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Rain Garden Design for Sustainable Stormwater Management and Environmental Awareness in University Campuses: A Case Study of Bursa Technical University

Üniversite Kampüslerinde Sürdürülebilir Yağmur Suyu Yönetimi ve Çevresel Farkındalığın Geliştirilmesine Yönelik Yağmur Bahçesi Tasarımı: Bursa Teknik Üniversitesi Örneği

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Abstract
Climate change intensifies water management problems in urban areas by increasing the risks of both droughts and floods. In this context, rain gardens, developed as nature-based solutions, have emerged as important components of urban blue infrastructure systems. The aim of this study is to evaluate the potential of rain garden applications in university campuses in terms of both urban water management and environmental awareness. Bursa Technical University Mimar Sinan Campus was selected as the study area, and field observations, spatial analyses, and a questionnaire survey conducted with Bursa Technical University students were carried out within the scope of the research. The findings revealed that university students have limited knowledge regarding the concept of rain gardens; however, such applications have a high potential to increase environmental awareness. Within the study, suitable areas for rain garden implementation on the campus were identified, and blue infrastructure design strategies were developed. The study demonstrates that university campuses can serve as important pilot areas for sustainable water management and environmental awareness development.

Öz
İklim değişikliği, kuraklık ve taşkın risklerini artırarak kentsel alanlarda su yönetimi sorunlarını derinleştirmektedir. Bu bağlamda, doğa temelli çözümler olarak geliştirilen yağmur bahçeleri, kentsel mavi altyapı sistemlerinin önemli bileşenleri olarak öne çıkmaktadır. Bu çalışmanın amacı, üniversite kampüslerinde yağmur bahçesi uygulamalarının hem kentsel su yönetimi hem de çevresel farkındalık açısından potansiyelini değerlendirmektir. Çalışma alanı olarak Bursa Teknik Üniversitesi Mimar Sinan Kampüsü seçilmiş; araştırma kapsamında arazi gözlemleri, mekânsal analizler ve Bursa Teknik Üniversitesi öğrencileriyle gerçekleştirilen anket çalışmaları yürütülmüştür. Elde edilen bulgular, üniversite öğrencilerinin yağmur bahçesi kavramına ilişkin bilgi düzeylerinin sınırlı olduğunu, ancak bu tür uygulamaların çevresel farkındalığı artırma açısından yüksek bir potansiyele sahip olduğunu ortaya koymuştur. Çalışma kapsamında kampüs içerisinde yağmur bahçesi uygulamaları için uygun alanlar belirlenmiş ve mavi altyapı tasarım stratejileri geliştirilmiştir. Sonuçlar, üniversite kampüslerinin sürdürülebilir su yönetimi ve çevresel farkındalığın geliştirilmesi açısından önemli pilot uygulama alanları olarak değerlendirilebileceğini göstermektedir.

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INTRODUCTION

Climate change has significantly altered the urban hydrological cycle, leading to irregular precipitation regimes, increased frequency of extreme weather events, and growing risks of both droughts and floods (Chukwuma, 2025). Rapid urbanization and the expansion of impervious surfaces such as roads, parking lots, and buildings prevent rainwater infiltration, accelerate surface runoff, and place considerable pressure on conventional urban drainage systems. As a result, traditional engineering-based stormwater management approaches have become increasingly insufficient under changing climatic conditions. Reports published by the Intergovernmental Panel on Climate Change (IPCC, 2021) emphasize that climate change intensifies hydrological imbalances, particularly in urban areas where impermeable surface ratios are continuously increasing. These processes not only increase flood risks but also reduce groundwater recharge, thereby deepening water scarcity and drought-related problems. In Türkiye, similar trends have been observed in recent years, where irregular precipitation patterns, rapid urban growth, and uncontrolled land-use changes have simultaneously increased drought vulnerability and urban flood risks (Akın & Akın, 2007; Yücel, 2015). Consequently, urban water management is no longer considered solely an infrastructure issue, but rather a multidimensional planning and ecological resilience challenge. Recent studies emphasize that conventional grey infrastructure systems alone are insufficient for addressing climate-induced hydrological risks, highlighting the necessity of integrating sustainable urban drainage systems and nature-based approaches into urban planning processes (Kaçmaz, 2021; Kocabaş, 2024).

One of the most critical consequences of climate change is the simultaneous occurrence of droughts and floods within the same geographical regions. This phenomenon, often referred to in the literature as the "drought–flood paradox," reflects the disruption of the natural hydrological balance. According to the IPCC (2021), increasing atmospheric temperatures accelerate evaporation and increase the atmosphere's moisture-holding capacity, resulting in more irregular yet more intense precipitation events. Long dry periods interrupted by sudden and extreme rainfall events have therefore become increasingly common in many urban environments. In highly urbanized watersheds, increasing impervious surfaces reduce infiltration capacity while accelerating surface runoff. This process transforms short-duration rainfall into rapid flood events while simultaneously limiting groundwater recharge and intensifying drought conditions. Based on literature, conventional drainage systems, which focus primarily on rapidly conveying stormwater away from urban areas, disrupt the natural water cycle and further exacerbate hydrological instability. Recent extreme rainfall events and subsequent water shortages experienced in Türkiye clearly illustrate this dual-risk structure.

