Criteria for defining ‘streets suitable for tree planting’: a model applied to Matosinhos and Leça da Palmeira (Portugal)

Paulo FARINHA-MARQUES
Department of Geosciences, Environment and Spatial Planning, Faculty of Sciences of University of Porto, Porto, Portugal, pfmarque@fc.up.pt

José Miguel LAMEIRAS
Department of Geosciences, Environment and Spatial Planning, Faculty of Sciences of University of Porto, Porto, Portugal, jmlameiras@fc.up.pt

Manuel Gentil REBELO
Department of Geosciences, Environment and Spatial Planning, Faculty of Sciences of University of Porto, Porto, Portugal, manuel.rebelo@fc.up.pt

Abstract

Urban tree planting is a key strategy for enhancing environmental resilience, public space quality, and climate change adaptation. Street trees contribute to urban microclimate regulation, air quality improvement, and stormwater management, while also fostering aesthetic and social benefits. However, spatial constraints and competing urban functions often limit opportunities for their systematic integration. Ensuring tree planting aligns with pedestrian accessibility, emergency corridors, and existing infrastructure requires a structured planning approach.

This study presents a model for identifying ‘streets suitable for tree planting’ based on spatial and functional criteria, applied to Matosinhos and Leça da Palmeira (Portugal). The model assesses key parameters such as street width, tree spatial requirements, and compatibility with essential functions, providing a strategic tool for prioritizing street tree planting efforts. This research underscores the necessity of incorporating street trees as a core urban infrastructure, rather than introducing them secondarily after other functions have been accommodated.

A spatial analysis of approximately 124 km of streets revealed that 50% of the street network meets the criteria for structured tree planting, balancing tree placement with pedestrian and emergency vehicle access. Of these, 27.2 km currently lack trees, highlighting significant potential for expanding green infrastructure. Even streets that do not fully meet the model’s criteria may accommodate trees under specific conditions, such as localized widenings, building setbacks, or adjacency to open spaces that create planting opportunities.

While challenges remain, including spatial conflicts and species selection constraints, the model emphasizes the importance of optimizing tree size and location for greater ecological return. Species adapted to local conditions and space-efficient planting strategies are essential in more constrained settings.

By identifying and mapping suitable streets, this approach supports more efficient resource allocation, fosters interdepartmental collaboration, and enhances decision-making. It provides a replicable framework for integrating trees as fundamental components of resilient and sustainable urban environments.

Keywords

Street trees, public space, spatial planning, urban green infrastructure, urban ecosystem.

Introduction

Urban trees are essential components of city infrastructure, offering a wide range of ecosystem services that support human and environmental well-being. The scientific literature (e.g. Nowak & Dwyer, 2007; Salmond et al., 2016; Tyrväinen et al., 2005) shows that: 1) trees contribute to a comfortable urban microclimate by providing shade and releasing moisture through evapotranspiration, thus reducing the heat island effect; 2) they improve air quality by capturing airborne pollutants and producing oxygen, and mitigate stormwater runoff by intercepting precipitation and increasing soil infiltration; 3) they promote biodiversity by providing habitat for wildlife in urban settings, and contribute to urban ecological connectivity; 4) trees enhance mental health and well-being, reduce stress, and encourage social interaction in public space; 5) their presence in streets enhances the aesthetic and experiential qualities of urban environments, and they also promote active mobility by improving walking conditions and offering shade, comfort, and a sense of place. Thus, urban tree planting is a vital strategy for enhancing urban resilience, mitigating climate change impacts, and improving quality of life in cities. However, despite the benefits trees offer in urban environments, spatial constraints and competing urban functions often limit the opportunities for integrating trees systematically into street networks.

