URBAN DESIGN International
https://doi.org/10.1057/s41289-025-00295-2

ORIGINAL ARTICLE

Linking ecological design and user preferences for climate adaptation on university campuses

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Received: 24 November 2024 / Accepted: 23 September 2025

Abstract
The process of adapting to changing climatic conditions has become a central theme not only in climate science but also in urban planning and various other fields. Given the unique characteristics of each urban area, it is crucial to tailor planning decisions to facilitate climate adaptation in accordance with local needs. College campuses, with their distinct administrative structures and diverse activities, provide an ideal context for formulating and implementing climate adaptation strategies. Campuses boast ample open-green spaces, rendering them potential catalysts for enhancing urban resilience to climate change and setting a model for broader urban planning practices. This study aims to establish a relationship between design decisions on campuses and user preferences within the context of urban climate adaptation. To achieve this, satisfaction levels, preferences, and expectations of 373 students and 400 employees using the İzmir Katip Çelebi University (IKCU) campus were gauged through questionnaires. Drawing insights from the survey's data results, a campus model is proposed to foster climate change adaptation and the creation of a resilient campus capable of withstanding potential climatic challenges in the future. The overarching objective of the study is to provide guidance to campuses facing similar challenges, assisting them in identifying specific problems and matching them with appropriate ecological design solutions.

Keywords Landscape design · Adaptation to climate change · University campuses · Campus landscape design · Climate change · User preferences

Introduction

The adaptation of university campuses to climate change is a critical research area, requiring a holistic approach that integrates ecological design principles, nature-based solutions, and user expectations. This study aims to develop a flexible campus model that enhances resilience to climate change by incorporating sustainable design principles. Unlike previous research, which primarily focuses on singular ecological aspects such as carbon footprint assessments (e.g., Çetin et al., 2021; Genta et al. 2022) or microclimate regulation studies (e.g., Qian & Yang 2018), this study adopts an integrated perspective that simultaneously considers user expectations, ecological design principles, and climate adaptation strategies. By examining İzmir Katip Çelebi University Çiğli Campus, the research evaluates practical applications of climate-adaptive campus design. The objectives of this study are twofold: (1) to analyze design and planning strategies that make university campuses climate-resilient and (2) to propose recommendations aligned with ecological design principles and user needs.

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Published online: 09 November 2025

The study's approach encompasses various sustainability-focused strategies, including reducing energy consumption, integrating self-sustaining infrastructure, optimizing stormwater management, selecting low-maintenance plant species, mitigating environmental pollution, and enhancing campus aesthetics. These strategies aim to improve quality of life, foster social well-being, and enhance the campus's ability to adapt to climate change. University campuses, often considered microcosms of urban systems, provide unique opportunities to act as experimental grounds for sustainable practices (Pauleit et al. 2019). This study addresses how urban ecosystems can be modeled at the micro-scale in the adaptation process of university campuses to climate change. Therefore, the literature review is structured first to explore sustainable approaches in urban environments and then delve deeper into their specific applications within university campuses.

Literature review

Sustainability and ecological design have become central paradigms in addressing the growing challenges posed by climate change, rapid urbanization, and biodiversity loss in urban environments (Van der Ryn & Cowan 2013; Madge 1997; Beatley 2011; Girardet 2014). The incorporation of green infrastructure, such as urban parks, green roofs, and forests, has gained prominence for its ability to enhance urban resilience, improve air quality, offer recreational spaces that support residents' well-being (Childers et al. 2015; Omole et al. 2024). Beyond their aesthetic contributions, urban green spaces play a crucial role in delivering essential ecosystem services, including carbon sequestration, stormwater management, and habitat preservation (Kothencz et al. 2017; Nasrullan & Syafri, 2024). Effective urban landscape design must prioritize the connectivity of green spaces to strengthen ecological resilience and improve overall urban living conditions (Puskás et al. 2021). Furthermore, the integration of nature-based solutions (NbS) into urban planning fosters a more balanced relationship between urban development and natural ecosystems, contributing to healthier and more adaptable urban environments (Scott et al. 2016).

The application of green architecture principles, such as vertical greenery and sustainable building materials, can significantly reduce the ecological footprint of campus developments (Okwandu 2024; Giai 2023). Additionally, campus green spaces, beyond their visual appeal, are essential components of broader sustainability strategies, supporting biodiversity conservation and offering recreational and restorative spaces for campus users (Larson et al. 2016). University campuses that embrace their local and global responsibilities toward environmental preservation and societal advancement, while actively seeking solutions and implementing necessary measures to address ecological and social challenges for the well-being of both people and ecosystems, can be characterized as sustainable campuses (Cole &Wright 2003). Given that university campuses accommodate diverse users and activities, their designs should encompass the varied needs of these stakeholders. Beyond being centers of academic study, university campuses comprise spaces that cater to a spectrum of needs, including accommodation facilities (Kalaycı Önaç et al., 2021). Although campus areas resemble scaled-down cities in terms of consumption and waste generation, they operate on a smaller scale. Numerous research findings concur that the promotion and execution of sustainability practices at higher education institutions can lead to decreased environmental degradation, waste, and pollution (Alshuwaikhat et al. 2017). Consequently, university campuses can be viewed as models of sustainable environmental development, offering insights into design and management practices that contribute to the establishment of sustainable cities (Lipschutz et al. 2017). In this context, planning that integrates stakeholder engagement and adheres to sustainability principles emerges as a pivotal element that positively impacts the success of campus design endeavors (Mohammed et al. 2022).