In response to these challenges, contemporary urban water management approaches increasingly emphasize the importance of retaining, infiltrating, storing, and reusing rainwater at its source rather than rapidly discharging it from urban systems. Within this framework, Nature-Based Solutions (NbS), Sustainable Urban Drainage Systems (SUDS), Low Impact Development (LID), and Water Sensitive Urban Design (WSUD) approaches have gained considerable importance. These approaches aim to integrate natural hydrological processes into urban environments while simultaneously improving ecological resilience and environmental sustainability. Recent studies published in landscape and urban ecology literature further emphasize that nature-based stormwater management systems play a critical role not only in flood mitigation but also in enhancing urban biodiversity, ecological connectivity, thermal comfort, and environmental resilience in rapidly urbanizing cities (Wang et al., 2024; Kumar et al., 2025). Rain gardens, bioswales, and other blue-green infrastructure components are increasingly recognized as multifunctional urban landscape systems that integrate hydrological performance with ecological and social benefits (Gill et al., 2007; Liu & Jensen, 2018).

The European Commission (2015) defines Nature-Based Solutions as approaches inspired and supported by natural processes that provide sustainable and multifunctional solutions to societal challenges. Similarly, the International Union for Conservation of Nature (Cohen et al., 2016) emphasizes that nature-based approaches contribute to ecosystem restoration, sustainable management, and climate adaptation strategies. Within this context, WSUD approaches prioritize the integration of rainwater into the natural hydrological cycle by promoting infiltration, reducing runoff, and improving water quality (Fletcher et al., 2015). Likewise, Low Impact Development strategies focus on capturing, retaining, and delaying stormwater runoff at its source to minimize hydrological disturbances and improve urban resilience.

Among these nature-based strategies, rain gardens have emerged as one of the most widely implemented and spatially adaptable sustainable drainage components. Rain gardens are vegetated landscape systems specifically designed to collect, temporarily store, infiltrate, and filter stormwater runoff generated from impervious urban surfaces. Beyond their hydrological functions, rain gardens also contribute to biodiversity enhancement, microclimatic regulation, ecological restoration, and visual landscape quality. Recent bibliometric and applied research studies demonstrate that rain gardens significantly contribute to runoff reduction, pollutant filtration, biodiversity support, and microclimatic improvement while simultaneously increasing the visual and educational value of urban open spaces (Wang et al., 2024). Furthermore, studies conducted in campus environments highlight that rain gardens can function as visible environmental learning tools that strengthen ecological awareness among university students (Doğmuşöz, 2024; Kaçmaz, 2021).

In recent years, the integration of nature-based solutions into planning and landscape design processes has also gained increasing attention in Türkiye. Such approaches are considered complementary to traditional engineering-based infrastructure systems and offer significant potential for enhancing urban resilience against climate change impacts. University campuses possess considerable potential for implementing and testing sustainable drainage systems due to their extensive open spaces, semi-public character, and flexible spatial structures.

In recent years, campuses have increasingly been considered experimental environments for climate adaptation and green infrastructure applications. Beyond their physical functions, rain gardens and other blue-green infrastructure elements contribute to environmental education by transforming ecological processes into visible and experience-based learning opportunities for students and campus users (Church, 2015; Kazanç & Esringü, 2024).

Although rain gardens have been widely investigated as sustainable stormwater management systems, studies integrating hydrological assessment, spatial suitability analysis, and environmental awareness evaluation within university campuses remain limited, particularly in Türkiye. Existing studies generally focus either on technical stormwater performance or ecological design aspects, while the educational role of rain gardens in campus environments is rarely examined. Therefore, this study integrates spatial analysis, hydrological assessment, and questionnaire-based environmental awareness evaluation to develop a rain garden proposal for Bursa Technical University Mimar Sinan Campus.

MATERIALS AND METHODS

Research Framework

This study was conducted to evaluate the potential of rain garden applications as a sustainable stormwater management strategy and an environmental awareness tool within university campuses. The methodological framework consisted of six consecutive stages: (1) literature review, (2) field observation and spatial analysis, (3) questionnaire survey, (4) site selection, (5) hydrological assessment, and (6) rain garden design proposal (Figure 1). Initially, a comprehensive literature review was carried out to examine climate change adaptation strategies, sustainable stormwater management approaches, blue–green infrastructure systems, and rain garden applications. Subsequently, field observations and spatial analyses were conducted to identify hydrological characteristics and runoff-generating areas within the campus. A questionnaire survey was then implemented to assess students’ awareness and perceptions regarding climate change, water management, and rain gardens. Based on the findings obtained from spatial analyses and survey results, suitable locations for rain garden implementation were determined. Hydrological calculations were performed to estimate runoff volume and evaluate the storage capacity requirements of the proposed system. Finally, a rain garden design proposal was developed by integrating hydrological performance criteria with landscape design principles. The overall methodological framework of the study is presented in Figure 1.

