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# Plant selection for rain gardens in temperate climates: The case of Izmir, Turkey

Burçin Burcu Doğmuşöz*

## Abstract

Rain gardens have gained importance in recent years as a green infrastructure strategy. These gardens, created to capture, filter, and absorb runoff from impervious surfaces, offer a sustainable method for addressing water-related challenges in urban areas. Incorporating rain gardens into urban areas not only addresses the challenges of heavy rainfall and flooding but also brings about ecological advantages by encouraging biodiversity, improving water quality, increasing resilience, and enhancing the aesthetic appeal of urban settings. Plant selection in rain gardens plays a crucial role in their effectiveness and sustainability. The research focused on exploring the importance of carefully choosing plants for rain gardens, aiming to help in selecting the most suitable flora and creating visually appealing, resilient, and ecologically important landscapes. For this purpose, Izmir Katip Celebi University was selected as a study area. The first step was to locate an appropriate space for a rain garden and evaluate its potential for a rain garden implementation. Next, plants suitable for a rain garden in a temperate climate were listed. Among these plants, those that can be found in Izmir were selected after contacting nurseries. Only fourteen of them were available. Utilizing the plants listed that align with the project requirements and the plant design criteria such as diverse color, high density, and proportion outlined in the literature review, a proposal for a rain garden design was recommended. Since the rain garden consists of three different zones (dry, wet, and moderate), the plants were arranged accordingly. This design was tailored to suit existing conditions, such as a temperate climate and proximity to the building. Factors like varying climate conditions or alternative rain garden placements were not accounted for in this design. Given the necessity for diverse plant selections in varying climates, research carried out across different regions holds significant value. This study, conducted in Izmir province, will enrich existing literature and provide municipalities with crucial guidance in plant selection in a rain garden project, offering valuable insights.

*Keywords: rain garden, plant selection, stormwater management, green infrastructure, urban resilience*

## 1. Introduction

Cities have become more densely populated, and green spaces that naturally allow water to permeate have been replaced by an expanding number of impermeable surfaces. According to Antia (2008), urbanization typically results in an increased amount of stormwater runoff and low baseflow rates. These changes in hydrology are also influenced by variations in evapotranspiration, the negative effects of climate change, and the physical characteristics of drainage networks. As a result, the amount of surface water has grown to a point that conventional stormwater systems are unable to adequately treat it (Walsh et al., 2005). Moreover, due to climate change, rainfall has been more intense than in past years. This has led to urban flooding, and the consequences for society are significant (Gold et al., 2019).

*(Corresponding author), Lecturer, Dr. İzmir Katip Çelebi University, Türkiye burcinburcu.dogmusoz@ikc.edu.tr
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Recently, the term "resilience" has gained importance in urban planning. This refers to the capacity of urban environments to withstand and recover from various shocks and stresses, including natural disasters, climate change, social disruptions, and economic challenges. There are several theories and approaches have been developed to inform the concept. One of them is Ecological design theory. Ecological design principles advocate for creating built environments that mimic natural ecosystems and processes (Yang et al. 2004). By integrating elements such as green roofs, permeable surfaces, and natural systems, urban planners can enhance the resilience of cities and communities to environmental stressors. Another theory that has been discussed in the urban planning literature is Sustainable Development Theory. This emphasizes the importance of balancing economic, environmental, and social considerations to meet the needs of present and future generations (Shi et al. 2019). In the context of resilience, this theory promotes strategies that enhance the long-term viability and health of urban systems by minimizing resource depletion, reducing environmental degradation, and fostering social equity. These theories provide conceptual frameworks for urban planners to design and manage cities that are more resilient to natural disasters. By integrating principles of sustainability, complexity, collaboration etc., planners can help create cities that are better able to withstand and thrive in the face of uncertainty and change.

Based on this, green infrastructure has gained significant popularity in recent years as communities seek ways to mitigate the adverse effects of urbanization on local ecosystems and water quality (Davis, 2005). Green infrastructure strategies such as green roofs, rain gardens, and bioswales have emerged as innovative and sustainable solutions for managing stormwater runoff while simultaneously providing ecological and economic benefits. These multifunctional features not only prevent flooding and erosion but also contribute to improved water quality, support local biodiversity, enhance urban resilience, and increase the aesthetic appeal of outdoor spaces (Dietz, 2007). Among them, rain gardens as a green infrastructure strategy can also play a crucial role in reducing the impact of heavy rains and urban runoff by allowing rainwater to be absorbed naturally into the ground, promoting groundwater recharge, and filtering out pollutants (Yuan & Dunnett, 2018).

Rain gardens represent a paradigm shift in sustainable landscape design, offering an innovative solution to mitigate the adverse impacts of urbanization on natural water systems. Rain gardens, as a sustainable landscape design, can be implemented in different areas such as residential, commercial, or public (Steiner & Doom, 2012). These eco-friendly installations not only beautify urban environments but also play a crucial role in managing stormwater runoff, reducing flooding, improving water quality, and enhancing biodiversity. Rain gardens are mostly ideal for public spaces to display low-impact planting with a high aesthetic value that is appealing to city dwellers and also, significantly increase local biodiversity (Dunnett & Clayden, 2007). Based on these benefits, rain gardens have been one of the most generally utilized sustainable urban stormwater management systems and studies related to rain gardens have increased. Research on rain gardens has primarily concentrated on its design principles related to enhancing pollutant retention and the capacity of stormwater capture and the results have revealed that the effectiveness of a rain garden largely depends on the careful selection of plant species (Johnston, 2011; Dylewski et al., 2011). Although planting design is an important stage of the design of rain garden plants to maximize their effectiveness and beauty, it is frequently overlooked. Planting design is not only an important factor for stormwater management, but also crucial for providing aesthetic value to ensure easy adoption by the public. Most studies have pointed out that the public shows more willingness to the acceptance of an ecological design if it has high aesthetic value (Baptiste, 2014).