Additionally, universities can serve as pioneers in formulating community engagement strategies to promote a sustainable world (Too and Bajracharya 2015; Chanseliani & McCowan, 2021). To attain a sustainable campus status, universities must strategize their activities, encompassing daily consumption patterns, waste management practices, and efficient water and energy utilization, all within the framework of sustainable approaches. Subsequently, campus design decisions should align with these overarching strategies (Alshuwaikhat and Abubakar 2008; Gherheş et al., 2024). While sustainability criteria encompass a range of factors, ecological considerations such as the conservation and restoration of biodiversity, the enhancement of ecosystem services, and the preservation of ecological integrity are integral components for these institutions. Notably, these ecological criteria hold significance in the context of sustainability evaluation scores attributed to universities (Orenstein, 2019).

It is essential to recognize that university campuses not only serve as educational institutions but also fulfill the recreational requirements of various stakeholders, especially students, by offering suitable physical environments (Vural et al. 2019; Wilkins et al. 2024). Moreover, the open-green spaces within university campuses serve multiple purposes. They contribute to maintaining the harmony between architectural structures and the environment, facilitate pedestrian and vehicular movement within the campus, establish a vital connection between individuals and their surroundings, allocate space for potential physical expansions, and enhance the aesthetic appeal of the campus (Ertekin and Çorbacı, 2010;

Yılmaz and Irmak 2012). Thoughtfully planned campuses play a pivotal role in catering to the needs of university faculty, students, as well as city residents, offering spaces for relaxation, entertainment, dining, social interactions, cultural engagements, sports activities, and educational pursuits (Atilla et al., 2016). To ensure the fulfillment of these diverse needs, research could be conducted at regular intervals to ascertain user preferences before the design, planning, and implementation phases. This approach not only reveals user satisfaction but also identifies emerging needs post-implementation (Vural et al. 2019). Incorporating ecological design principles is crucial in design endeavors aimed at fulfilling these requirements while maintaining sustainability.

Ecological design, often referred to as designs that harmonize with living processes to minimize environmental harm, plays a pivotal role in integrating sustainability into various contexts (Madge 1997). The fundamental objective of ecological design is to safeguard habitat quality by preserving flora and fauna, reducing resource depletion, and maintaining natural nutrient and water balances (Van der Ryn and Cowan 2013). In the realm of ecological campus design, particular attention is given to factors such as water and wind as essential components in combating climate change. Numerous researchers have formulated approaches that prioritize these factors. For instance, Amr et al. (2016) conducted a study titled "Water as an Ecological Factor for a Sustainable Campus Landscape" in Cairo, Egypt, where water resources are scarce. This study explored strategies like irrigation, rainwater harvesting, rainwater reuse, and reducing rainwater consumption implemented across three distinct modern university campuses to ensure sustainable water resource management. The findings reveal that these campuses generally curtailed their irrigation water demands by utilizing efficient sprinkler and drip irrigation methods and opting for local plant species that require less water. Nonetheless, the researchers noted a considerable reliance on drinking water instead of wastewater and gray water for plant irrigation, underscoring the need for a forward-looking system to enhance the utilization of these alternative water sources.

Many campuses hold significant potential to augment urban tree coverage due to their expansive open spaces, facilitating the integration of trees into city environments. The Shenyang Institute of Technology conducted an analysis of its campus ecosystem services, encompassing elements such as tree structure, energy conservation, carbon mitigation, air pollutant removal, stormwater management, and aesthetic enhancements. The study yielded insightful outcomes, emphasizing the environmental value of campus greenery (Wang et al. 2021).

In the research conducted by Çetin et al. (2021), a comprehensive assessment of the ecological footprint of Eskişehir Technical University Campus in Türkiye was carried out for the years 1990, 2018, and projections were made for 2035. The comparison between 1990 and 2018 unveiled a noteworthy transformation in land use, with pastures, agricultural lands, and natural vegetation patterns of 1990 giving way to structural developments, primarily the campus building, by 2018. The shifts in land use and land cover between these years led to a considerable change in the ecological footprint. Furthermore, extrapolating from the study's findings, it is projected that the carbon footprint could double by 2035, taking into account the anticipated developments of the study area in accordance with the zoning plan and the evolving user demographics. A related investigation conducted at Politecnico di Torino University campus focused on evaluating the ecological footprint of the institution. The computed ecological footprint was dissected into six principal consumption categories, encompassing transportation, energy, food, waste, water, and land usage. Remarkably, transportation was identified as the most substantial contributor, accounting for 49.4% of the overall ecological footprint attributed to the campus. Consequently, enhancing the appeal of public transportation, facilitating bicycle use, and promoting pedestrian accessibility within campus grounds assume paramount importance as these measures hold potential for curbing the institution's ecological footprint (Genta et al. 2022).

