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A Habitat-Template Approach to Green Wall Design in Mediterranean Cities

Miriam Patti, **Carmelo Maria Musarella** and **Giovanni Spampinato** *

AGRARIA Department, Mediterranea University of Reggio Calabria, 89122 Reggio Calabria, Italy; miriam.patti@unirc.it (M.P.); carmelo.musarella@unirc.it (C.M.M.)
* Correspondence: gspampinato@unirc.it

Abstract

Integrating nature-based solutions into sustainable urban design has become increasingly important in response to rapid urbanization and climate-related environmental challenges. As part of these solutions, green walls not only enhance the thermal and acoustic performance of buildings but also contribute to urban ecosystem health by supporting biodiversity. In this context, the careful selection of plant species is essential to ensure ecological efficiency, resilience, and low maintenance. This study presents a model for selecting plant species suitable for natural green walls in Mediterranean cities, with a focus on habitats protected under Directive 92/43/EEC. The selection followed a multi-phase process applied to the native flora of Italy, using criteria such as chorological type, life form, ecological indicator values, altitudinal range, and habitat type. Alien and invasive species were excluded, favoring only native Mediterranean species adapted to local pedoclimatic conditions and capable of providing ecosystem, esthetic, and functional benefits. The outcome of this rigorous screening led to the identification of a pool of species suitable for green wall systems in Mediterranean urban settings. These selections offer a practical contribution to mitigating the urban heat island effect, improving air quality, and enhancing biodiversity, thus providing a valuable tool for designing more sustainable and climate-adaptive buildings.

Keywords: nature-based solutions (NBSs); smart buildings; directive 92/43/ECC; Italian flora

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1. Introduction

One of the key objectives of the 2030 Agenda for Sustainable Development is to promote the creation of safer, more sustainable, and more resilient cities and communities [1]. Against a backdrop of rapid urbanization and mounting environmental concerns, smart buildings have emerged as a pivotal element in the discourse on sustainable urban design [2–5]. Recent studies have emphasized that plant-based solutions in urban design must increasingly respond to climate variability and biodiversity loss, particularly in water-limited regions such as those with a Mediterranean climate [6].

A fundamental component of smart buildings is the facade, which plays a crucial role in enhancing energy efficiency and overall sustainability [7,8].

Among the most effective nature-based solutions (NBSs); green walls (GWs) represent an innovative strategy to improve air and water quality, contribute to climate change mitigation, and promote biodiversity and territorial identity [9]. Green facades, green roofs, and more broadly, green infrastructure (GI) are now widely acknowledged as key components in the sustainable design of smart buildings due to their capacity to mitigate the urban heat island effect, reduce greenhouse gas emissions, and improve the esthetic and sensory quality of built environments [10,11]. Field studies in Mediterranean climates have confirmed that native plant assemblages not only improve esthetic outcomes but also enhance the thermal regulation and ecological stability of green walls [12,13].

Experimental studies have demonstrated that modular green walls can significantly reduce the surface temperature of buildings, thereby improving the urban microclimate [14]. Together with renewable energy technologies, they provide effective solutions to the environmental challenges posed by urbanization [15]. For instance, in cities like Athens and Rome, urban temperatures have risen by 0.3–0.5 °C per decade over the last 40 years, significantly intensifying the heat island effect [16]. Additionally, invasive plant species account for over 15% of urban flora in Mediterranean cities, raising ecological concerns [17].

Choosing the right plant species for green walls (GWs) is crucial for their effectiveness and long-term sustainability. As demonstrated by Raimondo et al. [18], selecting species based on their ecological strategies and functional traits significantly improves the resilience of vertical systems, particularly under drought and solar stress.

This selection process should be based on several criteria, including adaptability to local environmental conditions, resistance to abiotic stress, maintenance requirements, and the plants' ecological contributions to the urban ecosystem [14,19,20].

A key factor is climate: temperature, humidity, and water availability greatly affect plant survival. The Mediterranean climate is a temperate-warm type, characterized by hot, dry summers and mild, rainy winters, noted for seasonal precipitation patterns and frequent droughts [21]. These conditions necessitate the selection of plant species capable of withstanding high temperatures, summer aridity, and wide thermal fluctuations [22]. In Mediterranean regions characterized by water-limited climatic conditions, it is essential to prioritize species that are drought-resistant and adapted to seasonal variability [23]. Native or already locally adapted species are preferable, as they generally require fewer resources for irrigation and fertilization. On the contrary, the use of alien species must be avoided, as some pose a danger to natural habitats as they could spontaneously become invasive on a global scale [17,24,25]. In particular, the use of native and endemic species allows for the creation of naturalistic habitats in line with the objectives of the Habitat Directive [26]. This approach fosters biodiversity and enhances the ecological resilience of urban environments [5,17].

