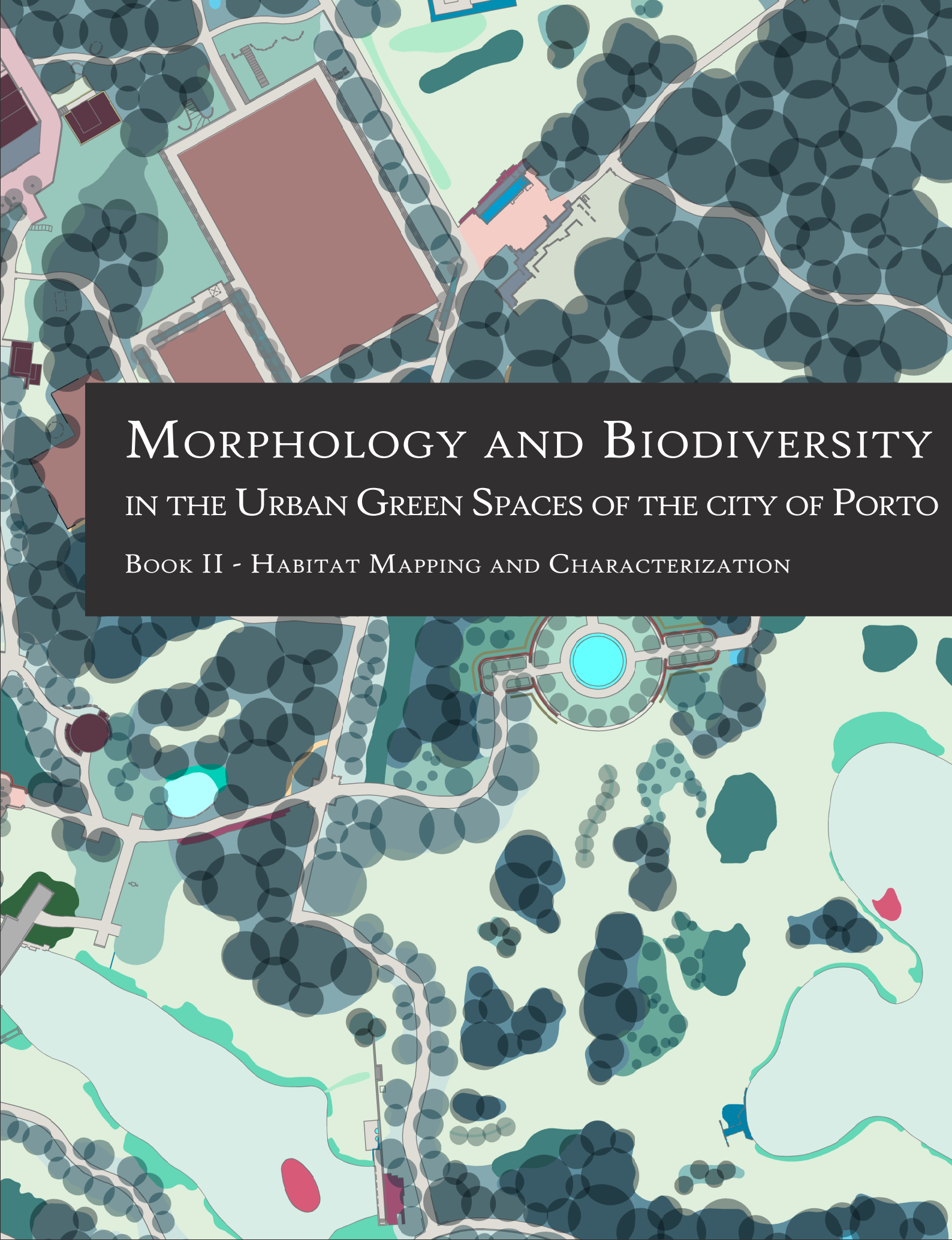


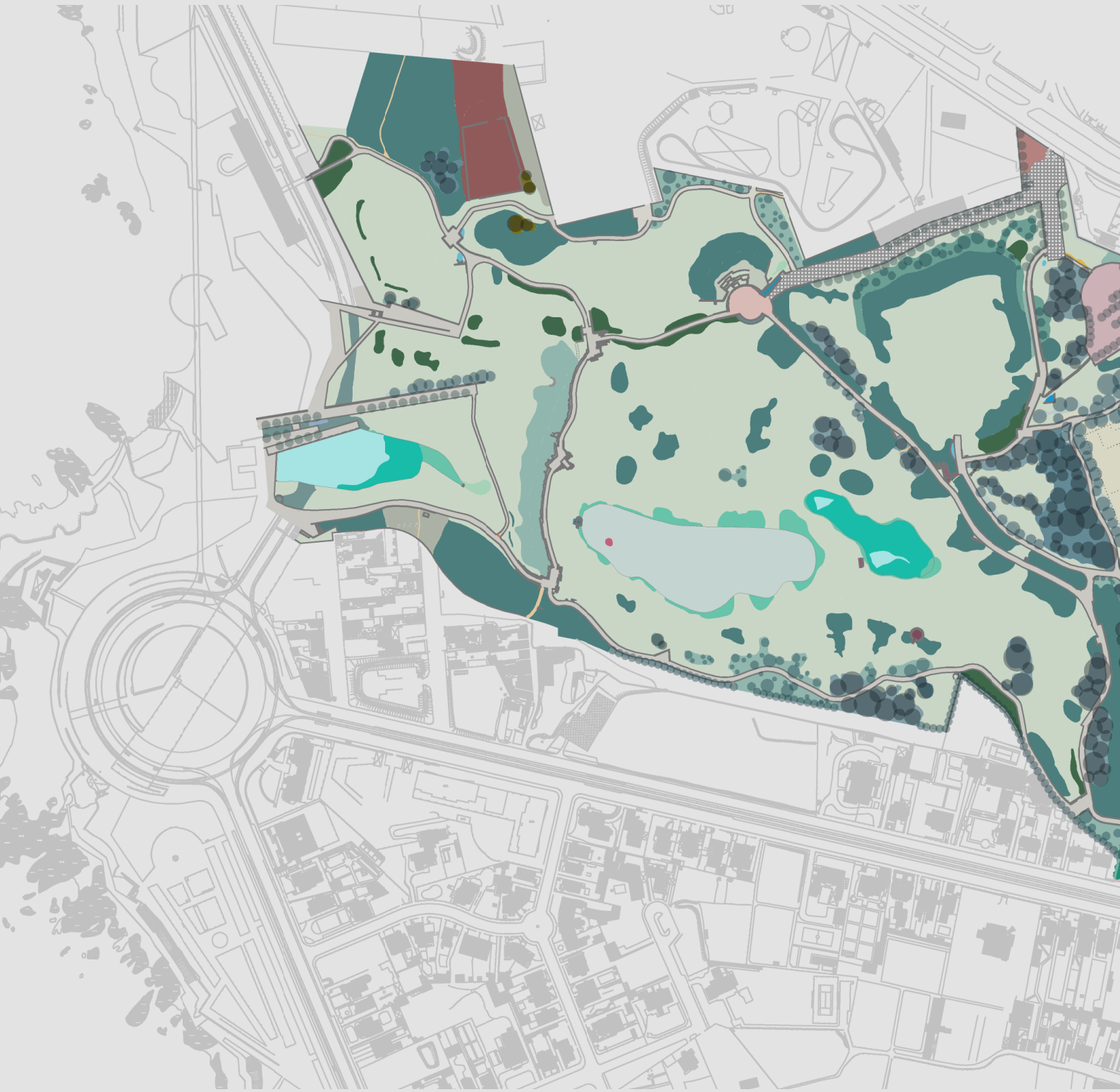
Morphology and Biodiversity

in the Urban Green Spaces of the city of Porto

Book II - Habitat Mapping and Characterization

2015

Paulo Farinha Marques, Cláudia Fernandes, Filipa Guilherme, José Miguel Lameiras, Paulo Alves, Robert Bunce



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CIBIO
Research Centre in Biodiversity and Genetic Resources
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Faculty of Sciences of University of Porto
Faculdade de Ciências da Universidade do Porto

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Contents

◄ Fig. 1: Casa Tait Garden: characteristic ambiance of 'Closed wood with understory'.

Preface

Urban habitats are unique for their close proximity with human beings in an increasingly urban world. They host *unique biodiversity assemblages*, due to the peculiar features of the urban environment. They also provide *multiple ecosystem services* that are most valuable for human wellbeing in the urban environment. These include, among others, regulation of air quality and local climate, control of water flows and mitigation of floods, or aesthetics and recreation. Understanding the structure, functioning and dynamics of these habitats is thus crucial to *take informed decision on planning and management* of urban green areas and networks. Global changes and the continuous growth of urban and metropolitan areas raise new challenges and render urban ecology an important area of modern ecological research.

Ecological monitoring is, not surprisingly, at the core of global and regional policy and management initiatives aimed to track the effects of *global change* on biodiversity, natural resources and ecosystem services. It refers to a wide set of methods and techniques to collect and analyse data on several components of (social-)ecological systems, and to synthesize them as *core indicators* that allow tracking stock, flow and change. Often, however, monitoring schemes fail to timely detect changes and to provide insights on the drivers and processes underlying those changes. One reason for this common caveat is the lack of *standardized methodological procedures*, which hamper comparisons across areas, time series analysis, and integration of individual programs into wider initiatives embedded in important global strategies or regional policy instruments.

The urban parks of the city of Porto are a core component of its ecological network and an important element in the wider *metropolitan ecological infrastructure*. The diversity of green areas, founded on the rich history of the city, on the complex terrain morphology, on the variety of management goals and regimes, and on the benign climatic conditions, renders the city of Porto a *unique urban ecology laboratory* to test innovative ideas, hypotheses and methodologies. This book as well the first volume and the research project within which they were produced are a good example of this endeavour. They should thus be of much interest and usefulness, not only for academy staff and researchers, but especially to *those technically or politically involved in urban planning and management*. All citizens interested in ecology and biodiversity, or simply motivated to understand their surrounding urban environment, will surely find this handbook interesting and useful as well.

João Honrado
Porto, January 2015

1 Introduction

The increasing global urbanization is a threat to biodiversity conservation of animals, plants and habitats. The process of urbanization changes local biodiversity patterns by fragmenting or destroying habitat patches and altering habitat composition and biophysical settings. Nevertheless, such disturbance creates opportunities for a new ecological context where some animals and plants thrive unexpectedly.

To act upon urban biodiversity, it is crucial to know what species can survive in the urban environment and to understand fauna and flora associations with the urban habitats. As a consequence of that, adequate information may be produced and influence planning design and management procedures in order to integrate urban development and biodiversity. Ecologists, landscape architects and urban planners have a special role in building a bridge between knowledge and practical measures and policies, to create intervention and conservation plans that are viable in public urban spaces.

Urban green areas can be considered an essential refuge for native biodiversity. They also fulfil important environmental services, by improving air quality, regulating microclimatic conditions, draining rainwater and minimizing noise levels. Green spaces also contribute to the health and well-being of residents and, every so often, they are the only chance of experiencing nature for the urban citizens.

This study takes place in the city of Porto (northern Portugal), the heart of a metropolitan area of nearly two million inhabitants. Its geographic, social and environmental setting together with high diversity of sites in a relatively dense urban fabric makes Porto an ideal place for a detailed green structure research in a southern European context. With a mild Atlantic climate, the city combines important natural habitats that occur close to each other (river Douro and its mouth, seafront, rocky escarpments, several streams with a few stretches still running in the open) with a high variety of man-made habitats with different location, size, use and spatial qualities.

Public parks, gardens and green squares were chosen as the object of study due to their relevance in the urban environment – they are designed, constantly influenced by maintenance and management and directly accessible by

◄ Fig. 2: Sophia Garden: 'Stairs' with modernist design well adjusted to landform, bordered with 'Rows of trees' (*Fraxinus angustifolia*).

the general public. A survey conducted in Porto by this research team identified 95 parks, gardens and green squares with public access. These were grouped according to different biophysical and anthropogenic features, through means of statistical procedures (Farinha-Marques et al., 2013). From these groups, a representative sample of 29 spaces was selected for a detailed study regarding the diversity of habitats, animal and plants. In this publication we present a selection of 8 green spaces that represent the selected sample in its main characteristics:

- City Park and Serralves Park were considered outliers by the previously mentioned analysis – they are exceptional spaces mainly due to their large dimension;

- Pasteleira Park, from group 1 is a large space, with naturalistic character and recreation oriented;

- Porto Botanical Garden represents group 2, which includes medium/large spaces, with conservation or recreation functions and of historical value;

- Group 3 is represented by Cordoaria Garden and Casa Tait Garden, green areas with medium/small dimensions, conservation function and mainly historical value;

- Group 4 includes Galiza Square and Carlos Alberto Square, among other recent spaces with small size, and generally have amenity or conservation purposes.

For the study of habitats, a specific methodology for survey and mapping was devised. We needed a habitat classification method that was easily convertible to spatial terms and applicable to urban settings. For that reason, we created a new urban habitat mapping methodology; this methodology was largely inspired on the work of European projects like BioHab (Bunce et al., 2005) and EBONE (Bunce et al., 2008, 2011; Halada et al., 2009), which has been adapted to urban context. The aim of these projects was to develop a framework for surveillance and monitoring of habitats and generate a list of General Habitat Categories applicable across Europe. This concept, being strongly based on spatial features, such as the shape and dimension of similar units (areal, linear and point elements), proved to be ideal for our study of habitat morphology. Additionally, the plant life forms that set up the base of habitat categories are a good indicator of habitat structure and environmental conditions.

Therefore, the presented methodology is based on land cover to classify Urban Habitat Categories, according to life forms (vegetation) and non life forms (artificial structures, bare soil or water surfaces). It suggests great potential for biodiversity surveys and monitoring schemes in a multitude of urban environments. Here we also present the results of its application to public parks, gardens and green squares in the city of Porto, Portugal.

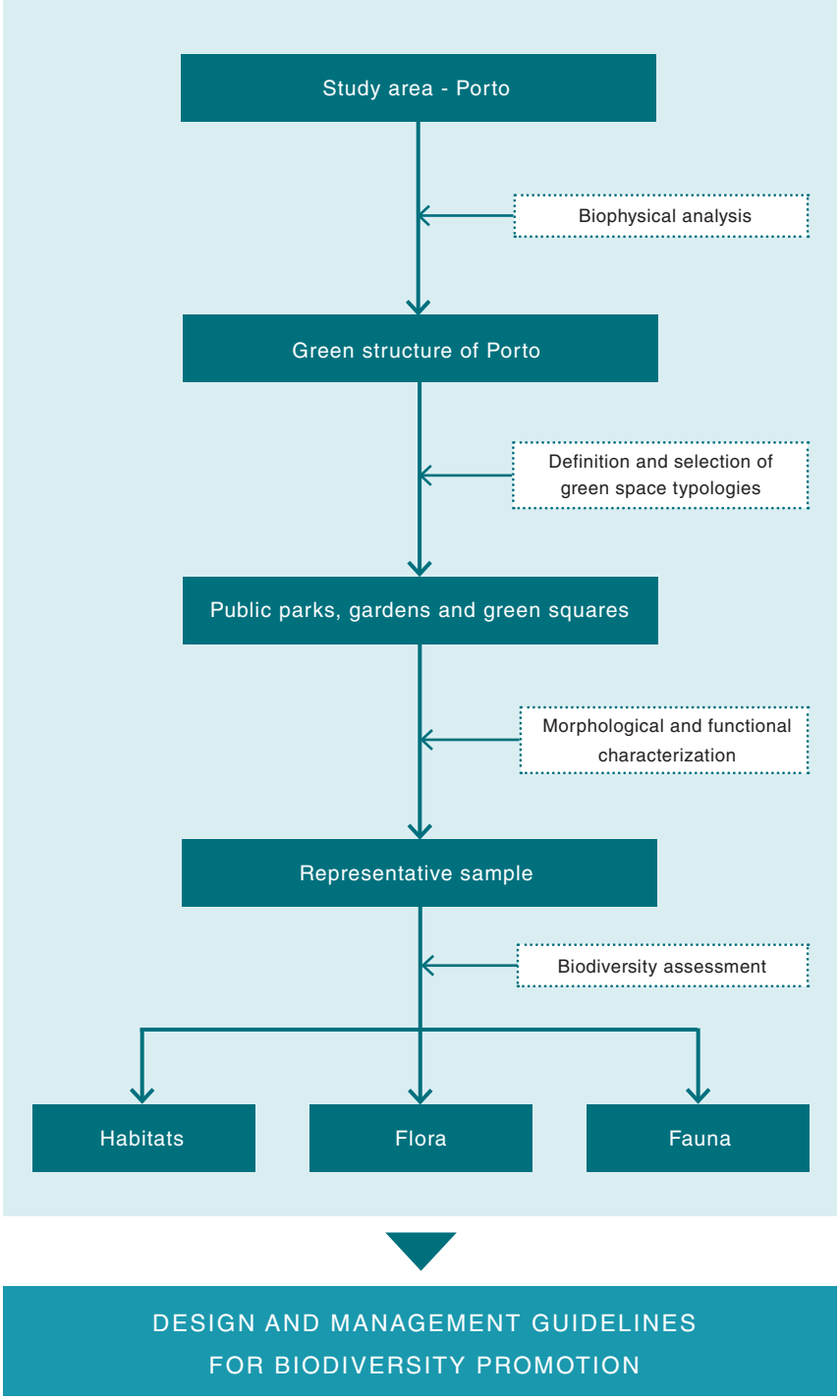


Fig. 3: Main steps of the research project.

2 METHODOLOGY

2.1 INTRODUCTION

The developed methodology aims at classifying and describing urban habitats in detail through a spatially explicit method. The main steps of the methodology are summarised in the following diagram (Fig. 4):

1. In the lab, spatial databases are carefully studied in order to identify different habitats and classify them according to their shape as *Areas*, *Lines* or *Points*; this produces the **initial map** that is to be taken into the field for further study of each habitat.

2. The **field map** is produced by confirming during fieldwork the information registered in the initial map and by adding new habitat elements only identified on site.

3. Then, **recording forms** are filled for each habitat element: i) the Life Forms and Non Life Forms with 10% cover or more are identified, as well as the dominant species; ii) the Urban Habitat Category is then determined with the aid of the Decision Tree (Fig. 37, page 31); iii) all the other attributes, such as Site Descriptors or Vegetation Layers, are also defined.

4. The resulting data can then be used to create the **final maps**: the **Habitats map**, the **Site Descriptors map** and the **Vegetation Layers map**. Other maps can also be produced according to different attributes.

◄ Fig. 4: Pasteleira Park: 'Pond' with naturalized margin, with *Pinus pinaster* woodland in the background.

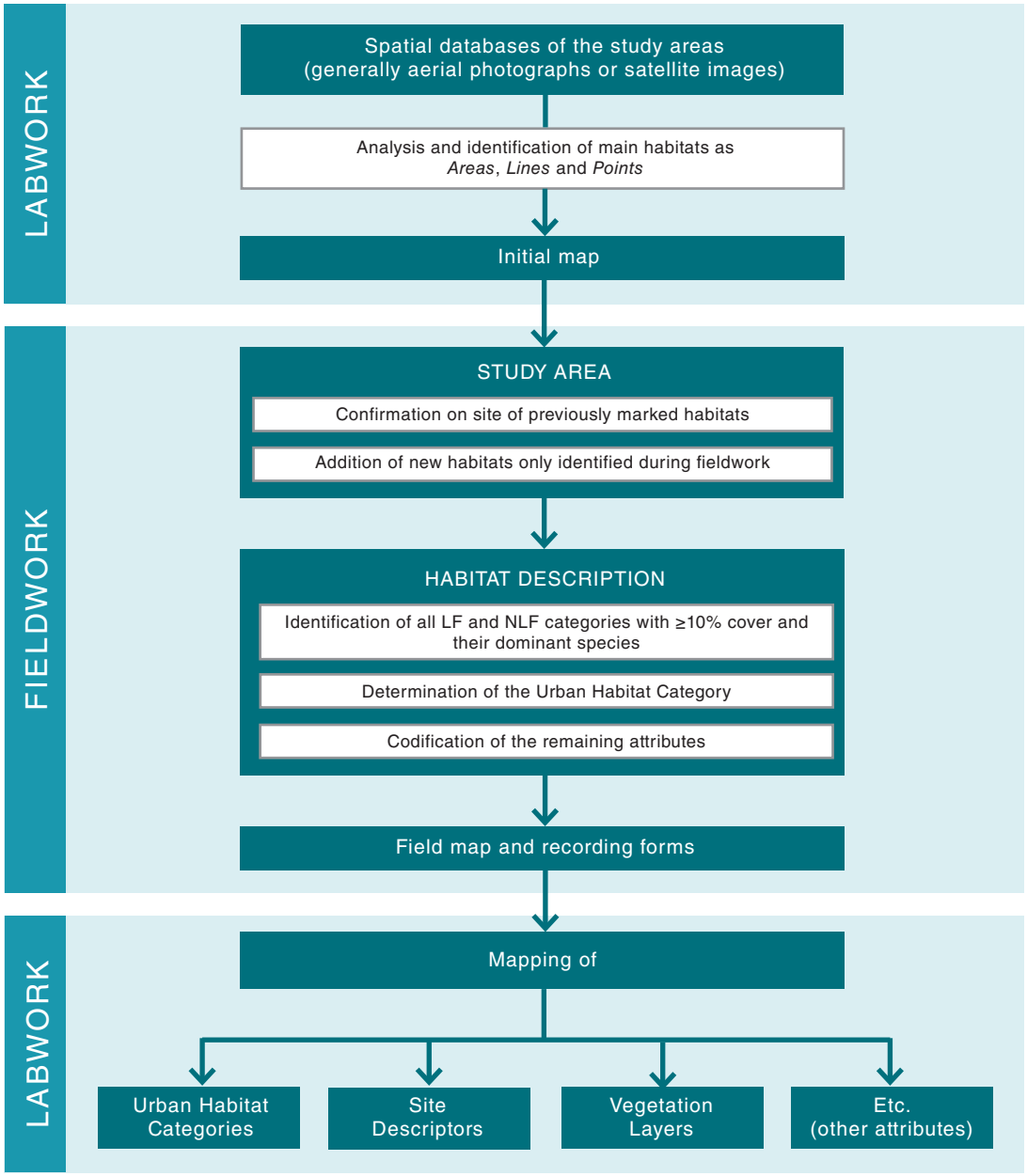


Fig. 5: Diagram of the urban habitat mapping methodology.

2.2 UNDERSTANDING THE URBAN HABITAT CATEGORIES

Urban Habitat Categories (UHC) are centred in the classification of Life Forms (LF) originally described by the Danish botanist Raunkiaer in the early Twentieth Century. The Life Forms are then linked to additional standard information regarding human use, environmental conditions and species composition. Plant Life Forms are a valuable concept for

habitat description as they directly reflect habitat structure and are applicable in different bio-geographical zones, as well as being good indicators of human disturbance and management regimes.

According to Raunkiaer classification, plants are organized in five major groups, depending on the position of the wintering buds: phanerophytes (buds above ground level), chamaephytes (buds close to the ground), hemicryptophytes (buds in the soil surface), cryptophytes (buds buried underground or in the water) and *therophytes* (without wintering buds, surviving as seeds during the unfavourable season). Some of these basic Life Forms are subdivided in this methodology: *phanerophytes* are divided in five height categories; *chamaephytes* are divided in three categories; *hemicryptophytes* have two leaf morphology types; and cryptophytes are classified according to the substrate where the wintering buds are located: *geophytes* (buds in dry soil), *helophytes* (buds in waterlogged soil) and *hydrophytes* (buds in the water).

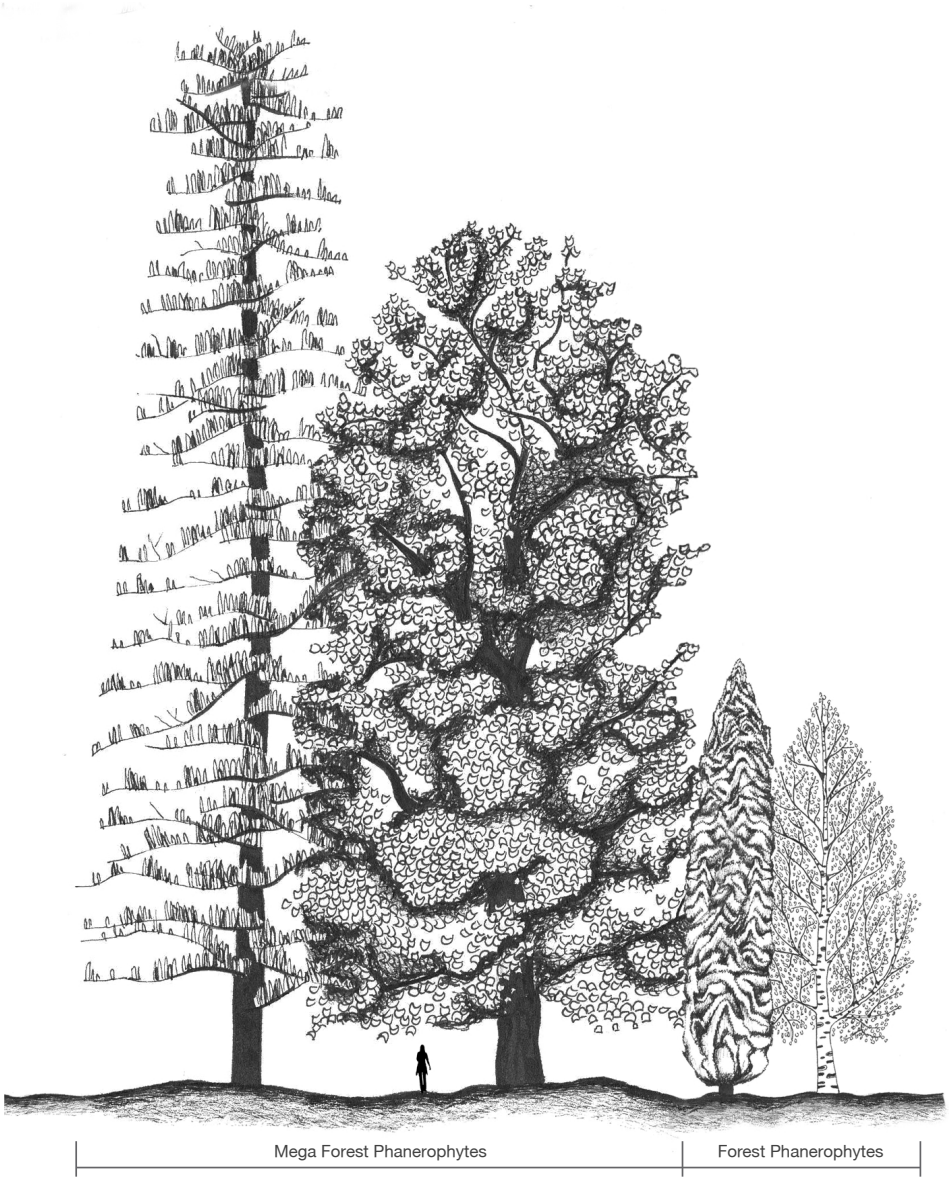


Fig. 6: Mega Forest Phanerophytes and Forest Phanerophytes.

