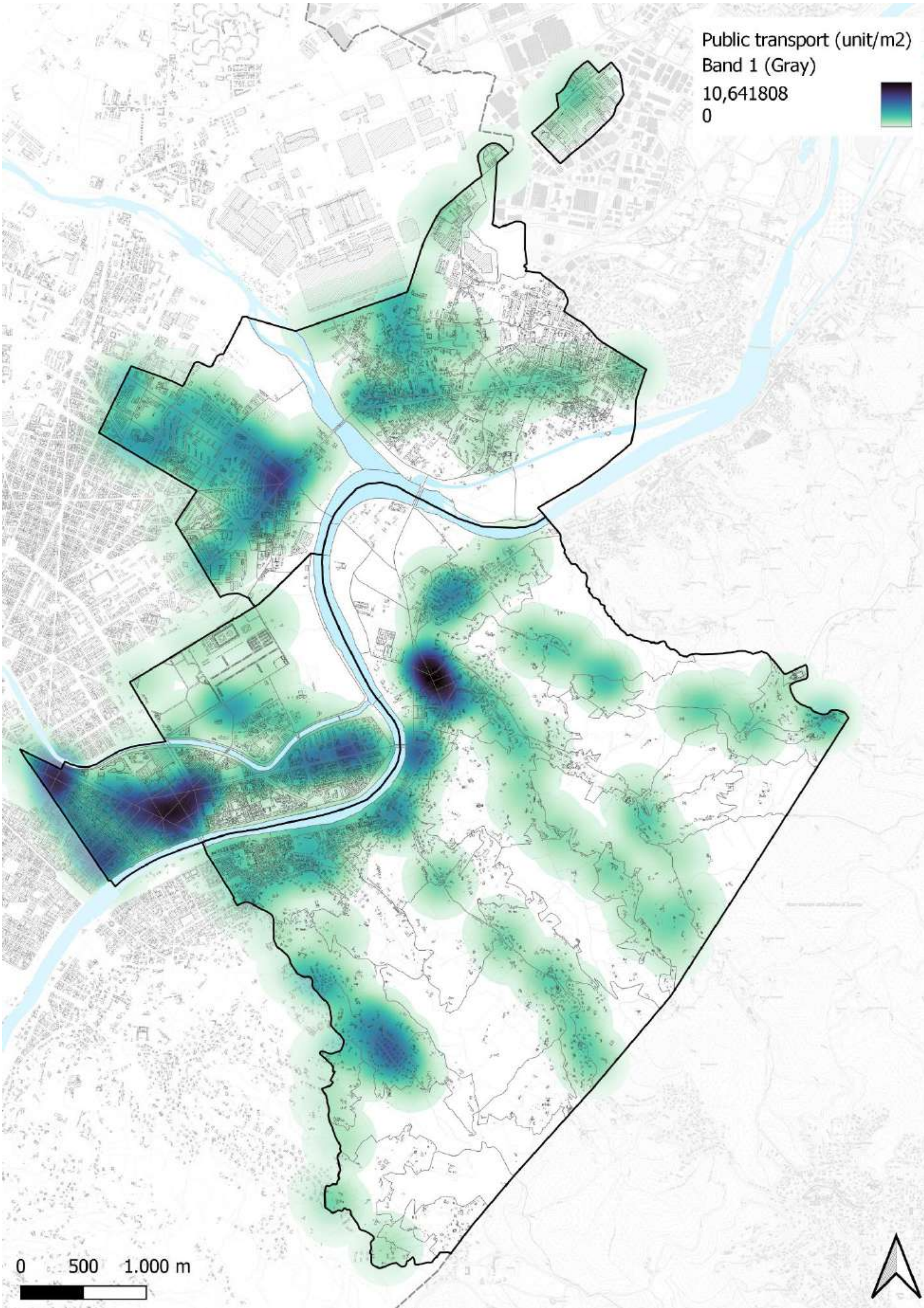

Figure 15: Spatial representation of the 'Public Transport' indicator.

12_PUBLIC WATER FOUNTAINS

Name	**Public Water Fountains**
Source indicator ID	49
Dimension	☒Built ☐Environmental ☐Social ☐Economic ☒Institutional
Topic	Infrastructures and network
Definition	Percentage of the total area of the census section within a 300-meter radius of one or more public water fountains.
Direction	☒positive ☐negative ☐not defined
Formula	$N = W / A \times 100$ N = Public Water Fountains W= Area covered by the 300-meter buffers around public water fountains A= Total surface of the census section
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	I Love Toret, 2022, https://ilovetoret.it/it/; Comune di Torino, Census sections (2024)
Timescale of reference	2024

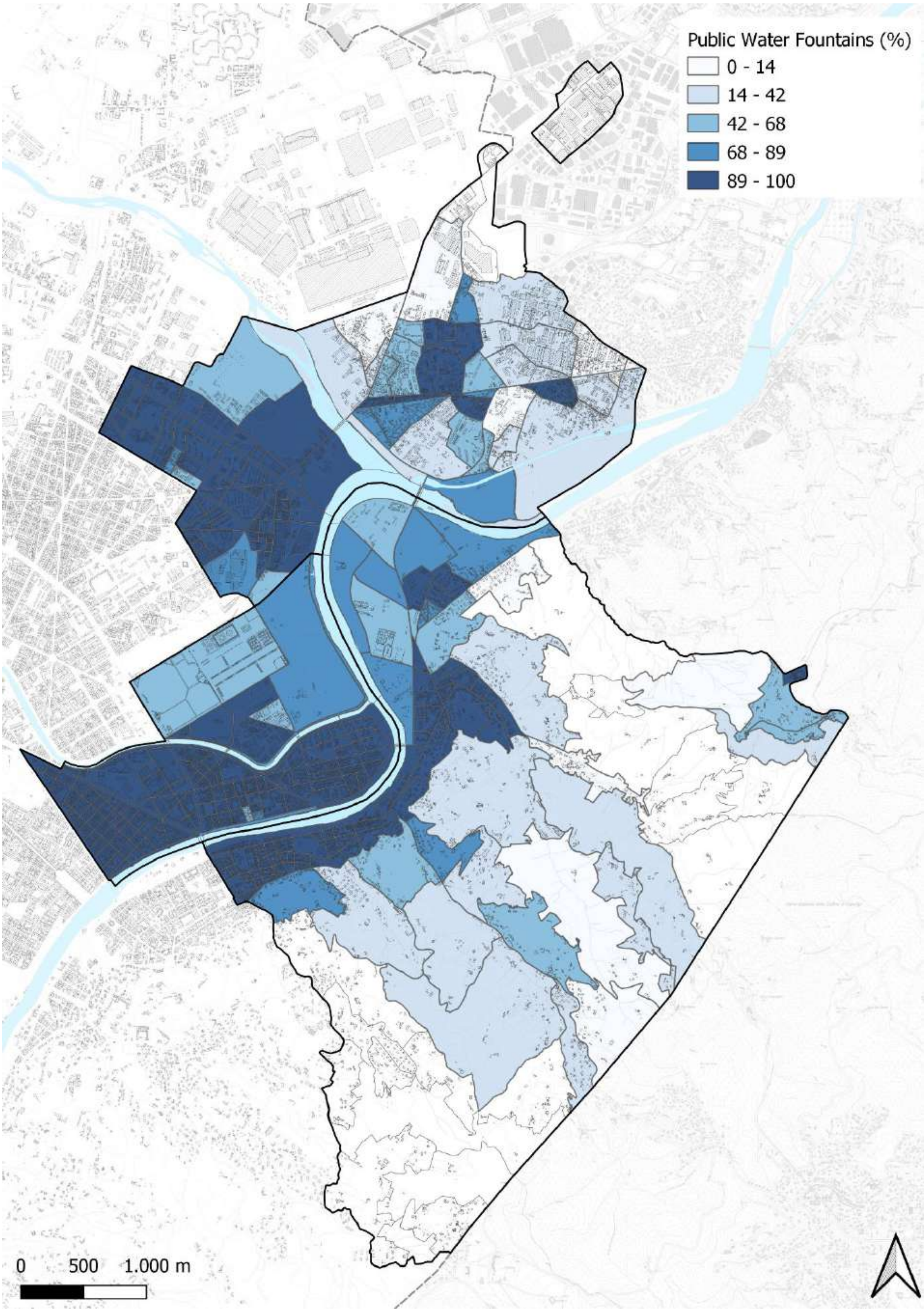

Figure 16: Spatial representation of the 'Public Water Fountains' indicator.

13_LAND TAKE

Name	**Land Take**
ID	104
Dimension	☒Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Land use
Definition	Percentage of the land take area within the census section.
Direction	☐positive ☒negative ☐not defined
Formula	N=K/A N = Land take K= Total land take area in the selected area A= Total surface of the selected area
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	Land Cover Piemonte (Regione Piemonte), 2023; Comune di Torino, Census sections (2024)
Timescale of reference	2023

