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A Rock Garden Design Integrating Aesthetic and Ecological Approaches in Botanical Gardens

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Rock gardens, inspired by naturally occurring rocky ecosystems, are pivotal components of sustainable landscape architecture that combine visual appeal with ecological function. This study presents a comprehensive planting design for a rock garden located within the botanical garden of Düzce University's Konuralp Campus, addressing both aesthetic considerations and climate-resilient ecological strategies. The design process integrated site-specific environmental variables such as topography, sunlight exposure, and drainage, along with plant selection criteria including native and exotic taxon combination preference, site-adapted, and seasonal dynamics. The resulting composition not only offers a rich, multi-seasonal visual experience but also functions as a biodiversity corridor and pollinator habitat. Moreover, by aligning with sustainable maintenance practices and exhibiting educational value, the proposed rock garden exemplifies how landscape design can simultaneously deliver ecosystem services and enhance visitor engagement. This approach offers a replicable model for climate-responsive and educationally functional botanical gardens. The proposed design was visualized through both two- and three-dimensional modeling tools to demonstrate its practical applicability and spatial experience.

KEYWORDS
planting design, site-adapted taxa, rock garden

Botanik Bahçelerinde Estetik ve Ekolojik Yaklaşımları Birleştiren Bir Kaya Bahçesi Tasarımı

Kaya bahçeleri, doğal kayalık ekosistemlerden ilham alan, görsel estetik ile ekolojik işlevselliği bir araya getiren sürdürülebilir peyzaj mimarisinin önemli bileşenlerindendir. Bu çalışma, Düzce Üniversitesi Konuralp Kampüsü'nde yer alan botanik bahçesi içerisindeki bir kaya bahçesi için hem estetik hem de iklim dayanıklı ekolojik stratejileri içeren kapsamlı bir bitkilendirme tasarımı sunmaktadır. Tasarım sürecinde, araziye özgü çevresel değişkenler (topografya, güneş ışığına maruz kalma, drenaj) ile, yerli ve egzotik takson kombinasyonları tercihi, bölgeye uyum sağlama ve mevsimsel dinamikleri içeren bitki seçimi kriterleri entegre edilmiştir. Ortaya çıkan kompozisyon, yalnızca zengin ve çok mevsimli bir görsel deneyim sunmakla kalmayıp, aynı zamanda biyolojik çeşitlilik koridoru ve tozlayıcılar için habitat işlevi de görmektedir. Ayrıca, sürdürülebilir bakım uygulamalarıyla uyumlu olması ve eğitsel bir değer taşıması sayesinde, önerilen kaya bahçesi tasarımı, peyzaj tasarımının ekosistem hizmetleri sunarken ziyaretçi etkileşimini de artırabileceğini göstermektedir. Bu yaklaşım, iklim duyarlı ve eğitimsel işlevselliğe sahip botanik bahçeleri için uygulanabilir bir model sunmaktadır. Önerilen tasarımın mekânsal deneyimi ve uygulanabilirliği, iki boyutlu ve üç boyutlu modelleme araçları ile görselleştirilmiştir.

ANAHTAR KELİMELER
bitkilendirme tasarımı, alan koşullarına uyumlu taksonlar, kaya bahçesi

1. INTRODUCTION

In the face of accelerating urbanization and biodiversity loss, botanical gardens play a pivotal role in the preservation, exhibition, and education of plant diversity (Chen & Sun, 2018; Norman et al., 2023). These gardens not only act as refuges for endemic and threatened species but also serve as living laboratories that promote ecological awareness and sustainable design practices (O'Donnell & Sharrock, 2017; Wassenberg et al., 2015). Among their various thematic components, rock gardens offer a unique opportunity to merge visual aesthetics with ecological functionality by replicating naturally occurring rocky ecosystems. Through the strategic integration of stone elements and drought-adapted plant species, rock gardens represent an innovative form of landscape architecture that harmonizes artistic expression with environmental resilience (Mitra, 2018; Rafiee et al., 2022; Ekren et al. 2024). The increasing frequency of climate-related stressors, such as soil erosion, further elevates the importance of such gardens, as they provide microhabitats for pollinators, act as biodiversity corridors, and demonstrate climate-resilient planting strategies (Lindemann-Matthies & Marty, 2013; Simonson et al., 2021; Çorbacı & Ekren 2022).

Despite their potential, the academic literature addressing the integrative design of rock gardens—particularly from a combined ecological and aesthetic perspective—remains limited. Much of the existing body of work either emphasizes the visual composition and symbolic aesthetics of rock gardens (Van Tonder & Lyons, 2005; Mitra, 2018) or focuses on their horticultural value without adequately exploring the role of plant selection in ecosystem services and climate adaptation (Tan et al., 2017). Furthermore, while planting design principles such as spatial balance, texture harmony, and seasonal variation are well recognized (Sim, 2001; Robinson, 2016), there is a notable scarcity of empirical studies that evaluate how these principles intersect with ecological sustainability, especially in the context of institutional gardens like arboreta and botanical gardens. On the national scale, this gap is even more pronounced. In Turkey, scholarly and educational resources on site-specific rock garden planting design remain sparse. While there are studies that focus on planting design techniques in general (e.g., Ayhan & Atabeyoğlu, 2022; Çiçek Kurdoğlu et al., 2022), and some research has addressed the planting and maintenance practices specific to rock gardens (Özdemir, 2007), there is a distinct lack of structured, research-based publications that integrate both the aesthetic and ecological dimensions of rock gardens. There is no comprehensive study that combines plant selection processes with planting design principles in a way that could serve as a pedagogical reference for landscape architecture students. The deficiency is especially evident in Turkish-language or locally contextualized literature that incorporates climate-adapted plant selection, seasonal composition, spatial visualization, and sustainable maintenance strategies. For students and early-career professionals aiming to develop proficiency in planting design, the absence of detailed and ecologically grounded rock garden case studies presents a critical obstacle to experiential learning and site-specific design development (Sim, 2001).

This study aims to address these critical gaps by presenting a scientifically grounded and visually demonstrative planting design proposal for a rock garden located within the botanical garden of Düzce University's Konuralp Campus. Employing a multi-criteria design approach, the proposal integrates environmental variables (e.g., topography, sunlight exposure, and drainage), aesthetic parameters (form, texture, scale, and color), and ecological considerations (the selection of native and compatible exotic taxa, pollinator support, and seasonal continuity). Furthermore, the design process is supported by two- and three-dimensional modeling tools to simulate spatial arrangement and visualize ecological functions. By offering a replicable and educationally rich model, this study contributes not only to the aesthetic discourse of planting design but also to the ecological resilience and pedagogical value of botanical institutions.

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2. MATERIAL AND METHOD

The study area is situated in Düzce, a city located in the Black Sea Region of Turkey (Figure 1). The research specifically focuses on the rock garden section within the botanical garden of Düzce University's Konuralp Campus.

