Planning for Environmental Justice. A Multi-methodological Approach

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Abstract. Urbanization is rapidly transforming natural landscapes, intensifying socio-environmental inequalities, and creating disparities in both the provision of ecosystem services (ES) and urban biodiversity. This paper suggests a multidisciplinary and multi-methodological approach to evaluate urban biodiversity, ES supply, and socioeconomic vulnerability to examine environmental justice. Based on the "Luxury Effect" hypothesis, which supposes a positive association between wealth and biodiversity in urban environments, the paper investigates the relationship between differences in urban nature and more general trends in social inequality. Biodiversity and green infrastructure may significantly improve urban quality of life, but the benefits are often unequally distributed, being wealthy communities usually favored more than others.

To bridge the gap between theory and practice, the study suggests a new framework integrating quantitative and qualitative data, like biodiversity surveys with geographical and multicriteria decision analysis (MCDA). The methodology will be tested and validated in four Italian cities - Milan, Rome, Turin, and Naples - each reflecting distinct ecological, social, and economic situations. Our technique identifies regional patterns of inequality and prioritizes areas for policy intervention by overlaying biodiversity and ES data over socioeconomic characteristics. This integrated paradigm advances theoretical discussions on environmental justice and encourages the development of more inclusive, data-driven urban planning methods. The approach is still in the validation phase but shows strong potential for scalability and adaptability across diverse urban contexts. Ultimately, the study aims to inform sustainable planning practices that ensure a fairer distribution of environmental benefits, enhancing cities' ecological resilience and social well-being.

Keywords: Ecosystem Services · Socio-economic analysis · Biodiversity

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1 Introduction

The urbanization rate is drastically increasing worldwide, and its impacts are driving many environmental changes at multiple scales, leading to land cover modifications, climate change, pollution levels and biogeochemical cycle alterations, and loss of biodiversity [1, 2]. In the last decades, people worldwide have increasingly concentrated in urban areas, with European cities well above the global rate of urbanization, making the equitable distribution of urban nature an urgent issue. Indeed, 68% of the world's population is projected to live in urban areas by 2050, and Europe's urbanization rate is expected to rise to 84% [3]. Expanding the built-up coverage to host urban dwellers and their activities is thus inevitable. The significant implications of people's overconcentration in cities are widely known undesirable side-effects such as congestion, pollution, and deterioration of people's quality of life [4, 5] since people in urban areas with low experiences of nature tend to have worse mental and physical health [6, 7]. Exposure to nature and related ecosystem services reduces the risk of poor mental health, cardiovascular disease mortality [8], healing times [9], respiratory illness, and allergies if green spaces in urban environments are properly planned [10], among others. Although people are persuaded to increase their health and well-being, they face environmental injustices in most of the largest cities, particularly concerning the inequality in urban green provision and related benefits [11]. Environmental injustice is described as the unfair distribution of environmental benefits across different social groups. The term originally related to the condition of unequal exposure of marginalized communities to environmental hazards [12, 13]; the concept has since evolved to encompass access to environmental goods, such as green spaces and related services, in contemporary urban contexts [14]. Environmental injustice has clear repercussions on contemporary urban planning patterns, with consequences such as environmental gentrification and social exclusion [15]. In most of the largest cities, the environmental injustice is strictly related to the socio-economic status [16, 17], giving rise to what is known as the Luxury Effect. The term Luxury Effect has been coined to describe a specific inequality in the urban green provision, thus an environmental injustice, hypothesizing a positive relationship between wealth and biodiversity in urban areas [18, 19].