Facilitating convenient pedestrian access within the campus proves pivotal in the endeavor to mitigate the carbon footprint, concurrently enhancing student comfort and curbing vehicular usage. Yerli and Özdede (2017) delved into the process of designing a sustainable and accessible campus layout within Düzce University Konuralp Campus in Turkiye. Central to their approach was the establishment of a primary pedestrian thoroughfare that remains unimpeded by vehicular traffic, seamlessly connecting disparate units across the campus. This pedestrian axis was thoughtfully surrounded by a mix of enclosed, semi-open, and open spaces, culminating in a botanical garden and aqueducts. The design was tailored to the regional setting, leveraging geographical and climatic data to formulate ecological wind corridors in harmony with prevalent wind patterns. The incorporation of a recreational forest further enriched the campus's ecosystem, providing a habitat for diverse flora and fauna communities (Yerli & Özdede, 2017).

In the pursuit of environmental benefits within sustainable campus design, microclimatic elements like wind can have a dual impact, potentially diminishing the frequency and quality of open space utilization through the introduction of thermal and mechanical discomfort. Thus, an imperative arises to devise ecologically aligned solutions for bioclimatic enhancement of open areas. To cultivate a campus characterized by health and comfort in Wuhu, China, a comprehensive investigation into wind conditions and the corresponding comfort levels in a school campus and its environs was conducted using computational fluid dynamics (CFD) methodology during both summer and winter seasons. The study entailed zoning wind speed conditions within the campus in accordance with the Bofor Scale to determine pedestrian wind comfort circumstances. The findings indicate that through targeted physical interventions on pedestrian pathways within the campus, wind comfort conditions for pedestrians in the face of winter winds were ameliorated. Moreover, the study noted an increase in ventilation levels, which had diminished due to heightened building heights, thereby showcasing the potential for enhanced wind comfort through strategic design adjustments (Qian & Yang 2018).

Promoting recycling and waste reduction comprehension on university campuses necessitates a multifaceted approach encompassing diverse campaigns, educational initiatives to bolster environmental consciousness, and the formulation of pertinent policies (Ali et al. 2021). The utilization of waste bins for waste sorting and recycling is prevalent. The design, placement, and color schemes of these waste bins wield a substantial impact on waste collection and separation efficacy. Thus, campus designs can leverage the potential to heighten human awareness and enhance waste segregation by judiciously configuring and situating waste bins (Leebai et al., 2021).

Furthermore, integrating landscape designs for campus access routes with plants of consistent diameter and height, characterized by captivating aesthetics and vigorous foliage growth, along with resilience against cold, drought, wind, and diseases, holds paramount significance. The dynamic alteration of plant colors in harmony with the seasons imparts a vibrant ambiance to the campus surroundings. Beyond their ornamental value, plants bestow constructive advantages such as augmenting aesthetic gratification, stimulating cognitive engagement, and fostering creativity (Jiangqiong & Mengnan 2014).

In addition to their contributions to the ecosystem, trees on campuses exert concentration-enhancing effects. A comprehensively designed campus, where individuals engage with nature, elevates students' cognitive abilities and consequently enhances the quality of education (Scholl & Gulwadi 2015). Evaluating open spaces within university campuses based on student usage patterns and characteristics, it has been established that verdant and open areas, including courtyards situated around classrooms, invigorate outdoor activities, confer spatial significance to users, and foster social gathering spots amidst classrooms (Reynolds 2002). Moreover, courtyards, well-defined pedestrian pathways, and terraces are spaces of significance for students, simultaneously fostering interdisciplinary interactions by promoting sustainable learning beyond classroom walls. These campus spaces cater not only to students' physical requirements but also address their Psychological needs by offering mental reprieve and rejuvenation (Hanan 2013; Neil 2002).

In educational settings situated within low- and high-density urban areas, architectural and landscape design strategies play a crucial role in crafting open-green spaces that alleviate stress. In the context of a compact campus, the constraints of high-density environments may limit open space dimensions, potentially impeding circulation and accessibility. Nonetheless, smaller open spaces facilitate more intimate contact with natural restorative elements and a controllable microclimate for physical comfort. It is equally imperative for health-conscious campus designs to incorporate diverse open spaces capable of adapting to various needs (Lau et al. 2014).

Based on the reviewed literature, climate adaptation studies on university campuses were thematically grouped under the categories presented in Table 1. While this classification provides an overview of the strategies addressed in previous research, it does not constitute a detailed critical appraisal of the individual study designs or their methodological strengths and weaknesses. As highlighted in the preceding literature discussion, existing research on the ecological footprint of university campuses, sustainable design approaches, and green infrastructure practices (e.g., Çetin et al., 2021; Genta et al. 2022; Qian & Yang 2018) has largely concentrated on individual ecological components (such as carbon footprint, green infrastructure, or microclimate conditions), often proposing singular rather than integrated solutions. The contribution of this study to the literature lies in its effort to develop a holistic model to adapt university campuses to climate change. It proposes a flexible campus model that integrates nature-based solutions, user expectations and design decisions, thereby offering a framework that can not only inform academic environments but also be adapted for urban green space planning. Furthermore, the evaluation of İzmir Katip Çelebi University Çiğli Campus differentiates the study from other studies by providing the opportunity to test the applicability of the recommendations through a concrete project.

The research question is: how can ecological design strategies on university campuses be aligned with user preferences to enhance climate adaptation in the context of Mediterranean climates?

In this context, the study proposes a flexible campus model that can adapt to the environmental conditions brought about by climate change. By integrating nature-based practices and design decisions, this model supports the holistic functioning of the urban ecosystem and serves as a model for the city.

