

A flora survey of a geological park in the Mediterranean region

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Received: 23 July; First decision: 6 Dec., 2023; Revised: 15 Dec., 2023; Accepted: 18 Dec., 2023

Abstract

The Barrocal Park is a 40-ha geological park located at the edge of the city of Castelo Branco, Portugal, that features diverse granite landforms. The Barrocal Park is integrated into the classified territories of the Naturtejo UNESCO Global Geopark and the Tejo|Tajo Internacional Transboundary Biosphere Reserve. The present study aimed to characterize the spontaneous flora of the Barrocal Park. The Köppen-Geiger climate classification of this region is Csa. The Barrocal landscape is characterized by fragments of climatophilic forests of *Quercus pyrenaica*, associated with rocky granite outcrops. In the subseral stages, *Adenocarpus lainzii*, *Adenocarpus complicatus*, *Cistus ladanifer*, *Cistus inflatus*, *Cytisus striatus*, *Cytisus multiflorus*, *Halimium umbellatum* and *Lavandula pedunculata* predominate. The Arisaro simorrhini-*Quercetum pyrenaicae* association is the only climatophilic series present in the study area. The plant communities comprise 132 plant species belonging to 108 genera and 45 families. The dominant Raunkiaer life form is therophytes

(45.5%), followed by hemicryptophytes (22.7%), and geophytes (12.9%). Eight species are endemic to the Iberian Peninsula, *Adenocarpus lainzii*, *Antirrhinum graniticum*, *Asphodelus serotinus*, *Cytisus multiflorus*, *Digitalis thapsi*, *Ferula communis* subsp. *catalaunica*, *Ornithogalum concinnum* and *Sedum arenarium*. Four invasive species were identified. Some of the native species have great potential as ornamental plants. Despite its main geoheritage value, the Barrocal park can also be valued for its spontaneous flora.

Introduction

Biodiversity inventories and monitoring provide essential information for many biological sciences, and they are vital for identifying key issues for policy and management goals. For example, they play a crucial role in assessing priorities for conservation, land use, sustainable management, pollution control and environmental impact assessments (Stork *et al.* 1996). Information on available resources and their distribution is the basis for

Keywords: Barrocal Park; invasive plants; ornamental plants; plant biodiversity; *Quercus pyrenaica*; spontaneous flora.

any conservation and management exercise. Plant surveys provide crucial information on what resources are available, how much of them we have and where they are located. (Uniyal & Singh 2014). Furthermore, regular plant surveys are important for understanding how populations are changing in the face of anthropogenic disturbance (Stork *et al.* 1996). Many spontaneous plants are highly important to agriculture, forestry, gardening and the pharmaceutical industry, while others have yet to be exploited. Native trees, shrubs and herbs form essential habitats for most other life forms. Overall, plant surveys are essential tools for understanding, conserving, and managing plant diversity and are crucial for the overall health and functioning of ecosystems and the well-being of human societies.

The Mediterranean floristic region is one of the richest hotspots in the world, with more than 24,000 species distributed in the large territory of the Mediterranean Basin (Vargas 2020). The Mediterranean climate is characterized by a long, hot and dry summer and is the most representative climate of mainland Portugal. In this territory 3314 vascular plant species are listed, plus 1006 in the Azores Archipelago and 1233 in Madeira (Sequeira *et al.* 2011).

The Barrocal park is a geological park located at the edge of the city of Castelo Branco, an inland city in Portugal (Figure 1). Castelo Branco is located in the landscape unit of the Beira Interior, where siliceous soils (schists or grauvaques and quartzites, with predominance of granites) predominate (Pinto-Gomes *et al.* 2003). The Barrocal Park contains representative and diverse granite landforms, that are of touristic value due to their aesthetic landscape interest and educational opportunities, because these granite landforms were shaped by different bioclimatic conditions which provided examples of climate change (Antunes *et al.* 2020). An wide variety of plants is adapted to silica-rich rocky soils and grows in this habitat. Currently, there is a clear concern regarding the selection of plants for urban planning proposals, suggesting that the choice should be based on the ecology of the area. This involves considering species that are part of the potential of natural vegetation (Machado 2023).

The Barrocal Park is a perfect example of the relationship between human occupation and nature: it holds archaeological remains dating back to at least the end of the II/beginning of the I millennium BC (Barrocal, n.d.). Despite its main geoheritage value, we believe that

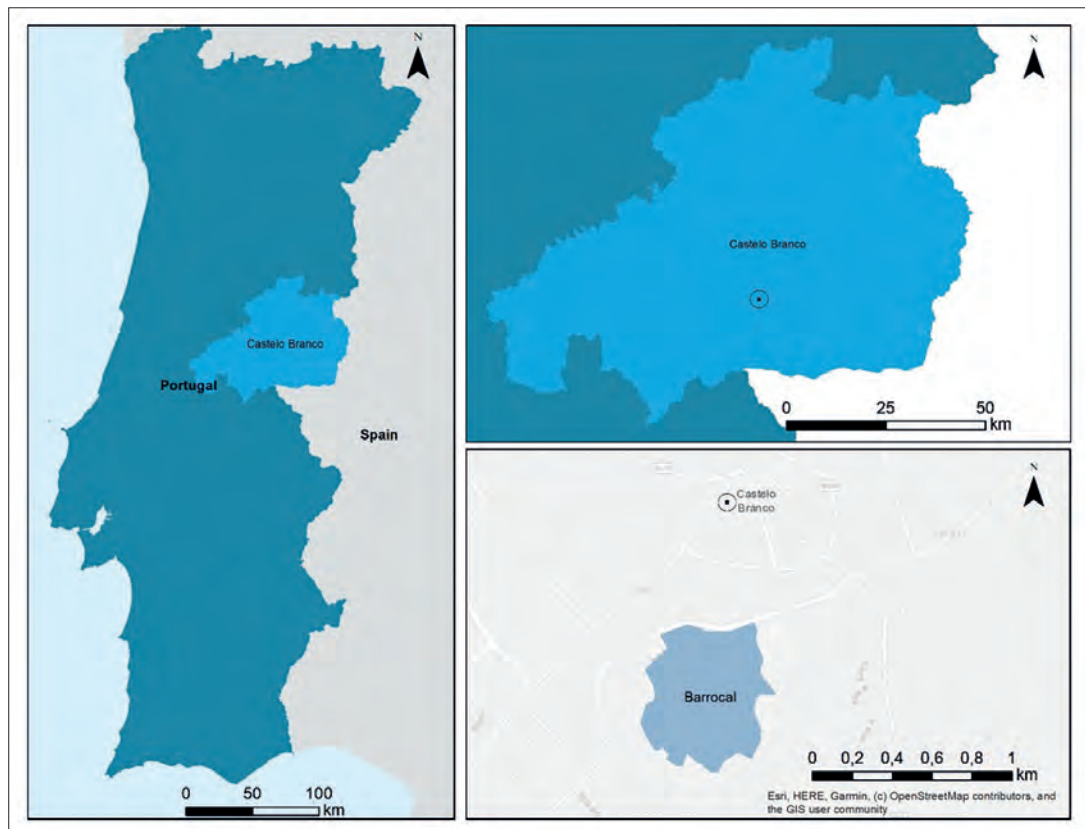


Figure 1 – Study area location.

the Barrocal Park can also be valued for its spontaneous flora. The present study aimed to characterize the spontaneous flora of Barrocal Park, Castelo Branco, Portugal.