A significant problem with current urban green infrastructure and sustainable stormwater management systems such as rain gardens is the overall lack of care for plant diversity and aesthetics (Yuan et al, 2017). The selection of suitable plants for a rain garden is a vital aspect of creating a functional and aesthetically pleasing ecosystem that effectively manages stormwater runoff (Dunnett et al., 2008). Rain gardens are more than just functional; they are living systems that can thrive when thoughtfully designed with the right plant species. The careful consideration of plant selection is key to ensuring the long-term success of a rain garden, as it directly impacts its ability to capture, filter, and infiltrate rainwater while enhancing the overall ecological value of the space. While studies have been focused on the design and substrate composition of rain gardens to increase its capture potential and pollutant retention, plant selection studies are not very common. Plant selection depends on some certain criteria such as the location of a rain garden, climate conditions etc. Since then, studies in different conditions and regions will be worth investigating. This study will investigate a rain garden application in temperate climate condition. In this study, we will explore the importance of plant selection for rain gardens and offer insights into choosing the right plants to maximize their effectiveness and create beautiful, resilient and environmentally beneficial landscapes in the context of City of Izmir. Finally, a rain garden design will be suggested.



## 2. Literature Review

### *2.1. Rain garden design*

A rain garden is a carefully designed and environmentally friendly landscaping feature that serves multiple functions such as enhancing the beauty of outdoor spaces, managing stormwater runoff efficiently and increasing biodiversity (Bray et al., 2012). This innovative approach to sustainable landscaping has gained significant popularity in recent years as communities and individuals seek ways to mitigate the adverse effects of urbanization on local ecosystems and water quality. Rain gardens are not only aesthetically pleasing but also play a crucial role in reducing the impact of heavy rains and urban runoff by allowing rainwater to be absorbed naturally into the ground, promoting groundwater recharge, and filtering out pollutants (Dorst et al., 2019). Rain gardens are planted depressions that use flora and soils to reduce excess runoff from buildings, pavements, and roadways (Burge et al., 2012) (Figure 1). They are mostly used in the public right-of-way, along streets and roads and next to buildings (Steiner and Domm, 2012). The purpose of a rain garden is to temporarily collect and soak up rainfall from a driveway, roof, or sidewalks. The groundwater can rehydrate thanks to the precipitation collected, and part of the stormwater is retained by the plants. They can collect runoff from rooftops, sidewalks and streets. In the current study, the plant selection of a rain garden design, which are located near buildings, was investigated. This design will collect rainfall from downspouts.


**Figure 1** An example of a rain garden design in Ankara, Turkey

Low, mid and high zones are the three primary parts of a rain garden (Figure 2). This part is the lowest part with high level of humidity (Luo et al., 2017). Plants that are water-resistant and able to tolerate sudden floods should be planted at low zone. This zone might also be called as ponding area. The reason is that when there has been rain, the low zone may have stood water. The mid zone is a sloping slope region with a moderate humidity percentage. This zone is semi-arid; thus, it is best to choose plants that can withstand the occasional presence of standing water or tolerate to periodic drought (Dunnet & Clayden, 2007). The high zone is the lowest moisture content of the layers. Since then, drought-resistant taxa should be chosen when planting in high zone. Moreover, when there is a big rainfall event and the rain garden is unable to contain all of the runoff, water is discharged into the overflow area (Luo et al., 2017).

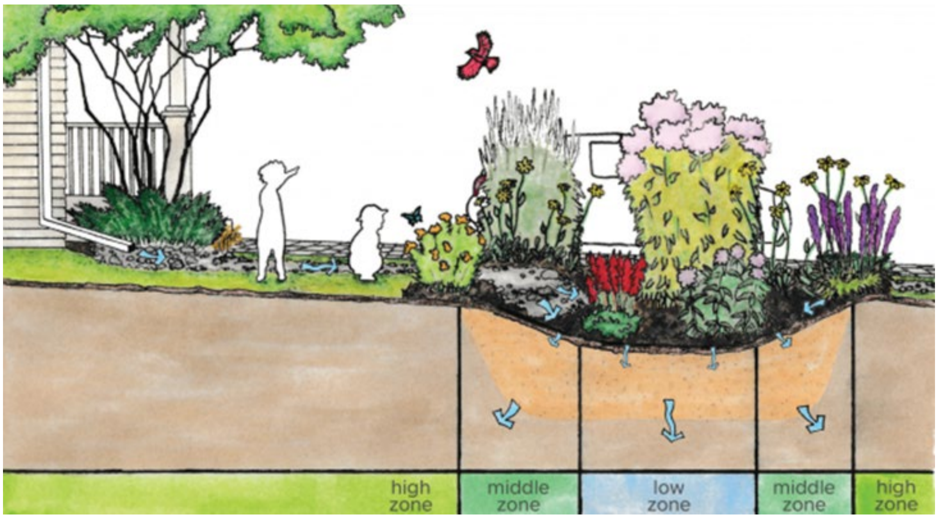


**Figure 2** A rain garden section with three zones (CVC, 2022)

### *2.2. The importance of plant selection in rain garden design*

Plant selection is a critical issue in rain garden design. When rain gardens are implemented, choosing the wrong species might lead to planting failure, which can have unpleasant visual impacts (Yuan et al, 2017). Moreover, there are studies that a rain garden's contribution to stormwater infiltration may be significantly reduced by the loss of vegetation (Yunusa & Newton, 2003). Therefore, even while the characteristics of the subsoil frequently have a significant impact in stormwater runoff treatment performance, the loss of vegetation as a consequence of failing to plant in a rain garden might result in a significant reduction in its contribution to stormwater infiltration. One of the main elements that contributes to the effectiveness of rain gardens is the health of the vegetation since it is essential to the supply of their ecosystem services. The ability of plants to withstand environmental stress under the unique conditions of rain gardens has a significant impact on the health of the vegetation there (Laukli et al., 2022). The key element influencing the ecosystem in rain gardens is moisture.

