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Integrating green infrastructure and cultural heritage for urban planning

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ABSTRACT

Green infrastructure is a promising and increasingly recommended approach for delivering essential ecosystem services in cities. However, current planning approaches largely regard the urban landscape as a grey matrix, with marginal land considered suitable for green infrastructure. Most European cities contain cultural heritage assets subject to strict conservation regulations, which are often the most likely sites for green infrastructure elements. Green infrastructure elements, however, can alter environmental conditions, perceptions, and patterns of use that are crucial for the long-term conservation of heritage assets. We develop an interpretative matrix to address interactions between green infrastructure and cultural heritage through cross-analysis of four green infrastructure planning criteria and thirteen cultural heritage conservation principles. The analysis identifies conditions of synergy and trade-off between green infrastructure implementation and cultural heritage conservation, with interactions shaped by physical, chemical, perceptual and usage-related relationships. Our framework suggests that cultural heritage does not inherently restrict green infrastructure implementation but instead requires planning approaches based on conservation-oriented principles and contextual assessment. Planning green infrastructure in accordance with cultural heritage conservation principles not only enables coexistence but can also support cultural heritage values, social acceptability, and cultural ecosystem services associated with green infrastructure.

1. Introduction

Green infrastructure is a strategic approach to urban transformation, recognising that natural and semi-natural systems can provide ecological, social, and cultural benefits when integrated into the urban landscape. The planning strategies for green infrastructure are based on a set of four criteria [1]. First, ecosystem-service targeting and multifunctionality: green infrastructure elements are planned and managed to deliver the ecosystem services most in demand in cities (e.g. cooling, stormwater retention, recreation) and to maximise synergies while minimising trade-offs, a principle widely recognised in green infrastructure scholarship and policy [2]. The second criterion, integrating green and grey infrastructure, reinterprets drainage channels, retention basins, and mobility corridors as opportunities for hybrid solutions that combine plants, permeable materials, and soil with conventional engineering [3]. Such integration provides multiple benefits, including flood mitigation, thermal comfort, and improved air quality, while redefining the aesthetic and ecological identity of the city [3]. Connectivity is the third criterion of green infrastructure, reflecting the principle that ecological processes and human interactions depend on spatial and functional continuity. The fourth criterion, social inclusion and equity, recognises that green infrastructure cannot be effective if its benefits are unevenly distributed. Local authorities are increasingly aware of the environmental justice implications of greening, striving to ensure that access to shade, clean air, and recreational space is not restricted to privileged neighbourhoods. Attention is also increasing to cultural inclusion, acknowledging that different communities perceive and use green spaces according to their traditions [4]. Together, these four criteria pursue a single overarching goal: creating cities interwoven with a continuous, accessible, and resilient green infrastructure designed to provide ecosystem services and improve the quality of life for urban dwellers.

Frameworks for green infrastructure planning are now well established and provide a consistent basis for integrating ecological and social objectives into the urban landscape. However, frameworks for green infrastructure planning generally treat the urban landscape as a relatively uniform (grey) matrix, addressing issues related to the ability of species to thrive in the urban landscape [5] and the spatial interactions between green and grey infrastructure to match the supply and demand of ecosystem services [6]. Focusing on green infrastructure without

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considering its interactions with grey infrastructure may jeopardise the social acceptability of green infrastructure and raise concerns about the conservation of built assets, particularly cultural heritage assets. In many cities, cultural heritage represents an important component of the urban landscape, whose conservation depends on the control of environmental conditions and patterns of use [7]. However, cultural heritage is often neglected or considered a constraint to green infrastructure, rather than as a component of the urban landscape with specific conservation requirements [8]. This issue is particularly critical in dense urban landscapes, where limited space often leads to developing green infrastructure on brownfields and marginal spaces that are part of, or closely connected to, cultural heritage such as historic gardens and archaeological sites. Consequently, interactions between green infrastructure elements and cultural heritage assets are a recurring phenomenon in urban landscapes [9].

The absence of a framework for addressing interactions between green infrastructure and cultural heritage is a limitation of current planning approaches and may result in unintended conservation risks. Green infrastructure implementation can alter environmental conditions, perceptions, and usage-related patterns that are crucial for the long-term conservation of heritage assets. Additionally, the absence of an integrated framework restricts the ability to identify potential synergies, including cases where green infrastructure may support heritage values and enhance place identity.