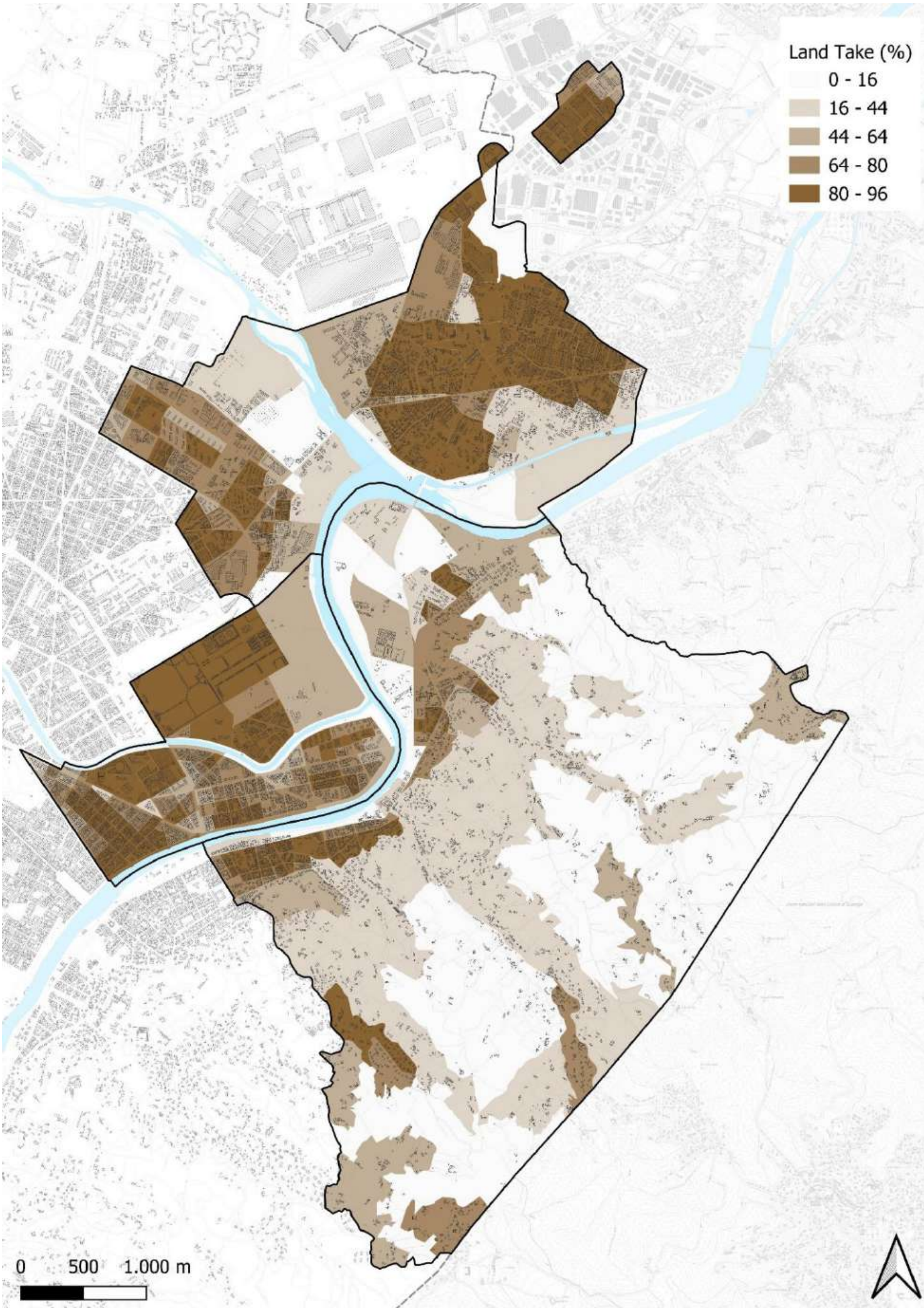

Figure 17: Spatial representation of the 'Land Take' indicator.

14_ECOLOGICAL NETWORK: FRAGILITY

Name	**Ecological Network: Fragility**
Source indicator ID	This indicator was not included in the original framework and was introduced at a later stage, in response to specific needs that emerged during the case study analysis.
Dimension	☐Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Natural/green spaces
Definition	Sensitivity to pressures such as pollution, exotic and invasive species, and anthropogenic disturbance in general.
Direction	☐positive ☒negative ☐not defined
Formula	N=F N = Fragility of the ecological network F= Class of fragility based on the ecological network analysis obtained with ENEA methodology
Unit of measure	Adimensional
Territorial scale of reference	Sub-district
Data source	Land Cover Piemonte (Regione Piemonte) 2023
Timescale of reference	2023

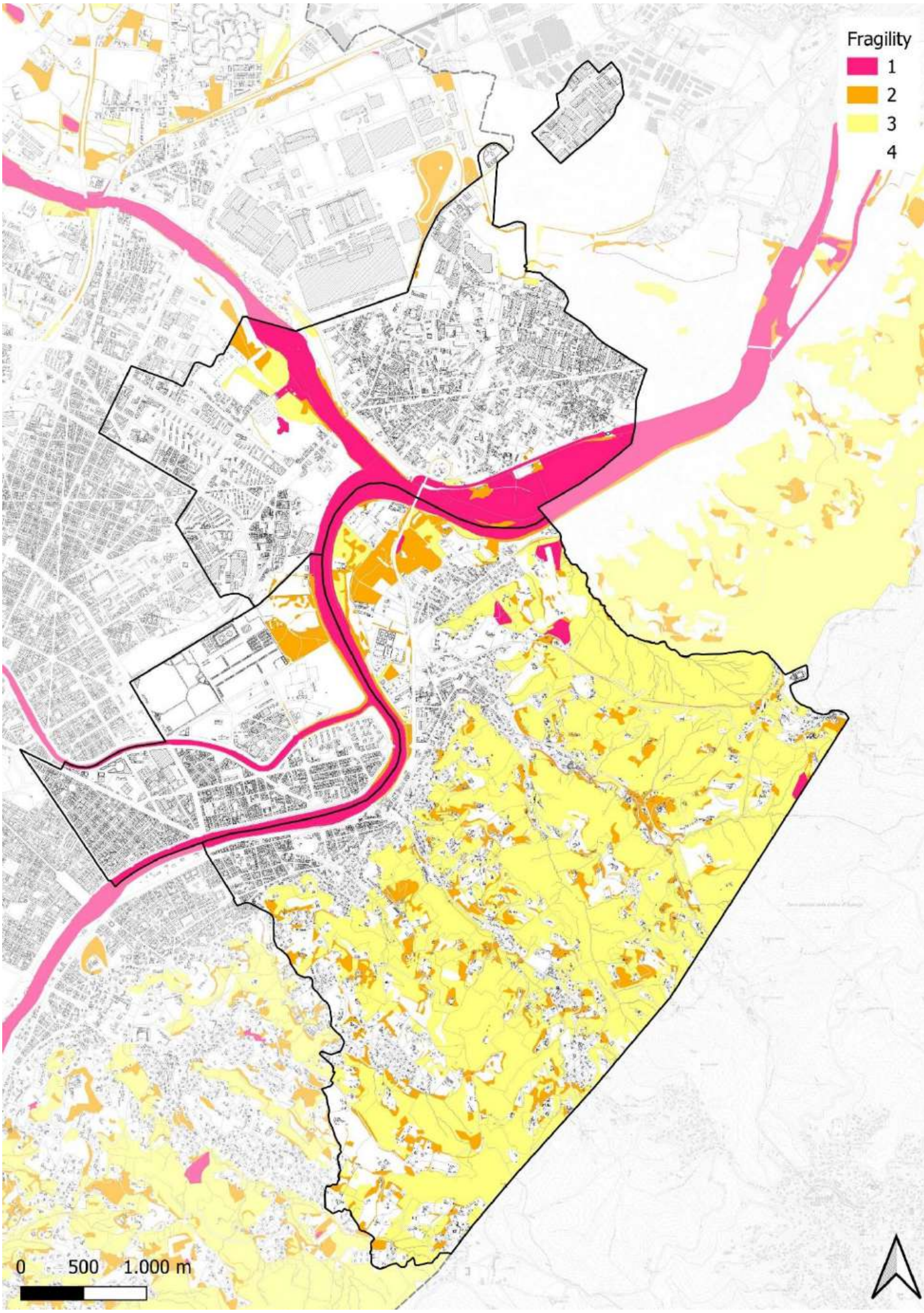

Figure 18: Spatial representation of the 'Ecological Network: Fragility' indicator.

15_ECOLOGICAL NETWORK: NATURALITY

Name	**Ecological Network: Naturality**
Source indicator ID	This indicator was not included in the original framework and was introduced at a later stage, in response to specific needs that emerged during the case study analysis.
Dimension	☐Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Natural/green spaces
Definition	Relevance/suitability of land uses for biodiversity conservation, simultaneously assessing their importance for both habitats and species.
Direction	☒positive ☐negative ☐not defined
Formula	$N = J$ N = Fragility of the ecological network J= Class of naturality based on the ecological network analysis obtained with ENEA methodology
Unit of measure	Adimensional
Territorial scale of reference	Sub-district
Data source	Land Cover Piemonte (Regione Piemonte) 2023
Timescale of reference	2023

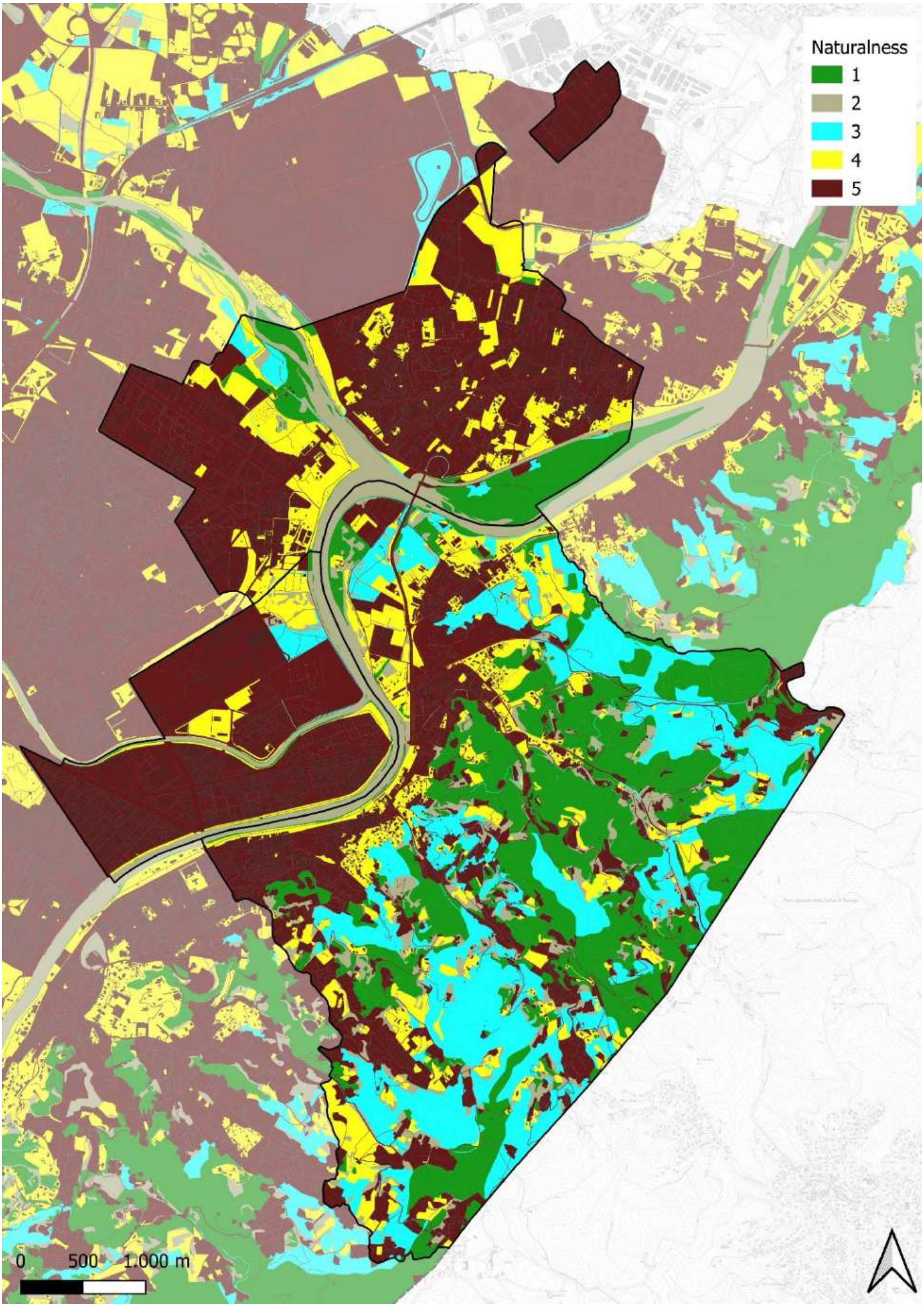

Figure 19: Spatial representation of the 'Ecological Network: Naturalness' indicator.