Materials and Methods

Study area

The Barrocal Park is a 40ha geological park located at the edge of the city of Castelo Branco, Portugal (39°48'57.36" N, 7°29'32.83" W; 405m a.s.l.), that features diverse granite landforms (Figure 1). The Barrocal Granite occurs mainly on the border of the pluton (i.e. large body of intrusive igneous rock) of Castelo Branco, which is located within the Central Iberian Zone of the Iberian Massif, central Portugal. The Castelo Branco pluton is composed of rocks with compositions that vary between granite and granodiorite (Antunes *et al.* 2020). The Barrocal Park is integrated into the classified territories of the Naturtejo UNESCO Global Geopark and the Tejo/Tajo Internacional Transboundary Biosphere Reserve. The park consists of two distinct areas in terms of landscape restoration: i) a restored (invasive species removal, removal of debris and path creation to avoid wandering) area located to the east, where paths and walkways are marked and several viewpoints are privileged observation platforms used to contemplate the Barrocal landscape; and ii) an area to the west not yet recovered and disturbed by the invasive species *Acacia dealbata* Link and the remnants of construction debris deposits.

The Köppen-Geiger climate classification for Castelo Branco is Csa (Figure 2). The average annual temperature in Castelo Branco is 15.9°C. July and August are the driest and hottest months with mean temperatures above 24°C on average. The highest values of the maximum average temperature occur in July and August, when the temperature is 32.0 and 31.8°C, respectively. The months of December, January, and February are the coldest with average temperatures less than 10°C. Approximately 760mm of precipitation falls annually. In winter, there is much more rainfall than in summer. Most precipitation falls in December and November, with averages of 122.3 and 121.4mm respectively. The months with the lowest precipitation

values are July and August, with averages of 7.8 and 7.7mm, respectively (IPMA, n. d.).

In bioclimatic terms, the study area is a pluvi-estational-oceanic mesomediterranean lower subhumid region (Monteiro-Henriques 2010).

Plant survey

A survey of vascular plants was carried out during field trips conducted between February 2022 and June 2023, mainly during the blooming and fruiting period of vegetation. We utilized an adaptation of the walking method described by Filgueiras *et al.* (1994). A photo of each plant species (leaf, stem, flower, and fruit) was collected using a high-resolution digital camera to construct a digital herbarium. This herbarium was used as a base for comparing and verifying the accuracy of the collected plants. Taxa identification was performed based on Castroviejo *et al.* (1986-2010), Franco (1971, 1984), and Franco & Afonso (1988). The names of taxa authors were verified using the International Plant Names Index (IPNI 2023) and the World Flora Online (WFO 2023). Species were classified according to Raunkiaer life form classes (Raunkiaer 1934). The perturbation index (PI), used to quantify forest degradation and therophytization, was calculated as the ratio of the sum of chamaephytes and therophytes to the total number of the species (Loisel & Gomila 1993):

$$PI = \frac{(\text{number of chamaephytes} + \text{number of therophytes})}{\text{full number of species}} \times 100$$

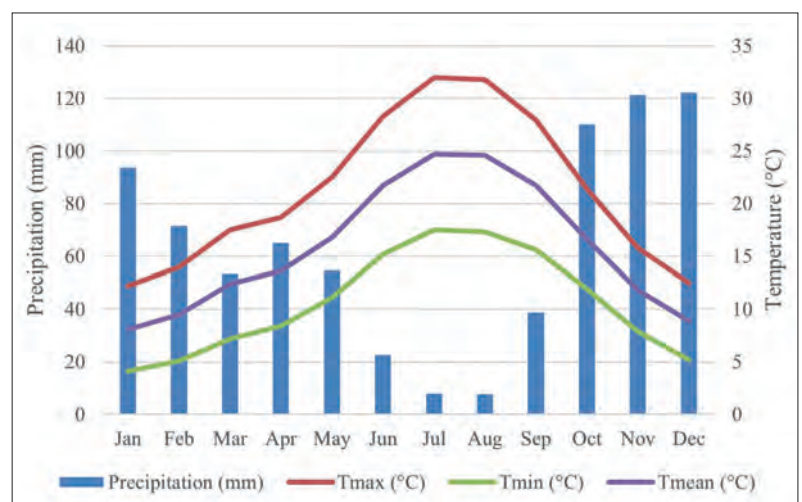


Figure 2 – Average temperatures and precipitation in the Castelo Branco region, Portugal, for the period 1981-2010 (IPMA 2023).

Results

Plant composition

A total of 132 species belonging to 108 genera and 45 families were identified (Table 1). The taxonomic diversity in the study area was 1.22 species per genus. The richest families were Fabaceae (24 species), followed by Asteraceae (16), Poaceae (9), Caryophyllaceae (7), Apiaceae (6), and Plantaginaceae (6). These six families accounted for 51.5% of the species identified (Figure 3).

On the other hand, 22 families (48.9%) were poorly represented, each having one species (0.8%). The genera with the highest number of species were *Vicia* spp. (6 species) and *Trifolium* spp. (5). Most of the species were angiosperms, with 106 species (80.3%) belonging to the magnoliopsid class and 24 (18.2%) to the liliopsid class (Table 2). One species belonging to Gymnosperms (*Pinus pinaster* Aiton) and one species from Pteridophytes (*Pteridium aquilinum* (L.) Khun) were also identified.

Table 1 – Database of the systematics and trait diversity of the flora in the Barrocal Park, Castelo Branco, Portugal (nativity: NAT - Native, EXO – Exotic, INV – Invasive, EIP - Endemic to the Iberian Peninsula; Raunkiaer life form: CHA – Chamaephyte, GEO – Geophyte, HCP - Hemicyptophyte, MCP - Microphanerophyte, MGP – Megaphanerophyte, MSP – Mesophanerophyte, NOP - Nanophanerophyte, THE – Therophyte).

