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Urban Green Regeneration: Design exploration for climate-resilient Streetscapes through NbS

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Rigenerazione Urbana *Green*: Progettare *Streetscapes* resilienti al clima attraverso NbS

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Abstract. La rigenerazione degli *streetscapes* urbani con soluzioni basate sulla natura (NbS) è cruciale per la neutralità e la resilienza climatica. Tuttavia, la *design research* è attualmente limitata e non riesce a innovare le pratiche consolidate di pianificazione e progettazione. La ricerca in corso intende contribuire a superare questi *gap*, definendo una metodologia operativa e linee guida per promuovere la rigenerazione *nature-based* e resiliente al clima degli streetscapes. L'approccio adottato è di *Research-by-Design*, articolato in tre fasi integrate: *Research of Design, Research through Design, Research for Design*. Il contributo si focalizzerà sulle prime due fasi, applicando e testando la metodologia operativa in maniera incrociata su due quartieri a Matera, Italia, e Riyad, Arabia Saudita.

Parole chiave: Resilienza Climatica; *Nature-based Solutions* (NbS); *Streetscapes*; Rigenerazione urbana; Progetto.

Introduzione

Il cambiamento climatico (CC) è un fenomeno globale con impatti profondi sulla vita urbana. Le città stanno affrontando rischi crescenti, tra cui inondazioni, siccità e ondate di calore, che esacerbano le loro vulnerabilità ecologiche, sociali ed economiche. Le città occupano meno del 3% della superficie terrestre (Lwasa *et al.,* 2022) ma contribuiscono per oltre il 70% alle emissioni globali di CO_2. Tra i maggiori responsabili della crisi climatica, devono affrontare sfide cruciali in termini di mitigazione e adattamento (World Bank Group, 2021). Con l'urbanizzazione crescente (UN DESA, 2019), molte città stanno puntando a diventare *carbon-neutral*, raggiungendo un equilibrio tra emissioni e assorbimento di CO_2 e, più in generale, *climate-neutral*, ottenendo emissioni nette pari a zero. Il Green Deal dell'Unione Europea, con la Climate Neutral and Smart Cities Mission (2021), prevede di rendere 100 città europee resilienti entro il 2030. Affrontare queste sfide implica esplorare sinergie tra neutralità climatica e strategie di mitigazione e adattamento (UNECE, 2011), con l'obiettivo di ottenere benefici ambientali, economici e sociali e migliorare la qualità degli spazi urbani. Le Nature-based Solutions (NbS), definite come azioni che affrontano simultaneamente sfide ambientali, sociali ed economiche ispirandosi ai processi naturali (Commissione Europea, 2015), offrono benefici significativi attraverso la riduzione delle emissioni di CO_2, in maniera diretta e indiretta (Cong *et al.,* 2023; Nat. Clim. Chang, 2023), e contribuiscono all'adattamento e alla resilienza (Commissione UE, 2021) agli effetti del CC.

Integrare la rigenerazione urbana verde e la resilienza climatica degli *streetscapes*

All'interno di una ricerca finanziata[1], si esplorano le intersezioni tra neutralità climatica, resilienza e NbS nell'ambito della Rigenerazione Urbana Green (RUG) degli streetscapes. La RUG, attraverso il modello della Green City (GreenCity Network, 2020) e l'implementazione di NbS, punta a ridurre le emissioni di carbonio, migliorare la resilienza climatica e la qualità degli spazi urbani, perseguendo al contempo obiettivi rigenerativi in maniera sinergica (Liu *et al.,* 2023). La ricerca si concentra sugli *streetscape*s, definiti come «the natural and built fabric of the street, and defined as

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Abstract. The regeneration of urban streetscapes through Nature-based Solutions is crucial for achieving climate neutrality and resilience. However, design research is limited to date and needs to impact current design and planning practices. Ongoing research attempts to go beyond present gaps to define an operational methodology and guidelines to mainstream streetscape's climate-resilient nature-based regeneration. The research adopts a Research-by-Design approach, structured in three integrative phases: (i) Research of Design, (ii) Research through Design, (iii) Research for Design. The contribution will go through the first two phases by applying and cross-testing the operational methodology in two neighbourhoods in Matera, Italy and Riyadh, Saudi Arabia.

Keywords: Climate resilience; Nature-based Solutions; Streetscapes; Urban regeneration; Design.

Introduction

Climate change (CC) is a global phenomenon that profoundly impacts urban life. Cities face increasing risks, including floods, droughts, and heat waves, exacerbating their ecological, social, and economic vulnerabilities. Although cities occupy less than 3% of the Earth's surface (Lwasa *et al.,* 2022), they contribute to over 70% of global CO_2 emissions. As major contributors to the climate crisis, cities must address crucial challenges related to mitigation and adaptation (World Bank Group, 2021, p. 20). With growing urbanisation (UN DESA, 2019), many cities aim to become carbon-neutral, achieving a balance between emissions and CO_2 absorption and, more generally, climate-neutral, meaning net-zero greenhouse gas emissions. The European Union's Green Deal, through the Climate Neutral and Smart Cities Mission (2021), aims to make 100 European cities climate-resilient by 2030. Addressing these challenges involves exploring synergies between climate neutrality, and mitigation-adaptation strategies (UNECE, 2011), seeking to achieve environmental, economic, and social benefits, besides improving the quality of urban spaces. Nature-based Solutions (NbS), defined as actions inspired from natural processes (European Commission, 2015), provide significant benefits by directly and indirectly reducing CO_2 emissions (Cong *et al.,* 2023; Nat. Clim. Chang, 2023). They contribute to adaptation and resilience (EU Commission, 2021) to the effects of CC.

