SUA Slovak University of Agriculture in Nitra
SUA·FHLE Faculty of Horticulture and Landscape Engineering

DOI: 10.2478/ahr-2026-0010
Acta hort regiotec, 29, 2026(1): 80–89

Research Article

Arboreta as Cultural Landscapes: Comparative Analysis of International Case Studies. Towards Guidelines for the Design of New Arboreta

Maria Rudka*[1, 2, 3], Catarina Patoilo Teixeira[1, 2, 3]

[1] *Universidade do Porto, Campus de Vairão, CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Vairão, Portugall*

[2] *Universidade do Porto, Faculdade de Ciências, Departamento de Geociências, Ambiente e Ordenamento do Território, Porto, Portugal*

[3] *Campus de Vairão, BIOPOLIS Program in Genomics, Biodiversity and Land Planning, CIBIO, Vairão, Portugal*

Article Details: Received: 2025-11-16 | Accepted: 2026-03-17 | Available online: 2026-05-31

Arboreta are designed and specialised green spaces that assemble organised living collections of tree and shrub species, dedicated to the conservation of biodiversity, research, education, and public engagement. Despite their recognised importance, the spatial and functional organisation of arboreta remains comparatively underexplored in the literature. This study addresses this gap by analysing how spatial structure supports their multifunctional roles. The main research question is: which spatial and organisational patterns characterise internationally recognised arboreta, and how can these inform the design of new ones? The study formulates design-oriented recommendations for arboreta, based on a comparative spatial analysis of ten internationally recognised reference cases. The selected arboreta were identified through their frequency of citation in the literature, ArbNet Level IV accreditation, and founding date listed by BGCI. The methodology follows a comparative case-study approach structured around four analytical axes: general characterisation, spatial and vegetation organisation, accessibility and services, and botanical collection organisation. All arboreta were georeferenced and vectorised within a standardised framework, producing comparable maps and tables that supported the analysis of shared variables. The results reveal consistent spatial and organisational tendencies across cases, alongside contextual specificities. Based on these findings, design recommendations were formulated, providing general guidelines applicable to the planning and design of new arboreta.

Keywords: reference arboreta, biodiversity conservation, scientific research, spatial organization, design recommendations

1 Introduction

Arboreta are designed and specialised green spaces that host curated living collections of trees and shrubs, functioning simultaneously as scientific infrastructures, conservation assets, and cultural landscapes (Cavender & Donnelly, 2019). Unlike botanical gardens, which typically encompass broader plant groups, arboreta focus primarily on woody species and often organise their collections according to ecological, geographic, or taxonomic criteria. As global ecosystems face accelerating pressures (e.g., habitat degradation and fragmentation, climate change, and biodiversity loss), arboreta have gained renewed strategic relevance. They play a strategic and multifunctional role, contributing to ex situ and *in situ* conservation, acting as living gene banks for threatened species, supporting scientific research and education, and providing opportunities for public engagement with nature (Hiscock, Lennon & Young, 2024; BGCI, 2025).

Although their biological and cultural significance is widely acknowledged, the spatial and functional organisation of arboreta remains comparatively underexplored. Existing literature tends to emphasise botanical, horticultural, or conservation perspectives, while offering fewer systematic analyses of how spatial layout (such as vegetation structure, circulation networks, visitor services, and botanic collections organisation) supports their mission (Heywood, 2017; Miller et al., 2016).

***Corresponding Author:** Maria Rudka, CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Campus de Vairão, Universidade do Porto, 4485-661 Vairão, Portugal e-mail: mariarudka.ap@gmail.com

In recent years, scientific literature has shown a gradual increase in publications specifically dedicated to arboreta and their roles (Teixeira & Ferreira, 2025). At the same time, new arboreta continue to be established worldwide, either as independent institutions or as extensions of botanical gardens (BGCI, 2025), reinforcing the need to understand how these spaces are conceptually framed and spatially organised. Examining consolidated international examples offers insight into the spatial principles that support conservation, research, education and recreation.

Building on this need, this article analyses ten internationally recognised reference arboreta to identify recurring spatial patterns and organisational principles. These findings are synthesised into design recommendations intended to inform the development of new arboreta in diverse contexts. The central research question guiding this work is: which spatial principles support the multifunctional role of arboreta, and how can these inform the design of new arboreta?

2 Material and Methods

2.1 Research Approach

This study adopts a comparative case-study methodology, commonly used in design-oriented and landscape architecture research (Francis, 1999; Francis, 2001; Meireles, 2015; Kaya, 2022). This approach enables the systematic examination of established arboreta to identify spatial patterns, organisational logics, and design strategies applicable to new arboretum projects. The methodological workflow is summarised in Figure 1.

2.2 Case Study Selection

Ten internationally recognised arboreta were selected through a multi-stage process. An initial pool of 52 arboreta worldwide was identified according to three criteria:

1. Frequency of citation in international literature (Teixeira & Ferreira, 2025).
2. ArbNet Level IV accreditation, the highest standard for arboretum management and research (ArbNet, 2025).
3. Founding date prior to 1910, according to BGCI (2025) records, ensuring institutional maturity.

From this initial dataset, ten arboreta were ultimately retained based on the availability and clarity of spatial data and the representativeness of their size and information quality. As a result, not all selected cases strictly meet all three criteria, which were used primarily to guide the initial identification of reference arboreta. Their geographic distribution is shown in Figure 2.

2.3 Data Sources and Spatial Processing

Data were gathered from ArbNet and BGCI databases (ArbNet, 2025; BGCI, 2025), official institutional sources, and the websites of each arboretum. Satellite imagery (Google Earth Pro; Google Maps) was used to verify spatial accuracy across cases. Institutional maps were georeferenced and vectorised into a standardised format to allow direct comparison. Spatial measurements were performed in AutoCAD, while diagrams and masterplans were produced in Adobe Illustrator to ensure graphical consistency. This workflow ensured methodological consistency and enabled both quantitative and qualitative interpretation of spatial structures and functional elements.