S. No.	Scientific name	Family	Nativity	Growth form	Raunkiaer life form
1	<i>Acacia dealbata</i> Link	Fabaceae	EXO; INV	Tree	MSP
2	<i>Adenocarpus lainzii</i> (Castrov.) Castrov.	Fabaceae	NAT; EIP	Shrub	NOP
3	<i>Adenocarpus complicatus</i> (L.) J. Gay	Fabaceae	NAT	Shrub	NOP
4	<i>Allium neapolitanum</i> Cirillo	Amaryllidaceae	NAT	Herb	GEO
5	<i>Anagallis arvensis</i> L.	Primulaceae	NAT	Herb	THE
6	<i>Anchusa undulata</i> L.	Boraginaceae	NAT	Herb	HCP
7	<i>Andryala integrifolia</i> L.	Asteraceae	NAT	Herb	HCP
8	<i>Andryala laxiflora</i> DC.	Asteraceae	NAT	Herb	THE
9	<i>Antirrhinum graniticum</i> Rothm.	Plantaginaceae	NAT; EIP	Herb	CHA
10	<i>Anthriscus caucalis</i> M.Bieb.	Apiaceae	NAT	Herb	THE
11	<i>Anthoxanthum aristatum</i> Boiss.	Poaceae	NAT	Herb	THE
12	<i>Arisarum simorrhinum</i> Durieu	Araceae	NAT	Herb	GEO
13	<i>Asphodelus serotinus</i> Wolley-Dod	Xanthorrhoeaceae	NAT; EIP	Herb	GEO
14	<i>Astragalus pelecinus</i> (L.) Barneby	Fabaceae	NAT	Herb	THE
15	<i>Avena barbata</i> Pott ex Link	Poaceae	NAT	Herb	THE
16	<i>Briza maxima</i> L.	Poaceae	NAT	Herb	THE
17	<i>Bromus hordeaceus</i> L.	Poaceae	NAT	Herb	THE
18	<i>Bryonia dioica</i> Jacq.	Cucurbitaceae	NAT	Climber	GEO
19	<i>Calendula arvensis</i> L.	Asteraceae	NAT	Herb	THE
20	<i>Campanula rapunculus</i> L.	Campanulaceae	NAT	Herb	HCP
21	<i>Centranthus calcitrapae</i> (L.) Dufr.	Valerianaceae	NAT	Herb	THE
22	<i>Chamaemelum mixtum</i> All.	Asteraceae	NAT	Herb	THE
23	<i>Chrysanthemum segetum</i> L.	Asteraceae	NAT	Herb	THE
24	<i>Cichorium intybus</i> L.	Asteraceae	NAT	Herb	HCP
25	<i>Cistus ladanifer</i> L. subsp. <i>ladanifer</i>	Cistaceae	NAT	Shrub	NOP
26	<i>Cistus inflatus</i> Pourr. Ex Demoly	Cistaceae	NAT	Shrub	NOP
27	<i>Clinopodium vulgare</i> L.	Lamiaceae	NAT	Herb	THE
28	<i>Coleostephus myconis</i> (L.) Rchb.f.	Asteraceae	NAT	Herb	THE
29	<i>Convolvulus arvensis</i> L.	Convolvulaceae	NAT	Climber	HCP
30	<i>Cortaderia selloana</i> (Schult. & Schult.f.) Asch. & Graebn.	Poaceae	EXO; INV	Herb	HCP
31	<i>Crataegus monogyna</i> Jacq.	Rosaceae	NAT	Shrub	MCP
32	<i>Crepis vesicaria</i> subsp. <i>taraxacifolia</i> (Thuill) Thell.	Asteraceae	NAT	Herb	THE
33	<i>Cynosurus echinatus</i> L.	Poaceae	NAT	Herb	THE
34	<i>Cytisus multiflorus</i> (L'Hér.) Sweet	Fabaceae	NAT; EIP	Shrub	NOP
35	<i>Cytisus striatus</i> (Hill) Rothm.	Fabaceae	NAT	Shrub	NOP
36	<i>Dactylis glomerata</i> L.	Poaceae	NAT	Herb	HCP
37	<i>Daphne gnidium</i> L.	Thymelaeaceae	NAT	Shrub	NOP
38	<i>Daucus carota</i> subsp. <i>carota</i> L.	Apiaceae	NAT	Herb	HCP
39	<i>Dianthus lusitanus</i> Brot.	Caryophyllaceae	NAT	Herb	CHA
40	<i>Digitalis thapsi</i> L.	Plantaginaceae	NAT; EIP	Herb	HCP