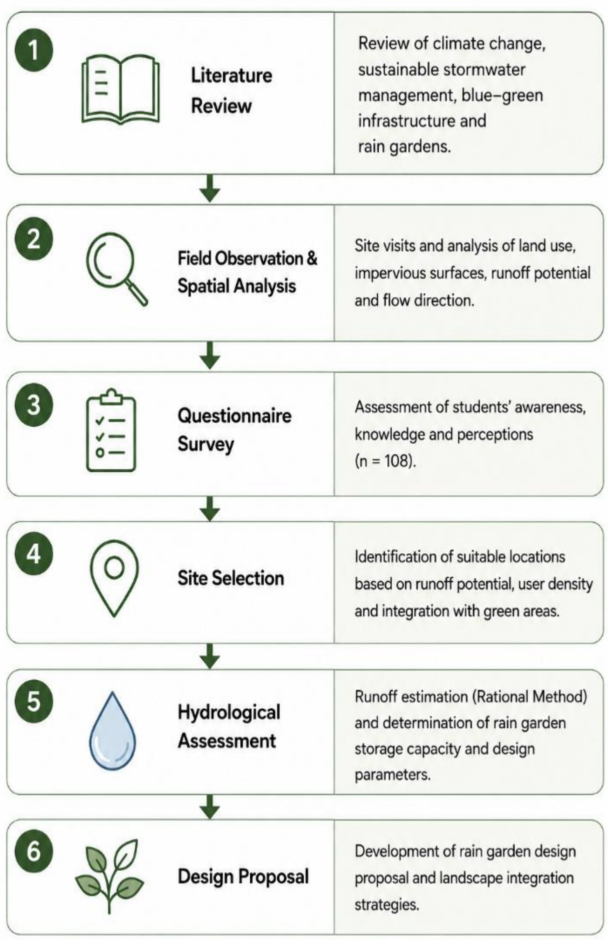

Figure 1. Methodological framework of the study

Study Area

The study was conducted at Bursa Technical University (BTU) Mimar Sinan Campus, located in the Yıldırım district on the eastern side of Bursa, Türkiye (40.1866° N, 29.1044° E) (Figure 2). The campus is integrated with the urban transportation network through its proximity to the Bursa–Ankara highway (D200/E90) and the BursaRay light rail system, providing high accessibility for students and visitors. Bursa exhibits a transitional climate influenced by both Mediterranean and Black Sea climatic conditions. Summers are generally hot and relatively dry, whereas winters are mild and rainy. Annual precipitation ranges between approximately 700 and 800 mm and is concentrated mainly during autumn and winter periods. The uneven temporal distribution of rainfall increases the importance of sustainable stormwater management practices and nature-based solutions within urban environments.

The campus is situated within the transition zone between the northern foothills of Uludağ Mountain and the Bursa Plain and presents partially sloped topographic conditions. These characteristics influence runoff generation, infiltration processes, and stormwater accumulation patterns across the site. Due to its extensive impervious surfaces, open green areas, pedestrian circulation network, parking facilities, and educational function, the campus provides a suitable environment for evaluating rain garden applications and environmental awareness related to sustainable water management.