2.4 Variables of Analysis

This analytical structure builds upon the framework originally developed in Rudka (2025). The comparative evaluation was structured around four analytical dimensions:

1. General characterisation: location, foundation year, area, number of species, governance, and access regime.
2. Spatial structure and vegetation organisation: land-use categories (dense forest, open to sparse forest, clearings, path network and paved areas, buildings and water features) and permeability.

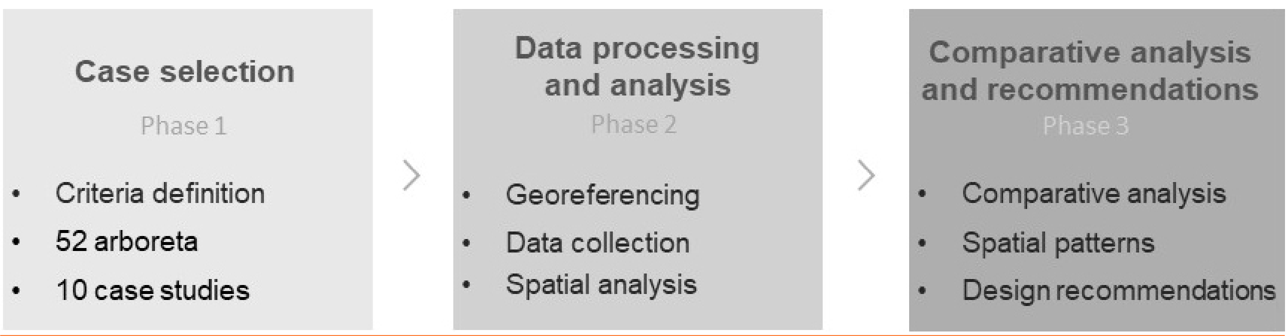


Figure 1 Methodological workflow of the study

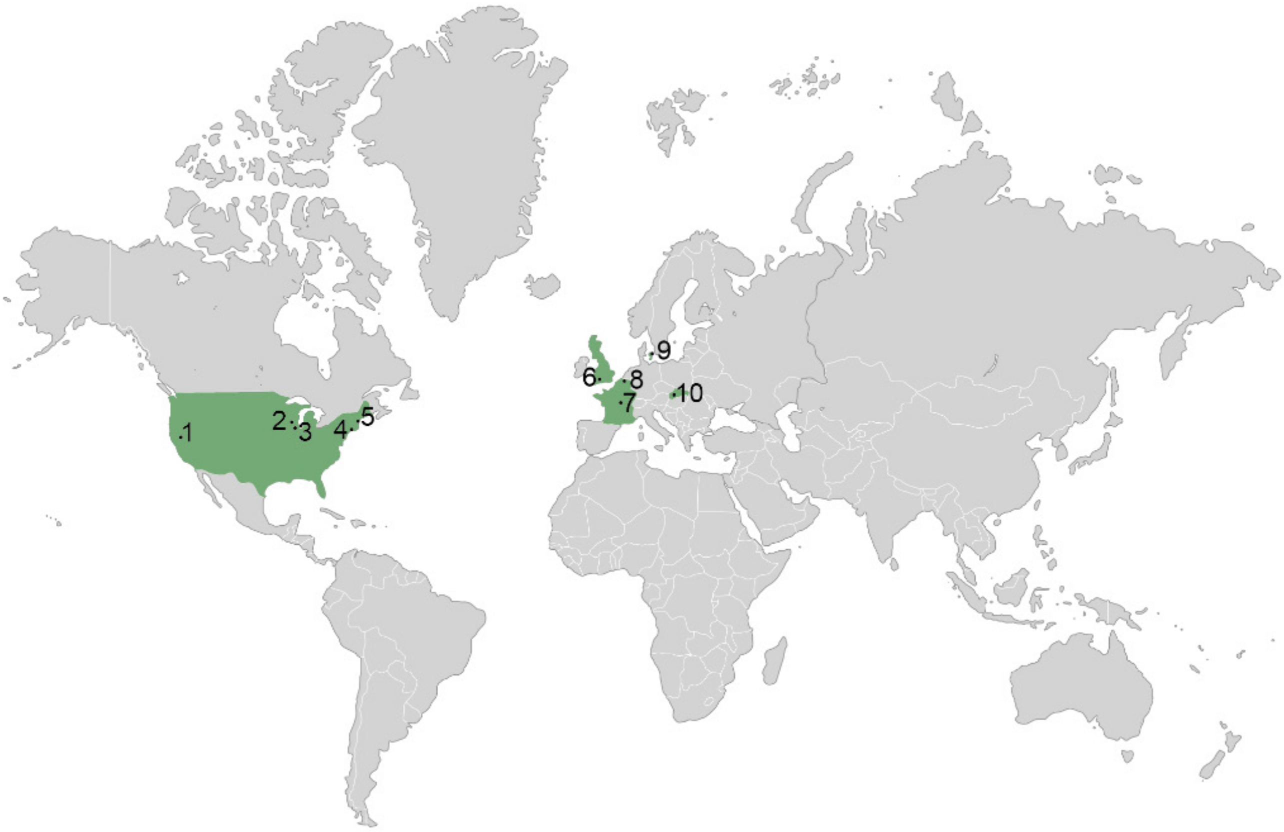


Figure 2 Geographic distribution of the ten selected arboreta
1 – UC Davis Arboretum and Public Garden; 2 – University of Wisconsin – Madison Arboretum; 3 – The Morton Arboretum; 4 – Bayard Cutting Arboretum; 5 – Arnold Arboretum of Harvard University; 6 – Westonbirt, The National Arboretum; 7 – L'Arboretum National des Barres; 8 – Geografisch Arboretum Tervuren; 9 – Hørsholm Arboretum; 10 – Arborétum Mlyňany

3. Accessibility and services: number and distribution of entrances, path hierarchy, 5, 10, 15 and>15 minute pedestrian accessibility ranges, and service distribution.
4. Botanical collection logic: taxonomic, geographical, biome-based, and ornamental principles of organisation.