Interweaving green urban regeneration and climate resilience streetscapes

This funded research project[1] explores intersections between climate neu-

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the design quality of the street and its visual effect [...] it includes buildings, the street surface, and also the fixtures and fittings that facilitate its use [...]» (Charwood in Rehan, 2013). Gli *streetscapes* sono risorse pubbliche diffuse e accessibili (Metha, 2019), ma spesso sottoutilizzate. Occupano, infatti, dal 15% al 30% dello spazio urbano (UN-Habitat, 2013). Le persone trascorrono da otto a dieci volte più tempo nelle strade rispetto ai parchi (Schwartz in Toomey, 2012). Per queste ragioni, sono stati elaborati framework operativi che guardano alla RUG degli *streetscapes* come opportunità di migliorare la resilienza urbana. Klemm *et al.* (2017) e Furchtlehner *et al.* (2022) hanno proposto linee guida per rafforzare le infrastrutture verdi urbane attraverso la rigenerazione *nature-based*. Cabanek *et al.* (2020) hanno creato un framework di progettazione biofilica applicato a sezioni stradali prototipiche. Tamminga *et al.* (2020) hanno definito un quadro conoscitivo per migliorare la resilienza climatica attraverso l'implementazione di NbS negli *streetscapes*; Chanse *et al.* (2021) hanno sviluppato un framework operativo per strade adattive al clima, attraverso proposte progettuali speculative di rigenerazione *nature-based*. Macaione *et al.* (2024) hanno elaborato un framework operativo alla scala di quartiere rivolto agli streetscape della città mediterranea. Città come Copenaghen, Barcellona, New York, Los Angeles, Melbourne e Toronto stanno rigenerando i loro *streetscapes* attraverso sperimentazioni che implementano strategie e azioni alla scala di quartiere per diventare *climate-neutral* and *climate-resilient*.

Gaps di ricerca

Nonostante diverse prospettive e discipline abbiano esaminato le relazioni tra rigenerazione degli *streetscapes*, NbS e resilienza climatica, emergono significativi *gap* di ricerca, soprattutto dal punto di vista della progettazione architettonico-urbana. Un primo *gap*, teorico-critico, con rilevanti implicazioni operative, riguarda il modo in cui oggi si guarda allo spazio della strada. La forma della strada è indissolubilmente legata a quella della città; interrogarsi sulla RUG della strada come problema urbano significa ridefinire il rapporto tra architettura e città (Secchi and Bochicchio, 2020) e natura. Riallacciandosi alla tradizione di studi sulla strada come spazio collettivo (Anderson, 1978; Rudofsky, 1969) e con l'intento di "restituire la strada al regno dell'architettura" (Gregotti, 1989), la ricerca si interroga su cosa sia uno *streetscape nature-based* e resiliente al clima, e sulle implicazioni spaziali nel supportare strategie di resilienza e neutralità climatica. Un secondo *gap* riguarda la ricerca *design-oriented*, piuttosto limitata nonostante la sua natura transdisciplinare e olistica possa affrontare meglio degli approcci prestazionali e settoriali correnti la complessità della RUG degli *streetscapes*. Questo *gap* si manifesta anche come una carenza di conoscenze riguardanti i principi di progettazione, le procedure e le metodologie operative, generalizzabili e replicabili, essenziali per il progresso e la trasformazione delle pratiche progettuali contemporanee.

Metodologia di ricerca

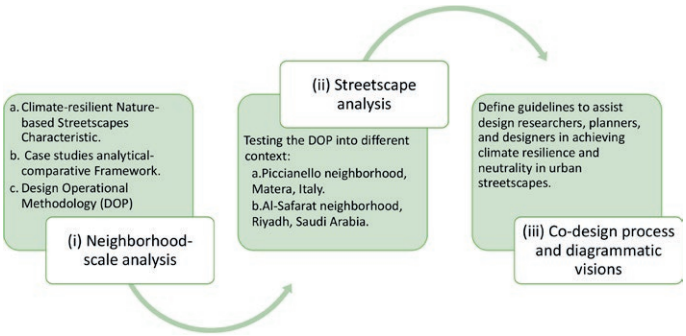
A partire dai *gap* individuati, la ricerca adotta un approccio di "*Research-by-Design*" (Hauberg, 2011); inoltre, riconosce come cruciale la dimensione transdisciplinare (Doucet and Janssens, 2023) dell'architettura e le sue "*designerly way of knowing*" (Cross, 2001; Findeli, 1999), nonché la complementarità tra ricerca transdisciplinare e disciplinare (Nicolescu, 2002, p. 45).