This study fills this gap by developing an interpretative framework to examine the synergies and trade-offs between green infrastructure planning and heritage conservation and to explore how conservation principles can inform green infrastructure planning.

2. Materials and methods

We adopted a qualitative approach to develop an interpretative framework for assessing interactions between green infrastructure planning criteria and cultural heritage conservation principles in urban

Table 1
Interpretative matrix of interactions between green infrastructure planning criteria (columns; [1]) and cultural heritage conservation principles (rows; [10]).

	Multifunctionality	Integration of green and grey infrastructure	Connectivity	Social inclusion and equity
Knowledge and respect for cultural heritage and its importance	Synergy: multifunctionality can enhance cultural ecosystem services	Synergy: cultural heritage assets can inform the type of green infrastructure interventions	Synergy: cultural heritage assets can strengthen perceptual and symbolic connectivity	Synergy: recognition of cultural values in green infrastructure planning supports intervention acceptability
Adequacy of feasibility studies and conservation plans	Synergy: integrated planning supports multifunctional outcomes	Synergy: detailed diagnostic analyses support compatibility and avoid negative material and perceptual impacts	Synergy: spatial analysis can anticipate effects on movement and spatial continuity	Synergy: informed planning supports socially acceptable outcomes
Use of cultural assets and regular maintenance	Synergy: enhanced cultural ecosystem services and experiential value	Synergy/Trade-off: green infrastructure may either reduce or increase maintenance requirements	Synergy/Trade-off: spatial proximity may enhance experiential connectivity or generate functional constraints	Synergy: support opportunities for meeting and community activities combining environmental and cultural dimensions
Prevention	No direct relationship identified	Synergy/Trade-off: green infrastructure may either mitigate or intensify chemical and physical risks	No direct relationship identified	No direct relationship identified
Maintenance of authenticity and integrity	Trade-off: multifunctionality may introduce uses or elements incompatible with heritage authenticity and integrity	Synergy/Trade-off: green infrastructure may recover historical landscape patterns or alter perceptual coherence	No direct relationship identified	No direct relationship identified
Collective and transparent decision-making process / Community involvement and public interest	Synergy: participatory processes increase awareness of ecosystem services	Synergy: shared knowledge improves integration of green and grey infrastructure	No direct relationship identified	Synergy: participatory decision-making enhances legitimacy, acceptability, and equity
Minimum intervention	No direct relationship identified	Trade-off: green infrastructure may increase the extent or frequency of interventions	No direct relationship identified	No direct relationship identified
Caution in design	No direct relationship identified	Trade-off: limited knowledge may increase the risk of unintended impacts on cultural heritage	No direct relationship identified	No direct relationship identified
Compatibility of proposals	No direct relationship identified	Synergy/Trade-off: materials, techniques, and plant species may be compatible or incompatible with heritage materials	No direct relationship identified	No direct relationship identified
Reversibility of interventions	No direct relationship identified	Synergy/Trade-off: green infrastructure may range from lightweight and reversible to long-term and poorly reversible solutions	No direct relationship identified	No direct relationship identified
Multidisciplinarity	Synergy: multidisciplinary collaboration supports multifunctional outcomes	Synergy: coordinated expertise improves integration of green infrastructure elements	No direct relationship identified	Synergy: multidisciplinary processes support more equitable decision-making
Effectiveness	No direct relationship identified	Trade-off: long-term ecological dynamics increase uncertainty in defining conservation performance outcomes	No direct relationship identified	No direct relationship identified
Accessibility and inclusion	Synergy: multifunctionality supports cognitive and experiential accessibility	Synergy: improved paths, surfaces, and spatial legibility enhance access	Synergy: increased ecological and social connectivity	Synergy: more equitable and inclusive enjoyment of cultural heritage assets

landscapes.

As a first step, we defined the green infrastructure planning criteria and cultural heritage conservation principles used in the framework by selecting two key reference documents from the scientific and policy literature, chosen because they provide concise and authoritative syntheses of green infrastructure planning criteria and cultural heritage conservation principles. For green infrastructure planning, we used the four criteria presented in *Urban Green Infrastructure Planning: A Guide for Practitioners* by Hansen et al. [1]: (i) ecosystem-service targeting and multifunctionality, (ii) integration of green and grey infrastructure, (iii) connectivity, and (iv) social inclusion and equity.

