Sustainable Urban Regeneration: Integrating Green Infrastructures and Nature-Based Solutions in Altamura

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Abstract. The integration of green infrastructures into urban planning has the potential to create more resilient and livable cities. This paper intends to present a co-programming path that has seen professionals and non-profit organizations collaborating with the Municipality of Altamura (Italy) in the development of planning tools and urban interventions based on the creation of new public spaces through the strategic use of NbS. It explores the concept of the "new public city" which prioritizes the creation of public spaces and green infrastructures as a means to improve the social and environmental sustainability of the urban environment.

A critical analysis, aimed at detecting the imprinting and the strategic role that empty spaces have assumed in defining urban settlements, is carried out, starting from a reconsideration of its known "claustri" in the historical city center. Is highlighted how this urban imprinting has been pivotal in the drafting of recent planning tools aiming to activate resilience-based urban regeneration (UR) processes in periurban areas. Afterwards, the green infrastructure's pilot project "IxE-CO^2", today under construction within the recent Parco San Giuliano suburban district, is presented and analyzed.

Finally, methodological aspects, challenges and opportunities are deduced from the planning tools and the pilot case.

Keywords: green infrastructures, urban regeneration, public city, nature-based solutions, urban resilience.

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1 Introduction

Cities are encountering escalating challenges due to climate change, population growth, and urbanization. These challenges can have significant impacts on the social and environmental sustainability of urban environments, making it important to find ways to improve the resilience of cities. One approach to enhancing the resilience of cities is through the integration of green infrastructures into urban planning. According to the "Reconciliation Urban Ecology" theory [1], green infrastructures will reduce the impact of the priority habitats' subtraction, particularly threatened by anthropic development. The concept of green infrastructure (GI) is defined as an interconnected network of green space maintaining natural ecosystem values and functions and providing associated benefits to humans.

Consequently, GI fosters improved connectivity between natural environments surrounding urbanized areas, reducing habitat fragmentation. This interconnectedness yields benefits on both environmental and social scales, contributing to ecosystem restoration and enhancing social welfare. Importantly, green infrastructure plays a vital role in mitigation policies aimed at reducing the loss of priority habitats.

Green infrastructure can be conceptualized as a strategic planning approach. In contrast, the concept of Nature-based Solutions (NbS) zeroes in on addressing problems and challenges of both environmental and social natures. NbS integrates the functional approach and design concepts of green infrastructure but tailors them to the unique and specific needs of cities [2]. In essence, NbS can be defined as dynamic solutions inspired and supported by nature. These solutions are not only cost-effective but also deliver simultaneous environmental, social, and economic benefits. They play a crucial role in enhancing resilience and aiding adaptation to climate change [3].

While both Green Infrastructure and NbS themes concentrate on utilizing specific types of green spaces to tackle distinct sustainability challenges, Green Infrastructure places a primary emphasis on a planning perspective. On the other hand, NbS represents a broader concept that encompasses a wide array of ecosystem services [4], with a primary focus on biodiversity conservation.

This paper aims to underscore the significance and potential of green infrastructures and Nature-based Solutions (NbS) within the framework of urban regeneration policies and processes in the city of Altamura, situated in the Bari metropolitan area. The reflection is initiated through an analysis of the built environment's morphology and an examination of recent urban planning and programming tools implemented by the public administration. Central to this exploration is the concept of a "new public city" which proves pivotal in understanding the integration of green infrastructures into urban planning. The new public city prioritizes the establishment of public spaces and green infrastructures as essential elements for enhancing the social and environmental sustainability of the urban environment. Emphasizing the creation of a sense of

community and belonging, this approach seeks to promote the health and well-being of city residents.

2 Context

Altamura, a mid-size city nestled in the Murge high plain - a territorial plateau situated in the heart of the Apulia Region - is renowned for its rich cultural and historical heritage. The city occupies an arid region where the availability and management of water resources have played a pivotal role in shaping human settlements throughout its history.

The morphology of Altamura is intricately linked to the availability and careful management of water resources. The urban fabric has been meticulously designed to optimize water collection, storage, and distribution. Built on a karst hill devoid of natural water sources, the city features a dense network of approximately eighty "claustri", collective courtyards and small squares surrounded by the houses of the old town. These spaces contribute to a serene and tranquil atmosphere amid the dense urban fabric. Over time, they have evolved into integral components of the city's urban form and social life, serving as gathering places for families and neighbors.