Table 1 Classification of literature according to climate adaptation category

Category	Climate adaptation strategies	References
Green infrastructure	Urban forests, green roofs, permeable surfaces	Childers et al. (2015); Omole et al. (2024); Lipschutz et al. (2017); Pauleit et al. (2019); Ertekin & Çorbacı (2010); Yılmaz & Irmak (2012)
Water management	Rainwater harvesting, efficient irrigation, gray water reuse	Amr et al. (2016); Orenstein (2019); Gherheş et al. (2024); Çetin et al. (2021)
Energy efficiency	Solar panels, wind energy, passive cooling strategies	Okwandu (2024); Alshuwaikhat & Abubakar (2008); Genta et al. (2022); Scott et al. (2016)
Transportation	Bicycle-friendly campus design, pedestrian pathways, public transport	Genta et al. (2022); Yerli & Özdede (2017); Mohammed et al. (2022); Kalaycı Önaç et al. (2021)
Biodiversity & ecology	Native plant selection, habitat conservation, pollinator gardens	Puskás et al. (2021); Reynolds (2002); Hanan (2013); Nasrullan & Syafri (2024); Wang et al. (2021); Larson et al. (2016)
User engagement	Participatory planning, awareness campaigns, eco-friendly initiatives	Too & Bajracharya (2015); Chanseliani & McCowan (2021); Cole & Wright (2003); Vural et al. (2019); Atilla et al. (2016)
Waste management	Recycling programs, waste segregation systems, awareness initiatives	Ali et al. (2021); Leebai et al. (2021)
Microclimatic design	Wind corridors, pedestrian comfort strategies, thermal comfort zones	Qian & Yang (2018); Jiangqiong & Mengnan (2014)

Materials and methods

Study area

The İzmir IKCU Çiğli Campus was selected as the study area due to its unique geographical, ecological, and socio-demographic characteristics, which align with the objectives of investigating climate adaptation through ecological design. Located in İzmir, Turkey—a city facing Mediterranean climatic challenges such as rising temperatures and irregular precipitation—the campus is surrounded by industrial zones, transportation corridors, and residential developments, which place significant ecological pressures on its open-green spaces. Spanning 70 ha, the campus offers substantial potential for implementing nature-based solutions (NbS) and serves as a microcosm of urban ecosystems, where ecological design interventions can be tested and scaled. Additionally, the diverse user base, comprising students, academic staff, and administrative personnel, provides valuable insights into user preferences and satisfaction with outdoor spaces, enabling a user-centered approach to ecological campus planning. These factors collectively position the İKÇU Çiğli Campus as an ideal setting for exploring integrated strategies to enhance climate resilience and sustainability in urban environments.

İKÇU Çiğli Campus is located in the north of İzmir, within the borders of Balatçık neighborhood, Çiğli District, as shown in Fig. 1.

The campus area is surrounded by İzmir Highway in the west, Anadolu Avenue in the east, a 35-m-wide highway and highway connection road in the north, and industrial and residential areas in the south. The total area of the campus is 70 ha and the current land use status of the campus is presented in Fig. 2.

Other materials

Materials used in the research; previous scientific studies on adaptation to climate change, ArcMap10.4 software for digitization and analysis of maps, AutoCAD 2016, Skecth-up, Lumion 10.5 and Adobe Photoshop CS6 software for ecological landscape design, drawing and modeling of campus focal areas, Microsoft Excel and IBM SPSS Statistics 26.0 (Statistical Package for Social Science) software for data collection, entry and analysis of user surveys. In addition, the satellite image of 2022 downloaded from USGS was used to prepare the campus land use map.

Methods

The research employed a mixed-methods design, structured around four basic stages (Fig. 3). The first stage involved collecting both qualitative and quantitative data through an extensive literature review and user surveys. This mixed-methods approach was adopted to combine the strengths of numerical analysis with the contextual insights of qualitative inquiry, thereby providing a more comprehensive understanding of campus outdoor space use and perceptions. This stage aimed to identify ecological design criteria and user needs, laying the groundwork for subsequent phases. Surveys are widely recognized as effective tools for gathering stakeholder feedback in