2.5 Analytical Procedures

The analysis combined quantitative measurements (land-use areas, species richness, circulation hierarchy, accessibility metrics) with qualitative assessments (spatial pattern interpretation, circulation logic, and typological comparison of collection organisation). Each arboretum was analysed individually and subsequently compared to identify recurring strategies, which were synthesised into design-oriented recommendations (Francis, 1999; Meireles, 2015).

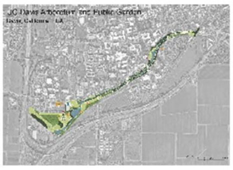
3 Results

3.1 Analysis and Comparison Between Selected Arboreta

3.1.1 General Characterisation

The selected arboreta show wide variation in size, species richness, governance, and access regimes (Figure 3). Differences in size and collection breadth (Figures 4 and 5) range from compact and linear areas embedded with university campuses (e.g., UC Davis, 33 ha) to extensive and multi-sector examples such as Wisconsin (658 ha). Species richness does not correlate directly with area: some large arboreta maintain comparatively modest collections (e.g., Tervuren, ~700 species). Nevertheless, the largest institutions, such as Morton and Wisconsin, exceed 4,000 taxa. These contrasts reflect divergent institutional missions, curatorial priorities, and historical trajectories.

Governance models also vary (academic institutions, governmental agencies, non-profit organisations, and hybrid structures), thus directly influencing access regimes: university-based arboreta are generally free, while national or foundation-run sites generally require

UC Davis Arboretum and Public Garden	University of Wisconsin-Madison Arboretum	Morton Arboretum	Bayard Cutting Arboretum	Arnold Arboretum of Harvard University
Location: Davis, California, USA **Founded**: 1936 **Area**: 33 ha **Species**: 2500 **Governance**: National government + academia (University of California) **Access**: Year-round, free	**Location**: Madison, Wisconsin, USA **Founded**: 1934 **Area**: 658 ha **Species**: 5000 **Governance**: Academia (University of Wisconsin) **Access**: Year-round, free	**Location**: Lisle, Illinois, USA **Founded**: 1922 **Area**: 545 ha **Species**: 4100 **Governance**: Non-profit organisation **Access**: Year-round, paid admission (15.35 €)	**Location**: Great River, Long Island, New York, USA **Founded**: 1887 **Area**: 64 ha **Species**: 350 **Governance**: Local government **Access**: Open year-round, paid admission (6.82 €)	**Location**: Boston, Massachusetts, USA **Founded**: 1872 **Area**: 118 ha **Species**: 2147 **Governance**: Academia (University of Harvard) **Access**: Year-round, free
				

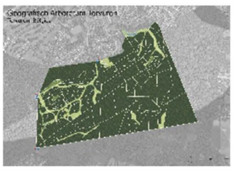
Westonbirt, The National Arboretum	L'Arboretum National des Barres	Geografisch Arboretum Tervuren	Hørsholm Arboretum	Arborétum Mlyňany
Location: Tetbury, England, United Kingdom **Founded**: 1829 **Area**: 240 ha **Species**: 2500 **Governance**: National government (Forestry England) **Access**: Year-round, paid admission (13.87 €)	**Location**: Nogent-sur Vernisson, France **Founded**: 1873 **Area**: 42 ha **Species**: 2600 **Governance**: National government **Access**: Seasonal, paid admission (5 €)	**Location**: Tervuren, Bélgium **Founded**: 1902 **Area**: 308 ha **Species**: 700 **Governance**: Non-profit organisation **Access**: Year-round, free	**Location**: Hørsholm, Denmark **Founded**: 1936 **Area**: 38 ha **Species**: 2000 **Governance**: Academia (University of Copenhagen) **Access**: Year-round, free	**Location**: Vieska nad Žitavou, Slovakia **Founded**: 1892 **Area**: 66 ha **Species**: 2000 **Governance**: Academia (Slovak Academy of Science **Access**: Open year-round, paid admission (5 €)
				

Figure 3 General characterisation of the ten selected arboreta, including their masterplans

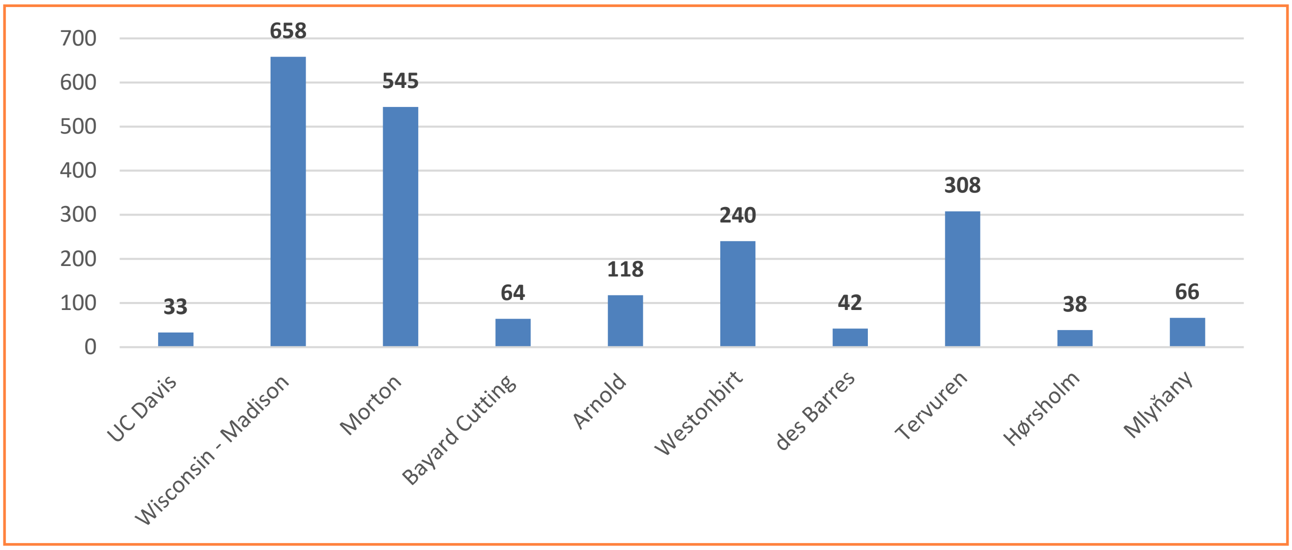


Figure 4 Size of the selected arboreta (ha)