S. No.	Scientific name	Family	Nativity	Growth form	Raunkiaer life form
41	<i>Diploaxis catholica</i> (L.) DC.	Brassicaceae	NAT	Herb	THE
42	<i>Dittrichia viscosa</i> (L.) Greuter	Asteraceae	NAT	Herb	CHA
43	<i>Echium plantagineum</i> L.	Boraginaceae	NAT	Herb	HCP
44	<i>Erodium botrys</i> (Cav.) Bertol.	Geraniaceae	NAT	Herb	THE
45	<i>Ferula communis</i> subsp. <i>catalaunica</i> (Pau ex C.Vicioso) Sánchez-Cux. & M.Bernal	Apiaceae	NAT; EIP	Herb	HCP
46	<i>Foeniculum vulgare</i> Mill.	Apiaceae	NAT	Herb	HCP
47	<i>Fraxinus angustifolia</i> Vahl	Oleaceae	NAT	Tree	MSP
48	<i>Fumaria officinalis</i> L.	Papaveraceae	NAT	Herb	THE
49	<i>Gagea foliosa</i> subsp. <i>ellyptica</i> A. Terracc.	Liliaceae	NAT	Herb	GEO
50	<i>Galactites tomentosus</i> Moench.	Asteraceae	NAT	Herb	THE
51	<i>Geranium molle</i> L.	Geraniaceae	NAT	Herb	THE
52	<i>Gladiolus illyricus</i> W.D.J.Koch	Iridaceae	NAT	Herb	GEO
53	<i>Halimium umbellatum</i> (L.) Spach	Cistaceae	NAT	Shrub	CHA
54	<i>Helichrysum stoechas</i> subsp. <i>stoechas</i> (L.) Moench	Asteraceae	NAT	Shrub	CHA
55	<i>Hordeum murinum</i> L.	Poaceae	NAT	Herb	THE
56	<i>Hyacinthoides hispanica</i> (Mill.) Rothm.	Asparagaceae	NAT	Herb	GEO
57	<i>Hymenocarpus lotoides</i> (L.) Vis.	Fabaceae	NAT	Herb	THE
58	<i>Hypericum linariifolium</i> Vahl.	Hypericaceae	NAT	Herb	HCP
59	<i>Hypericum perforatum</i> L.	Hypericaceae	NAT	Herb	HCP
60	<i>Hypochaeris radicata</i> L.	Asteraceae	NAT	Herb	HCP
61	<i>Iris planifolia</i> (Mill.) T.Durand & Schinz	Iridaceae	NAT	Herb	GEO
62	<i>Jasione montana</i> L.	Campanulaceae	NAT	Herb	HCP
63	<i>Juncus effusus</i> L.	Juncaceae	NAT	Herb	HCP
64	<i>Lathyrus clymenum</i> L.	Fabaceae	NAT	Herb	THE
65	<i>Lavandula pedunculata</i> (Mill.) Cav.	Lamiaceae	NAT	Shrub	CHA
66	<i>Linaria spartea</i> (L.) Chaz.	Plantaginaceae	NAT	Herb	THE
67	<i>Linum bienne</i> Mill.	Linaceae	NAT	Herb	HCP
68	<i>Lolium multiflorum</i> Lam.	Poaceae	NAT	Herb	THE
69	<i>Lonicera periclymenum</i> L.	Caprifoliaceae	NAT	Climber	NOP
70	<i>Lupinus angustifolius</i> L.	Fabaceae	NAT	Herb	THE
71	<i>Lupinus luteus</i> L.	Fabaceae	NAT	Herb	THE
72	<i>Malva sylvestris</i> L.	Malvaceae	NAT	Herb	HCP
73	<i>Malva tournefortiana</i> L.	Malvaceae	NAT	Herb	HCP
74	<i>Medicago polymorpha</i> L.	Fabaceae	NAT	Herb	THE
75	<i>Mercurialis ambigua</i> L.f.	Euphorbiaceae	NAT	Herb	THE
76	<i>Misopates orontium</i> (L.) Raf.	Plantaginaceae	NAT	Herb	THE
77	<i>Muscari comosum</i> (L.) Mill.	Asparagaceae	NAT	Herb	GEO
78	<i>Narcissus bulbocodium</i> L. subsp. <i>bulbocodium</i>	Amaryllidaceae	NAT	Herb	GEO
79	<i>Olea europaea</i> L. var. <i>sylvestris</i> (Mill.) Lehr	Oleaceae	NAT	Tree	MSP
80	<i>Opuntia ficus-indica</i> (L.) Mill.	Cactaceae	EXO; INV	Shrub	MCP
81	<i>Ornithogalum concinnum</i> Salisb.	Asparagaceae	NAT; EIP	Herb	GEO
82	<i>Ornithopus compressus</i> L.	Fabaceae	NAT	Herb	THE
83	<i>Orobanche rapum-genistae</i> Thuill.	Orobanchaceae	NAT	Herb	THE
84	<i>Oxalis pes-caprae</i> L.	Oxalidaceae	EXO; INV	Herb	GEO
85	<i>Papaver rhoeas</i> L.	Papaveraceae	NAT	Herb	THE
86	<i>Paronychia argentea</i> Lam.	Caryophyllaceae	NAT	Herb	HCP
87	<i>Pinus pinaster</i> Aiton	Pinaceae	NAT	Tree	MGP
88	<i>Plantago lagopus</i> L.	Plantaginaceae	NAT	Herb	HCP
89	<i>Plantago coronopus</i> L.	Plantaginaceae	NAT	Herb	HCP
90	<i>Pteridium aquilinum</i> (L.) Khun	Dennstaedtiaceae	NAT	Herb	GEO
91	<i>Quercus pyrenaica</i> Willd.	Fagaceae	NAT	Tree	MSP
92	<i>Quercus rotundifolia</i> Lam.	Fagaceae	NAT	Tree	MSP
93	<i>Raphanus raphanistrum</i> subsp. <i>Raphanistrum</i> L.	Brassicaceae	NAT	Herb	THE
94	<i>Reseda media</i> Lag.	Resedaceae	NAT	Herb	THE
95	<i>Retama sphaerocarpa</i> (L.) Boiss.	Fabaceae	NAT	Shrub	NOP
96	<i>Romulea ramiflora</i> Ten.	Iridaceae	NAT	Herb	GEO
97	<i>Rubia Peregrina</i> L.	Rubiaceae	NAT	Climber	HCP
98	<i>Rubus ulmifolius</i> var. <i>ulmifolius</i> Schott	Rosaceae	NAT	Climber	NOP
99	<i>Rumex acetosa</i> L.	Polygonaceae	NAT	Herb	HCP

S. No.	Scientific name	Family	Nativity	Growth form	Raunkiaer life form
100	<i>Rumex acetosella</i> subsp. <i>angiocarpus</i> (Murb.) Murb.	Polygonaceae	NAT	Herb	HCP
101	<i>Rumex induratus</i> Boiss. & Reut.	Polygonaceae	NAT	Herb	HCP
102	<i>Ruscus aculeatus</i> L.	Asparagaceae	NAT		GEO
103	<i>Salix salviifolia</i> Brot.	Salicaceae	NAT	Shrub	MCP
104	<i>Sedum arenarium</i> Brot.	Crassulaceae	NAT; EIP	Herb	THE
105	<i>Senecio lividus</i> L.	Asteraceae	NAT	Herb	THE
106	<i>Serapias cordigera</i> L. subsp. <i>cordigera</i>	Orchidaceae	NAT	Herb	GEO
107	<i>Silene gallica</i> L.	Caryophyllaceae	NAT	Herb	THE
108	<i>Silene latifolia</i> Poir.	Caryophyllaceae	NAT	Herb	THE
109	<i>Silene scabriflora</i> Brot.	Caryophyllaceae	NAT	Herb	THE
110	<i>Solanum nigrum</i> L.	Solanaceae	NAT	Herb	THE
111	<i>Sonchus asper</i> (L.) Hill	Asteraceae	NAT	Herb	THE
112	<i>Spergula arvensis</i> L.	Caryophyllaceae	NAT	Herb	THE
113	<i>Spergularia purpurea</i> G.Don	Caryophyllaceae	NAT	Herb	THE
114	<i>Teesdalia nudicaulis</i> (L.) W.T.Aiton	Brassicaceae	NAT	Herb	THE
115	<i>Thapsia villosa</i> L.	Apiaceae	NAT	Herb	HCP
116	<i>Tolpis barbata</i> (L.) Gaertn.	Asteraceae	NAT	Herb	THE
117	<i>Torilis arvensis</i> (Huds.) Link	Apiaceae	NAT	Herb	THE
118	<i>Trifolium angustifolium</i> L.	Fabaceae	NAT	Herb	THE
119	<i>Trifolium arvense</i> L.	Fabaceae	NAT	Herb	THE
120	<i>Trifolium repens</i> L.	Fabaceae	NAT	Herb	HCP
121	<i>Trifolium stellatum</i> L.	Fabaceae	NAT	Herb	THE
122	<i>Trifolium tomentosum</i> L.	Fabaceae	NAT	Herb	THE
123	<i>Tuberaria guttata</i> (L.) Fourr.	Cistaceae	NAT	Herb	THE
124	<i>Umbilicus rupestris</i> (Salisb.) Dandy	Crassulaceae	NAT	Herb	HCP
125	<i>Urginea maritima</i> (L.) Baker	Asparagaceae	NAT	Herb	GEO
126	<i>Urospermum picroides</i> (L.) Scop. ex F.W.Schmidt	Asteraceae	NAT	Herb	THE
127	<i>Vicia angustifolia</i> L.	Fabaceae	NAT	Herb	THE
128	<i>Vicia benghalensis</i> L.	Fabaceae	NAT	Herb	THE
129	<i>Vicia dasycarpa</i> Ten.	Fabaceae	NAT	Herb	THE
130	<i>Vicia disperma</i> DC.	Fabaceae	NAT	Herb	THE
131	<i>Vicia lutea</i> L.	Fabaceae	NAT	Herb	THE
132	<i>Vicia sativa</i> L.	Fabaceae	NAT	Herb	THE