trality, resilience, and Nature-based Solutions (NbS) within the context of Green Urban Regeneration (GUR) of streetscapes. Through the Green City model (GreenCity Network, 2020) and the implementation of NbS, GUR aims to reduce carbon emissions, enhance climate resilience, and improve the quality of urban spaces, while synergistically pursuing other regenerative goals (Liu *et al.,* 2023). The research focuses on streetscapes, defined as «the natural and built fabric of the street, and the design quality of the street and its visual effect [...] it includes buildings, the street surface, and also the fixtures and fittings that facilitate its use [...]» (Charwood in Rehan, 2013). Streetscapes are widely accessible public resources (Metha, 2019), yet they are often underutilised. They occupy between 15% to 30% of urban space (UN-Habitat, 2013), and people spend eight to ten times more time in streets than in parks (Schwartz in Toomey, 2012). Operational frameworks have thus been developed to view GUR of streetscapes as an opportunity to enhance urban resilience. Klemm *et al.* (2017) and Furchtlehner *et al.* (2022) proposed guidelines to strengthen urban green infrastructure through nature-based regeneration. Cabanek *et al.* (2020) created a biophilic design framework for prototypical street sections. Tamminga *et al.* (2020) defined a knowledge framework for enhancing climate resilience by implementing NbS in streetscapes. Chanse *et al.* (2021) developed an operational framework for climate-adaptive streets through speculative design proposals for nature-based regeneration. Macaione *et al.* (2024) created an operational framework at the neighbourhood scale focused on streetscapes in Mediterranean cities. Cities such as Copenhagen, Barcelona, New York, Los Angeles, Melbourne, and Toronto, are regenerating their streetscapes through urban experiments that implement nature-based strategies and solutions at the neighbourhood scale to improve climate neutrality and resilience.

Research gaps and questions

Despite various perspectives and disciplines examining the relationships between streetscape regeneration, NbS, and climate resilience, significant research gaps have emerged, especially from urban and architectural design. A primary theoretical-critical gap, with significant operational implications, concerns the current perspective of street space. The form of the street is inextricably linked to that of the city; hence, examining GUR of streets as an urban issue entails redefining the relationship between architecture, the city (Secchi and Bochicchio, 2020), and nature. Building on the tradition of studies on streets as collective spaces (Anderson, 1978; Rudofsky, 1969), and with the goal of "returning the street to the realm of architecture" (Gregotti, 1989), this research explores what constitutes a climate-resilient, nature-based streetscape, along with the spatial implications of supporting resilience and climate neutrality strategies. A second gap relates to design-oriented research, which remains limited despite its transdisciplinary and holistic nature. It could address the complexity of GUR for streetscapes more effectively than current performance-based and sectoral approaches. This gap also manifests as a deficiency in knowledge concerning design principles, procedures, and operational

01 | Diagramma della metodologia della ricerca, elaborazione degli Autori
Methodological phase diagram, Authors' elaboration



La ricerca adotta una metodologia "*design-as-search*" (Nijhuis and Bobbink, 2012), strutturata in tre fasi integrate (Fig. 1):
- *Research of Design*: mira a definire che cosa sia uno *streetscape* nature-based e climatico- resiliente ed una metodologia operativa space-based per la sua rigenerazione, replicabile in diversi contesti urbani alla scala di quartiere;
- *Research through Design*: tratta la metodologia operativa come ipotesi da verificare e affinare tramite l'applicazione in diversi contesti a scala di quartiere. Progettazione e ricerca si intrecciano, generando conoscenza attraverso il processo progettuale stesso;
- *Research for Design*: si propone di elaborare linee guida per promuovere resilienza e neutralità climatica nella rigenerazione urbana *nature-based* degli *streetscapes* attraverso un approccio fondato sulla modificazione dello spazio.

Il metodo iterativo consente di affinare progressivamente la metodologia, trasformandola in linee guida concrete. La scala di quartiere è stata scelta per la sua capacità di connettere ambienti urbani di diverse dimensioni e gestire la complessità. L'applicazione della metodologia operativa su due contesti, consentirà di sviluppare riflessioni e orientare futuri sviluppi.

Research of Design

Caratteristiche degli Streetscape nature-based resilienti al clima

Con l'obiettivo di definire cosa sia uno *streetscape nature-based* e resiliente al clima, a partire da una literature review nell'ambito della *design research* condotta attraverso articoli accademici (databases: Scopus, Web of Science, Google Scholar) e documenti e report di pianificazione e progettazione urbana, è stata sviluppata una tassonomia di caratteristiche, organizzate per tematiche (Tab. 1). Tali caratteristiche sono state utilizzate per valutare sia i casi studio selezionati sia, durante la fase di *Research through Design*, per esaminare le trasformazioni previste.

Quadro analitico-comparativo dei casi studio

Circa 40 casi studio tra città dell'UE e degli US (Macaione *et al.* 2024), all'avanguardia nella rigenerazione *nature-based* e resiliente al clima, sono stati selezionati, analizzati e confrontati (Tab. 2). Per quanto riguarda i criteri specifici, i progetti selezionati sono stati analizzati per comprendere: (a) le vulnerabilità pre-intervento; (b) le strategie progettuali adottate, (c) quali NbS sono state implementate, quali i benefici previsti/ottenuti e i processi ecologici attivati; (d) le azioni e i dispositivi spaziali messi in campo; (e) il processo progettuale, attraverso i suoi principi, metodi e procedure. La raccolta di casi studio ha fornito una conoscenza approfondita sul fenomeno della rigenerazione nature-based degli *streetscapes* urbani, individuando tendenze e prospettive future. Inoltre, la tassonomia dei casi studio servirà anche come catalogo di best practices e sarà parte delle linee guida finali della ricerca.

Definizione preliminare della Metodologia Operativa

A partire dal confronto tra processi progettuali dei casi studio analizzati e da una literature review specifica dedicata ai framework progettuali, è stata definita, in via preliminare, una me-

methodologies that are generalisable, replicable and crucial for advancing and transforming contemporary design practices.