On the one hand, socio-economic factors can influence the presence of urban biodiversity, affecting a wide range of taxonomic groups (e.g. plants, birds, insects) [18–21]. Indeed, recent research has found a positive association between household income and plant diversity in various U.S. cities [18], and similarly, a study in the mid-sized European city of Vitoria-Gasteiz showed that neighborhoods with higher educational attainment, a proxy for socio-economic status, also had greater tree and bird species richness, thus empirically confirming the Luxury Effect [17]. On the other hand, the Luxury Effect needs to be further investigated since there is currently no consensus on the issue; it may depend on specific contexts rather than being a universal concept [22]. Indeed, the Luxury Effect is present in multiple geographies and for multiple taxa, including birds [18, 19, 21, 23]. For example, there is evidence that socio-economic factors, such as income level, are significantly positively correlated with birds' species richness [19] and abundance [24]. Birds can deliver different Ecosystem Services (ES); however, there is a paucity of literature explicitly measuring ES about the presence of species in the heterogeneous urban landscape [25].

Cities are crucial places to understand these fundamental changing processes, and where ecologists and urban planners should work together to develop policies and strategies to ensure a better urban life while maximizing biodiversity and urban ecosystem functions [1, 26]. Guaranteeing urban sustainable development is key to addressing Goal 11 of the Sustainable Development Agenda [27] and can contribute to tackling the global environmental crisis we face.

To bridge this knowledge gap, our study investigates how socio-economic disparities affect urban biodiversity, particularly birds, and access to ES where wealthy neighborhoods experience greater biodiversity and green space benefits, ultimately informing sustainable planning practices and ensuring environmental justice.

2 State of the Art

The introduction clearly shows the crucial role of green spaces in impacting life quality and environmental equity. However, their unequal distribution negatively affects the most disadvantaged segments of the population and exacerbates the existing gap. Considering the main important concepts previously stated, such as biodiversity, Ecosystem Services (ES), and socio-economic assessment, within this section, the most used methodologies for their analysis will be explored by considering the focus of the research and the spatial analysis. Within this context, urban green spaces refer to public or semi-public accessible vegetated areas in an urban context that provide a range of ES, combating many urban ills. These areas - i.e., parks, forests, tree-lined streets, green corridors, riverbanks, urban agriculture, community gardens - are diverse, varying in size, vegetation cover, species richness, and environmental quality [28, 29].

2.1 Assessing Biodiversity

Biodiversity is essential to promote ecosystem functioning [30] in urban areas, and its monitoring allows us to understand how ecological communities react to anthropogenic pressures [31]. In a world that is experiencing a progressive loss of human-nature interactions ('extinction of experience,' [32]), cities can offer opportunities for urban dwellers to stay connected with nature, and the numerous interactions occurring in urban areas, even if with nonnative or pest species, can be crucial for biodiversity conservation worldwide [33]. Understanding how to manage urban biodiversity is relevant to ensure positive cascade effects on the ecosystem functioning and maximizing associated ES [31].

Sampling methods used to assess biodiversity can vary depending on the objectives of the assessment, the target taxa, and the study area. Biodiversity experts perform surveys to collect data on species, communities, or habitats in a defined amount of space and time. Surveys can provide a snapshot of environmental and biological features occurring in the study area. Importantly, they can allow the investigation of species diversity and abundance – i.e., the presence/absence of a species, how many species (and individuals per species) are present – and their spatial distribution [34]. Direct observation or passive sampling methods can be used to collect data on biodiversity. Standard animal sampling designs, primarily employed also in urban contexts [31], can involve the collection of data through, for example, point counts (e.g., very common in bird studies [35]) and Pollard's

transects (e.g., defined for butterfly studies, [36, 37] whereas circular or round plots can be used to survey vegetation. Standard methods can include, but are not limited to, (i) physical traps (e.g., pan traps, pitfall traps) and nets (to capture the specimen directly, e.g., amphibians, mammals, reptiles, invertebrates like bees, butterflies, ants, or spiders), (ii) passive acoustic recorders (e.g., for bats, birds, amphibians) and camera traps (e.g., for mammals), (iii) opportunistic data collection through Citizen Science programs [31]. The precise area to conduct the survey (e.g., point count, plot) or to locate the trap (e.g., camera trap) can be selected randomly or by following a grid/transect disposition. The development of citizen science programs is increasing worldwide, especially for taxa like birds and butterflies, and they are also known to improve public engagement with nature and increase the availability of data valuable to understand the dynamics of urban biodiversity [38]. Furthermore, museum collections and atlas data can contribute to biodiversity assessment [31]. All these methodologies should be adapted to the objectives of the evaluation.