Another key criterion concerns plant morphology and growth habitat. In green facades, which rely on climbing plants, species with strong adhesion capacity, such as *Parthenocissus tricuspidata* (Siebold & Zucc.) Planch. (Boston ivy) and *Hedera helix* L. subsp. *helix* (common ivy), are commonly used. In green walls (GWs), on the other hand, herbaceous perennials, ferns, and grasses that develop in artificial substrates are typically employed [27]. Foliage density and the leaf area index (LAI) play a crucial role in the thermal regulation of GWs: denser canopies ensure greater efficiency in evaporative cooling [24]. The use of species with differing water requirements and phenological cycles allows for optimal ecological performance throughout the year. Studies have shown that plant selection must consider not only thermal performance but also adaptability to external conditions and long-term maintenance needs [28].

In addition to functional aspects, plants are selected for the ecosystem services they provide. Species with a high capacity to absorb atmospheric pollutants contribute to improving air quality and mitigating the urban heat island effect [29–31]. Furthermore, species with high carbon sequestration capacity—such as those with greater woody biomass—are particularly effective in enhancing the environmental sustainability of buildings [32].

Finally, design and esthetics also play an important role. The selection of plants with seasonal flowering, decorative foliage, or chromatic variation can enhance the visual impact of buildings and improve the perception of urban spaces [33].

Therefore, the accurate selection of plant species not only ensures the technical success of GWs but also amplifies their environmental and social benefits, establishing them as increasingly relevant elements in sustainable urban planning [34]. In this context, esthetic aspects such as seasonal flower display, chromatic foliage variation, and plant texture were considered key design drivers. These visual attributes contribute to user well-being, building identity, and the regeneration of neglected spaces, aligning GW interventions with principles of therapeutic landscapes and biophilic design [19,35].

The objective of this study is to develop a selection strategy for Mediterranean native species most suitable for the implementation of a green wall in an urban context, using ecological and functional criteria based on data from Italian flora. This study aims to identify species that can ensure not only ecological efficiency and environmental sustainability of the system but also adaptation to climatic conditions and esthetic requirements, thereby promoting the conservation of local biodiversity in urban environments.

2. Materials and Methods

The selection of plant species suitable for green wall (GW) installations in a Mediterranean urban context—specifically within an Italian city—was carried out following the semi-automated selection process summarized in Figure 1 and described in detail below:

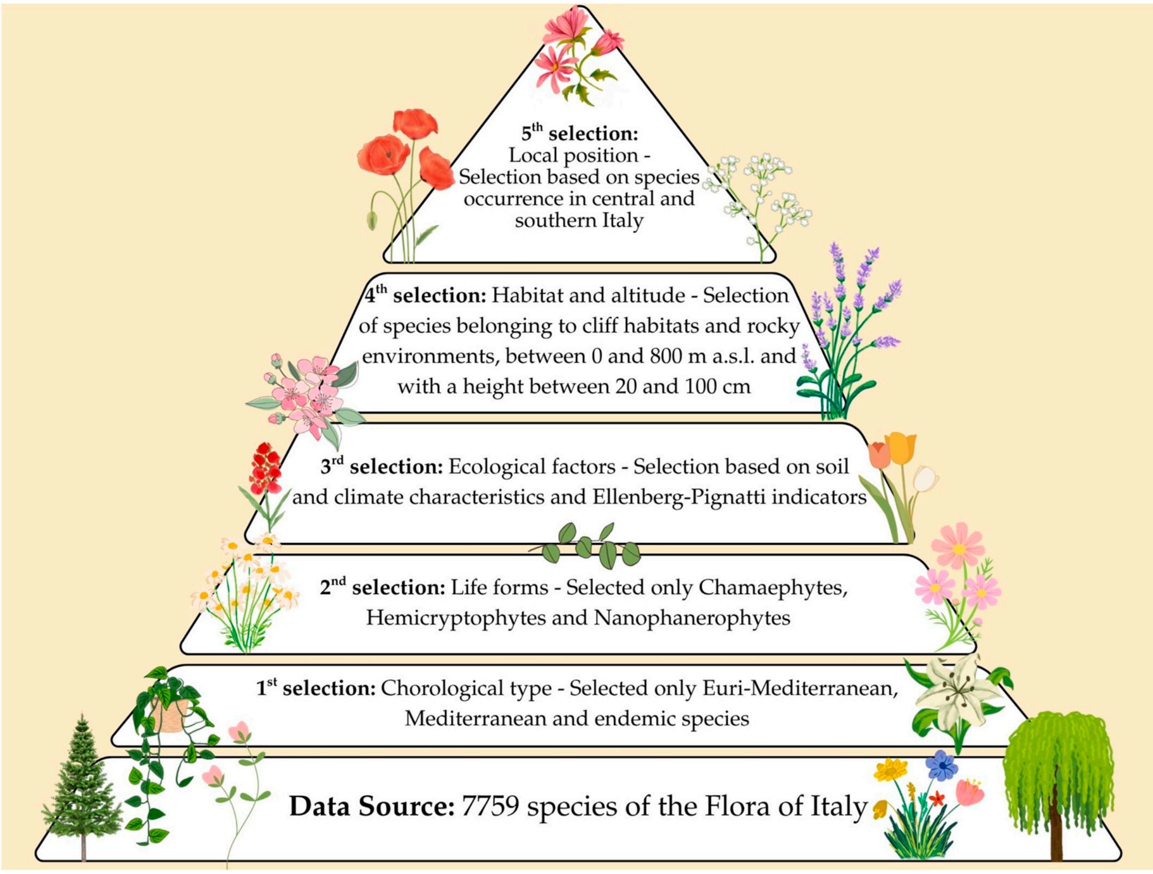

Figure 1. Semi-automated selection process of plant species potentially suitable for integration into green walls in Mediterranean urban environments (graphic design created with Canva by the author Miriam Patti).