16_ECOLOGICAL NETWORK: RELEVANCE

Name	**Ecological Network: Relevance**
Source indicator ID	This indicator was not included in the original framework and was introduced at a later stage, in response to specific needs that emerged during the case study analysis.
Dimension	☐Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Natural/green spaces
Definition	Importance of the area for biodiversity conservation.
Direction	☒positive ☐negative ☐not defined
Formula	$$N=R$$ N = Fragility of the ecological network R= Class of relevance based on the ecological network analysis obtained with ENEA methodology
Unit of measure	adimensional
Territorial scale of reference	Sub-district
Data source	Land Cover Piemonte (Regione Piemonte) 2023
Timescale of reference	2023

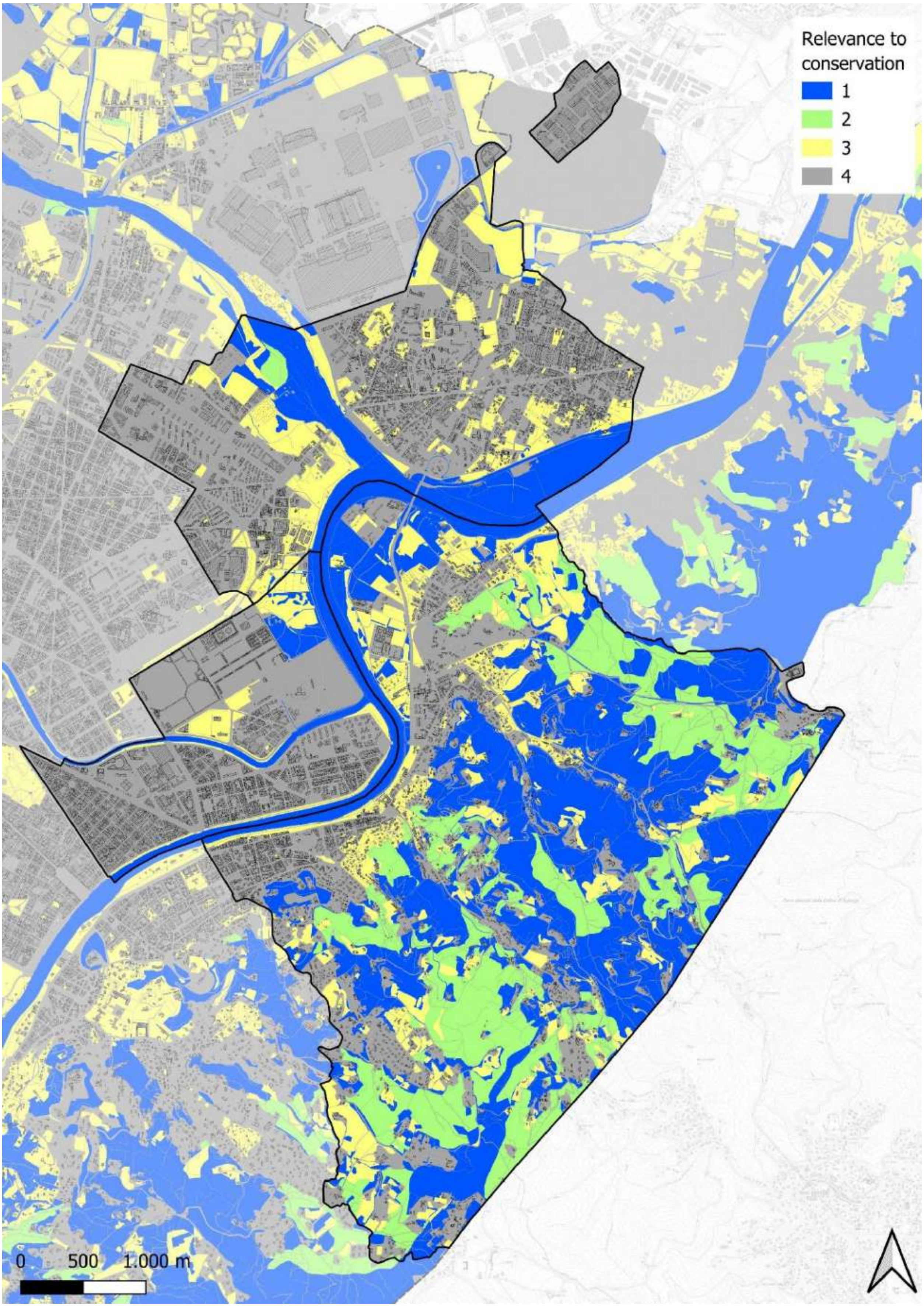

Figure 20: Spatial representation of the 'Ecological Network: Relevance to Conservation' indicator.

17_FOREST COVER

Name	**Forest cover**
Source indicator ID	**57**
Dimension	☐Built ☒Environmental ☐Social ☐Economic ☒Institutional
Topic	Natural/green spaces
Definition	Proportion of forest coverage within the census section.
Direction	☒positive ☐negative ☐not defined
Formula	$N = Ag / A$ N = Forest cover A_g = Global surface of forest cover A = Surface of the selected area
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	Land Cover Piemonte (Regione Piemonte) 2023, field “lcp”, all classes included within CLC-level I “3. Forest and semi natural areas” Comune di Torino, Census sections (2024)
Timescale of reference	2023

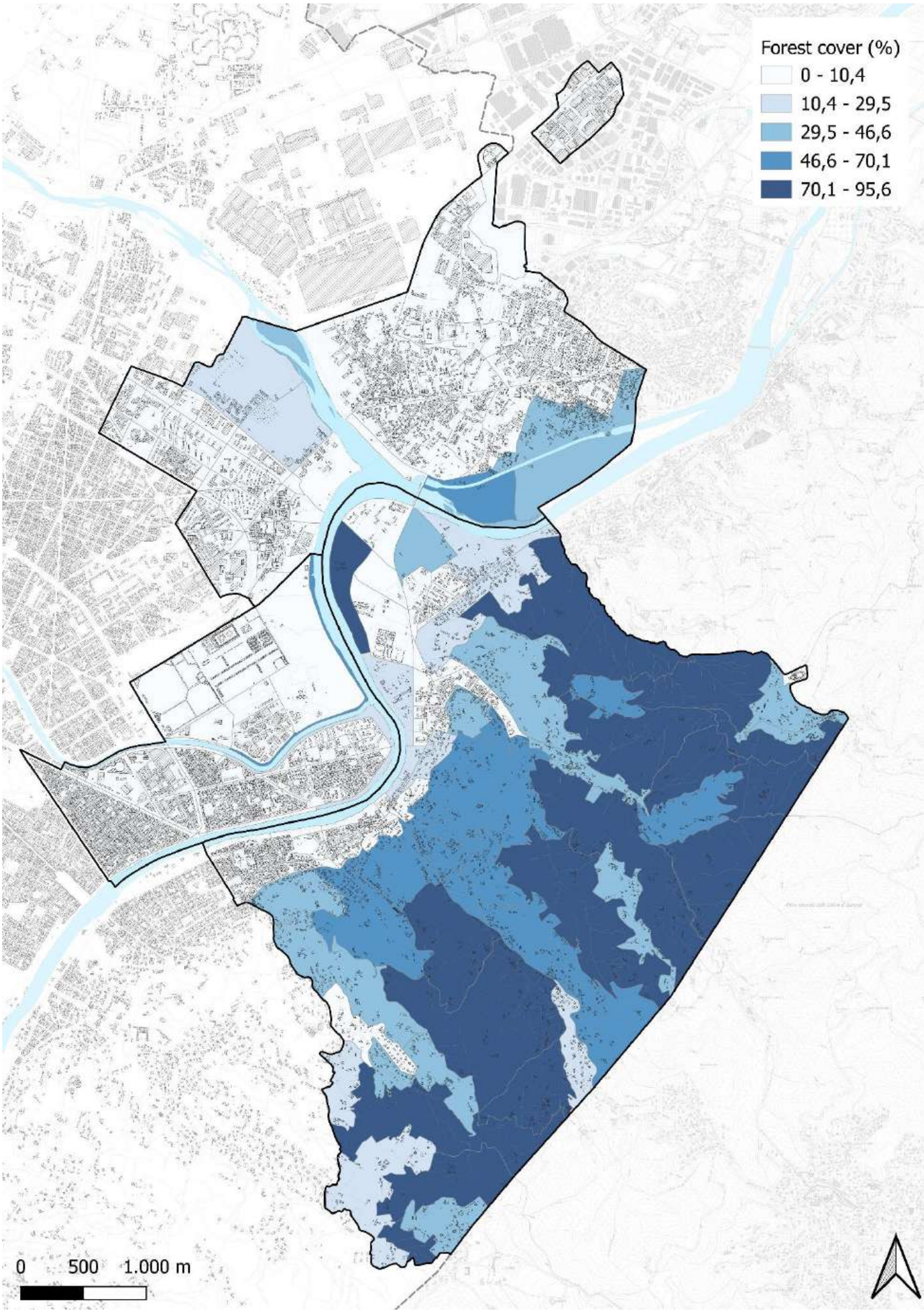

Figure 21: Spatial representation of the 'Forest Cover' indicator.