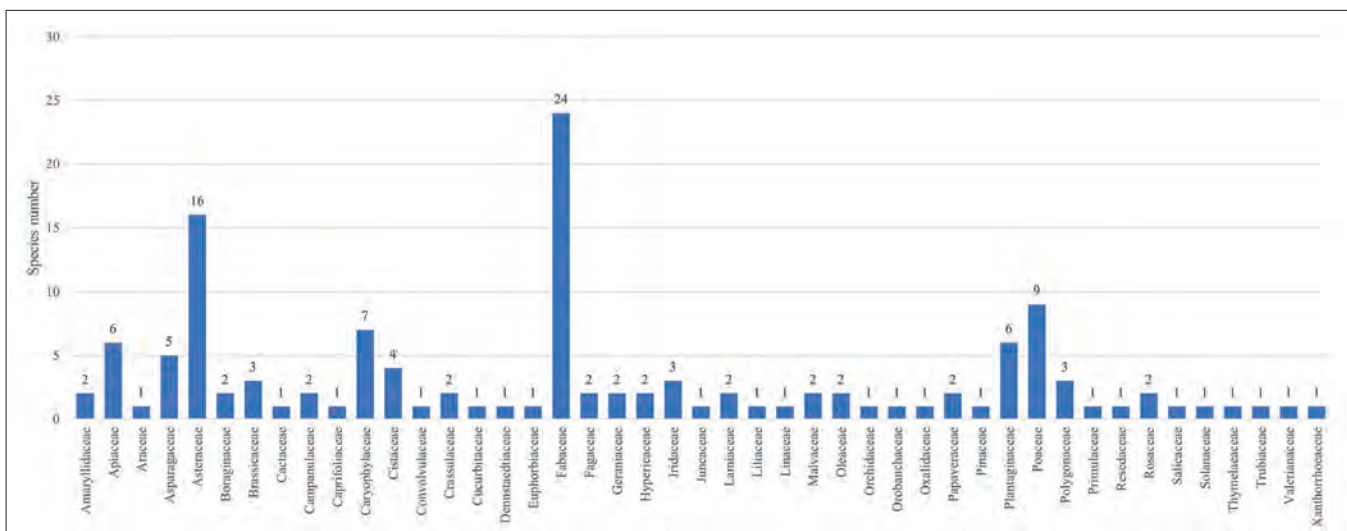


Figure 3 – Histogram of the flora composition of the 45 surveyed families in the Barrocal park, Castelo Branco, Portugal.

Eight species (6.1%) endemic to the Iberian Peninsula were identified: *Adenocarpus lainzii* (Castrov.) Castrov., *Antirrhinum graniticum* Rothm., *Asphodelus serotinus* Wolley-Dod, *Cytisus multiflorus* (L’Hér.) Sweet, *Digitalis*

thapsi L., *Ferula communis* subsp. *catalaunica* (Pau ex C.Vicioso) Sánchez-Cux. & M.Bernal, *Ornithogalum concinnum* Salisb. and *Sedum arenarium* Brot. (Figure 4).

Table 2 – Taxonomic account of flora diversity.

Taxonomic group	Families	Genera	Species	Herbs	Shrubs	Trees	Climbers
Angiosperms							
Magnoliopsida	36	86	110	86	14	5	5
Liliopsida	7	20	20	19	1	---	---
Gymnosperms	1	1	1	---	---	1	---
Pteridophytes	1	1	1	1	---	---	---
Total	45	108	132	106	15	6	5

In addition, despite not being endemic to the Iberian Peninsula, several species stand out for their beauty and have potential as ornamental, such as *Dianthus lusitanus* Brot., *Gladiolus illyricus* Koch., *Hyacinthoides hispanica* (Mill.) Rothm., *Iris planifolia* (Mill.) T.Durand & Schinz, *Narcissus bulbocodium* L. subsp. *bulbocodium* and *Romulea ramiiflora* Ten (Figure 5).

Four species, *Acacia dealbata*, *Cortaderia selloana* (Schult. & Schult.f.) Asch. & Graebn., *Opuntia ficus-indica* (L.) Mill. and *Oxalis pes-caprae* L., classified as invasive (Decree-law 92/2019) were detected. *O. ficus-indica* has an exceptional status, according to the cited Decree-law: its cultivation is allowed,

as long as some rules for the control of the species are observed. *Acacia dealbata* (the invasive species with the largest distribution), and *O. ficus-indica* (with a very restricted distribution area), occur in the northwestern zone of the park in an area previously disturbed by anthropogenic activity (granite quarries and construction debris deposits).

Three toxic species were identified, *Daphne gnidium* L., *Ferula communis* subsp. *catalaunica* (Pau ex C.Vicioso) Sánchez-Cux. & M.Bernal and *Urginea maritima* (L.) Baker.