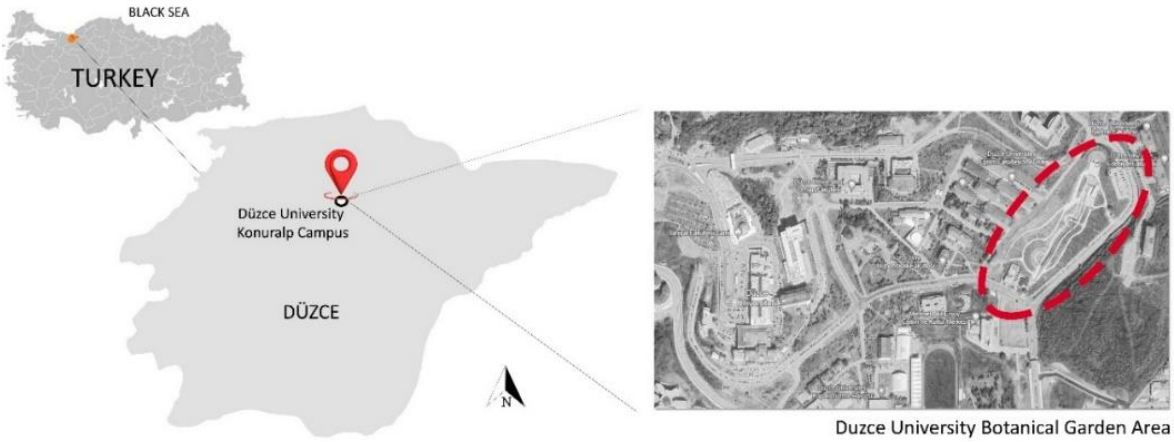


Figure 1. *Location of study area*

The botanical garden, located on the Konuralp Campus of Düzce University, spans a total of 5.2 hectares. This expansive area is divided into 39 thematically distinct sections, including an arboretum, Mediterranean maquis plants, medicinal and aromatic plants, and a welcome garden. Additionally, two parcels on the eastern side of the botanical garden were designated for the development of rock gardens.

This research was structured into five distinct phases, each representing a critical step in the planning and implementation of a rock garden design. In the first phase, the project area was identified: two plots within the botanical garden were selected as the study location for rock garden implementation. The second phase involved detailed on-site analysis, focusing on environmental parameters such as topography, soil characteristics, solar exposure, and water availability. It is noteworthy that the designated area lacked any pre-existing vegetation, providing a clean slate for design. The third phase focused on the identification and selection of suitable plant taxa for the rock garden. At this stage, a combination of native and resilient exotic plant taxa aligned with the design objectives were prioritized. Similar evaluations emphasizing the balanced use of native and exotic plants in urban green spaces were also highlighted by Kahveci (2021). The plant selection process was guided by Hitchmough's (2004) methodology, which emphasizes the integration of aesthetic and structural design principles (Figure 2). Subsequently, the proposed taxa were evaluated according to ecological functionality and design attributes such as color, texture, and seasonal variation. In terms of color, the selection process considered the most visually dominant attributes of each taxon, prioritizing flowers when present, followed by distinctive foliage and, in certain cases, fruit or stem coloration. The aim was not to capture all possible color traits of a taxon simultaneously, but rather to emphasize the feature that provides the greatest visual impact within the composition. Dominant colors were determined based on phenological characteristics (e.g., peak flowering or seasonal foliage change) reported in the literature and nursery catalogues, and cross-checked with field observations. This approach ensured that color use in the design was both ecologically grounded and aesthetically coherent. The finalized taxa list served as a foundational reference for the composition of the planting design.

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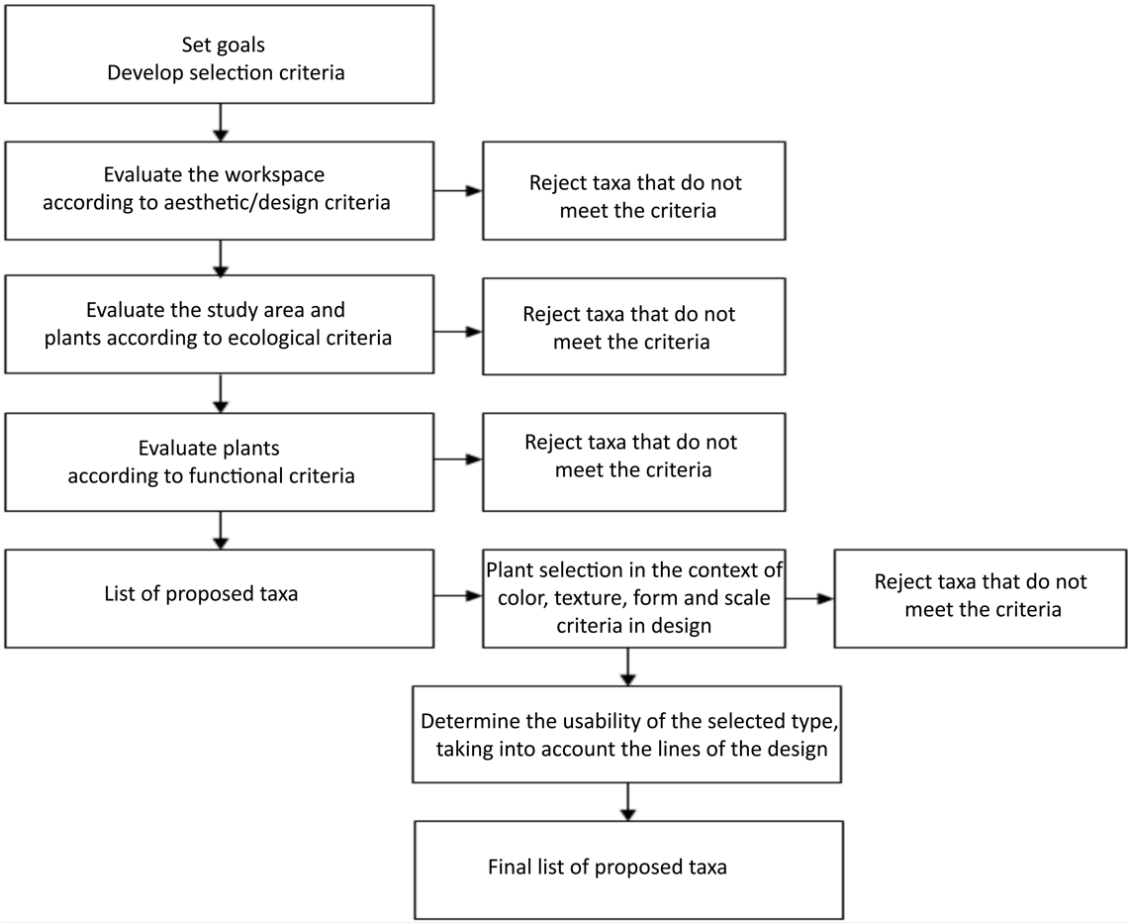


Figure 2. *Plant selection process in design (adapted from Hitchmough 2004).*

During the composition stage, plant taxa were selected and organized in accordance with well-established design principles—such as balance, unity, hierarchy, proportion, harmony, contrast, and emphasis—which are widely recognized in planting design literature (e.g., Robinson, 2016; Schutzki, 2005). These principles were used as guiding criteria in the arrangement of taxa, ensuring that plant attributes such as growth habit, coloration, texture, and spatial behavior contributed to a composition that is both aesthetically appealing and functionally coherent. In the fifth phase, the proposed compositions were initially visualized in two dimensions using AutoCAD software, through detailed plan drawings and cross-sectional views to effectively communicate the design intent. Finally, the design was modeled in three dimensions using SketchUp (2018) and Lumion (7.5), which enabled a more immersive and spatially accurate representation of how the proposed landscape would appear upon real-world implementation.