Research methodology

Based on the identified gaps, the research adopts a "Research-by-Design" approach (Hauberg, 2011). Moreover, it recognises the crucial transdisciplinary dimension (Doucet and Janssens, 2023) of architecture and its "designerly ways of knowing" (Cross, 2001; Findeli, 1999), as well as the complementarity between transdisciplinary and disciplinary research (Nicolescu, 2002). The research employs a "design-as-search" methodology (Nijhuis and Bobbink, 2012), structured in three integrated phases (Fig. 1):
- Research of Design: aims to define what constitutes a nature-based and climate-resilient streetscape, as well as a space-based operational methodology for its regeneration, replicable in various urban contexts at the neighbourhood scale;
- Research through Design: treats the operational methodology as a hypothesis to be tested and refined through its application in various neighbourhood-scale contexts. Here, design and research are closely intertwined, generating knowledge through the design process itself;
- Research for Design: seeks to develop guidelines to promote resilience and climate neutrality in the nature-based urban regeneration of streetscapes through a space-modification approach.

The iterative method allows for the progressive refinement of the operational methodology, ultimately transforming it into actionable guidelines. The neighbourhood scale has been chosen for its ability to connect urban environments of varying sizes and manage complexity. The application of the operational methodology in two contexts will enable the development of insights and guide future developments.

Research on design

Characteristics of nature-based and climate-resilient Streetscapes

With the aim of defining what constitutes a nature-based and climate-resilient streetscape, a taxonomy of characteristics was developed based on a literature review within the field of design research. The research was conducted on academic articles (databases: Scopus, Web of Science, Google Scholar) and urban planning and design documents and reports. Organised into thematic areas (Tab. 1), these characteristics were used to evaluate both the selected case studies and, during the Research through Design phase, to examine the proposed transformations.

Analytical-comparative framework of case studies

About 40 case studies from EU and US cities (Macaione *et al.,* 2024), at the forefront of nature-based and climate-resilient regeneration, were selected, analysed, and compared (Tab. 2). Regarding specific criteria, the selected projects were analysed to understand: (a) pre-intervention vulnerabilities; (b) the design strategies adopted; (c) which NbSs were implemented, the expected/achieved benefits, and the ecological processes activated; (d) the spatial actions and devices employed; (e) the design process, through its principles, methods, and procedures. This

Tab. 01 | Caratteristiche degli Streetscapes resilienti al clima e Nature-based, elaborazione di A. Raffa
Climate-resilient Nature-based Streetscape Characteristics, elaboration by A. Raffa

Tab. 02 | Framework analitico-comparativo dei casi studio, elaborazione di A. Raffa
The analytical-comparative framework of case studies, elaboration by A. Raffa

Tab. 01 |

Themes	Characteristic
Ecology & Biodiversity	Ecological connectivity; Green Infrastructure & NbS; Vegetation layering; Native vegetation; Wildlife habitat; Soil and water quality
Climate	Stormwater management; Flooding Mitigation; Heat Mitigation; Drought resistance; Extremes Preparedness; Carbon Storage and Sequestration
Mobility	Slow mobility; Public Multi-modality; Sustainable Mobility
Wellbeing & Health	Accessibility; Active transportation; Air quality; Noise reduction; Social Interaction & Cohesion; Experience
Social Equity & Inclusivity	Accessibility; Safety & Security; Social Equity; Cultural Sensitivity; Program; Empowerment
Energy & Smart	Reduce consumption; Energy efficiency; Smart Infrastructure; Smart Monitoring
Value Creation	Property Value Enhancement; Economic Development; Tourism & Recreation; Green Economy

Tab. 02 |

1. Case studies Selected criteria	Definition Criteria
Urban Regeneration	Regeneration of abandoned, underused or in use infrastructural spaces
Climate-Resilient Green Solutions	Implement NbS and Green Infrastructure to adapt and mitigate to climate change effects
Sustainable Urban Planning initiatives	Developed in cities whit consistent planning initiatives concerning Climate resilience and neutrality, Nature-based and Green Infrastructures initiatives
21st Century Development	Developed after 2000, both built and unbuilt
EU and US Projects	Developed in US and EU
Award / Relevance	Design by relevant design firm, competition winning proposal or grant recipients
2. Case studies Analytical criteria	**Definition Criteria**
2.1. General Criteria	
Location	Type: Coastal, Delta, River, Mountain (World Bank, 2021)
Climate	Climate: A (tropical), B (arid), C (temperate), D (continental) (Köppen classification)
	Climate hazards: Heat, Flood, Drought; Wind
Grey Infrastructure	Shape: Linear, Network, Radial, Grid Extension
Planning	Relevant City Planning initiative
Design	Design Firm
2.2. Specific Criteria	
Vulnerabilities	Valued through Themes and Characteristics
Strategies	Valued through Themes and Characteristics
Nature based Solutions	Family &Technique
(World Bank, 2021)	Benefits
	Process
Nature-based	Spatial Action
Space solutions	Spatial Dispositive
Design Process	Features:
	Interdisciplinary; Multi-Scalarity; Multi-Temporality; Multi-Stakeholder Collaboration; Context Sensitivity
	Methods
3. Case studies Comparative criteria	**Definition Criteria**
	Climate: Climate, Climate Hazards
	Grey Infrastructure: Shape, Extension
	Vulnerabilities & Strategies
	Nature based Solutions: Family & Techniques
	Nature-based Space Solutions: Spatial Action, Spatial Dispositive
	Design Process: Features

phase provided in-depth knowledge on the phenomenon of nature-based regeneration of urban streetscapes, identifying current trends and future perspectives. Additionally, the taxonomy of case studies will serve as a catalogue of best practices, and will be part of the final research guidelines.