Making planting recommendations based on how plants respond to and adapt to rain garden moisture dynamics is crucial. The success of plants in rain gardens relies on the diversity of plant types used. This diversity impacts the long-term stability and visual appeal of the vegetation while also contributing to biodiversity conservation and minimizing stormwater runoff (Dunnett et al., 2008). It is advised to use flora with high plant variety in rain gardens, such as taxonomically varied wildflower meadows and grasslands (Dunnett & Clayden, 2007). The inadequate understanding leading to insufficient plant diversity and improper plant choices negatively impacts the success of rain gardens (Shaw & Schmidt, 2003). Although taxonomically diverse plantings are important in rain garden design, they have mostly been underestimated. The diversity in plantings can influence local biodiversity and ensure the enduring beauty and stability of plant communities. Enhancing the variety of species in urban plantings could potentially optimize the ecosystem's ability to offer services, aligning with the concept that higher biodiversity supports the stability of community and ecosystem functions (Norton et al., 2016). Plantings that are taxonomically varied, such prairies and wildflower meadows, have more species richness than typical plantings. As mentioned earlier, incorporating these plantings in rain gardens offers multiple environmental advantages while also preserving the vegetation's role in managing stormwater. (Dunnett et al., 2008). Ordinarily, decorative grass, perennial flowers, and woody shrubs that thrive in both dry and wet situations are used to plant rain gardens. Perennial mixtures (especially blooming forbs and decorative grasses) are gaining popularity as alternative plant alternatives. Perennials, with their deep-rooted, long-lasting qualities, are ideal choices for rain garden planting. They enhance the ecological value of the garden and come in a wide range of colors, shapes, and sizes, making it easy to create visually stunning rain gardens, in addition to improving stormwater infiltration and evaporation (Hitchmough &Wagner, 2013).



Overall, the effectiveness of a rain garden largely depends on the careful selection of plant species suited to its unique conditions. Before starting the research related to plant selection, it's crucial to understand the role that plants play in rain gardens. These green infrastructure elements are designed to capture, filter, and absorb stormwater runoff from roofs, driveways, and other impermeable surfaces. Plants in rain gardens contribute to this process in several ways: infiltration, filtration, biodiversity and aesthetics. According to the findings of several studies, not all of the plants that are frequently suggested for inclusion in rain gardens performed well in testing, indicating the need for more area-specific rain garden plant study. Since then, studies in different regions are worth investigating.

### *2.3. Plant selection criteria*

When selecting plants for a rain garden, it's essential to consider various factors to ensure their suitability and success. Criteria for plant selection that have been discussed in literature is shown in Figure 3. First, choosing plant species that are well-suited to current climate conditions, including temperature ranges, precipitation levels, and soil types is a very important criterion (Yuan & Dunnett, 2018). Native plants are often a great choice because they have evolved to thrive in specific local conditions. Moreover, native plants are often more resilient in the face of changing weather patterns and require less maintenance, making rain garden more cost-effective to maintain (Malaviya et al., 2019). In local plant selection, accessibility is also important, meaning that they should be available in existing nurseries. For instance, in this study, not all local plants were accessible because they were not available in nurseries. Secondly, the effectiveness of rain garden plantings depends on the variety of plants used. A diverse selection of plants with different root systems, sizes, and growth patterns can help increase the overall water-holding capacity of a rain garden. This, in turn, leads to better stormwater management as different plants absorb water at varying rates. (Dunnett et al., 2008). Different plant species also uptake various nutrients and pollutants from the water. A diverse selection of plants ensures a more comprehensive filtration and purification process, leading to cleaner water that recharges groundwater or enters local water bodies (Steiner & Doom, 2012). Moreover, wide variety of native plants in a rain garden creates a rich ecosystem and the seasonal variations in color, texture, and height because of plant diversity create a landscape that is aesthetically pleasing (Dunnett et al., 2008).

Next criterion is the selection of plants based on rain gardens' different moisture zones. Like mentioned, rain gardens consist of the rain garden consists of three different zones. Each zone has different humidity levels and, accordingly, different plant requirements. Making planting recommendations based on how plants respond to and adapt to rain garden moisture dynamics is crucial (For instance, for wet zones, water-tolerant plants should be selected because they can absorb excess water during heavy rains and gradually release it back into the soil, preventing flooding and erosion (Dylewski et al., 2011). Next, selecting low-maintenance species to reduce the effort needed to upkeep the rain garden is also important. In urban public places, poor maintenance can transform rain gardens into unpleasant look. Low maintenance plants require less water, fertilizer, and pesticide use, promoting a more eco-friendly and sustainable approach (Yang et al., 2013). These plants reduce the amount of time and money spent on garden maintenance, making rain gardens more feasible for homeowners and communities with limited resources. Low maintenance plants tend to more resilient, contributing to the longevity and health of your rain garden (Dunnett & Clayden, 2007).



Finally, since rain gardens can be implemented at different areas such as along streets or roads, close proximity to buildings etc., each type of rain gardens are required unique planting design. For example, plants beside roads and streets must also be resistant to pollutants and splashes from the road (Shaw & Schmidt, 2003). Morever, rain gardens are required different needs in different regions such as cold climates, hot climates etc. More significantly, it is essential to be able to handle de-icing salt, which is frequently used in cold areas to maintain roads throughout the winter (Shaw & Schmidt, 2003). Since then, species for planting along roads in cold weather should be tolerant to salt.