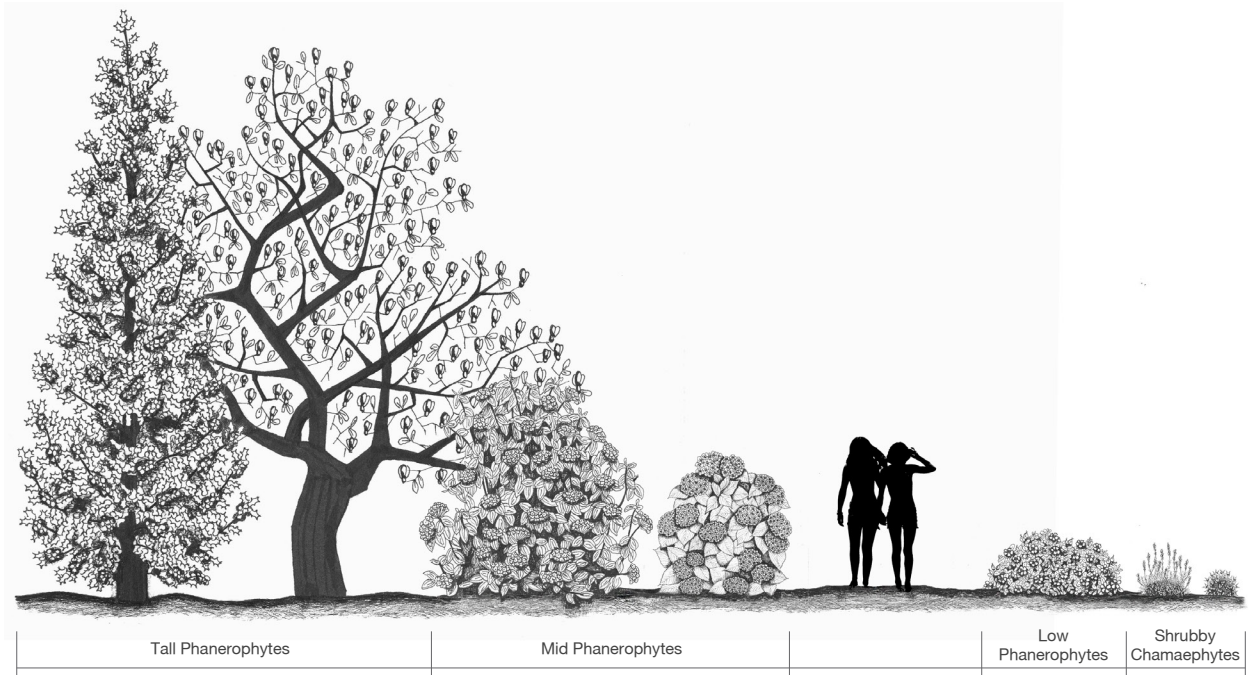


Fig. 7: Tall Phanerophytes, Mid Phanerophytes, Low Phanerophytes and Shrubby Chamaephytes.

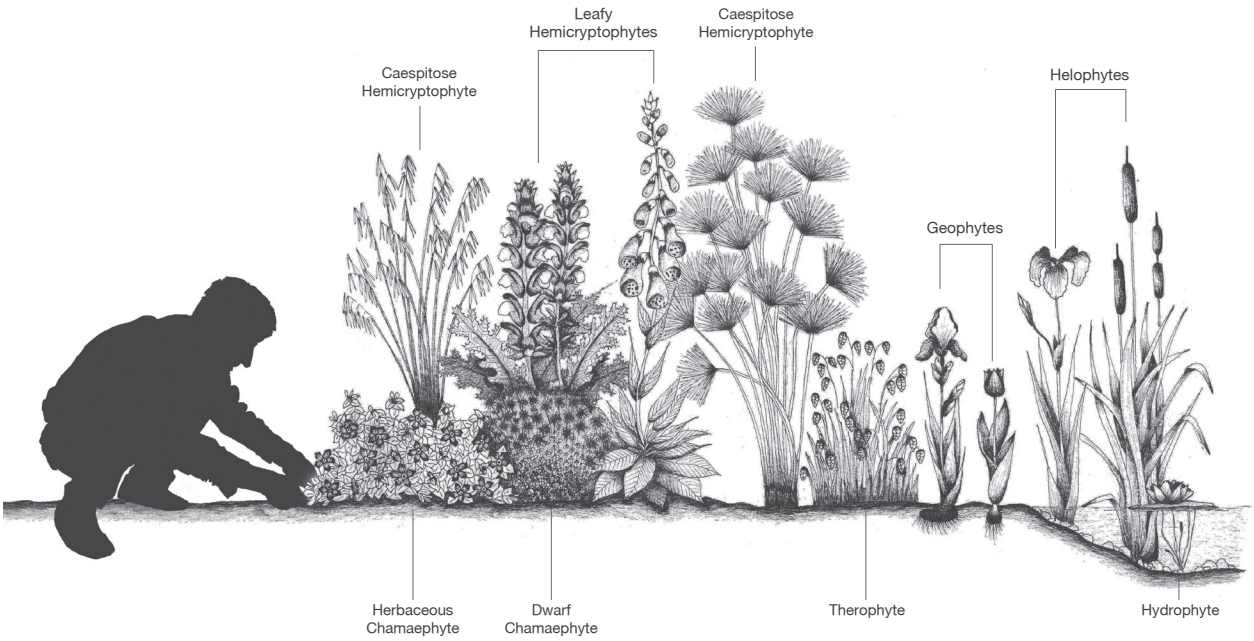


Fig. 8: Herbaceous and Dwarf Chamaephytes, Leafy and Caespitose Hemicryptophytes, Therophytes, Geophytes, Helophytes and Hydrophytes.

Super-categories	Categories	Sub-categories	Life Form Qualifiers
ABE Artificial Built Elements	STR - Built structure AQE - Aquatic element PAV - Pavement RUB - Rubbish	VGT - With vegetation NVG - Without vegetation	
SPV Sparsely Vegetated	SEA - Sea AQU - Aquatic ICE - Ice and snow TER - Terrestrial LIT - Organic Litter		BRY - Bryophytes LIC - Lichens CYA - Cyanophytes
	ROC - Bare rock BOU - Boulders STO Stones GRV - Gravel SAN - Sand EAR - Earth		
TRS Trees and Shrubs	DCH - Dwarf chamaephytes SCH - Shrubby chamaephytes LPH - Low phanerophytes MPH - Mid phanerophytes TPH - Tall phanerophytes FPH - Forest phanerophytes GPH - Mega forest phanerophytes	DEC - Winter deciduous EVR - Evergreen CON - Coniferous NLE - Non-leafy evergreen SUM - Summer deciduous	SMA - Small leaved (EVR) LAR - Large leaved (EVR) LOS - Winter deciduous (CON) PAL - Palms and cycads SRO - Stem rosettes CUS - Cushions CAC - Stem succulents BAM - Bamboos and canes BUT - Butresses (FPH and GPH) CAU - Caulistic trees (FPH and GPH) LIA - Lianes CRE - Creepers PAR - Parasites
HER Wetland Herbaceous	SHY - Submerged hydrophytes EHY - Emergent hydrophytes HEL - Helophytes		FLO - Floating plants (SHY) LEA - Plants with floating leaves (SHY)
HER Terrestrial Herbaceous	LHE - Leafy hemicryptophytes CHE - Caespitose hemicryptophytes THE - Therophytes GEO - Geophytes HCH - Herbaceous chamaephytes CRY - Cryptogams		TUS - Tussock grasses (CHE) BRY - Bryophytes (CRY) LIC - Lichens (CRY)

Fig. 9: Classification of Urban Habitat Categories and optional Life Form Qualifiers.

For the habitat categories, 16 Life Forms, and five leaf retention strategies of shrubs and trees, are considered, which are then grouped into three super-categories. Habitat patches dominated by built and artificial structures, such as buildings and paved areas, as well as non-vegetated zones are considered in separate divisions comprising Non Life Form (NLF) categories, in which there are 15 categories grouped into two super-categories. Additionally, there are 21 optional Life Form Qualifiers that can be used to better characterise the habitat elements without increasing the number of Urban Habitat Categories (Figure 9).

2.3 DEFINITION AND DESCRIPTION OF URBAN HABITAT CATEGORIES (UHC)

2.3.1 Artificial Built Elements (ABE)

This super-category consists of artificial structures, including impervious surfaces, buildings and other constructed elements. These Non Life Form (NLF) categories must be completed with information regarding the presence (or absence) of vegetation in the element.

- **Built Structure (STR)**: all buildings and walls, as well as every constructed element, without water, that extend more than 30 cm above the ground.

- **Aquatic Element (AQE)**: all built aquatic features as fountains, bird baths, tanks, pools, ponds, lakes and artificial rivers or streams, entirely surrounded by an artificial margin made of concrete or other solid construction material.

- **Pavement (PAV)**: all built surfaces created for human movement, generally covered with impervious materials (e.g. concrete, asphalt, macadam, flagstones, bricks, cobbles), such as pathways, walkways and tracks.

- **Rubbish (RUB**): every type of artificial or man-made waste.

Fig. 10: Built Structure (STR), in the rural settlement of City Park.

Fig. 11: Aquatic Element (AQE), in Serralves Park.

Fig. 12: Pavement (PAV) of cobbles, in Pasteleira Park.

Furthermore, there are mandatory sub-categories to complement the information above:

- **With Vegetation (VGT)**: artificial element with 30% of vegetation cover or more, such as a wall with a climber attached, a tank filled with waterlillies or a square with trees.

- **Without Vegetation (NVG)**: artificial element with less than 30% of vegetation.

It is important to note that all percentages and measurements assume specific rounding rules associated to this methodology (see page 28).

Fig. 13: Different built elements without vegetation - a building (STR/NVG) and a square (PAV/NVG), in Porto.

Fig. 14: A pergola covered by vegetation (STR/VGT), in Serralves Park.

Fig. 15: A paved square with trees (PAV/VGT), in Pasteleira Park.

2.3.2 Sparsely Vegetated (SPV)

Non-built elements with less than 30% vegetation cover are classified as Sparsely Vegetated categories. The type of vegetation cover, if any, can be recorded as Life Form Qualifiers.

- **Sea (SEA)**: sea below mean water mark.

- **Aquatic (AQU)**: inland water bodies with less than 30% vegetation cover (otherwise the codes EHY or SHY should apply); artificial lakes and ponds with a naturalized character also fall in this category.

- **Ice/Snow (ICE)**: permanent ice or snow.

- **Terrestrial (TER)**: every type of non-vegetated soil (sub-categories below).

- **Organic Litter (LIT)**: leaf litter, mulches of shredded organic matter, dead fallen trees, and other types of organic matter covering the ground.

Fig. 16: Atlantic Ocean (SEA), in Praia da Luz.

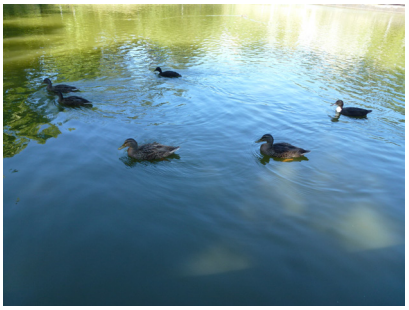


Fig. 17: Inland water body (AQU), in Pasteleira Park.

Fig. 18: Leaf litter (LIT), in a woodland in Serralves Park.

Terrestrial habitats (TER) are classified in more detail, according to the sediment size or substrate type.

- **ROC**: continuous rock surface divided by cracks, crevices or gullies.
- **BOU**: boulders over 0.20m in diameter.
- **STO**: rocks and stone between 0.05m and 0.20m in diameter.
- **GRV**: gravel between 0.01m and 0.05m in diameter.
- **SAN**: sand between 0.001m and 0.01m in diameter.
- **EAR**: earth, mud, silt, clay and bare soil below 0.001m in diameter.

Life Form Qualifiers for SPV categories

- **BRY**: bryophytes, includes both mosses and liverworts.
- **LIC**: lichens.
- **CYA**: cyanophyta and algae.

2.3.3 Trees and shrubs (TRS)

For woody habitats, the first stage is the definition of the height categories. It is important to note that not all plants included in the group of trees and shrubs have ligneous secondary thickening, e.g. palms and bananas, which is the botanical definition of woody, but for practical reasons are still included within this life form. The second stage is the definition of the deciduous/evergreen character and leaf morphology, as height alone is not sufficient to convey the necessary information on the characteristics of the environment. Because of their unique character, an exception is made of cacti and succulents where the mean height of the plant should be used to determine the height category rather than the level of the buds.

- **Dwarf chamaephytes (DCH)**: dwarf shrubs, buds below 0.05m.

- **Shrubby chamaephytes (SCH)**: undershrubs, buds between 0.05-0.30m.
- **Low phanerophytes (LPH)**: low shrubs, buds between 0.30-0.60m.
- **Mid phanerophytes (MPH)**: mid shrubs, buds between 0.60-2.00m.
- **Tall phanerophytes (TPH)**: tall shrubs, buds between 2.0-5.0m.
- **Forest phanerophytes (FPH)**: trees between 5.0-40m.
- **Mega forest phanerophytes (GPH)**: trees over 40m.

Fig. 19: *Helichrysum italicum*, a shrubby chamaephyte (SCH).

Fig. 20: *Bergenia cordifolia*, a low phanerophyte (LPH).

Fig. 21: *Diosma ericoides*, a mid phanerophyte (MPH).

Fig. 22: *Acer palmatum* 'Dissectum Atropurpureum', a tall phanerophyte (TPH).

Fig. 23: *Ulmus minor*, a forest phanerophyte (FPH).

The following sub-categories are mandatory and must be combined with the height category for trees and shrubs:

- **Winter deciduous (DEC)**: trees and shrubs that lose their leaves in winter.
- **Evergreen (EVR)**: trees and shrubs that do not shed their leaves seasonally.
- **Coniferous (CON)**: trees and shrubs with needle or scaly leaves.

- **Non-leafy evergreen (NLE)**: trees and shrubs without functional leaves or with short lasting leaves.

- **Summer deciduous (SUM)**: trees and shrubs that lose their leaves in summer.

Fig. 24: Deciduous leaves of *Quercus robur* (DEC).

Fig. 25: Evergreen leaves of *Laurus nobilis* (EVR).

Fig. 26: Coniferous needles of *Cedrus atlantica* 'Glauca' (CON).

Life Form Qualifiers for TRS categories

- **PAL:** palm trees and cycads.
- **SRO**: stem rosettes are rosettes on top of the stem.
- **CUS**: cushion plants distinctive of xeric conditions.
- **CAC**: swollen stems cacti and succulents with residual leaves or scales.
- **BAM**: bamboos and canes are herbaceous plants, but with buds above ground level.
- **BUT**: trees with buttress trunks.
- **CAU**: tree with stem fruits.

There are also additional qualifiers for specific leaf morphologies:

- **EVR/SMA**: small leaved (leaf length less than 2cm).
- **EVR/LAR**: large leaved (leaf length over 2cm).
- **EVR/FLE**: fleshy leaved.
- **CON/LOS**: lose needles in winter (winter deciduous)

Epiphytes, lianas and creepers

Some species survive above the ground only with the support of other plants or artificial structures. In these cases, the life form category should indicate the height that the plant reaches and leaf morphology type, followed by the qualifier indicating the plant behaviour:

- **LIA**: lianas, plants that use trees, shrubs or built structures for support without being attached.

- **CRE**: creepers and stranglers, plants that attach themselves to trees, shrubs or built structures rather just using them as support.
- **PAR**: Parasites, plants which depend on trees or shrubs for nutrients.

2.3.4 Wetland Herbaceous (HER)

- **Submerged hydrophytes (SHY)**: plants that grow in aquatic conditions with the whole plant in water, excluding aquatic bryophytes.

- **Emergent hydrophytes (EHY)**: plants that grow in aquatic conditions and have emergent shoots out of the water.

- **Helophytes (HEL)**: plants with buds in waterlogged conditions.

Fig. 27: *Nymphaea* sp., an emergent hydrophyte (EHY).

Fig. 28: *Typha latifolia*, a helophyte (HEL).

Certain species exhibit a high plasticity and change their structure according to environmental conditions. In these cases, the same species can be recorded as having a different life form according to the local habitat characteristics (e.g. *Oenanthe crocata* can occur as HEL in waterlogged situations but GEO in drier conditions). In these situations, the actual condition of the soil surface is what must be recorded. However, the presence of terrestrial vegetation in what is clearly a temporary waterlogged place, e.g. a puddle after heavy rain, should be recorded as terrestrial HER and not wetland HER.

Life Form Qualifiers for Wetland HER categories

Life Form Qualifiers for the SHY category

- **FLO**: floating plants.
- **LEA**: plants with floating leaves.

2.3.5 Terrestrial Herbaceous (HER)

- **Leafy hemicryptophytes (LHE)**: biannual or perennial broad leaved herbaceous species, sometimes named forbs.

- **Caespitose hemicryptophytes (CHE)**: perennial monocotyledonous grasses, sedges and rushes (Poaceae, Cyperaceae and Juncaceae) regardless as to whether they have rhizomes.

- **Therophytes (THE)**: annual plants that survive during the unfavourable season as seeds.

- **Geophytes (GEO)**: plants with buds below the soil surface (rhizomes, bulbs, tubers, etc.).

- **Cryptogams (CRY)**: bryophytes and lichens growing in the soil surface and some aquatic bryophytes; cryptogams growing on rock surfaces are recorded as Life Form qualifiers to the appropriate TER divisions.

Fig. 29: *Bellis perennis*, a leafy hemicryptophyte (LHE).

Fig. 30: *Dactylis glomerata*, a caespitose hemicryptophyte (CHE).

Fig. 31: *Tagetes patula*, a therophyte (THE).

Fig. 32: *Agapanthus africanus*, a geophyte (GEO).

Fig. 33: *Armeria maritima*, a herbaceous chamaephyte (HCH).

- **Herbaceous chamaephytes (HCH)**: perennial herbaceous plants with buds between 5 and 30 cm height.

Life Form Qualifiers for Terrestrial HER categories

Life Form Qualifiers for the CHE category

- **TUS**: tussock grasses typical of xeric conditions.

Life Form Qualifiers for the CRY category

- **BRY**: mosses and liverworts.
- **LIC**: lichens.

2.4 FIELD WORK PREPARATION

The mapping procedure is divided into two major stages: 1) the initial drawing of the main habitat patches; 2) the field recording of habitat attributes. The first task is the drawing of the main habitat patches on an initial map with the help of GIS or CAD software, based on the analysis of aerial and/or satellite imagery, as well as other available spatial data. This phase is critical in ensuring that the fieldwork runs efficiently, especially as the work is being performed in an ever-changing urban context where high level of detail can be recorded on the basic template. If a field computer is available, the initial maps can be taken into the field in digital media and then directly altered or corrected.

Thus, the initial habitat record is based on the definition of relatively homogeneous patches with different morphological types – *Areas*, *Lines* and *Points* – in order to capture the diversity of different environments in an urban context. The minimum mappable size for *Areas* has been defined as 100m^2 and, for *Lines*, the minimum mappable length is10 m. *Points* should only be recorded in case of exceptional ecological or cultural relevance. The entire survey area must be mapped; all elements should be recorded in the same map and every component of the survey area must be included as an *Area*, *Line* or *Point* or be part of one.

2.4.1 Rules for separating map elements

Each element is identified with a unique Alpha Code, which is an alphanumerical code combining capital letters and numbers, used to link the habitat attributes in the recording sheet to the geographical information on the map. A new mappable element should be separated from the surrounding elements in the case of:

- Change in dominant UHC (see page 29);
- Change of more than 30% in the cover of a LF or NLF category (see page 28);
- Change of at least 30% in the cover of a species in the whole element;
- Change in Site Descriptor (see page 38).

The initial drawing of habitat patches complying with the separation rules must be confirmed in the field, prior to the recording of habitat attributes.

2.4.2 Mapping *Areas*, *Lines* and *Points*

All habitat patches larger than 100 m^2 and with a non-linear shape should be mapped as *Areas*. Features with a linear form wider than 7m, such as large roads and broad rivers, should be mapped as *Areas*.

Narrow patches, with a length over 10 m and a width between 0.5 m and 7 m, should be mapped as *Lines*. Additionally, linear elements must follow a ratio 'width / length' lower or equal to 1/5. Linear habitats must consist of relatively continuous extensions of LF or NLF categories that should cover more than 30% of the length of the element. There are however some exceptions to the recording of important linear elements:

- Walls and watercourses should always be recorded even if less than 0.5 m wide, as long as they are at least 10m long;
- The width of lines of trees does not include the canopy, i.e. if the element is composed of an obvious single row of trees it should be recorded as a *Line* even if the canopy width exceeds 7 m;
- Lines of trees and shrubs should always be recorded as such, when there is a clear intention of alignment and the individual plants are not more than 5 m apart from each other;
- Intricate habitats composed of multiple linear elements close to each other (points can also be included) should be mapped as *Areas* (e.g. a formal garden) to avoid highly complex maps;
- *Lines* can be mapped taking only into account one of the height categories (both LF or NLF) ; in this case, the mapped *Line* will be overlapping with other *Lines* or *Areas* and should always be assessed as a separate entity (e.g. not be included in area calculations).

Habitat patches smaller than 100 m^2 or shorter than 10 m in length can be recorded as *Points*. These should only be recorded if they play a significant role in the survey area, which is defined by, at least, one of the following criteria:

1. The *Point* contributes to habitat diversity – the element represents a particular habitat, distinct from the surroundings and is absent as an *Area* or *Line*; this element must only be recorded if larger than 4 m^2 (e.g. a large tree in an extensive meadow);
2. The *Point* affects the ecological functions on a larger scale – the element is important as a habitat, but has also a significant influence on the wider context, either by inducing important ecological processes that go beyond the

actual habitat patch, or by affecting existing ecological processes acting on a larger scale, e.g. a tree which can be a staging post for bird migrations or a small pond in a dry grassland);

3. The *Point* has botanical significance - the element includes a botanical specimen that differs from its context (e.g. rare or endemic native plants or rare cultivated plants);
4. The *Point* has cultural significance - the element includes a human artefact with valuable historical or artistic connotations (e.g. a classified monument).

2.5 FIELD WORK

2.5.1 Recording Form

As mentioned above, once the initial map is drafted, the habitat elements are then confirmed *in situ*. The fieldwork subsequently consists of filling the Recording Form with the habitat qualifiers. The Recording Form identifies each mapped habitat element and describes its attributes. *Areas*, *Lines* and *Points* should be recorded in different sheets; *Lines* and *Points* can have simpler recording sheets in order to speed up the recording process.

The dominant Urban Habitat Category is the main attribute of each element, but other qualifiers improve and refine habitat description, especially in the event of identical UHC. Besides the Alpha Code, the recording form has three fields (Figure 34; complete Recording Form in Annex, pages 92-95):

- Field 1: Urban Habitat Category (UHC);
- Field 2: Full list of Life Form (LF) and Non Life Form (NLF) categories and dominant species;
- Field 3: Site Descriptors.

α Code	Field 1	Field 2				Field 3
	Urban Habitat Category	Full list of LF and NLF categories				Site Descriptor
		LF and NLF categories	%	Species	%	
A1	FPH/DEC	FPH/DEC	70	Que rob	80	Closed wood
		CHE	50	Agr cur	50	
		LHE	40	Dig pur	70	

Fig. 34: Recording Form example, showing the species *Quercus robur* (Que rob). *Agrostis curtisii* (Agr cur) and *Digitalis purpurea* (Dig pur) in a Forest Phanerophytes Deciduous (FPH/DEC) habitat.

2.5.2 Full list of Life Form (LF) and Non Life Form (NLF) categories and dominant species (Field 2)

Although the UHC is the main habitat attribute, the list of existing LF and NLF categories should be completed first in Field 2, as the dominant UHC depends on the percentage cover of each category present in each habitat element (see the Decision Tree in Figure 37). It should be noted that the decision on UHC must be made in the field, since it is better to assess the habitats on site.

The presence of 10% or more of each LF and NLF categories is then recorded in Field 2, followed by the appropriate Life Form Qualifier, if applicable. The percentage covers are recorded in sets of ten, i.e. the actual percentage must be rounded to the nearest 10% band (e.g. 35% cover should be recorded as 40%). To better evaluate the vertical

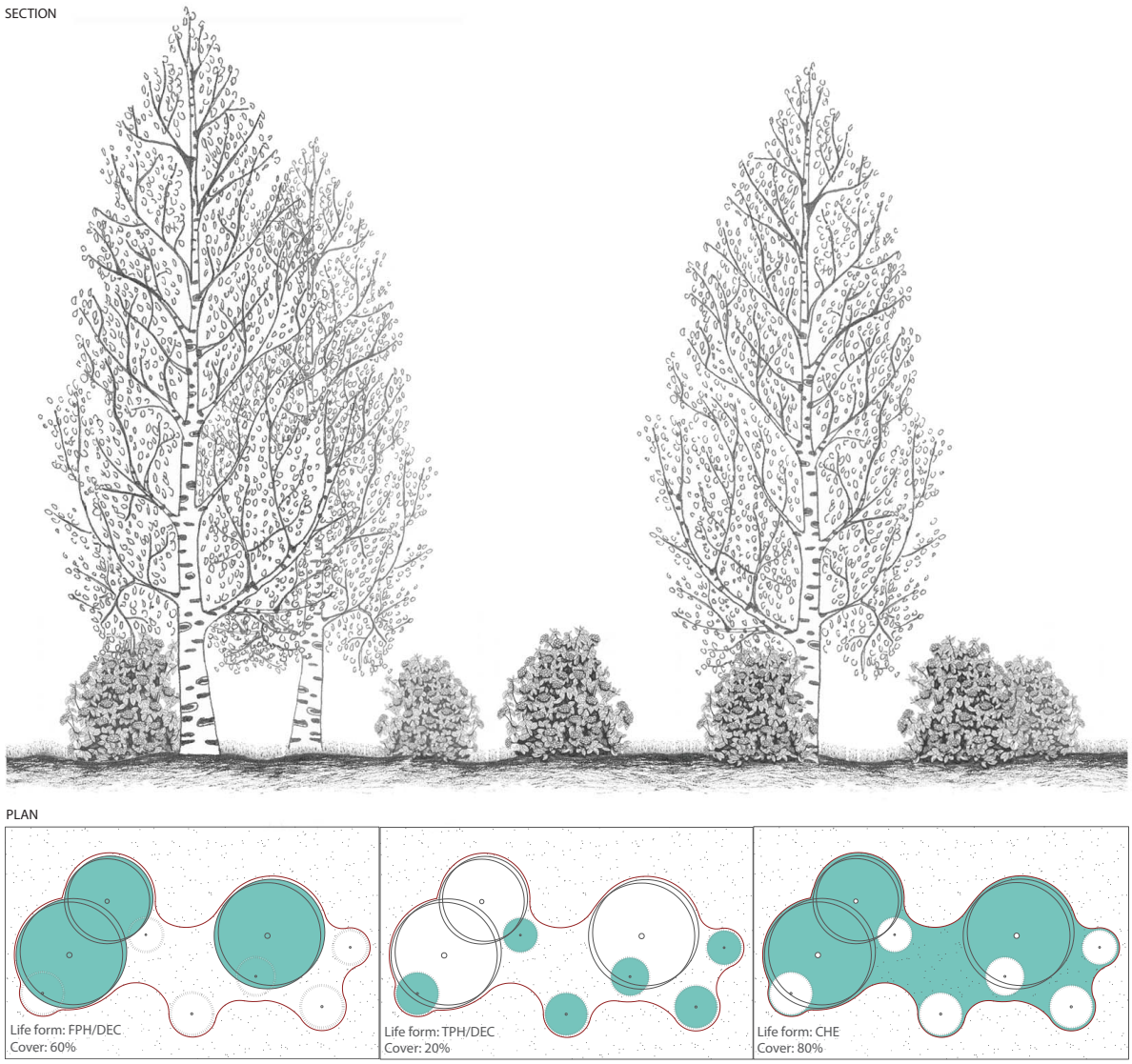


Fig. 35: The cover of each LF or NLF category is measured individually, separately from the others.

diversity, all the existing LF and NLF height categories should be measured individually and recorded to their full extent, regardless of whether they are covered by a higher layer. The percentage of every LF and NLF category must be measured through an estimate of cover in each range of heights, by vertical projection, usually generating overlapping height categories (Figure 35); each height category cannot surpass 100% cover, but it is usual to have multiple layers adding to more than 100%.