A street can be defined as a public linear space within the urban fabric that strongly influences the function, morphology, and character of cities (Farinha-Marques et al., 2021; Lamas, 2000). Streets are multifunctional public spaces that primarily facilitate circulation between different urban areas, providing access to both public and private spaces. Beyond human and vehicular flows, streets also support natural flows such as wind, water, and biodiversity. Infrastructures for essential urban services like drainage, sanitation, and lighting are often embedded within them. Unlike highways or railways, which exclude pedestrian presence, streets maintain a public and multifunctional character (Cowan, 2005; Department for Transport, 2007), making them key areas for social interaction and environmental enhancement.

Streets are typically bounded by private urban spaces, most commonly buildings, and in some cases by adjacent open spaces such as parks, squares, or gardens. Being a linear element, the primary constraint in street multifunctionality is spatial – width becomes a determining factor in whether a street can effectively support tree planting along with essential circulation functions (Farinha-Marques et al., 2021). The successful integration of trees into the urban streetscape requires a careful approach that balances ecological goals with functional street requirements (Farinha-Marques et al., 2022).

To achieve sustainable and impactful urban tree planting, a structured planning approach is necessary. This approach must reconcile the spatial requirements of healthy tree growth with essential street functions. Without such integration, tree planting initiatives may result in conflicts, underperformance, or premature tree loss due to poor site conditions or maintenance challenges. This paper introduces a model for identifying ‘streets suitable for tree planting’, based on the concept of the ‘minimum street tree’ and its inherent spatial needs.

The study explores how the spatial requirements of this ‘minimum street tree,’ when considered alongside essential street functions, determine the minimum street width necessary for effective and sustainable street tree planting.

Methodology

The methodology is based on a functional and spatial analysis of the street environment, focusing on reconciling the three key elements of a tree-lined street: pedestrian circulation, emergency vehicle access, and viable street trees. Therefore, ‘streets suitable for tree planting’ are defined as those that can accommodate systematic and structural tree planting by providing sufficient spatial conditions for the survival of, at least, the ‘minimum street tree’, without compromising the essential circulation functions of the street, namely pedestrian and emergency vehicle circulation (Farinha-Marques et al., 2021).

Streets must guarantee adequate space for pedestrian movement along the edges of the street. We recommend a minimum width of 2 m for each pedestrian corridor to ensure the safe crossing of wheelchairs and/or baby strollers, while also enhancing social life and quality of life on the sidewalk (Department for Transport, 2021). A corridor for the circulation and operation of emergency vehicles should also be safeguarded, with a recommended minimum width of 6 m and clear height of 4 to 5 m (Portaria n.° 135/2020, de 2 de Junho), which guarantees the unobstructed circulation of a large emergency vehicle.

The ‘minimum street tree’ is defined as the smallest tree, at 20-30 years of age, considered viable for providing meaningful ecosystem services in a street environment (Farinha-Marques et al., 2021). For the specific context of Northwestern Portugal, based on the literature and the recent developments of narrow tree varieties in nurseries, the ‘minimum street tree’ is based on the following spatial characteristics:

- Minimum expected height of 12 m (after 20-30 years), capable of forming a clean bole of at least 4 m, to avoid interfering with circulation, and corresponding 8 m canopy (ratio of ⅓ bole to ⅔ canopy) to optimize ecological performance.
- Narrow and/or columnar canopy, with potential growth up to 4 m wide, to reduce competition for space.

To maximize the viability of the tree, several spatial requirements should be considered, regarding its establishment in the street. We recommend that the dimension and positioning of the tree ensures a minimum distance from the canopy to building façades or property lines of, at least, 1 m, to minimize pruning and other maintenance operations, which will have positive impacts on tree survival and on budget allocation. Likewise, we recommend that the trees are planted in permeable strips or tree pits with at least 2 m, for the ‘minimum street tree’, to enhance soil volume and improve root health.