1. Data source: The starting point was the comprehensive list of plant species included in *Flora d'Italia* [36–39], totaling 7759 taxa.
2. First selection step: A chorological filter was applied, selecting only Mediterranean and Euro-Mediterranean species, including endemics, as these are best suited to the environmental conditions of Mediterranean cities [40].
3. Second selection step: Species were further filtered based on plant growth forms, considering the structural characteristics of GW systems. The life forms considered were those defined by Raunkiaer [41], as reported in the digital database of *Flora d'Italia* [36–39]. Specifically, Chamaephytes, Hemicryptophytes, and Nanophanerophytes (*sensu* Raunkiaer) were selected, since it is believed that due to their structure, they are suitable for use in GWs. Chamaephytes are semi-shrubs, small shrubs, and cushion plants with low buds; hemicryptophytes are herbaceous perennials with buds at the ground level; and nanophanerophytes are small woody plants usually densely branched from the base. Conversely, Therophytes, Hydrophytes, Geophytes, and Phanerophytes were excluded for the following reasons: Therophytes are annual species and do not ensure continuous coverage; Hydrophytes require aquatic environments; Geophytes spend part of the year in dormancy below ground; and Phanerophytes include trees and large shrubs that are generally too bulky for vertical systems. These three life forms—Chamaephytes, Hemicryptophytes, and Nanophanerophytes—have proven to be structurally compatible with limited substrates, frequent exposure, and seasonal stress, as also confirmed by other studies on vertical greenery in Mediterranean areas [22,42]. Furthermore, the life form classification by Raunkiaer [41] provides a structural basis for evaluating plant adaptability in artificial systems such as green walls.
4. Third selection step: The remaining species were screened based on pedoclimatic and ecological characteristics. This was achieved by applying the Ellenberg Indicator Values [43], as revised and adapted for Italian flora by Pignatti et al. [39], in conjunction with minimum altitude data reported in the same database. The Ellenberg–Pignatti indicators provide an ecological scale expressing the environmental preferences of plant species along several gradients. Each index is represented by a numerical value indicating a species' tolerance or adaptation to a specific environmental factor. The indicators considered were
   - Light (L)—the preference for shaded or sunlit environments ($0 \leq x \leq 12$).
   - Temperature (T)—the distribution of species along a thermal gradient, from colder to warmer areas ($0 \leq x \leq 12$).
   - Continentality (K)—sensitivity to seasonal thermal variation along the oceanic–continental climate continuum ($0 \leq x \leq 9$).
   - Moisture (U)—species' water requirements, from arid to highly humid or submerged environments ($0 \leq x \leq 12$).
   - Nutrients (N)—soil fertility requirements for plant growth, from poor to nutrient-rich soils ($0 \leq x \leq 9$).

These indicators were used to identify species most compatible with the ecological conditions typical of GW installations, ensuring greater adaptability and long-term survival.

The optimal values used for species selection are presented in detail in Table 1.

The selected threshold values for ecological indicators were chosen to reflect the environmental constraints typical of Mediterranean summers [44]. In particular, species with a moisture value (U) ≤ 5 were retained to account for prolonged drought conditions, while light values (L) $7 \leq x \leq 12$ represent species adapted to intense solar exposure. These thresholds are consistent with those used in ecological studies of Mediterranean flora [36,40] and were selected to identify plants with high resilience to abiotic stress. The chosen temperature values (T) $7 \leq x \leq 12$ ensure adaptability to high summer temperatures typical of urban surfaces. By combining these indicators, we filtered species already ecologically predisposed to the harsh conditions of vertical GI environments.

Table 1. Ecological indicator values (Ellenberg–Pignatti) considered for the selection of plant species for use in green walls.

Ellemberg–Pignatti Indicator	Original Range	Considered Range
L	$0 \leq x \leq 12$	$7 \leq x \leq 12$
T	$0 \leq x \leq 12$	$7 \leq x \leq 12$
K	$0 \leq x \leq 9$	$2 \leq x \leq 7$
U	$0 \leq x \leq 12$	$0 \leq x \leq 5$
N	$0 \leq x \leq 9$	$0 \leq x \leq 5$

L—light; T—temperature; K—continentality; U—moisture; N—nutrients.

Additionally, the combination of high light ($L \geq 7$) and low moisture may amplify stress levels, and only species with proven adaptive traits under such interactions were retained.

This approach is grounded in ecological theory, as Ellenberg–Pignatti values are widely used proxies for plant responses to light, moisture, temperature, and nutrient availability in European ecological contexts [33–36,40]. These indicators are considered reliable predictors of plant behavior under environmental stress, including those typical of vertical infrastructures.