We derived cultural heritage conservation principles from the *European quality principles for EU-funded interventions with potential impact upon Cultural Heritage* [10], which synthesises internationally recognised conservation approaches. From this source, we identified 13 principles: (i) knowledge and respect for cultural heritage and its importance, (ii) adequacy of feasibility studies and conservation plans, (iii) use of cultural assets and regular maintenance, (iv) prevention, (v) maintenance of authenticity and integrity, (vi) collective and transparent decision-making process/community involvement and public interest, (vii) minimum intervention, (viii) caution in design, (ix) compatibility of proposals, (x) reversibility of interventions, (xi) multidisciplinarity, (xii) effectiveness, and (xiii) accessibility and inclusion.

In the second step, we conducted a qualitative cross-analysis by developing an interpretative matrix in which the four green infrastructure planning criteria were compared with the 13 conservation principles. For each intersection, we examined whether interactions involved physical and chemical processes as well as perceptual and usage-related relationships. Based on this interpretative comparison, we classified each interaction into one of three categories: synergy, when green infrastructure was found to support or enhance conservation objectives; trade-off, when it introduced potential conflicts or risks; or no direct relationship, when no clearly identifiable interaction emerged from current knowledge. Cells labelled “synergy/trade-off” indicate context-dependent relationships.

The framework is intended as an interpretative tool rather than a predictive or quantitative model. Its purpose is not to measure the magnitude of interactions, but to clarify how conservation principles can inform green infrastructure planning in urban landscapes with heritage assets and to support future empirical applications.

3. Results

The interpretative matrix (Table 1) highlights recurring patterns in the interactions between green infrastructure planning criteria and conservation principles. The integration of green and grey infrastructure displays the highest number of interactions. Multifunctionality and social inclusion also demonstrate frequent interactions, while connectivity shows fewer direct interactions. The interpretative matrix suggests that synergies may be more frequent than trade-offs, although many interactions remain context-dependent. The results of the cross-analysis are presented below for each conservation principle, focusing on the implications for green infrastructure implementation.

3.1. Knowledge and respect for cultural heritage and its importance

Planning requires explicit analysis of how green infrastructure affects conservation, visual coherence, spatial sequences, and symbolic interpretations of cultural heritage [6], as changes in these aspects may either diminish cultural heritage value or strengthen identity through place attachment and relational engagement with cultural heritage.

3.2. Adequacy of feasibility studies and conservation plans

Integrated analysis of physical, chemical, perceptual, and usage-related interactions between green infrastructure and cultural heritage is required to anticipate material and perceptual impacts, evaluate compatibility, and identify conditions under which multifunctionality can be achieved without compromising heritage conservation [7].

3.3. Use of cultural assets and regular maintenance

Green infrastructure can alter local environmental conditions [11]. Plants and soil may increase moisture levels, induce root stress, and promote biological colonisation, intensifying deterioration mechanisms [12]. At the same time, they can reduce exposure to solar radiation, wind, and rain, moderating temperature and moisture fluctuations and exerting a protective influence on built surfaces. As a result, green infrastructure may either reduce or increase maintenance requirements.

3.4. Prevention

Preventive conservation requires that green infrastructure interventions are preceded by a systematic assessment of potential risks to cultural heritage assets. This includes evaluating the effects of plants, soil, and water on material stability, microclimatic conditions, and long-term degradation processes. Prevention should therefore be implemented through early-stage risk assessment and the integration of mitigation strategies into the design of green infrastructure.

3.5. Maintenance of authenticity and integrity

Green infrastructure implementation may lead to the introduction of elements not originally associated with cultural heritage assets, which can alter perceptual coherence, the legibility of cultural heritage assets, and the meanings linked to the asset's original intent. However, research in cultural heritage conservation shows that green infrastructure elements, when designed in continuity with the cultural character of a place, can also support the recovery of lost cultural patterns and strengthen the visual attributes that support authenticity [7].

3.6. Collective and transparent decision-making process/Community involvement and public interest

Both cultural heritage conservation and green infrastructure implementation require decision-making processes based on stakeholder involvement and transparent evaluation of public interest. Research in cultural heritage conservation has shown that conservation outcomes are improved when local communities, technical experts, and institutional actors contribute to defining values, assessing impacts, and identifying acceptable forms of change [13]. Studies on green infrastructure implementation have similarly shown that inclusive and participatory processes enhance acceptability, improve long-term stewardship, and support more resilient ecological solutions [14].