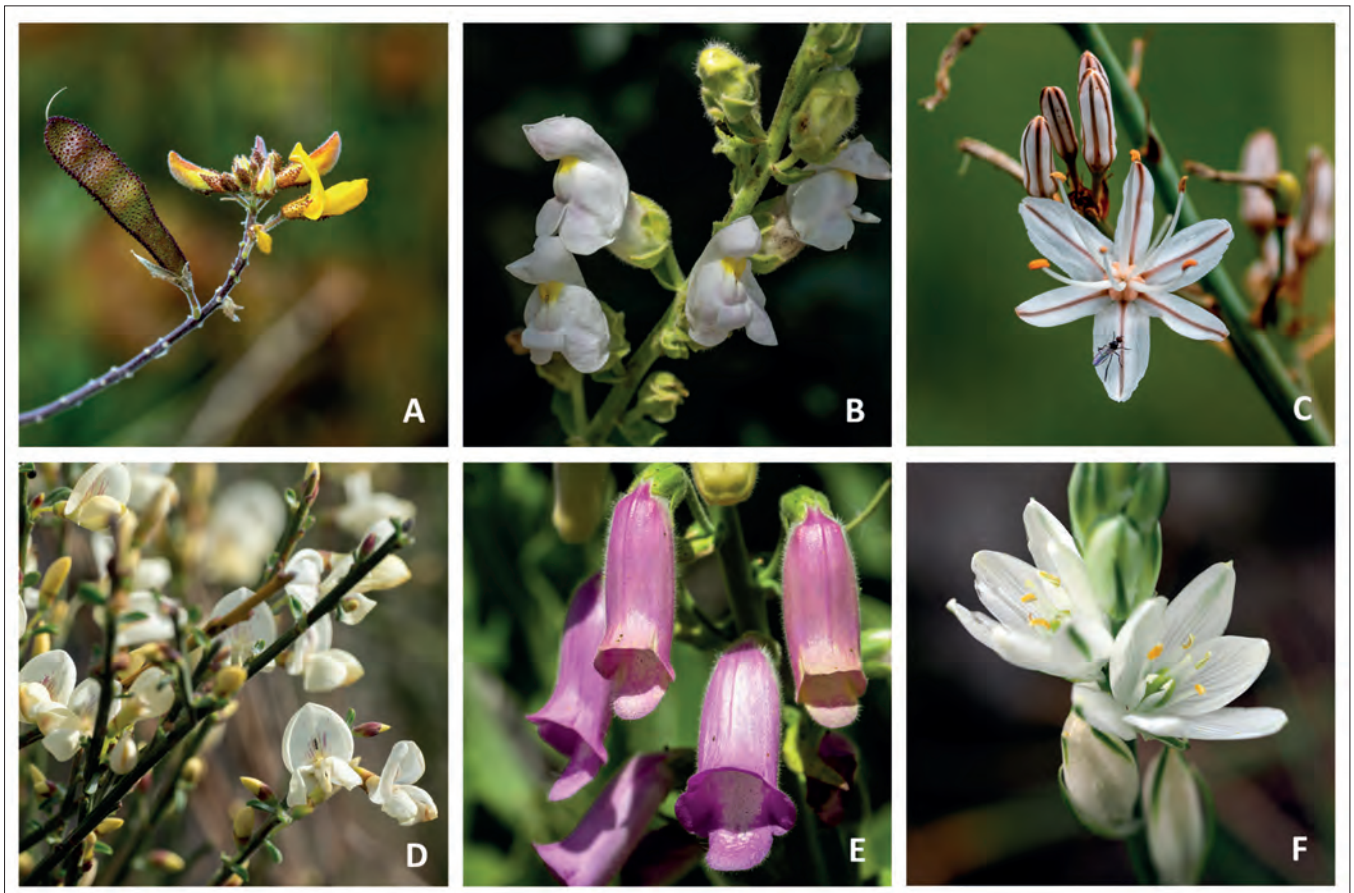


Figure 4 – Some endemic species to the Iberian Peninsula found in the Barrocal Park; A – *Adenocarpus lainzii*; B – *Antirrhinum graniticum*; C – *Asphodelus serotinus*; D – *Cytisus multiflorus*; E – *Digitalis thapsi*; F – *Ornithogalum concinnum*.

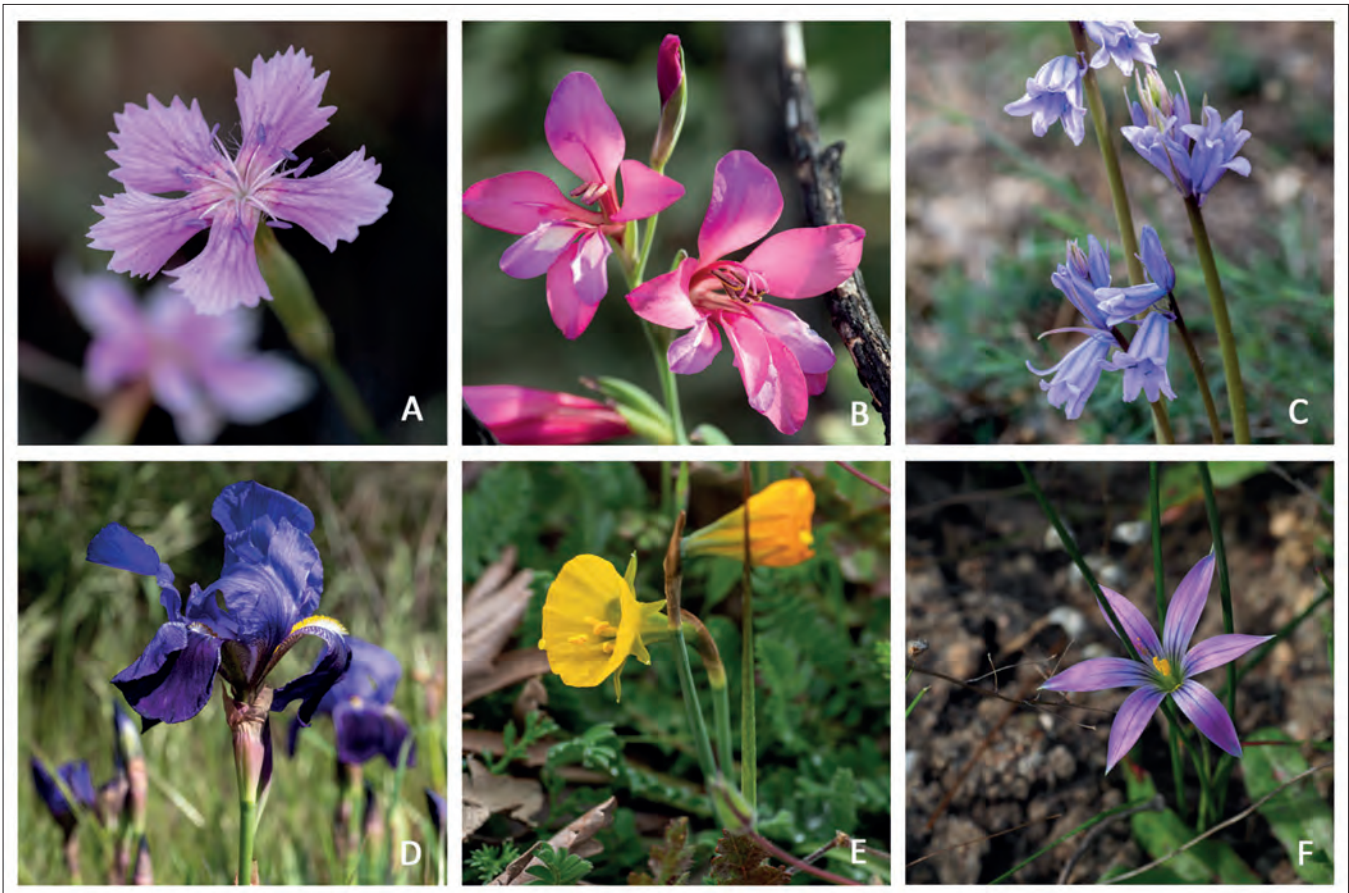


Figure 5 – Non-endemic species with ornamental value found in the Barrocal Park; A – *Dianthus lusitanus*; B – *Gladiolus illyricus*; C – *Hyacinthoides hispanica*; D - *Iris planifolia*; E – *Narcissus bulbocodium*; F - *Romulea ramiflora*.