Operational methodology

Based on the comparison of design processes from the analysed case studies and a specific literature review focused on design frameworks, a preliminary operational methodology was defined, structured in three stages (Tab. 3). The methodology, in particu-

Tab. 03| Metodologia operativa di progetto, elaborazione di A. Raffa
Design Operational Methodology, elaboration by A. Raffa

todologia operativa articolata in tre momenti (Tab. 3). La metodologia, in particolare, è stata informata dal lavoro condotto per gli *streetscapes* di Los Angeles (UFEC, 2021) e Groningen (Felixx, Groningen Municipality, 2021), in cui il contributo dell'approccio architettonico-urbano alla trasformazione è cruciale.

Tra *Research through e for Design*

La metodologia operativa è stata sperimentata a Piccianello, Matera (Italia), e ad Al Safarat, Riyadh (Arabia Saudita), rivelando le loro differenze climatiche, morfologiche, di distribuzione del verde nei loro *streetscapes* (Tab. 4). Piccianello, sviluppatosi per fasi successive, alterna episodi di qualità architettonica, come il quartiere moderno di Spine Bianche (Aymonino e altri, 1954-59) (Fig. 3), ad espansioni recenti con carenze di verde e qualità urbana. Al Safarat (Speer, 1978-82), invece, nasce da un progetto unitario post-moderno che reinterpreta la tradizione architettonica locale dentro ad un disegno urbano di quartiere giardino europeo (Fig. 4). Entrambi i loro *streetscapes* sono vulnerabili al cambiamento climatico; in particolare, le proiezioni climatologiche indicano

| Tab. 03

Climate-resilient Nature-based Streetscape Design Operational methodology	
1_Neighborhood-scale Analysis and Priority Areas	
Mapping analysis	GIS-based Mapping to explore the entanglements between climate stress, carbon emissions, ecological and mobility patterns in relation to streets infrastructure
Climate Stress	Heat maps; Flood maps; Wind maps (both to date and projections)
Carbon Emission	Carbon Dioxide emission maps, per business days and seasonal
Ecological patterns	Ecological connectivity; Green Infrastructure & NbS; Green space and social inequalities/vulnerabilities
Street infrastructure	Street Typological characterization and related impervious surfaces
Flow analysis	Slow Mobility; Public Multi-modality; Sustainable Mobility; Security
People's Understanding	Understand values people address to the street infrastructure inside the neighborhood
Vulnerability & Opportunities	Identify present and future vulnerabilities and potential opportunities for streetscape climate resilient nature-based regeneration at the neighborhood scale level
Prioritization I	Space-based prioritization for interventions (areas)
Neighborhood area	Mapping + Vulnerability & Opportunities analysis and Community meeting with local residents and stakeholders
2_Streetscape-scale Analysis and Generative Sections	
3D Street Analysis	Characterize street space according to its morphology, green features, gray infrastructures, uses and flows, people perception
Morphological	Street's dimension; building density and façade; design; materials; urban furnishing
Green Features	NbS, Tree Canopy and green spaces health
Grey infrastructure	Sewage, irrigation, lightning systems
Uses and Flows	Usability for pedestrians and public uses patterns
People's Perception & Understanding	Consider residents' perception concerning street space quality and use local knowledge to understand fragilities, needs and expectations Community meeting with local residents and stakeholders
Vulnerabilities & Opportunities (Transect Analysis)	Integrating street characterization and residents' perception and knowledge to have a more comprehensive understanding of vulnerabilities and opportunities at the street scale level
Prioritization II	Space-based prioritization for interventions (streets)
Generative Sections (one per typology)	3D Street Analysis+ Vulnerability & Opportunities Transect analysis and Community meeting with local residents and stakeholders
3_Co-Design	
Diagrammatic street sections	Through a holistic and multi-disciplinary design approach define alternative diagrams for each generative section which implements NbS Families and Techniques, according to different time scale (2050 and 2100)
Diagrammatic street Assessment	Assess diagrammatic sections design outputs according to parameters and Sub-parameters from Tab. 01, their possible benefits compared to present condition
Final diagrammatic street layout	Define a final diagrammatic street layout, through an interactive and well-rounded community engagement process
Three Tier Method	Decompose the layout according to the Three Tier method. The approach involves breaking down the intervention into phases based on complexity, economic feasibility, and levels of community participation

Tab. 04| Confronto tra i casi studio, elaborazione di A. Raffa
Comparison between case studies, elaboration by A. Raffa

Tab. 04 |

Applicational Case studies	**Piccianello**	**Al-Safarat**
Neighborhood		
Location	Matera	Riyadh
Climate (Coppen classification)	Cfa (C-Temperate, f-No dry season, a-Hot summer)	BWh (B-Dry, w-Arid desert, h-Hot)
Grey Infrastructure Typology	Network, Radial	Network, Radial
Road and Streets	37,8%	16,6 %
Green and public spaces (ratio)	22,0%	30,9%
Planning Framework (climate & resilience)	Sustainable Urban Mobility Plan (2022)	Green Riyadh Project (2019); Riyadh Sustainability (2021)
Dates	From 1900 Spine Bianche neigh. 1954-1959	1978-1982
Streetscape		
Vulnerabilities		
Climatic	Flooding; heatwaves; Heat island effect; drought; wind	Flooding; heatwaves; Heat island effect; drought; wind
Ecological	Lack of ecological connectivity; Biodiversity loss; Soil & water pollution; lack of vegetation	Biodiversity loss; Soil & water pollution
Mobility	Lack of slow mobility; lack of multimodality; lack of sustainable mobility	Lack of slow mobility; lack of multimodality
Wellbeing & Health	Lack of accessibility to green areas & public space; lack of Active mobility; Air, Noise, light pollution; lack of Social Interaction & Cohesion; lack of experience	Lack of Active transportation; Air, Noise, light pollution; lack of experience
Social Equity & Inclusivity	Lack of Safety & Security; lack of social equity; unequal green space distribution; lack of programming	Lack of social equity; lack of empowerment; gentrification
Energy & Smart	High energetic consumption; lack of efficiency; lack of smart infrastructure & monitoring	Lack of adoption of renewable energy sources; lack of efficiency; insufficient monitoring
Value Creation	Lack of commercial activities	Tourism & Recreation; Green Economy
Nature-based solutions		
Techniques (existing)		
	Pocket parks; Natural Playgrounds; Street Treen canopies; Green avenues	Ecological forest corridors; Pocket parks; Natural Playgrounds; Street tree canopies; Green avenues; Permeable pavements