18_GREEN-SHADED PATHWAYS

Name	**Green-Shaded Pathways**
Source indicator ID	This indicator was not included in the original framework and was introduced at a later stage, in response to specific needs that emerged during the case study analysis. However, it can be considered a derivation of Indicator No. 63 "Public Urban Trees", as it uses a buffer approach to estimate the area potentially covered by tree shade.
Dimension	☐Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Natural/Green Spaces
Definition	Percentage of pedestrian circulation area within a 10-meter buffer from at least one tree, over the total pedestrian circulation area of the census section.
Direction	☒positive ☐negative ☐not defined
Formula	$N = S/A \times 100$ N = Green-Shaded Pathways S= Area of pedestrian circulation covered by a 10-meter buffer around trees A= Total pedestrian circulation area within the census section
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	Carta Tecnica Comunale (Comune di Torino), 2024; Alberate (Comune di Torino), 2025; Comune di Torino, Census sections (2024)
Timescale of reference	2025

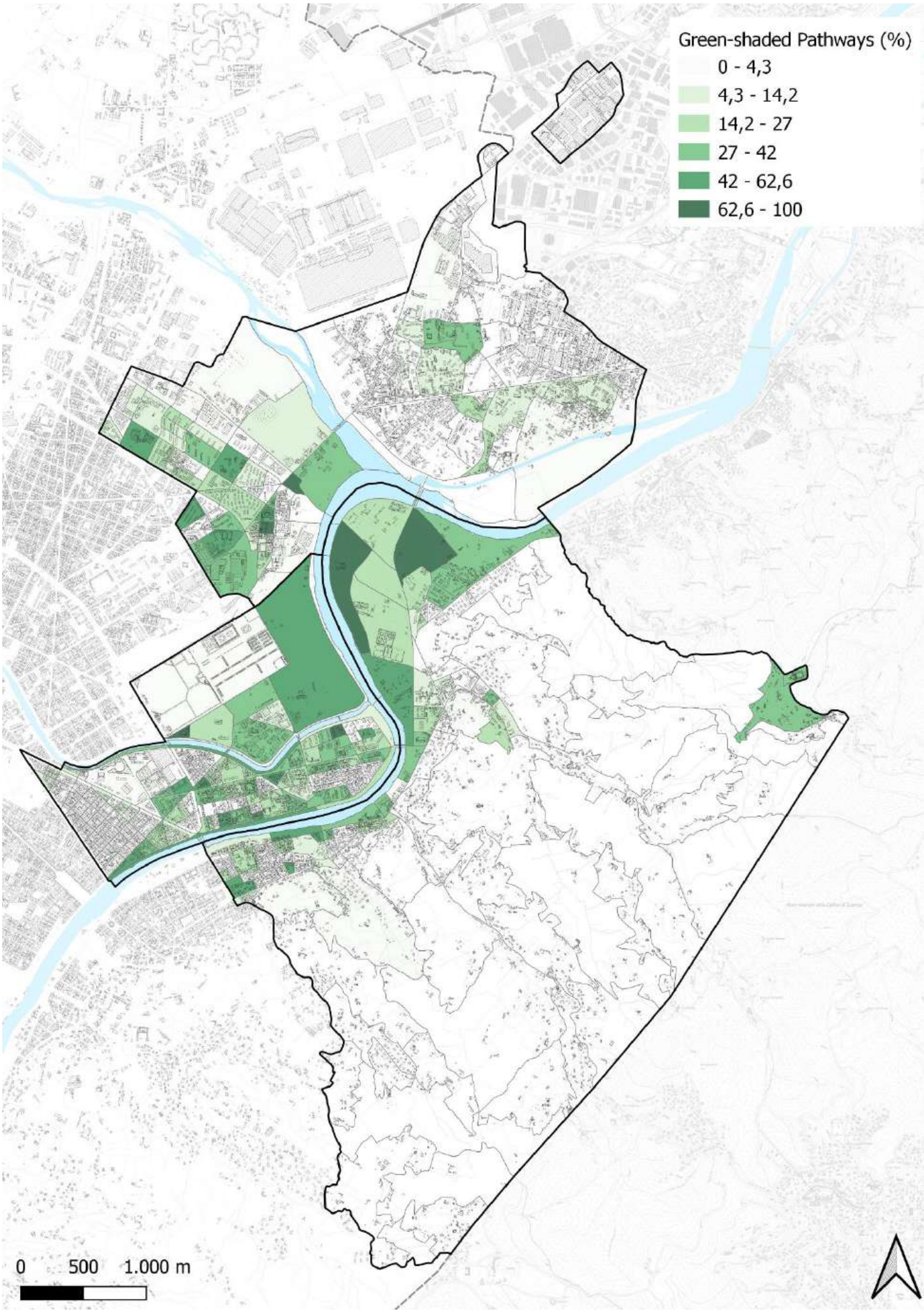

Figure 22: Spatial representation of the 'Green-shaded Pathways' indicator.

19_IMPERVIOUSNESS

Name	**Imperviousness**
Source indicator ID	64
Dimension	☒Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Natural/green spaces
Definition	Proportion of impermeable surfaces that prevents the infiltration of water into the ground, over the total area.
Direction	☐positive ☒negative ☐not defined
Formula	$N = A_g/A$ N = Imperviousness, expressed as a percentage A_g = Global surface of the impervious areas A = Surface of the selected area
Unit of measure	%
Territorial scale of reference	sub-district
Data source	LCP 2023, field "imp_2022_perc" (% imperviousness, polygon average based on 10m pixels, from REMOTE SENSING Consumo di suolo ISPRA2022, Sentinel2 - NDVI2023)
Timescale of reference	2023

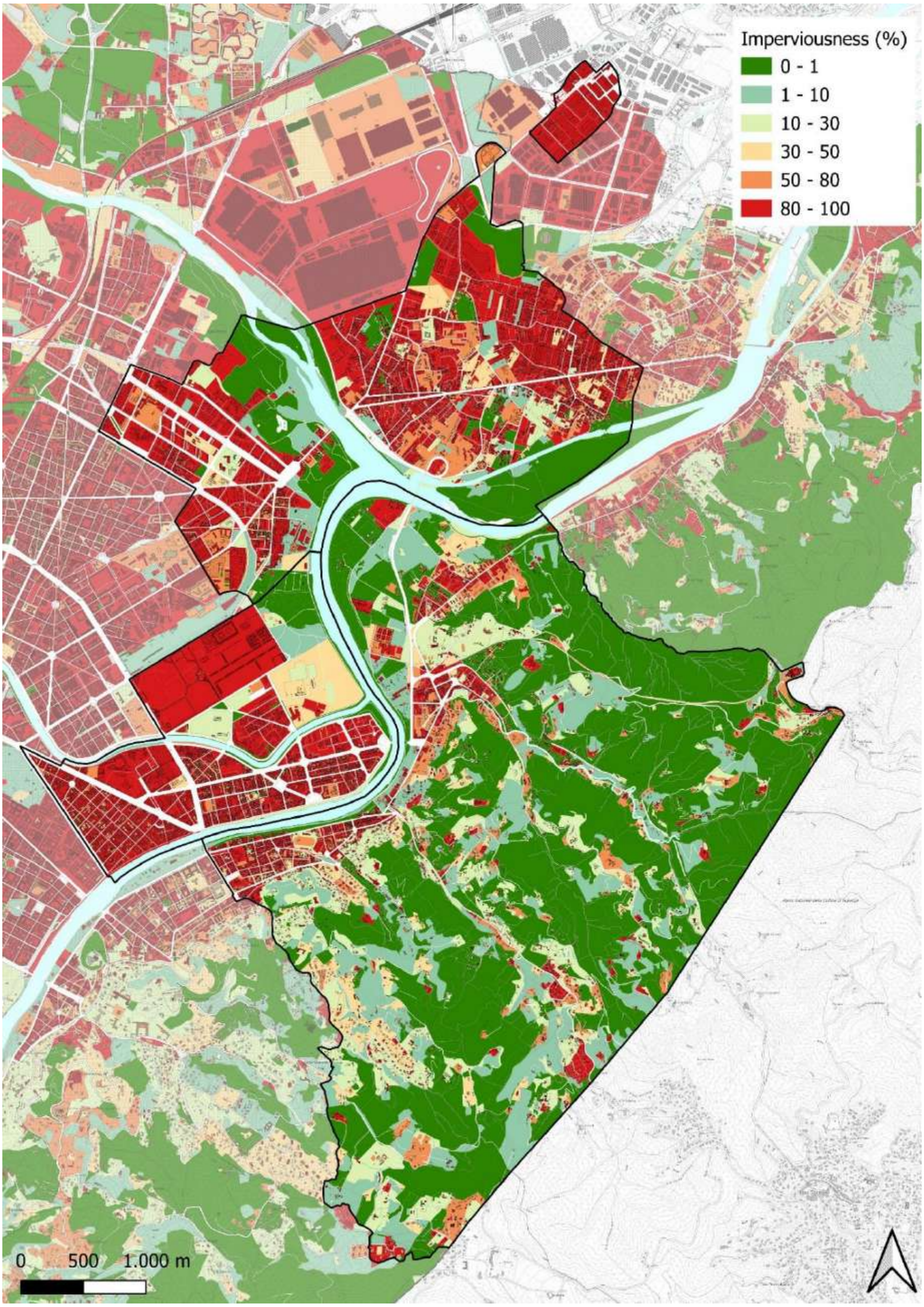

Figure ***23****: Spatial representation of the 'Imperviousness' indicator.*

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20_NDVI

Name	**NDVI**
Source indicator ID	61
Dimension	☐Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Natural/green spaces
Definition	Normalized difference vegetation Index. It provides informations on the presence and condition of vegetation on the Earth's surface.
Direction	☐positive ☐negative ☒not defined
Formula	$$N = \frac{NIR - Red}{NIR + Red}$$ *N*= Normalized Difference Vegetation Index where *Red* and *NIR* stand for the spectral reflectance measurements acquired in the red (visible) and near-infrared regions, respectively
Unit of measure	adimensional
Territorial scale of reference	Sub-district
Data source	Land Cover Piemonte (Regione Piemonte) 2023, field “ndvi_2023_perc”
Timescale of reference	2023