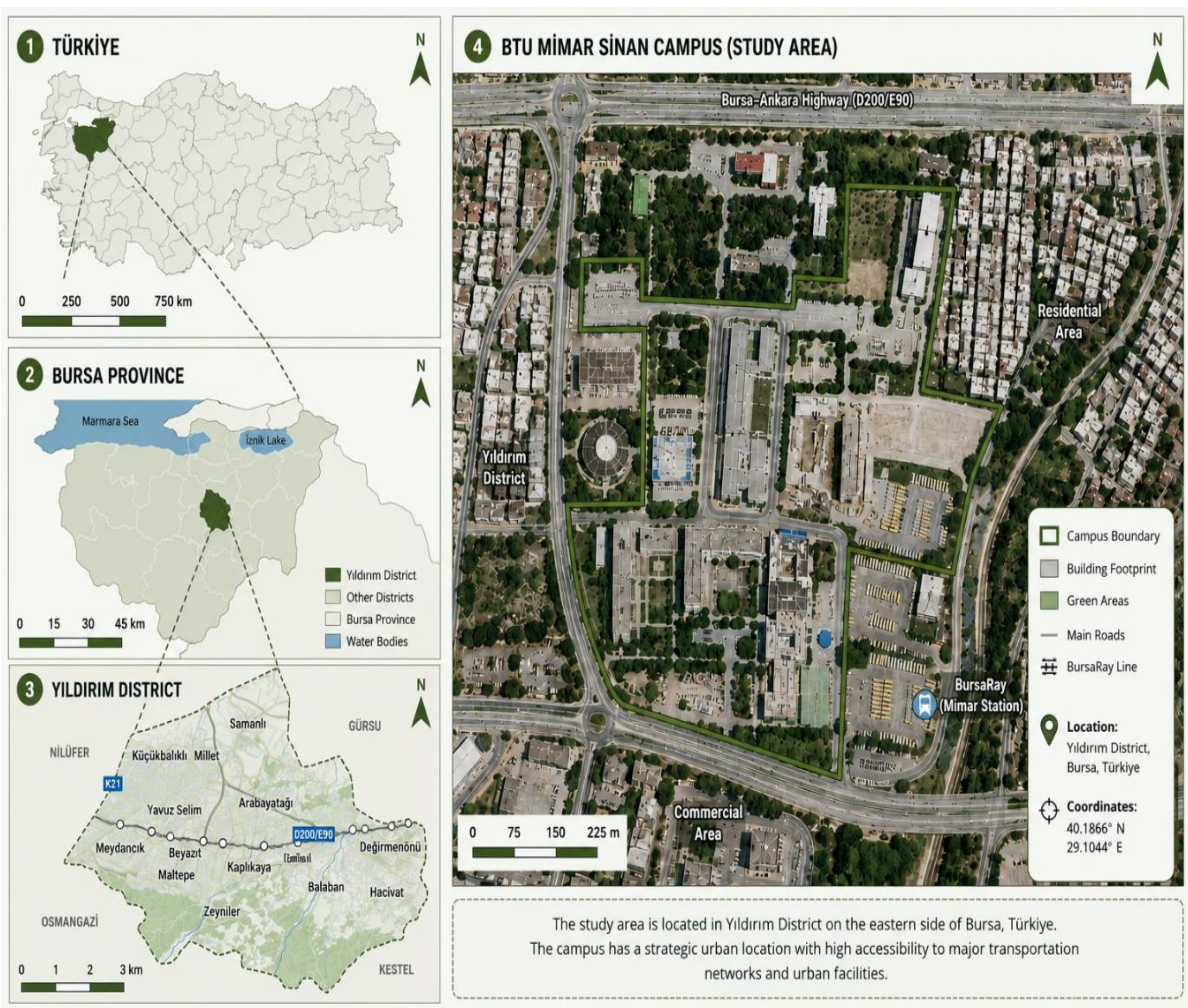

Figure 2. Location and spatial context of Bursa Technical University Mimar Sinan Campus

Spatial Analysis

Field observations and spatial analyses were conducted to investigate land-use characteristics, impervious surface distribution, and hydrological conditions within the campus environment. Site visits focused on identifying buildings, transportation corridors, parking areas, pedestrian routes, green spaces, and locations with runoff accumulation potential. The analyses revealed that transportation corridors, parking lots, service roads, and other impervious surfaces generate substantial surface runoff during rainfall events. In contrast, existing green spaces provide opportunities for infiltration and ecological integration. Particular attention was given to areas where runoff generated from impervious surfaces could be intercepted and directed toward nature-based stormwater management systems. The findings obtained from field observations formed the basis for subsequent site selection and rain garden design stages.

Questionnaire Survey

A questionnaire survey was conducted to evaluate students' awareness, knowledge, and perceptions regarding climate change, water resources, drought, and rain gardens. The survey was implemented on a voluntary basis among students studying at Bursa Technical University Mimar Sinan Campus. A total of 108 students participated in the study, representing various academic departments and providing an interdisciplinary sample structure. The questionnaire consisted of three sections. The first section collected demographic information, including age, gender, academic department, and class level. The second section assessed participants' knowledge and awareness regarding climate change, the impacts of climate change on water resources, drought-related education, familiarity with rain gardens, and observations of rainwater management practices on campus. The third section evaluated participants' opinions and attitudes toward rainwater harvesting and rain garden implementation within university campuses (Table 1). The collected data were analyzed using descriptive statistical methods. Frequency and percentage distributions were calculated and presented through tables and graphical representations.

Table 1. Questionnaire structure

Section	Content
Demographics	Age, gender, department
Awareness	Climate change, drought, rain gardens
Attitudes	Support for rain garden implementation

Site Selection

Potential locations for rain garden implementation were determined using a multi-criteria assessment approach. The evaluation considered both hydrological and spatial factors to ensure that the proposed intervention could effectively manage stormwater while remaining visible and accessible to campus users. The site selection process was based on field observations and qualitative spatial assessment, following criteria commonly used in green infrastructure and bioretention planning studies (Davis et al., 2009; Ahiablame et al., 2012). The site selection process was based on the criteria in Table 2.

Based on these criteria, the northern entrance zone of the campus was identified as the most suitable location for rain garden implementation due to its high runoff generation potential, strategic location within the circulation system, and visibility to a large number of campus users.

Table 2. Site selection criteria used for rain garden implementation

Criteria	References
Surface runoff potential	Davis et al. (2009); Ahiablame et al. (2012)
Runoff flow direction	Davis et al. (2009)
Impervious surface concentration	Shuster et al. (2005)
User density and visibility	Church (2015); Kazanç & Esringü (2024)
Accessibility	Church (2015); Liu & Jensen (2018)
Integration with existing green spaces	Gill et al. (2007); Liu & Jensen (2018)

Hydrological Assessment

The hydrological performance of the proposed rain garden system was evaluated using the Rational Method, one of the most widely applied approaches for estimating peak runoff in small urban catchments and stormwater management studies (Chow et al., 1988; Akan & Houghtalen, 2003). The method has also been frequently used in low-impact development and bioretention design studies (Davis et al., 2009; Ahiablame et al., 2012). The runoff discharge was calculated using: $Q = C \times i \times A$ (Akan & Houghtalen, 2003).