Lifeform spectra

The dominant lifeform of the flora was herbs with 106 species (80.3%), followed by shrubs with 15 species (11.4%), trees with 6 species (4.5%), and climbers with 5 species (3.8%).

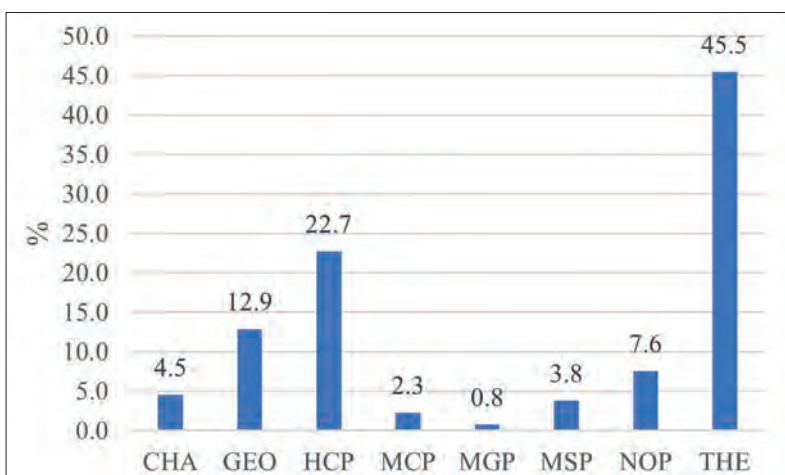


Figure 6 – Distribution of Raunkiaer's life forms in the Barrocal Park, Castelo Branco, Portugal. CHA – Chamaephyte, GEO - Geophyte, HCP - Hemicryptophyte, MCP - Microphanerophyte, MGP – Megaphanerophyte, MSP – Mesophanerophyte, NOP - Nanophanerophyte, THE – Therophyte.

The dominant Raunkiaer lifeforms were therophytes, which contributed 60 species (45.4%), followed by hemicryptophytes, 30 (22.7%); geophytes, 17 (12.9%); nanophanerophytes, 10 (7.6%); chamaephytes, 6 (4.5%); mesophanerophytes, 5 (3.8%); microphanerophytes, 3 (2.3%); and megaphanerophytes, 1 (0.8%) (Figure 6). The perturbation index (PI) of the surveyed area was 50.0%.

Discussion

The studied area is included in the West Iberian Mediterranean biogeographic Province, Luso-Extremadurese Subprovince, Todedanian-Taganian Sector, and South Beirese District (Rivas-Martinez *et al.* 2014). This territory is under the climatic influence of the dry to sub-humid mesomediterranean floor, which is characterized by a markedly hot and dry summer (Costa *et al.* 1998). This area is characterized by the presence of sclerophyllous vegetation with evergreen leaves, which is

well-adapted to summer dryness, given the very scarce water availability and high temperatures. From a geobotanical point of view, this biogeographical unit is dominated by climatophilic forests of Pyrenean oak (*Quercus pyrenaica* Willd), cork oak (*Quercus suber* L.), and, residually, holm oak (*Quercus rotundifolia* Lam.), and are often simplified and reduced to meadows with scattered trees (Ribeiro, 2021). The South Beirese district contains a climatic domain divided between marcescent forest, namely, the oak forest of *Arisaro simorrhini-Quercetum pyrenaica* and potential evergreen vegetation (cork oaks and holm oaks) (Pinto-Gomes *et al.* 2007; Vila-Viçosa 2012). The potential climatophilous vegetation of the Castelo Branco region is dominated by black oak (*Quercus pyrenaica*) to the north and by cork oak (*Quercus suber*) to the south, where the first occurs on granites and the second occurs on schist and quartzite substrates, particularly on cooler slopes. These two vegetation climaxes correspond to two distinct vegetation series (Machado 2023).

Specifically, the Barrocal landscape is characterized mainly by fragments of climatophilic forests of *Quercus pyrenaica* (the *Quercus-Fagetea* class) associated with rocky granite outcrops. The holm oak (*Q. rotundifolia*) (*Quercetea ilicis* class) has a residual representation. The *Arisaro simorrhini-Quercetum pyrenaicae* association is the only climatophilic series present in the study area.

In the granitic substrates of Barrocal Park, brooms (*Cytisus* species) belonging to the *Cytisetum multifloro-erocarpi* association predominate and they represent the high shrub stage. These species are included in the alliance *Genistion floridae* (*Cytisetea scopario-striati*) and, together with the brooms of *Genisto falcatae-Adenocarpum anisochili* (*Ulici europaei-Cytisium striati*), constitute the second phase of replacement of the oak groves of *Q. pyrenaica* in this region (Ribeiro, 2021). The cover of the *Cytisetea scopario-striati* class, which groups these communities, has increased in recent decades due to the abandonment of agricultural land (which was initially gained from millennial anthropic destruction of natural Iberian forests (Costa *et al.* 2003)). In the Barrocal Park, the class *Cytisetea scopario-striati* comprises shrubby communities of nanophanerophytes and microphanerophytes dominated by leguminous species of the genera *Cytisus* spp. and *Adenocarpus* spp. This tall bush vegetation

comprises the species *Cytisus striatus* (Hill) Rothm., *Cytisus multiflorus* (L'Hér.) Sweet, *Adenocarpus complicatus* (L.) J.Gay and *Adenocarpus lainzii* (Castrov.) Castrov. In the low scrub, *Cistus ladanifer* L., *Cistus inflatus* Pourr. ex J.-P.Demoly, *Halimium umbellatum* (L.) Spach and *Lavandula pedunculata* (Mill.) Cav., can be found. The white broom (*Cytisus multiflorus*) and the yellow broom (*Cytisus striatus*) have massive flowering and therefore provide a high floral resources in the spring. In the understory, in addition to aromatic and honey species, such as French lavender (*Lavandula pedunculata*) and rockrose (*Cistus ladanifer*), there are species with small edible fruits, such as hawthorn (*Crataegus monogyna* Jacq.) and bramble (*Rubus ulmifolius* Schott). Species of medicinal interest, such as St. John's wort (*Hypericum perforatum* L.), mallow (*Malva sylvestris* L.), and Mediterranean plantain (*Plantago lagopus* L.), can be found in the herbaceous layer. In places with full sun exposure, in the crevices of rocky outcrops, the association *Digitalis thapsi-Dianthetum lusitani* (*Rumici indurati-Dianthion lusitani* alliance), dominated by *Dianthus lusitanus* with the presence of the Iberian endemic *Digitalis thapsi*, can be found. On rocky granite platforms, in small accumulations of soil between rocky fissures or in thin soil platforms, communities of the Iberian endemic *Sedum arenarium* are frequent.