For each LF category, the cover of each species in its height category should be estimated visually. All species with 30% or more of its LF category are recorded, as well as their percentage cover (also rounded to 10% bands).

Each species is recorded in a separate row and the scientific name should be used in an abbreviate form: only the first three letters of the genus and of the species name (e.g. *Araucaria heterophylla* becomes 'Ara het'); in situations of equivocal nomenclature make sure they are well differentiated (e.g. *Pinus pinea* and *Pinus pinaster* must have different codes). When it is not possible to identify a plant species in the field, a specimen or a sample should be collected for later identification by a specialist.

2.5.3 Urban Habitat Category (Field 1)

The first step for the definition of the UHC is to determine the dominant super-category, through means of percentage cover, as shown in the dichotomous Decision Tree in Figure 37. In each mapped habitat element, the percentage of each super-category consists of the overall cover of all categories LF or NLF categories belonging to the same super-category, from a vertical perspective, i.e. only the higher layers are considered if they are overlapping lower layers of the same super-category (Figure 36).

Following the definition of the super-category, the UHC will be formed by a single LF or NLF category or by a combination of two categories within each super-category. There is a maximum of 160 permitted UHCs – 16 ABE; 82 TRS; 6 wetland HER; 21 terrestrial HER; and 14 SPV, plus 21 SPV-TER (see each category and allowed combinations in the following pages). No other UHCs and combinations are allowed, as it would create an unmanageable number of UHCs.

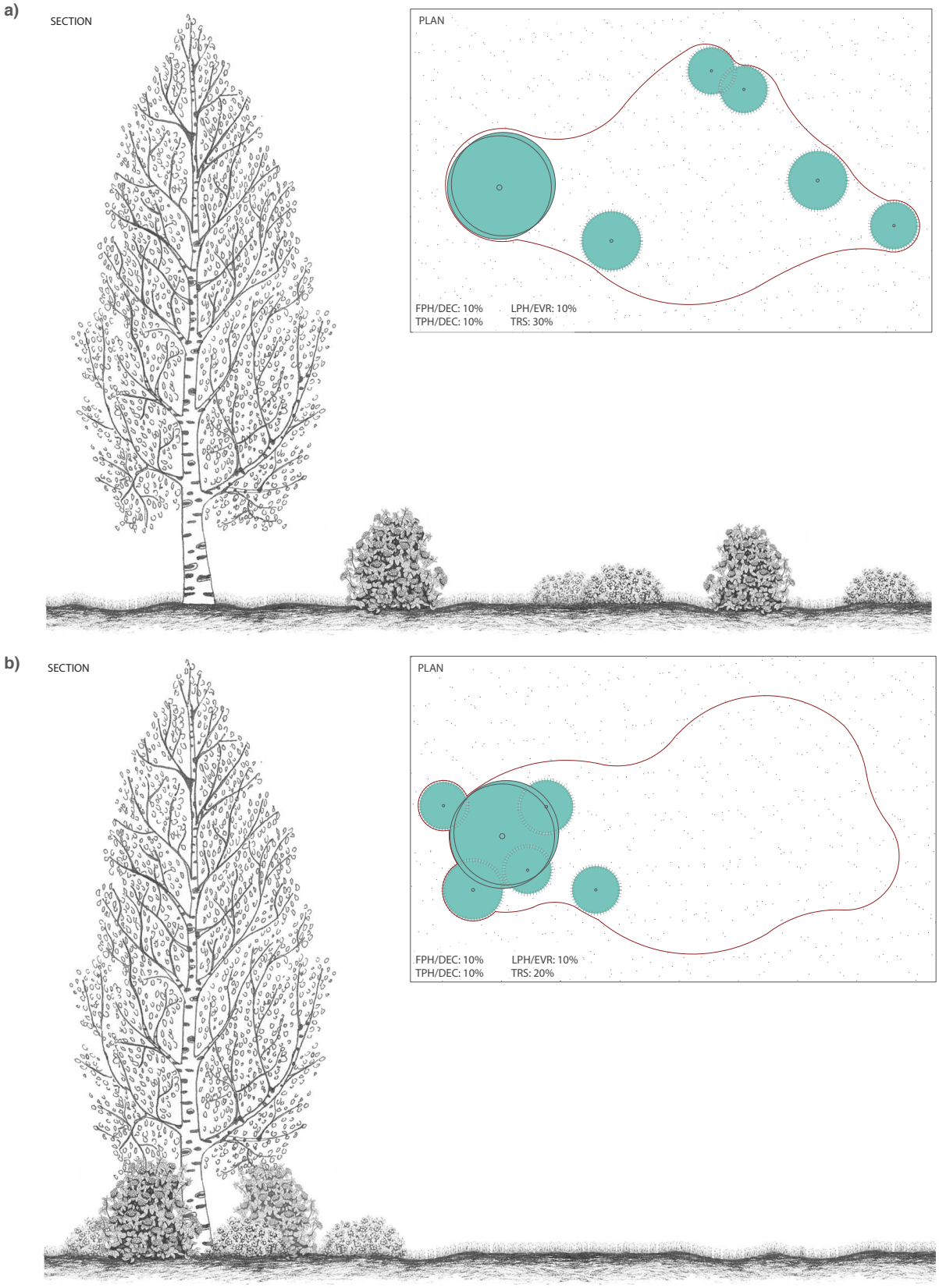


Fig. 36: To determine the total cover of each super-category, all the existing categories (LF or NLF) are measured together.
a) In this example, three categories of the Trees and Shrubs (TRS) super-category occur, with a total cover of 30%, i.e. according to the decision tree, the UHC will be from the TRS super-category; b) In this example, three categories measured individually correspond to values of FPH/DEC 10%, TPH/EVR 10%, LPH/EVR 10%, but measured as a whole and considering they overlap in space, the total cover of TRS is only 20%, i.e. according to the decision tree, the UHC will be from a different super-category (see Figure 37).

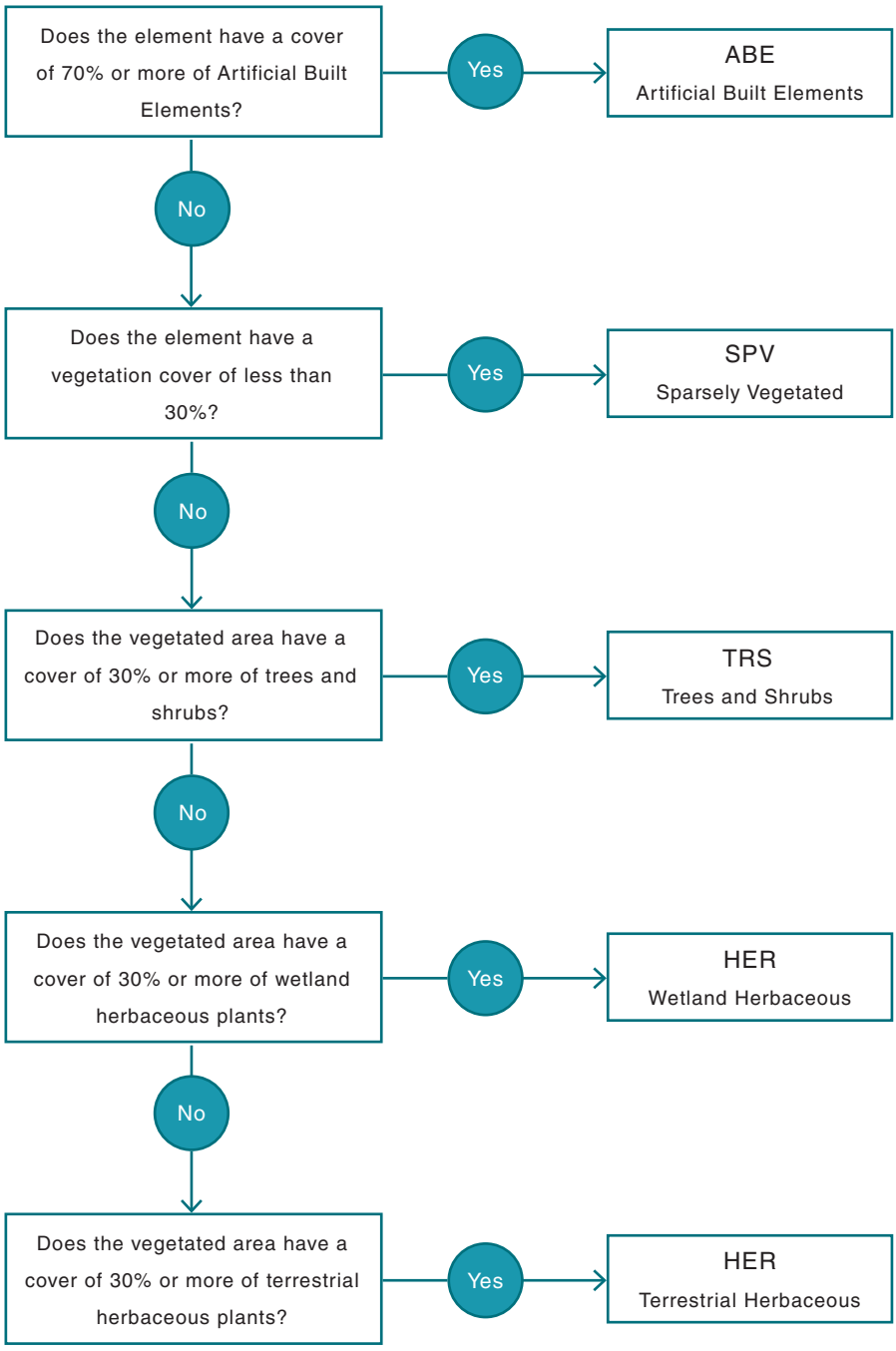


Fig. 37: Decision Tree for the super-categories.

Percentage rules for determining the UHC

The general rules for UHC determination are:

1. The UHC will be a single code if one of the LF or NLF categories has a 70% proportion considering the two most abundant categories in the previously determined super-category;

2. The UHC will be a double code if the two most abundant LF or NLF categories in the previously determined super-category have a proportion of 40% to 60%.

This means that, in some cases, recalculations must be made in order to determine the UHC. As an example, a habitat patch with PAV 50%, LHE 30%, CHE 20% would be defined as LHE/CHE, since these categories make up 60% and 40%, respectively, of the HER super-category.

However, for the ABE and TRS super-categories, the procedure is slightly different.
In the case of ABE, the exception occurs when NLF categories with different heights occur in the same place, overlapping (e.g. a pergola - STR, over pavement - PAV); this causes the co-dominance of NLF categories in the range of 40-100%. Additionally, it should be mentioned that ABE habitats will always be classified with double (dominant category, plus presence or absence of vegetation; e.g. AQE/VGT) or triple codes (co-dominant categories, plus presence or absence of vegetation; e.g. STR/PAV/NVG).

For the TRS super-category, it is only allowed to combine two LF of the same height category. The highest LF category with 30% cover or more takes precedence over the lower categories. Thereafter, if the highest category is composed of one leaf morphology sub-category with a 70% proportion or more (of the considered height category), the UHC will consist of a double code (height category/leaf retention type); if that height category has two sub-categories with a 40-60% proportion the UHC will be a triple code combination (height category/leaf retention type 1/leaf retention type 2).

The precedence rules, provided in the next few pages, designate the order in which the categories must combine. Additionally, if there are equal proportions of three LF or NLF categories the precedence rules indicate the correct combination to apply (e.g. LHE 30%, CHE 30%, THE 30% would be LHE/CHE).

Artificial Built Elements (ABE)

The UHCs in this super-category and their precedence rules are indicated in the following table.

Artificial built elements	ABE
Built structure with vegetation	STR/VGT
Built structure without vegetation	STR/NVG
Aquatic element with vegetation	AQE/VGT
Aquatic element without vegetation	AQE/NVG
Pavement with vegetation	PAV/VGT
Pavement without vegetation	PAV/NVG
Rubbish with vegetation	RUB/VGT

Rubbish without vegetation	RUB/NVG
Built structure / Aquatic element with vegetation	STR/AQE/VGT
Built structure / Aquatic element without vegetation	STR/AQE/NVG
Built structure / Pavement with vegetation	STR/PAV/VGT
Built structure / Pavement without vegetation	STR/PAV/NVG
Built structure / Rubbish with vegetation	STR/RUB/VGT
Built structure / Rubbish without vegetation	STR/RUB/NVG
Aquatic element / Pavement with vegetation	AQE/PAV/VGT
Aquatic element / Pavement without vegetation	AQE/PAV/NVG

The total vegetation cover in Artificial Built Elements (ABE) is recorded in Field 2 under the code VGT, and complemented with the corresponding LF categories (identical to TRS and HER categories). Furthermore, it should be kept in mind that in the case of combinations, the total cover of VGT refers to the entire habitat and not only to the NLF category where it occurs.

Sparsely Vegetated (SPV)

These first five categories can be used individually or in combination, without the TER subdivisions, in the following way:

Sparsely vegetated	SPV
Sea	SEA
Aquatic	AQU
Ice and snow	ICE
Terrestrial	TER
Organic Litter	LIT
Sea / Ice	SEA/ICE
Sea / Terrestrial	SEA/TER
Sea / Organic Litter	SEA/LIT
Aquatic / Ice	AQU/ICE
Aquatic / Terrestrial	AQU/TER
Aquatic / Organic Litter	AQU/LIT
Ice / Terrestrial	ICE/TER
Ice / Organic litter	ICE/LIT
Terrestrial / Organic Litter	TER/LIT

If it is adequate for the purpose of your study, you can subdivide the TER category according to soil particle size. The UHCs and combinations are as follows:

Terrestrial	TER
Bare rock	ROC
Boulders	BOU
Stones	STO
Gravel	GRV
Sand	SAN
Earth	EAR
Rock / Boulders	ROC/BOU
Rock / Stones	ROC/STO
Rock / Gravel	ROC/GRV
Rock / Sand	ROC/SAN
Rock / Earth	ROC/EAR
Boulders / Stones	BOU/STO
Boulders / Gravel	BOU/GRV
Boulders / Sand	BOU/SAN
Boulders / Earth	BOU/EAR
Stones / Gravel	STO/GRV
Stones / Sand	STO/SAN
Stones / Earth	STO/EAR
Gravel / Sand	GRV/SAN
Gravel / Earth	GRV/EAR
Sand / Earth	SAN/EAR

Trees and Shrubs (TRS)

The following precedence rules apply to TRS categories:

- The height categories are mutually exclusive and cannot be combined with other height categories.
- The precedence is given to the tallest category with at least 30% cover; for example, in the case of FPH 10%, TPH 30%, MPH 40%, the UHC is TPH, followed by its respective leaf morphology.
- The order of precedence is set by the conceptual nutrient/environmental demands of the species groups, i.e. winter deciduous species are generally in temperate conditions, whereas summer deciduous are in xeric situations. Precedence rules are used for combinations, e.g. MPH/DEC 30%, MPH/EVR 30%, MPH/CON 30% would be MPH/DEC/EVR.
- If none of the height categories reaches 30% cover, the UHC will be determined by the most abundant height

category; in case of equal proportions, the precedence is given to the highest category (for example, FPH/CON 10%, TPH/EVR 10%, TPH/CON 10%, MPH/DEC 20%, would be TPH/EVR/CON).

The following table clarifies every possible UHC and combination in the TRS super-category and indicates the precedence rules for leaf sub-categories.

Trees and shrubs	TRS
Dwarf chamaephytes winter deciduous	DCH/DEC
Dwarf chamaephytes evergreen	DCH/EVR
Dwarf chamaephytes coniferous	DCH/CON
Dwarf chamaephytes winter deciduous / evergreen	DCH/DEC/EVR
Dwarf chamaephytes winter deciduous / coniferous	DCH/DEC/CON
Dwarf chamaephytes evergreen / coniferous	DCH/EVR/CON
Shrubby chamaephytes winter deciduous	SCH/DEC
Shrubby chamaephytes evergreen	SCH/EVR
Shrubby chamaephytes coniferous	SCH/CON
Shrubby chamaephytes non-leafy evergreen	SCH/NLE
Shrubby chamaephytes summer deciduous and/or spiny cushion	SCH/SUM
Shrubby chamaephytes winter deciduous / evergreen	SCH/DEC/EVR
Shrubby chamaephytes winter deciduous / coniferous	SCH/DEC/CON
Shrubby chamaephytes winter deciduous / non-leafy evergreen	SCH/DEC/NLE
Shrubby chamaephytes winter deciduous / summer deciduous	SCH/DEC/SUM
Shrubby chamaephytes evergreen / coniferous	SCH/EVR/CON
Shrubby chamaephytes evergreen / non-leafy evergreen	SCH/EVR/NLE
Shrubby chamaephytes evergreen / summer deciduous	SCH/EVR/SUM
Shrubby chamaephytes coniferous / non-leafy evergreen	SCH/CON/NLE
Shrubby chamaephytes coniferous / summer deciduous	SCH/CON/SUM
Shrubby chamaephytes non-leafy evergreen / summer deciduous	SCH/NLE/SUM
Low phanerophytes winter deciduous	LPH/DEC
Low phanerophytes evergreen	LPH/EVR
Low phanerophytes coniferous	LPH/CON
Low phanerophytes non-leafy evergreen	LPH/NLE
Low phanerophytes summer deciduous	LPH/SUM
Low phanerophytes winter deciduous / evergreen	LPH/DEC/EVR
Low phanerophytes winter deciduous / coniferous	LPH/DEC/CON
Low phanerophytes winter deciduous / non-leafy evergreen	LPH/DEC/NLE
Low phanerophytes winter deciduous / summer deciduous	LPH/DEC/SUM
Low phanerophytes evergreen / coniferous	LPH/EVR/CON
Low phanerophytes evergreen / non-leafy evergreen	LPH/EVR/NLE

Low phanerophytes evergreen / summer deciduous	LPH/EVR/SUM
Low phanerophytes coniferous / non-leafy evergreen	LPH/CON/NLE
Low phanerophytes coniferous / summer deciduous	LPH/CON/SUM
Low phanerophytes non-leafy evergreen / summer deciduous	LPH/NLE/SUM
Mid phaneropytes winter deciduous	MPH/DEC
Mid phaneropytes evergreen	MPH/EVR
Mid phaneropytes coniferous	MPH/CON
Mid phaneropytes non-leafy evergreen	MPH/NLE
Mid phaneropytes summer deciduous	MPH/SUM
Mid phanerophytes winter deciduous / evergreen	MPH/DEC/EVR
Mid phanerophytes winter deciduous / coniferous	MPH/DEC/CON
Mid phanerophytes winter deciduous / non-leafy evergreen	MPH/DEC/NLE
Mid phanerophytes winter deciduous / summer deciduous	MPH/DEC/SUM
Mid phanerophytes evergreen / coniferous	MPH/EVR/CON
Mid phanerophytes evergreen / non-leafy evergreen	MPH/EVR/NLE
Mid phanerophytes evergreen / summer deciduous	MPH/EVR/SUM
Mid phanerophytes coniferous / non-leafy evergreen	MPH/CON/NLE
Mid phanerophytes coniferous / summer deciduous	MPH/CON/SUM
Mid phanerophytes non-leafy evergreen / summer deciduous	MPH/NLE/SUM
Tall phanerophytes winter deciduous	TPH/DEC
Tall phanerophytes evergreen	TPH/EVR
Tall phanerophytes coniferous	TPH/CON
Tall phanerophytes non-leafy evergreen	TPH/NLE
Tall phanerophytes summer deciduous	TPH/SUM
Tall phanerophytes winter deciduous / evergreen	TPH/DEC/EVR
Tall phanerophytes winter deciduous / coniferous	TPH/DEC/CON
Tall phanerophytes winter deciduous / non-leafy evergreen	TPH/DEC/NLE
Tall phanerophytes evergreen / coniferous	TPH/EVR/CON
Tall phanerophytes evergreen / non-leafy evergreen	TPH/EVR/NLE
Tall phanerophytes evergreen / summer deciduous	TPH/EVR/SUM
Tall phanerophytes coniferous / non-leafy evergreen	TPH/CON/NLE
Tall phanerophytes coniferous / summer deciduous	TPH/CON/SUM
Forest phanerophytes winter deciduous	FPH/DEC
Forest phanerophytes evergreen	FPH/EVR
Forest phanerophytes coniferous	FPH/CON
Forest phanerophytes summer deciduous	FPH/SUM
Forest phanerophytes winter deciduous / evergreen	FPH/DEC/EVR
Forest phanerophytes winter deciduous / coniferous	FPH/DEC/CON

Forest phanerophytes evergreen / coniferous	FPH/EVR/CON
Forest phanerophytes evergreen / summer deciduous	FPH/EVR/SUM
Forest phanerophytes coniferous / summer deciduous	FPH/CON/SUM
Mega forest phanerophytes winter deciduous	GPH/DEC
Mega forest phanerophytes evergreen	GPH/EVR
Mega forest phanerophytes coniferous	GPH/CON
Mega forest phanerophytes summer deciduous	GPH/SUM
Mega forest phanerophytes winter deciduous / evergreen	GPH/DEC/EVR
Mega forest phanerophytes winter deciduous / coniferous	GPH/DEC/CON
Mega forest phanerophytes evergreen / coniferous	GPH/EVR/CON
Mega forest phanerophytes evergreen / summer deciduous	GPH/EVR/SUM
Mega forest phanerophytes coniferous / summer deciduous	GPH/CON/SUM

Wetland Herbaceous (HER)

The presence of over 30% of these three classes takes precedence over terrestrial Herbaceous LF categories. The UHCs and the order in combinations are determined by the ranking given below.

Wetland Herbaceous	HER
Submerged hydrophytes	SHY
Emergent hydrophytes	EHY
Helophytes	HEL
Submerged hydrophytes / Emergent hydrophytes	SHY/EHY
Submerged hydrophytes / Helophytes	SHY/HEL
Emergent hydrophytes / Helophytes	EHY/HEL

Terrestrial Herbaceous (HER)

The table below provides the UHCs and combinations, as well as the precedence rules for equal proportions of Terrestrial Herbaceous life forms.

Terrestrial Herbaceous	HER
Leafy hemicryptophytes	LHE
Caespitose hemicryptophytes	CHE
Therophytes	THE

Geophytes	GEO
Herbaceous chamaephytes	HCH
Cryptogams	CRY
Leafy hemicryptophytes / Caespitose hemicryptophytes	LHE/CHE
Leafy hemicryptophytes / Therophytes	LHE/THE
Leafy hemicryptophytes / Geophytes	LHE/GEO
Leafy hemicryptophytes / Herbaceous chamaephytes	LHE/HCH
Leafy hemicryptophytes / Herbaceous chamaephytes	LHE/CRY
Caespitose hemicryptophytes / Therophytes	CHE/THE
Caespitose hemicryptophytes / Geophytes	CHE/GEO
Caespitose hemicryptophytes / Herbaceous chamaephytes	CHE/HCH
Caespitose hemicryptophytes / Cryptogams	CHE/CRY
Therophytes / Geophytes	THE/GEO
Therophytes / Herbaceous chamaephytes	THE/HCH
Therophytes / Cryptogams	THE/CRY
Geophytes / Herbaceous chamaephytes	GEO/HCH
Geophytes / Cryptogams	GEO/CRY
Herbaceous chamaephytes / Cryptogams	HCH/CRY

2.5.4 Site Descriptors (Field 3)

In this methodology, Site Descriptors intend to provide a common name for each type of space, linking ecological and landscape approaches and aiding the perception of the space. The following tables aim to provide comprehensive lists of sites commonly present in the urban context, but these can be enriched or altered to satisfy different settings or research objectives.

Vegetation structures	*Description*
Row of trees	Trees planted at regular intervals in a single row
Tree alley / tree avenue	Planted trees lining paths or roadways, sometimes in double rows on each side
Tree border	Long strip dominated by trees edging a path or a wall, or surrounding an open area, where the shrub and herbaceous layer are not expressive
Group of trees	Small group of trees or a large single tree
Orchard	Area cultivated with fruit trees, regularly maintained
Open wood	Woodland with 30-70% of tree cover, with a reduced understory
Closed wood	Woodland with more than 70% of tree cover, with a reduced understory

Fig. 38: ‘Tree alley / tree avenue’, in City Park.

Fig. 39: ‘Open wood’, in D. João III Square.

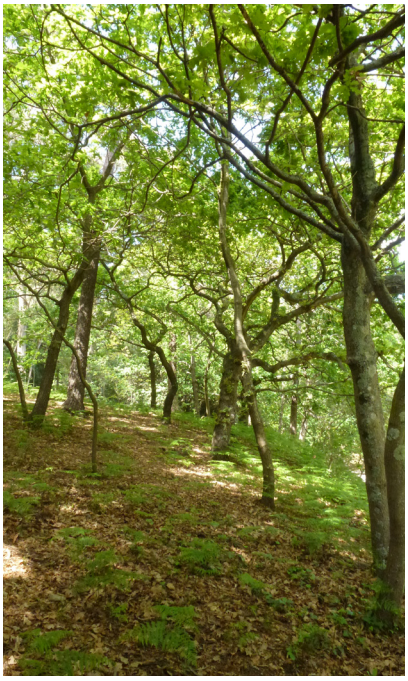


Fig. 42: ‘Closed wood’, in Serralves Park.

Fig. 40: ‘Closed wood’ with understory, in City Park.

Fig. 41: ‘Multi-layered border’, in Serralves Park.

Fig. 43: ‘Formal garden with trees’, in Cordoaria Garden.

Fig. 44: ‘Formal garden’, in the Botanical Garden of Porto.

Fig.45: ‘Thicket’, in City Park.

Fig. 46: ‘Shrub patch’, in Serralves Park.

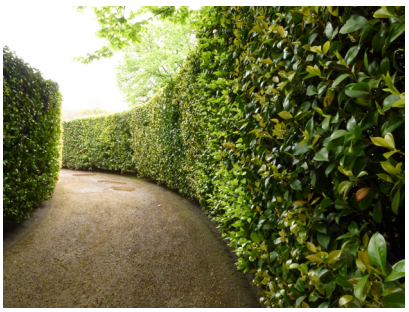


Fig. 47: ‘Hedge’, in Serralves Park.

Fig. 48: ‘Herbaceous / Shrub border’, in the Botanical Garden of Porto.

Fig. 49: ‘Tall meadow’, in Serralves Park.

Fig. 50: ‘Lawn’, in City Park.

Fig. 51: ‘Marginal vegetation’, in City Park.