2.2 Assessing Ecosystem Services Provision

ES have garnered significant attention across various fields in recent years, being applied in stakeholder awareness decision-making processes for planning, policy design, and sustainable development [39]. ES are the subject of numerous steering documents and guidelines for international organizations (e.g., the United Nations Environment Programme (UNEP), the International Union for Conservation of Nature (IUCN), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). They also represent the topic of a growing number of scientific studies that have explored the possibilities of implementing an ES-based strategy, emphasizing their crucial role in supporting decision-makers (among the many: [40–42] ES are widely considered an effective tool for identifying and communicating the benefits and values of nature related to human health and well-being, particularly in urban areas [43]. Climate change is a major contributor to global greenhouse gas (GHG) atmospheric emissions and disproportionately affects metropolitan areas. [44, 45]. Cities are particularly vulnerable to climate change, including urban heat islands, floods, and biodiversity loss, which endanger people's health and well-being, highlighting the need for more progressive urban planning. Within this context, urban green spaces play a critical role in enhancing the provision of ES and climate change adaptation, including urban stormwater regulation, carbon sequestration, urban cooling capacity, air purification, and habitat preservation. These ES are all strictly connected to several human benefits, such as recreational opportunities and social cohesion.

Ensuring the availability and accessibility of nature in cities is a matter of environmental sustainability and a priority of public health and social equity, especially in the climate change era.

Generally, citizens who are vulnerable to socio-economic aspects are often the most at risk from environmental hazards [46] and receive the least amount of assistance from ES providers and Green and Blue Infrastructure (GBI) [47]. The unequal distribution of ES in cities worsens social inequality by making it harder for marginalized groups to adapt to environmental stresses. ES assessment is a valuable tool for advancing environmental equality as it has the potential to shed light on the distribution of these advantages,

supporting strategies that aim to equal and inclusive ES provision and access for all socioeconomic groups. Thus, one of the most essential methodological strategies for closing the gap between ecological information, planning, and policy is mapping and evaluating ES [48, 49].

Understanding the spatial distribution of ES is critical for assessing the multifunctional roles that natural and semi-natural areas play within cities, as well as analyzing how various segments of the urban population have access to environmental benefits. Some discrepancies, such as those in the quantity and quality of green areas in urban neighborhoods and the recreational and social possibilities available, can be identified by comparing variations in the ES distribution. Patterns of disparity in the benefit of areas with high ES capacity are revealed using ES spatial modelling.

2.3 Assessing the Socio-Economic Dimension

Socio-economic studies play a key role in analyzing urban inequalities and supporting research on the distribution of green spaces, accessibility to services, and environmental impacts on the population. By integrating geospatial methodologies with statistical and economic approaches, these studies make it possible to identify the most vulnerable areas and develop more inclusive urban planning strategies. In detail, this analysis could be created by applying the quantitative and qualitative methodology to reveal whether low-income neighborhoods have fewer green spaces or whether these are of lower quality, whether there are barriers to access for specific categories of users, and whether urban sprawl is occurring sustainably or exacerbating inequalities [50].

Assessing how urban green space affects health, well-being, and economic development is relevant, and it is evident that there is a correlation between high levels of pollution, the heat island effect, and worsening mental health. From an economic perspective, green areas affect property's market value by generating phenomena such as gentrification [51]. Given the complexity of the problem and the territorial distribution of the criteria, a spatial multicriteria analysis is suggested to consider conflictual values and visually represent the analysis. Geographic Information System software allows us to map inequalities, identifying areas with less green space or more pollution [52]. At the same time, statistical analysis and econometric models, such as multiple regressions and spatial models, are used to correlate socio-economic variables with environmental factors [53, 54].