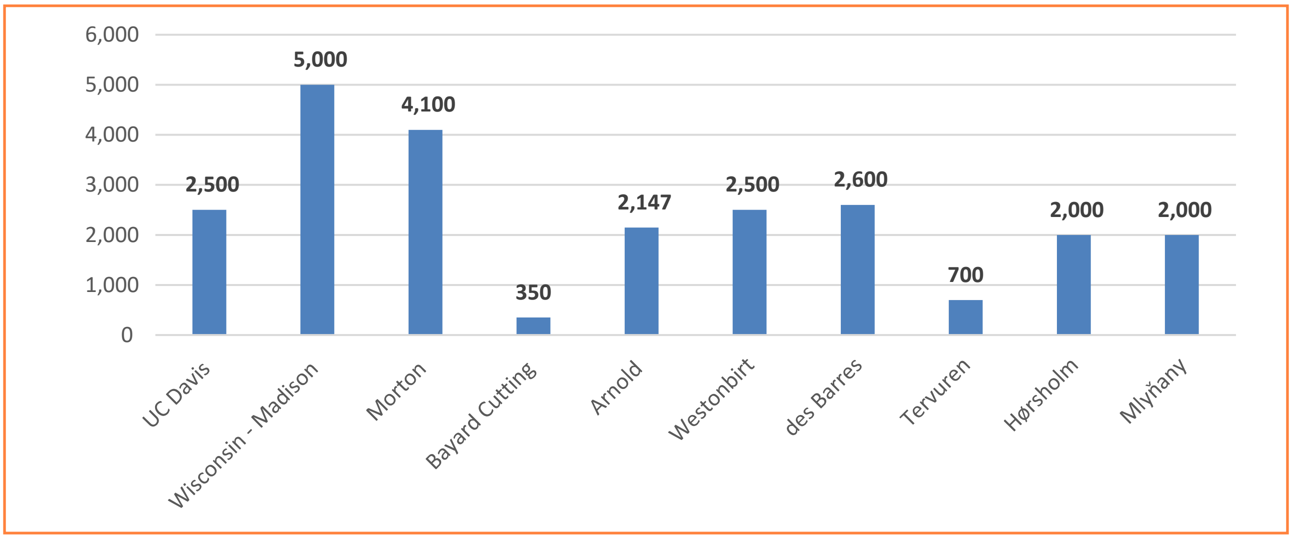


Figure 5 Species richness of the selected arboreta

paid admission. Overall, mission and governance appear to influence collection depth and visitor accessibility more strongly than size alone.

3.1.2 Spatial Structure and Vegetation Organisation

The spatial structure of the selected arboreta is strongly vegetation-driven, with dense forest as the dominant land-use category in all cases (Figure 6). Dense canopy occupies 58% (±16%) of total area, while clearings represent around 20% (±8%), typically located near main paths and entrances and providing openness and social or visual relief. Open to sparse forest is less common (8% ±7%), usually forming a transition between dense forest and clearings.

Impervious surfaces remain low: path networks and paved areas representing ~7% while buildings account for ~1%, resulting in high overall permeability 92% (±4%) (Figure 7). Water features show high variability (6% ±9%), playing a structuring role in arboreta such as Hørsholm and Wisconsin, but nearly absent in Westonbirt and des Barres, reflecting differences in hydrology, topography, and historical landscape development.

Overall, these results reveal a consistent spatial model characterised by vegetation-led structure and high permeability, reinforcing the ecological and immersive character of internationally recognised arboreta.

3.1.3 Accessibility and visitor infrastructure

Entrance distribution and path hierarchy strongly influence walkability and visitor experience (Figure 8). Compact arboreta such as Bayard Cutting, des Barres, Hørsholm and Mlyňany have over 60% of their area