Fig. 1 Location of the study area

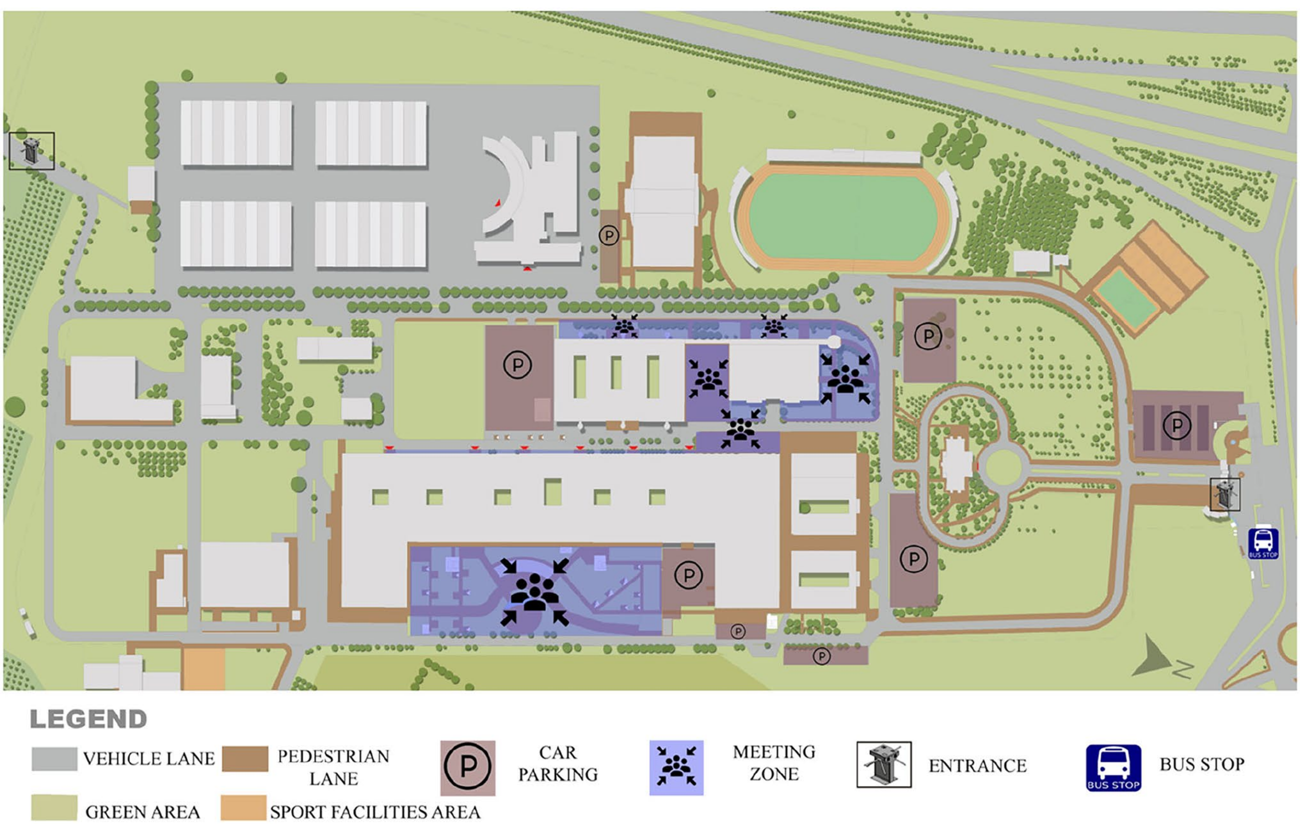


Fig. 2 İzmir IKCU Çiğli Campus current land use map

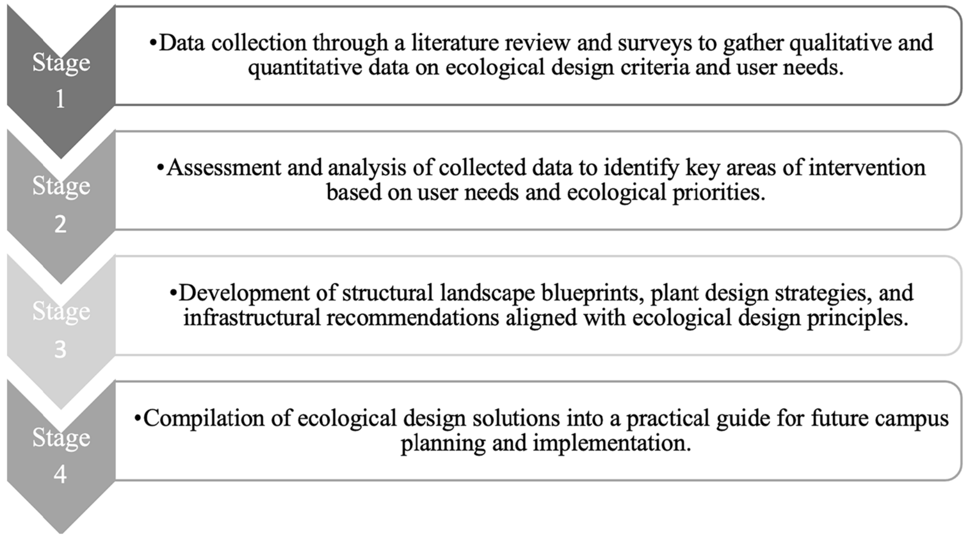


Fig. 3 Method flow chart

campus sustainability research, particularly when assessing user behavior, satisfaction, and expectations (Hami & Abdi 2021; Vural et al. 2019).The sample size and statistical methods employed in this study were carefully selected to ensure the reliability and validity of the findings. The sample size and statistical methods employed in this study were carefully selected to ensure the reliability and validity of the findings. A margin of error of 0.05 within a 95% confidence interval was applied, aligning with widely accepted standards in social and environmental research. This approach resulted in a representative sample of 773 participants, including 373 undergraduate and graduate students and 400 academic and administrative staff members. While the absolute number of staff respondents slightly exceeds that of students, this discrepancy reflects differences in voluntary response rates rather than intentional weighting. Given that students outnumber staff in the overall campus population, this imbalance is acknowledged as a limitation. However, the total sample size still exceeds the statistically required threshold, and non-parametric tests (Mann–Whitney U and Kruskal–Wallis) were employed to minimize potential bias from unequal group sizes. As the primary aim of the study was to establish a holistic model incorporating the perspectives of both user groups rather than comparing them separately, the data were analyzed collectively. Future research will address this limitation by applying stratified sampling techniques to better mirror the actual demographic composition of the campus population (Hami & Abdi 2021; Vural et al. 2019)." While the absolute number of staff respondents ($n = 400$) slightly exceeds that of students (n = 373), this discrepancy reflects differences in response rates rather than intentional weighting. Given that the survey was voluntary, staff participation was proportionally higher. Although this introduces a minor imbalance, the overall sample size is statistically robust. To mitigate potential biases, non-parametric tests suitable for unequal group sizes were applied. A margin of error of 0.05 within a 95% confidence interval was applied, a decision informed by its widespread acceptance as the conventional threshold for statistical reliability in social and environmental research, balancing rigor with practical applicability. This approach resulted in a total of 773 voluntary participants, including 373 undergraduate and graduate students and 400 academic and administrative staff members. Recruitment was conducted through online surveys distributed via institutional mailing lists and campus announcements. While this strategy ensured participation across key user groups (Hami & Abdi 2021; Vural et al. 2019), it relied on convenience sampling and may carry potential self-selection bias, which should be considered when interpreting the findings. For data analysis, descriptive statistical methods, along with Mann–Whitney U and Kruskal–Wallis tests, were used to examine group differences and identify significant patterns in survey responses. These non-parametric tests are particularly suitable for ordinal data and datasets that do not meet normality assumptions, making them highly effective for analyzing survey data (Pallant 2020; Ribeiro et al. 2021). The application of these statistical tools ensures a robust and methodologically sound analysis, enhancing the generalizability and reliability of the study's results (Huang et al. 2019; Vural et al. 2019). The questionnaire was structured using four distinct scales. The initial section concentrated on socio-demographic inquiries, probing into personal characteristics that could influence users' outdoor utilization behaviors and expectations. These attributes included age, gender, duration of association with the university, role within the university, and the specific department of affiliation. The subsequent portion delved into users' prevailing habits in relation to outdoor spaces within the campus. In the third segment, a scale was deployed to assess the degree of contentment derived from the current outdoor amenities. The fourth section involved applying a scale devised to identify the expectations associated with outdoor facilities planned for the campus's development. This methodological approach facilitated a comprehensive exploration of participants' outdoor utilization patterns, contentment levels, and future expectations.