5. Fourth selection of species according to habitat type, growing altitude, and plant height: Only species from purely Mediterranean habitats of community interest [26], such as cliffs, grasslands, garrigue, and scrub—listed in Table 2—were selected. Only species with a natural distribution between 0 and 800 m a.s.l. were considered, excluding those whose minimum altitudinal range starts at 700 m or higher, as they are typically associated with montane habitats. Furthermore, only species with an average adult height between 20 cm and 1 m were retained, as this height range is structurally and functionally suitable for integration into green wall systems.

Table 2. Habitat types considered for the selection of plant species to be used in green walls in Mediterranean cities.

Selected Habitats			
Habitat Macro-Category		Habitat Type	
Code	Name	Code	Name
12	Vegetated sea cliffs and gravel beaches	1240	Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp.
53	Thermo-Mediterranean and pre-steppe scrublands	5320	Low formations of *Euphorbia* close to cliffs
		5330	Thermo-Mediterranean and pre-desert scrub
54	Phryganas	5410	West Mediterranean clifftop phryganas (*Astragalo-Plantaginetum subulatae*)
		5420	*Sarcopoterium spinosum* phryganas
		5430	Endemic phryganas of the *Euphorbio-Verbascion*

Table 2. *Cont.*

Selected Habitats			
Habitat Macro-Category		**Habitat Type**	
Code	**Name**	**Code**	**Name**
62	Semi-natural dry grassland formations and shrub-covered facies	6210 (*)	Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (* important orchid sites)
		6220 *	Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea
		62A0	Eastern sub-mediterranean dry grasslands (*Scorzoneretalia villosae*)
82	Rocky slopes with chasmophytic vegetation	8210	Calcareous rocky slopes with chasmophytic vegetation
		8220	Siliceous rocky slopes with chasmophytic vegetation
		8230	Siliceous rock with pioneer vegetation of the *Sedo-Scleranthion* or of the *Sedo albi-Veronicion dillenii*
		8240 *	Limestone pavements
93	Mediterranean sclerophyllous forests	9320	*Olea* and *Ceratonia* forests
		9340	*Quercus ilex* and *Quercus rotundifolia* forests
		9330	*Quercus suber* forests

* Priority habitat according to Directive 92/43/EEC.

Species included in the reference physiognomic combinations of the Italian Interpretation Manual of Habitats [45,46] were considered. Finally, all species occurring above 800 m a.s.l. were excluded.

6. Fifth and final selection of species based on their distribution in Central and Southern Italy, excluding those absent from these areas: At this stage, regional-scale distribution was also considered to define species pools for use in each Italian region with a Mediterranean climate. This step is particularly important for endemic species—sometimes restricted to a single region—as it prevents the use of such species outside their natural range, thus safeguarding local biodiversity.

Species nomenclature was updated according to the Portal of the Flora of Italy [47].

3. Results

The application of the selection procedure led to the identification of 368 taxa belonging to the Mediterranean flora, potentially suitable for use in green walls (GWs) in the central and southern Mediterranean regions of Italy, through the following preliminary results:

1. First selection—based on chorological type: From a total of 7759 species, 4296 species were selected.
2. Second selection—based on growth characteristics, i.e., the life form of plants: From 4296 species, 2226 species were selected.
3. Third selection—based on pedoclimatic and ecological characteristics: From 2226 species, the selection was narrowed down to 1308 species.
4. Fourth selection—based on habitat type, growth altitude and plants height: From 1308 species, 666 species were selected.

5. Fifth selection—based on species distribution, limited to Central and Southern Italy: The result was the selection of 368 species, identified as potential candidates for implementation in smart GI within the Mediterranean area.

The list of selected species, including the following information: updated scientific name, family, life form, chorological type, Ellenberg–Pignatti indicators, plant height (cm), plant diameter (cm), altitude (m a.s.l.), pollination, dispersal, flower color, and regional distribution, is reported in Table S1.

The analysis of taxonomic composition revealed a total of 44 families, with a predominance of species belonging to the Asteraceae (59), followed by Fabaceae (36), Brassicaceae (29), Lamiaceae (29), and Caryophyllaceae (27) families.

The complete list of families, along with the number of taxa per family, is provided in Table 3.

Table 3. Families of taxa potentially suitable for use in green wall structures in Central–Southern Mediterranean Italy, and the corresponding number of taxa per family.

N°	Family	Number of Taxa
1	Acanthaceae	1
2	Amaranthaceae	2
3	Apiaceae	14
4	Asparagaceae	3
5	Aspleniaceae	1
6	Asteraceae	59
7	Boraginaceae	7
8	Brassicaceae	29
9	Campanulaceae	7
10	Capparaceae	2
11	Caprifoliaceae	2
12	Caryophyllaceae	27
13	Cistaceae	15
14	Convolvulaceae	3
15	Crassulaceae	6
16	Cystopteridaceae	1
17	Dipsacaceae	4
18	Ephedraceae	2
19	Ericaceae	2
20	Euphorbiaceae	8
21	Fabaceae	36
22	Geraniaceae	1
23	Hypericaceae	3
24	Lamiaceae	29
25	Linaceae	3
26	Malvaceae	1
27	Plantaginaceae	12
28	Plumbaginaceae	20
29	Poaceae	19
30	Polygalaceae	5
31	Polygonaceae	3
32	Primulaceae	3
33	Pteridaceae	1
34	Ranunculaceae	1
35	Rosaceae	2
36	Rubiaceae	12
37	Rutaceae	3
38	Scrophulariaceae	8
39	Solanaceae	1
40	Tamaricaceae	1
41	Thymelaeaceae	2
42	Urticaceae	1
43	Valerianaceae	4
44	Violaceae	2
TOT	44	368

An analysis of the life forms of the plant species selected for the green walls was carried out to identify those most represented among the selected species (Figure 2).