Open wood with understory	Woodland with 30-70% of tree cover, with a well-developed understory, usually impeding the passage
Closed wood with understory	Woodland with more than 70% of tree cover, with a well-developed understory, usually impeding the passage
Multi-layered border	Long strip with a mixed composition of herbaceous plants or shrubs with trees edging a path or a wall, or surrounding an open area
Formal garden with trees	Garden with a strong geometrical character, emphasizing straight lines, right angles and circles, with tree cover
Formal garden	Garden with a strong geometrical character, emphasizing straight lines, right angles and circles, without tree cover
Botanical collection	Thematic collection of living plants with educational or scientific interest
Thicket	Dense patch of tall shrubs, obstructing the passage and the view
Scrub	Area dominated by natural or naturalized shrubs and tall herbaceous plants
Shrub patch	Patch of shrubs continuously covering a certain area; it can also include large single shrubs
Hedge	Line of closely spaced shrubs or trees, planted and trained to form a barrier or to mark the boundary of an area
Row of shrubs	Shrubs planted at regular intervals in a single row
Herbaceous / Shrub border	Long strip with herbaceous plants or/and shrubs edging a path or a wall, or surrounding an open area
Raised bed	Cultivated area enclosed or supported by a wall or similar structure
Raised bed with trees	Same as raised bed, but also with single or groups of trees
Bed	Delimited area cultivated with flowers, vegetables or herbs
Bed with trees	Same as bed, but also with single or groups of trees
Allotment	Portion of land divided in small plots, generally owned by local government or associations, each of which is cultivated by individuals or families
Vegetable garden	Small land plot cultivated with vegetables, herbs or other plants for food or other direct human use
Cultivated field	Large area cultivated with annual crops
Tall meadow	Area covered by annual and perennial grasses and forbs, subject to infrequent cuts in order to keep a tall plant height (mowing, grazing, etc.)
Short meadow	Area covered by annual and perennial grasses and forbs, subject to frequent cuts in order to keep a short plant height (mowing, grazing, etc.)
Lawn	Area covered mainly with perennial grasses (>70%), intensively maintained and controlled
Waterlogged patch	Vegetation present in soils temporarily saturated with water
Marsh	Wetland dominated by herbaceous plants
Swamp	Wetland dominated by woody plants
Reed bed	Area dominated by tall grass-like plants, growing in or near water
Marginal vegetation	Vegetation characteristic of moist soils, adjacent to a water element
Riparian gallery	Wooded corridors along rivers or wetlands
Riparian woodland	Wooded area in the floodplain of a water element
Dune slack	Interdunal wetland
Salt marsh	Coastal wetland with saline soils

Water features	*Description*
Spring	Site where water naturally emerges from the ground
Artificialized spring	Site where water from a spring, underground aquifer or piped waterline is conducted to the surface through man-made channels or similar structures
Watercourse	Flowing body of water
Canalised watercourse	Modified watercourse (e.g. sections straightened, banks smoothed), following the same direction as the natural watercourse
Canal	Constructed element mainly for irrigation, water supply or boat traffic
Drainage channel	Constructed conduit for the removal of water or waste water
Ditch	Excavated channel, for irrigation or drainage
Waterfall	Vertical flow of water in the course of a stream or river, following an abrupt change of level of the river bed
Cascade	Simulated cascade in a given water element
Lake	Relatively large and deep water body, with standing or slow-moving freshwater, located inland
Pond	Relatively small and shallow body of standing or slow-moving water
Lagoon	Shallow body of saline or brackish water separated from deeper sea by a bar
Temporary pond	Ponds that are only filled with water for part of the year
Infiltration basin	Shallow artificial depression designed to retain and infiltrate storm water through permeable soils into the groundwater aquifer
Grotto with water	Artificial ornamental cave flooded with water
Fountain	Piece of architecture which pours water into a basin or jets it into the air to supply drinking water and/or for a decorative effect
Tank	Open container or pool for storing water
Water well	Artificial excavation, hole or structure for the purpose of withdrawing water
Water display	Complex water jets and/or cascades with ornamental and entertaining functions
Reflecting pool	Shallow pool of water, undisturbed by fountain jets, for a reflective surface

Fig. 52: 'Watercourse', River Douro.

Fig. 53: 'Canal', in Serralves Park.

Fig. 54: 'Lake', in City Park.

Fig. 55: 'Tank', in Serralves Park.

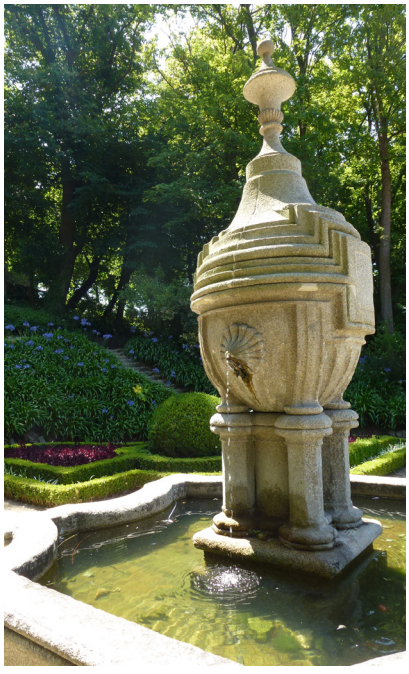


Fig. 56: 'Fountain', in the Gardens of Palácio de Cristal.

Built elements	*Description*
Wall	Solid vertical structure that defines, divides or protects an area
Retaining wall	Structure built to support soil and prevent it from advancing forward
Dam	Large barrier impounding rivers or underground streams
Weir	Smaller barrier to water flow, pooling water behind it while also allowing it to flow steadily over their tops
Levee or dike	Raised river bank, controlling water level and preventing floods
Seawall	Coastal defence structure that protects the shoreline from the action of tides and waves
Bridge	Constructed structure that spans a gap
Building	A closed structure with walls and a roof
Outdoor performing venue	Constructed structure with the purpose of supporting outdoor cultural events or ceremonies, such as bandstands, stages, amphitheatres, etc.
Green roof	Building with its roof covered with vegetation and its growing medium
Greenhouse	Building or structure with glass or plastic walls and roof in which plants are grown
Pergola	Structure in the form of a trelliswork roof, walls or columns, used to support and train climbing plants
Belvedere	Architectural structure sited to take advantage of a fine or scenic view
Terrace (unpaved)	Levelled surface supported by retaining walls, with natural ground cover
Shed	Simple one-story structure, open or closed, used for storage or as a workshop
Animal shed	Building or structure used to enclose animals
Folly	Decorative construction whose main function is ornamental or recreational
Artistic / decorative element	Artistic or decorative objects framed in a permanent or temporary display
Grotto	Artificial ornamental cave
Island (artificial)	Portion of land surrounded by water, man-made
Mound	Artificial landforms, hills or earth elevations
Benches	Piece of furniture, on which several people may sit at the same time
Underground ventilation	Grid or similar equipment belonging to a ventilation system
Construction site	Site with a highly dynamic nature where something is being built or repaired, or where construction materials are kept
Rubble / Debris	Small temporary deposit of litter, discarded refuse and scattered remains of something destroyed
Dumping ground	Place where waste or garbage is gathered or stored
Archaeological site	Edification or evidence of archaeological interest

Fig. 57: 'Retaining wall', in City Park.

Fig. 58: 'Bridge', in Gardens of Palácio de Cristal.

Fig. 59: 'Outdoor performing venue' (bandstand), in Cordoaria Garden.

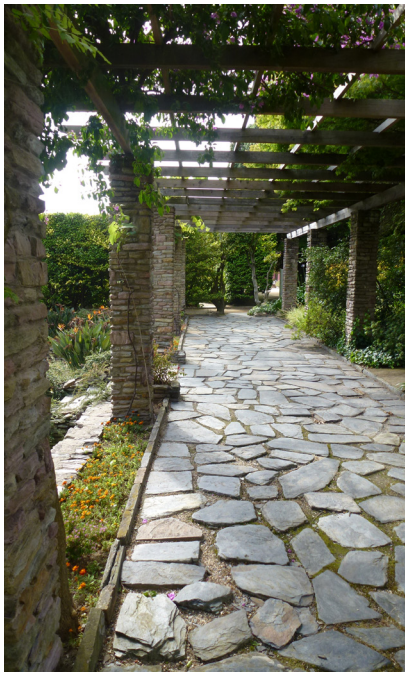


Fig. 60: ‘Pergola’, in Porto Botanical Garden of Porto.

Fig. 61: ‘Greenhouse’, in Serralves Park.

Fig. 62: ‘Grotto’, in S. Roque Park.

Fig. 63: ‘Building’, in Serralves Park.

Surfaces and paved areas	*Description*
Sidewalk	Paved footpath at the side of a road for the use of pedestrians
Path	Paved path for pedestrians
Dirt trail	Path created by stepping on a vegetated area
Road	Route designed to allow the travel by motor vehicles or carts
Cycle lane	Path for the use of bicycles, segregated from other traffic
Railway	Track consisting of parallel rails, over which wheeled vehicles may travel
Stairs	Contiguous set of steps connecting two or more levels
Ramp	Inclined surface connecting two levels
Underground access	Stairs, ramps, escalators or lifts connecting to an underground level
Patio	Paved outdoor space, adjoining a house, with some degree of enclosure
Terrace (paved)	Raised flat platform, supported by retaining walls
Sitting area	Paved area with sitting structures (benches)
Car park / Parking lot	Outdoor area where motor vehicles can park
Playground	Small area with dedicated play equipment, usually for children
Picnic area	Outdoor area with picnic equipment
Sports area	Outdoor playing area with sports equipment
Paved area	Outdoor paved area with no evident function
Ornamental ground cover	Inert ground cover with decorative or maintenance functions (e.g. pebbles, gravel, clay, mulch)

Abandoned area	Area with evidence of a previous land use, but currently being invaded by spontaneous vegetation
Non-vegetated area	Area with little or no vegetation due to naturally occurring environmental conditions

Fig. 64: 'Sidewalk', in Carlos Alberto Square.

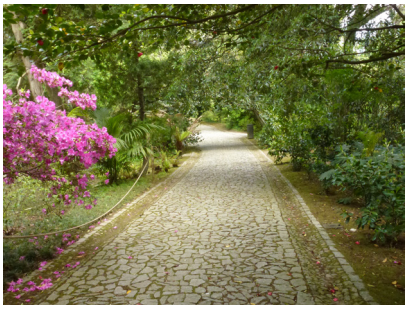


Fig. 65: 'Path', in Serralves Park.

Fig. 66: 'Dirt trail', in Serralves Park.

Fig. 69: 'Cycle lane', at the entry of Pasteleira Park.

Fig. 67: 'Stairs', in Gardens of Palácio de Cristal Garden.

Fig. 68: 'Patio', in City Park.

Fig. 70: 'Sitting area', in Pasteleira Park, Porto.

Fig. 71: 'Playground', in Palácio de Cristal Garden.

Geomorphological elements	*Description*
Cliff	Vertical or near vertical area of rock
Rock outcrop	Visible exposure of bedrock
Beach	Shore of a body of water, usually sandy or pebbly
Dune	Ridge or hill of sand piled up by the wind
Island (natural)	Portion of land surrounded by water, formed by natural processes

Fig. 72: 'Rock outcrop', in São Roque Park.

Fig. 73: 'Beach', Praia dos Ingleses.

2.5.5 Other attributes

This urban habitat mapping methodology aims to be simple and flexible. In addition to the previously mentioned attributes, other qualifiers can also be included if they follow the aim of the study. The original methodology (EBONE project; Bunce et al., 2011), applies further qualifiers to classify environmental conditions, management regimes, etc. As an example, Environmental Qualifiers indicate soil conditions for the vegetation, such as moisture and acidity, and are to be used only in vegetated areas, and Global Qualifiers are used to indicate exceptional situations (e.g. accessibility, change since previous monitoring, etc.). A complete list and description of other attributes is available in the Manual for Habitat and Vegetation Surveillance and Monitoring (Bunce et al., 2011), and if necessary extra attributes can be created.

For the purpose of our study, we intended to analyse the vertical structure of vegetation, so **Vegetation Layers** were considered as an additional attribute (see page 48).

2.5.6 Practical example

To demonstrate the recording process, we will use an example (City Park, Porto, Portugal). The first step consists on drafting the initial map based on remotely detected imagery and other sources of spatial data; in this case Google Earth 2007 image was the main source of information. Photo-interpretation allowed the drawing of habitat patches – Areas, Lines and Points (Figure 74).

Fig. 74: Initial map based on the analysis of satellite imagery, drawn over Google Earth image (©Google, 2007).

During fieldwork, i) previously drawn habitat patches are verified and adjusted to fit current size and condition; ii) habitat patches not easily visible through remote imagery are now drawn; iii) all habitat patches are assigned a unique alpha code. This task results in the habitat map final format (Figure 75).

Fig. 75: Final field map, after adjustments.

The habitat attributes for each *Area, Line* or *Point* are registered in the recording form, as shown below (Figures 76-78).

α Code	Field 1	Field 2				Field 3
	Urban Habitat Category	Full list of LF and NLF categories				Site Descriptor
		LF and NLF categories	%	Species	%	
…						
A288	THE	THE	60	Pla cor	50	Short meadow
		CHE	20	Fes aru	50	
		LHE	20	Pla lan	60	
A289	FPH/DEC	FPH/DEC	80	Aln glu	50	Thicket
		MPH/EVR	30	Rub ulm	100	
		GEO	20	Oen cro	70	
		LHE	20	Tri rep	30	
		CHE	10	Cyn dac	30	
		EAR	30			
A290	CHE	CHE	60	Fes aru	70	Short meadow
		LHE	30	Pla lan	60	
		THE	10	Vul myu	40	
A291	FPH/EVR	FPH/EVR	90	Met exc	100	Thicket
		EAR	50			
		LIT	50			
…						

Fig. 76: Example of the filling of the recording form for *Area*.

α Code	Field 1	Field 2		Field 3
	Urban Habitat Category	Species	%	Site Descriptor
…				
L277	FPH/DEC	Sal atr	30	Marginal vegetation
		Iri pse	30	
		Oen cro	30	
A278	CHE/GEO	Pas urv	30	Marginal vegetation
		Oen cro	30	
…				

Fig. 77: Example of the filling of the recording form for *Line*.

α Code	Field 1	Field 2		Field 3
	Urban Habitat Category	Species	%	Site Descriptor
…				
P27	FPH/DEC	Sal sep	100	Island (artificial)
…				

Fig. 78: Example of the filling of the recording form for *Point*.

2.6 GRAPHICAL REPRESENTATION

The spatial nature of the methodology provides a strong foundation for the graphical representation of the study areas. Habitat patches can be represented according to each of the recorded attributes, and additional new information can be obtained from the data gathered in the field.

For the purpose of this study, habitat elements are graphically identified in thematic maps according to UHCs, Site Descriptors and Vegetation Layers. **Vegetation Layers** were determined through the analysis of LF categories and the visual estimation of plant height (through photo analysis and in situ) present in each habitat patch. The layer height indicates the total height of the plants and not the position of the buds, as follows:

Tall trees - over 5 m (GPH and FPH belong to the highest layer);

Tall shrubs and small trees - between 2 m and 5 m (TPH height category);

Medium shrubs and tall herbaceous plants - between 60 cm and 2 m (MPH and some tall HER);

Small shrubs and medium herbaceous plants - between 30 cm and 60 cm (most LPH, SCH, DCH, GEO, and some LHE, CHE, THE and HCH);

Groundcovers and aquatic plants - lower than 30 cm (most HER categories and some DCH and SHC, provided that they are below 30 cm tall or above the water level);

As an example, *Acanthus mollis* is an Herbaceous Leafy Hemicryptophyte (LHE), but it usually grows to the height of a shrub and thus it should be included in the layer of Medium shrubs and tall herbaceous plants, although it is still recorded as LHE. In each habitat element, only the layers with 30% cover or more are considered.
The combination of layers in each element is then represented by a color scheme.

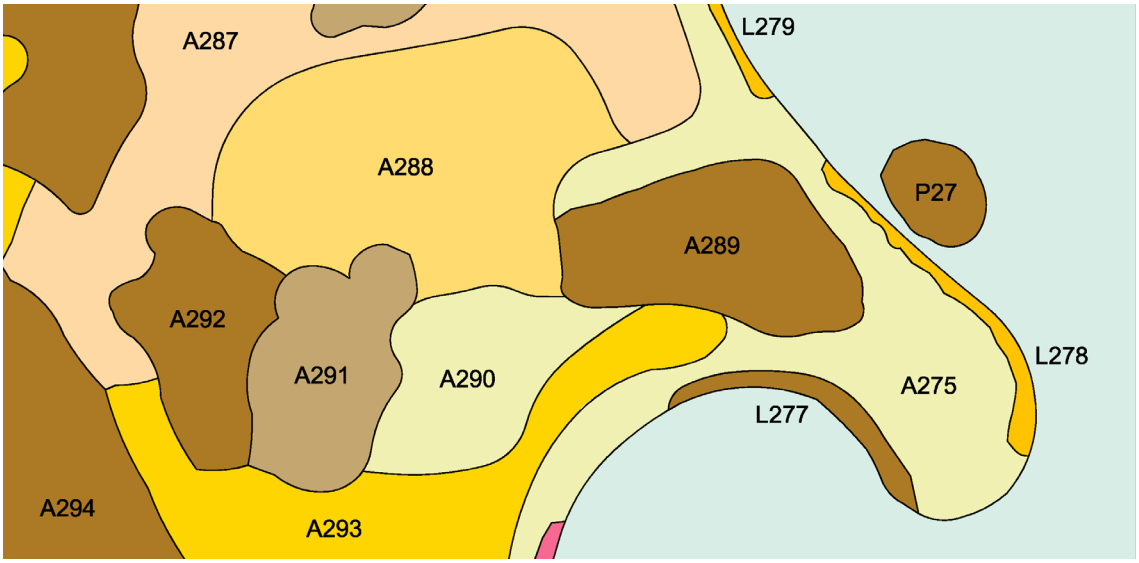


Fig. 79: Representation of the Habitats, after fieldwork.

3 Characterization of parks, gardens and green squares of the city of Porto

The newly developed methodology was used to assess the urban habitats of 29 parks, gardens and green squares, all with public access. Here we present a sub-set of 8 of these green spaces representative of the diversity of these green space typologies of Porto:

1. City Park

2. Serralves Park

3. Pasteleira Park

4. Porto Botanical Garden

5. Cordoaria Garden

6. Casa Tait Garden

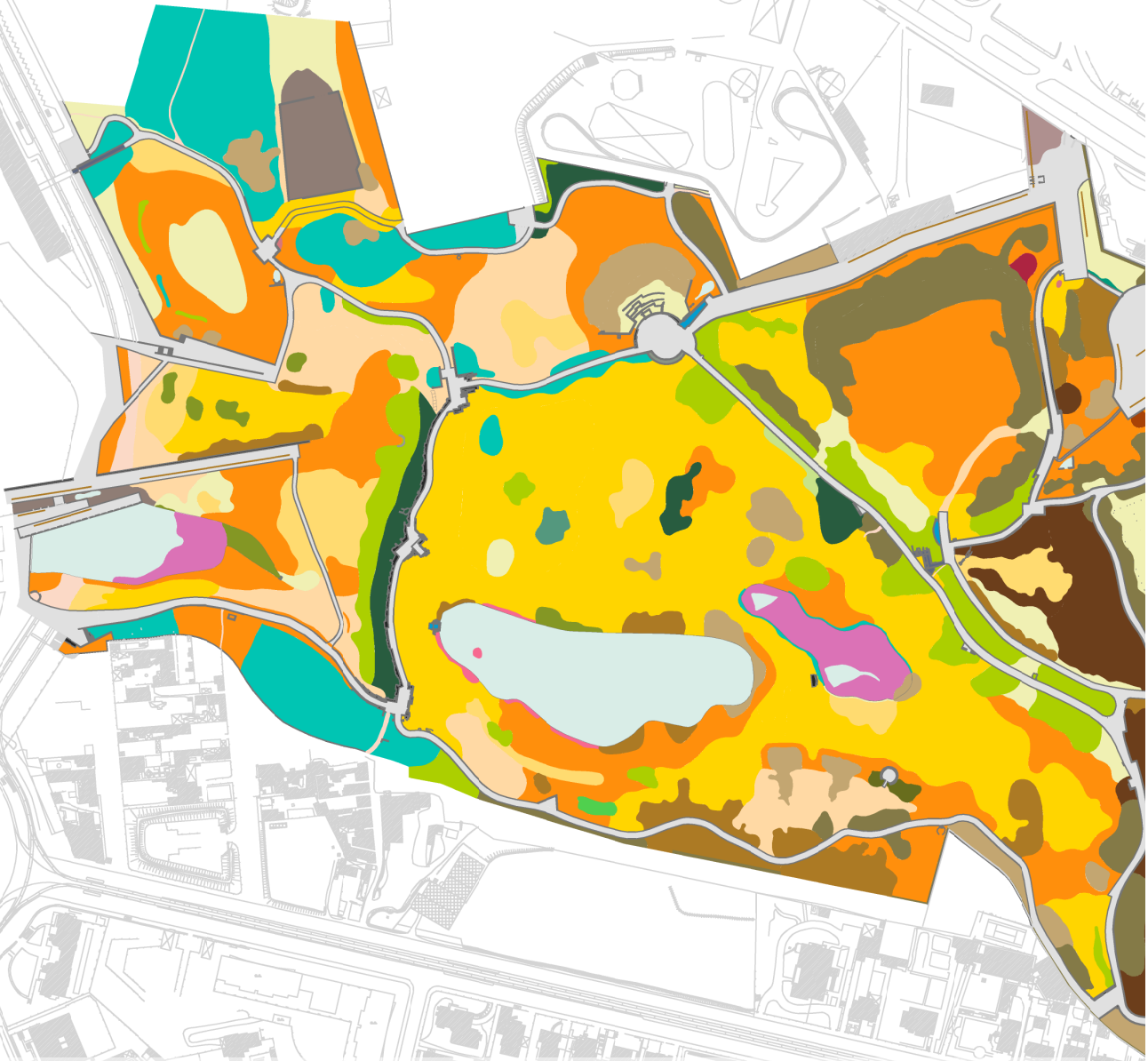
7. Sophia Garden and Galiza Square

8. Carlos Alberto Square

In the present chapter, these green spaces are represented by a set of three maps and characterized according to their Urban Habitat Categories, Site Descriptors and Vegetation Layers.

City Park

Habitats



Trees and Shrubs (TRS)

- Forest Phanerophytes Winter Deciduous (FPH/DEC)
- Forest Phanerophytes Evergreen (FPH/EVR)
- Forest Phanerophytes Coniferous (FPH/CON)
- Forest Phanerophytes Winter Deciduous / Evergreen (FPH/DEC/EVR)
- Forest Phanerophytes Winter Deciduous / Coniferous (FPH/DEC/CON)
- Forest Phanerophytes Winter Deciduous / Non-Leafy Evergreen (FPH/DEC/NLE)
- Forest Phanerophytes Evergreen / Coniferous (FPH/EVR/CON)
- Tall Phanerophytes Winter Deciduous (TPH/DEC)
- Tall Phanerophytes Evergreen (TPH/EVR)
- Tall Phanerophytes Coniferous (TPH/CON)
- Tall Phanerophytes Winter Deciduous / Evergreen (TPH/DEC/EVR)
- Tall Phanerophytes Evergreen / Coniferous (TPH/EVR/CON)
- Mid Phaneropytes Evergreen (MPH/EVR)
- Mid Phanerophytes Coniferous (MPH(CON)
- Mid Phaneropytes Non-Leafy Evergreen (MPH/NLE)
- Shrubby Chamaephytes Evergreen (SCH/EVR)

Terrestrial Herbaceous (HER)

- Caespitose Hemicryptophytes (CHE)
- Therophytes (THE)
- Geophytes (GEO)
- Leafy Hemicryptophytes / Caespitose Hemicryptophytes (LHE/CHE)
- Leafy Hemicryptophytes / Therophytes (LHE/THE)
- Caespitose Hemicryptophytes / Therophytes (CHE/THE)
- Caespitose Hemicryptophytes / Geophytes (CHE/GEO)

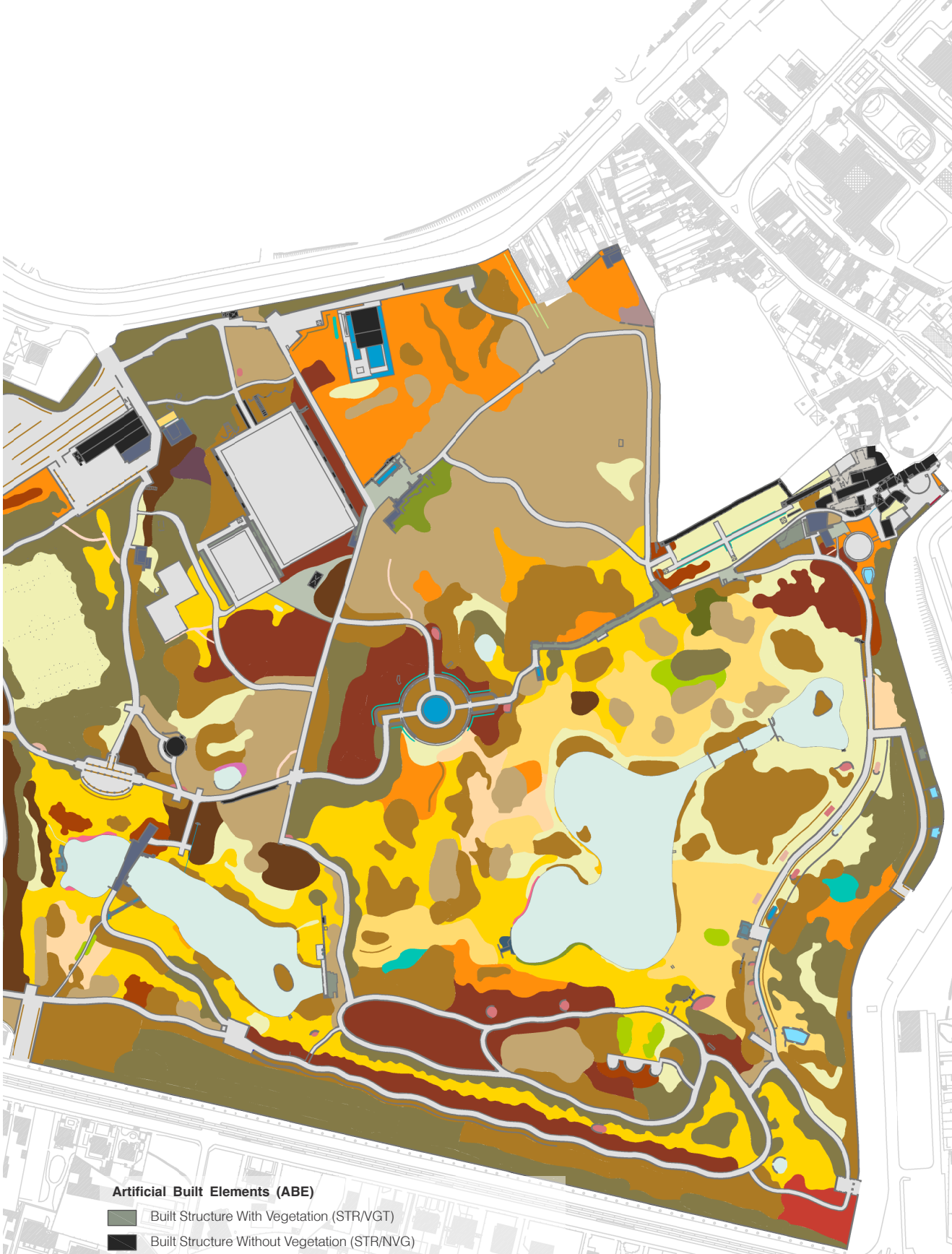
Wetland Herbaceous (HER)

- Helophytes (HEL)

Sparsely Vegetated (SPV)

- Aquatic (AQU)
- Organic Litter (LIT)
- Gravel (GRV)
- Sand (SAN)
- Earth (EAR)
- Gravel / Earth (GRV/EAR)

Fig. 80: Habitats of the City Park.



Artificial Built Elements (ABE)

- Built Structure With Vegetation (STR/VGT)
- Built Structure Without Vegetation (STR/NVG)
- Built Aquatic Element With Vegetation (AQE/VGT)
- Built Aquatic Element Without Vegetation (AQE/NVG)
- Pavement With Vegetation (PAV/VGT)
- Pavement Without Vegetation (PAV/NVG)
- Rubbish without vegetation (RUB/NVG)
- Built Structure / Built Aquatic Element Without Vegetation (STR/AQE/NVG)
- Built Structure / Pavement With Vegetation (STR/PAV/VGT)
- Built Structure / Pavement Without Vegetation (STR/PAV/NVG)

0 20 50 100 m N

City Park
Site Descriptors

Vegetation structures
- Row of trees
- Tree alley
- Tree border
- Group of trees
- Open wood
- Closed wood
- Open wood with understory
- Closed wood with understory
- Multi-layered border
- Thicket
- Scrub
- Shrub patch
- Hedge
- Row of shrubs
- Raised bed
- Raised bed with trees
- Bed
- Bed with trees
- Vegetable garden
- Tall meadow
- Short meadow
- Lawn - sports field
- Waterlogged patch
- Reed bed
- Marginal vegetation

Water features
- Drainage canal
- Lake - artificial
- Pond - artificial
- Temporary pond
- Infiltration basin
- Fountain
- Tank
- Water display

Built elements
- Wall
- Retaining wall
- Weir
- Bridge
- Building
- Pergola
- Belvedere
- Terrace (unpaved)
- Shed
- Folly
- Island (artificial)
- Benches
- Construction site

Surfaces and paved areas
- Sidewalk
- Path
- Dirt trail
- Road
- Patio
- Terrace (paved)
- Sitting area
- Parking lot
- Sports area
- Abandoned area
- Non-vegetated area

Fig. 81: Site descriptors of the City Park.