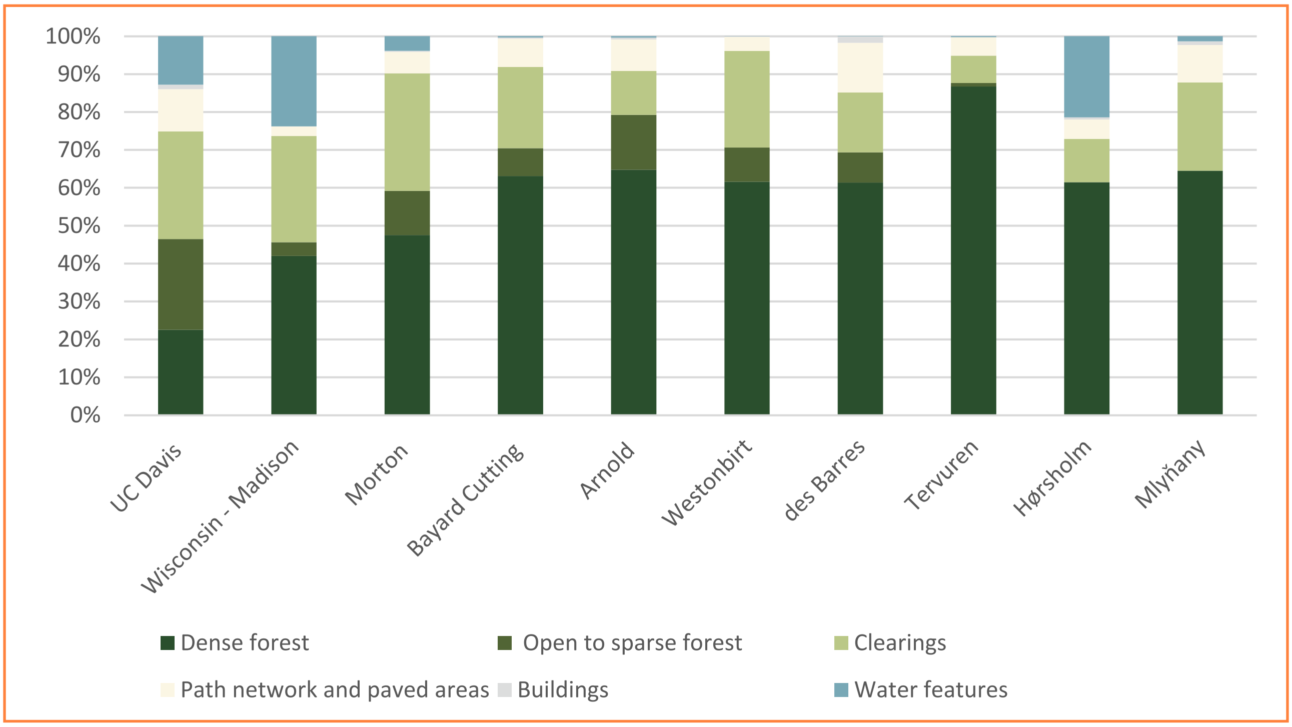


Figure 6 Spatial composition (%) of the selected arboreta

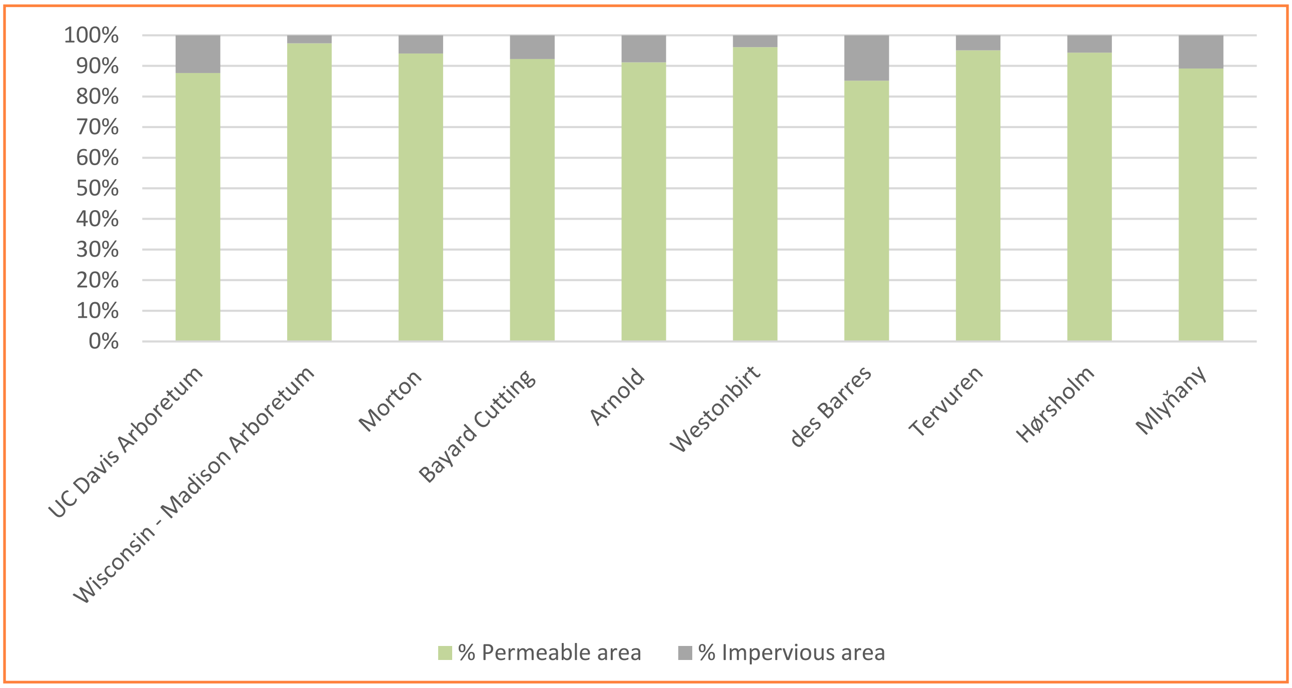


Figure 7 Permeable and impervious area (%) of the selected arboreta

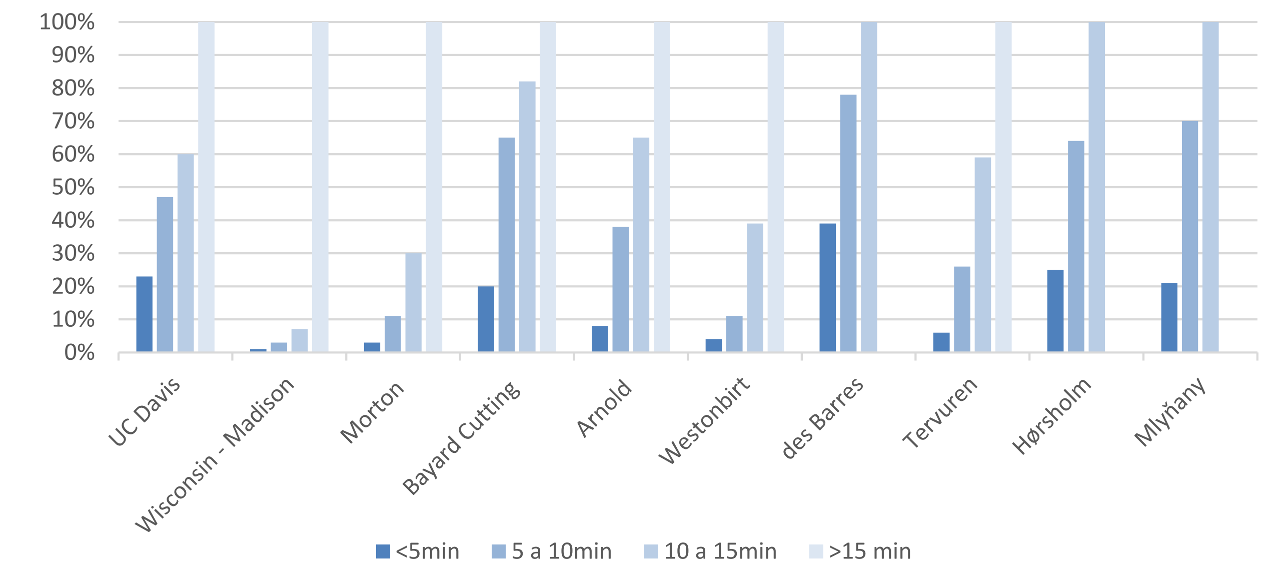


Figure 8 Accessibility within 5, 10, 15 and >15minute walking from main entrances in the selected arboreta