- Q = runoff discharge (m^3/s)
- C = runoff coefficient
- i = rainfall intensity
- A = drainage area

Within the scope of the study, the drainage area contributing to the selected site was calculated as 240 m^2. The runoff coefficient was accepted as 0.90 due to the predominantly impervious surface characteristics of the area. Rainfall intensity was assumed as 100 mm h^{-1} as a conservative design storm scenario frequently adopted in small-scale bioretention and stormwater management studies (Davis et al., 2009; Ahiablame et al., 2012). This value was adopted as a design storm scenario for demonstration purposes. The hydrological assessment served as a basis for estimating runoff generation and guiding the sizing of the proposed rain garden system. Rather than functioning as a full-scale stormwater management facility, the proposed rain garden was designed as a demonstration-scale pilot application intended to enhance environmental awareness, illustrate nature-based stormwater management practices, and provide localized runoff retention within the campus environment. Accordingly, the design parameters were determined by considering both hydrological functionality and educational landscape value.

Rain Garden Proposal

Based on the results of spatial analyses, site selection, and hydrological assessment, a rain garden design proposal was developed for the selected campus location. The proposed system was designed as a multilayered green infrastructure element consisting of vegetation soil, filtration media, gravel drainage layers, geotextile materials, and perforated drainage pipes. Native and climate-adapted plant species were recommended to enhance ecological performance and reduce maintenance requirements. In addition to stormwater retention and infiltration functions, the proposed rain garden was conceived as an educational and demonstrative landscape element aimed at increasing environmental awareness among students. The integration of visible green infrastructure systems within university campuses can contribute to sustainable water management while simultaneously supporting climate change education and environmental literacy. The geometric storage volume of the proposed rain garden system was estimated to range between 0.55 and 0.79 m^3, while the effective water storage capacity varied between 108 and 192 liters depending on the void ratio of the drainage materials. As a pilot-scale application, the proposed system is intended to provide localized runoff retention and infiltration benefits while demonstrating the principles of nature-based stormwater management. Therefore, the design should be considered primarily as an educational and awareness-oriented intervention rather than a full-scale runoff control facility for the entire contributing drainage area. For rainfall events exceeding the storage capacity of the proposed system, an overflow outlet connected to the existing drainage infrastructure is recommended to safely convey excess runoff and prevent localized flooding. Such an approach would increase the hydraulic resilience of future full-scale implementations.

RESULTS

Participant Profile

A total of 108 students participated in the survey. Female participants constituted 69.4% of the sample, while male participants represented 30.6%. The majority of respondents were between 20 and 21 years of age (47.2%), followed by the 22–23 age group (32.4%). Participants represented a broad range of academic disciplines, with the highest participation rates from Landscape Architecture (14.8%), Mechanical Engineering (13.9%), Business Administration (13.0%), Food Engineering (12.0%), and Forestry Engineering/Forest Industrial Engineering (12.0%). The remaining 34.3% of participants were distributed among various other academic departments (Table 3, Figure 3). Overall, the sample was predominantly composed of undergraduate students, reflecting the demographic structure of the university population. The interdisciplinary composition of the sample enabled the evaluation of environmental awareness from students representing both engineering and design-related disciplines.

Table 3. Demographic characteristics of participants

Variable	Category	n	%
Gender	Female	75	69.4
	Male	33	30.6
Age group	≤19 years	8	7.4
	20–21 years	51	47.2
	22–23 years	35	32.4
	≥24 years	14	13.0
Academic department	Landscape Architecture	16	14.8
	Mechanical Engineering	15	13.9
	Business Administration	14	13.0
	Food Engineering	13	12.0
	Forestry Engineering/Forest Industrial Engineering	13	12.0
	Other Departments*	37	34.3

*Other Departments include Chemical Engineering/Chemistry, Bioengineering, Psychology, Industrial Engineering, Mechatronics Engineering, Architecture, International Trade and Logistics, Sociology, Computer Engineering, Maritime Engineering, and Mathematics