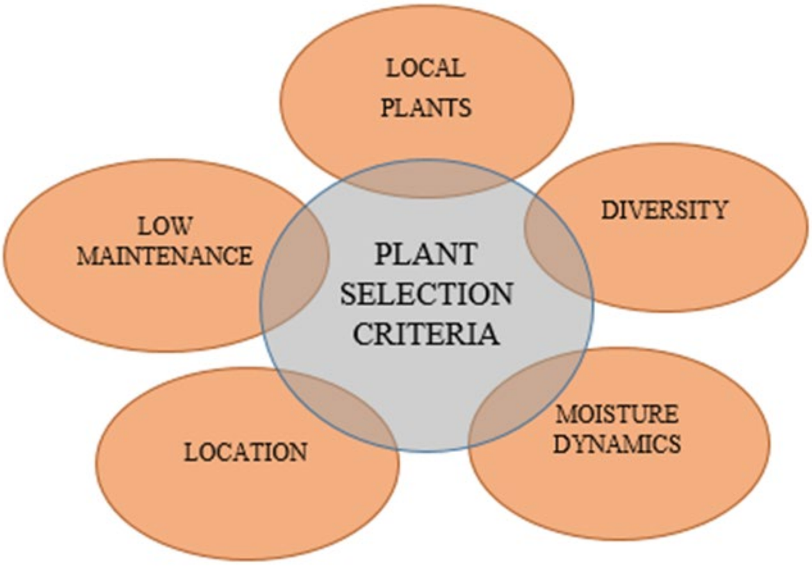


**Figure 3** Plant selection criteria for rain garden design

### *2.4. Planting Design Criteria*

Plants play a particularly important role in creating aesthetic and functional spaces, and they play an important role in softening hard surfaces and materials such as stones, walls and buildings used in landscaping. The physical attributes of plants—texture, form, size, and color—are what provide a landscape interest, diversity, and aesthetic appeal. According to Hannebaum (1998), plant design principles are form, texture, color, simplicity, variability, emphasis, balance and sequence. Ideas like color, texture, and size were also used to explore the principles of aesthetics. According to studies, these ideas affect people's choices for landscapes. When plants are used as compositions, certain design principles affect them. These principles play a role in many compositions. According to Hannebaum (1998), plant design principles can be listed as form, texture, color, simplicity, variability, emphasis, balance, sequence and scale.

Bell (2004) has stated that color is one of the most important landscape elements in visual perception. Human emotions may be revealed through different colors. Studies on ecological design have paid more attention to landscapes with different types of color selection (Harris et al., 2018). The most significant components of a landscape might be the colors of plants, texture, and shape to convey aesthetic impressions (Daniel, 2001). Color often draws the majority of people's attention when they first see a landscape. When evaluating and estimating the visual quality of a landscape, plant color has a big impact (Harris et al., 2018). Several authors have suggested that dense vegetation producing a complex landscape might be a more effective ecological process

(Bjerke et al., 2006). Its complex scene may also stimulate people's interest in its unexplored features, adding to its attraction (Kaplan, 1987). According to Bingqian et al (2020), proportion is also important in plant design. The size of the plants and their presence side by side in the compositions reveal their dimensionality in the designs.

Overall, there are many different physical attributes that increase the aesthetic value of planting design. Within the scope of the research, plant design principles such as color, density and proportion are discussed. Since rain garden design allow to use specific types of plants, the other design principles such as texture, form are not appropriate to discuss in the context of the current study. Since rain gardens have functional properties in addition to their aesthetic value, both of these criteria should be considered when designing them. Based on these identified principles, "density" planting design criteria is important when designing a rain garden. Firstly, a densely planted rain garden can be visually appealing, creating a vibrant landscape. (Hartman & Robison, 2017). Moreover, a dense planting ensures that rain gardens effectively capture and absorb stormwater runoff. The roots of plants help to improve its infiltration capacity and allowing water to drain more readily into the ground. A higher density of plants means more roots, which act as natural filters, trapping sediment and pollutants as water passes through the soil (Hartman & Robison, 2017). In summary, density plant design plays a crucial role in the effectiveness and functionality of rain gardens. By ensuring a high density of plants, designers can enhance stormwater management, prevent erosion, improve water quality, support biodiversity and enhance aesthetics.



Another design principle is "proportion". Properly proportioned plantings enhance the visual impact of the rain garden, creating focal points, contrasts, and spatial depth (Franti & Rodie, 2007). Moreover, consideration of plant proportions can influence maintenance requirements for the rain garden. Balancing fast-growing and slow-growing plants, as well as deciduous and evergreen species, can help maintain a consistent appearance and minimize the need for frequent pruning or replanting. The proportion of plants also affects the rain garden's ability to manage stormwater effectively. A balanced mix of plants with different root depths and growth habits helps maximize water absorption and infiltration, enhancing the garden's ability to mitigate flooding and reduce runoff. In summary, the proportion of plants is an important aspect of rain garden design that influences both its aesthetic appeal and functional performance.

"Color" criterion is also one of the important factors while designing rain garden. The colors of plants contribute significantly to the overall visual appeal of the rain garden. Incorporating plants with varying colors ensures that the rain garden remains visually interesting throughout the year. Moreover, certain flower colors are more attractive to pollinators such as bees, butterflies, and hummingbirds and this can attract pollinator to the rain garden, promoting biodiversity and ecosystem health. By carefully selecting plants with a variety of colors and arranging them thoughtfully within the garden, designers can create visually appealing and ecologically functional landscapes that enhance the overall quality of the environment. Finally, a rain garden design will be suggested based on plant selection and plant design criteria.

## 3. Methodology

### *3.1. Research design*

The steps in the research design are illustrated in Figure 4. These steps include area selection, plant selection and design of a rain garden. The first step was to identify a suitable area for a rain garden and assess its suitability for creating a rain garden based on its current condition. The next step was to find suitable plants for the rain garden in temperate climate, establish criteria for plant selection, and list the plants that meet the criteria for the selected area. Finally, a rain garden design that met all the criteria was suggested. These stages are three important components of the current study.