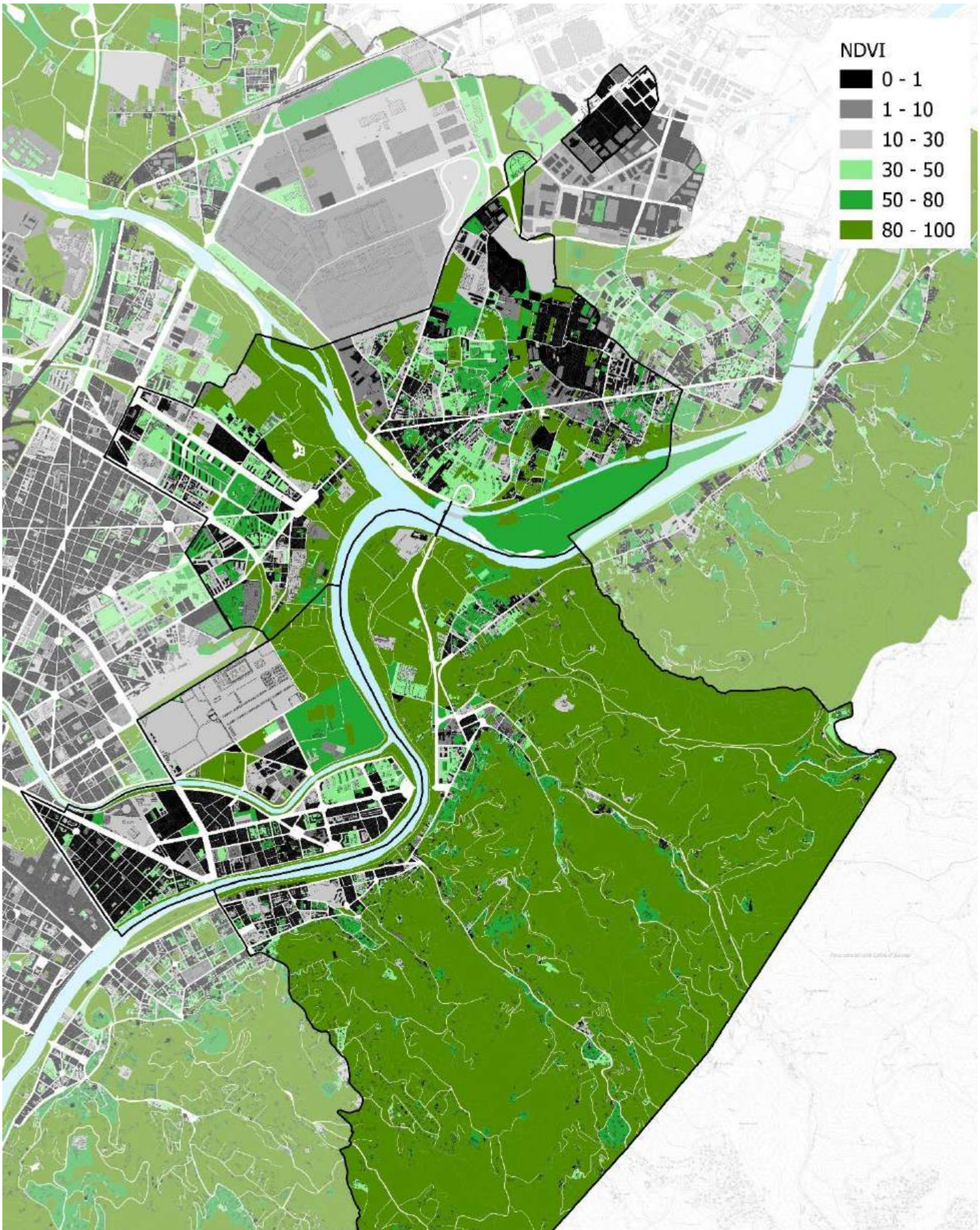

Figure 24: Spatial representation of the 'NDVI' indicator.

21_ PUBLIC URBAN TREES

Name	**Public Urban Trees**
Source indicator ID	63
Dimension	☒Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Natural/green spaces
Definition	Number of public urban trees.
Direction	☒positive ☐negative ☐not defined
Formula	N = T N = Public Urban Trees T = Number of public urban trees
Unit of measure	unit
Territorial scale of reference	Sub-district
Data source	Alberate (Comune di Torino), 2025; Comune di Torino, Census sections (2024)
Timescale of reference	2025

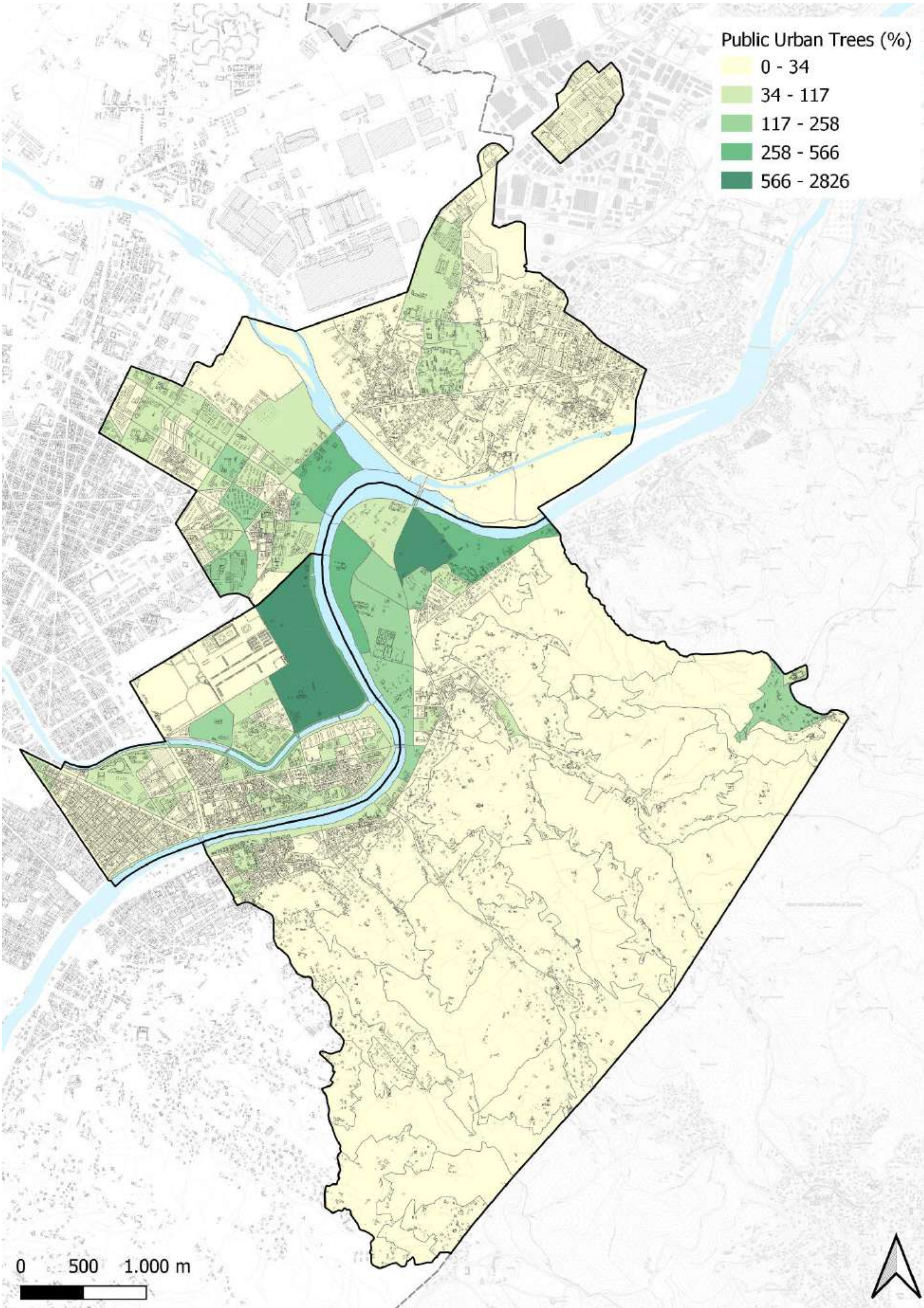

Figure 25: Spatial representation of the 'Public Urban Trees' indicator.

22_TREE COVER DENSITY

Name	**Tree Cover**
Source indicator ID	67
Dimension	☐Built ☒Environmental ☐Social ☐Economic ☐Institutional
Topic	Natural/green spaces
Definition	Extent of land area covered by the canopy of trees.
Direction	☒positive ☐negative ☐not defined
Formula	$$\boldsymbol{N = \frac{A_c}{A}}$$ N= Tree cover density, expressed as a percentage A_c = area covered by tree canopy A= surface of the selected area
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	Copernicus Dataset, Tree Cover Density 2018 (raster 10 m), Europe, 3-yearly (2018). DOI (raster 10 m): https://doi.org/10.2909/486f77da-d605-423e-93a9-680760ab6791
Timescale of reference	2018

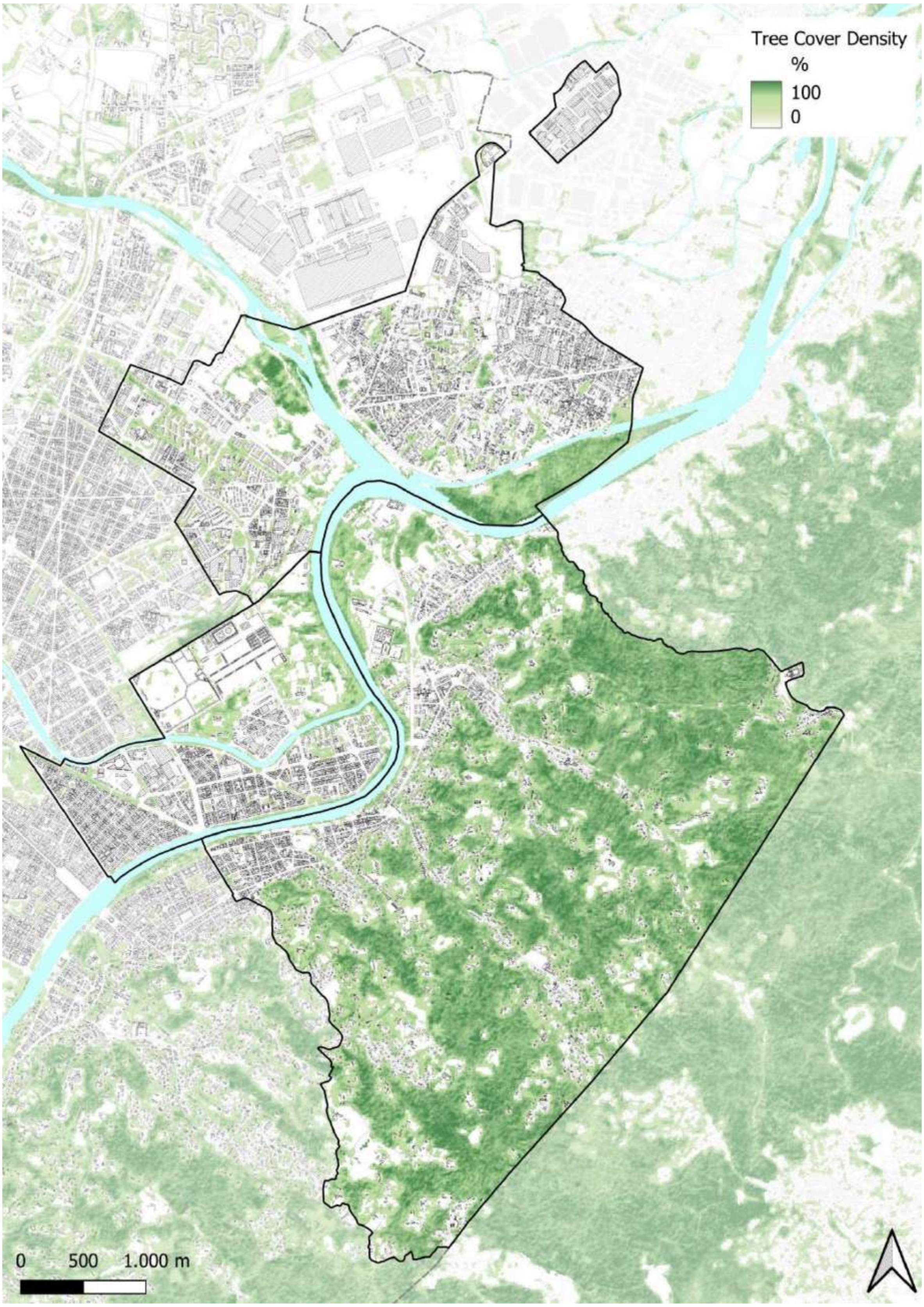

Figure 26: Spatial representation of the 'Tree Cover' indicator.