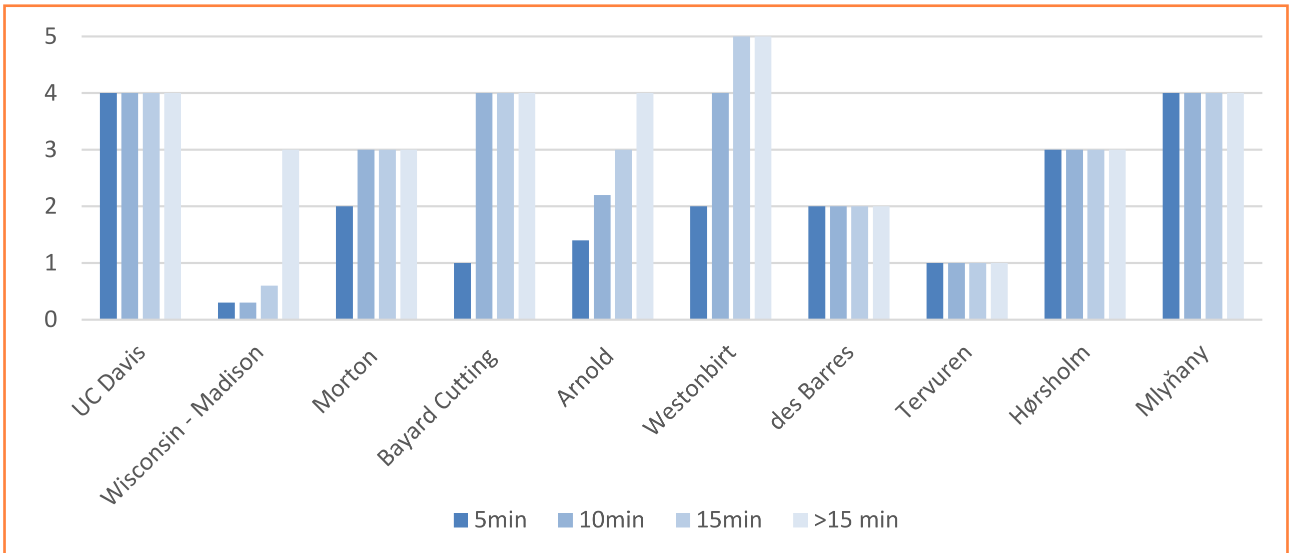


Figure 9 Number of services accessible within 5, 10, 15 and >15 minutes from primary entrances in the selected arboreta

accessible within 10 minutes from main entrances, reflecting efficient circulation and well-distributed gateways. In contrast, extensive arboreta like Wisconsin require more than 15 minutes to reach large areas due to broader natural settings, water barriers, and lower path density.

Accessibility patterns are closely related to the distribution of services (Figure 9). UC Davis, Bayard Cutting, Westonbirt and Mlyňany offer four or more service types within 10 minutes walking range, suggesting strong integration between entrances and amenities. Conversely, Wisconsin and Tervuren place services farther from entrances, prioritising immersion and natural continuity over immediate convenience.

Circulation hierarchy remains consistent across cases (Figure 10): main paths average 3 m in width, while secondary paths range between 1.5 and 2 m, forming clear and legible movement structures.

Overall, the comparative analysis reveals distinct accessibility models rather than a uniform pattern. Compact arboreta, such as Bayard Cutting and Mlyňany, prioritise short distances and proximity between entrances and services, while extensive sites like Wisconsin-Madison and Tervuren favour immersion and ecological continuity. Despite these contrasts, all cases rely on pedestrian circulation supported by a clear path hierarchy.

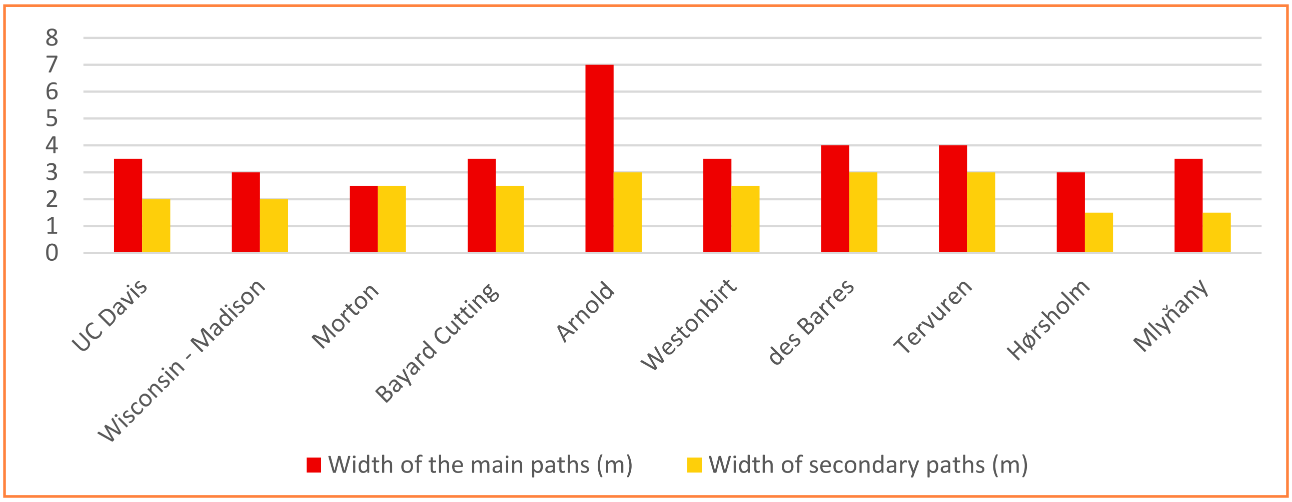


Figure 10 Width (m) of main and secondary paths in the selected arboreta

3.1.4 Botanical Collections Logic

The organisation of botanical collections (Table 1) reveals three main criteria occurring with similar frequency: geographic, taxonomic, and ornamental, each present in six of the ten arboreta. Geographic organisation emphasises regional or continental representation, (e.g., UC Davis, Tervuren, Mlyňany) while taxonomic layouts, common in academically oriented arboreta such as Arnold and Hørsholm, facilitate morphological comparison and scientific learning. Ornamental arrangements, evident in Westonbirt, Bayard Cutting, and des Barres, enhance aesthetic and sensory experiences. Biome-based organisation is less common, found only in Morton and Wisconsin, where the aim is to represent complete ecosystems such as prairies or savannas. Overall, combined models prevail, with Morton notably integrating all four criteria, while others, like Arnold or Tervuren, privilege a single dominant logic.