3.7. Minimum intervention

The principle of minimum intervention requires that green infrastructure is designed to limit additional stress on cultural heritage and, therefore, the need for additional maintenance operations. This principle is closely related to preventive approaches.

3.8. Caution in design

Cautious design requires systematic assessment of ecological processes that influence the stability and legibility of cultural heritage. Diagnostic analysis and environmental modelling are necessary to evaluate the impacts of green infrastructure, ensuring it does not cause material degradation, reduce visibility, disrupt spatial sequences, or compromise the understanding of cultural heritage assets.

3.9. Compatibility of proposals

When supported by historical documentation and adequate assessment, green infrastructure can be compatible with cultural heritage conservation and can support heritage value by reinstating spatial structures and design intentions associated with the historic landscape [7]. Ensuring compatibility requires careful selection of plant species and substrates, with priority given to native plants to maintain ecological and cultural coherence. In addition, attention to plant traits (e.g. root traits) and ecological processes is essential to avoid adverse interactions with historic materials.

3.10. Reversibility of interventions

Reversibility of green infrastructure elements should be ensured when vulnerable cultural heritage assets are present. Modular planting units, controlled rooting environments, and independent supports limit physical and chemical interactions and allow safe removal when required. In such contexts, lightweight greening solutions that restrict root development and substrate load provide ecological functions without compromising material stability.

3.11. Multidisciplinarity

Cultural heritage conservation demands expertise to address material, spatial, and social complexity, while green infrastructure planning requires knowledge of ecosystem service provision and ecological attributes. Effective integration of the two fields depends on coordinated work among conservation specialists, landscape ecologists, botanists, and urban planners to ensure ecological functions and heritage values are jointly assessed within a coherent framework.

3.12. Effectiveness

Ecological processes evolve over time and interact with heritage materials in ways that are not fully predictable. Ensuring effectiveness therefore requires defining performance objectives in advance and establishing systematic monitoring to track interactions between green infrastructure and cultural heritage assets.

3.13. Accessibility and inclusion

Green infrastructure can enhance accessibility and inclusion by improving circulation, spatial legibility, and overall usability of cultural heritage assets. Evidence indicates that exposure to connected and walkable green infrastructure elements supports increased pedestrian movement and facilitates more equitable access for diverse users, as greener and more walkable routes are preferentially used in urban mobility patterns [15].

4. Discussion

In this study, cultural heritage is regarded as a pre-existing component of the urban landscape, whose conservation imposes constraints on spatial transformations. Planning green infrastructure in urban landscapes in accordance with cultural heritage conservation principles not only enables coexistence but can also support cultural heritage values, as well as the social acceptability and cultural ecosystem services associated with green infrastructure. This suggests that planning approaches should move beyond constraint-based interpretations of heritage and instead adopt conservation-informed design strategies that actively integrate heritage values into green infrastructure planning.

All four green infrastructure planning criteria can be interpreted in relation to cultural heritage conservation principles, though with varying frequency. The integration of green and grey infrastructure is the criterion most frequently interpreted in relation to cultural heritage conservation principles, due to its direct relevance to material compatibility, physical integrity, and long-term conservation requirements. Multifunctionality and social inclusion are also frequently interpreted in relation to cultural heritage conservation principles, as both criteria relate to the provision of cultural ecosystem services and patterns of use, while introducing pressures related to maintenance, compatibility, and intensity of use. Connectivity is less frequently interpreted in relation to cultural heritage conservation principles, yet it plays an important role in the use of both green infrastructure and cultural heritage. The lower frequency of interactions between conservation principles and connectivity may reflect the more indirect nature of connectivity-related interactions, which are mediated through spatial configuration, movement patterns, and user experience rather than direct material or conservation processes.

The higher frequency of synergies compared to trade-offs suggests that the presence of cultural heritage assets does not inherently limit green infrastructure implementation but rather calls for planning approaches grounded in conservation-oriented principles and contextual assessment. Importantly, our findings shift the focus from identifying constraints to understanding the conditions under which synergies can be achieved, highlighting the role of material choices and spatial configuration in shaping outcomes. The trade-offs identified depend on the characteristics and implementation modalities of green infrastructure, rather than on intrinsic incompatibilities between green infrastructure and cultural heritage.