Moreover, these "claustri" serve as pivotal urban interfaces connected to underground cisterns and wells. Historically, these structures were instrumental in collecting and storing rainwater during the rainy season, ensuring a sustainable water supply for the community during the dry season [5].

In response to the escalating challenges posed by climate change and population growth [6], Altamura has proactively responded with recent urban planning tools. Notably, the Programmatic Document of Urban Regeneration and the Integrated Urban Sustainable Development Strategy signify a shift towards resilience and sustainability [7].

Strategically crafted initiatives aim to fortify the city's territorial project, revitalize key radial roads, and initiate urban regeneration in peri-urban zones. Devised by the municipality in 2017 through the interinstitutional lab Iperurbano, comprising third-sector organizations and professionals, this medium-to-long-term urban planning tool aims to promote the city's sustainable development through:

- strengthening the strategic scenario of the "City-countryside pact" in the Puglia Landscape Plan [8], integrating resilient infrastructures that blend immaterial and physical elements, emphasizing the reintroduction of nature into the urban context;
- enhancing and complementing Quaroni's urban regulatory plan from the 1970s, fostering connectivity between suburbs and established urban areas, including public amenities;
- revitalizing the identity of main radial roads, transforming them into "resilience matrixes" featuring new public spaces and green infrastructures;

- activating urban regeneration processes in peri-urban areas to experiment and test solutions that enhance the resilience of the existing urban fabric amidst evolving urban, climate, and environmental conditions.

The goal of these efforts is to create a more livable and connected city that is better able to withstand the impacts of climate change and other stressors.

Simultaneously, a notable transformation in the management of municipal green areas has taken root over the past decade. This shift towards sustainability practices has resulted in not only reduced management costs but also a transformative evolution from traditional grass lawns to diverse and ecologically beneficial urban meadows [9]. The adoption of this approach aligns with key legislative frameworks, including the European Directive 2009/128/EC (implemented in Italy with Legislative Decree No. 150 of August 14, 2012), the law of January 14, 2013, No. 10, titled "Rules for the Development of Urban Green Spaces," and the "Minimum Environmental Criteria" outlined in the Ministerial Decree of December 13, 2013.

Guided by these European directives and minimum environmental criteria, the management policies initiated in 2013 reflect a significant departure from conventional aesthetics, embracing a more functional and environmentally conscious paradigm. These ongoing efforts are anchored in four key principles:

- differentiation in the maintenance of turfgrass lawns;
- improvement of machinery equipment to eliminate the need for pesticide and herbicide applications;
- management of trees to support their growth and preserve their natural architecture;
- enhancement of skills and knowledge for green maintenance workers.

The transition from a grass lawn to a flower meadow throughout the year has led to a reduction in grasses, replaced by leaf species such as *Trifolium repens* and flowering species such as *Taraxacum officinale*, *Bellis perennis,* etc. This shift, facilitated by a reduced cutting frequency (4/year) [10] contributes to the natural evolution of urban landscapes.

At the urban scale, the natural transition from the meadow-heavy landscape to more natural-looking landscapes based on wildflower meadows can offer more ecological benefits and improve urban biodiversity, despite also altering the appearance and usability of the respective greenspaces. Furthermore, since 2020, the progressive reduction in the periodic mowing of the grass according to the biological life cycle has allowed the complete elimination of herbicides and led to the growth of spontaneous species.

3 Case study

A standout illustration of Altamura's commitment to sustainability unfolds in the Parco San Giuliano suburban district, currently hosting the groundbreaking IxE-CO^2

green infrastructure pilot project [11]. Spanning 120 hectares, this residential district has poor accessibility. Here resides 10% of the total city population made up of around 2,000 families.

The winning proposal emerges from a participatory co-design process engaging citizens, students, graduates, practitioners, and academics, strategically seeking regional funding. The project is shaped by an incremental and adaptive strategy rejecting a hierarchical plan [12], and tackles local challenges such as hydrogeological instability, water management, heat islands, biodiversity loss, and service deficiencies.