3. RESULTS AND DISCUSSION

We assessed the current condition of Parcels 9 and 10, located in the eastern section of the Düzce University Botanical Garden (Figure 3). These parcels were examined within the framework of a rock garden landscape design project. The spatial characteristics of the site were thoroughly analyzed to inform the development of a planting design that would be both aesthetically appealing and functionally effective. The botanical garden is characterized by a generally sloping topography. Stairs were positioned at the center, as well as along the northern and southern edges of the parcels, to facilitate visitor access and visual observation. Currently, the site contains only structural components such as flooring, stairs, and retaining walls. Rocks and stones have not yet been introduced, but their integration is planned as part of the forthcoming vegetative design. The plots

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receive full sun exposure, and the planting design was planned accordingly, taking into account these light conditions.

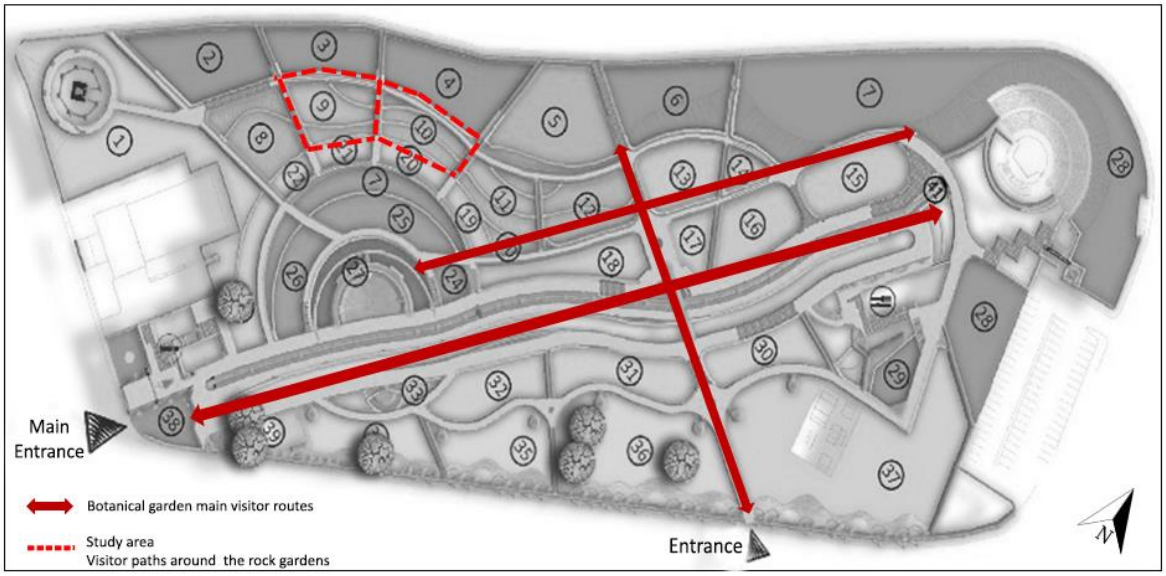


Figure 3. *Current situation analysis of the study area*

A total of 36 plant taxa were used in the rock garden design, and their composition was based on the plant design criteria. While dwarf plants were generally selected, fastigiata taxa were added to the composition by considering the feature of being an accent element in the design and size criterion. These plants are strategically placed to create emphasis in the garden and provide diversity with different heights and textures. *Carex oshimensis* Nakai 'Evergold' was the most preferred taxa in design. This taxon is a plant with high aesthetic value and green leaves with yellow stripes. The fine, elegant leaf texture is a pleasant contrast to the hard, dense stone textures in rock gardens. It is also highly ecologically compatible, with low maintenance requirements.

Evaluation of rock gardens is an important stage in planting design. This evaluation examined how plants are used in terms of size, texture, color, and form (Table 1). Size is a fundamental criterion in rock garden design. For example, dwarf plants are often foregrounded and often used as ground cover or as an edge plant (Relf & Appleton, 2015). Taxa such as *Ajuga reptans* L., *Carex* sp., *Gazania rigens* (L.) Gaertn., and *Festuca* sp. were spread between the stones, providing a natural look and covering the garden ground for an aesthetic texture. Medium-sized plants, such as *Coreopsis grandiflora* Hogg ex Sweet, *Crocosmia* × *crocosmiiflora* (Lemoine) N.E.Br., and *Dianthus barbatus* L., are placed in the central part of rock gardens. These plants are usually planted on top of stones or in open areas, creating a perception of depth (Eksi & Rowe, 2019) in the garden. Tall plants are used in the background, center, and sometimes in the corners (Nagashima & Hikosaka, 2011). *Betula pendula* Roth, *Acer palmatum* Thunb. 'Dissectum Viridis,' *Acer palmatum* 'Katsura,' *Juniperus communis* 'Hibernica,' were chosen to balance the scale of the garden and create a visual focal point.

Table 1. *Characteristics of rock garden plant taxa and aesthetic elements (phenological, size, texture, color, blooming time and form)*

Plant Taxa Name	Height (cm)	Texture	Color	Blooming Time	Form
Acer palmatum Thunb.'Dissectum Garnet'	250	F	red (L)	Sp	W
Acer palmatum Thunb. 'Dissectum Viridis'	180-300	F	green (L)	Sp	W
Acer palmatum Thunb.'Katsura'	150-270	F	yellow, orange (L)	Sp	V