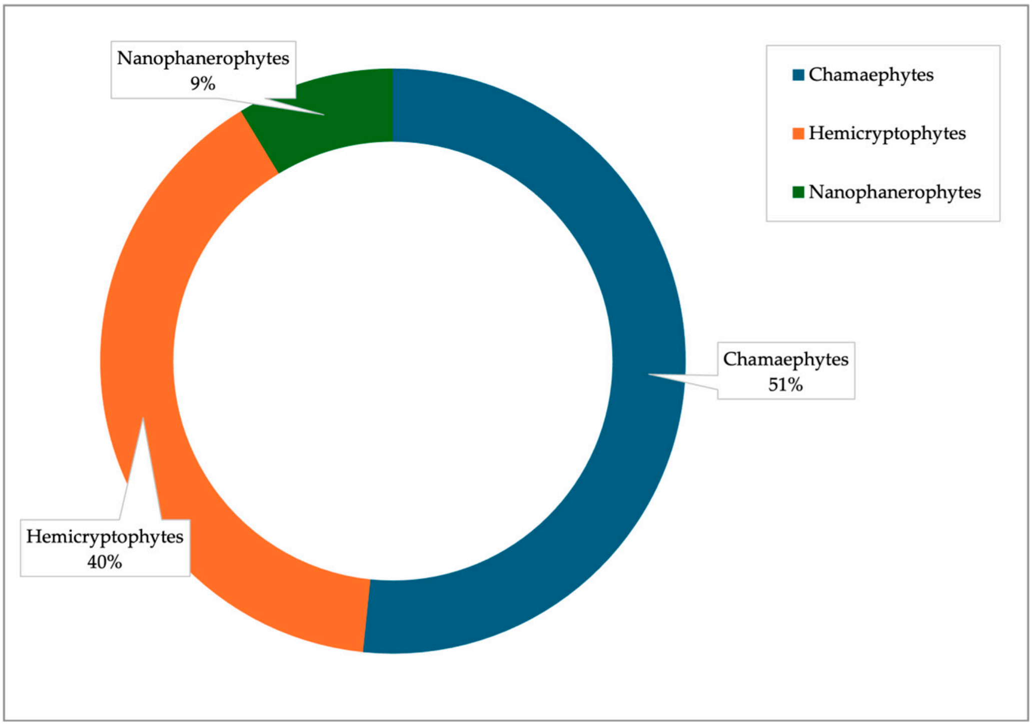

Figure 2. Life forms of the species selected as potentially suitable for use in green walls.

The most represented life forms among the selected species are Chamaephytes (51%), followed by Hemicryptophytes (40%), with a smaller proportion of Nanophanerophytes (9%).

The predominance of Chamaephytes is particularly relevant to the project, as these species typically exhibit a shrubby growth habit and greater resilience in vertical environments.

The high occurrence of Hemicryptophytes is also consistent with their well-known ability to withstand stress conditions and regenerate rapidly.

Regarding chorological type (Figure 3), only Mediterranean and Euri-Mediterranean species were selected, including endemics.

Specifically, most species were found to be Endemic (44%): among these, a large proportion are Island endemics (45%, 91 species), while the remaining endemic species are from Central–Southern Italy or are sub-endemic.

Other chorotypes include Steno-Mediterranean (37%), Euri-Mediterranean (15%), and Mediterranean-Mountain (3%) species. A small percentage of Eurasiatic species (1%) was also recorded.

Regarding the occurrence of taxa in South–Central Italy, Figure 4 shows the selected regions of the Italian Peninsula and the number of taxa for each region.

The regional distribution of selected species highlights a clear geographical gradient: the number of taxa increases significantly from north to south, with the highest numbers recorded in the southern Italy (Sicily: 184; Calabria: 175; Sardinia: 171), followed by Apulia (164), Campania (156), Tuscany (153), Basilicata (151) and Abruzzo (123). The selected taxa for each region can be found in Table S1.