The data were collected by the survey method, transferred to the Microsoft Excel program, organized, cleaned, and made suitable for analysis. Descriptive statistical methods, Mann–Whitney *U* and Kruskal–Wallis tests were used in the analysis. Data analyses were tested using the IBM SPSS Statistics 26.0 (Statistical Package for Social Science) package program.

The second phase of the methodology involved assessing the data collected from the questionnaires administered during the initial stage. In the second stage, survey results and data from the literature review were analyzed to identify key intervention zones within the campus. This phase aligns with the approach taken in previous campus studies, where spatial analysis and stakeholder input were combined to prioritize ecological and functional interventions (Cetin et al. 2021; Yerli & Özdede, 2017). Through a comprehensive lens, taking into account the desires and necessities of students, as well as administrative and academic personnel, the study identified pivotal areas warranting focused attention. This encompassed scrutinizing utilization patterns, ecological sustainability, and the inherent natural and cultural attributes of the locale. Subsequently, the third stage focused on developing structural landscape blueprints, plant design strategies, and infrastructural recommendations based on ecological design principles. Such approaches are common in sustainable campus planning projects, where design strategies integrate user feedback and environmental goals (Amr et al. 2016; Genta et al. 2022). These proposals were meticulously developed for the identified focal and problematic zones, aligning with the overarching goal of fostering urban adaptation in the face of climate change. The foundation for these endeavors was rooted in ecological design criteria. In the final stage, the findings from the previous stages were consolidated into a comprehensive ecological design guide. This guide serves as a reference for campus planners and stakeholders dealing with similar climate adaptation challenges. Similar compilations have been produced in earlier campus-focused sustainability research to ensure replicability and scalability of the findings (Too & Bajracharya 2015; Hollstein et al. 2009). This concluding phase of the methodology encompassed the compilation of ecological design solutions tailored to address pertinent challenges and fulfill expectations. This compilation served as a practical guide for practitioners navigating analogous issues within their respective campuses.

Results

Within the scope of the research, a survey was conducted to determine the outdoor usage habits, satisfaction levels, and expectations of the people working and studying at the Çiğli Campus of İKÇÜ. In order to determine the socio-demographic characteristics of the users participating in the survey, descriptive statistical analysis was applied to the data, and the findings are presented in Table 2.

According to the analysis data, 51.6% of the respondents were female and 48.4% were male. While 42.1% of the respondents are between the ages of 17–24, 2.9% are aged 50 and over; 29.4% of the participants stated that they have been a member of İKÇU for more than 5 years.

A frequency analysis was conducted to assess the outdoor usage habits of the survey participants within the campus premises. The outcomes of this analysis are presented in Table 3. The analysis, as depicted in Table 2, illustrates a notably low level of engagement across all the provided statements pertaining to the general utilization patterns of the campus's outdoor spaces. In the context of the Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), the highest level of participation, quantified with an average of 2.86, was observed in response to statements such as "I use the sitting areas in the campus" and "The open areas on the campus can be used comfortably in summer." Conversely, the lowest level of engagement, with an average score of 1.12, emerged for the statement "I do activities such as skating/skateboarding in the open areas of the campus."