0 20 50 100 m
N

City Park

Vegetation Layers

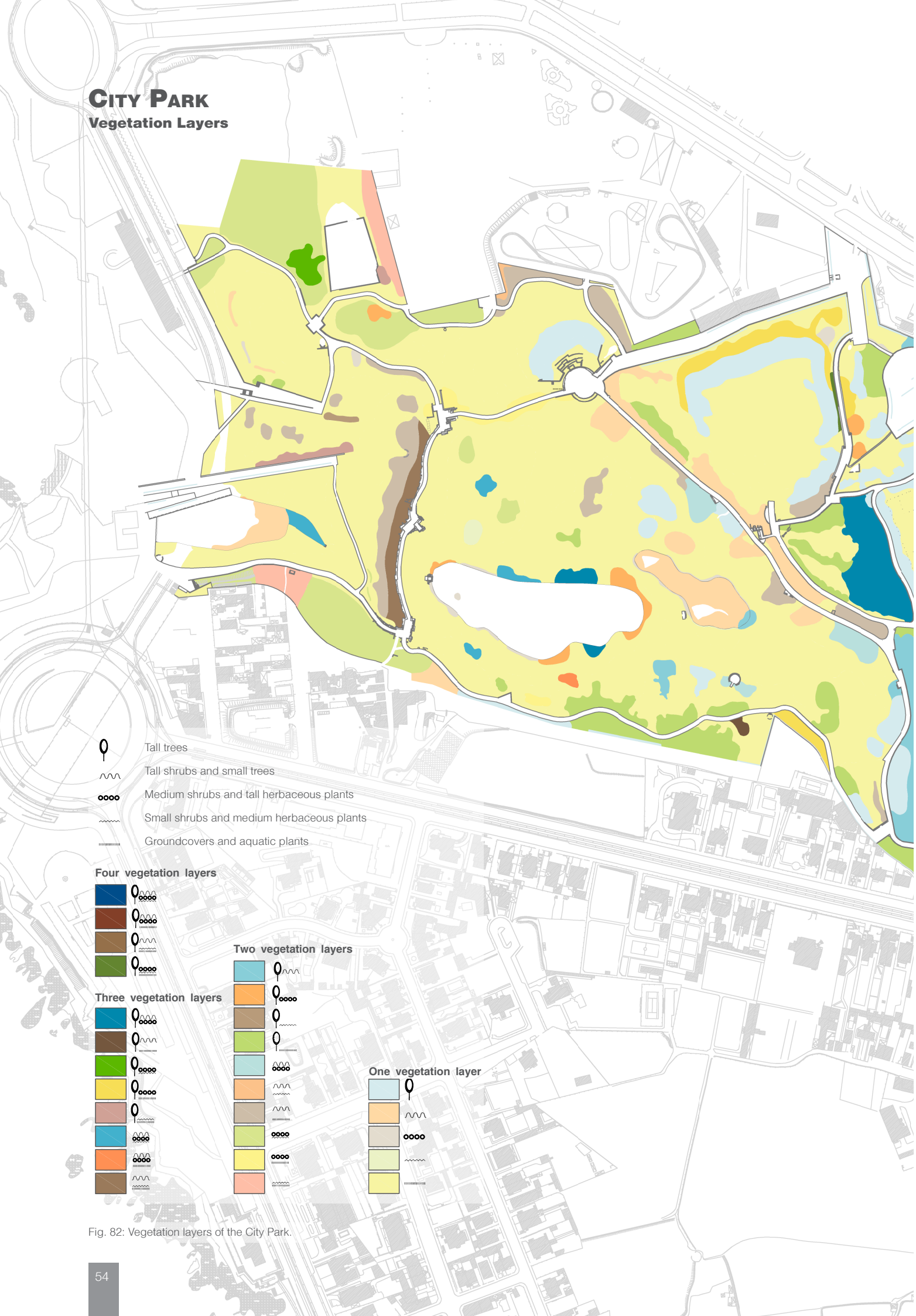


Fig. 82: Vegetation layers of the City Park.


0 20 50 100 m
N

City Park

The City Park is a successful example of a large scale public space in the Portuguese context. Such achievement is a result of a favourable combination of factors related to its size, naturalistic design style, climatic amenity, previous land use (rural history) and location next to the Atlantic Ocean. In short, the City Park is a complex equation of countless variables, difficult to decode but challenging – the quintessential outlier in this set of green spaces.

For the analysed parameters, the three maps that characterize the park suggest a division in three areas: a northern area, densely wooded and heavily equipped; an eastern area more intricately elaborate and rich in meandering lines; and a western area more open and simplified.

The northern area is characterized by 'Closed woods' (the dominant landscape feature), 'Borders', 'Short meadows' and 'Lawn'. It is crossed by a network of 'Paths', connecting the numerous Built Structures (STR): 'Buildings', 'Parking lot', 'Sports areas', 'Sitting areas' and 'Terraces'.

In the 'Closed woods' there is a slight predominance of Forest Phanerophytes Evergreen (FPH/EVR) thanks to the pre-existing woodland of *Eucalyptus globulus*. It is also worth mentioning the smaller patches of Forest Phanerophytes Winter Deciduous (FPH/DEC) composed by *Populus nigra*, *Platanus* × *acerifolia* and *Tilia americana*, and patches of Forest Phanerophytes Coniferous (FPH/CON) with *Pinus pinaster*, *P. pinea* and × *Cupressocyparis leylandii*. These are the structural species for the northern area in terms of cover and spatial design.

'Multi-layered borders' assume a relevant role in this northern area: near the northern boundary of the park, Forest Phanerophytes Coniferous (FPH/CON), such as × *Cupressocyparis leylandii* and *Pinus* spp., form a protective barrier from the exterior; extending along the north side of the 'Sports areas', the dominant life forms are Forest Phanerophytes Deciduous (FPH/DEC), represented by *Quercus robur* and *Populus nigra*, and, to a lesser extent, Forest Phanerophytes Evergreen / Coniferous (FPH/EVR/CON), with *Metrosideros excelsa* and *Pinus pinaster*. Forest Phanerophytes Coniferous (FPH/CON), mainly with × *Cupressocyparis leylandii* and *Pinus pinea*, are also dominant in an expressive 'Tree border', edging the 'Lawn'. The 'Lawn' is the most significant area of Caespitose Hemicryptophytes (CHE), dominantly covered with *Poa pratensis*. 'Open woods' and 'Closed woods with understory' are uncommon; they are both dominated by Forest Phanerophytes Deciduous and/or Coniferous with different combinations of *Quercus robur*, *Platanus* × *acerifolia*, *Pinus pinaster* and *Pinus halepensis*.

In this area there are few 'Short meadows' and the largest develops around the *Pavilhão da Água* (Water Pavilion thematic centre) and is characterized by the combination of Leafy Hemicryptophytes (LHE), with *Trifolium repens*, and Caespitose Hemicryptophytes (CHE), with *Paspalum dilatatum*. This 'Short meadow' is subject to occasional waterlogging which led to the identification of some 'Waterlogged patches', where Caespitose Hemicryptophytes (CHE), such as *Poa supina*, dominate, sometimes combined with Leafy Hemicryptophytes (LHE/CHE), with *Plantago lanceolata* and *Paspalum dilatatum*.

Water Features have little expression in this northern area but some 'Water displays', 'Infiltration basins' and 'Tanks' were recorded. Two 'Ponds' can be identified and one of them is classified as a 'Temporary pond'. The 'Temporary pond' shows a more spontaneous and naturalized character and despite its small size it supports a rich wildlife community, particularly of amphibians. The other 'Pond' exhibits a more defined margin where 'Reed beds' grow, forming a habitat dominated by Helophytes (HEL), thanks to the prevalence of *Typha latipholia*.

As far as the vegetation layering is concerned, most habitats are mainly organized in two layers, generally represented by tall trees with groundcovers.

Fig. 83: 'Multi-layered border'.

Fig. 84: 'Temporary pond', enclosed by 'Closed woods with understory'.

Fig. 87: 'Closed wood', dominated by *Pinus pinaster*.

Fig. 85: 'Building' and 'Water displays' - Water Pavillion.

Fig. 86: 'Short meadow', surrounded by 'Thickets', 'Groups of trees' and 'Closed woods'.

Contrary to the northern area where Water Features have little expression, the eastern area of the park is evidently structured around two large 'Lakes', with meandering margins where 'Riparian vegetation' thrives in a diversity of floristic compositions, occurring in several layers. Some of the recorded life forms are: Forest Phanerophytes Winter Deciduous (FPH/DEC - *Alnus glutinosa*), Tall Phanerophytes Winter Deciduous (TPH/DEC - *Salix atrocinerea*), Geophytes (GEO - *Oenanthe croccata*), Caespitose Hemicryptophytes (CHE - *Juncus effusus*) and Leafy Hemicryptophytes (LHE - *Mentha* x *sativa*). In the lakes, 'Islands' of Forest Phanerophytes Deciduous (FPH/DEC) were implemented, with impressive specimens of *Salix* × *sepulcralis*. Other Water Features ('Fountains', 'Temporary ponds' and 'Infiltration basins') significantly contribute to the water management, climatic comfort and wildlife promotion, while offering important areas for leisure, enjoyment and visual amenity. Some of these habitats, Built Aquatic Elements (STR/AQE/VGT and AQE/VGT), highlight the presence of aquatic vegetation, such as *Pontederia cordata*, *Typha latifolia* and *Nymphea alba*.

The areas adjacent to the 'Lakes' are dominated by 'Short meadows' that reveal different compositions. Those associated with the eastern 'Lake' are mainly based in annual life forms (THE, with *Poa annua* and *Plantago coronopus*) and Caespitose Hemicryptophytes (CHE, with *Festuca arundinacea*, *Lolium perenne*, and *Cynodon dactylon*). Along the central 'Lake', a combination of the above categories (CHE/THE, with *Festuca arundinacea*, *Plantago coronopus* and *Dactylis glomerata*) prevails. The life forms of the previous habitats tend to associate with Leafy Hemicryptophytes, establishing other habitats of LHE/CHE (*Plantago lanceolata* and *Cynodon dactylon*, *Trifolium repens* and *Dactylis glomerata*) and LHE/THE (*Trifolium resupinatum* and *Vulpia myurus*), particularly near some patches of 'Closed wood with understory'.

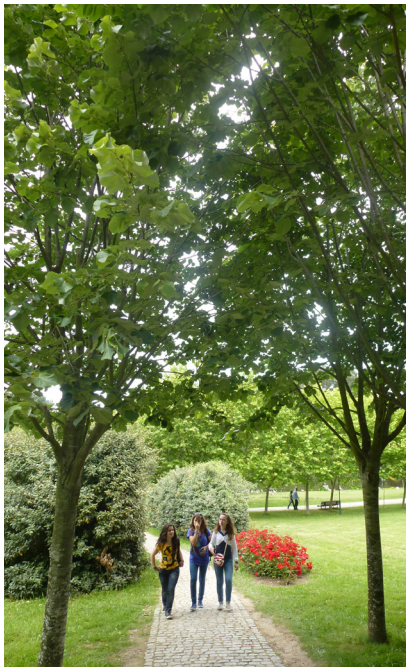


Fig. 88: 'Path' leading to the central 'Lake', bordered with exotic flora.

Fig. 89: Eastern 'Lake', edged by 'Marginal vegetation'.

Fig. 90: 'Tree border' of *Pinus pinea*.

Fig. 91: 'Infiltration basin' by a 'Path', in a 'Closed wood' context.

Fig. 92: The rural settlement integrates 'Buildings', 'Patios' and 'Pergolas'.

These 'Closed woods with understory' punctuating the 'Short meadow' are based on Deciduous life forms (FPH/DEC, with *Alnus glutinosa*, *Populus alba*, *Fraxinus excelsior*, *Platanus* × *acerifolia*) and Evergreen life forms. Although the latter seem to be less abundant they are more diverse regarding height categories: Forest Phanerophytes Evergreen (FPH/EVR, with *Acacia melanoxylon* and *Metrosideros excelsa*), Tall Phanerophytes Evergreen (TPH/EVR, with *Melaleuca armillaris*) and Mid Phanerophytes Evergreen (MPH/EVR, *Rubus ulmifolius*). Conifers are concentrated in the north, usually combined with Evergreens (FPH/EVR/CON, *Metrosideros excelsa* and × *Cupressocyparis leylandii*) and, less often, with Deciduous (FPH/DEC/CON, *Platanus* × *acerifolia* and *Pinus pinea*).

'Open woods' are less frequent and occur in three main areas. One area can be seen near the old rural settlement and is classified as Tall Phanerophytes Deciduous / Evergreen (TPH/DEC/EVR, with *Platanus* × *acerifolia* and *Olea europaea*). A few areas around the centre of this eastern zone, with and without understory, are mainly dominated by Forest Phanerophytes Deciduous (FPH/DEC, with *Fraxinus excelsior*, *Alnus glutinosa*, *Quercus rubra*, *Salix*

atrocinerea). Near the south-eastern end, a couple of areas display different combinations of Phanerophyte life forms, mainly of Coniferous and Deciduous species, with few Evergreens (*Cupressus macrocarpa*, *Pinus halepensis*, *Populus alba*, *Tilia americana* and *Magnolia grandiflora*).

The view shed generated by the 'Lakes' is encircled by 'Paths' that are often placed at a higher levels, allowing the experience of wide views. When accessing the park through the south-eastern entrance, where the predominance of *Populus nigra* and *Casuarina cunninghamiana* determined the Forest Phanerophytes Deciduous / Non-leafy Evergreen (FPH/DEC/NLE) habitat, it is possible to walk northward or westward towards the Atlantic. In any case, the route goes along the more heavily wooded patches of this area that can be classified as 'Closed woods', 'Closed woods with understory' and 'Tree borders'. These habitats develop along the eastern and southern boundaries of the park, buffering the urban commotion. They are composed mainly by Forest Phanerophytes Coniferous (FPH/CON), where *Pinus pinea* and × *Cupressocyparis leylandii* lead the floristic composition. The presence of some patches of Forest Phanerophytes Deciduous (FPH/DEC, with *Platanus* × *acerifolia*, *Salix atrocinerea* and *Acer negundo*) introduces some airiness and lightness to these compact and dark woods. Further into the inside and along the 'Paths', there are 'Tree borders' following a linear style of plantation and patches of 'Closed wood', with and without understory. These habitats are described as Forest Phanerophytes Deciduous (FPH/DEC) and Forest Phanerophytes Coniferous (FPH/CON), and combinations of both (FPH/DEC/CON), again relying on *Pinus pinea*, × *Cupressocyparis leylandii*, *Platanus* × *acerifolia*, *Populus alba*, *Acer negundo* and *Betula pendula*. With lower expression, there are also some patches of Forest Phanerophytes Evergreen (FPH/EVR) dominated by *Metrosideros excelsa* and *Eucalyptus globulus*.

Occasionally, 'Tree alleys', 'Rows of trees' and 'Rows of shrubs' interrupt the naturalistic layout, imposing some geometry. The vegetation seems more restrained, aligned with 'Paths' and embellishing 'Sitting areas'. One can easily identify 'Tree alleys' and 'Rows of trees' of *Platanus* × *acerifolia* and *Liriodendron tulipifera*, and, to a lesser extent, 'Rows of shrubs' with *Elaeagnus ebbingei* and *Rhododendron* sp.

The Built Structures are concentrated in the rural settlement. 'Buildings', 'Patios', 'Terraces' and 'Pergolas' (supporting *Wisteria sinensis* and *Vitis vinifera*) are signs of the previous uses, but that still leave room for ornamental vegetation, such as the 'Rows of shrubs' of *Camellia japonica* (Mid Phanerophyte Evergreen, MPH/EVR) adorning the access to the rural area and the 'Bed' of *Lavandula dentata* (Shrubby Phanerophyte Evergreen, SCH/EVR) bordering the entry to the restaurant area.

Regarding the vegetation layering, a significant variety of combinations can be identified, reaching a maximum of four layers. There is a considerable amount of habitats with two layers: tall trees and groundcovers; tall trees and medium shrubs. Additionally, a large portion of the eastern area is dominated by only one layer (groundcovers).

Fig. 93: Western 'Lake' with 'Marginal vegetation' and 'Meadows' dotted with young *Pinus pinea*.

Fig. 94: 'Reed beds' covering a large 'Pond' nearby the western 'Lake'.

Fig. 95: *Populus nigra* punctuating a large 'Short meadow', with 'Shrub patches' in the background.

Fig. 96: 'Multi-layered border' edged by a 'Retaining wall'.

Fig. 97: 'Thickets' and 'Closed woods' over 'Short meadows'.

The western area differs from the previous ones due to the greater simplification, especially affecting Site Descriptors. This distinction clearly reflects a younger area of the City Park, which was the last to be intervened and open to the public. Its less consolidated character manifests in several ways. For example, there are hardly any arboreal elements, except for those concentrated in a few 'Closed woods', with and without understory. These are dominated by Forest Phanerophytes Deciduous (FPH/DEC, with *Quercus robur* and *Populus nigra*) or Forest Phanerophytes Evergreens (FPH/EVR, with *Eucalyptus globulus* and *Acacia melanoxylon*).

'Open woods' also occur, mainly dominated by Forest Phanerophytes Coniferous (FPH/CON, with × *Cupressocyparis leylandii*) and Forest Phanerophytes Deciduous (FPH/DEC, with *Crataegus monogyna*).

On the other hand, 'Thickets' are the main woody habitat in the area and are typically dominated by Evergreen species (*Metrosideros excelsa*, *Melaleuca armillaris*), with both Forest Phanerophyte and Tall Phanerophyte life forms (FPH/EVR and TPH/EVR). 'Scrubs' have a significant expression in this western area. In the north and south, they are predominantly occupied by *Rubus ulmifolius* (Mid Phanerophytes Evergreen, MPH/EVR); in the central area they are dispersed in small patches of Mid Phanerophytes Non-leafy Evergreen (MPH/NLE, with *Ulex europaeus*) and Caespitose Hemicryptophytes (CHE, with *Dactylis glomerata*).

Other habitats also dominated by shrubby life forms are present in the young 'Multi-layered borders' and 'Shrub patches', such as Mid Phanerophytes Evergreen (MPH/EVR) and Tall Phanerophytes Evergreen (TPH/EVR) mainly

dominated by *Melaleuca armillaris* and *Metrosideros excelsa*, Tall Phanerophytes Deciduous (TPH/DEC) represented by *Tamarix gallica* and Tall Phanerophytes Evergreen / Coniferous (TPH/EVR/CON) with *Elaeagnus ebbingei* and *Pinus pinea*.

The mapping procedures suggests a subdivision of herbaceous habitats on this area into three parts: one more homogeneous, composed by a 'Short meadow' structured around the 'Lake' where a combination of Caespitose Hemicryptophytes / Therophytes was settled (CHE/THE, with *Paspalum dilatatum* and *Plantago coronopus*); other in the north, based on 'Short meadows' of Leafy Hemicryptophytes / Caespitose Hemicryptophytes (LHE/CHE, with *Trifolium repens* and *Paspalum dilatatum*); and, finally, the portion bordering the Atlantic, which is more reticulated and with increased diversity of habitats.

It is also worth mentioning the 'Riparian vegetation', with *Salix atrocinerea* (FPH/DEC and TPH/DEC), *Baccharis halimifolia* (FPH/EVR), *Melaleuca armillaris* (FPH/EVR), *Tamarix gallica* (TPH/DEC), *Rubus ulmifolius* (MPH/EVR), *Oenanthe croccata* and *Iris pseudacorus* (GEO), that develop on the banks of the 'Lake' and the 'Ponds'. Some of these Water Features are colonized by 'Reed beds', dominated by *Typha latifolia* (HEL).
The vegetation layering is very incipient and the entire area is practically covered by only one layer, which almost always consists of groundcovers. A greater complexity is found along the 'Paths', in the surroundings of the 'Lake' and bordering the large clearings in the north.

Fig. 98: *Eucalyptus globulus* wood with remarkable specimens.

Serralves Park

Habitats

Trees and Shrubs (TRS)

- Forest Phanerophytes Winter Deciduous (FPH/DEC)
- Forest Phanerophytes Evergreen (FPH/EVR)
- Forest Phanerophytes Coniferous (FPH/CON)
- Forest Phanerophytes Winter Deciduous / Evergreen (FPH/DEC/EVR)
- Forest Phanerophytes Winter Deciduous / Coniferous (FPH/DEC/CON)
- Forest Phanerophytes Evergreen / Coniferous (FPH/EVR/CON)
- Tall Phanerophytes Winter Deciduous (TPH/DEC)
- Tall Phanerophytes Evergreen (TPH/EVR)
- Tall Phanerophytes Winter Deciduous / Evergreen (TPH/DEC/EVR)
- Mid Phaneropythes Winter Deciduous (MPH/DEC)
- Mid Phaneropytes Evergreen (MPH/EVR)
- Low Phanerophytes Evergreen (LPH/EVR)

Terrestrial Herbaceous (HER)

- Caespitose Hemicryptophytes (CHE)
- Therophytes (THE)
- Geophytes (GEO)
- Cryptogams (CRY)
- Leafy Hemicryptophytes / Caespitose Hemicryptophytes (LHE/CHE)
- Leafy Hemicryptophytes / Therophytes (LHE/THE)
- Caespitose Hemicryptophytes / Therophytes (CHE/THE)

Wetland Herbaceous (HER)

- Helophytes (HEL)

Sparsely Vegetated (SPV)

- Organic Litter (LIT)
- Earth (EAR)

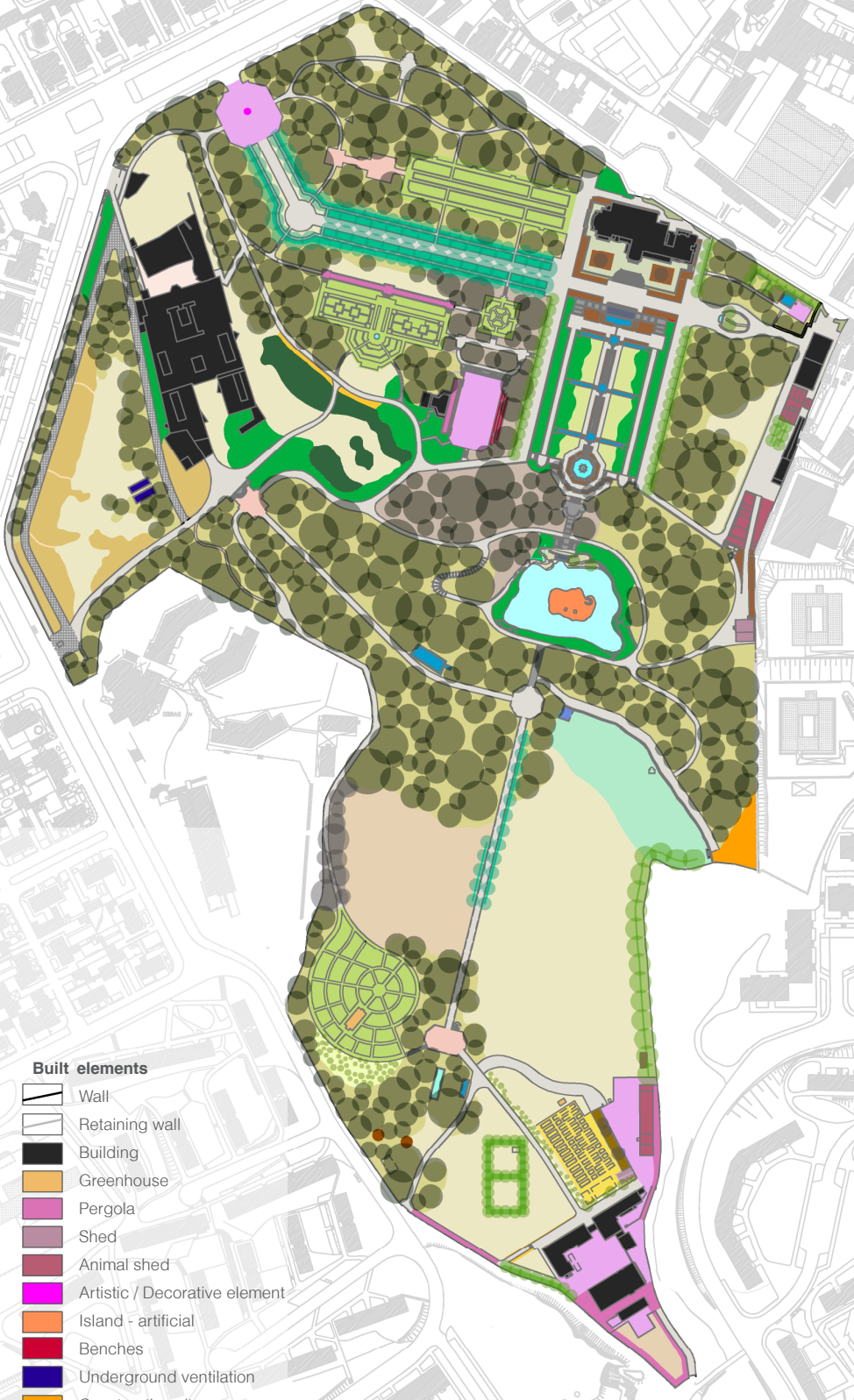
Artificial Built Elements (ABE)

- Built Structure With Vegetation (STR/VGT)
- Built Structure Without Vegetation (STR/NVG)
- Built Aquatic Element With Vegetation (AQE/VGT)
- Built Aquatic Element Without Vegetation (AQE/NVG)
- Pavement With Vegetation (PAV/VGT)
- Pavement Without Vegetation (PAV/NVG)
- Rubbish with vegetation (RUB/VGT)
- Built Structure / Aquatic Element Without Vegetation (STR/AQE/NVG)
- Built Structure / Pavement With Vegetation (STR/PAV/VGT)
- Built Structure / Pavement Without Vegetation (STR/PAV/NVG)

0 20 50 100 m N

Fig. 99: Habitats of the Serralves Park.