In contrast, logistic regression models predict the probability that a given population uses green spaces (or does not) [55]. An interesting aspect of [56] is the gap between the perception of environmental benefits and their usability. In addition, some studies adopt economic valuation models to estimate the value of green spaces [57] by combining financial and environmental data to measure the value of urban green space by applying Willingness to Pay (WTP) as a methodology to measure how much people would be willing to pay for environmental improvements [58]. Other approaches, which could be more qualitative and participatory, use interviews, surveys, and focus groups to collect data on perceptions of green spaces and the experiences of different communities [56]. Among the criteria to analyze for socio-economic studies, it is possible to mention the average income of the population [59, 60], gender inequality [60], education level, and environmental awareness [56].

2.4 Gaps in the Studies Analyzed

Despite the existing studies and the high interest in this topic, the integration between different disciplines and fields of research described above deserves to be explored in more depth. A limited combination of qualitative and quantitative data emerges from the literature analyzed. [61] apply a technical approach that does not consider the social value provided by green spaces and does not measure the perception of users. [57] is intensely focused on economic evaluation but lacks a strong socio-spatial component. Another criticality is the selection of case studies, mainly big cities, where the problem of green distribution is most apparent. Still, they neglect suburbs and small towns, where green might be there but poorly managed or inaccessible [56].

To overcome these gaps, developing more integrated studies with an approach that combines spatial, economic, and social analyses is essential, as well as adopting participatory methodologies and long-term studies. This can guide decision-makers in making more conscious and sustainable decisions, which can help mitigate the Luxury Effect and foster environmental justice.

3 Methodological Approach Proposal

Considering the critical issues raised in the previous section, an integrated approach involving public agencies, academics, and civil society is essential. This will ensure that urban planning considers economic efficiency, social inclusion, and environmental sustainability. Given this premise, the paper proposes a multi-methodological approach based on the main features of biodiversity, ES, and socio-economic assessment, combining their strengths to obtain an interdisciplinary approach (Fig. 1). Within this context, the theoretical part will be presented, while the future development of the research will consider its application.

Spatial visualization and analysis are the starting point of the methodological proposal since they are fundamental in identifying urban disparities and developing more sustainable and inclusive urban planning strategies. Given the complexity of the problem to be addressed and the sometimes-conflictual values to be considered [62, 63], a Multi-criteria Decision Analysis (MCDA) is the most consistent approach to be applied. It can collect both qualitative and quantitative data to manage different needs and expectations elicited by various stakeholders, and to provide guidelines and suggestions to aid the decision [64]. Each discipline involved deserves to be investigated with coherent criteria and spatially visualized to understand the correlation with the Luxury Effect. Regarding the socio-economic dimension, given the objective of replicating the methodology in different Italian cities, indicators have been selected considering their availability at the national scale since the project is part of the National Biodiversity Future Center. Considering studies already developed on this topic [17, 20, 65, 66], it has been selected a consistent set of criteria consisting of the evaluation of i) the market value of residential buildings, ii) the income of the population, iii) the age, and precisely the percentage of elderly people (>65 years old), and iv) the level of education. The aggregation of that data allows us to obtain a representative index of the socio-economic condition of citizens. At the same time, for the analysis of the ES provision, it is strategic to analyze aspects that support the comprehension of the quality of the green spaces, not only given

by their presence [67]. Crucial and robust indicators are: i) carbon storage, estimating the current amount of carbon stored; ii) habitat quality, estimating the distribution of habitat and vegetation types across a landscape and assessing their level of degradation; iii) urban cooling, estimating the index of heat mitigation, and iv) urban stormwater retention, estimating the runoff retention, and groundwater recharge. Given the high synergies among those criteria, performing a principal component analysis to reduce strongly correlated data could be strategic before the aggregation in a final quality index [68].