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Plant Taxa Name	Height (cm)	Texture	Color	Blooming Time	Form
Agapanthus africanus (L.) Hoffmanns.	60-90	M	blue (F)	S	C
Ajuga reptans L.	15-20	M	blue (F), purple(L)	Sp	S
Armeria maritima (Mill.) Willd.	15-30	F	pink (F)	Sp	C
Betula pendula Roth	350-400	M	white (S), green, yellow (L)	Sp	C,W
Carex oshimensis Nakai 'Everest'	30-60	C	green and White (L)	S	C
Carex oshimensis Nakai 'Evergold'	30-40	C	green and yellow (L)	S	C
Coreopsis grandiflora Hogg ex Sweet	45-60	F	yellow (F)	S	C
Cornus alba L.'Sibirica'	120-210	M	green (L), red (S)	Sp	V
Crocosmia × *crocosmiiflora* (Lemoine) N.E.Br.	60-90	F	orange (F)	S	V
Cupressus sempervirens L.'Stricta'	1200	C	green (F)	-	CL
Dianthus barbatus L.	30-60	F	pink, white (F)	Sp	C
Festuca glauca Vill.'Elijah Blue'	20-30	M	blue-green (L)	S	C
Gazania rigens (L.) Gaertn.	20-25	M	yellow-orange (F)	Sp	C
Hakonechloa macra (Munro) Honda	30-60	F	green (L)	-	C
Hakonechloa macra (Munro) Honda 'Aureola'	30-45	F	golden yellow-green (L)	-	C
Hebe Juss.'Emerald Gem'	30-45-60	M	green (L)	S	C
Heuchera L. 'Lime Rickey'	20-45	M	light green (L)	S	C
Heuchera L. 'Marmalade'	45-50	M	orange, red (L)	S	C
Hypericum calycinum L.	30-60	M	yellow (F)	S	S
Juniperus communis L. 'Hibernica'	150-450	M	blue-green (L)	-	CL
Juniperus horizontalis Moench	15-60	M	gray-blue (L)	-	S
Liriope muscari (Decne.) L.H. Bailey	30-60	M	purple (F)	S	C
Liriope muscari (Decne.) L.H. Bailey 'Gold Band'	30-60	M	purple (F), green-yellow (L)	S	C
Muhlenbergia capillaris (Lam.) Trin.	60-90	F	pink (F)	S	C
Pinus mugo Turra 'Winter Gold'	150	M	golden yellow (L)	-	C
Pinus nigra J.F.Arnold 'Nana'	150-200	M	green (L)	-	C
Pittosporum tobira (Thunb.) W.T.Aiton 'Nana'	80-100	M	green (L)	Sp	C
Rosmarinus officinalis L.	60-180	M	blue (F)	Sp	S
Sedum acre L.	7	F	yellow (F)	S	C
Spiraea ×*bumalda* Burv.	100-150	F	pink (F)	Sp	S
Stachys byzantina K.Koch	15-20	C	silvery gray (L)	S	C
Stipa tenuissima Trin.	30-60	F	green-golden yellow (L)	S	C
Yucca filamentosa L.	90-200	C	green (L), white (F)	S	C

(Texture; F:Fine texture, M:Medium texture, C:Coarse texture. Color; L:Leaf, F:Flower, S:Stem. Blooming Time; Sp: Spring, A:Autumn, S:Summer. Form; W:Weeping form, V:Vase, C:Clumping, S:Spreading, CL: Columnar)

The different textures of plants provide visual and tactile variety. Rough textured plants are used to mimic the hard structure of natural rock formations, whereas softer textured plants are preferred to add a pleasant touch to the garden (Mitra, 2018). In the garden, *Spirea bumalda*, *Carex* sp., *Festuca* sp., and *Muhlenbergia capillaris* (Lam.) Trin. were used to soften the hard texture of the rocks. The choice of color also greatly influences the aesthetics of the garden. Red (*Acer palmatum* Thunb. 'Dissectum Garnet'), orange (*Crocosmia* × *crocosmiiflora* (Lemoine) N.E.Br.) and yellow (*Hakonechloa macra* (Munro) Honda 'Aureola', *Coreopsis grandiflora* Hogg ex Sweet) add vibrancy to the garden, while shades of green (*Juniperus communis* L. 'Hibernica', *Cupressus sempervirens* L. 'Stricta') provide a harmonic balance (Figure 4). Color in planting design not only creates visual appeal but also evokes psychological responses, where warm hues such as red and orange stimulate excitement and energy, while green tones are associated with calmness and harmony (Lindemann-Matthies & Marty, 2013; Robinson, 2016). Plant shape plays a critical role in

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determining the structural layout of the garden. Plants with weeping forms (*Spirea bumalda* Burv., *Muhlenbergia capillaris* (Lam.) Trin.) are used to soften the edges of rocks and mimic natural waterfalls, while upright and columnar forms (*Juniperus communis* L. 'Hibernica') provide a visual impact by emphasizing vertical perception (Schutzki, 2005).



Figure 4. *Rock garden vegetal design considering the design criteria for aesthetic evaluation*

Rock garden design should not only focus on visual appeal but should also consider ecological factors and maintenance requirements to create sustainable and thriving garden ecosystems (Abdulrazzaq et al., 2020; Çiçek Kurdoğlu et al., 2022). Plants such as *Agapanthus africanus* (L.) Hoffmanns. and *Gazania rigens* (L.) Gaertn. have moderate water requirements and are suitable for arid environments, thereby reducing the need for frequent watering (Table 2). Additionally, *Carex oshimensis* Nakai 'Everest' and *Carex oshimensis* Nakai 'Evergold' thrive in partial shade conditions, making them ideal choices for areas with limited sunlight exposure. Conversely, *Acer palmatum* Thunb., 'Dissectum Garnet', and *Coreopsis grandiflora* Hogg ex Sweet prefer full sun exposure and require adequate light for healthy growth. Climate change affects the ability of plant taxa to locate favorable climatic conditions and develop appropriate adaptation mechanisms. In this context, the potential impacts of climate change should be carefully considered when selecting plant taxa for use in rock gardens. For example, rising temperatures and prolonged drought conditions necessitate the use of site-adapted taxa with low water requirements, such as *Sedum* sp. and *Stipa* sp., along with taxa well suited to arid environments, like *Festuca* sp. In contrast, under conditions of increasing frequency and intensity of heavy rainfall events, it is essential to incorporate moisture-tolerant taxa with effective drainage and water-retention capacities, such as *Carex* sp., *Festuca glauca* Vill. 'Elijah Blue', *Hakonechloa macra* (Munro) 'Aureola', *Sedum acre* L., and *Yucca filamentosa* L. Therefore, these taxa were intentionally included in the design to ensure ecological resilience, reduce maintenance needs, and enhance the long-term sustainability of the rock garden under future climate scenarios.

Understanding the specific ecological requirements of each plant taxa is fundamental to the success and long-term sustainability of rock garden design (Yuan & Kim, 2024). Maintenance-related considerations—including pruning needs, soil preferences, and pest management strategies—also play a vital role in ensuring the enduring health and vitality of the garden (Basha-Jakupi et al., 2021). By incorporating ecological assessments and maintenance requirements into the design process, rock gardens can achieve a well-balanced integration of aesthetic value and ecological performance

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(Tongyun, 2024). In the current design, ecological compatibility was prioritized, with a preference for taxa adapted to full sun or semi-shaded conditions. Particular attention was given to maintaining a balanced distribution of evergreen and deciduous taxa across seasons, thereby ensuring year-round visual appeal and functionality—even in winter. Climate change significantly influences how plant taxa locate suitable climatic conditions and develop adaptive strategies (Loidi Arregui et al., 2012). Within the context of rock garden design, it is imperative to account for climate change impacts during the plant selection phase (Tomatis et al., 2023). For instance, elevated temperatures and prolonged droughts necessitate the inclusion of site-adapted taxa with low water requirements, such as *Sedum* sp., *Stipa* sp., and *Festuca* sp., which are well-suited to arid environments. By contrast, in response to the increasing frequency of extreme rainfall events, taxa tolerant of high soil moisture and with effective water-retention capacities—such as *Carex* sp., *Festuca glauca* Vill.'Elijah Blue', *Hakonechloa macra* (Munro) 'Aureola,' *Sedum acre* L., and *Yucca filamentosa* L.—should be incorporated into the design. Accordingly, these taxa were selected in this study to enhance the garden's resilience and adaptability under future climatic conditions, contributing to both ecological stability and reduced maintenance demands (Simonson et al., 2021).