The project introduces a modular design system with elements like drainage materials, NbS, and SuDS (Sustainable Urban Drainage Systems), providing guidelines for urban acupuncture interventions. This approach aims to create new public spaces in the neighborhood grounded in ecosystem services (ES) principles [13]. IxE-CO^2's goal is to establish a 1km-long GI, revitalizing the historic “Fornaci” grey road into a green axis and cycle-pedestrian link. This transformative initiative connects the Day Care Center, the agricultural area's edge, and the school complex beyond the megalithic walls. It counters the perception of detachment from the city, fostering community engagement along the way.

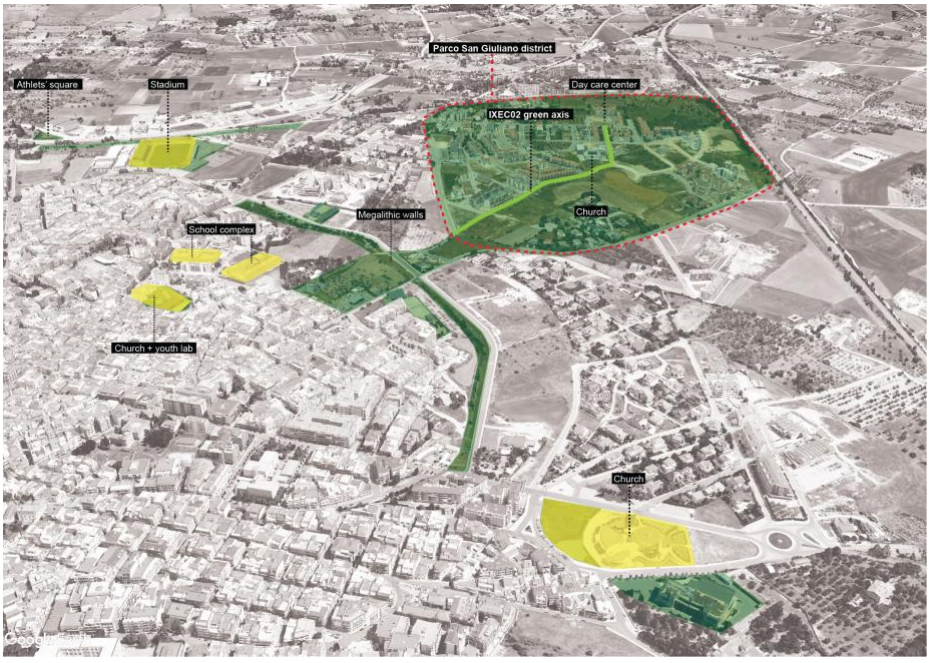

Fig. 1. aerial view of the Parco San Giuliano neighborhood, Saverio Massaro, 2019

Fig. 2. Plan of the project IxE-CO^2, Donato Colonna, Gaetano De Francesco, Saverio Massaro, Courtesy of Municipality of Altamura, 2020

Fig. 3. Axonometric view of the project IxE-CO^2, Donato Colonna, Gaetano De Francesco, Saverio Massaro, Courtesy of Municipality of Altamura, 2020.

Fig. 4. IxE-CO^2 green axis along Fornaci street, Saverio Massaro, 2023.

Fig. 5. side view of IxE-CO^2 green axis along Fornaci street, Saverio Massaro, 2023.

Fig. 6. side view of IxE-CO^2 green axis along Fornaci street, Saverio Massaro, 2023.

Fig. 7. top view of IxE-CO^2 garden area, Saverio Massaro, 2023.

A central of the project is its meticulous consideration of the base module. This foundational unit, measuring 2.5x2.5x2.5 meters, serves as a versatile building block, configurable into 10-meter-long modules with diverse functions such as green modules, seating areas, game-leisure spaces, and parking-rest areas. Integrated canopies further enhance the functionality by supporting vertical greenery and NbS.

The cycle and pedestrian path are composed of a draining pavement bordered by Trani stone curbs that delineate the route, making the modular sequence of the intervention clear. This design recalls the sequence of urban rooms found in the historic center's courtyards.