A key direction for future research is the translation of existing knowledge about interactions between green infrastructure and cultural heritage into planning insights. The effects of environmental and ecological processes linked to green infrastructure elements on cultural heritage assets are well established but are rarely interpreted in relation to the spatial and functional attributes of urban landscapes. Our study calls for a shift from identifying interactions to interpreting them in planning terms, which requires knowledge of how interactions vary with the spatial configuration and composition of green infrastructure elements, as well as with the characteristics and vulnerability of cultural heritage assets.

While the proposed framework offers an interpretation of interactions between green infrastructure and cultural heritage, it remains primarily conceptual. Furthermore, the framework does not yet differentiate interactions by specific heritage typologies, ecological conditions, or climatic contexts. Empirical validation across diverse urban contexts will be essential to assess the robustness and transferability of the framework and to support its application in planning practice.

5. Conclusions

The framework presented in our study addresses a critical gap in current urban planning approaches by demonstrating that cultural heritage can inform planning choices and enhance cultural ecosystem services. This is particularly relevant in Europe, where cultural heritage assets are widely distributed across urban landscapes and often intersect with areas targeted for green infrastructure implementation. Our framework adopts a context-sensitive approach to assess the potential for establishing a shared understanding of the integrated system of green infrastructure and cultural heritage, maximising the benefits of green infrastructure implementation while minimising potential risks to cultural heritage assets. Grounded in conservation-oriented principles and multidisciplinary collaboration, our approach is intended to foster more culturally informed green infrastructure strategies.

CRediT authorship contribution statement

Elisabetta Zendri: Writing – original draft, Investigation, Funding acquisition, Conceptualization. **Edy Fantinato:** Writing – original draft, Investigation, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

[1] Hansen R, Rall E, Chapman E, et al. Urban green infrastructure planning: a guide for practitioners. Green Surge. 2017.
[2] Hoover FA, Meerow S, Coleman E, et al. Why go green? Comparing rationales and planning criteria for green infrastructure in U.S. city plans. Landscape Urban Plan 2023;237:104781. https://doi.org/10.1016/j.landurbplan.2023.104781.
[3] Li F, Liu X, Zhang X, et al. Urban ecological infrastructure: an integrated network for ecosystem services and sustainable urban systems. J Clean Prod 2017;163: S12–8. https://doi.org/10.1016/j.jclepro.2016.02.079.
[4] McKinney ML, VerBerkmoes A. Beneficial health outcomes of natural green infrastructure in cities. Curr Landsc Ecol Rep 2020;5:35–44. https://doi.org/10.1007/s40823-020-00051-y.
[5] Moreno-García P, Savage A, Salgado AL, et al. The effects of urbanization on species interactions. Nat Cities 2025;2:693–702. https://doi.org/10.1038/s44284-025-00288-w.
[6] Liu L, Palaiologou F, Schmidt-III R. Green Infrastructure morphology: integrating urban morphological perspectives for sustainable urban development. J Urban Manag 2025;14:1231–52. https://doi.org/10.1016/j.jum.2025.05.004.
[7] Taylor K, Lennon J. Cultural landscapes: a bridge between culture and nature? Int J Herit Stud 2011;17:537–54. https://doi.org/10.1080/13527258.2011.618246.
[8] Graham B, Ashworth GJ, Tunbridge JEA. A geography of heritage: power, culture and economy. London: Arnold; 2000.
[9] Bandarin F, van Oers R. Reconnecting the City: the historic urban landscape approach and the future of urban heritage. Chichester: Wiley-Blackwell; 2015.
[10] Icomos. European quality principles for EU-funded interventions with potential impact upon Cultural Heritage. Paris: ICOMOS; 2020.
[11] Camuffo D. Microclimate for cultural heritage. 3rd ed. Amsterdam: Elsevier; 2019.
[12] Viles HA. Microbial geomorphology: a neglected link between life and landscape. Geomorphology. 2012;157–158:6–16. Doi: 10.1016/j.geomorph.2011.03.021.
[13] Aas C, Ladkin A, Fletcher J. Stakeholder collaboration and heritage management. Ann Tour Res 2005;32:28–48. https://doi.org/10.1016/j.annals.2004.04.005.
[14] Reed MS. Stakeholder participation for environmental management: a literature review. Biol Conserv 2008;141:2417–31. https://doi.org/10.1016/j.biocon.2008.07.014.
[15] Marquet O, et al. GPS-based activity space exposure to greenness and walkability is associated with increased accelerometer-based physical activity. Environ Int 2022; 165:107317. https://doi.org/10.1016/j.envint.2022.107317.