Table 2. *Ecological evaluation and maintenance considerations for rock garden planting design*

Plant Taxa Name	Pollination	Sunlight requirement	Water requirement	Maintanance
Acer palmatum Thunb.'Dissectum Garnet'	-	Ss	M	L
Acer palmatum Thunb. 'Dissectum Viridis'	-	Ss	M	L
Acer palmatum Thunb.'Katsura'	-	Ss	M	L
Agapanthus africanus (L.) Hoffmanns.	P	Fs	M	L
Ajuga reptans L.	P	Ss	M	L
Armeria maritima (Mill.) Willd.	-	Fs	M	L
Betula pendula Roth	-	Fs	M	L
Carex oshimensis Nakai 'Everest'	-	Ss	M	L
Carex oshimensis Nakai 'Evergold'	-	Ss	M	L
Coreopsis grandiflora Hogg ex Sweet	P	Fs	M	L
Cornus alba L.'Sibirica'	-	Fs	M	L
Crocosmia × *crocosmiiflora* (Lemoine) N.E.Br.	P	Fs	M	L
Cupressus sempervirens L.'Stricta'	-	Fs	M	L
Dianthus barbatus L.	P	Fs	M	M
Festuca glauca Vill.'Elijah Blue'	-	Fs	M	M
Gazania rigens (L.) Gaertn.	P	Fs	M	M
Hakonechloa macra (Munro) Honda	P	Ss	M	L
Hakonechloa macra (Munro) Honda 'Aureola'	P	Ss	M	L
Hebe Juss.'Emerald Gem'	-	Fs	M	M
Heuchera L. 'Lime Rickey'	-	Ss	M	M
Heuchera L. 'Marmalade'	-	Ss	M	M
Hypericum calycinum L.	P	Fs	M	L
Juniperus communis L. 'Hibernica'	-	Fs	M	L
Juniperus horizontalis Moench	-	Fs	M	L
Liriope muscari (Decne.) L.H. Bailey	P	Ss	M	L
Liriope muscari (Decne.) L.H. Bailey 'Gold Band'	-	Ss	M	L
Muhlenbergia capillaris (Lam.) Trin.	P	Fs	M	L
Pinus mugo Turra 'Winter Gold'	-	Fs	M	L
Pinus nigra J.F. Arnold 'Nana'	-	Fs	M	L

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Plant Taxa Name	Pollination	Sunlight requirement	Water requirement	Maintanance
Pittosporum tobira (Thunb.) W.T. Aiton 'Nana'	-	Fs	M	L
Rosmarinus officinalis L.	P	Fs	M	L
Sedum acre L.	-	Fs	L	L
Spiraea ×bumalda Burv.	P	Fs	M	M
Stachys byzantina K. Koch	P	Fs	M	L
Stipa tenuissima Trin.	-	Fs	L	L
Yucca filamentosa L.	P	Fs	M	L

(P: Pollinator plant. Light; Ss: Semi-shade, Fs: Full sun, Water requirement; M: Medium water requirement, L: Low water requirement. Maintanance; L: Low requirement, M: Medium requirement)

The planting designs developed for the sections within the two designated rock garden parcels are presented in detail in Figure 5. These vegetative compositions aim to establish a sustainable and visually engaging landscape, effectively harmonizing aesthetic appeal with ecological functionality.



Figure 5. *Distribution of parcels from the study area.*

The plant palette employed in Parcel 9A is distinguished by its diverse textures and rich color variations (Figure 6). Ground cover taxa such as *Carex oshimensis* Nakai 'Evergold' and *Carex oshimensis* Nakai 'Everest' are anticipated to establish a dense vegetative layer at the base, enlivening the space with their vivid green and golden foliage in early spring. Concurrently, the emergence of fresh green leaves on *Betula pendula* Roth marks the seasonal transition. Vertical accent elements, including *Cornus alba* L.'Sibirica' and *Pinus nigra* J.F. Arnold 'Nana', provide structural height and visual interest at upper canopy levels. Additionally, taxa like *Juniperus horizontalis* Moench and *Pinus mugo* Turra 'Winter Gold' contribute to the spatial dynamism of the design through their year-round chromatic and textural expressions. The integration of *Betula pendula* Roth and *Sedum acre* L. enhances the garden's naturalistic aesthetic, while ornamental grasses such as *Festuca glauca* Vill. 'Elijah Blue' and *Hakonechloa macra* (Munro) Honda enrich the composition with a vibrant palette and fine-textured visual appeal.

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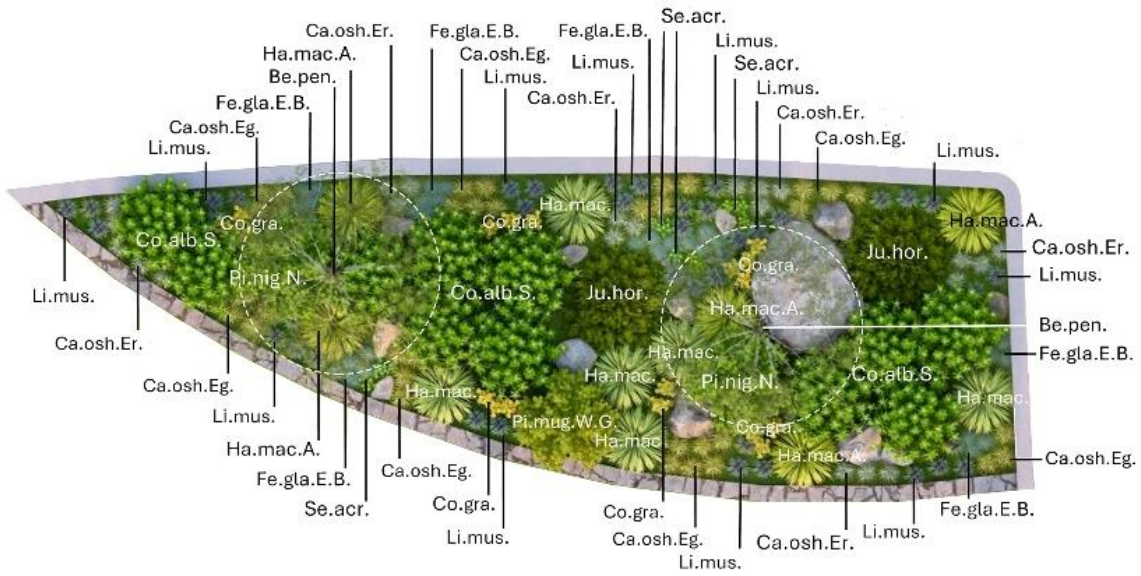


Figure 6. *Proposed planting design for parcel 9A*

Parcel 9B presents a rich assemblage of plant taxa distinguished by their diverse textures and vibrant color profiles (Figure 7). Taxa such as *Ajuga reptans* L., *Betula pendula* Roth, and *Coreopsis grandiflora* Hogg ex Sweet contribute foundational elements to the visual and structural composition. Japanese maple cultivars—*Acer palmatum* Thunb. 'Katsura' and *Acer palmatum* Thunb. 'Dissectum Garnet'—serve as focal points, particularly noted for their vivid autumn foliage, which enhances seasonal dynamism. A careful balance of natural hues and plant forms was maintained throughout the parcel to achieve visual coherence. Low-growing taxa such as *Hypericum calycinum* L. and *Hebe* Juss. 'Emerald Gem' introduce movement and vitality, while *Stachys byzantina* and *Festuca glauca* Vill. 'Elijah Blue' offer a refined contrast through their soft, silvery textures. Ornamental taxa with moderate water requirements, such as *Agapanthus africanus* (L.) Hoffmans, were incorporated to provide structural foliage and seasonal floral display, supported by regular irrigation. Seasonal interest is further enriched by *Ajuga reptans* L., with its blue-violet spring blooms, and *Coreopsis grandiflora* Hogg ex Sweet, offering a burst of yellow floral color.