23_GREEN URBAN SPACES

Name	**Green urban spaces**
Source indicator ID	59
Dimension	☐Built ☒Environmental ☒Social ☐Economic ☐Institutional
Topic	Services
Definition	Number of inhabitants within the census section with access to a green urban area less than 300m away.
Direction	☒positive ☐negative ☐not defined
Formula	N = G N = accessibility to green urban spaces G = number of inhabitants living less than 300 m from green areas
Unit of measure	Unit
Territorial scale of reference	Sub-district
Data source	Città di Torino, Piano strategico dell'infrastruttura verde, 2021; CTC 2024 - layer "Urban greenspace"; Comune di Torino, Census sections (2024)
Timescale of reference	2021

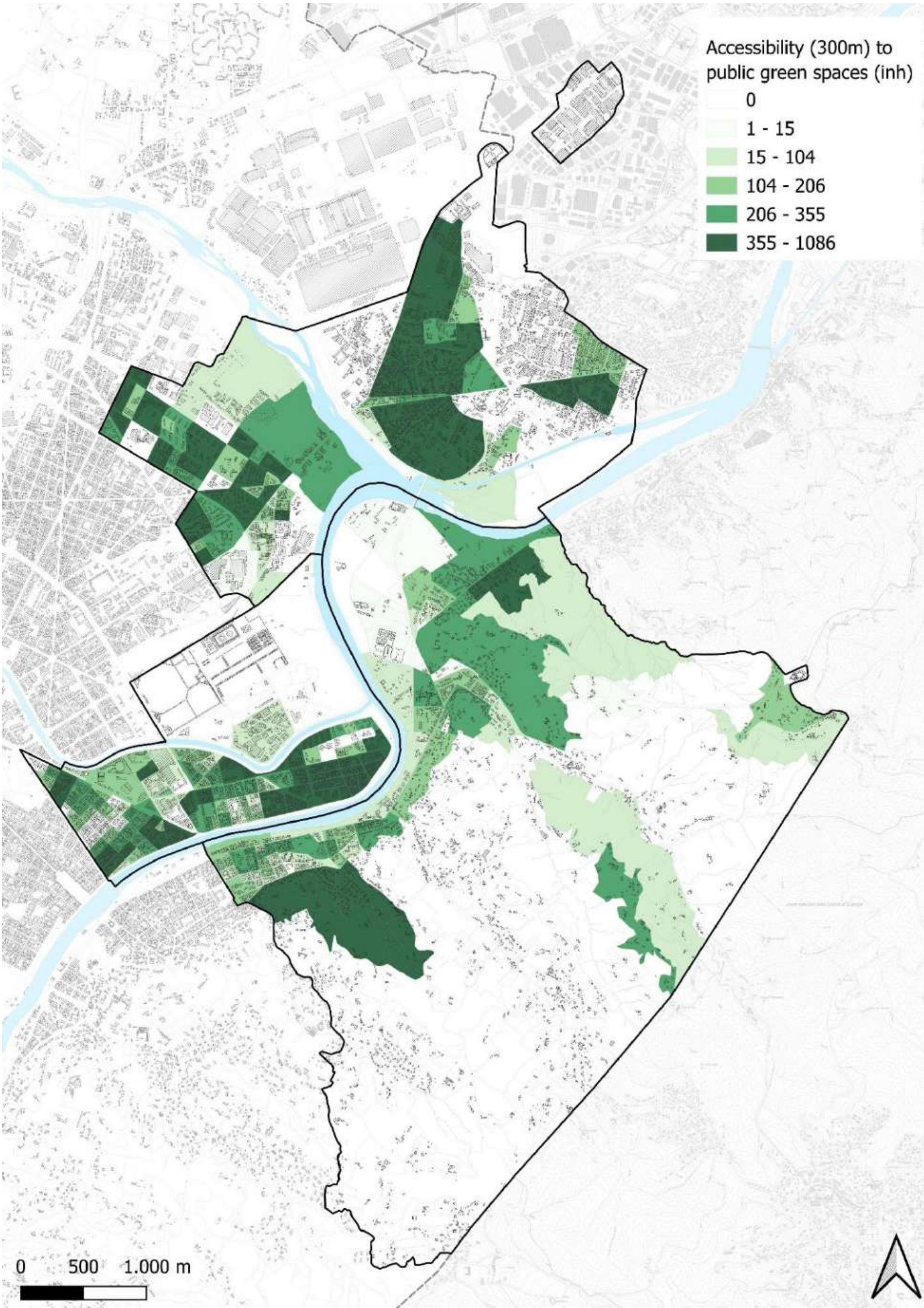

Figure 27: Spatial representation of the 'Public Green Spaces' indicator.

24_GENERAL PRACTITIONERS

Name	**General Practitioners**
Source indicator ID	78
Dimension	☐Built ☐Environmental ☐Social ☐Economic ☒Institutional
Topic	Services
Definition	Distance of the census section centroid to the nearest general practitioner.
Direction	☐positive ☒negative ☐not defined
Formula	QGIS Algorithm provided by QGIS Distance to nearest hub (points) (qgis:distancetonearesthubpoints). Given an origin and a destination layers, this algorithm computes the distance between origin features and their closest destination one.
Unit of measure	m
Territorial scale of reference	Sub-district
Data source	Medici di Medicina Generale (Azienda Sanitaria Locale Città di Torino), 2025; Comune di Torino, Census sections (2024)
Timescale of reference	2025

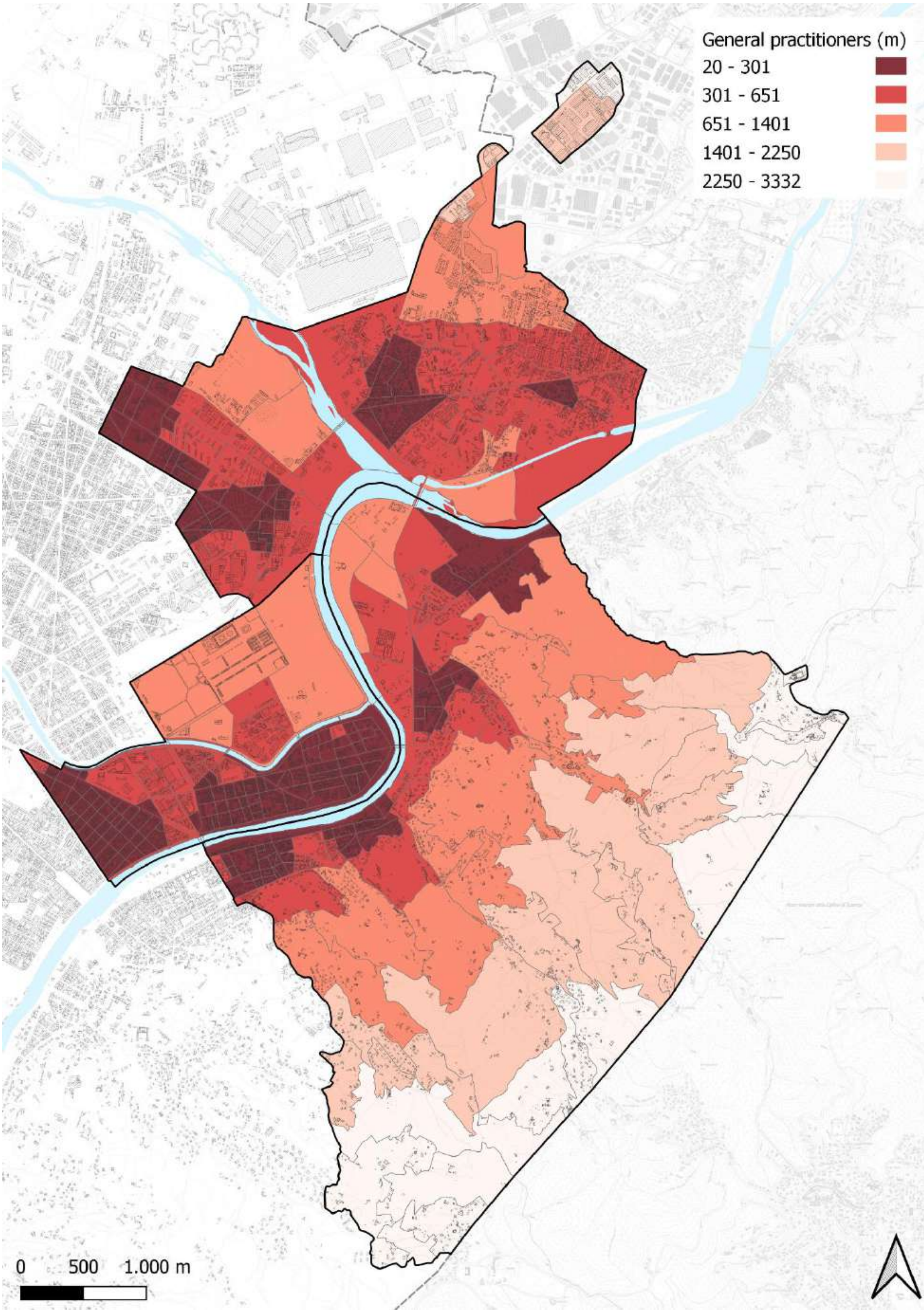

Figure 28: Spatial representation of the 'General Practitioners' indicator.