This preliminary analysis and its spatial visualization, supported by bivariate analysis, allow the combination of these two disciplines, Social and Economic studies, and Urban planning, to understand where policies for green area improvement should be concentrated to distribute the natural capital and its benefits equally. Within this context, the contribution of biodiversity is missing, which is essential to analyze the Luxury Effect. The approach proposes the integration of a third layer consisting of data on bird species richness collected through point counts. Overlapping this additional information will allow us to understand if the wealthiest areas, and with a more significant provision of ES, are related to higher biodiversity. In this context, evidence and research are as strategic as urgent to support policies, better management practices, and strategies towards environmental justice. This objective can be achieved only by considering the perception of residents and policymakers about the benefits provided by natural capital. In addition to collecting quantitative data, the methodology proposes the support of surveys to assess a more qualitative dimension, eliciting the intangible values of users to understand whether there is adequate equity in the use of green areas.

Spatial mapping of ES through MCDA approaches represents a strategic methodological innovation to address the complexity and multidimensionality of urban planning challenges. This combination allows for the spatial prioritization of interventions by balancing ecological, social, and economic criteria, and can support deliberative processes by defining trade-offs and synergies. The contribution raises attention on how to operationalize environmental justice and equity through data-informed, spatially explicit planning strategies.

By integrating these elements, the methodology can provide a comprehensive, multidimensional analysis of cities and urban areas from the perspective of green gentrification and the Luxury Effect to inform practical policy recommendations. The method proposed is still under review and needs additional tests to be validated, especially the analysis and integration of tangible and intangible values. Still, it is promising, given the support of robust methodologies applied in different disciplines and combined comprehensively.

4 How to Validate and Test the Methodological Approach

Although the concept of ES has improved our knowledge of the connections between ecological processes and human well-being, its use in assessments focused on environmental justice is still in its infancy [69–71]. By combining biodiversity, ES, and socioeconomic data, this approach has the potential to go beyond traditional environmental justice analyses, which are frequently only concerned with the distribution of environmental harms. This triple articulation makes it possible to comprehend how patterns of environmental

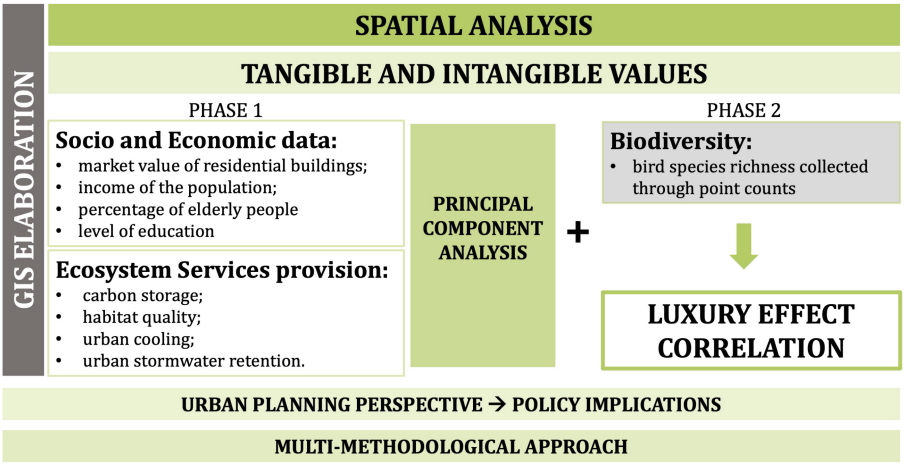

Fig. 1. Scheme of the approach proposed.

injustice are created or perpetuated by the interaction of ecological degradation, service delivery, and socio-economic vulnerability. In addition to strengthening our conceptual understanding of environmental inequality, this method offers a stronger foundation for creating just and long-lasting policy solutions.