Fig. 8. axonometric views of project's module-base units, Gaetano De Francesco, Courtesy of Municipality of Altamura, 2019.

The project's species selection is guided by a comprehensive set of criteria, including adaptability to climate change, carbon sequestration capacity, resilience to water scarcity, limited production of volatile organic compounds, and a commitment to longevity with minimal allergenicity. Furthermore, the design takes into account the impact of heat islands on plant species, ensuring the selection of species that thrive under altered urban conditions. Thanks to the use of permeable materials and the creation of green areas, impermeable asphalt surfaces are reduced. This yields favorable outcomes for water drainage, mitigating downstream flow. Upon the finalization of the developments and the removal of asphalt in the remaining segment, the linear garden will assume the role of a rain garden. It will function as an area that receives water during heavy rainfall.

The Green Infrastructure represents a new transitional space through which a sustainable microclimate is redefined in a neighborhood designed for automobiles and characterized by significant heat island effects. The introduction of GI brings comfort and biodiversity, mitigating the adverse effects of rainfall and fostering social interactions in public spaces.

The proposal is based on a careful study of species' physiological and management characteristics. Qualitatively and quantitatively integrating shrub and tree species, selection criteria encompassed various traits:

- Climate change adaptability
- High atmospheric CO^2 sequestration
- Survivability in conditions of relative water scarcity
- Limited volatile organic compound production
- Structural solidity of crown and stem
- Good transplant tolerance
- Longevity despite unexpected adverse events
- Reduced or absent allergenicity
- Pathogen tolerance or unattractiveness
- Deep roots or non-damaging soil.

Analyzing the area's design, consideration was given to the impact of heat islands on plants, affecting urban livability and plant species. Consequences of this phenomenon [14] include a shorter rest season, fewer frost days, a prolonged growing season, and a shift in phenological phases.

The choice of species was made according to the absorption capacity of CO^2 and other polluting substances, through the use of the Qualiviva Project sheet [15] together with information and data made available by the REBUS (REnovation of Public Buildings and Urban Spaces) network - Workshop on urban regeneration and climate change [16].

The IxE-CO^2 project not only envisions a carbon sink but also demonstrates a proactive approach to sustainability. Upon completion, the project is expected to annually absorb emissions equivalent to approximately 407 cars, making a substantial contribution to reducing pollutants in the area. This emphasis on careful planning and carbon sequestration underscores the potential for sustainable urban development when coupled with a broader policy focusing on sustainable mobility and associated urban amenities.

Table 1. CO^2 absorption calculation sheet, Paolo Direnzo, 2023.

OUTPUT VALUES		
	Quantity	Unit of measure
NEW TREES	236	
CO2 STORED NEW PLANT	1155	kg
CO2 ASSIMILATED NEW PLANT	1374	kg/y
MATURE PLANTS	236	
CO2 STORED MATURE PLANTS	547154	kg
CO2 ASSIMILATED MATURE PLANTS	83972	kg/y
03 CUT DOWN	22,6	kg/y
N02 CUT DOWN	22,6	kg/y
S02 CUT DOWN	28,44	kg/y
PM 10 CUT DOWN	45,01	kg/y
BALANCE IN/OUT C02		
average emission of a car	120	g/km
average annual mileage	11200	km
average annual emission per mileage	1344	kg/y
C02 stored in new plant	1.155	kg
no. of cars whose emissions are on average absorbed by new plants	0,86	n
C02 stored mature plants	547.154	kg
no. of cars whose emissions are absorbed on average by mature plants	407,11	n

In essence, the Parco San Giuliano case study not only exemplifies Altamura's commitment to sustainable urban development but also serves as a model for NbS, participatory processes, and the creation of resilient, green public spaces within the urban fabric.

4 Participatory process overview

Community involvement in the project was a dynamic, multistage process, strategically designed to foster active participation and gather diverse perspectives. Below each stage is outlined, highlighting the distinctive role each played in shaping the community-driven initiatives.

Stage 1. Defining a proposal for regional funding

In May 2018, the Municipality of Altamura, in collaboration with the urban laboratory Iperurbano, initiated a participatory design process with the goal of submitting a proposal for the regional call "Green Infrastructures" included in the Regional Operational Program 2014–2020.