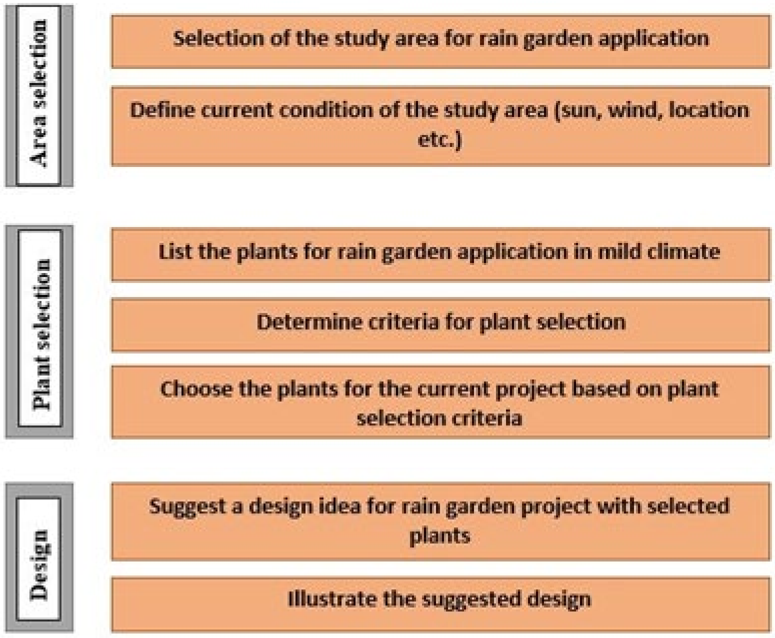


**Figure 4** Research design

### *3.2. Study area*

The Sponge City Izmir initiative, introduced by the Izmir Metropolitan Municipality, seeks to mitigate flooding through the collection of rainwater. Since the importance of public participation has been realized in the context of Sponge City, as part of the upcoming second project, approximately 10,000 citizens will be provided with the necessary plants to create rain gardens as part of their implementation. For this study, İzmir Kâtip Çelebi University was selected as study area. The implementation of a rain garden will be carried out on the campus within the scope of an ongoing project. This project to be undertaken on the campus could contribute as an example to the ongoing work led by Izmir Metropolitan Municipality.

After performing site assessments at different places on the IKCU campus, the research site was decided upon as being an inside space close to the Science and Engineering Building (Figure 5). Three key considerations served as the foundation for choosing this location. First and foremost, the area's slope and soil composition were significant physical characteristics that may have an influence on how well a rain garden was implemented. The research site's appropriateness for a rain garden was established by an in-depth soil investigation and slope assessment. Second, the choice of the research site was significantly influenced by an area's physical and visual accessibility. In order to guarantee easy access and aesthetic integration with the next building, the study site that was chosen underwent a thorough evaluation. When choosing the research location for a rain garden, microclimate conditions were still another important consideration. While some of the plants meant for gardens need full sunlight, others thrive in partial shade. The predominant breeze on campus has the potential to readily impact several plants.


**Figure 5** The selected area for rain garden design

Izmir's climate is defined as temperate and moderate climate. In comparison to the summer, Izmir receives more precipitation during the winter season. Izmir has average annual temperatures of 17.1 °C (62.7 °F) and rainfall totals 742 mm (29.2 inches) each year (Figure 6). Since Izmir has a moderate climate condition, plants that are suitable for this climate were selected for rain garden design. The area for the rain garden was determined by calculating the roof area where water would collect. By estimating the average rainfall and surface runoff, it was calculated that an approximate area of 75 square meters would be needed for the rain garden.

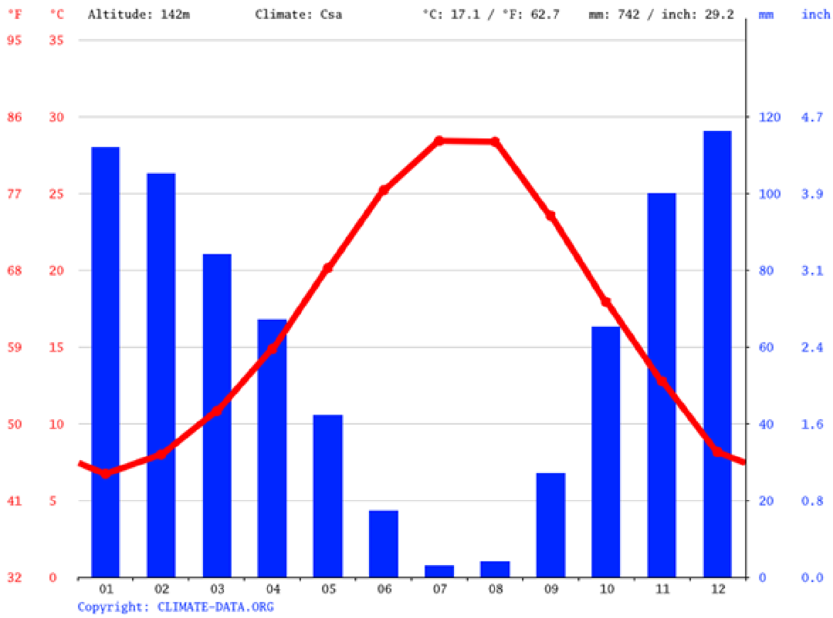


**Figure 6** Climate condition in Izmir (tr.climate-data.org)

### 3.3. Plant selection

Plant selection for the project was made according to the criteria mentioned above: climate conditions, location of the rain garden, different moisture zones, plant diversity, and plants required low maintenance. Plants which are suitable for temperate climate conditions were listed below after a detailed investigation (Table 1). Moreover, they are categorized as their light and moisture range. These plants are the most preferred rain garden plants in temperate climate conditions (O'Farrell, 2021; Yuan, 2016). Yuan (2016)'s study give the detailed information about rain garden plants and share the plant lists based on different conditions such as sunlight requirements (Steiner & Domm, 2012), moisture tolerance (Woelfle-Erskine & Uncapher, 2012) etc. Table 1 was created after examining suggested plant lists. Since this project will be implemented next to a building and collecting water from roofs, the requirements such tolerant to salt, vehicle emissions etc. for the implementation for rain gardens along roads or streets were not taken into consideration.