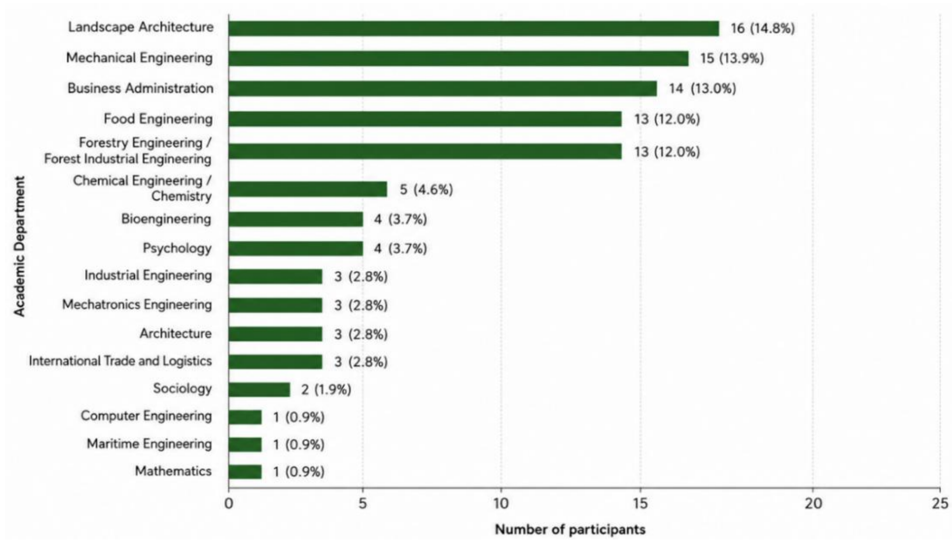

Figure 3. Distribution of participants by academic department

Awareness of Climate Change and Water-Related Issues

The findings revealed that most participants considered themselves knowledgeable about climate change. Specifically, 48.6% of respondents stated that they had sufficient knowledge regarding climate change, while 45.8% reported partial knowledge. Only 5.6% indicated that they had no knowledge about the subject. Awareness of the impacts of climate change on water resources was found to be considerably high. Approximately 85.2% of participants stated that they were aware of the relationship between climate change and water-related issues such as drought, water scarcity, and changing precipitation patterns. This result suggests that the water-related consequences of climate change are relatively well understood among university students. However, despite this relatively high awareness level, participation in educational activities related to drought and water management remained limited. Only 15.7% of respondents stated that they had previously attended any training, seminar, workshop, or awareness activity concerning drought, whereas 84.3% reported no such experience (Figure 4). This finding indicates a notable gap between general environmental awareness and active participation in environmental education programs.

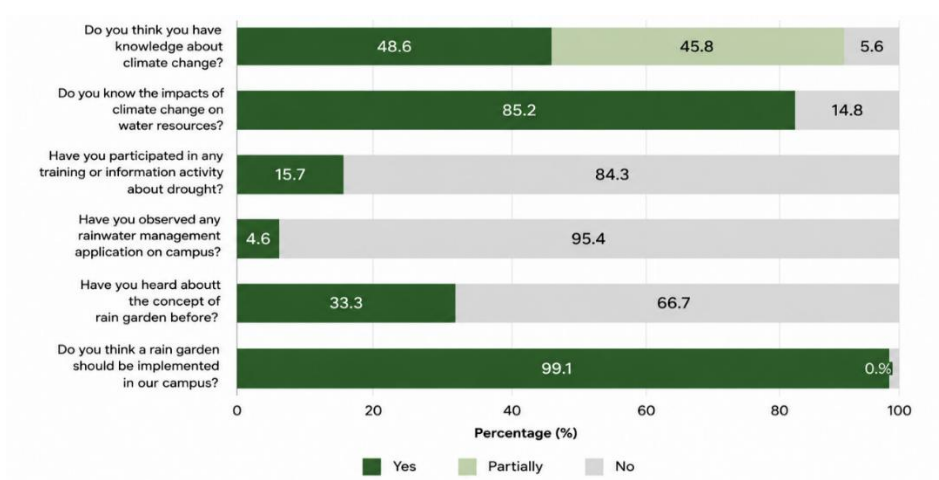

Figure 4. Climate change awareness and rain garden perceptions among university students.

Awareness of Rain Gardens

The survey results demonstrated that awareness of the rain garden concept among university students was relatively low. While 33.3% of participants stated that they had previously heard of rain gardens, 66.7% reported that they were unfamiliar with the concept. Participants were also asked whether they had observed any rainwater management applications on campus. The vast majority of respondents (95.4%) indicated that they had not encountered such applications within the university campus, while only 4.6% answered positively (Figure 4). These findings suggest that sustainable stormwater management practices are either absent or insufficiently visible within the campus environment. Consequently, students have limited opportunities to interact with or learn from nature-based water management solutions in their daily campus experience.

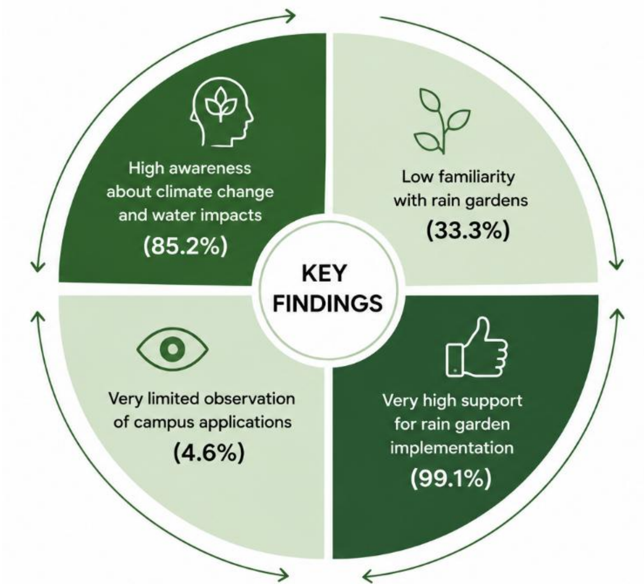

Figure 5. Synthesis of the awareness gap and support for rain garden implementation