25_HOSPITAL

Name	**Proximity to hospital**
Source indicator ID	79
Dimension	☒Built ☐Environmental ☒Social ☐Economic ☒Institutional
Topic	Services
Definition	Distance of the census section centroid to the nearest hospital.
Direction	☐positive ☒negative ☐not defined
Formula	QGIS Algorithm provided by QGIS Distance to nearest hub (points) (**qgis:distancetonearesthubpoints**). Given an origin and a destination layers, this algorithm computes the distance between origin features and their closest destination one.
Unit of measure	m
Territorial scale of reference	Sub-district
Data source	Comune di Torino (AperTO), layer “Ospedali” (2011); Comune di Torino, Census sections (2024)
Timescale of reference	2011

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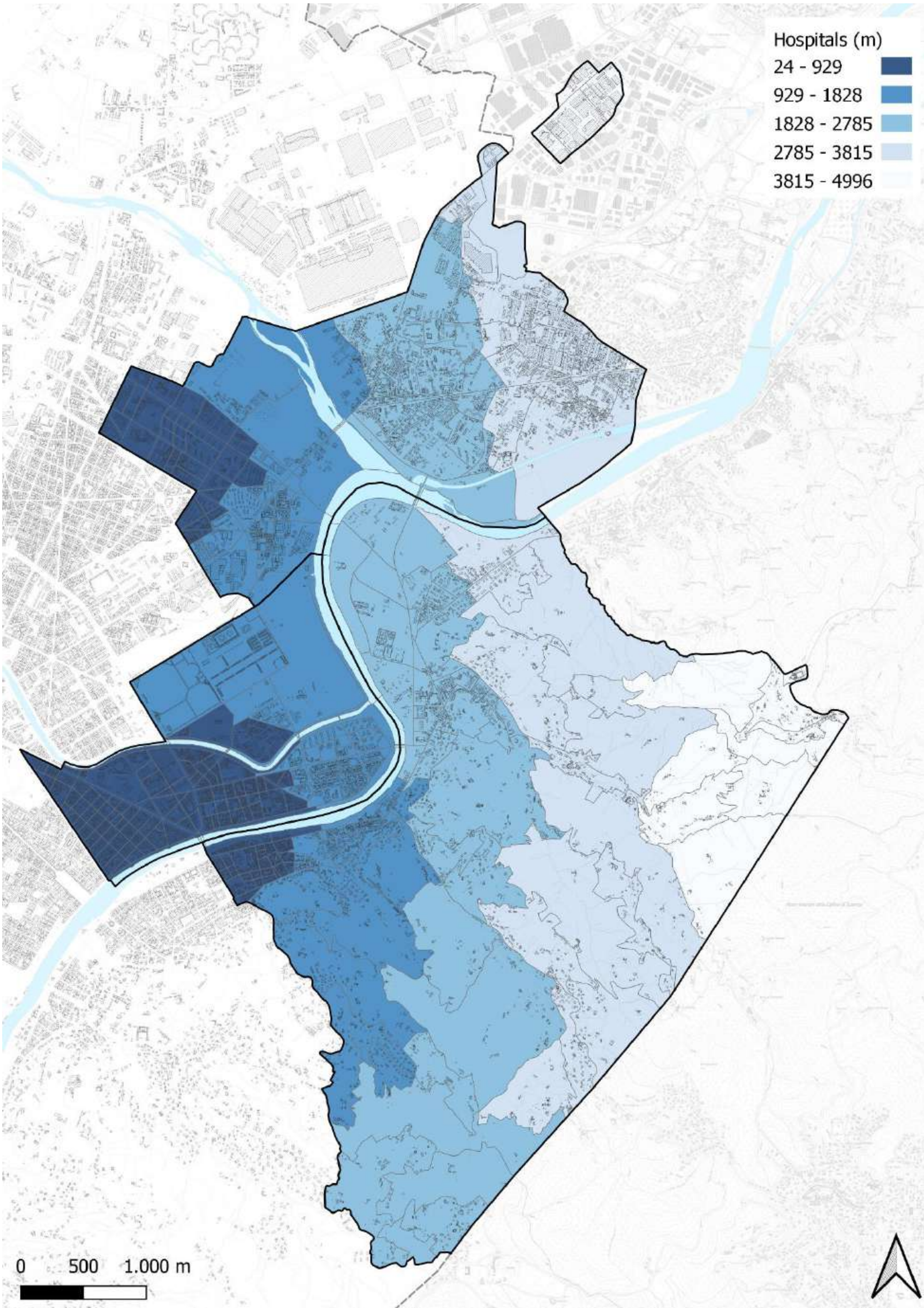

Figure 29: Spatial representation of the 'Hospital' indicator.

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26_PUBLIC EDUCATIONAL FACILITIES

Name	**Public Educational Facilities**
Source indicator ID	83
Dimension	☒Built ☐Environmental ☒Social ☐Economic ☐Institutional
Topic	Services
Definition	Distance of the census section centroid to the nearest public educational facility.
Direction	☐positive ☒negative ☐not defined
Formula	QGIS Algorithm provided by QGIS Distance to nearest hub (points) (qgis:distancetonearesthubpoints). Given an origin and a destination layers, this algorithm computes the distance between origin features and their closest destination one.
Unit of measure	m
Territorial scale of reference	Sub-district
Data source	Comune di Torino (AperTO), layer “scuole_aree_geo” (2012) CTC 2024, layer “Settlement Unit” Comune di Torino, Census sections (2024)
Timescale of reference	2012 – 2024

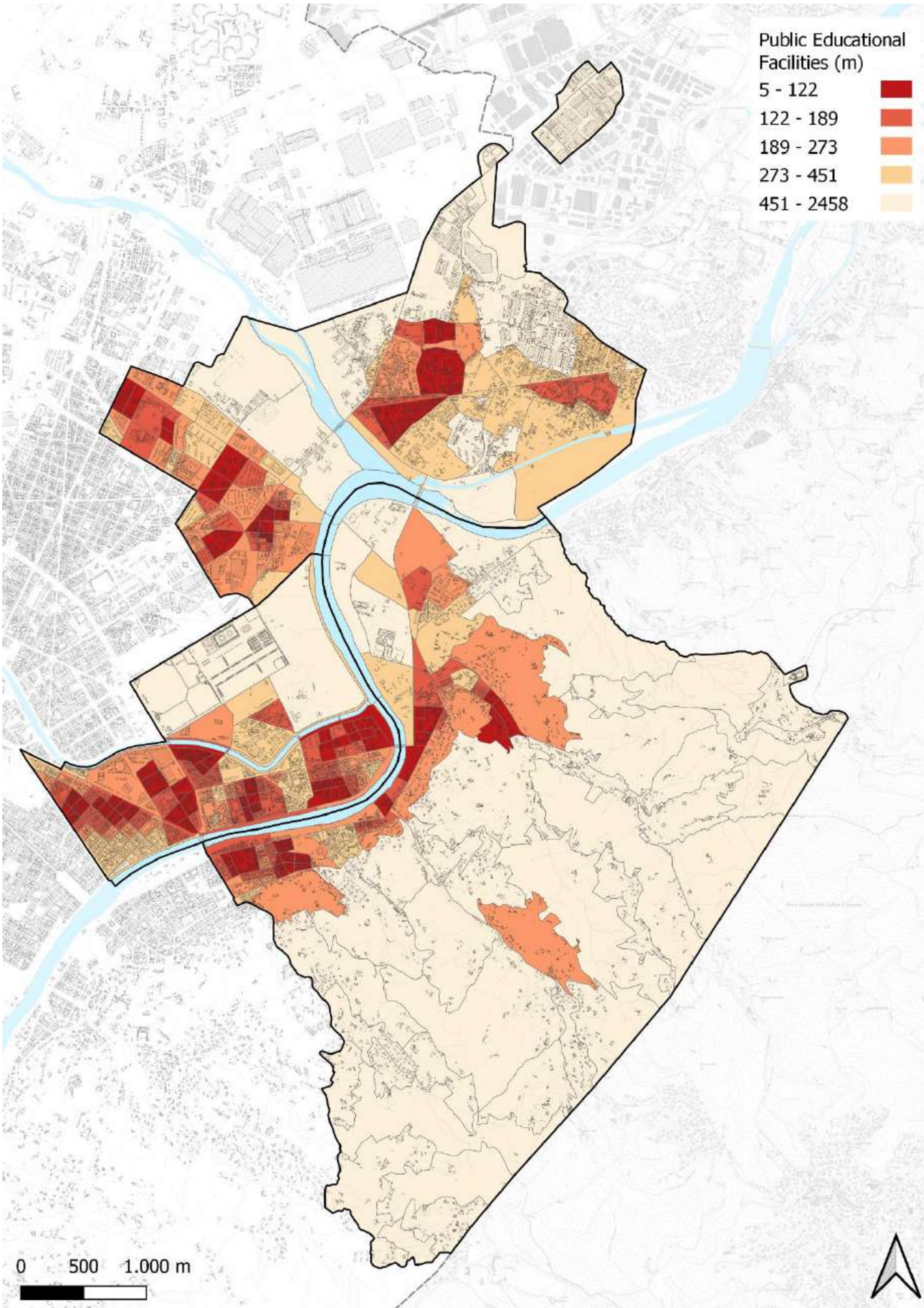

Figure 30: Spatial representation of the 'Public Educational Facilities' indicator

27_PUBLIC SERVICES

Name	**Public Services**
Source indicator ID	This indicator was not included in the original framework and was introduced at a later stage, in response to specific needs that emerged during the case study analysis. While it is conceptually related to the No. 81 “Proximity Index,” it shifts the focus toward the actual provision and spatial coverage of services, rather than their mere nearness.
Dimension	☒Built ☐Environmental ☒Social ☐Economic ☒Institutional
Topic	Services
Definition	Percentage of surface occupied by public service facilities over the total surface of the census section. Public green areas are excluded and addressed through separate indicators.
Direction	☒positive ☐negative ☐not defined
Formula	$N = S/A \times 100$ N = Public Services S = Public Services Area A= Total surface of the census section
Unit of measure	%
Territorial scale of reference	Sub-district
Data source	Piano Regolatore Generale (Comune di Torino), update 2024; Comune di Torino, Census sections (2024)
Timescale of reference	2024