The minimum street width for ‘streets suitable for tree planting’, here determined as 10 m, was calculated by considering the spatial needs of the ‘minimum street tree’ in conjunction with the essential circulation functions of the street, as illustrated in Figure 1. Streets narro-

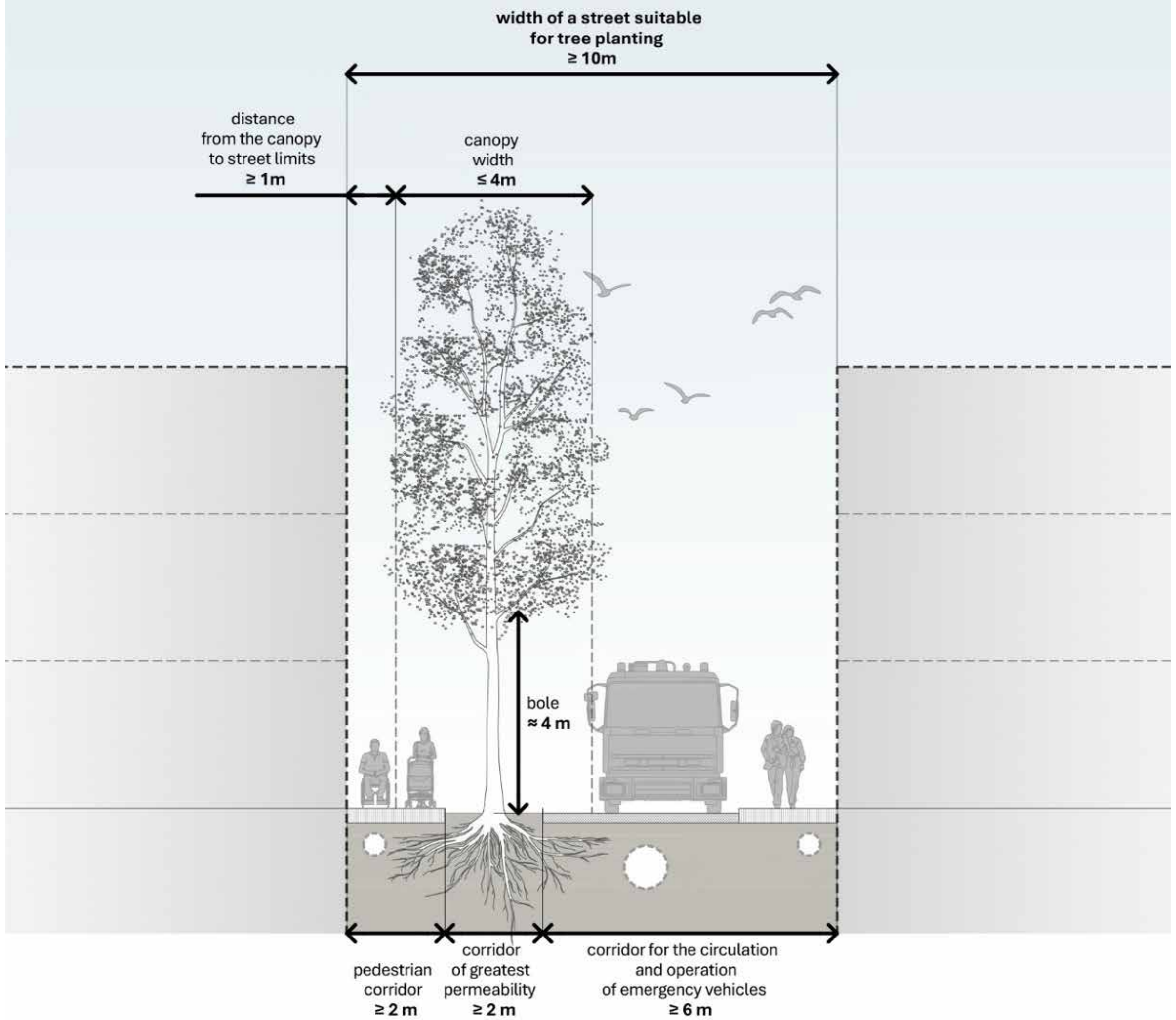

Figure 1. Representation of the minimum street suitable for tree planting.

wer than 10 m are classified as 'not suitable for tree planting' under the systematic and structural approach of this study due to conflicts between these essential functions and the presence of the 'minimum street tree'.