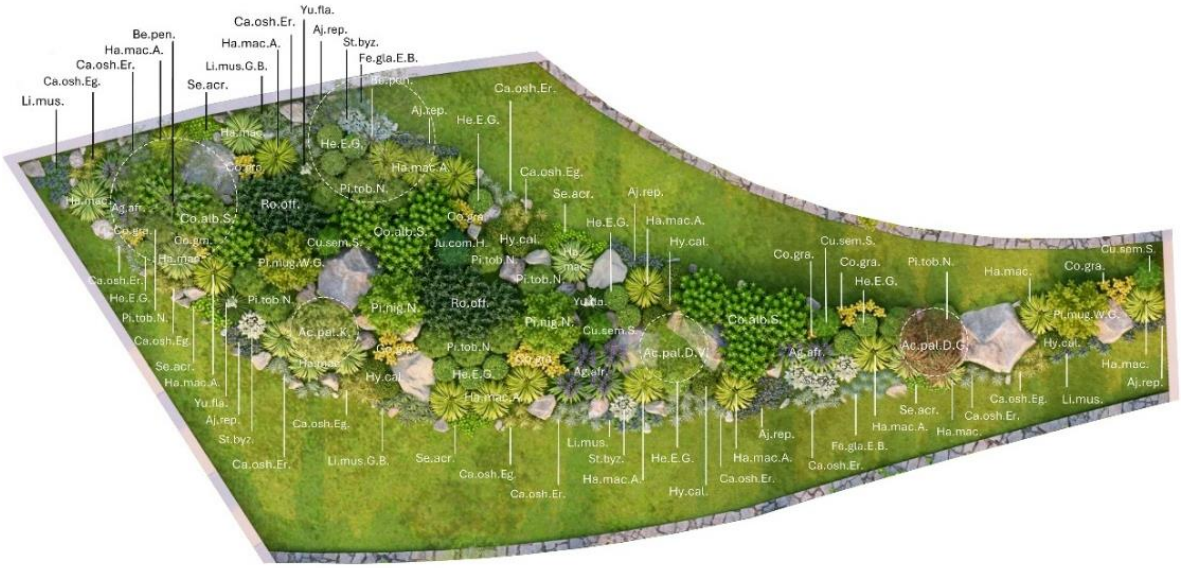


Figure 7. *Proposed planting design for parcel 9B*

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Parcel 9C is enriched with aromatic and ground cover plants such as *Rosmarinus officinalis* L. and *Juniperus horizontalis* Moench, *Cornus alba* L. 'Sibirica' and *Acer palmatum* Thunb. 'Dissectum Viridis' give the garden an accent effect with their seasonal color changes and vertical forms (Figure 8). *Gazania rigens* (L.) Gaertn. and *Carex oshimensis* Nakai 'Everest' attract attention with their bright colors, while *Hakonechloa macra* (Munro) Honda 'Aureola' takes place in the composition with its aesthetic texture. *Rosmarinus officinalis* L. is effective, with small purple flowers in spring. *Carex oshimensis* Nakai 'Evergold' and 'Everest' reflect the energy of spring with their fresh green and golden leaves. *Gazania rigens* (L.) Gaertn. adds vibrancy to springs with brightly colored flowers. In summer, *Festuca glauca* 'Elijah Blue' gives a feeling of coolness with its blue leaves. *Hakonechloa macra* (Munro) Honda 'Aureola' adds movement and shine with its golden leaves, while *Cornus alba* L. 'Sibirica' protects its green foliage. In autumn, *Acer palmatum* Thunb. 'Dissectum Viridis' turns yellow and orange, while *Carex oshimensis* taxa display soft colors in autumn.



Figure 8. *Proposed planting design for parcel 9C*

In Parcel 9D, plants such as *Armeria maritima* (Mill.) Willd. and *Acer palmatum* Thunb. 'Dissectum Garnet' offer a variety of colors and textures, creating a striking composition (Figure 9). *Carex oshimensis* Nakai 'Evergold' and *Stipa tenuissima* Trin. give the garden a vibrant and dynamic look. In this plot, the natural color tones and forms of the plants were used in an aesthetic balance and harmony. Taxa such as *Muhlenbergia capillaris* (Lam.) Trin. and *Hebe* Juss. 'Emerald Gem' add vibrancy and variety to their composition, whereas plants such as *Dianthus barbatus* L. and *Pinus mugo* Turra 'Winter Gold' stand out as accent elements. *Armeria maritima* attracts attention with its pink flowers in spring.

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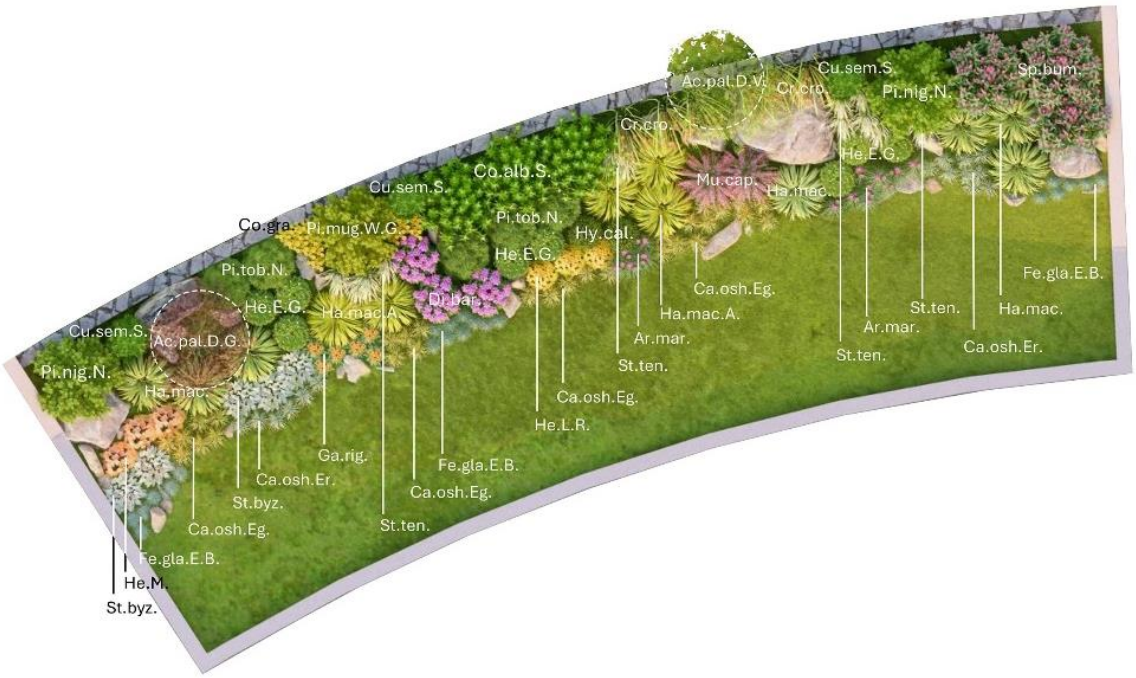