Larger and more diverse arboreta tend to adopt multiple criteria, while smaller or more specialised ones simplify their interpretative structure. These differences reflect not only size and species richness but also each institution's scientific and educational mission.

3.2 Cross Case Synthesis and Design Recommendations

The comparative analysis of the ten reference arboreta reveals consistent spatial and curatorial tendencies despite differences in scale, geography, and institutional mission. These patterns can be translated into design-oriented recommendations for the development of new arboreta:

Arboretum design should prioritise a forest-dominant structure with high permeability. Across all ten cases, dense forest typically represents around 58% (±16%) of total area, while impervious surfaces remain minimal (~7% circulation and ~1% buildings), resulting in ~92% (±4%) permeable cover. This consistent pattern across arboreta of widely varying size and governance suggests that vegetation dominance is not incidental

Table 1 Organisation of botanical collections in each arboretum

Arboretum	Biome-based	Geographic	Ornamental	Taxonomic
UC Davis	No	Yes	Yes	No
Wisconsin – Madison	Yes	No	No	No
Morton	Yes	Yes	Yes	Yes
Bayard Cutting	No	No	Yes	Yes
Arnold	No	No	No	Yes
Westonbirt	No	No	Yes	Yes
des Barres	No	Yes	Yes	Yes
Tervuren	No	Yes	No	No
Hørsholm	No	Yes	No	Yes
Mlyňany	No	Yes	Yes	No

but a defining spatial principle, supporting ecological continuity, biodiversity, and an immersive visitor experience.

Impervious surfaces should be maintained at a minimum. None of the analysed arboreta exceed 10% impervious cover, regardless of visitor numbers or service provision. Keeping built and paved areas below this threshold aligns with reference practice and should guide future arboretum design.

Walkability should be supported by a hierarchy of paths and a strategic distribution of services. The analysis reveals two distinct accessibility models: compact arboreta such as Bayard Cutting and Mlyňany place over 60% of their area within 10 minutes of main entrances, while extensive sites such as Wisconsin-Madison and Tervuren prioritise landscape immersion over proximity. In both models, a clear path hierarchy (main paths averaging 3 m, secondary paths between 1.5 and 2 m) ensures legibility. New arboreta should adopt the model most appropriate to their scale, ensuring that service nodes are reachable within 10–15 minutes from main entrances.

Water features should be scaled according to site dimension. In the analysed cases, water features show high variability (6% ±9% of total area), playing a structuring role in some arboreta, while nearly absent in others. Smaller arboreta (<50 ha) benefit from multiple small water features, whereas larger ones (>50 ha) perform better with fewer but extensive water bodies.

Botanical collections should be organised through hybrid curatorial logics. Geographic, taxonomic, and ornamental criteria each appear in six of the ten arboreta, while biome-based organisation is less common. Combined models prevail, while others privilege a single dominant logic. Larger and more diverse arboreta tend to adopt multiple criteria, while smaller or more specialised ones simplify their interpretative structure.