This approach guided the analysis of the study area of Matosinhos and Leça da Palmeira, in Portugal, regarding the suitability of its streets to accommodate trees. These civil parishes are located in the Municipality of Matosinhos, a coastal city in Northern Portugal, where the proximity of the Atlantic Ocean highly influences its predominantly mediterranean temperate climate (Figure 2).

Using the cartographic databases provided by the Municipality of Matosinhos, the width was measured for 124 km of streets, in a GIS environment. Main roads, highways and railways were not considered in this study, due to their exclusion of pedestrian traffic; tunnels, viaducts and bridges have also not been included, due to their restrictions for the occurrence of trees.

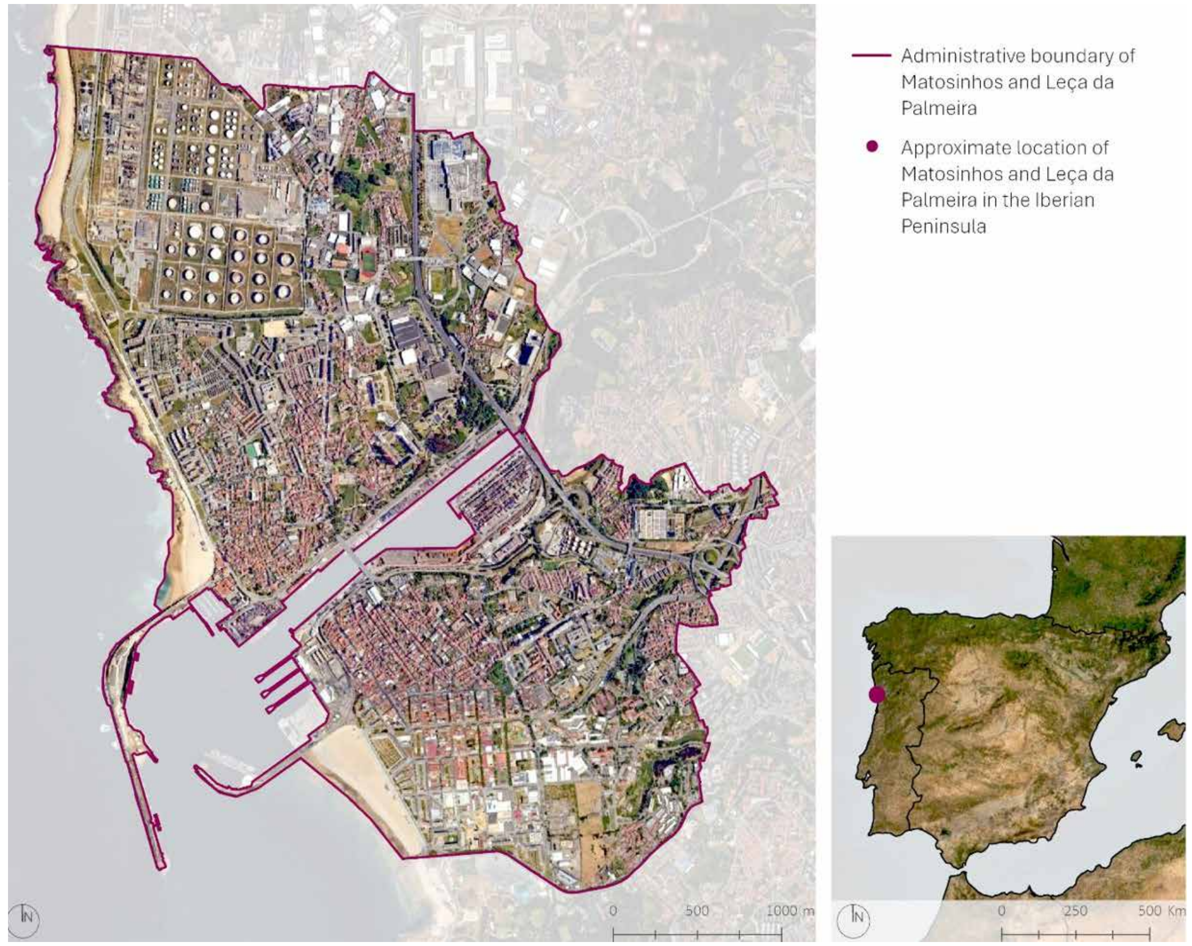

Figure 2. Study area.

Results

This approach identified 62.3 km of 'streets suitable for tree planting', which is equivalent to around half of the existing streets (Figure 3). In these streets, it is possible to make the presence of street trees compatible with the existence of an emergency corridor suitable for large rescue vehicles, and a pedestrian corridor accessible to people with reduced mobility, without compromising either function.

In 33.4 km, corresponding to 26.9% of the streets in the study area (Figure 3), it will not be possible to articulate street tree planting in a systematic and structural way, while complying with the minimum dimensions previously stipulated for these three elements (street tree, emergency corridor and pedestrian corridor). However, in these streets that were considered as 'not suitable for tree planting', the presence of trees may be allowed in exceptional cases, subject to a detailed analysis of the conditions of each site. Examples of such exceptional situations include facade setbacks, localized street widenings or intersections with other streets that increase the available width and allow for tree planting without compromising accessibility or circulation.

Streets associated with public open spaces (28.2 km, 22.8% of the streets; Figure 3) are