lar, was informed by the work carried out for the streetscapes of Los Angeles (UFEC, 2021) and Groningen (Felixx, Groningen Municipality, 2021), where the contribution of the architectural-urban approach to transformation is crucial.

Research through and for design

The Operational Methodology was tested in Piccianello, Matera (Italy), and Al Safarat, Riyadh (Saudi Arabia), revealing the climatic, morphological, and green space distribution differences within their streetscapes (Tab. 4). Piccianello, developed in successive phases, alternates episodes of architectural quality, such as the modern neighbourhood of Spine Bianche (Aymonino *et al.,* 1954-59) (Fig. 3), with more recent expansions characterised by a lack of green space and urban quality. In contrast, Al Safarat (Speer, 1978-82) emerged from a unified postmodern design that reinterprets local architectural traditions within a European garden-like neighbourhood urban layout (Fig. 4). Both of their streetscapes are vulnerable to climate change; specifically, climatological projections suggest that Piccianello will experience future conditions similar to the current ones in Al Safarat.

Discussion

Addressing data availability challenges

The regeneration of streetscapes often encounters challenges due to the lack of detailed data for neighbbourhood-scale mapping. Information on climate, carbon emissions, and vegetation cover is frequently fragmented or only available at broader scales. To overcome these limitations, researchers should integrate technologies such as remote sensing, satellite imagery, and citizen science, capitalising on residents' observations regarding microclimates and local issues. Participatory workshops can complement qualitative and quantitative data, improving mapping efforts and the identification of local vulnerabilities.

Perception and public engagement

The transition to multifunctional streetscapes requires considering community perceptions. While people in Al Safarat perceive the streets as monofunctional (Chaiechi *et al.* 2022; Katar 2022; Sultan *et al.* 2021), Piccianello shows greater variety in the use of spaces. Communication strategies tailored to the local context, including visual tools such as model and infographics, can help raise community awareness about the benefits of NbS, such as flood risk reduction and enhanced biodiversity. In vulnerable neighbourhoods like Piccianello, designers should focus on the immediate benefits of NbS within long-term strategies. In areas like Al Safarat, where there is greater climate awareness, designers should emphasise how transformations in streetscapes can promote long-lasting resilience (Moscatelli and Raffa, 2023).

Implementing inclusive and collaborative co-design processes

Co-design is crucial in reconciling diverse interests and creating shared visions in the RUG of streetscape. Workshops and public forums, supported by visual tools such as models and maps, facilitate dialogue between citizens, experts, and authorities. The collaborative decision-making process focused on defining action priorities in alignment with local

02 | Quartiere Piccianello (sopra) e Al Safarat (sotto). Aree verdi e copertura arborea, sistema infrastrutturale e mappa termica, elaborazione di A. Raffa e M. Moscatelli
Piccianello neighbbourhood (top) and Al Safarat (bottom). Green areas and tree canopy, infrastructural system and heat map, elaboration by A. Raffa and M. Moscatelli



needs, integrating feedback to refine proposals continuously. This flexible approach ensured ongoing community engagement, keeping the project responsive to evolving circumstances and needs.

Developing adaptive and context-sensitive design solutions

Adaptive design solutions must balance immediate needs with long-term sustainability, prioritising quick improvements for vulnerable communities within long-term visions. Adopting flexible and modular approaches facilitates gradual implementation, supported by pilot projects that highlight the benefits of NbS. Integrating NbS into broader urban resilience strategies is essential, focusing on public health, energy efficiency, and social inclusion, ensuring alignment with urban goals through multisectoral collaborations.

Conclusions: Limitations and further developments

The RUG of streetscapes aims to create urban environments capable of adapting to the effects of climate change, reducing carbon emissions, and enhancing resilience, including climate resilience. This approach integrates natural processes into architectural and urban design, addressing CC-related risks to generate multi-level benefits, including improving the quality of urban spaces. From a design perspective, this means redefining the relationship between streets, cities, and natural elements, innovating established practices, and overcoming sector-specific technical approaches. Knowledge of local contexts, robust data collection, inclusive co-design processes, and adaptive solutions are essential for an effective RUG of streets. However, neighbourhood-level interventions may need to address the complexity of broader urban networks fully. Research experiments demonstrate the importance of spatial dimension, not only in terms of outcomes but also regarding the process itself. In the future, with many pilot experiments across various contexts, it will be possible to refine the operational methodology and support its replicability. Once this phase is complete, researchers will develop design guidelines for nature-based and climate-resilient streetscape regeneration to help cities achieve climate neutrality and resilience goals while improving spatial quality.