Attitudes Toward Rainwater Management Applications

Despite the limited awareness regarding rain gardens, participants demonstrated highly positive attitudes toward sustainable rainwater management practices. An overwhelming majority of respondents (99.1%) stated that rainwater harvesting and reuse systems should be implemented within university campuses, whereas only 0.9% expressed negative opinions (Figure 5).The findings indicate that although students may not possess detailed technical knowledge about rain gardens, they are highly supportive of environmentally sensitive and nature-based stormwater management strategies. This result highlights the considerable potential of university campuses as both demonstration sites and educational environments where visible green infrastructure interventions can enhance environmental awareness while contributing to sustainable water management.

Spatial Analysis and Site Selection Findings

Field observations and spatial analyses conducted within Bursa Technical University Mimar Sinan Campus revealed that impervious surfaces such as parking areas, pedestrian circulation routes, and service roads constitute significant surface runoff production zones. These areas were identified as priority intervention zones due to their high runoff generation potential and dense user activity. Based on multi-criteria evaluation, the northern entrance zone (security gate area) was determined as the most suitable location for the proposed rain garden application. The selected area is directly associated with parking surfaces and pedestrian circulation, making it a critical point for stormwater accumulation and management. Topographical analyses demonstrated that the existing slope conditions naturally direct runoff toward specific low points, enabling controlled water collection and infiltration. In addition, the proximity of the selected area to existing green spaces supports the integration of the proposed rain garden into the overall campus landscape structure. The visibility and accessibility of the northern entrance area also increase its educational and awareness-building potential. Therefore, the proposed rain garden was evaluated not only as a hydrological infrastructure component but also as an ecological landscape element capable of promoting environmental awareness among campus users.

Hydrological Calculations and Design Findings

The stormwater runoff generated within the selected drainage area was estimated using the Rational Method ($Q = C \times i \times A$). The drainage area was calculated as 240 m^2, while the runoff coefficient was accepted as 0.90 due to the predominantly impervious surface characteristics of the site. Rainfall intensity was considered as 100 mm h^{-1}. Based on these parameters, the peak runoff discharge was estimated at approximately 0.006 m^3 s^{-1} (6.0 L s^{-1}). Volumetric calculations indicated that the total geometric volume of the proposed rain garden system ranged between 0.55 and 0.79 m^3. Considering the void ratio of the gravel drainage layer, the effective water storage capacity was estimated to vary between 108 and 192 liters. As a pilot-scale demonstration project, the proposed rain garden is intended to provide localized runoff retention and infiltration while illustrating sustainable stormwater management practices within the campus environment. Although the system is not designed to manage the entire runoff volume generated from the contributing drainage area, it can contribute to reducing localized surface flow, increasing infiltration, and enhancing environmental awareness regarding nature-based water management solutions.

DISCUSSION

The findings of this study demonstrate that university campuses possess significant potential for the implementation of nature-based stormwater management strategies, both in terms of hydrological performance and environmental awareness generation. The results indicate that although students generally exhibit a high level of awareness regarding climate change and water-related challenges, their familiarity with rain gardens and sustainable drainage systems remains relatively limited. This finding reveals a gap between general environmental awareness and specific knowledge of nature-based urban water management practices.

The survey results showed that 85.2% of participants were aware of the impacts of climate change on water resources, whereas only 33.3% had previously heard of rain gardens. Similar findings have been reported in studies suggesting that awareness of climate change does not necessarily translate into familiarity with sustainable urban drainage practices or green infrastructure systems (Fletcher et al., 2015). Nature-based stormwater management concepts often remain invisible within everyday urban environments, limiting opportunities for experiential learning and public engagement (Ahiablame et al., 2012). Despite this limited familiarity, an overwhelming majority of respondents (99.1%) supported the implementation of rainwater collection and management systems on university campuses. This result suggests that students are highly receptive to environmentally responsible solutions even when their technical understanding is limited. Similar trends have been identified in studies examining environmental attitudes among young adults, where visible ecological interventions positively influence environmental perception, pro-environmental behavior, and sustainability engagement (Church, 2015; Kazanç & Esringü, 2024).

Another important finding is the limited participation in drought-related educational activities. Only 15.7% of participants reported attending any seminar, training, or awareness program related to drought or water management. This result indicates that environmental issues are often discussed theoretically, while practical and experiential learning opportunities remain insufficient. Previous studies emphasize that sustainability education becomes more effective when ecological processes are integrated into daily campus life through visible and interactive landscape interventions (Velazquez et al., 2006; Leal Filho et al., 2018). In this context, university campuses should function not only as educational institutions but also as living laboratories where sustainable practices can be directly observed and experienced. The spatial analyses revealed that impervious surfaces such as parking lots, service roads, and circulation areas generate substantial runoff within the campus environment. Similar studies have demonstrated that increasing impervious surface coverage significantly alters natural hydrological processes by accelerating runoff generation, reducing infiltration, and increasing pressure on urban drainage systems (Shuster et al., 2005; Davis et al., 2009). The identification of the northern entrance zone as the most suitable location for rain garden implementation highlights the importance of integrating hydrological suitability, user density, and spatial visibility within sustainable drainage planning.