Site Descriptors



Vegetation structures

- Row of trees
- Tree alley
- Tree border
- Orchard
- Open wood
- Closed wood
- Closed wood with understory
- Multi-layered border
- Formal garden
- Thicket
- Scrub
- Hedge
- Herbaceous / Shrub border
- Row of shrubs
- Raised bed with trees
- Bed
- Bed with trees
- Vegetable garden
- Tall meadow
- Short meadow
- Lawn
- Waterlogged patch

Water features

- Artificialized spring
- Drainage channel
- Cascade
- Pond
- Fountain
- Tank
- Reflecting pool

Built elements

- Wall
- Retaining wall
- Building
- Greenhouse
- Pergola
- Shed
- Animal shed
- Artistic / Decorative element
- Island - artificial
- Benches
- Underground ventilation
- Construction site
- Rubble / Debris

Surfaces and paved areas

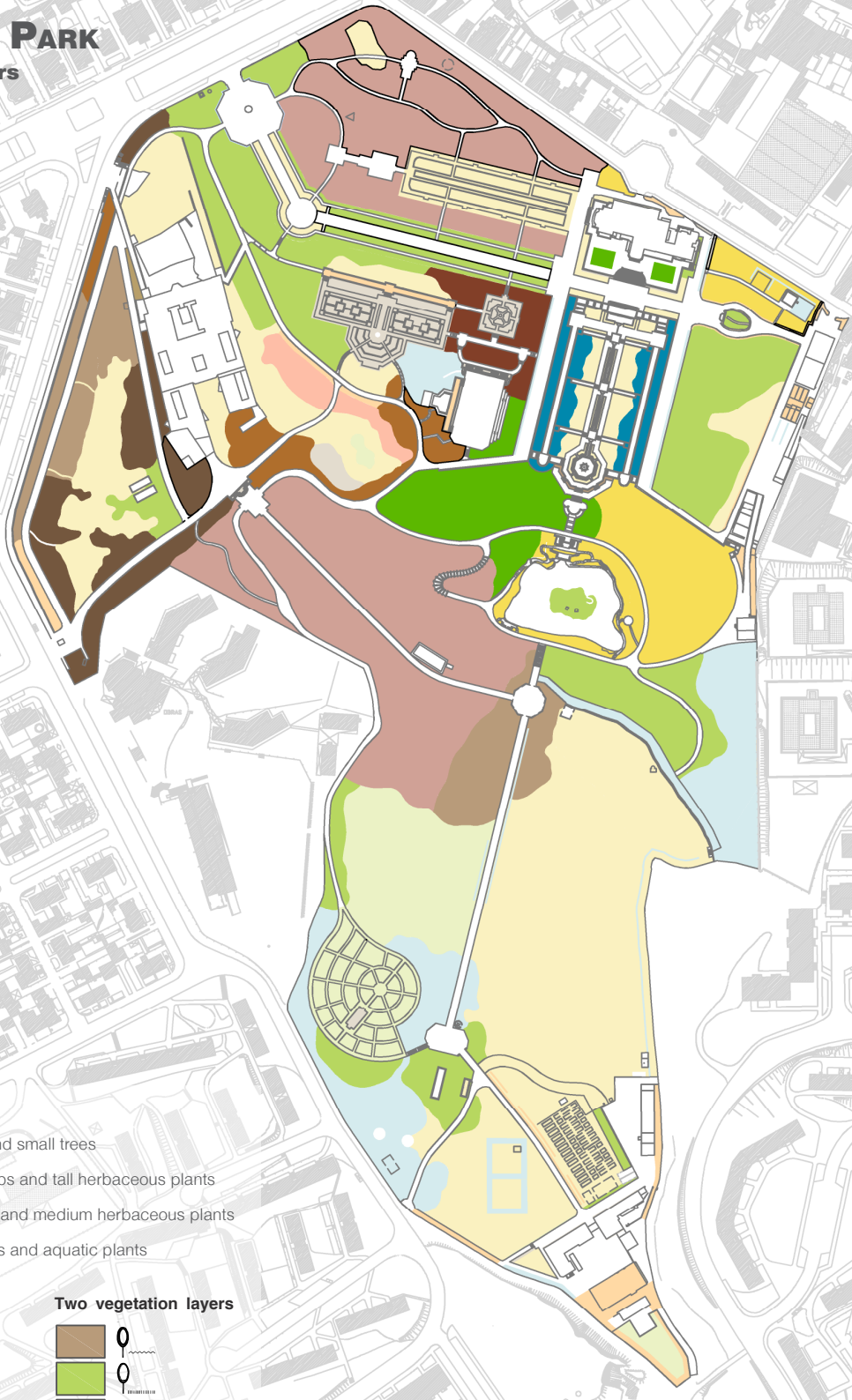
- Path
- Dirt trail - footpath
- Road
- Stairs
- Patio
- Terrace (paved)
- Sitting area
- Paved area

0 20 50 100 m N

Fig. 100: Site descriptors of the Serralves Park.

Serralves Park

Vegetation layers



Tall trees

Tall shrubs and small trees

Medium shrubs and tall herbaceous plants

Small shrubs and medium herbaceous plants

Groundcovers and aquatic plants

Four vegetation layers

Three vegetation layers

Two vegetation layers

One vegetation layer

0 20 50 100 m

N

Fig. 101: Vegetation layers of the Serralves Park.

Serralves Park is a large and diverse designed green space with a rich mosaic of habitats of different age and complexity. It combines several spatial layouts and land uses, where formal gardens occur together with woodlands and fields. It is a very popular cultural asset in the city, constantly visited by a significant number of people.

Two distinct large areas can be easily identified: the northern and the southern area. The northern area, with a more formal design, has a higher tree cover and higher density of vegetation layers. The southern area is more open, simplified, with relics of a former rural land use.

Therefore, in the north, Forest Phanerophytes are abundant in the form of 'Closed woods', 'Tree alleys' and 'Rows of trees'. They occur in different combinations of deciduous, evergreen and coniferous species. The floristic richness is expressed in a long list of dominant species. The most common deciduous species are *Liquidambar styraciflua*, *Fagus sylvatica*, *Aesculus* × *carnea*, *Betula alba*, *Tilia* spp., *Quercus* spp.. Among the evergreen trees, it is worth mentioning *Quercus ilex* and *Quercus suber*, *Laurus nobilis*, *Brachychiton populneus* e *Banksia integrifolia*, and the coniferous are well represented by large specimens of *Taxus baccata*, *Cedrus libani* and *Cedrus atlantica*, *Sequoiadendron giganteum*, *Pinus pinaster* and *Pinus pinea*.

The northern woods often open to unexpected clearings. Some of the clearings are composed by simple 'Short meadows' and 'Lawns', covered by Caespitose and Leafy Hemicryptophytes (CHE and LHE/CHE) or less commonly combined with annuals (CHE/THE and LHE/THE). In other clearings, Mid Phaneophytes Evergreen (MPH/EVR) stand out in the 'Formal gardens' – *Buxus sempervirens* in the lateral parterre and the rose garden and *Helichrysum petiolare* in the sundial garden.

Fig. 102: A 'Formal garden' with a sundial at the centre.

Fig. 103: Central parterre garden with 'Beds', 'Paths', 'Tanks' and a 'Fountain' in the foreground.

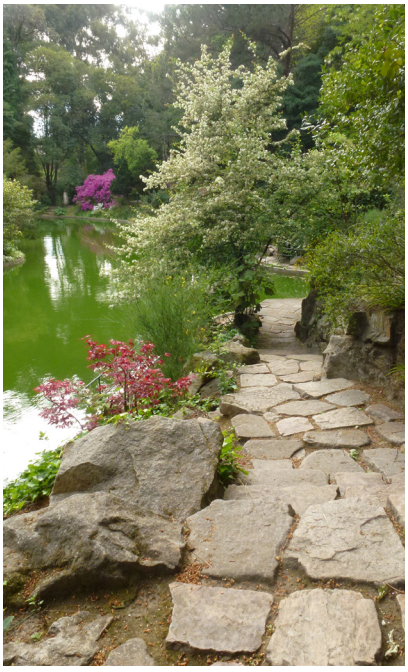


Fig. 106: 'Pond' bordered by a 'Path' of irregular stones.

Fig. 104: 'Tree alley' of *Liquidambar styraciflua*.

Fig. 105: 'Closed woods' edging a clearing of 'Short meadow' near the northern boundary.

The habitats Tall Phanerophytes Deciduous (TPH/DEC) and Tall Phanerophytes Evergreen (TPH/EVR), and the combination of both (TPH/DEC/EVR), were mainly recorded as Lines. Their presence may seem secondary in the maps, but a more attentive observation, particularly on site, may reveal its importance in the design and structuring of the park. Several types of 'Borders' and 'Hedges', sometimes in association with 'Walls' and flanking 'Paths', are well represented by *Crataegus monogyna*, *Prunus laurocerasus*, *Prunus spinosa* and *Corylus avellana*; likewise centenary specimens of *Camellia japonica* produce impenetrable hedges enclosing intimate and isolated nooks. These Lines create exceptional conditions for habitats, guide the views and induce sudden surprise effects by opening the sight to interest areas.

Accordingly, the northern section exhibits a higher complexity of vegetation layers. Most of the habitat elements show a combination of two or three layers, among which the tall trees assume a dominant role but are always together with lower layers. It is also worth mentioning that 'Multi-layered borders' contribute greatly to the vertical diversity; the combinations of tall trees, tall shrubs and medium/low shrubs only appear in this type of vegetation structures. There are also simpler areas regarding the vegetation layering, showing only one layer: groundcovers in the herbaceous 'Meadows' and medium shrubs in the 'Formal gardens'.

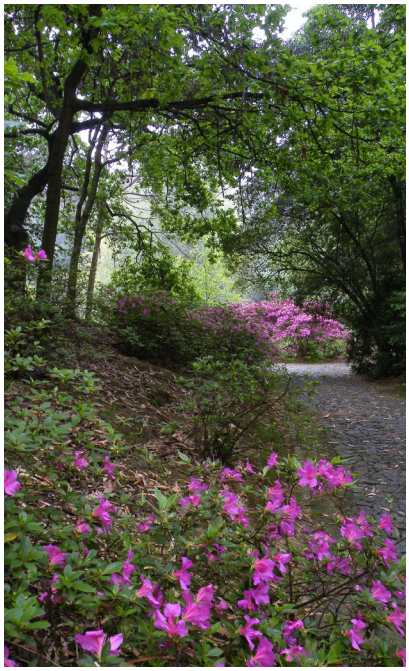


Fig. 107: 'Closed wood with understory' marked by *Rhododendron* sp.

Fig. 108: The 'Formal garden', with a collection of herbs and clipped shrubs.

Fig. 109: 'Waterlogged patch', with a grazed 'Short meadow' in the distance.

Fig. 110: 'Tall meadow', with *Lupinus luteus* and *Raphanus raphanistrum*.

Fig. 111: Old farm 'Building' with climbing roses.

In the southern part, several clearings stand out, each one with its ecological function and landscape context. The indigenous breeds of domestic animals preserved by the park graze in the large 'Short meadow' of Leafy Hemicryptophytes/ Therophytes (LHE/THE); on the other side, annual species (THE) bloom every year in the 'Tall

meadow' grown to feed the beehives; the 'Formal garden', composed mainly by aromatic plants, is essentially based on Low Phanerophytes life forms (*Lavandula stoechas*, *L. angustifolia*, *Rosmarinus officinalis*, *Teucrium fruticans*, *Foeniculum vulgare*, *Salvia splendens*, *Helichrysum italicum*, *Santolina chamaecyparissus*, *Pelargonium* spp.). It introduces a geometric element in this area with a more naturalistic character. Closer to the rural 'Buildings', there is another 'Short meadow' with a set of 'Rows of trees', and, on the opposite side, the 'Vegetable garden' combines a productive function with educational purposes. *Prunus persica* and *Cydonia oblonga* align to form 'Orchards', enclosing the rural landscape at the southern end of the farm.

Regarding the vegetation layers, the southern portion is very simplified. Most of the area is only covered with one vegetation layer, either herbaceous groundcover ('Short meadows'), medium herbaceous plants ('Tall meadows') or tall trees ('Closed woods'). Tall trees and herbaceous groundcover overlap in some confined areas.

When comparing the Built Elements in the park, there are major differences between the northern and the southern areas. In the north, there is a higher presence of large 'Buildings' supporting cultural events (Museum of Contemporary Art) and administrative services (Serralves Villa). In the south there are above all Built Structures to support rural and educational activities, such as 'Greenhouses', 'Sheds' and 'Animal sheds'. 'Sitting areas', 'Benches' and 'Pergolas' are recorded throughout the park. 'Pergolas' in the northern area are usually planted with exotic climbers, such as *Bougainvillea spectabilis*, *Wisteria floribunda* and *Rosa* spp.; in the southern area, 'Pergolas' (*ramadas*) are dominantly covered with productive varieties of *Vitis vinifera*.

The connection between the two parts of the park is made through an evident axis, that starts from the main house and develops southward, flanked by a series of 'Beds', 'Tanks' and a 'Fountain'; it is interrupted to allow room for a larger 'Pond', and continues at a lower level with a 'Tree alley' of *Aesculus* × *carnea*.

Among the Water Features, the central 'Pond' is the most emblematic element, but many other punctuate the park ('Fountain', 'Reflecting pool', 'Artificialized spring' and 'Drainage canal'). Although they are more discreet, they are crucial to its amenity, ecological balance and biophysical functioning. A small-scale wetland can be identified, associated with the large 'Short meadow' where the animals graze; this 'Waterlogged patch' is a valuable asset for biodiversity in the urban context.

Serralves Park reveals an exceptional landscape complexity determined by the combination of multiple habitats in a rather large area for the city of Porto. Relatively common habitats occur here in larger dimensions, alongside with smaller patches of unexpected habitats, now rare in the urban context. This unique mosaic of spatial and biological diversity is stimulated by the ongoing intense design and management which confirms the nature of a great garden.

Pasteleira Park

The layout of Pasteleira Park reveals an evident dichotomy. It is composed by two areas separated by a road, and these exhibit clearly distinct compositions and proportions of Habitats and Site Descriptors.

The eastern side is dominated by the habitat Forest Phanerophytes Coniferous (FPH/CON). Here there is a preponderance of *Pinus pinaster*, sometimes forming a dense 'Closed wood', or in a more sparse manner creating 'Open woods'. This same species also grows together with *Quercus suber*, forming a significant patch of Forest Phanerophytes Evergreen / Coniferous (FPH/EVR/CON). For its rarity and ecological importance in this urban context, it is worth mentioning the presence of a patch of Forest Phanerophytes Deciduous / Evergreen (FPH/DEC/EVR), dominated by oaks (*Quercus suber* and *Quercus robur*). There are two distinct 'Short meadows' in this eastern area – in the north caespitose species are dominant (CHE) while annual and leafy herbaceous (LHE/THE) occur together in the south.

The western side is essentially characterized by an extensive 'Short meadow', where the dominant life forms are Caespitose Hemicryptophytes (CHE), sometimes with annual species (CHE/THE). This meadow is bordered in the

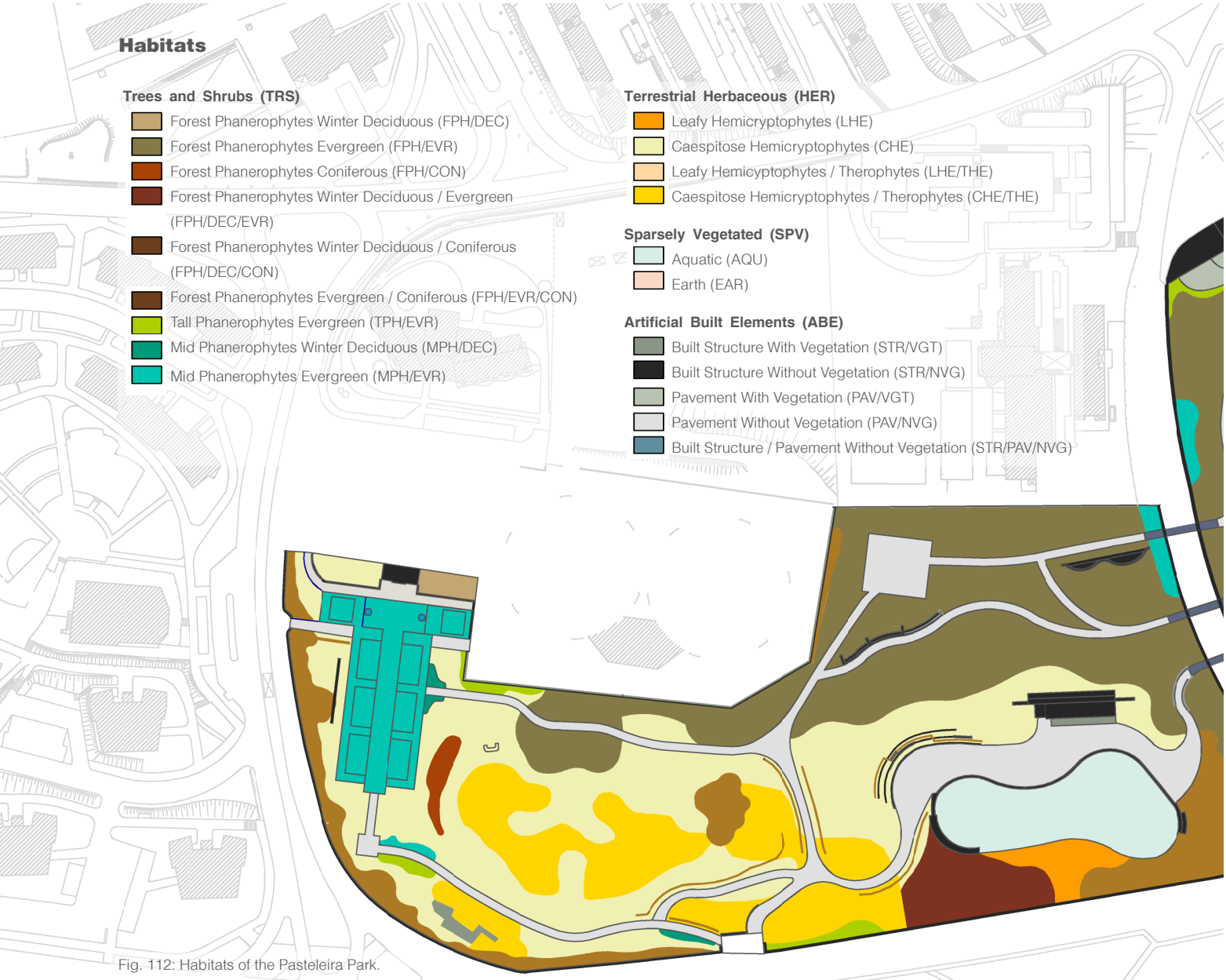
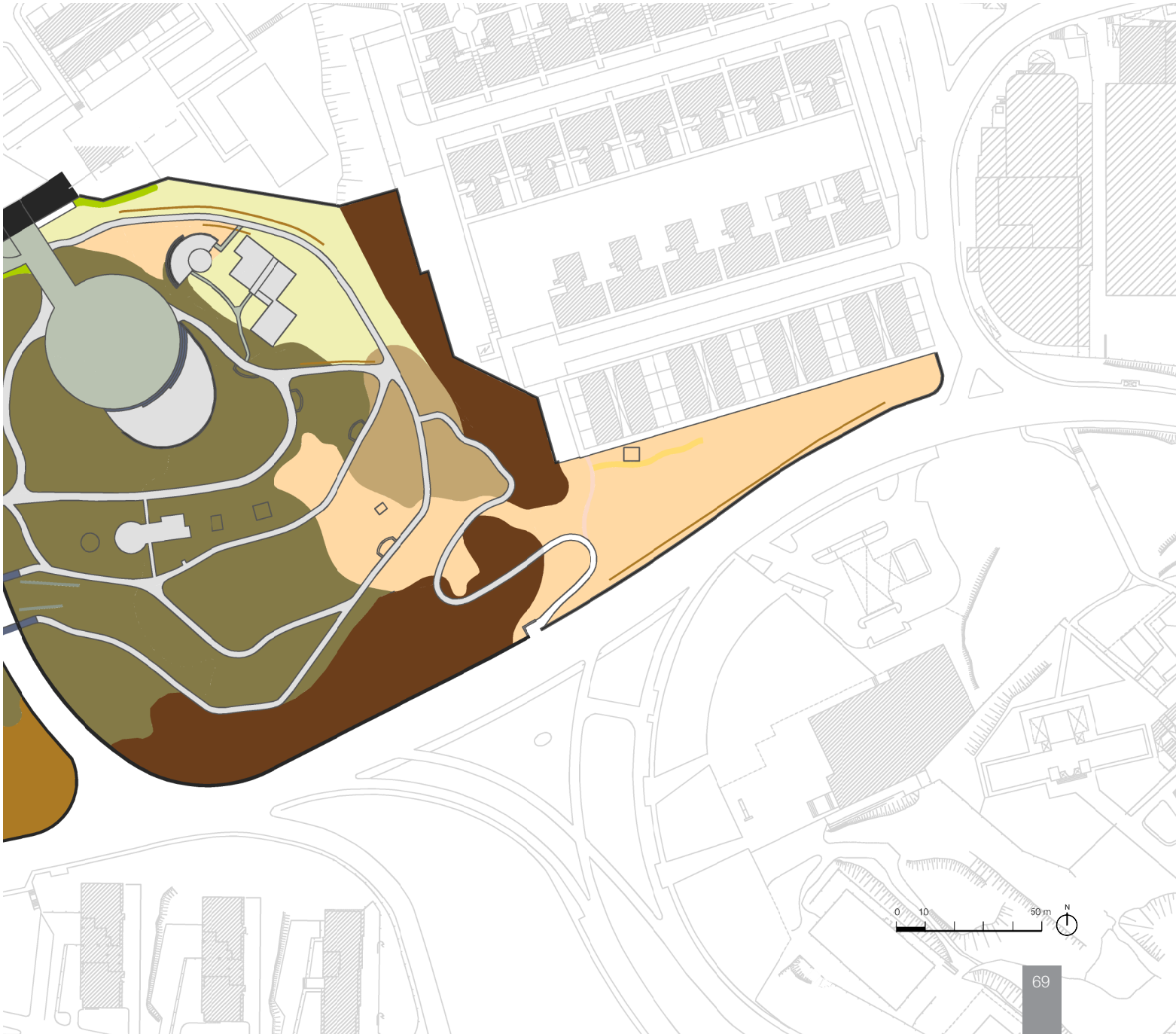


Fig. 112: Habitats of the Pasteleira Park.

north by a ‘Closed wood’ of *Pinus pinaster* (FPH/CON) and delimited in the west by a ‘Formal garden’ (MPH/EVR) and a ‘Multi-layered border’ (FPH/DEC). The ‘Paths’ are sometimes flanked by ‘Rows of trees’ (FPH/DEC, with *Quercus rubra*, *Liquidambar styraciflua*, *Populus nigra*, *Liriodendron tulipifera* and *Tilia americana*). The ‘Pond’, also located in this side of the park, is the most relevant Water Feature; others, recorded as ‘Infiltration basins’ and ‘Ditch’, were strategically positioned in order to control the drainage processes.

Being a public park designed for recreation and enjoyment, several Built Elements are dispersed throughout the space: ‘Pergolas’, ‘Folly’, ‘Artistic/Decorative elements’, ‘Outdoor performing venue’ and several ‘Benches’. Some Surfaces and Paved Areas, such as ‘Playgrounds’, ‘Sitting areas’ and ‘Terraces’ also fulfil social purposes.

The vegetation layering is clearly dominated by the presence of two layers, which are mainly a combination of tall trees and groundcovers. In the patches with only one layer, herbaceous cover has a central role. More complex combinations are restricted to residual patches.



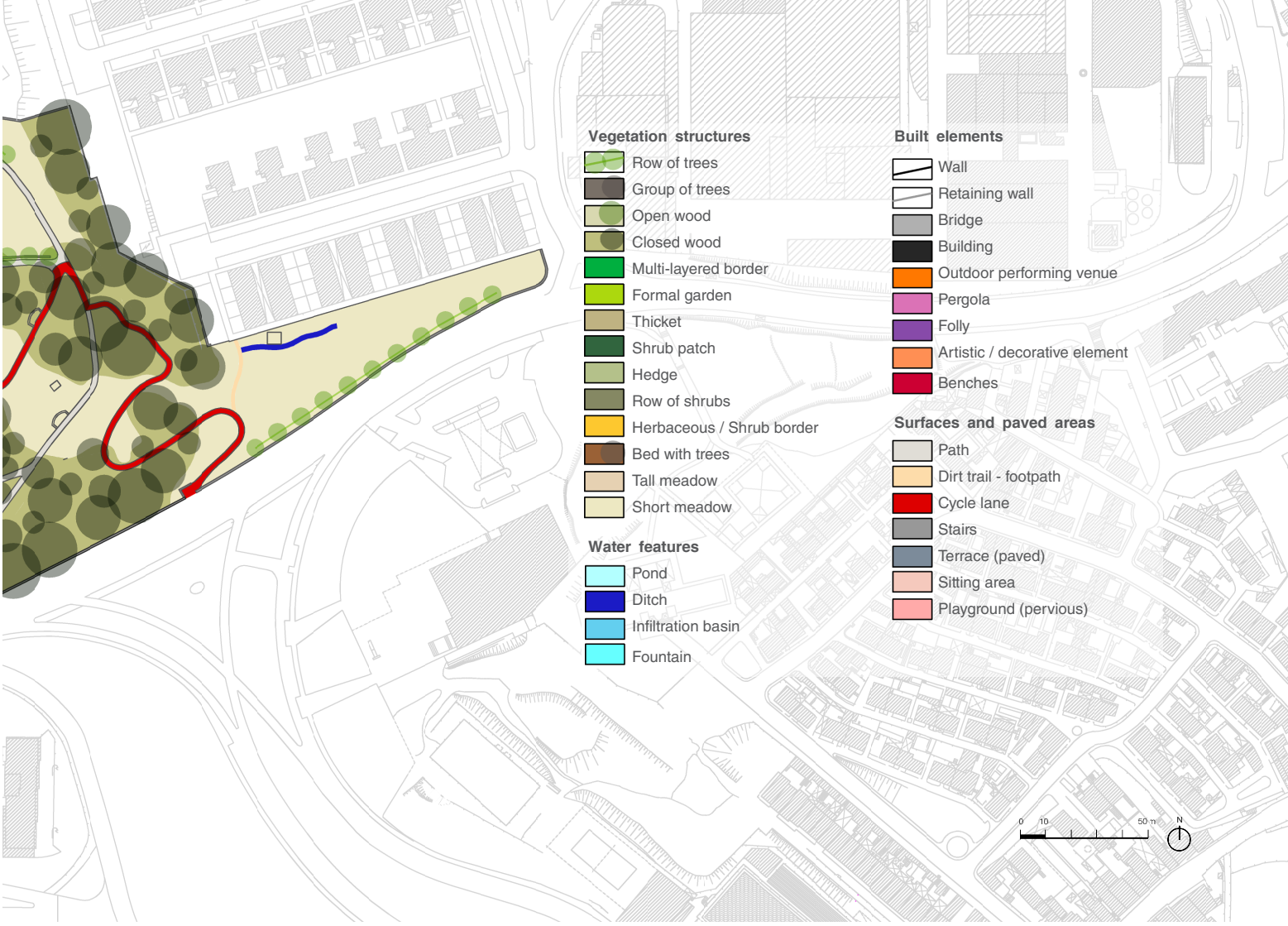
Pasteleira Park

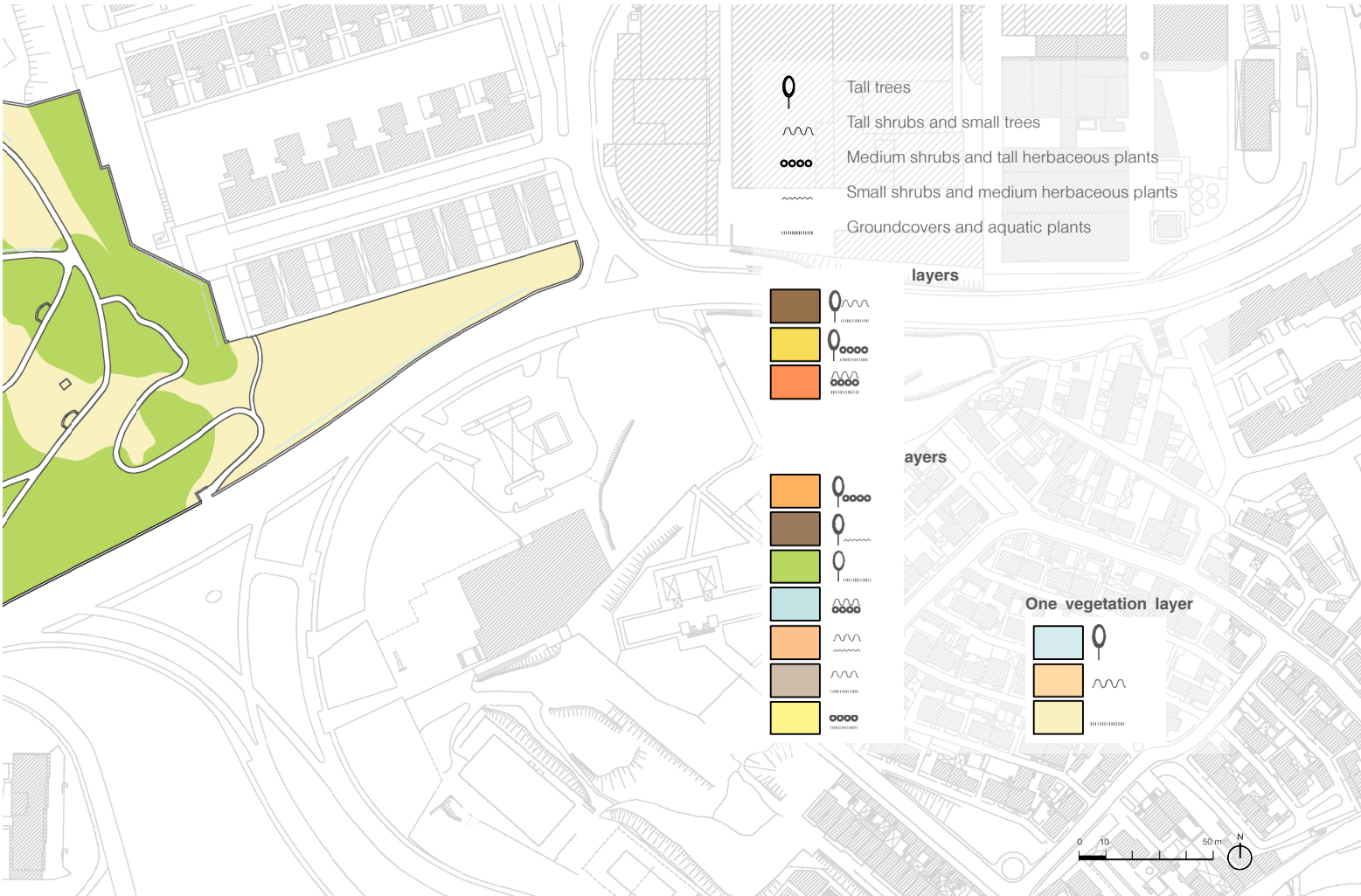
Site Descriptors

Fig. 113: Site descriptors of the Pasteleira Park.