**Table 1** List of plants in temperate climate condition for rain garden

| | | **Light Range** | | | **Moisture Range** | | | |
|---|---|---|---|---|---|---|---|---|
| **Scientific name** | Common name | Full Sun | Partial Sun/Shade | Full Shade | Dry | Moderate | Wet | Current Design |
| ***Acorus gramineus*** | Sweetflag | X | X | X | X | X | X | |
| ***Andropogon gerardii*** | Big bluestem | X | X | | X | X | | |
| ***Aronia arbıtifolia*** | Red Chokeberry | X | X | | | X | | |
| ***Asclepias tuberosa*** | Butterfly milkweed | X | | | X | X | | |
| ***Aster laevis*** | Smooth Aster | X | X | | | X | | X |
| ***Athyrium filix-femina*** | Lady Fern | | | X | | | X | |
| ***Cistus creticus*** | Cretan Rockrose | X | X | | X | X | | X |
| ***Cercis occidentalis*** | Western Redbud | X | X | | X | X | | X |
| ***Cyperus papyrus*** | Paper Plant | X | X | | | | X | X |
| ***Cornus 'Midwinter Fire'*** | Bloodtwig | X | X | | | X | X | X |
| ***Cortaderia Selloana*** | Pampas grass | X | X | | X | X | | X |
| ***Cyperus longus*** | Merebook ponf plants | X | X | X | | | X | |
| ***Juncus acutus*** | Spiny rush | X | | | | X | X | |
| ***Juncus effusus*** | Soft Rush | X | X | | X | X | | X |
| ***Heuchera Americana*** | Alumroot | | X | X | | X | X | |
| ***Ilex verticillata*** | Winterberry | X | X | | | | X | X |
| ***Iris douglasiana*** | Douglas Iris | X | X | | X | X | | |
| ***Lobelia cardinalis*** | Cardinal flower | | | X | | X | X | |
| ***Osmunda cinnamomea*** | Cinnamon Fern | X | X | | | X | X | |
| ***Pennisetum alopecuroides*** | Fountain grass | X | X | | X | X | | X |
| ***Phlox divaricata*** | Woodland Phlox | | X | X | | X | X | |
| ***Physocarpus capitatus*** | Pacific ninebark | X | X | | | X | X | |
| ***Ribes sanguineum*** | Red-flowering currant | X | X | | | X | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Ruscus aculeatus*** | Butcher's broom | | X | X | X | | | X |
| ***Sambucus canadensis*** | Elderberry | X | X | | X | X | | |
| ***Lavandula angustifolia*** | English Lavender | X | X | | X | X | | X |
| ***Lythum salicaria*** | Purple Loosetrife | X | X | | | X | X | |
| ***Miscanthus sinensis*** | Japanese silver grass | X | X | | | X | X | |
| ***Typha Latifolia*** | Broadleaf Cattail | X | X | | | | X | X |
| ***Vaccinium ovatum*** | Evergreen huckleberry | X | X | X | | X | X | |
| ***Vitex angus-castus*** | Chaste Tree | X | X | | | X | | X |



## 4. Results and Discussion

In the current study, plants were selected based on rain garden plant selection criteria. There are many different plants which can be used in a rain garden design but since this rain garden design will be implemented in a temperate climate condition, plants are listed in this climate condition. The next step was to check if the listed plants can be found in the city of Izmir. The rain garden design will be implemented in İzmir Kâtip Çelebi University Cigli Campus. Based on this, nurseries which is close to 15 mil away from the district of Cigli were reached out via phone or email to reduce the transportation cost. Only nurseries which belong to government or Ministry of Forestry were called and the private nurseries were elimanted since the project only have a limited budget to purschase plants. There was only one nursery in Karsiyaka belong to Ministry of Forestry and four nurseries belong to municipalities in Karsiyaka, Cigli, Bornova, Karabaglar, Guzelbahce. Based on this, the plants which can be available were marked in Table 1. Only fourteen of them were available in the context of this study. The detailed information with these selected plants were shared in the below (Table 2).

**Table 2** Selected plants for rain garden project

| Plant name | Type | Color | Maintenance | Height | Area | Season of Interest |
|---|---|---|---|---|---|---|
| **Zone 1** | | | | | | |
| ***Cortaderia selloana*** | Ornamental Grasses | | Low | 180 cm-3 m | 180-240 cm | Summer(Late)<br>Fall<br>Winter |
| ***Juncus effusus*** | Ornamental Grasses, Perennials | | Low | 60-120 cm | 60-120 cm | Spring<br>Summer<br>Fall<br>Winter |
| ***Pennisetum alopecuroides*** | Ornamental Grasses | | Low | 90-120 cm | 90-120 cm | Spring(Mid, Late)<br>Summer(Early, Mid, Late)<br>Fall |
| ***Ruscus aculeatus*** | Evergreen Shrub | Red (fruit) | Low | 40-75 cm | 50-100 cm | Spring<br>Winter |
| **Zone 2** | | | | | | |
| ***Aster laevis*** | Perennials | Purple | Low | 60-120 cm | 30-60 cm | Summer (Late)<br>Fall |
| ***Cistus creticus*** | Shrubs | Pink | Low | 60-150 cm | 60-90 cm | Spring (Late)<br>Summer |
| ***Cercis occidentalis*** | Shrubs | Pink | Low | 3-4.6 m | 3-4.6 m | Winter (Late)<br>Spring |
| ***Lavandula angustifolia*** | Shrubs | Purple | Average | 60-90 cm | 80-90 cm | Spring (Late)<br>Summer (Early, Mid) |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Vitex angus- castus*** | Shrubs | Purple | Low | 120 cm-4.6 m | 120 cm-3.7 m | Summer (Mid, Late) |
| **Zone 3** | | | | | | |
| ***Cyperus papyrus*** | Perennials | | Low | 150cm-3.7 m | 60-150 cm | |
| ***Cornus 'Midwinter Fire'*** | Shrubs | Red | Low | 150-180 cm | 150-180 cm | Spring (Late) |
| ***Ilex verticillata*** | Shrubs | Red (fruit) | Low | 180 cm-3 m | 180cm-3 m | Spring(Early, Late)<br>Summer<br>Fall<br>Winter |
| ***Typha latifolia*** | Perennials | | Average | 90-210 cm | 30-60 cm | Spring<br>Summer<br>Fall<br>Winter |

Based on the listed plants which are suitable for the current project and plant design criteria discussed in literature review, a rain garden design was suggested (Figure 3). This design includes nine plants from the list. For zone 1(dry zone), *Cortaderia selloana, Juncus effusus and Pennisetum alopecuroides* were selected. These plants are drought-tolerance since the zone 1 is the lowest moisture layer. For zone 2 (moderate zone), *Lavandula angustofolia, Aster laevis and Cistus cretius* were selected. This zone was suitable for plants that can endure intermittent periods of standing water or are resilient to occosional drought. For zone 3 (wet zone), *Ilex verticillata, Cornus 'Midwinter Fire'* and *Typha latifolia* were selected. These plants are water-resistant and capable of withstanding sudden floods. One of the most crucial criteria in rain garden selection, which is the selection of plants based on different zones, has been met. Moreover, these plants are suitable for the selected areas as they are tolerant to partial sun or shade. Another criterion for plant selection, which is low maintenance, has also been fulfilled. Choosing low-maintenance plants reduces the necessity for extensive attention and resources. Native plants, once rooted, usually demand less watering, fertilizing, and pest management, presenting cost-efficient and environmentally friendly options for rain gardens. Only *Lavandula angustifolia* and *Typha latifolia* are needed average maintenance compare to other plants in the list.