The proposed rain garden system was intentionally designed as a pilot-scale educational intervention rather than a full-capacity stormwater treatment facility. Consequently, the storage volume was determined according to demonstration and awareness objectives while maintaining basic runoff retention functionality. This approach aligns with contemporary perspectives emphasizing the multifunctionality of green infrastructure systems. Rain gardens are increasingly recognized not only as stormwater management tools but also as landscape elements capable of supporting biodiversity, improving microclimatic conditions, enhancing visual quality, and strengthening environmental education (European Commission, 2015). In addition to their hydrological functions during wet periods, rain gardens continue to provide ecological, aesthetic, and educational value during dry periods by supporting biodiversity, improving landscape quality, and creating attractive outdoor learning environments.

Hydrological calculations further demonstrated that even small-scale rain garden systems can contribute to localized stormwater management within campus environments. The estimated storage capacity of 108–192 liters suggests that the proposed pilot-scale system can provide temporary runoff retention and infiltration benefits at the site level. Although the storage volume is limited relative to the total runoff generated from the contributing drainage area, the system can help reduce localized surface flow while serving as a demonstrative example of nature-based stormwater management. Furthermore, its strategic location within the campus increases its educational visibility and potential to enhance environmental awareness among students and visitors. It should be noted that the proposed rain garden represents a pilot-scale demonstration application intended primarily for educational and awareness purposes rather than a full-capacity stormwater treatment facility. From a broader perspective, the findings suggest that university campuses can serve as experimental environments for sustainable drainage practices in Türkiye. Although sustainable urban drainage systems and nature-based solutions have become increasingly prominent within climate adaptation policies worldwide, their practical implementation in Turkish cities remains relatively limited. Campus-scale pilot applications may therefore contribute to increasing public familiarity, institutional experience, and societal acceptance of nature-based water management approaches. Considering that Bursa receives approximately 700–800 mm of annual precipitation, mainly during autumn and winter, the proposed pilot-scale rain garden is expected to contribute to intercepting first-flush runoff and promoting infiltration during frequent rainfall events. However, larger-scale applications incorporating interconnected rain gardens and overflow structures would be required to effectively manage high-intensity storm events.

Finally, the findings support the argument that sustainable drainage systems should not be evaluated solely according to engineering performance criteria. Instead, they should be considered multifunctional landscape infrastructures integrating hydrological, ecological, educational, and social dimensions. Such an integrated perspective is increasingly emphasized within climate adaptation and urban resilience literature and is considered essential for promoting sustainable water management in rapidly urbanizing environments (Gill et al., 2007; Liu & Jensen, 2018).

CONCLUSION

Climate change and rapid urbanization have significantly altered the natural hydrological cycle, increasing both drought and flood risks in urban environments. In this context, sustainable and nature-based stormwater management approaches have become increasingly important for improving urban resilience and ecological sustainability. Among these approaches, rain gardens represent multifunctional landscape systems that contribute not only to stormwater management but also to environmental awareness, ecological enhancement, and spatial quality.

This study evaluated the potential of rain garden applications within Bursa Technical University Mimar Sinan Campus from both hydrological and educational perspectives. The findings demonstrated that university students generally possess awareness regarding climate change and water-related problems; however, their knowledge of rain gardens and sustainable drainage systems remains limited. Despite this limited familiarity, participants expressed highly positive attitudes toward the implementation of rainwater management systems on campus. This result highlights the importance of visible and experience-based ecological interventions in strengthening environmental awareness. Spatial analyses revealed that impervious surfaces such as parking areas and circulation routes generate considerable surface runoff within the campus environment. Based on hydrological suitability, user density, accessibility, and visibility criteria, the northern entrance zone of the campus was identified as the most appropriate location for rain garden implementation. Hydrological calculations further indicated that the proposed system has sufficient runoff retention and temporary storage capacity to contribute to localized stormwater management.

The study also emphasizes that university campuses have significant potential to function as experimental and educational platforms for sustainable drainage systems. Rain gardens should therefore be considered not only as technical infrastructure elements but also as pedagogical and ecological landscape components that increase environmental interaction and awareness among users. From a broader perspective, the findings suggest that sustainable drainage systems and nature-based solutions should be more actively integrated into planning, landscape design, and campus development processes in Türkiye. Increasing the visibility of such applications within public and semi-public environments may contribute to the wider societal acceptance of climate adaptation strategies and sustainable water management approaches.

Finally, this study provides a conceptual and spatial framework for future rain garden applications in university campuses and similar urban environments. Future studies may further strengthen this framework through long-term hydrological monitoring, water quality measurements, and user perception analyses in implemented pilot projects. The originality of the study lies in integrating environmental awareness assessment, spatial suitability analysis, hydrological calculations, and campus-scale rain garden design within a single methodological framework. The proposed approach provides a transferable model for sustainable stormwater management in university campuses and similar urban environments.

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