Vegetation Layers

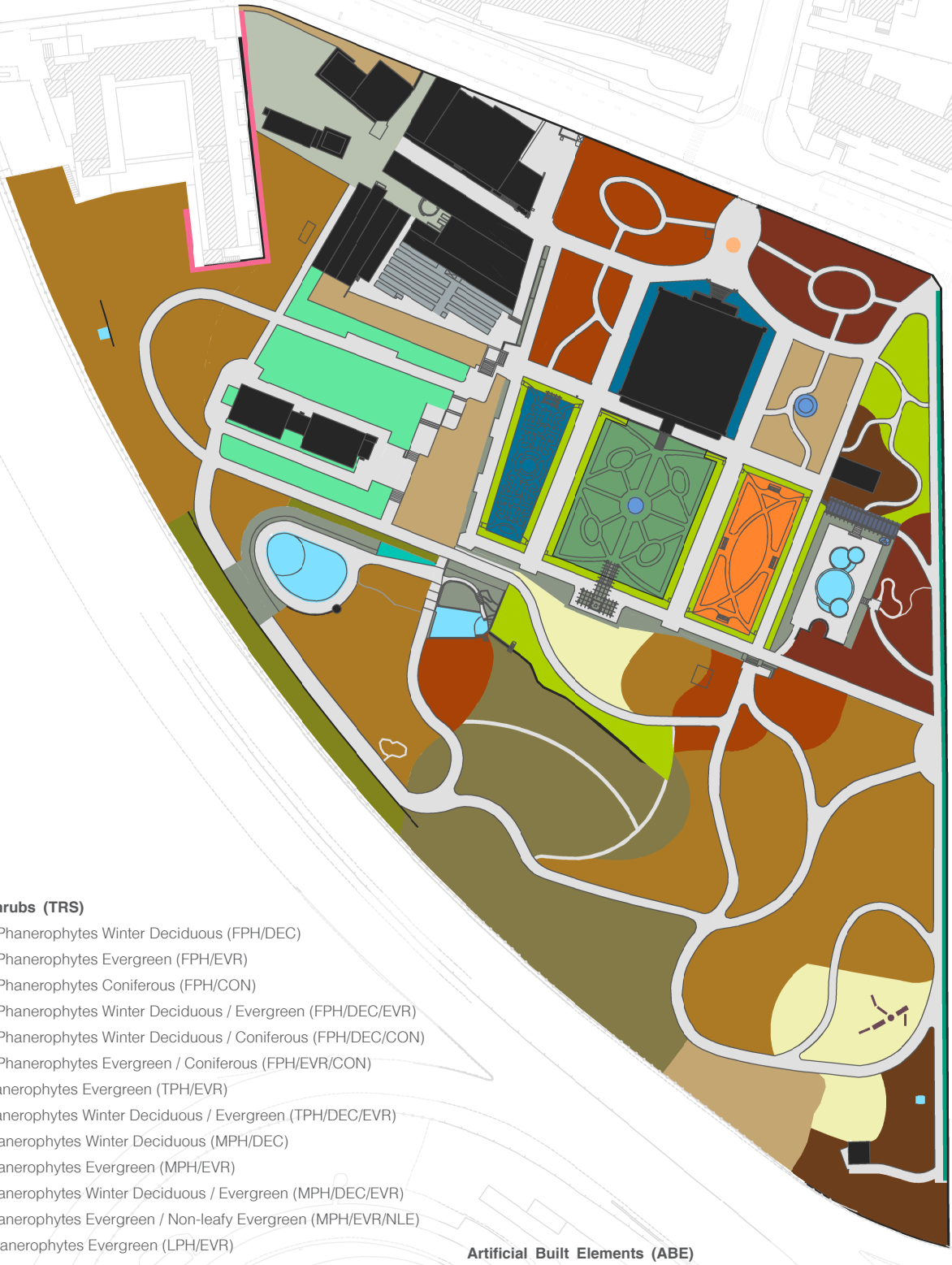
Fig. 114: Vegetation layers of the Pasteleira Park.


Vegetation structures
Row of trees
Group of trees
Open wood
Closed wood
Multi-layered border
Formal garden
Thicket
Shrub patch
Hedge
Row of shrubs
Herbaceous / Shrub border
Bed with trees
Tall meadow
Short meadow
Water features
Pond
Ditch
Infiltration basin
Fountain
Built elements
Wall
Retaining wall
Bridge
Building
Outdoor performing venue
Pergola
Folly
Artistic / decorative element
Benches
Surfaces and paved areas
Path
Dirt trail - footpath
Cycle lane
Stairs
Terrace (paved)
Sitting area
Playground (pervious)
0
10
50 m
N


Tall trees
Tall shrubs and small trees
Medium shrubs and tall herbaceous plants
Small shrubs and medium herbaceous plants
Groundcovers and aquatic plants
layers
ayers
One vegetation layer
0
10
50 m
N

Porto Botanical Garden

Habitats



Trees and Shrubs (TRS)

- Forest Phanerophytes Winter Deciduous (FPH/DEC)
- Forest Phanerophytes Evergreen (FPH/EVR)
- Forest Phanerophytes Coniferous (FPH/CON)
- Forest Phanerophytes Winter Deciduous / Evergreen (FPH/DEC/EVR)
- Forest Phanerophytes Winter Deciduous / Coniferous (FPH/DEC/CON)
- Forest Phanerophytes Evergreen / Coniferous (FPH/EVR/CON)
- Tall Phanerophytes Evergreen (TPH/EVR)
- Tall Phanerophytes Winter Deciduous / Evergreen (TPH/DEC/EVR)
- Mid Phanerophytes Winter Deciduous (MPH/DEC)
- Mid Phanerophytes Evergreen (MPH/EVR)
- Mid Phanerophytes Winter Deciduous / Evergreen (MPH/DEC/EVR)
- Mid Phanerophytes Evergreen / Non-leafy Evergreen (MPH/EVR/NLE)
- Low Phanerophytes Evergreen (LPH/EVR)

Terrestrial Herbaceous (HER)

- Caespitose Hemicryptophytes (CHE)
- Geophytes (GEO)
- Leafy Hemicryptophytes / Caespitose Hemicryptophytes (LHE/CHE)
- Leafy Hemicryptophytes / Geophytes (LHE/GEO)

Sparsely Vegetated (SPV)

- Organic Litter (LIT)

Artificial Built Elements (ABE)

- Built Structure With Vegetation (STR/VGT)
- Built Structure Without Vegetation (STR/NVG)
- Built Aquatic Element With Vegetation (AQE/VGT)
- Built Aquatic Element Without Vegetation (AQE/NVG)
- Pavement With Vegetation (PAV/VGT)
- Pavement Without Vegetation (PAV/NVG)
- Built Structure / Pavement With Vegetation (STR/PAV/VGT)
- Built Structure / Pavement Without Vegetation (STR/PAV/NVG)

0 10 50 m N

Fig. 115: Habitats of Porto Botanical Garden.

Site Descriptors

Vegetation structures

- Tree border
- Open wood
- Closed wood
- Closed wood with understory
- Multi-layered border
- Formal garden
- Botanical collection
- Hedge
- Herbaceous / Shrub border
- Raised bed
- Raised bed with trees
- Bed
- Short meadow

Built elements

- Wall
- Retaining wall
- Building
- Greenhouse
- Pergola
- Terrace (unpaved)
- Shed
- Artistic / Decorative element

Water features

- Pond
- Fountain
- Tank

Surfaces and paved areas

- Path
- Stairs
- Paved area

0 10 50 m N

Fig. 116: Site descriptors of Porto Botanical Garden.

Porto Botanical Garden

Vegetation Layers

Fig. 117: Vegetation layers of Porto Botanical Garden.

The Botanical Garden exhibits an extraordinary complexity of habitats, site descriptors and a combination of vegetation layers. These qualities reflect decades of dedication to education and research in Botany which resulted in a diverse and distinctive floristic collection. It is also worth mentioning its historical value associated with an eclectic private garden of the late 19th century, as well as its literary value connected with famous Portuguese authors of the 20th century, such as Sophia de Mello Breyner Andresen and Ruben Andresen Leitão.

A large extent of the garden is covered by 'Closed woods', in which Forest Phanerophyte habitats dominate. These 'Closed woods' occur mainly along the boundaries of the property, forming a protective frame that surrounds the central gardens. At the northern side, near the main entrance and the main 'Building', four habitats stand out: 1) Forest Phanerophytes Winter Deciduous / Evergreen (FPH/DEC/EVR, with *Liquidambar styraciflua*, *Acer palmatum*, *Quercus robur*, *Camellia japonica* and *Rhododendron* spp.); 2) Forest Phanerophytes Winter Deciduous / Coniferous (FPH/DEC/CON, with *Cedrus* spp., *Araucaria* spp. and *Tilia cordata*); 3) Forest Phanerophytes Evergreen (FPH/EVR, with *Camellia japonica*, *Phoenix canariensis* and *Metrosideros excelsa*); 4) Forest Phanerophytes Evergreen / Coniferous (FPH/EVR/CON, with *Magnolia grandifolia* and *Cedrus libani*).

The southern half of the garden, where the Arboretum lays, is dominated by Forest Phanerophytes Deciduous (FPH/DEC, with *Platanus* × *acerifolia*, *Betula pendula*, *Nyssa sylvatica*, *Carpinus betulus* and *Fagus sylvatica* 'Purpurea') and Forest Phanerophytes Coniferous (FPH/CON, with *Abies* spp., *Picea* spp., *Thuja* spp. and *Chamaecyparis* spp.). Also relevant in this area but with a lower expression, there are patches of Forest Phanerophytes Evergreen (FPH/EVR, with *Quercus suber*) and Forest Phanerophytes Evergreen / Coniferous (FPH/EVR/CON, with *Eucalyptus* spp. and *Sequoia sempervirens*).

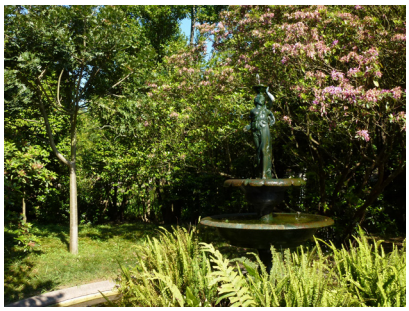


Fig. 118: 'Fountain' with a bronze statue, located in a 'Closed wood with understory'.

Fig. 119: The historic 'J' 'Formal garden', enclosed by Camellia 'Hedges'.

Fig. 122: *Jacaranda mimosifolia* in the edge of a 'Closed wood'.

Fig. 120: Cacti and succulents 'Botanical collection'.

Fig. 121: 'Path' through the Arboretum 'Closed wood'.

The ‘Formal gardens’ occupy a central position in the garden close to the main ‘Building’, forming a complex clearing, with a more open and airy feel. They consist of diverse habitats, such as Low Phanerophytes Evergreen (LPH/EVR, with *Buxus* spp.), Mid Phanerophytes Deciduous / Evergreen (MPH/DEC/EVR, with *Rosa* spp. and *Lavandula angustifolia* ‘Munstead’) and Leafy Hemicryptophytes / Caespitose Hemicryptophytes (LHE/CHE, with *Festuca arundinacea* and *Lotus pedunculatus*). These gardens are surrounded by trimmed ‘Hedges’ of several cultivars of *Camellia japonica* (TPH/EVR), which stand out as an remarkable feature of the Botanical Garden. Also adorning the building is a set of ‘Multi-layered borders’ of Low Phanerophytes Evergreen (LPH/EVR, with *Lavandula stoechas*, *Cistus salviifolius*, *Helichrysum italicum* and *Halimium umbellatum*).

Fig. 123: Larger lily ‘Pond’.

Fig. 124: *Carpinus betulus*, in the ‘Closed wood wood’ of the Arboretum.

Fig. 125: ‘Raised beds’ with *Lantana camara* and *Juniperus* sp.

The educational and research character is more evident in the ‘Botanical collection’ of cacti and succulent plants, with habitats of Mid Phanerophytes Evergreen / Non-leafy Evergreen (MPH/EVR/NLE) and Forest Phanerophytes / Evergreen (FPH/EVR); they reveal species, such as *Aloe* spp., *Agave* spp., *Cereus* spp., *Opuntia* spp. and *Cordyline australis*. This character is reinforced by the ‘Greenhouses’ (STR/NVG) and ‘Raised beds with trees’ (STR/PAV/VGT) formerly used for plant nurseries. The ‘Short meadows’ are residual and dominated by Caespitose Hemicryptophytes (CHE, with *Festuca rubra* and *Dactylis glomerata*).

Several Water Features have been identified, such as ‘Ponds’, ‘Fountains’ and ‘Tanks’, which greatly contribute to the amenity and also favour the wildlife diversity. They are scattered throughout the space and vegetation develops in the larger ones (AQE/VGT), namely *Nymphaea alba*, *Cyperus papyrus* and *Lemna minor*. These structures belong to a diverse group of Artificial Built Elements (ABE) along with numerous Built Structures (STR) and Pavements (PAV), with or without vegetation.

The complexity is also evident in the vegetation layering. The Botanical Garden is among the studied places with a high diversity of layer combinations (15 combinations out of 31 possible). Much of the Garden is occupied by areas dominated by the presence of two layers, especially of tall trees with groundcovers or low / medium shrubs.

Fig. 126: Smaller ‘Ponds’ in the Schist Garden, abundantly covered by Wetland Herbaceous plants. ►

Cordoaria Garden

Nowadays, Cordoaria Garden exhibits a complex design and plant organization that influences the interpretation of the site. Overall, it is characterized by the prevalence of 'Formal gardens', with more or less tree cover, where Forest and Mid Phanerophytes have a dominant presence. The tree cover shows different combinations of Deciduous and Coniferous forms. Among these, it is worth mentioning the habitat patch of Forest Phanerophytes Coniferous (FPH/CON) that harbours the most emblematic *Araucaria bidwilii* in the city of Porto; and the 'Multi-layered border' of FPH /CON that embellishes the central 'Pond' (AQE/NVG) and where magnificent specimens of *Sequoiadendron giganteum*, *Cedrus atlantica* 'Glauca' and *Metrosideros excelsa* stand. In the Forest Phanerophytes Deciduous habitats (FPH/DEC), the tree diversity is significant: *Quercus rubra*, *Quercus robur*, *Liquidambar styraciflua*, *Acer saccharinum*, *Fagus sylvatica*, *Prunus serrulata* and *Magnolia* × *soulangeana*. *Tilia* spp. adorning the southern 'Sitting area' and 'Sidewalk' should also be highlighted. There are two areas, located south and north of the 'Pond', where the shrub layer is predominant (MPH/EVR) but confined to monospecific lines of *Buxus sempervirens* 'Myrtifolia'. The garden has also a structural axis marked by a large and lush 'Tree alley' of centenary *Platanus* × *acerifolia* (FPH/DEC). Between this alley and the road, lies a long herbaceous slope covered with a 'Short meadow' (LHE/CHE).

The combination of various vegetation layers results in six different typologies. However, while the groundcover layer and the tall tree layer can either appear individually or combined, the shrub layer is always together with other layers.

Fig. 127: Habitats of the Cordoaria Garden.

Site Descriptors

Vegetation structures

- Row of trees
- Tree alley
- Closed wood
- Multi-layered border
- Formal garden with trees
- Formal garden
- Short meadow

Surfaces and paved areas

- Sidewalk
- Path
- Dirt trail - footpath
- Railway
- Stairs
- Underground access
- Sitting area
- Paved area

Water features

- Pond

Built elements

- Outdoor performing venue
- Artistic /Decorative element
- Benches

Fig. 128: Site descriptors of the Cordoaria Garden.

Vegetation Layers

- Tall trees
- Tall shrubs and small trees
- Medium shrubs and tall herbaceous plants
- Small shrubs and medium herbaceous plants
- Groundcovers and aquatic plants

Three vegetation layers

Two vegetation layers

One vegetation layer

Fig. 129: Vegetation layers of the Cordoaria Garden.

Casa Tait Garden

Casa Tait Garden is essentially dominated by four types of habitats. The 'Closed wood with understory' harbours an atypical floristic diversity, but, ultimately, it is the magnificence of some specimens of *Acer pseudoplatanus* and *Magnolia grandiflora*, just to mention a few, that determines the habitat category of Forest Phanerophytes Deciduous/ Evergreen (FPH/DEC/EVR). In close proximity, a remarkable patch of *Camellia japonica* creates an area of Forest Phanerophytes Evergreen (FPH/EVR). The large 'Formal garden' represents a Leafy Hemicryptophytes / Caespitose Hemicryptophytes habitat (LHE/CHE), dominated by *Stenotaphrum secundatum*; in the old 'Orchard', an herbaceous cover with a majority of *Paspalum dilatatum* reveals a Caespitose Hemicryptophytes habitat (CHE). Other habitats, although more dispersed and residual, occur, such as a 'Hedge' of *Ligustrum lucidum* (TPH/EVR) and the two small 'Formal gardens' with roses (MPH/DEC). Built Structures with Vegetation (STR/VGT) are frequent, as there are plentiful 'Raised beds' and 'Walls' covered with plants.

Regarding the vegetation layering, there are numerous different combinations of vegetation layers. The 'Closed wood with understory' is the more complex area, where four vegetation layers are simultaneously present. In other areas of the garden, the tendency is the presence of only one layer. The most significant areas where two layers occur are the rose 'Formal gardens' and the camellia 'Closed wood'.

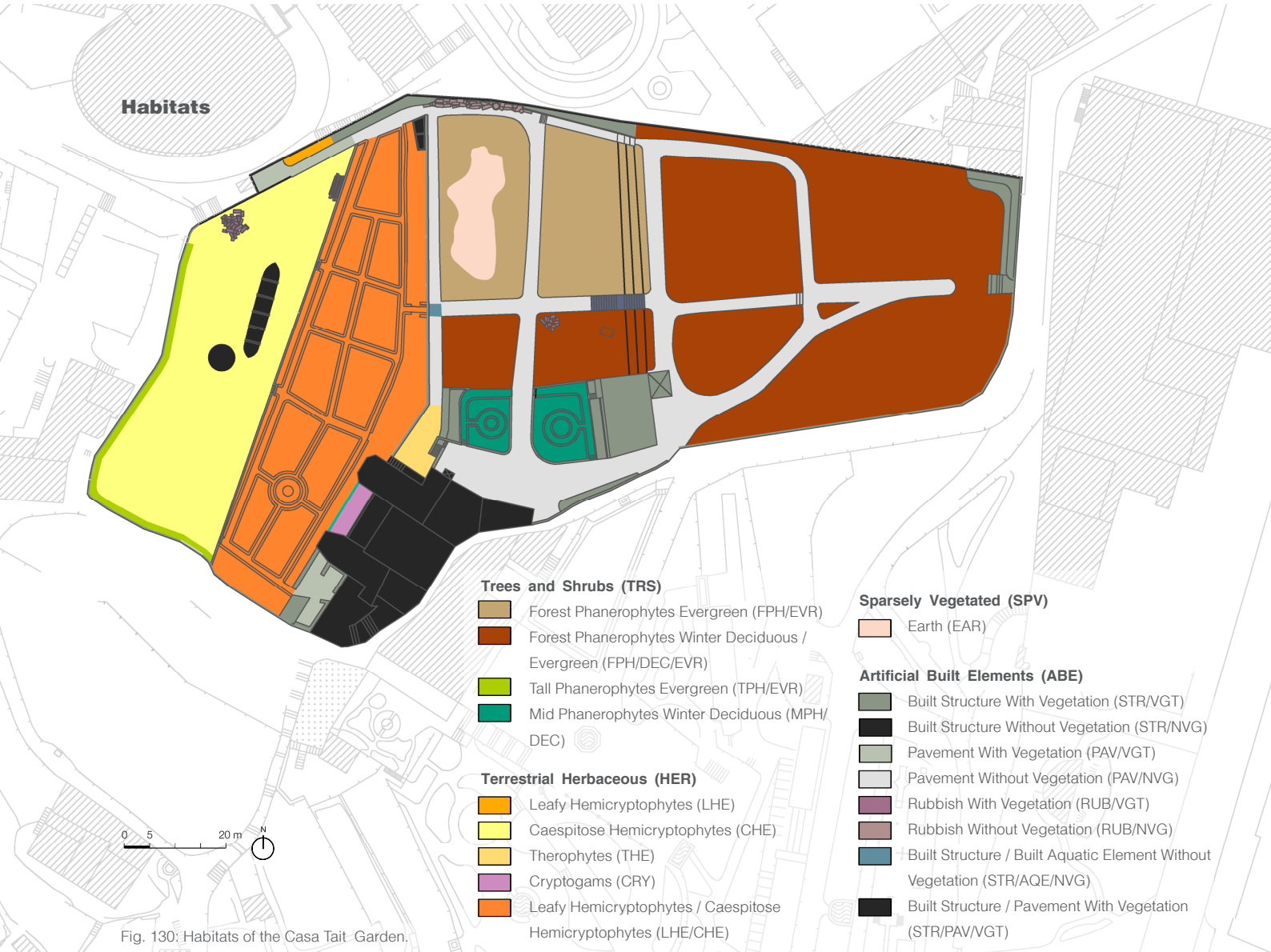


Fig. 130: Habitats of the Casa Tait Garden.

Site Descriptors

Fig. 131: Site descriptors of the Casa Tait Garden.

Vegetation Layers

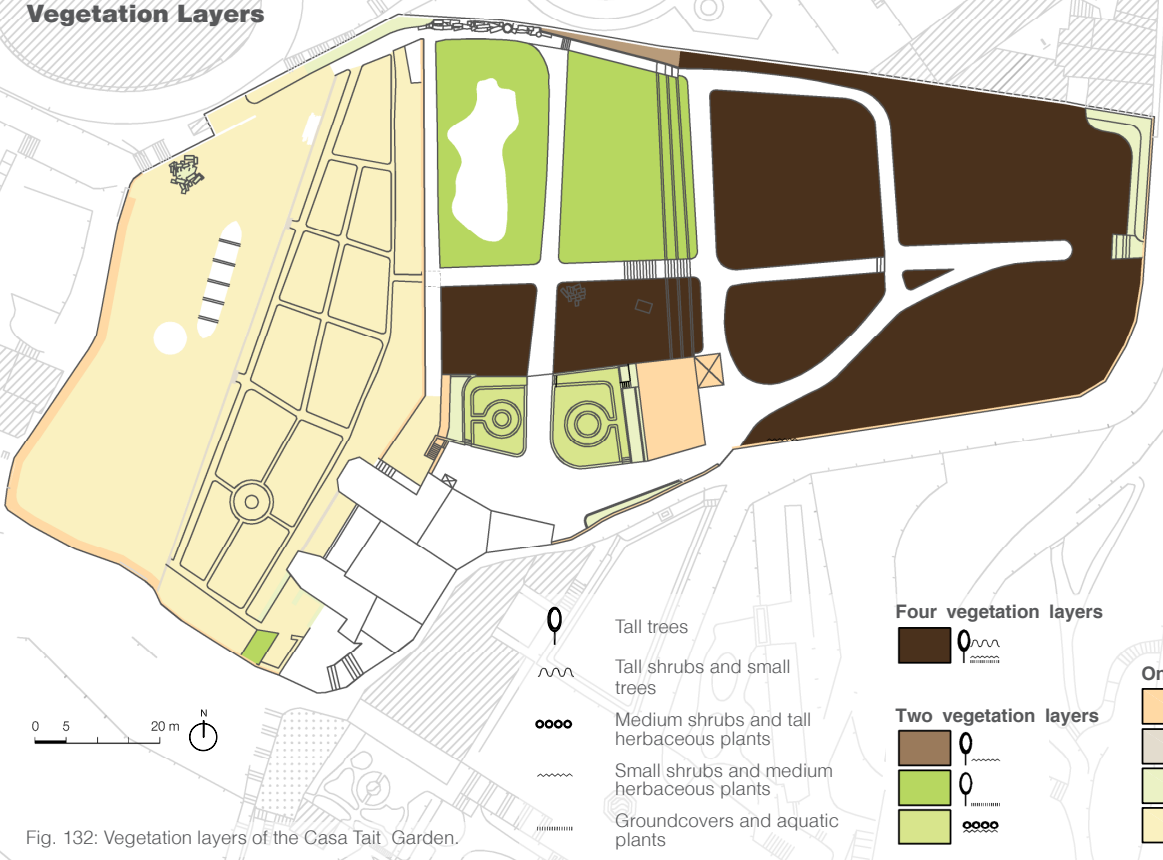


Fig. 132: Vegetation layers of the Casa Tait Garden.

Sophia Garden and Galiza Square

Sophia Garden is an intentionally designed space and therefore it shows some complexity in all analysed parameters, especially regarding the existing Urban Habitat Categories. In the Habitats map, we can identify eleven different categories of Trees and Shrubs (TRS), two of Terrestrial Herbaceous (HER) and four of Artificial Built Elements (ABE). The identified Site Descriptors are divided into four categories, where the Vegetation Structures are dominant. The analysis of the vegetation layering reveals the presence of all vegetation layers in ten distinct combinations.

The central area of the garden is characterized by a 'Short meadow' composed essentially by Leafy Hemicryptophytes / Caespitose Hemicryptophytes (LHE/CHE). This large clearing is crossed by two 'Paths' (PAV/NVG) beside which 'Rows of trees' (FPH/DEC) are organized. In the margins of the garden, alongside the 'Sidewalk', there are several 'Herbaceous / Shrub borders' and a 'Multi-layered border' with a great floristic diversity; these Vegetation Structures combine between deciduous, evergreen and coniferous species, at different stages of development. This circumstance determined a multiplicity of UHCs from the Trees and Shrubs super-category, among which we can find: Tall Phanerophytes Deciduous / Evergreen (TPH/DEC/EVR) with co-dominance of *Tibouchina urvilleana* and *Syringa vulgaris*; Mid Phanerophytes Deciduous / Coniferous (MPH/DEC/CON) combining *Juniperus* × *media* 'Pfitzeriana' and *Forsythia* × *intermedia*; and Shrubby Chamaephytes Deciduous / Evergreen (SCH/DEC/EVR), where *Potentilla fruticosa* and *Lavandula dentata* co-dominate.