The participatory activities engaged not only residents but also involved associations, municipal technicians, businesses, and stakeholders. A local association of photographers actively contributed by creating a photographic map of the neighborhood, supporting the design process. Civic imagination was nurtured, transforming challenges and conflicts into meaningful resources. The neighborhood's *community map* became a dialogue space, enabling citizens, stakeholders, and economic partners to express their demands and share their knowledge of the area, unveiling aspirations, visions, and territorial awareness. Approximately 40 individuals,

along with businesses and members of the neighborhood committee, actively participated.

Stage 2. Implementing the granted proposal

In May 2019, the Municipality of Altamura, in collaboration with the University of Basilicata, organized an intensive design workshop entitled Parco San Giuliano Cantiere Aperto. This workshop, mandated by the municipal administration, aimed to develop projects at the urban-architectural scale, defining newly equipped public spaces and proposing hybrid functional programs. The 30+ participants included individuals and associated professionals, non-profit cultural organizations, students, and recent graduates.

The workshop encompassed co-design laboratories, training seminars, professional development updates, public reviews, and final presentations of works. It provided an opportunity to align the agendas of the municipality with the University's educational and third-mission activities.

Stage 3. Immaterial actions within the project

More recently, immaterial actions alongside construction activities have been promoted. These actions involve information, training, awareness of slow mobility, environmental education, and the use and management of public spaces. Achieved through workshops, walks, and seminars, these initiatives complement physical interventions, fostering a holistic approach to urban regeneration involving a wide range of participants.

5 Conclusions

The strategic direction of policies in Altamura, linking urban regeneration and green infrastructures, underscores an incremental, adaptive UR process for creating a new public city. The toolkit approach emphasizes adaptability over rigid solutions. Situated, in-action, multi-stakeholder participatory processes, organized by the Municipality and Iperurbano lab, engage citizens in co-planning, mapping, and information activities. The involvement method focuses on participatory urbanism and placemaking, with activities in planned neighborhoods.

Renaturalizing the urban fabric involves desealing, preserving actions, and systematic use of Nature-based Solutions (NbS), enhancing environmental and economic benefits. However, the effectiveness of NbS in environmental improvement is highly vulnerable. For instance, in this project, the inclusion of trees has been instrumental in gaining benefits like carbon sequestration and mitigating the impact of the heat island effect. Specific tree species have been chosen for their adsorptive capabilities, absorbing maximal air pollutants, a crucial factor in mitigating air pollution. Additionally, the NbS approach offers extensive opportunities for biodiversity protection.

The selection and quantity of species employed in this project will shape the future outcomes of the green infrastructure. Inadequate implementation and maintenance practices could lead to adverse effects. NbS ought to be built upon indigenous species, considering their broad geographical origins. To safeguard species impacted by climate change, NbS should leverage assisted migration, creating tailored and suitable habitats to counteract the effects of climate change and the endangerment of plant and animal species.

Particularly, the IxE-CO^2 project presents a new cultural model for nature-based regeneration. New challenges and opportunities can be foreseen. To enhance the positive impacts of such proposals, it is crucial to:

- implement UR processes coherently with the management of urban green areas, necessitating the training of new green workers and companies specializing in green maintenance;
- develop new skills for adaptive mapping processes, integrating nature-based solutions and connecting various urban processes to establish an evolving, incremental planning system;
- explore the replicability of the toolkit used in the pilot project, starting with extending the GI beyond the megalithic walls.

Moreover, variations in costs due to the pandemic and war have impacted the project and its realization, adding a layer of complexity and highlighting the importance of adaptive strategies in the face of unforeseen challenges.

The co-programming approach in Altamura highlights the value of collaboration among professionals, non-profit organizations, and the municipality in crafting planning tools and urban interventions. These interventions focus on creating new public spaces through the strategic application of NbS. Utilizing them as sensors to gather meaningful information can enhance participatory processes, empowering residents and reinforcing community relations.

The IxE-CO2 project, particularly, illustrates its potential to address localized vulnerabilities and introduce new Ecosystem Services (ES) through a participatory co-design process. This collaborative model holds promise for replication in other cities and communities aiming to proficiently manage UR processes and enhance urban resilience.

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