The collected data underwent frequency analysis to ascertain the satisfaction levels of the participants concerning various attributes within the open areas of the campus. These attributes encompassed urban facilities, ecological value, bio-climatic comfort, environmental management, and land use possibilities. The outcomes of this analysis are detailed in Table 4. Upon reviewing the data presented in Table 4, it becomes evident that both the level of satisfaction with the campus's open spaces and the degree of engagement with the statements expressing their opinions are generally subdued. Respondents demonstrated the lowest mean value of agreement, 1.94, with the statement "Transportation facilities (traffic, public transportation, etc.) are sufficient on campus." On the other hand, the highest mean agreement value, 3.59, was expressed for the statement "Green Campus practices in universities support high quality of life."

The opinions of campus users participating in the survey were subjected to frequency analysis to elucidate their expectations from the campus outdoors. The outcomes of this analysis are depicted in Table 5. Among the findings,

Table 2 Findings related to socio-demographical characteristics

Variable	N (%)	Variable	N (%)
Gender		Unit	
Female	396 (51.6%)	Rectorship	10 (1.6%)
Male	371 (48.4%)	Faculty of Naval Architecture and Maritime	3 (0.5%)
Age		Faculty of Engineering and Architecture	135 (21.6)
17—24	324 (42.1%)	Faculty of Forestry	8 (1.3%)
25—29	106 (13.8%)	Faculty of Health Sciences	32 (5.1%)
30—39	216 (28.1%)	Faculty of Economics and Administrative Sciences	82 (13.1%)
40—49	102 (13.2%)	Faculty of Tourism	32 (5.1%)
50+	22 (2.9%)	Faculty of Fisheries	12 (1.9%)
Year		Graduate School of Health Sciences	51 (8.2%)
1	106 (13.9%)	Graduate School of Natural and Applied Sciences	1 (0.2%)
2	131 (17.2%)	Graduate School of Social Sciences	40 (6.4%)
3	158 (20.8%)	School of Foreign Languages	15 (2.4%)
4	142 (18.7%)	Faculty of Pharmacy	16 (2.6%)
5+	224 (29.4%)	Faculty of Humanities and Social Sciences	107 (17.1%)
Non-response	12 (1.6%)	Vocational School of Health Services	26 (4.2%)
Position		Faculty of Islamic Sciences	51 (8.2%)
Undergraduate student	313 (40.5%)	Çelebi Vocational School	1 (0.2%)
Graduate student	60 (7.8%)	Faculty of Art and Design	17 (0.5%)
Academic personnel	247 (32%)	Non-response	148 (19.1%)
Administrative personnel	153 (19.8%)		

the lowest expectation was registered for the possibility of bird watching on campus, with a mean of 3.00. Notably, 34% of respondents indicated agreement levels of "4—agree" or "5—strongly agree," implying that this proportion of campus users held bird watching expectations. In contrast, the survey unveiled that the highest level of participation pertained to the proposition to augment green areas on campus, with a mean score of 4.24, closely followed by the aspiration to increase plant diversity, which garnered a mean score of 4.16.

The analysis revealed that the statements under the 'expectations scale' regarding outdoor campus usage received the highest average rating, with a mean score of 3.66, indicating a relatively high level of agreement among respondents. In contrast, the 'existing usage habits scale' received the lowest average rating, with a mean score of 2.02, suggesting a lower level of alignment with the surveyedbehaviors (as presented in Table 6).

H_0: The distribution of the data conforms to the normal distribution.

H_1: The distribution of the data does not fit the normal distribution.

According to the results of Kolmogorov–Smirnov and Shapiro–Wilk normality tests, it is seen that all three scales do not exhibit normal distribution (H_0 accept: $p < 0.05$). Accordingly, non-parametric tests were preferred in the analysis of the variables (Table 7).

This study focuses on establishing climate-compatible landscape design choices through their correlation with user expectations. The landscape design decisions, geared towards addressing the challenges identified within the studied sample area, were formulated with the goal of enhancing resilience to climate change. The proposed campus landscape design approach, which is outlined in Fig. 4, encapsulates the essence of the study's efforts in this direction.

In line with the results of the analyses and user surveys, the issues to be included in the landscape design model that will contribute to the adaptation of the campus to climate change are listed in Table 8:

According to the results of the survey; In order to meet the preferences and expectations of the users and to increase the sustainability of the campus, 3 focus areas where ecological design criteria can be applied and which are in the most intensive use of the campus have been determined (Fig. 5). The selection of the three focus areas in this study was driven by their high frequency of use, strategic spatial positioning, and potential for ecological and functional enhancement. Prioritizing intensively used areas aligns with the principle of maximizing environmental, social, and economic benefits within limited resources, ensuring that proposed interventions address the most pressing needs. High-use areas, such as the Campus Main Entrance and Rectorate Building vicinity, the Faculty of Engineering and Architecture vicinity, and the Central Classrooms Building vicinity, were chosen