The plant survey revealed that Fabaceae (24 species), Asteraceae (16 species), and Poaceae (9 species) were the most species-rich families, constituting the main bulk of the plant species (37.1%). These three families were reported as the most dominant in the flora of the Mediterranean (Abbas *et al.* 2020; Chebli *et al.* 2023). This can be attributed to the efficient seed dispersal capabilities, migration efficiency, and wide ecological range of tolerance of these plants, in addition to the local conditions of water availability and soil depth (Abbas *et al.* 2020).

In the Barrocal Park, therophytes constitute the most abundant form of life, contributing to 45.4% of the total number of species. According to Raunkiaer's normal spectrum (Raunkiaer, 1934), therophytes exhibited the maximum deviation (+32.4%), while geophytes exhibited the minimum (+6.9%). In contrast, a negative deviation of -31.5% was observed for phanerophytes, followed by chamaephytes (-4.5%), and hemicryptophytes (-3.3%). The perturbation index of

the studied area, used to quantify therophytization (Habib *et al.* 2020), was 50.0%. This index is similar to that reported (54%) for a forest rangelands in the southern mediterranean region of northern Morocco (Chebli *et al.* 2023). As reported by several authors (Benabadi *et al.* 2009; Chebli *et al.* 2023), most of the forests in the Mediterranean basin are experiencing a therophytization process, which could be explained by human disturbance. Because of their ability to cope with thermo-xeric climatic conditions, therophytes are the richest group in the Mediterranean area (Lazarina *et al.* 2019)

Therophytes are mainly associated with warm and dry lowland sites with a high degree of precipitation seasonality, and are often subject to current or historic human land use (Lazarina *et al.* 2019; Di Biase *et al.* 2020; Irl *et al.* 2020). In unpredictable environments, it is advantageous to be short-lived to take advantage of specific precipitation events and then survive long periods of unfavourable conditions as a seed (Irl *et al.* 2020). However, it is important to note that in the Barrocal Park, the mesophanerophyte group, which includes the species *Quercus pyrenaica*, as well as the nanophanerophyte group, which includes species of the genera *Adenocarpus* spp., *Cistus* spp. and *Cytisus* spp., cover the largest surface area of the Park.

Wild spontaneous flora is a source of plants with decorative qualities that can be used in an ecologically sound way in individual gardens, in public green spaces in urban and rural areas; these plants have some special agrobiological characteristics, namely ecological plasticity and high hardiness (Ilie & Cosmulescu, 2023). Native plants are adapted to the local climate and soil conditions where they occur naturally and provide nectar, pollen, fruits and seeds, that serve as food for native butterflies, other insects, birds and other animals. The use of native plants in gardens is a way to protect biodiversity and ecosystems. The vast majority of invasive alien plants in Europe were initially introduced and used as ornamental plants (Hulme, 2007). Some of the worst invasive weeds in the Mediterranean region were introduced as ornamental plants, such as *Carpobrotus edulis* (L.) N.E.Br., *Cortaderia selloana* (Schult. & Schult.f.) Asch. & Graebn, *Hakea sericea* Schrad., *Ipomoea acuminata* Roem. & Schult, *Lantana camara* L. and *Pittosporum undulatum* Vent. The Mediterranean Basin is considered particularly at risk because its climatic

conditions potentially allow the establishment of subtropical and tropical species and in the context of climate change, these threats may increase (Brunel *et al.* 2010). The introduction of ornamental species of wild flora into urban landscapes is an important objective in the context of sustainable development and the enhancement of a natural resource base, along with biodiversity conservation. In the Barrocal Park there are native species with ornamental potential that have high ecological plasticity, which is very important for the management of green spaces in the context of climate change. The spontaneous plants of the Barrocal Park are adapted to drought and acidic soils, and some species have the potential to be used for ornamental purposes in public or private spaces, namely, *Asphodelus serotinus*, *Dianthus lusitanus*, *Gladiolus illyricus*, *Hyacinthoides hispanica*, *Iris planifolia*, and *Ornithogalum concinnum*, among others. In this context, for each species, it is important to study techniques that allow breaking seed dormancy, favouring germination, as well as appropriate vegetative multiplication techniques.

The main aim of the Barrocal Park was to provide protection and access to an old quarried area, currently subject to natural regeneration, through a system of raised paths and viewpoints designed to respect and highlight the experience with granitic landforms (Antunes *et al.* 2020). Despite its main geoheritage value, the Barrocal Park can also be valued for its spontaneous flora. In this context, it is important to raise visitors awareness so that they do not walk outside the marked paths, in order not to trample spontaneous plants.

Conclusions

The assessment of plant diversity at the local and regional levels allows us to understand the current state and develop effective management strategies for conservation. In this study, an inventory of the spontaneous flora in the Barrocal Park, Castelo Branco, Portugal, was carried out and 132 species were identified. The Barrocal landscape is characterized mainly by fragments of climatophilic forests of *Quercus pyrenaica* (*Quercus-Fagetum* class) associated with rocky granite outcrops. The holm oak (*Q. rotundifolia*) (*Quercetum ilicis* class) has a residual representation. The *Arisaro simorrhini-Quercetum pyrenaicae*

association is the only climatophilic series present in the study area. The flora is dominated by the Asteraceae, Fabaceae and Poaceae families, and there is a prevalence of therophytes. Among the spontaneous flora existing in the Barrocal Park, eight species are endemic to the Iberian Peninsula and many others stand out for their beauty. The presence of invasive plants should imply the existence of an eradication plan followed by monitoring. The spontaneous plants in the Barrocal Park are extremely resilient to drought and acid soils, and some species have the potential for ornamental use in public or private areas. Despite its primary geoheritage value, the Barrocal Park can also be valued for its spontaneous flora, which contributes to local biodiversity.

Acknowledgments

CERNAS-IPCB [UIDB/00681/2020] is funding by the Portuguese National Funding Agency for Science, Research and Technology (FCT).

Thanks to Natália Roque for her assistance in creating the location map for Barrocal Park.

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