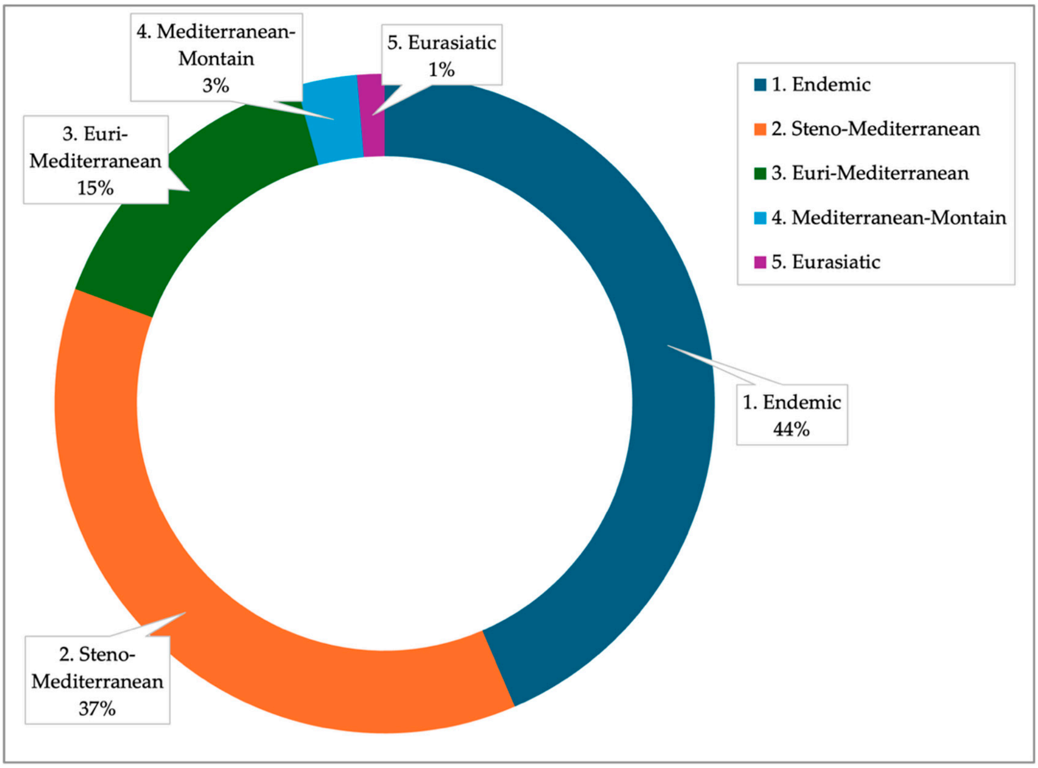

Figure 3. Chorological types of the species selected as potentially suitable for green walls in the Mediterranean region. 1. Endem.—Endemic; 2. Steno-Medit.—Steno-Mediterranean; 3. Euri-Medit.—Euri-Mediterranean; 4. Medit.-Mont.—Mediterranean-Mountain; 5. Eurasiat.—Eurasiatic.

Figure 4. Number of taxa in the central–southern Italian regions. ABR—Abruzzo; BAS—Basilicata; CAL—Calabria; CAM—Campania; LAZ—Lazio; LIG—Liguria; MAR—Marche; MOL—Molise; PUG—Apulia; TOS—Tuscany; SAR—Sardinia; SIC—Sicily; UMB—Umbria.

4. Discussion

The selection of 368 native Mediterranean species, achieved through a rigorous process based on ecological, chorological, and functional criteria, demonstrates the possibility of constructing a scientifically grounded model for selecting species to be used in vertical green infrastructure (GI). This approach, oriented towards naturalness and sustainability, aligns perfectly with the international debate on the use of nature-based solutions (NBSs) in urban environments [48], highlighting the potential of local species to help mitigate environmental impacts in Mediterranean cities.

The choice of Chamaephytes and Hemicryptophytes life forms among the selected species is confirmed by the adaptability of these life forms to the typical conditions of green walls (GWs), such as high solar exposure, limited water availability, and restricted substrate volume. Chamaephytes are distinguished by their capacity to withstand thermal and water stress, thanks to their compact structure and reduced leaf area—features already emphasized by Pan et al. [49] in an experimental study on various plant species applied to a modular vertical system.

Among the Chamaephytes selected as potentially usable in GWs are, for example, numerous species belonging to the Apiaceae family such as *Pimpinella tragium* Vill. and *Crithmum maritimum* L. Within the Asteraceae family is the *Centaurea* genus that lends itself very well to use, and more *Jacobaea maritima* (L.) Pelser & Meijden and *Ptilostemon gnaphaloides* (Cirillo) Soják subsp. *gnaphaloides*. Among the Brassicaceae family, the most representative species belong to the *Brassica* genus, followed by *Iberis semperflorens* L. and *Lobularia maritima* (L.) Desv., while within the Fabaceae family there are *Lotus cytisoides* L. and *Ononis natrix* L. subsp. *ramosissima* (Desf.) Batt.

Among the Hemicryptophytes, on the other hand, we have many species belonging to the Apiaceae family, such as *Athamanta sicula* L. and *Pimpinella anisoides* V.Brig.; there are also many Asteraceae, including the genera *Centaurea* and *Crepis.* Among the Fabaceae family, the most represented genera are *Biscutella* and *Erysimum*, while for the Fabaceae family, it is the genus *Astragalus*.

Among the Poaceae, however, the most representative species are some perennial herbs with a scapose hemicryptophyte biological form such as *Hyparrhenia hirta* (L.) Stapf and *Tricholaena teneriffae* (L.f.) Link.