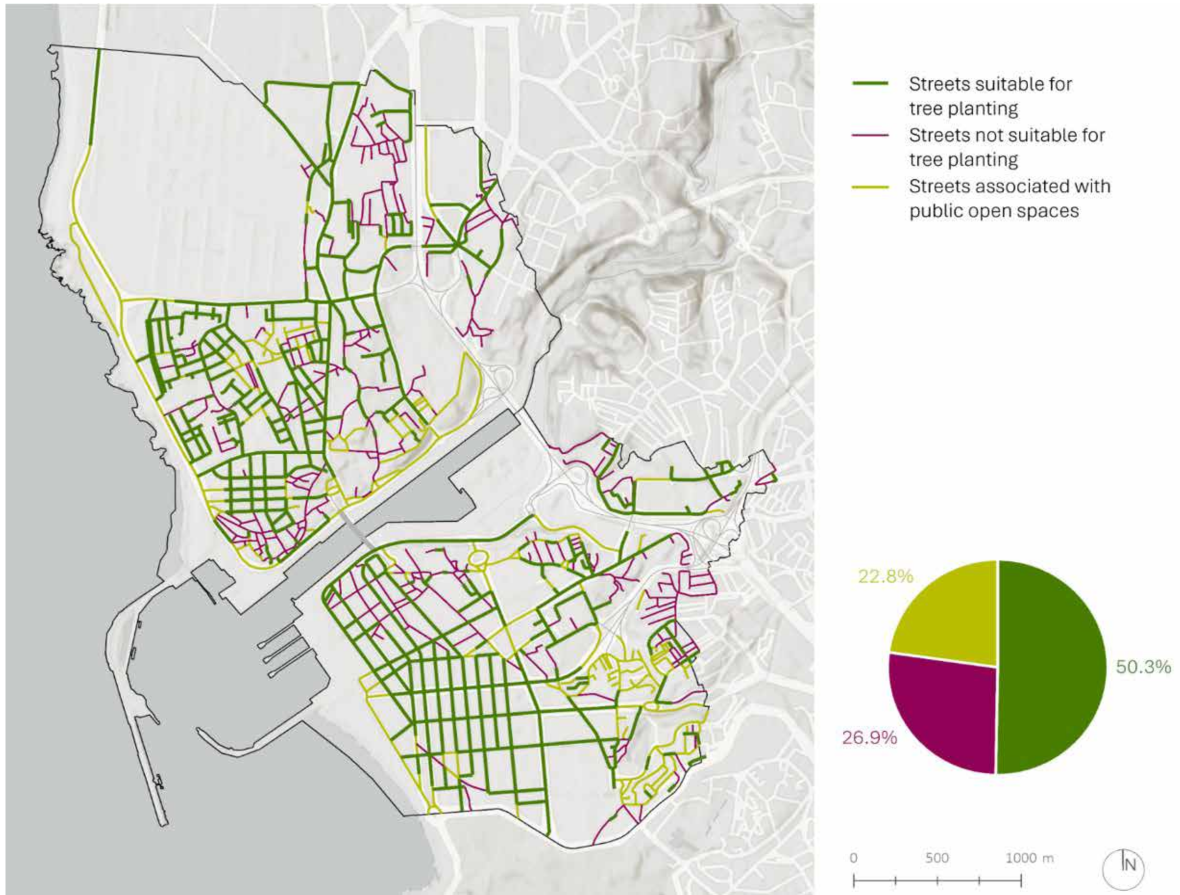

Figure 3. Streets suitable for tree planting.

excluded from this approach, since the opportunity introduced by the presence of the open space, as well as the possible presence of trees in the open space, will influence the space available for street tree planting. In these particular cases, tree planting on the street, as well as in the open space, will have to be planned case-by-case in order to be optimally adapted to the specific characteristics of each site.

Focusing only on the 'streets suitable for tree planting', around 35.1 km are already occupied by trees (Figure 4). This means that approximately 27.2 km of streets still offer the opportunity for systematic tree planting in Matosinhos and Leça da Palmeira (Figure 4). This significant potential underscores the value of a structured approach to maximize green infrastructure.

Discussion

The identification and mapping of 'streets suitable for tree planting' offer a strategic advantage for urban planning in Matosinhos and Leça da Palmeira. By assessing street width across the network, the municipality can prioritize interventions in areas with the highest potential for successful tree establishment and ecosystem service provision. This targeted approach enhances the efficiency of resource allocation and project implementation.