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A. Raffa: parr.: Intertwining green..., Research Gaps..., Research Methodology, Research of..., Between Research...; M. Moscatelli: par: Discussion. A. Raffa and M. Moscatelli: Introduction, Conclusion. A. Raffa contribution comes from the research activity inside the project Urban Green Shape (2022-2025), funded by PON R&I and FSE-REACT-EU, Axis IV – Action IV.4 and Action IV.6; Contract number 38-G-14879-1, CUP C49J2104334000, Sc. Res. I. Macaione. Research group: NatureCityLAB, I. Macaione, B, Andaloro. M. Moscatelli collaborated to test and verify the operational methodology on the Saudi case and thanks the SA Lab and the PSU for supporting the publication.

NOTES

[1] Urban Green Shape (2022-2025), founded by PON R&I and FSE-REACT EU, Axis IV – Action IV.4 and Action IV.6, contract number: 38-G-14879-1, CUP C49J2104334000, Res. sc. I. Macaione.

03 | Piccianello. Sezione diagrammatica con Nbs, processi e benefici, elaborazione di A. Raffa. Le icone utilizzate sono tratte da World Bank 2021
Piccianello. A diagrammatic section with Nbs, process and benefits, elaboration by A. Raffa. The icons used are taken from World Bank 2021

che Piccianello in futuro sperimenterà condizioni analoghe a quelle attuali di Al Safarat.

Discussione

A partire dall'applicazione comparata della metodologia operativa nei due contesti selezionati, sono emersi limiti e possibilità che hanno contribuito ad un suo affinamento in vista di future sperimentazioni progettuali e che verranno di seguito discussi.

Affrontare la sfida della disponibilità di dati
La rigenerazione degli *streetscapes* si scontra spesso con la mancanza di dati dettagliati per mappature a scala di quartiere. Informazioni su clima, emissioni di carbonio e copertura vegetale spesso risultano frammentate o disponibili solo su scale più ampie. Per superate tali limiti, è necessario combinare tecnologie come il *remote-sensing*, immagini satellitari e la *citizen science*, valorizzando le osservazioni dei residenti su microclimi e criticità locali. Workshop partecipativi possono integrare dati qualitativi e quantitativi, migliorando la mappatura e l'identificazione delle vulnerabilità locali.

Percezione e coinvolgimento pubblico
La transizione verso *streetscapes* multifunzionali richiede di considerare le percezioni della comunità. Mentre ad Al Safarat le strade sono viste come monofunzionali (Chaiechi *et al.* 2022; Katar 2022; Sultan *et al.* 2021), Piccianello mostra maggiore varietà nell'uso dei loro spazi. Strategie comunicative adattate al contesto locale, che includano strumenti visivi come modelli e infografiche, possono sensibilizzare le comunità sui benefici delle NbS, come la riduzione del rischio di inondazioni e il potenziamento della biodiversità. In quartieri vulnerabili come Piccianello è fondamentale che i progettisti si concentrino sui benefici immediati delle NbS all'interno di strategie a lungo termine. In ambiti come Al Safarat caratterizzati da maggiore consapevolezza climatica, l'accento deve essere posto su come le trasformazioni negli *streetscapes* possano promuovere una resilienza duratura (Moscatelli and Raffa, 2023).

Implementare processi di co-design inclusivi e collaborativi
Il co-design è fondamentale per conciliare interessi diversi e creare visioni condivise nella RUG degli *streetscapes*. Workshop e forum pubblici, supportati da strumenti visivi come modelli

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04 | Al Safarat. Sezione diagrammatica con Nbs, processi e benefici, elaborazione degli Autori. Le icone utilizzate sono tratte da World Bank 2021
Al Safarat. A diagrammatic section with Nbs, process and benefits, Authors' elaboration. The icons used are taken from World Bank 2021