The analysis of the floristic composition revealed a high incidence of taxa belonging to the families Asteraceae, Fabaceae, Brassicaceae, and Lamiaceae, already known to include species with high adaptability to extreme environmental conditions and for tolerance to thermal and water stress [50]. The dominance of these families can be attributed to their ecological plasticity and pioneer strategies, which are particularly suited to anthropogenic and stress-prone environments [22,23]. Their typical traits—such as drought tolerance, efficient root systems, and reduced leaf surfaces—facilitate plant survival in low-moisture, high-exposure vertical settings. Supporting this, recent two-year trials on Mediterranean green roofs demonstrated that drought-tolerant perennials significantly improve survival and reduce irrigation needs, highlighting their potential for vertical applications as well [23].

Furthermore, many of these species play an essential ecological role in supporting urban biodiversity, particularly for pollinating insects [51]. These species are also highly valuable for supporting various other faunal groups, such as birds and butterflies, which are notably sensitive to the presence of native vegetation in urban residential landscapes [52,53]. This ecological role is also reinforced by recent findings showing that native perennials selected for green roofs and walls in the Mediterranean region offer high habitat value for pollinators and other fauna, supporting ecological connectivity in fragmented urban areas [22].

More generally, the creation of habitats that mimic the natural ones listed in Annex 1 of Habitats Directive 92/43/EEC [26] within the urban ecosystem is an important solution for increasing the levels of connectivity of these ecosystems with surrounding natural and semi-natural ones, and with the Natura 2000 Network as a whole [54].

The integration of Ellenberg–Pignatti ecological indicators proved to be an effective tool for selecting species capable of withstanding the pedoclimatic conditions typical of vertical structures. Species with high values for light and temperature and low values for moisture and nutrients were found to be more compatible with the exposed and stress-prone environments of green walls [55,56]. However, it is important to note that these indicators are based on observations in natural settings and may underestimate the intensity of urban stressors such as high surface reflectance, urban heat traps, and air pollution. This limitation will be addressed in future empirical trials aimed at validating species performance under real urban conditions.

The focus on Mediterranean habitats, as defined by the Habitats Directive 92/43/EEC [26], characterized by poorly developed and oligotrophic soils, favored the selection of species already naturally adapted to shallow, low-nutrient, and poorly retentive soils. The ecological adaptations of these species strengthen their potential for use in low-maintenance, resource-efficient GW systems [57]. It is important to note that many of the species selected naturally occur in habitats with shallow soils, high exposure, and limited water availability—such as rocky outcrops, cliffs, and garrigue—conditions that closely resemble the microclimatic and structural features of artificial green wall systems. Their morphological and physiological adaptations (e.g., reduced leaf surface, sclerophylly, deep or fasciculate root systems) make them promising candidates for vertical greening applications. Moreover, the simultaneous presence of multiple stressors—such as high light intensity and limited moisture—was considered during the selection process, as only species with ecological strategies enabling them to thrive under such compound stress conditions were included.

In addition to ecological performance, green walls must also meet technical and safety requirements, particularly with regard to fire risk. Vertical greenery systems can accumulate dry biomass, especially under poor maintenance or in drought-prone regions, potentially increasing flammability [58]. Certain Mediterranean species rich in essential oils or resins are known to be more combustible and should be evaluated cautiously in facade applications [59]. Current recommendations from fire safety studies suggest selecting low-flammability species, using non-combustible support structures, and maintaining sufficient irrigation and biomass control [19,60].

While fire behavior was not part of the present selection process, future stages of this research—conducted in collaboration with architectural and engineering partners—will integrate fire safety criteria and code compliance into the plant selection model.

The geographic focus on regions with a Mediterranean bioclimate, specifically in central and southern Italy, including the surrounding islands, promotes the use of local and regional Mediterranean plants, in accordance with the principles of ecological nature-based criteria for urban design, as native plants are more likely to provide resources for urban animals and increase biodiversity in urban green space [35]. The utilized methodology avoids the standardization of GI, promoting *site-specific* solutions, as advocated by ecological urbanism [61], and it ensures the preservation of native biodiversity and local landscape identity.

This approach allows species to be selected based on their distribution and occurrence in the region, ensuring sustainable use of the local flora.

The results show a clear trend towards a greater representation of selectable taxa in central, southern, and insular Italian regions, particularly Sicily and Sardinia, which exhibit the highest availability of Mediterranean species suitable for vertical greening systems. This finding can be interpreted considering the ecological diversity of these areas, often characterized by rupicolous, coastal, and xeric environments that promote the presence of native species adapted to extreme conditions like those of GW systems [50].

Recent studies have emphasized how the biodiversity of Mediterranean regions represents an important resource for the development of nature-based solutions (NBSs), as many spontaneous Mediterranean species are naturally adapted to water scarcity, high solar radiation, and nutrient-poor soils—conditions typical of urban contexts [6,62].