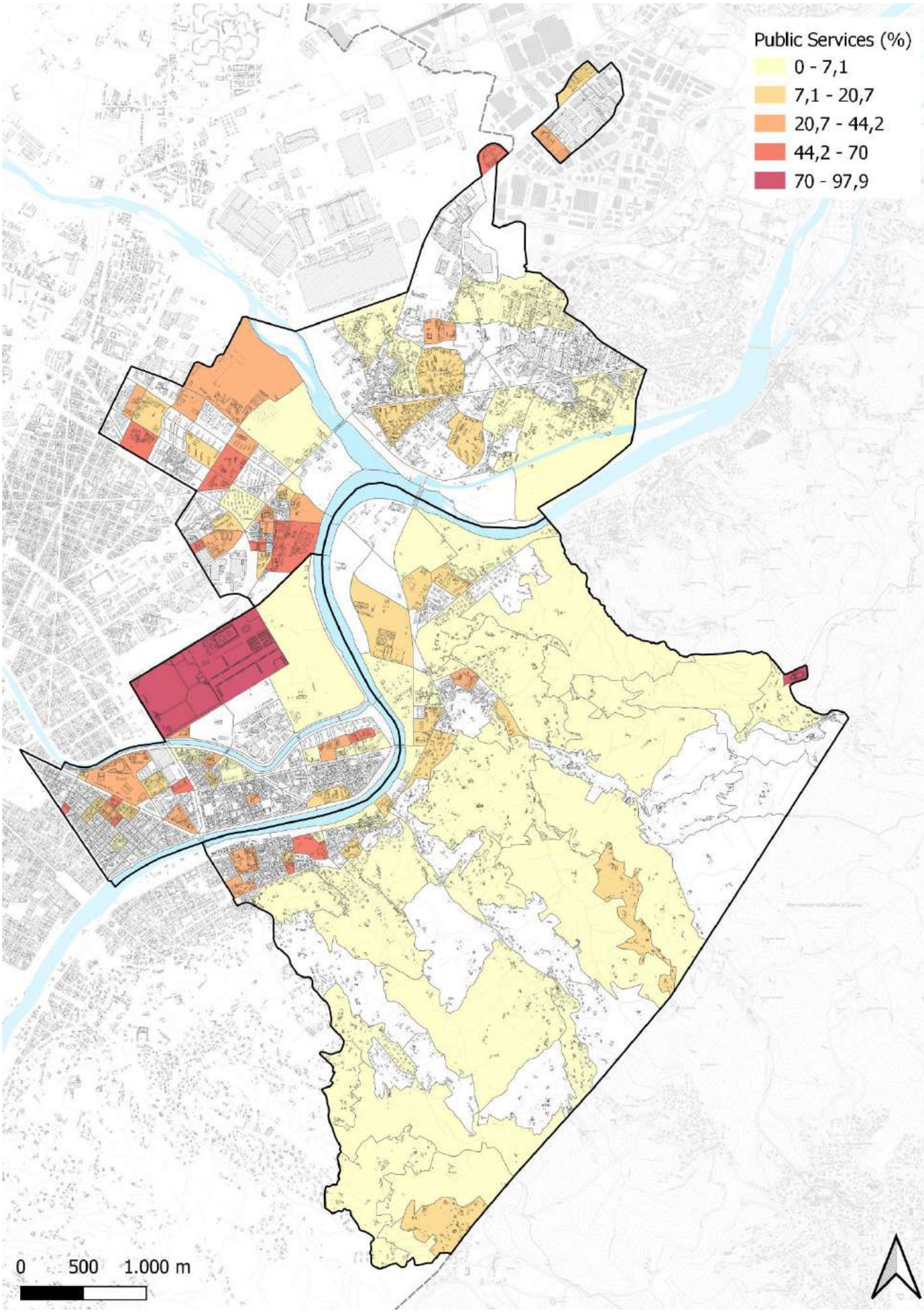

Figure 31: Spatial representation of the 'Public Services' indicator.

28_PUBLIC SPORT FACILITIES

Name	**Public Sport Facilities**
Source indicator ID	85
Dimension	☒Built ☐Environmental ☒Social ☐Economic ☐Institutional
Topic	Services
Definition	Distance of the census section centroid to the nearest public sport facility.
Direction	☐positive ☒negative ☐not defined
Formula	QGIS Algorithm provided by QGIS Distance to nearest hub (points) (**qgis:distancetonearesthubpoints**). Given an origin and a destination layers, this algorithm computes the distance between origin features and their closest destination one.
Unit of measure	m
Territorial scale of reference	Sub-district
Data source	AperTO (Comune di Torino), 2011; Comune di Torino, Census sections (2024)
Timescale of reference	2011

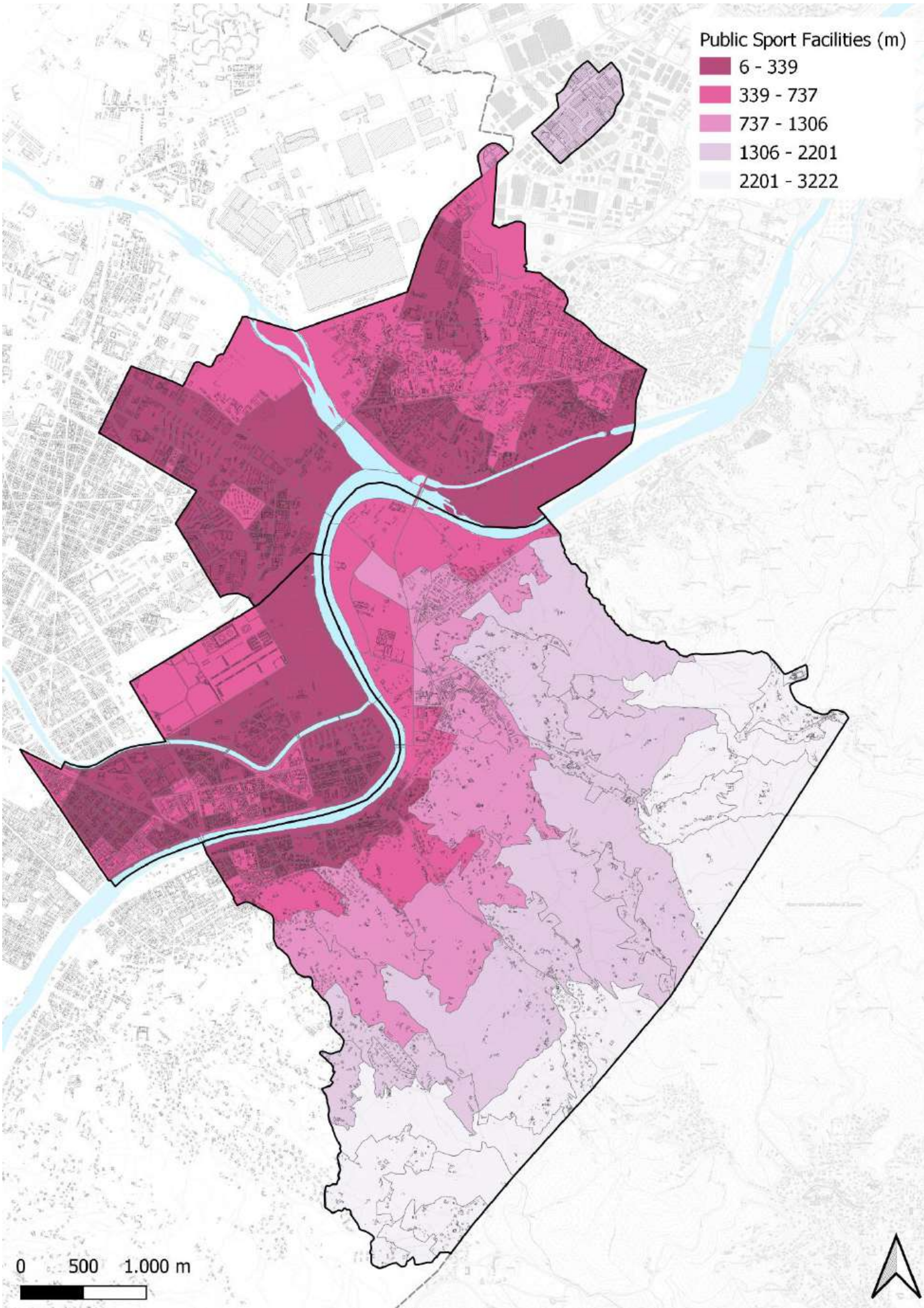

Figure 32: Spatial representation of the 'Public Sport Facilities' indicator.

4. Discussion and Conclusion

Thanks to the use of multiple mapping formats, the complexity of the territory under analysis becomes immediately evident. The proposed case study spans from densely urbanized environments to minimally anthropized areas that exemplify natural contexts, demonstrating its wide applicability in different urban and territorial contexts. The analysis of indicators (and, in some cases, indexes) directly reveals this diversity, allowing observers (regardless of their prior familiarity with the territory) to perceive the contrasts across the landscape. Indeed, numerous factors influence a territory's level of resilience. These include both internal and external factors, such as social support systems, community, as well as access to resources and opportunities.

The spatial configuration and characteristics of settlements help to highlight key aspects of resilience capacity: from the plain to the hill, from the river to the mountain, from the park to the city, the impact of human activity and natural features becomes evident through the indicators taken into consideration. Nevertheless, a significant challenge lies in the interpretation of these data. It is essential to contextualize the indicators within the territorial settings and its specific components. Equally crucial is the development of an appropriate method of interpolation, capable of synthesizing the different aspects into a coherent analytical framework. Future investigations will be necessary to combine these indicators systematically, with the objective of creating a synthetic and comprehensive representation of the territory’s capacity to absorb, adapt to, and transform in response to crisis events. Such a representation is particularly valuable for informing territorial policies and multi-level governance strategies within DRR and CCA domains. These policies can then be oriented toward optimizing interventions, prioritizing vulnerable areas, and supporting anticipatory planning to reduce risk and build long-term adaptive capacity.

This capacity can represent an aim of territorial policies to optimize interventions and other strategies, and in a feedback process, in order to enhance their resilience and better cope with adversity. This capacity should inform territorial policies and guide strategic interventions, ultimately enhancing resilience through a feedback process that aligns assessment with action. In this context, the importance of scale in resilience planning becomes evident. As Elmqvist (2014) suggests, transformations at smaller spatial scales are often necessary to sustain resilience at urban or regional levels. In our case, the downscaling of indicators within the Po River corridor in Turin illustrates how localized evaluations can uncover spatial disparities, support more targeted interventions, and contribute to overarching urban resilience objectives.The mapping methodology applied in the Turin case study provided valuable insights, mainly due to the city’s inherent characteristics, which appear predisposed to the implementation of resilience-oriented strategies. Turin benefits from a well-established service structure, morphological features that facilitate walkability, and a significant presence of green areas and infrastructure – all of which contribute to a favorable context for urban resilience initiatives. Future applications of this methodology could extend to the examination and comparison of other Italian and European contexts. Such comparative analyses would help determine whether the high scores observed in Turin are specific to its urban fabric or indicative of broader patterns typical of the Italian context as a result of national urban planning regulations. In terms of policy, the proposed methodology offers potential for operational activation by informing the selection of intervention strategies at the municipal level. It could guide the allocation of resources and facilitate the implementation of context-specific solutions, enabled through the active and informed involvement of local communities.

The Turin case study highlights the necessity of advancing multi-scalar strategies and policies for resilience planning in the Anthropocene era. At the regional level, it is essential to establish a strategic vision based on shared agreements between stakeholders and institutions. This vision should aim to empower individuals and integrate regional planning tools for climate transition and resilience into decision-making processes

(Brunetta, 2015). Concurrently, regulatory frameworks and innovative design approaches for a just and green transition must integrate local design and planning tools (Giudice, Novarina, Voghera, 2023), promoting co-design and co-management processes.

Within this framework, the case study explains that fostering territorial resilience requires new cognitive tools and interpretative methods to support decision-making that bridges strategic and local planning levels. While the district-level assessment presents certain limitations—particularly in defining large-scale policy directions—it remains effective for addressing local needs. Moreover, it offers a foundation for developing connections across different planning scales, ultimately aiming to foreground the social values and principles that underpin transformative resilience.

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