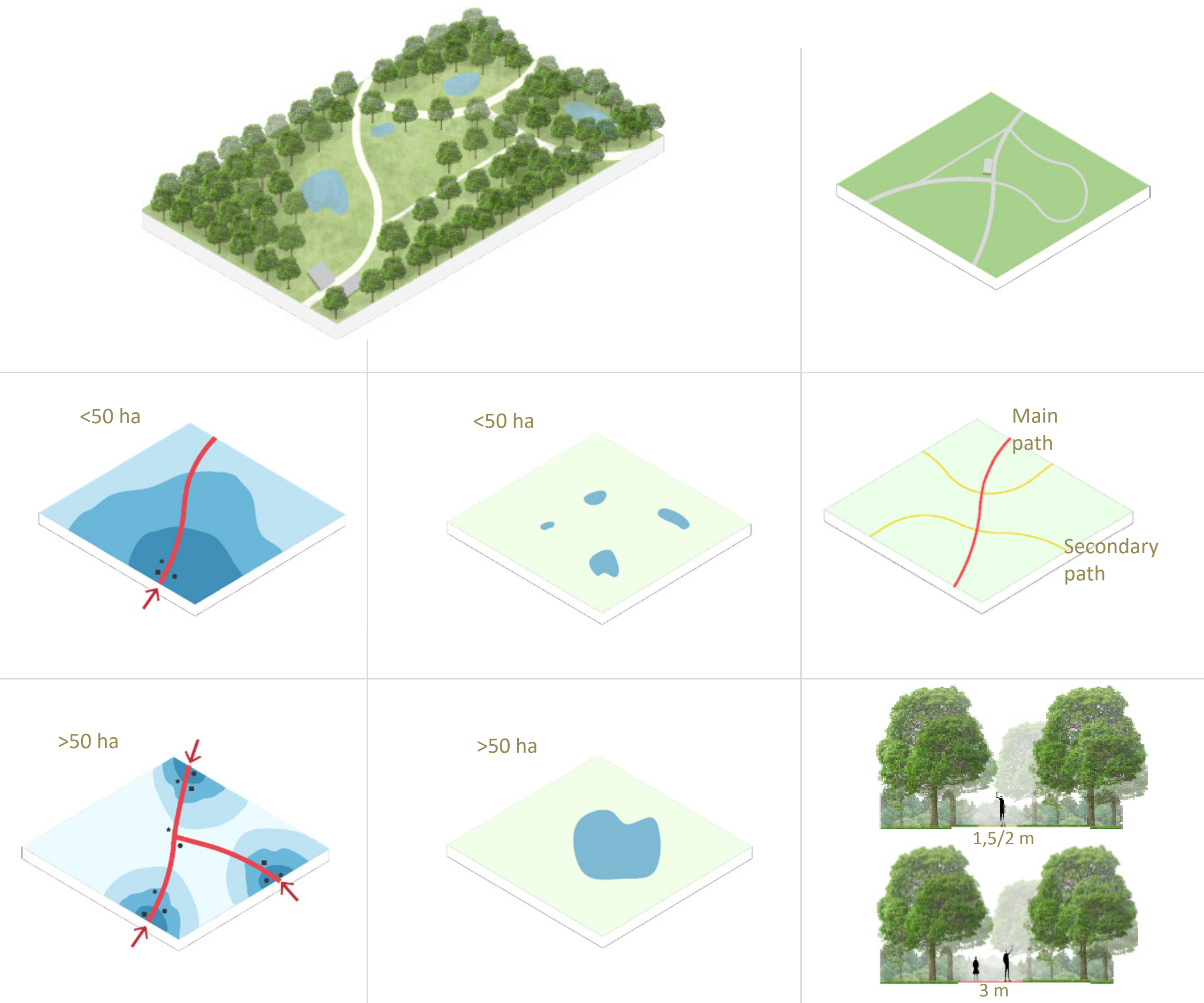


Figure 11 Synthesis of spatial patterns across the reference arboreta, including land-use distribution, permeability, accessibility ranges, water typologies, path hierarchy and recommended path widths

New arboreta should consider combining taxonomic, geographic and ecological principles, complemented by ornamental composition to support interpretation and visitor experience.

These recommendations provide an empirical basis for the design of new arboreta (Figure 11).

4 Discussion and Conclusions

This study highlights both the diversity and underlying coherence of spatial approaches found in reference arboreta worldwide. Despite contextual differences, they consistently integrate ecological integrity, accessibility, and educational purpose within vegetation-dominated and highly permeable landscapes.

The findings of this study align with previous research highlighting the role of arboreta and botanical gardens in biodiversity conservation and public engagement (Miller et al., 2016; Cavender & Donnelly, 2019). However, this study contributes by explicitly linking spatial organisation with functional performance, offering a design-oriented perspective that remains underexplored in the literature.

The synthesis of spatial and organisational patterns presented here provides an empirical foundation for the design of new arboreta. However, the study is limited by the heterogeneity of available data, temporal variation in mapping sources, and the absence of field-based visitor analysis. The ten selected arboreta are geographically concentrated in North America and Europe, reflecting the distribution of ArbNet Level IV accreditation and the availability of spatial data. Arboreta in different climatic contexts may exhibit substantially different spatial logics shaped by distinct vegetation structures, visitor cultures, and institutional histories; the recommendations proposed here should therefore be applied with caution outside the temperate contexts represented in the sample. Future research should integrate spatial metrics with ecological performance indicators and user experience assessments and expand the geographic and climatic range of comparative case studies, advancing the evidence base for arboretum planning and management.

This study demonstrates that internationally recognised arboreta share a coherent spatial model despite differences in scale, geography, and institutional mission. Vegetation dominance, high permeability, hierarchical circulation, and hybrid collection logics emerge as consistent organising principles across the ten analysed cases. Translated into design recommendations, these findings provide an empirical foundation for practitioners and institutions developing new arboreta: a task for which spatially grounded guidance has until now been largely absent from the literature. As new arboreta continue to be established globally in response to accelerating biodiversity loss and climate change, evidence-based design principles become not only useful but necessary.

Acknowledgments

Work developed under the scope of the Education for Biodiversity Conservation Chair – a project funded by Fundação Belmiro de Azevedo (FBA) and Fundação para a Ciência e Tecnologia (FCT).

References

ArbNet. (2025). *ArbNet*. Retrieved January 2025, from https://arbnet.org/

BGCI – Botanic Gardens Conservation International. (2025). Garden search. Retrieved August 2025, from https://www.bgci.org/resources/bgci-databases/gardensearch/

Cavender, N., & Donnelly, G. (2019). Intersecting urban forestry and botanical gardens to address big challenges for healthier trees, people, and cities. *Plants People Planet*, 1(4), 315–322. https://doi.org/10.1002/ppp3.38

Francis, M. (1999). *A case study method for landscape architecture*. Landscape Architecture Foundation.

Francis, M. (2001). A case study method for landscape architecture. *Landscape Journal*, 20(1), 15–29. https://doi.org/10.3368/lj.20.1.15

Heywood, V. H. (2017). *Plant conservation in the Anthropocene: Challenges and future prospects*. https://doi.org/10.1007/978-3-319-55747-3

Hiscock, S., Lennon, S., & Young, B. (2024). Celebrating botanic gardens. *Plants People Planet*, 6(2), 251–253. https://doi.org/10.1002/ppp3.10472

Kaya, M. (2022). *From remediation to landscape design: Design tactics and landscape typologies derived from post-industrial experiences*. Landscape Research. https://doi.org/10.1080/01426397.2022.2150754

Meireles, F. (2015). *Da especificidade do parque português contemporâneo*. https://hdl.handle.net/10216/94540

Miller, J. S., Lowry, P. P., Aronson, J., Blackmore, S., Havens, K., & Maschinski, J. (2016). Conserving biodiversity through ecological restoration: The potential contributions of botanical gardens and arboreta. *Candollea*, 71(1), 91–98. https://doi.org/10.15553/c2016v711a11

Rudka, M. N. (2025). *Arboretos de referência: Identificação, caraterização e recomendações para o desenho*. https://hdl.handle.net/10216/170738

Teixeira, C. P., & Ferreira, V. R. (2025). *Mapping arboretum research: Trends, gaps, and opportunities for biodiversity conservation, society, and climate resilience*. Plants, People, Planet (pp. 1–19). https://doi.org/10.1002/ppp3.70136