Choosing plant species that are well-suited to current climate conditions was also discussed as an important factor in rain garden plant selection. Choosing plants that are native or well-suited to the environment not only helps rain gardens handle water efficiently but also nurtures local ecosystems, enriches biodiversity, and adds to the aesthetic appeal of the area. Their resilience and adaptability to diverse conditions establish them as crucial elements of sustainable and flourishing urban settings. For this purpose, plants which were suitable for Izmir weather conditions were selected and their availability was confirmed by contacting local nurseries in Izmir. Only available plants were chosen and included in the current design. Finally, since the efficiency of rain garden relies on the variety of plants utilized, it is important to choose a diverse selection of plants. Considering this criterion, plants of varying sizes and different root systems were selected to aim for an increased water retention capacity in the rain garden.

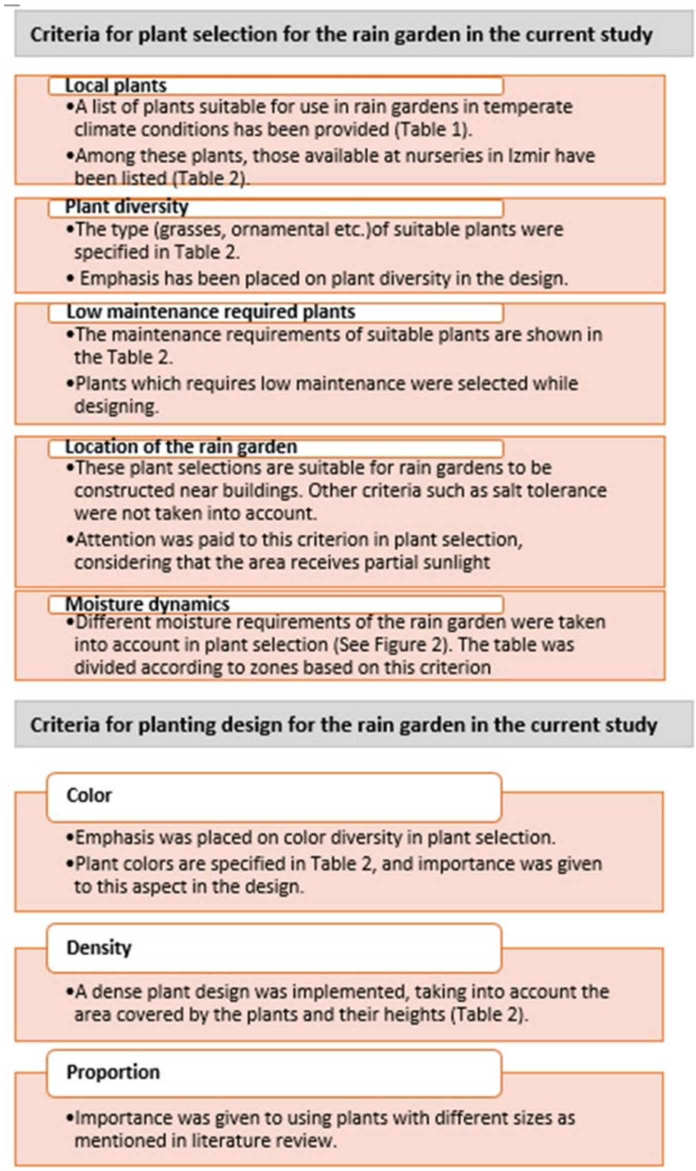


**Figure 7** Summary of the criteria considered in the rain garden design in the current study

After all the plant selection criteria was met, plants were designed based on plant design criteria discussed in the literature (Figure 7). Since different types of color selection has been gained more attention in ecological design, plants with diverse color palettes were selected such as *Lavandula angustifolia, Ilex verticillata, Cistus creticus* etc. By including plants that bloom at different times and possess diverse colors, the rain garden maintains its attractiveness in every season. Moreover, high-density planting design was discussed as an important factor to attract people's attention. Accordingly, while designing the rain garden, plants of varying heights and spacing were selected to create a sense of density such as *Ilex verticillata, Juncus effusus, Typha latifolia* etc. Proportion is a significant factor in plant design as well. Since then, when designing, attention was paid to ensuring that the plants harmonize proportionally in terms of their sizes. Additionally, choosing perennial plants such as *Aster laevis, Juncus effusus* and *Cyprus papyrus* with long lifespans reduces the need for frequent replanting, contributing to the garden's sustainability.