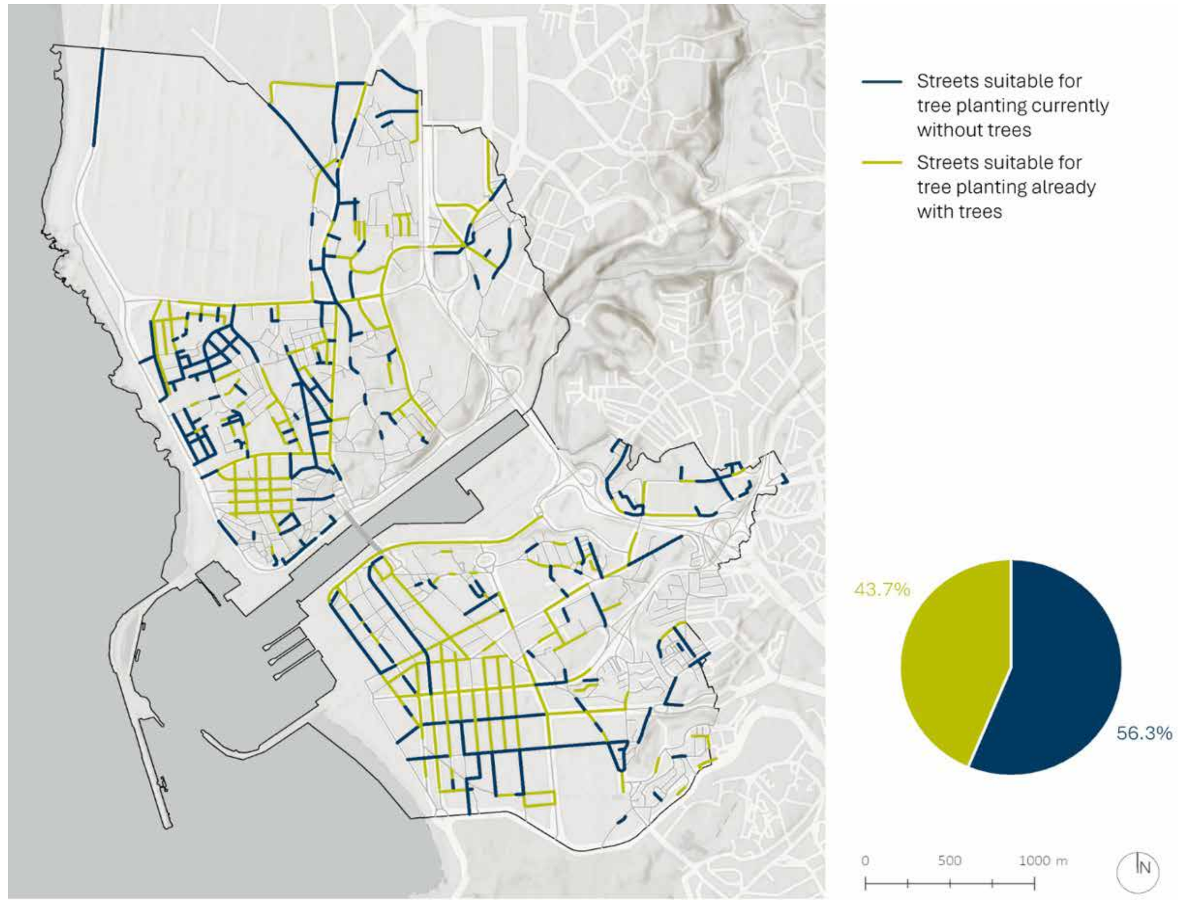

Figure 4. Streets suitable for tree planting, according to the current existence of trees.

The concept of the 'minimum street tree' provides a practical foundation for establishing spatial guidelines that balance biological viability with urban functionality. By specifying minimum canopy and bole dimensions, the model helps avoid the frequent mistake of planting undersized trees that fail to deliver meaningful ecosystem services. Moreover, the explicit correlation between street width and tree size highlights the importance of maximizing tree dimensions within the available space, as larger trees tend to offer significantly greater ecological and social benefits.

The 10 m threshold reflects the fundamental spatial trade-offs inherent in street design. The allocation of space for pedestrian corridors and emergency vehicle access directly impacts the available space for tree planting. It also reflects the importance of proactively planning for trees as infrastructural elements rather than retrofitting them into leftover spaces.

Nonetheless, it is crucial to acknowledge that urban conditions are highly variable. In certain scenarios, even streets narrower than 10 m may accommodate trees through design adaptations. Localized street widening or building setbacks can enable tree planting in constrained environments. This flexibility is essential in historical areas or dense urban fabrics where street dimensions are very limited. The presence of adjacent open spaces also introduces opportunities to extend tree canopy coverage beyond the street itself. Where public gardens, squares, or corridors are present, tree planting strategies should be integrated across the broader public realm to maximize ecological and social benefits.

Species selection is another critical factor, as street trees must adapt to local conditions. For example, in Matosinhos and Leça da Palmeira, species must be resilient to coastal winds, high humidity, and occasional salinity. Choosing resilient trees that are tolerant to pollution and capable of thriving in compacted soils is crucial for the long-term success of planting initiatives in streets. Narrow or columnar species are particularly valuable in space-constrained streets, where lateral canopy spread must be limited.

Moreover, spatial planning must consider the lifecycle of the tree. Tree pits and root zones must be designed to accommodate growth over decades. Soil volume, permeability, and access to water and nutrients are essential for healthy root development and canopy growth. In this regard, coordinated efforts between urban planners, arborists, landscape architects, and civil engineers are key.