In the northern square, there is a 'Closed wood' where the impressive presence of a lush *Acer negundo* determines the habitat of Forest Phanerophyte Winter Deciduous (FPH/DEC), surrounded by a small 'Short meadow' (LHE/CHE). The space is further enriched by some Water Features, such as 'Tanks' and 'Cascades'.

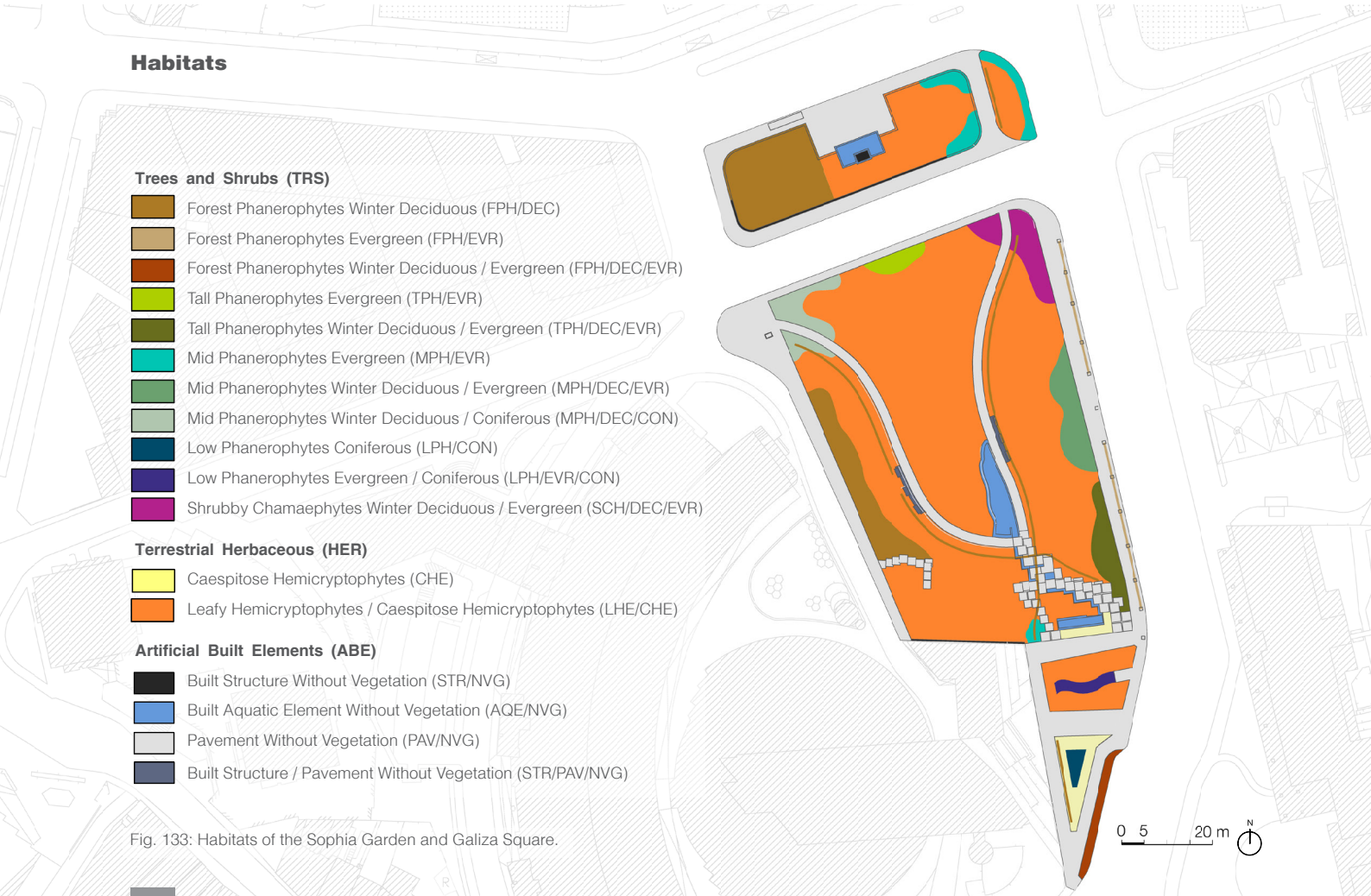


Fig. 133: Habitats of the Sophia Garden and Galiza Square.

Site Descriptors

Fig. 134: Site descriptors of the Sophia Garden and Galiza Square.

Vegetation Layers

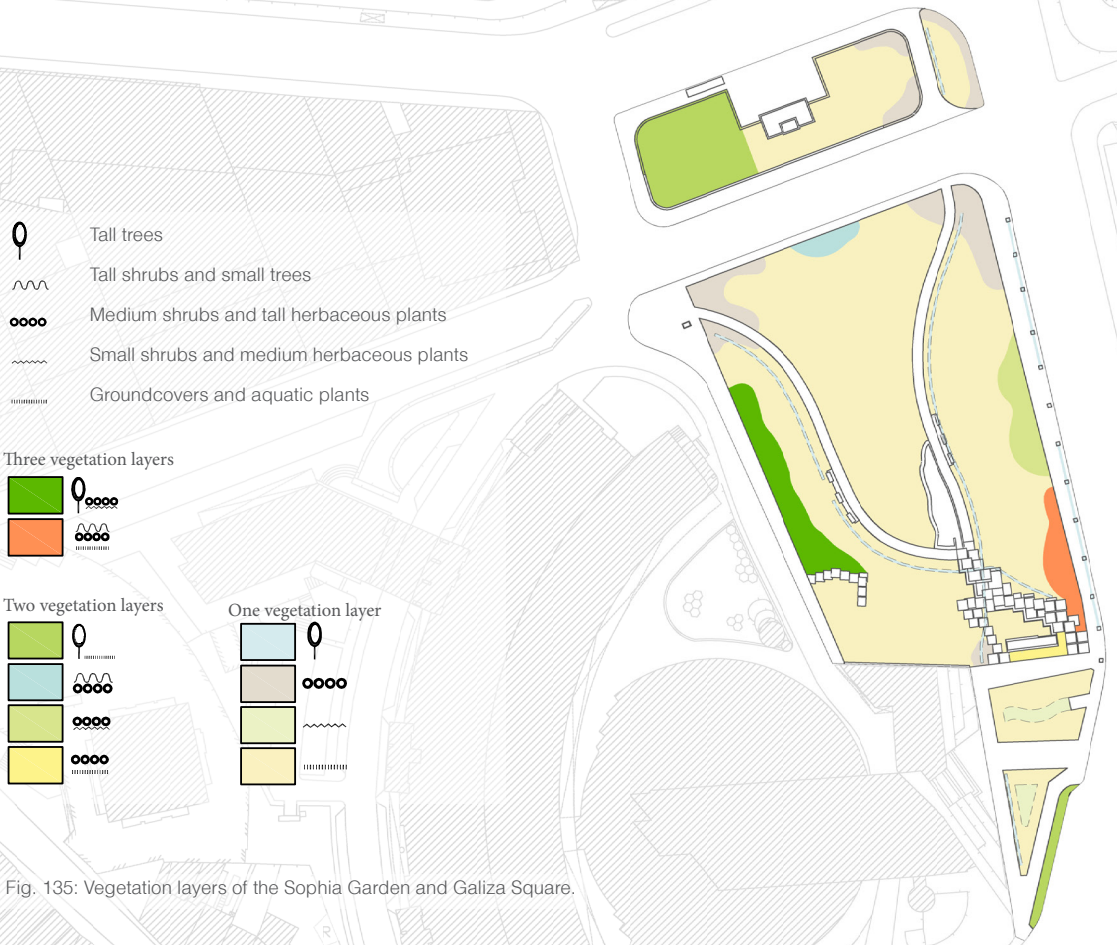


Fig. 135: Vegetation layers of the Sophia Garden and Galiza Square.

Carlos Alberto Square

In Carlos Alberto Square, the paved areas and the vegetation are structured along several radial axes, originating in an 'Artistic/Decorative element' positioned in the centre of the northern area. Being a square, it naturally exhibits a large Pavement over which some 'Beds' and two 'Rows of shrubs' are distributed. In these Vegetation Structures, there is an important floristic diversity regarding Trees and Shrubs (TRS) that is recorded as distinct Urban Habitat Categories. Thus, Forest Phanerophytes Winter Deciduous (FPH/DEC) are concentrated in the smaller elements located north, with a dominant presence of *Magnolia* × *soulangeana*. Surrounding the central sculpture, there are Tall Phanerophytes Evergreen (TPH/EVR), represented by *Chamaerops humilis*; and in the more rectilinear areas, along the east and west, there are mainly Low Phanerophytes Evergreen (LPH/EVR).

Concerning the layering of the vegetation, there is a greater complexity in the northern 'Beds with trees'; diverse combinations of the higher layers (tall trees) with intermediate layers (medium and small shrubs and perennials) can be identified. The lateral 'Beds' only display small shrubs and medium herbaceous plants together with 'Rows' of tall and medium shrubs.

Habitats

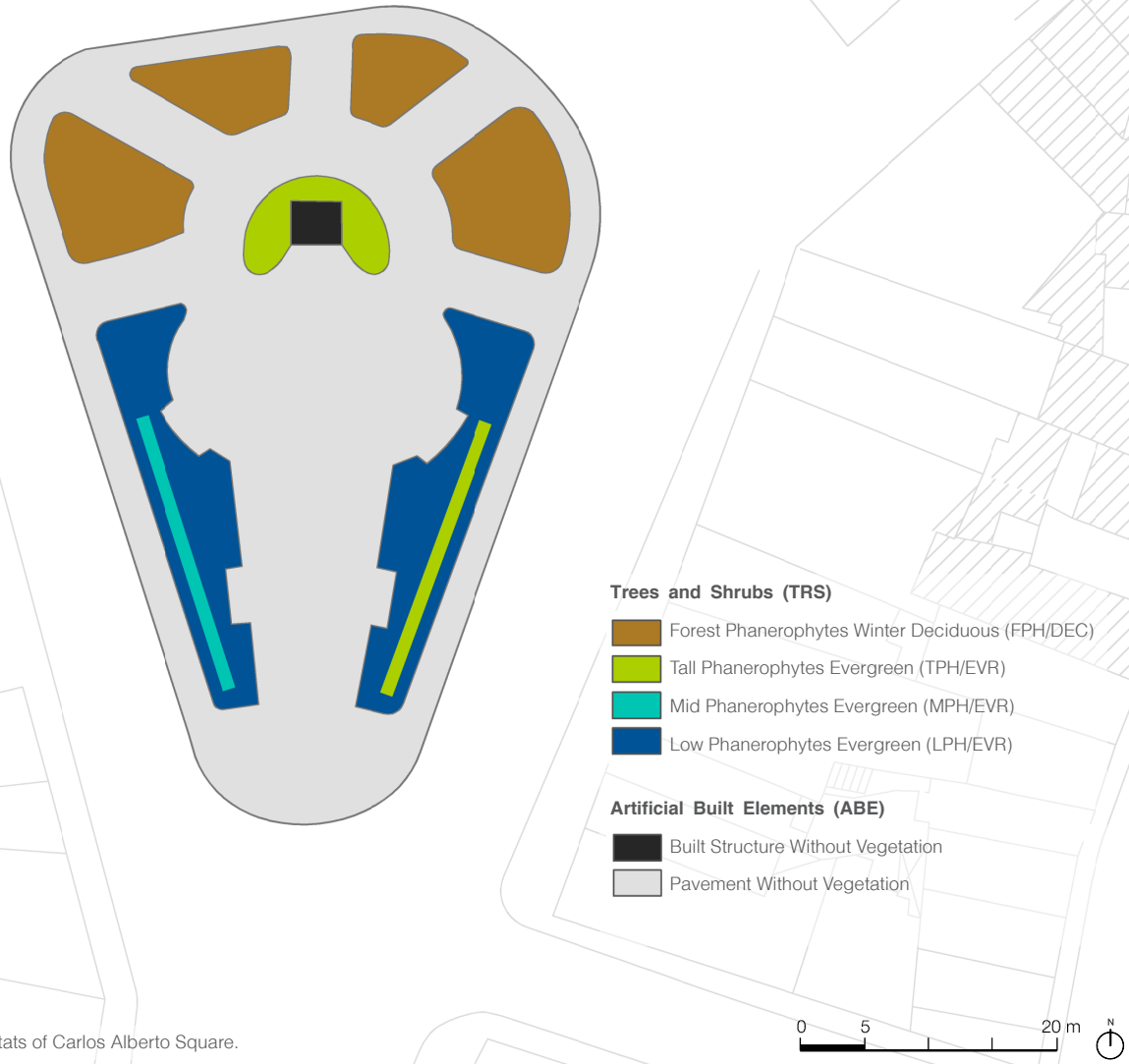
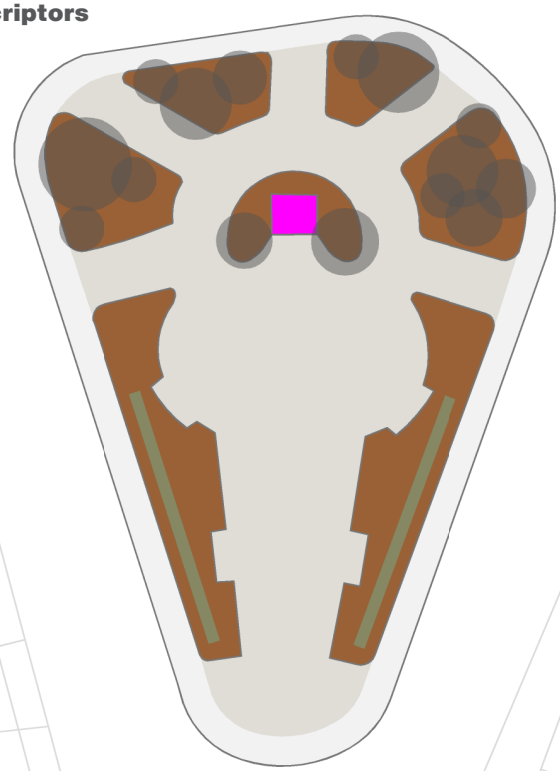


Fig. 136: Habitats of Carlos Alberto Square.

Site Descriptors



Vegetation structures

- Bed
- Bed with trees
- Row of shrubs

Built elements

- Artistic / Decorative element

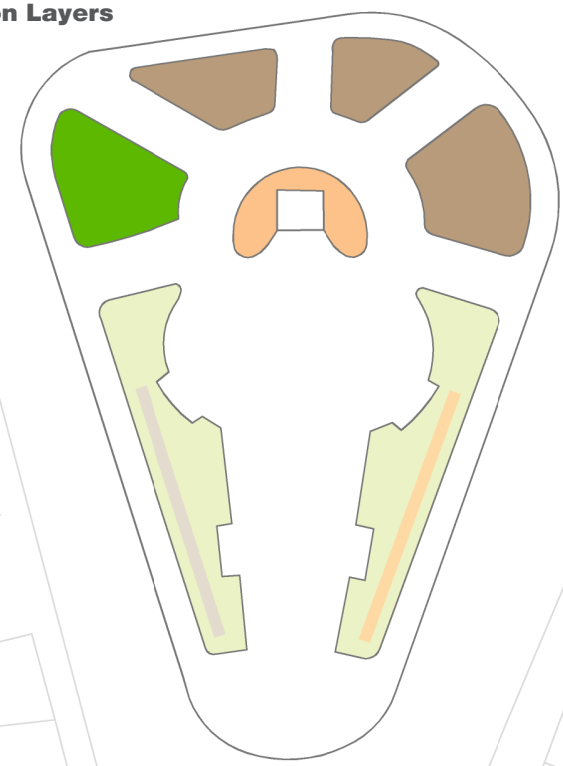
Surfaces and paved areas

- Sidewalk
- Path

0 5 20 m N

Fig. 137: Site descriptors of Carlos Alberto Square.

Vegetation Layers



- Tall trees
- Tall shrubs and small trees
- Medium shrubs and tall herbaceous plants
- Small shrubs and medium herbaceous plants
- Groundcovers and aquatic plants

Three vegetation layers

Two vegetation layers

One vegetation layer

0 5 20 m N

Fig. 138: Vegetation layers of Carlos Alberto Square.

4 Synthesis and future perspectives

This research aims to contribute to a better understanding and promotion of the relationship between biodiversity, spatial form and management within the urban environment. This contribution to a deeper understanding of urban ecosystems is particularly important for planning, design, management and decision-making on the urban landscape. With the development of an urban habitat mapping methodology, the research team intends to lay a common base for urban ecology studies through the use of land cover and plant life form concepts. The proposed methodology has the advantage of being highly communicative due to its spatial character that is easily translated onto visual representations. The different attributes can be represented in maps (Urban Habitat Categories, Site Descriptors, Vegetation Layers, etc.) showing different perspectives and possibilities for urban planning and green infrastructure improvement.

On the other hand, the complex concepts and procedures can became a barrier to the application of this methodology outside of the scientific and academic world. This methodology involves long learning periods and it can be very time consuming during fieldwork as well. This is due to the intricate, complex and disturbed nature of urban habitats, which require a highly detailed description.

Urban parks, gardens and squares vary in terms of biological content, size, shape, perviousness, connectivity, proximity to existing natural environments, etc. It is important to know more about some of these factors, their relation to biodiversity and how such information can be used to promote more biodiverse green spaces in the urban matrix. Relationships between biodiversity indicators and spatial design are to be examined based on data collected on the field, in order to identify which compositions and combinations have more positive impact on plants and animals.

Urban parks, gardens and green squares are fundamental spaces for the conservation and promotion of biodiversity as well as the development of healthier and integrative cities. Their multipurpose design based on a matrix of diverse habitats socially accessible and aesthetically pleasing facilitates the interaction of humans, plants and animals, in a network of public spaces, with minimum conflict and general environmental benefits for city life.

◄ Fig. 139: Cordoaria Garden: ‘Formal garden with trees’.

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◄ Fig. 140: Pasteleira Park: 'Open wood', here marked by the presence of *Quercus suber*.

6 Annexes

6.1 Recording Form (*Areas*, *Lines* and *Points*)

Version 1 - Vegetation Layers

Version 2 - other attributes

6.2 Recording Form (Simplified version for *Lines* and *Points*)

Version 1 - Vegetation Layers

Version 2 - other attributes

◄ Fig. 141: Casa Tait Garden: 'Formal garden' highlighted with clipped hedges of *Buxus sempervirens.*

RECORDING FORM (*AREAS*, *LINES* AND *POINTS*)

Location: ____

Date: ____________________ Observers: ____________________

α code	Field 1	Field 2				Field 3	Field 4
	Urban Habitat Category	**Full list of LF and NLF categories**				**Site Descriptors**	**Vegetation Layers**
		LF and NLF categories	**%**	**Species**	**%**		

Notes

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RECORDING FORM (*AREAS*, *LINES* AND *POINTS*)

Location: ____

Date: ____________________ Observers: ____________________

α code	Field 1	Field 2				Field 3	Field 4
	Urban Habitat Category	**Full list of LF and NLF categories**				**Site Descriptors**	*other attributes*
		LF and NLF categories	**%**	**Species**	**%**		
Notes							

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RECORDING FORM (SIMPLIFIED VERSION FOR *LINES* AND *POINTS*)

Location: ____

Date: ______________________ Observers: ______________________

α code	Field 1	Field 2		Field 3	Field 4
	Urban Habitat Category	**Dominant species**		**Site Descriptors**	**Vegetation Layers**
		Species	**%**		

Notes

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RECORDING FORM (SIMPLIFIED VERSION FOR *LINES* AND *POINTS*)

Location: ____

Date: ______________________ Observers: ______________________

α code	Field 1	Field 2		Field 3	Field 4
	Urban Habitat Category	**Dominant species**		**Site Descriptors**	*other attributes*
		Species	**%**		

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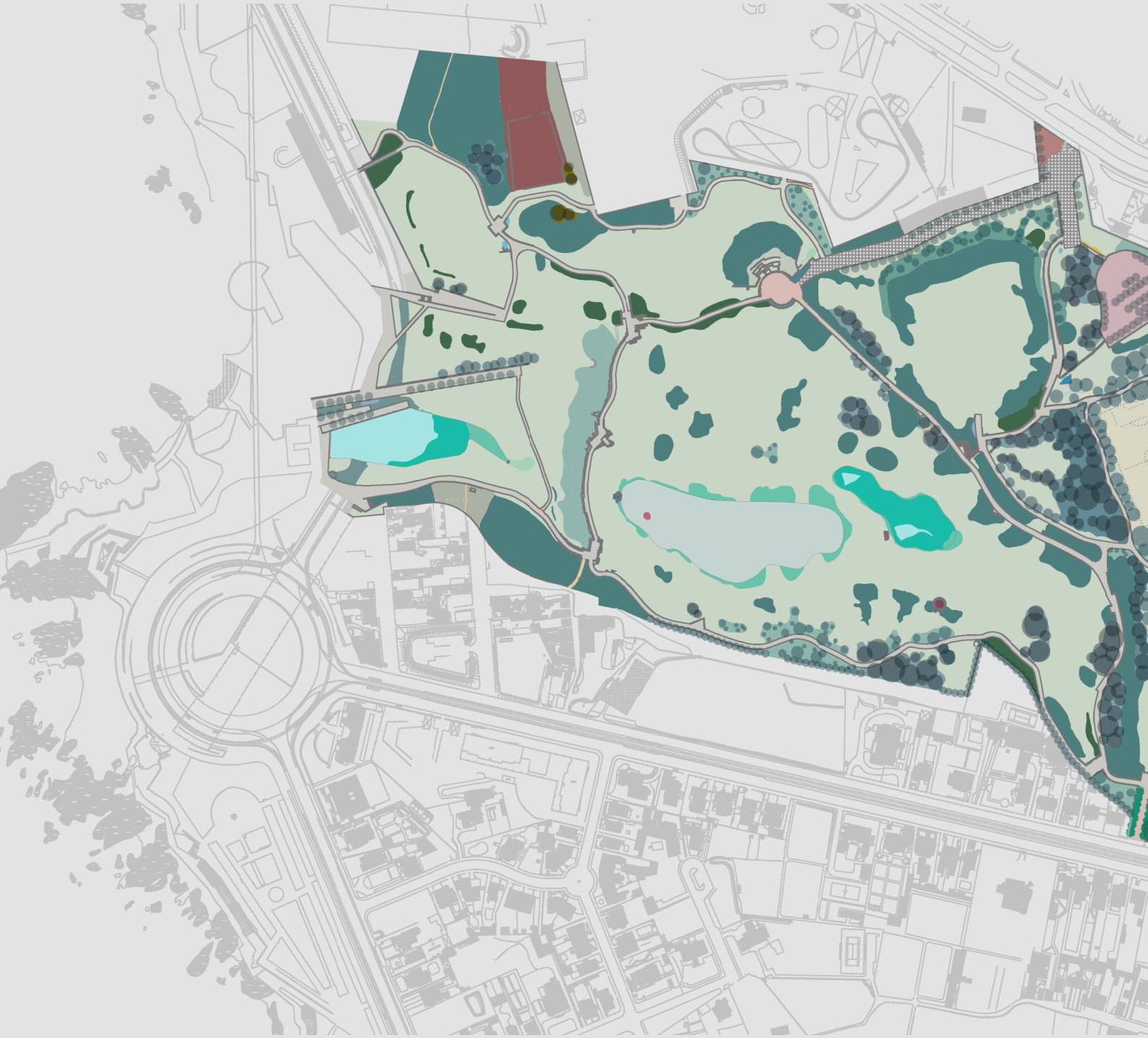

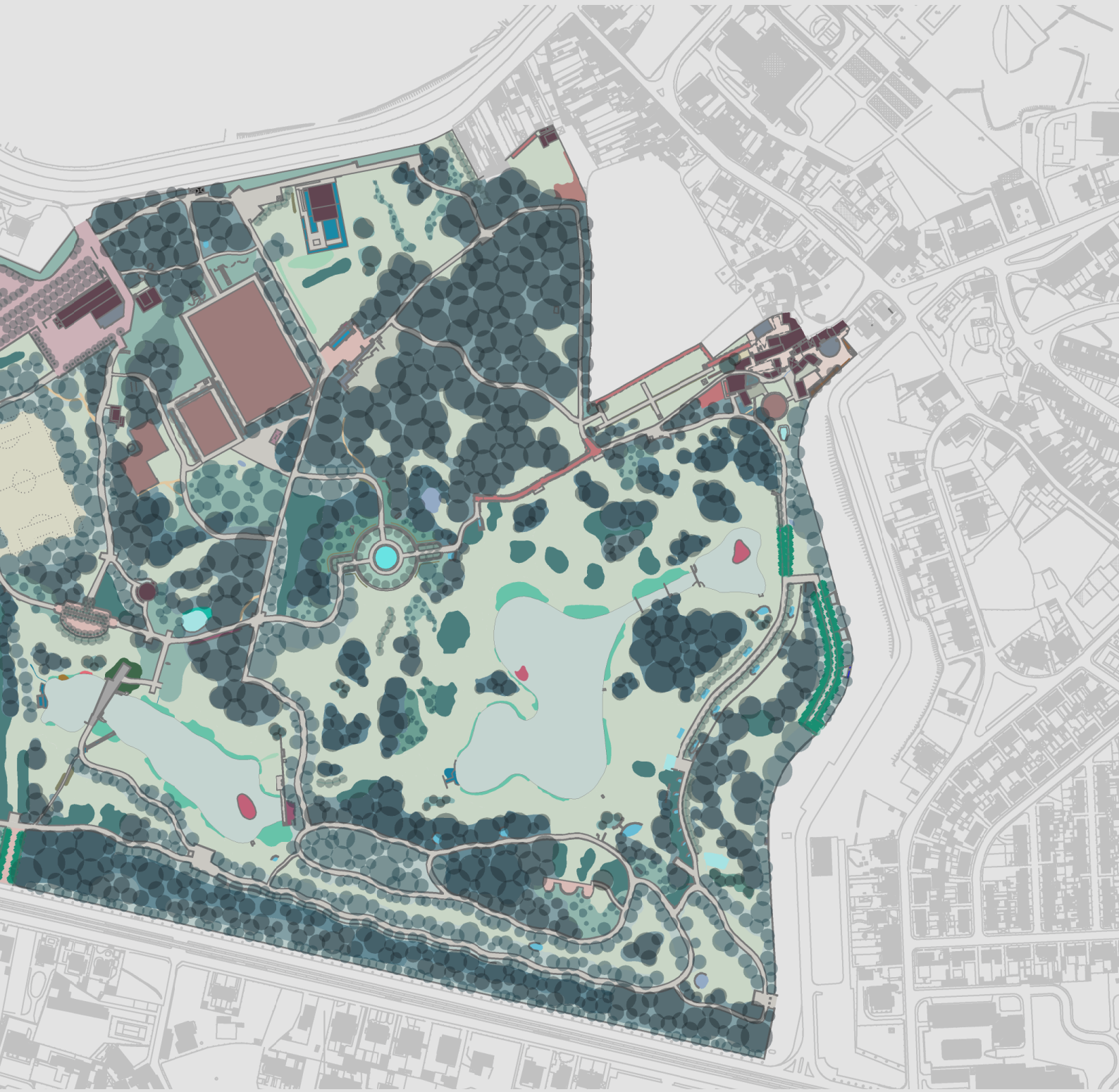

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