Figure 9. *Proposed planting design for parcel 9D*

In parcel 10A, where *Liriope muscari* (Decne.) L.H. Bailey, *Carex oshimensis* Nakai 'Evergold', *Cornus alba* L. 'Sibirica', *Carex oshimensis* Nakai 'Everest', *Hakonechloa macra* (Munro) Honda, *Festuca glauca* Vill. 'Elijah Blue', *Betula pendula* Roth, *Juniperus horizontalis* Moench, *Coreopsis grandiflora* Hogg ex Sweet and *Pinus mugo* Turra 'Winter Gold' taxa were used, an aesthetic and functional arrangement was made in accordance with vegetative design criteria (Figure 10). *Cornus alba* L. 'Sibirica' and *Betula pendula* Roth are effective with stems that stand out with their color aesthetics in winter. *Hakonechloa macra* (Munro) Honda and *Festuca glauca* Vill. 'Elijah Blue' provide a vibrant texture on the ground, while *Pinus mugo* Turra 'Winter Gold' stands out as an accent element with its yellow leaves in winter. These plants can prevent erosion and increase soil stability on slopes. *Juniperus horizontalis* Moench is used as a ground cover with high soil retention capacity. These plants, selected in accordance with the botanical garden criteria, offer visual interest to visitors throughout the four seasons.

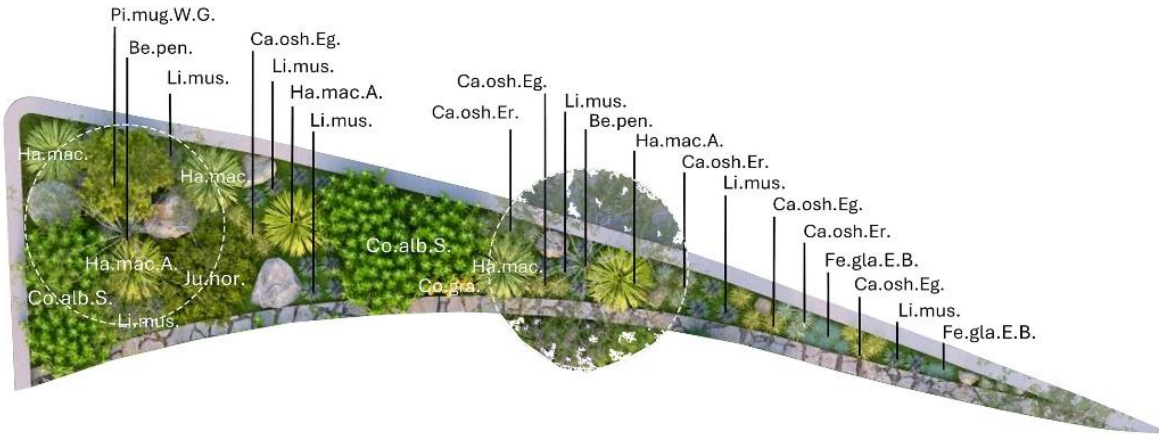


Figure 10. *Proposed planting design for parcel 10A*

Parcel 10B employs (Figure 11) a diverse range of taxa, including *Ajuga reptans* L., *Yucca filamentosa* L., *Carex oshimensis* Nakai 'Evergold', *Betula pendula* Roth, *Liriope muscari* (Decne.)

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L.H. Bailey ‘Gold Band’, *Hakonechloa macra* (Munro) Honda ‘Aureola’, *Cupressus sempervirens* L. ‘Stricta’, *Pinus nigra* J.F. Arnold ‘Nana’, *Cornus alba* L. ‘Sibirica’, and *Agapanthus africanus* (L.) Hoffmans, to create a visually appealing and structurally sturdy design. While *Yucca filamentosa* L. and *Cupressus sempervirens* L. ‘Stricta’ act as vertical accents*, Liriope muscari* (Decne.) L.H. Bailey ‘Gold Band’ and *Hakonechloa macra* (Munro) Honda ‘Aureola’ provide soft textures and gradual color transitions on the ground. *Betula pendula* Roth and *Carex oshimensis* Nakai ‘Evergold’ serve to stabilize soil and prevent erosion on slopes. The inclusion of *Yucca filamentosa* L. contributes to ecological resilience by enhancing drought tolerance within the planting composition.



Figure 11. *Proposed planting design for parcel 10B*

In Parcel 10C, the vertical and horizontal movement of space is emphasized by the inclusion of taxa such as *Acer palmatum* Thunb. ‘Dissectum Garnet’ and *Cupressus sempervirens* L. ‘Stricta.’ Additionally, plants such as *Pittosporum tobira* (Thunb.) W.T.Aiton ‘Nana’ and *Juniperus communis* L. ‘Hibernica’ contributed to the spatial depth of the area. *Carex oshimensis* Nakai ‘Evergold’ and ‘Everest’ add soft textures and color transitions to the ground layer. Meanwhile, taxa like *Hakonechloa macra* (Munro) Honda ‘Aureola’ and *Coreopsis grandiflora* Hogg ex Sweet draw attention with their vibrant colors in the summer, while *Rosmarinus officinalis* offers evergreen foliage and fragrance. The sloping terrain is protected by the inclusion of taxa with erosion and soil retention properties, such as the *Sedum acre* L. and *Gazania rigens* (L.) Gaertn. In the spring, the leaves of *Acer palmatum* Thunb. ‘Dissectum Garnet’ and the flowers of *Coreopsis grandiflora* Hogg ex Sweet stand out, while in the summer, *Gazania rigens* (L.) Gaertn. and *Hypericum calycinum* L. catch the eye with their brightly colored blooms. As autumn arrives, *Hakonechloa macra* (Munro) Honda ‘Aureola’ and *Pittosporum tobira* (Thunb.) W.T.Aiton ‘Nana’ add warm tones to the landscape. Finally, in winter, *Pinus mugo* Turra ‘Winter Gold’ and *Cupressus sempervirens* L. ‘Stricta’ bring life to the landscape with their green and golden hues (Figure 12).

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Figure 12. *Proposed planting design for parcel 10C*

In Parcel 10D, a balanced and harmonious composition was created by selecting plants according to their texture, color, form, and growth habits (Figure 13). On the ground, plants such as *Festuca glauca* Vill. 'Elijah Blue' and *Stachys byzantina* K.Koch provide a textural contrast with their soft and gray tones, while taxa such as *Cupressus sempervirens* L. 'Stricta' and *Pinus nigra* J.F.Arnold 'Nana' used as vertical elements create spatial depth and accentuating vertical lines. In addition, deciduous taxa such as *Acer palmatum* Thunb. 'Dissectum Viridis' and *Acer palmatum* Thunb. 'Katsura' offer a dynamic visual impact by changing leaf colors throughout the four seasons.