Nevertheless, empirical research that methodically incorporates these three dimensions is still scarce despite its conceptual promise. Current research frequently ignores them or uses disjointed approaches, missing the chance to develop a truly transformative and interdisciplinary framework for evaluating and addressing environmental justice. Bridging this gap represents a critical frontier for both research and practice about different disciplines (social, environmental, economic, and planning), emphasizing the inherently multidisciplinary nature of the approach proposed in the article.

As a future perspective, to validate the theoretical framework and evaluate its applicability across various urban contexts, our methodological approach will be operationally tested in four Italian cities: Rome, Milan, Naples, and Turin. These metropolitan areas, while all situated within the same national context, represent diverse geographic, climatic, socio-economic, and ecological profiles, offering a range of urban scales and governance structures. This diversity provides a significant opportunity to test the flexibility and robustness of the framework across different urban realities.

This comparative analysis will allow for investigating the contribution of biodiversity, ES, and socio-economic variables in distributing environmental justice patterns. It can contribute to identifying the presence of mechanisms related to the Luxury effect and reflect on how structural inequalities in planning decisions have created the conditions for these dynamics to develop. Urban planning plays a fundamental role in attenuating or reinforcing these patterns: for example, planning policies, land use regulations and investments (real estate or infrastructure) have the capacity, directly or indirectly, to shape and influence the distribution of resources, often embedding structural advantages or disadvantages in the urban fabric [72]. The application of this method in several case studies enables the identification of context-specific dynamics by applying the

framework to several case studies while recognizing similarities and differences that can guide more comprehensive, scalable approaches to equitable and sustainable urban planning.

Through this comparative application, the research aims to identify which variable exerts the most significant influence on the distribution of environmental injustices in each urban area considered. By discerning the most salient drivers in each case study, the project can generate both locally specific insights and broader, generalizable knowledge. Finally, this process supports the development of scalable and adaptable planning and policy strategies sensitive to place-based complexities while aligning with the overarching goals of equity and sustainability.

5 Conclusions and Future Perspectives

The current contribution proposes an overview of the current state of the art of multidisciplinary studies to investigate the distribution and accessibility of green spaces in urban areas often characterized by substantial socio-spatial inequalities, with particularly significant effects on vulnerable communities. Phenomena such as the Luxury Effect are recurrent in cities worldwide, primarily where land-use planning promotes real estate development and aesthetic improvement rather than social equity. At the same time, green gentrification emerges as a critical problem: interventions aimed at improving environmental quality by creating or enhancing green areas often result in higher property prices and the displacement of poorer populations. This contradicts the principles of environmental and social justice on which such interventions should be based, helping to perpetuate or even exacerbate pre-existing inequalities.

The studies analyzed also highlight the lack of integrated approaches capable of combining spatial, economic, and social analyses and adopting a longitudinal perspective to monitor the effects of urban greening projects over time. In addition, the limited involvement of local communities and social actors in the decision-making process is a further obstacle to creating more inclusive and sustainable cities. Furthermore, planning strategies that actively address equity, affordability, social inclusion, and ecological and aesthetic goals must direct urban regeneration processes, ensuring that the transformation of urban space benefits all inhabitants.

Given these premises, it seems crucial to direct future research and urban policies toward a more inclusive, integrated, and participatory approach. There is a need to develop analysis models capable of considering the spatial distribution of urban green space and its actual and perceived accessibility by different social groups, including older people, children, migrants, women, and people with disabilities. Public policies must overcome the Luxury Effect by ensuring an equitable distribution of green spaces, even in less affluent neighborhoods. At the same time, they must address the risk of green gentrification through tools such as accessible housing, resident community protection, and urban design criteria that consider the socio-economic diversity of territories. In addition, it is essential to promote continuous and participatory monitoring, involving citizens and local actors in decisions and assessing the long-term impact of policies. Through a more coherent integration of quantitative (GIS, statistical models) and qualitative (surveys, interviews, focus groups) analyses, it will be possible to build more just and resilient cities where urban greening is not a privilege of the few but a right for all.

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