The spatialization of results facilitates communication and collaboration among professionals from different disciplines. Visualizing which streets are suitable for tree planting helps identify patterns, constraints, and opportunities, supporting more informed decision-making. This contributes to the integration of green infrastructure into broader urban planning efforts, reinforcing the importance of cross-sectoral coordination in developing resilient and liveable cities.

Conclusion

This study presents a spatial model for identifying streets suitable for tree planting, grounded in the concept of the 'minimum street tree' and the functional requirements of the urban street. The model establishes a 10-meter minimum width threshold for structured, long-term street tree integration, providing a valuable framework for urban planners and decision-makers.

The application of this model to the study area of Matosinhos and Leça da Palmeira demonstrates its practical relevance. With approximately 50% of the local street network deemed suitable for tree planting, significant opportunities exist to enhance green infrastructure, improve urban liveability, and increase climate resilience.

Ultimately, this research contributes to a broader understanding of how to integrate trees as fundamental elements of urban infrastructure. By aligning ecological goals with spatial realities, the approach supports the creation of healthier, more sustainable, and more liveable cities.

Acknowledgements: This work was developed in the scope of "Plano de Arborização de Matosinhos e Leça da Palmeira", a collaboration between the Municipality of Matosinhos and the Faculty of Sciences of the University of Porto.

References

Cowan, R. (2005). The Dictionary of Urbanism. Streetwise Press.

Department for Transport. (2007). Manual for Streets. Thomas Telford Publishing.

Department for Transport. (2021). Inclusive Mobility. A Guide to Best Practice on Access to Pedestrian and Transport Infrastructure. UK Government. Crown copyright

Farinha-Marques, P., Guilherme, F., Fernandes, C., Lameiras, J. M., Rebelo, M. G., Araújo, R., Aguiar Pinto, F., Santiago, J., Monteiro, A., Madureira, H., Valença, M., Moreira, M., & Pacheco, M. (2021). Plano de arborização da cidade do Porto. Caracterização e diagnóstico da situação existente. Faculdade de Ciências da Universidade do Porto. https://sigarra.up.pt/fcup/pt/pub_geral.pub_view?pi_pub_base_id=644474

Farinha-Marques, P., Guilherme, F., Fernandes, C., Lameiras, J. M., Rebelo, M. G., Araújo, R., Aguiar Pinto, F., Santiago, J., Valentim, N., Monteiro, A., Madureira, H., & Valença, M. (2022). Plano de arborização da cidade do Porto. Plano. https://sigarra.up.pt/fcup/pt/pub_geral.pub_view?pi_pub_base_id=644494

Lamas, J. M. (2000). Morfologia urbana e desenho da cidade (2a edição). Fundação Calouste Gulbenkian, Fundação para a Ciência e a Tecnologia.

Nowak, D. J., & Dwyer, J. F. (2007). Understanding the Benefits and Costs of Urban Forest Ecosystems. In Urban and Community Forestry in the Northeast (pp. 25–46). Springer Netherlands. https://doi.org/10.1007/978-1-4020-4289-8_2

Portaria n.o 135/2020, de 2 de Junho, Diário da República, 1.a Série, N.o 107.

Salmond, J. A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., Dirks, K. N., Heaviside, C., Lim, S., MacIntyre, H., McInnes, R. N., & Wheeler, B. W. (2016). Health and climate related ecosystem services provided by street trees in the urban environment. Environmental Health, 15(Suppl 1). https://doi.org/10.1186/s12940-016-0103-6

Tyrväinen, L., Stephan Pauleit, Klaus Seeland, & Sjerp de Vries. (2005). Benefits and Uses of Urban Forests and Trees. In Cecil C. Konijnendik, Kjell Nilsson, Thomas B. Randrup, & Jasper Schipperijn (Eds.), Urban Forests and Trees. Springer.