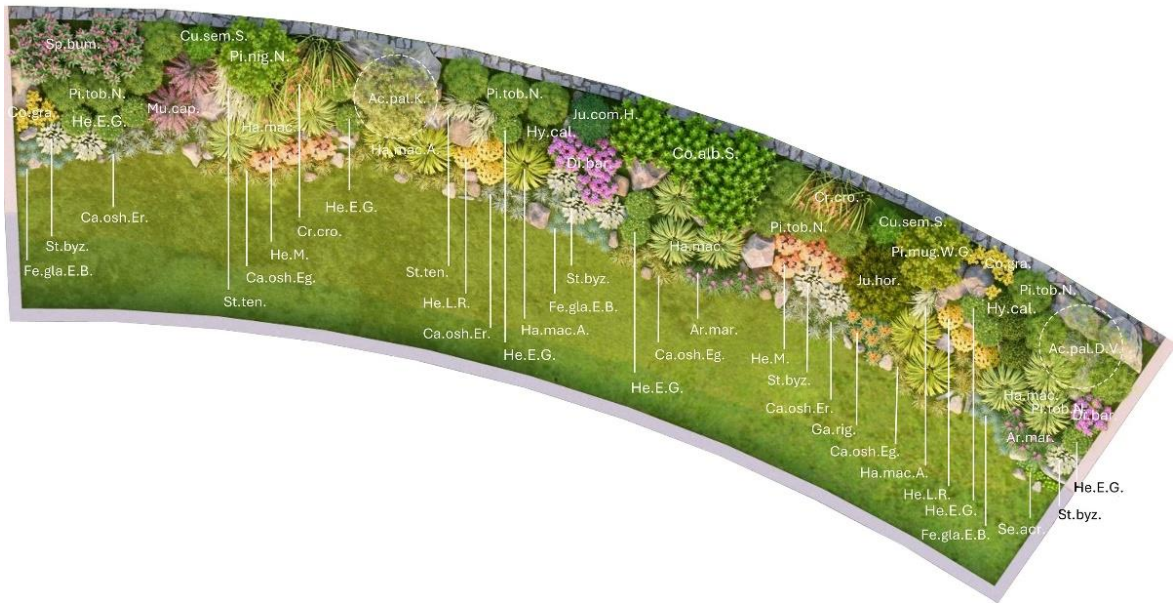


Figure 13. *Proposed planting design for parcel 10D*

When designing a rock garden, it is essential to carefully consider the selection of plants that will comprise the seasonal cycle. This choice guarantees the aesthetic and ecological functionality of the garden throughout the year, thus making it a dynamic and visually appealing space. By incorporating a diverse range of plants that exhibit flowering and defoliation at different times of the year, the garden will display seasonal progression, with different plants taking the center stage at different times (Table 3). The rock garden within the botanical garden was designed to fulfill both scientific and educational goals. In addition to aesthetic considerations, the plant selection process also considered both ecological and phenological factors (Schutzki, 2005; Chang et al., 2008).

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Furthermore, the incorporation of plants that highlight botanical diversity as design elements is emphasized, as the garden serves as an educational space where visitors can identify plant taxa and gain knowledge about ecosystems (Bayındır, 2023). Plant arrangement was determined by evaluating their growth patterns, colors, and textures. The organic forms and shades of the plants were used to achieve a balance. Specifically, dwarf plants and conifers added small-scale details and subtle textures to the gardens (Wang et al., 2024). Fastigiata plants function as vertical accent elements, imparting a garden with dynamic appearance (Rebek & Holmes, 1990; Schutzki, 2005). They create a visual hierarchy and depth by contrasting the horizontal spread of other plants.

Table 3. *Seasonal plant distribution and visual dynamics in the rock garden design*

SPRING SEASON		
	During the spring season, *Crocosmia* × *crocosmiiflora* (Lemoine) N.E.Br. and *Dianthus barbatus* L. bloom in a vibrant color display. *Ajuga reptans* L., with its blue flowers, and *Liriope muscari* 'Gold Band,' with its golden leaves, also stand out during this period.	
SUMMER SEASON		
	In the summer months, the attention-grabbing hues of *Heuchera* 'Marmalade' and *Muhlenbergia capillaris* create a striking landscape, while the blue flowers of *Agapanthus africanus* provide a bright and cheerful appearance. *Spiraea* ×*bumalda* and *Coreopsis grandiflora* Hogg ex Sweet contribute to the garden's aesthetic appeal with their pink and yellow flowers, respectively. *Pittosporum tobira* 'Nana' and *Cupressus sempervirens* 'Stricta' offer year-round greenery and serve as structural frameworks.	
AUTUMN SEASON		
	In autumn, the dramatic color change of *Acer palmatum* Thunb. 'Dissectum Viridis' and 'Katsura' leaves has a striking effect on the landscape. *Hakonechloa macra* 'Aureola,' with its bronze leaves, and *Cornus alba* 'Sibirica,' with its bright red branches, both stand out during this time. The golden yellow leaves of *Betula pendula* Roth and *Pinus mugo* 'Winter Gold' provide a visual feast, while *Acer palmatum* 'Dissectum Garnet' showcases its red leaves for an aesthetic image.	

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WINTER SEASON		
	During winter, evergreens such as *Cupressus sempervirens* 'Stricta' and *Pinus nigra* 'Nana' keep the landscape vibrant. *Cornus alba* 'Sibirica's red branches create a stunning contrast in snow-covered landscapes. *Juniperus horizontalis* and *Hebe* 'Emerald Gem' provide a green texture even under snow. *Carex oshimensis* Nakai 'Evergold' and *Stipa tenuissima* add color to the winter months with their green and gold hues, respectively. *Stachys byzantina* offers textural variety under snow.	

4. CONCLUSION

The present study offers a design proposal for botanical gardens, advocating an approach that highlights the significance of plant selection and can serve as an inspiration for other spaces. In the planning and construction of the rock garden in the botanical garden, various factors were considered, including ecological compatibility, maintenance requirements, and suitability to the plants' natural habitats. This approach resulted in a balanced and sustainable rock garden that was both aesthetically pleasing and functional. The plants chosen for the garden were selected based on their ability to prevent soil erosion, increase water retention, and stabilize sloping terrain. In addition, the low maintenance requirements and high adaptability of these plants make them a sustainable option for botanical garden visitors. The use of flowering plants also supports biodiversity by creating a habitat for pollinators, whereas the balanced distribution between deciduous and evergreen plants creates a visually rich and diverse landscape. In summary, the design and construction of rock gardens offer sustainable landscape options that are in harmony with the natural environment. These gardens play an important role in biodiversity conservation and as educational spaces, but it is also important to consider local conditions and management factors. Although this study provides an example of a rock garden vegetative design that can be implemented in Düzce, Turkey, it is also intended to support similar studies in the literature and serve as a basis for inspiring future research.

Author Declarations and CRediT Roles

There is no conflict of interest. No financial support has been received. Ethical committee approval is not required. Generative artificial intelligence tools have not been used. It has not been previously presented or published. The data are presented within the article.

Investigation: TGD; Methodology: TDG; Resources: TDG; Visualization: SD; Writing – original draft: TGD; Writing – review & editing: TDG.

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