From a practical standpoint, species with compact growth, high drought resistance, and fast vegetative recovery—such as *Lavandula multifida* L. and *Jacobaea maritima* (L.) Pelser & Meijden—should be prioritized in modular GW systems. Additionally, GW typology should influence plant choice: for example, cascading species like *Micromeria graeca* L.) Benth. ex Rchb. and *Helichrysum italicum* (Roth) G.Don may be better suited to vertical panels with overhangs, while more erect hemicryptophytes like *Crepis aspromontana* Brullo, Scelsi & Spamp. and *Pimpinella anisoides* V.Brig. fit well in inset modules. For example, for *Crepis aspromontana* and *Pimpinella anisoides*, studies on fruit viability and germination have already been conducted [63]. Some of the species mentioned before are grouped in Figure 5.

Figure 5. Some of the species that can be used in green walls: (**a**) *Lavandula multifida* L. (Lamiaceae) (Ph. Giuliana Mazzacuva); (**b**) *Helichrysum italicum* (Roth) G.Don (Asteraceae) (Ph. Giovanni Spampinato); (**c**) *Micromeria graeca* L. Benth. ex Rchb. (Lamiaceae) (Ph. Giovanni Lento); (**d**) *Crepis aspromontana* Brullo, Scelsi & Spamp. (Asteraceae) (Ph. Miriam Patti).

These preliminary guidelines are intended to inform landscape architects and planners in the design of efficient and context-appropriate vertical greenery systems.

To enhance practical utility, Table S1 also includes the size of each plant in height and diameter, their regional distribution, flower color, pollination, and seed and fruit dispersal. These attributes are essential for landscape architects and urban planners, as they enable them to select species suited to specific technical constraints and visual outcomes.

5. Conclusions

This study developed and applied a methodological approach based on ecological, chorological, and functional criteria for the selection of native Mediterranean species to be employed in green walls (GWs) within urban contexts, taking the Italian territory and its flora as a case study. The selection of 368 taxa, obtained through a stepwise procedure grounded in environmental indicators (Ellenberg–Pignatti), habitat classification, and geographic distribution, demonstrates the feasibility of strategically and ecologically integrating local vegetation into vertical green infrastructure (GI).

An additional advantage of this approach is its transferability to other Mediterranean climate regions, such as Spain and Greece. By adapting ecological indicators and regional floristic databases—e.g., Flora Ibérica [64]—the same methodology can be replicated in different contexts, reinforcing its value as a tool for localized, climate-adapted plant selection.

The results highlight the potential of Mediterranean species—particularly Chamaephytes and Hemicryptophytes—to adapt to environmental stress conditions such as poor soils, intense sunlight, and limited water availability, which are typical of vertical GI. The prevalence of families such as Asteraceae, Fabaceae, and Brassicaceae further confirms the effectiveness of using pioneer and resilient species in urban ecological infrastructure. These results align with previous research: Bellini et al. [23], for instance, observed a dominance of perennial herbaceous species on Mediterranean green roofs under water stress—an outcome consistent with our findings. Similarly, Carlucci et al. [14] emphasized the importance of drought-tolerant taxa in vertical systems in Apulia. Our study confirms and expands upon these approaches, offering a broader taxonomic foundation and a replicable selection framework.

Building on these ecological insights, the territorial approach adopted here helps avoid the standardization of urban green design while promoting local biodiversity and reducing the risk of introducing alien species and causing habitat fragmentation.

While ecological suitability is essential, from a safety perspective, vertical plant-based systems must also consider fire hazards. Some Mediterranean species, due to their biomass structure and volatile compound content, can exhibit high flammability—especially when dry or poorly maintained [59]. Green infrastructure (GI) can pose fire risks in the absence of proper irrigation and biomass control [58]. Regulatory guidelines therefore recommend using fire-resistant materials for module construction, avoiding highly resinous plants, and maintaining adequate moisture content [60].

Beyond ecological and technical aspects, understanding the human dimension is also essential. Incorporating social and perceptual indicators will help evaluate the impact of green walls on urban quality of life and public acceptance. The integration of ecological knowledge with participatory design may foster more effective, durable, and context-sensitive urban solutions.

This research offers a replicable and transferable model for the ecological selection of native species suitable for green walls in Mediterranean-type climates, contributing concretely to the broader debate on nature-based solutions and climate adaptation in urban areas. While based on robust floristic and ecological criteria, this study represents an initial step that requires empirical validation. Experimental trials—currently underway at the

AGRARIA Department of the Mediterranea University of Reggio Calabria—aim to assess plant performance in terms of survival, vegetative cover, and ecosystem service delivery (e.g., temperature mitigation, biodiversity support, CO_2 absorption) under modular systems and controlled irrigation. Pilot installations in Mediterranean cities will provide further insights into environmental functionality and user perception, helping refine the selection model and enhance its practical application.

Moreover, to ensure real-world applicability, this study is part of a broader interdisciplinary project. Collaborative research with architects and engineers is ongoing to explore structural integration, fire safety protocols, and irrigation infrastructure. This coordinated approach is essential to bridge the gap between scientific plant screening and the technical, regulatory, and design requirements necessary for successful green wall implementation in complex urban environments.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/buildings15142557/s1, Table S1: List of all the species selected.

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Abbreviations

The following abbreviations are used in this manuscript:

GI	Green Infrastructure
GW	Green Wall
LAI	Leaf Area Index
NBS	Nature-Based Solutions

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