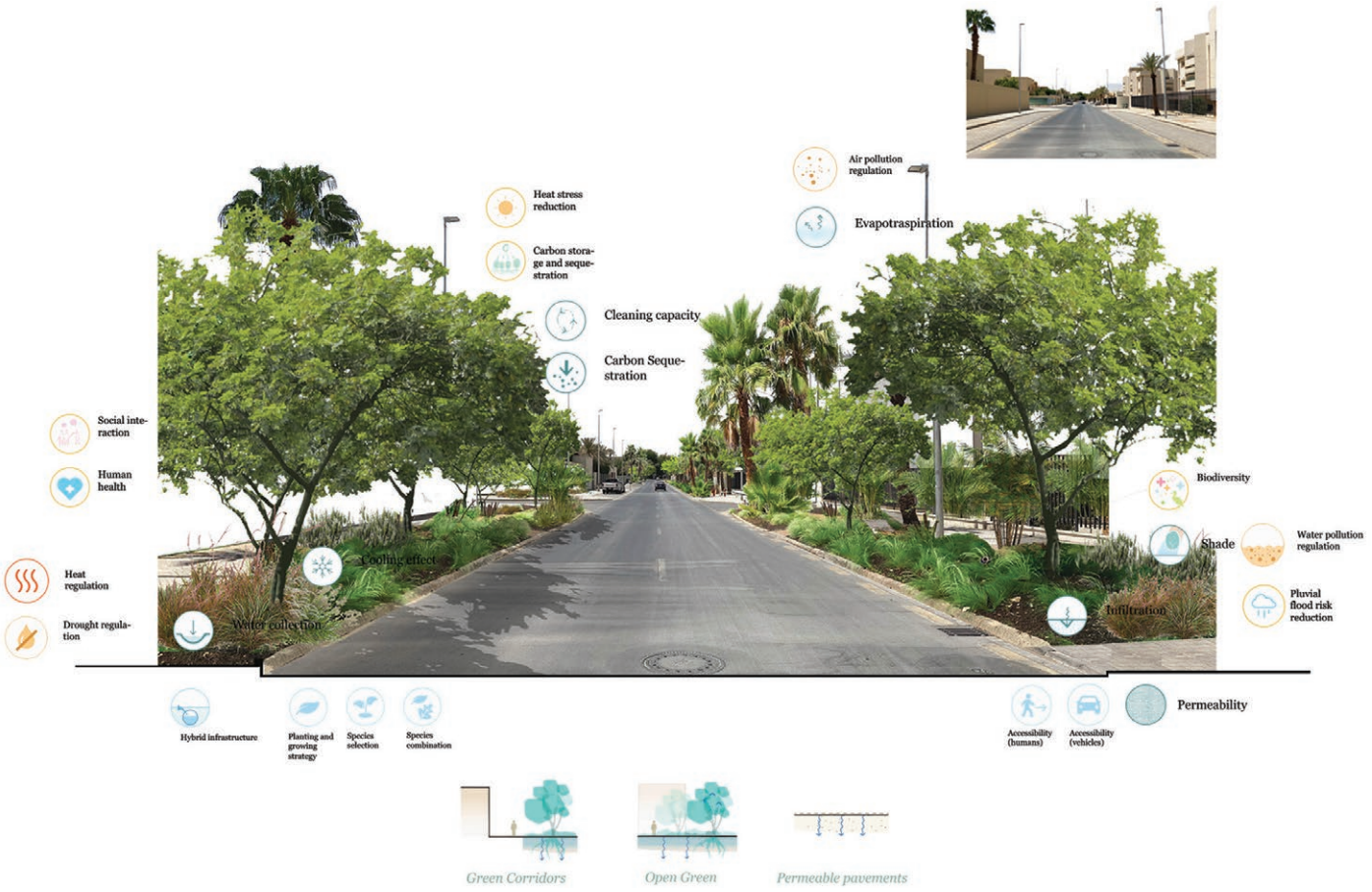
e mappe, facilitano il dialogo tra cittadini, esperti e autorità. Il processo decisionale collaborativo si è focalizzato sulla definizione delle priorità delle azioni in accordo con le esigenze locali, integrando feedbacks per un costante affinamento delle proposte. Quest approccio flessibile ha garantito un coinvolgimento continuo della comunità, mantenendo il progetto reattivo alle circostanze e alle necessità in evoluzione.

Sviluppare soluzioni di design adattive e sensibili al contesto
Le soluzioni di progettazione adattiva devono bilanciare le esigenze immediate con la sostenibilità a lungo termine, privilegiando miglioramenti rapidi per le comunità vulnerabili all'interno di visioni di lungo periodo. L'adozione di approcci flessibili e modulari facilita un'implementazione graduale, supportata da progetti pilota che evidenziano i benefici delle NbS. È essenziale integrare le NbS in strategie di resilienza urbana ampie, orientate a salute pubblica, efficienza energetica e inclusione sociale, garantendo l'allineamento con obiettivi urbani attraverso collaborazioni multisettoriali.

Conclusioni: limitazioni e sviluppi futuri

La RUG degli *streetscapes* intende realizzare ambienti urbani capaci di adattarsi agli effetti del CC, ridurre le emissioni di carbonio e migliorare la resilienza, anche climatica. Questo approccio integra processi naturali nella progettazione architettonico-urbana, affrontando i rischi legati al CC, con l'obiettivo di generare benefici multi-livello, compreso migliorare la qualità degli spazi urbani. Dal punto di vista progettuale, ciò significa ridefinire il rapporto tra strada, città ed elemento naturale, innovando pratiche consolidate e superando approcci tecnici settoriali. Per una RUG efficace delle strade sono fondamentali la conoscenza dei contesti locali, una solida raccolta di dati, processi inclusivi di co-progettazione e soluzioni adattive. Tuttavia, gli interventi a livello di quartiere potrebbero non considerare la complessità delle reti urbane più ampie. Le sperimentazioni di ricerca condotte mostrano l'importanza della dimensione spaziale, non solo rispetto all'esito ma anche riguardo al processo stesso. In futuro, con un numero significativo di sperimentazioni-campione in diversi contesti,

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sarà possibile precisare la metodologia operativa e sostenere la sua replicabilità. Una volta conclusa questa fase, verranno elaborate linee guida progettuali per la rigenerazione *nature-based* e climatico-resiliente degli *streetscapes* per supportare le città nel raggiungimento degli obiettivi di neutralità e resilienza climatica, simultaneamente al miglioramento della qualità spaziale.

ATTRIBUZIONE, RICONOSCIMENTI, DIRITTI D'AUTORE

A. Raffa: parr.: Integrare la …, Gap e …, Metodologia…, Research of …, Tra Research through…; M. Moscatelli: parr. Discussione…; A. Raffa e M. Moscatelli: Introduzione, Conclusioni. Il contributo di A. Raffa deriva dall'attività di ricerca condotta nel progetto Urban Green Shape (2022-2025), finanziato su fondi PON R&I e FSE-REACT EU, Asse IV – Azione IV.4 e Azione IV.6, numero contratto: 38-G-14879-1, CUP C49J2104334000, Res. sc. I. Macaione. Gruppo di ricerca: NatureCityLAB, I. Macaione, B. Andaloro. M. Moscatelli ha collaborato ad applicare e testare la metodologia operativa sul caso saudita e ringrazia il SA Lab e la PSU per il supporto alla pubblicazione.

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