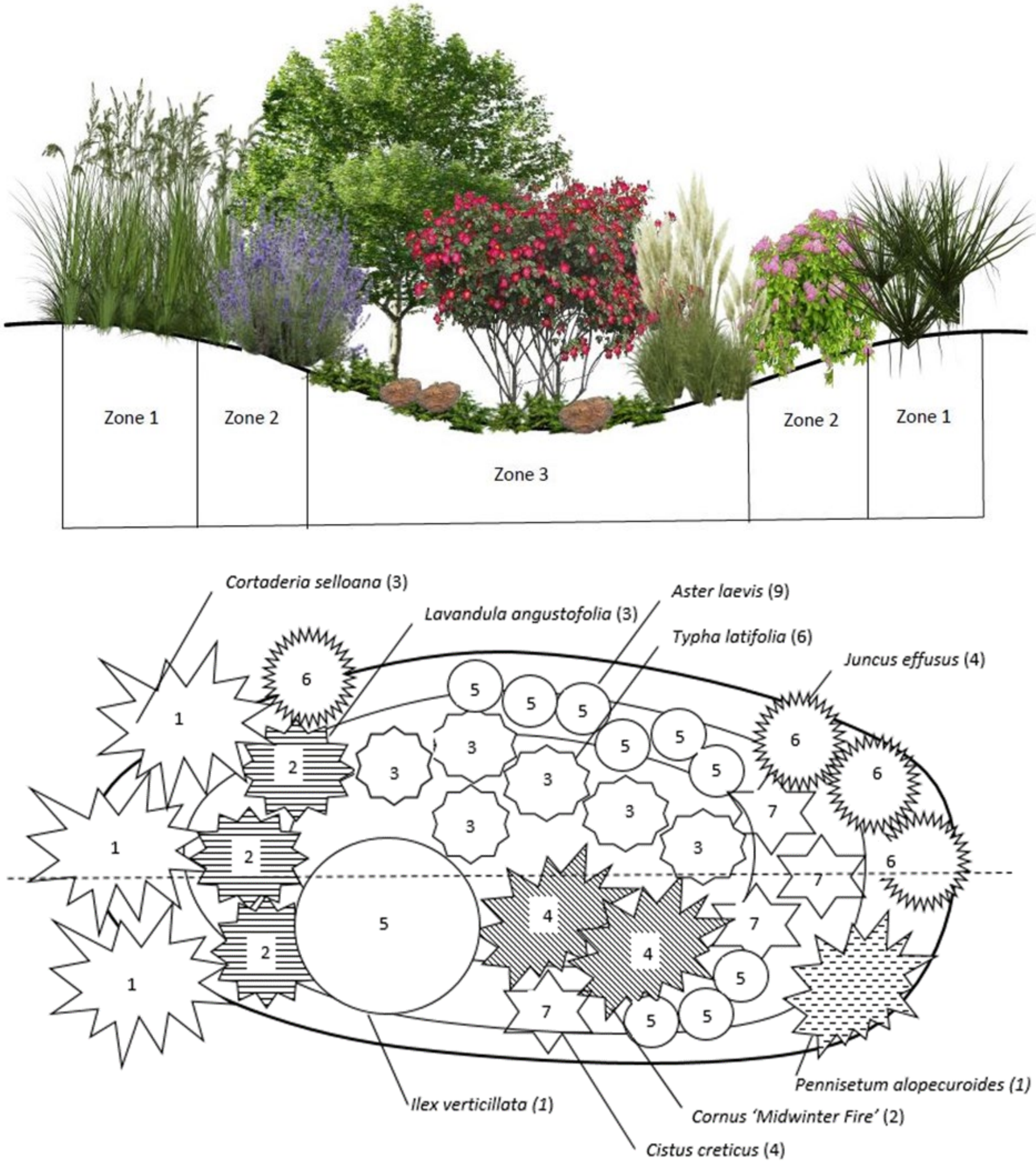


**Figure 8** Suggested rain garden design

Taking all these criteria into account, the rain garden design was developed (Figure 8). In other words, it was designed to meet both the plant selection criteria and the plant design criteria. The numbers and names of the plants are indicated on the image. This rain garden will be built next to the building to collect water from the roof. As seen in the image, emphasis was placed on color diversity, proportion, and density in the design. This design has been created to fit current conditions such as temperate climate and being constructed next to the building. Other criteria, such as different climate conditions or alternative rain garden locations, have not been taken into consideration.

## 5. Conclusion

Rain gardens provide a balance between nature and urban infrastructure, offering multifaceted benefits that increase urban resilience. Plant selection is a crucial step in the creation of a successful rain garden. Plants serve as the key element of the rain gardens' functionality and also, provide ecological and aesthetical value. Choosing the right plant species is essential for rain gardens as it directly impacts their appearance and effectiveness in functioning properly. Careful consideration of plant species based on their ability to thrive in varying moisture conditions, root structures, sizes, and maintenance requirements directly influences the garden's efficiency in water retention, filtration, and supporting biodiversity. The right plant selection contributes not only to the garden's visual value but also to its resilience, fostering a sustainable ecosystem and enhancing its capacity to mitigate stormwater runoff.

Because different plant selections are required in different climate conditions, studies conducted in various regions will be valuable. This study conducted in Izmir province will contribute to the literature and serve as a guiding resource for municipalities in plant selection, offering valuable insights. This study proposes species distribution in various zones of rain gardens implemented next to a building in temperate climates as its primary result. Nevertheless, additional research is necessary to confirm these recommendations. The adequacy of the plants chosen in this study for integration into rain gardens next to buildings cannot be completely determined until their reactions are assessed after implementation. Moreover, exploring the behavior of these species in rain gardens located in diverse regions with varying temperate climates would be beneficial. Additionally, investigating the impact of planting time could provide valuable insights. Springtime planting might enhance initial plant survival rates by allowing enough time for the development of a strong root system before facing autumn floods. Yet, considering that flooding might occur in the summer as well, the best timing for planting in rain gardens could rely on the specific climatic conditions during the establishment year. Further research might evaluate the effectiveness of this suggested rain garden after its implementation and provide a detailed investigation into how the plants evolve over time.

In conclusion, the importance of choosing the right plants for rain gardens cannot be emphasized enough. These thoughtfully selected plants are the main components of an efficient ecosystem that can handle stormwater runoff while fostering biodiversity and ecological balance. Their capacity to adjust to local environments, increase water absorption, nurture wildlife, and require minimal maintenance makes them vital elements of sustainable and resilience urban environments.


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## Resume

*Dr. Burcin Burcu Dogmusoz received her bachelor's degree in Landscape Architecture from Ankara University. After graduation, she earned a full scholarship from the Republic of Turkish Ministry of National Education, which funded both her master's and Ph.D. degrees in United States. She completed her master's degree in Landscape Architecture and Ph.D. at North Carolina State University. Currently, she is a lecturer in the department of City ad Regional Planning at Izmir Katip Celebi University. Her research focuses on green inftastructure strategies. So far, she has participated in research projects and studies, as well as well-known international conferences.*