Table 3 Area usage habits frequency table

Variables	Mean	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Non-response
Sports and Physical Activities							
I do sports activities at the campus outdoor areas	1.72	462 (59.8%)	140 (18.1%)	115 (14.9%)	41 (5.3%)	15 (1.9%)	0
I ride my bike in the campus open spaces	1.35	606 (78.8%)	90 (11.7%)	47 (6.1%)	17 (2.2%)	9 (1.2%)	4 (0.5%)
I do activities such as skating/skateboarding in campus open areas	1.12	720 (93.3%)	21 (2.7%)	21 (2.7%)	8 (1.0%)	2 (0.3%)	1 (0.1%)
I do outdoor activities such as yoga/Pilates etc., on campus	1.16	698 (90.3%)	42 (5.4%)	23 (3.0%)	7 (0.9%)	3 (0.4%)	0
I attend university festivities	2.13	308 (39.9%)	201 (26.0%)	160 (20.7%)	61 (7.9%)	42 (5.4%)	1 (0.1%)
Study and Leisure Activities							
I use outdoor areas to study on campus	1.93	353 (46.1%)	193 (25.2%)	151 (19.7%)	55 (7.2%)	13 (1.7%)	8 (1.0%)
I use the outdoor areas of the campus to spend time alone or with my friends	2.78	115 (14.9%)	189 (24.5%)	260 (33.7%)	169 (21.9%)	39 (5.1%)	1 (0.1%)
I use the outdoors of the campus for spending time in between classes	2.64	176 (23.3%)	167 (22.1%)	204 (27.1%)	163 (21.6%)	44 (5.8%)	19 (2.5%)
I spend my extracurricular times in the open areas of the campus	2.41	186 (24.6%)	235 (31.1%)	198 (26.2%)	107 (14.2%)	29 (3.8%)	18 (2.3%)
I spend time on campus outside of class	2.37	237 (31.4%)	206 (27.3%)	155 (20.6%)	107 (14.2%)	49 (6.5%)	19 (2.5%)
I use the sitting areas on the campus	2.86	67 (8.7%)	229 (29.8%)	268 (34.9%)	153 (19.9%)	52 (6.8%)	4 (0.5%)
I watch the scenery on the campus	1.70	459 (59.5%)	151 (19.6%)	112 (14.5%)	30 (3.9%)	19 (2.5%)	2 (0.3%)
Use of Open and Green Areas							
I use the open green areas on the campus more than the indoor areas	2.79	117 (15.2)	220 (28.6%)	199 (25.9%)	170 (22.1%)	62 (8.1%)	5 (0.6%)
I use the outdoor spaces on the campus a lot more, which provide privacy	2.34	200 (26.4%)	243 (32.1%)	202 (26.7%)	82 (10.8%)	30 (4.0%)	16 (2.1%)
The campus open areas can be used comfortably in the summer season	2.86	113 (14.7%)	184 (24.0%)	234 (30.5%)	174 (22.7%)	63 (8.2%)	5 (0.6%)
The campus open areas can be used comfortably in the winter season	2.02	258 (33.7%)	296 (38.7%)	158 (20.7%)	43 (5.6%)	10 (1.3%)	8 (1%)
I walk in the open areas of the campus	2.41	188 (24.4%)	235 (30.4%)	223 (28.9%)	94 (12.2%)	32 (4.1%)	1 (0.1%)
Cultural and Recreational Activities							
I do bird watching at the campus open areas	1.25	662 (85.9%)	51 (6.6%)	40 (5.2%)	11 (1.4%)	7 (0.9%)	2 (0.3%)
I picnic at the campus open areas	1.25	645 (83.5%)	78 (10.1%)	38 (4.9%)	7 (0.9%)	4 (0.5%)	1 (0.1%)
I do artistic activities on the campus open spaces	1.24	661 (85.5%)	63 (8.2%)	35 (4.5%)	7 (0.9%)	7 (0.9%)	0

because they serve as key social, academic, and functional hubs. These zones experience significant pedestrian and social activity, making them ideal for impactful interventions that enhance thermal comfort, biodiversity support, and stormwater management. Improvements in such areas not only deliver immediate benefits to a large number of campus users but also serve as replicable models for future design interventions in less-frequented zones. This approach ensures that ecological design solutions are highly visible, user-centered, and aligned with broader sustainability goals, while addressing the dynamic needs of a diverse campus population effectively.

The research outcomes pinpointed specific focal zones for which ecological design recommendations were devised. These areas encompass the campus main entrance and the vicinity surrounding the Rectorate building, the space adjacent to the Faculty of Engineering and Architecture building, as well as the vicinity surrounding the Central Classrooms building. These identified focal points are outlined in Table 9, encapsulating the essence of the study's findings.

Table 4 Satisfaction level frequency table

Variables	Mean	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Non-response
Furniture and Facilities							
The outdoor furniture of the campus is ergonomic and uniquely designed	2.45	158 (20.5%)	246 (31.9%)	233 (30.3%)	124 (16.1%)	9 (1.2%)	3 (0.4%)
The outdoor furniture of the campus is sufficient in number	2.04	251 (32.6%)	318 (41.2%)	127 (16.5%)	70 (9.1%)	5 (0.6%)	2 (0.3%)
Bicycle transportation facilities (bike paths and parks) are sufficient within the campus	2.43	190 (24.6%)	212 (27.4%)	238 (30.8%)	116 (15.0%)	17 (2.2%)	0
Sports fields are sufficient on the campus	2.63	133 (17.4%)	199 (26.0%)	270 (35.3%)	139 (18.2%)	23 (3.0%)	9 (1.2%)
There is sufficient space suitable for cultural activities such as festivals/theaters, etc., on the campus	2.47	174 (22.5%)	229 (29.7%)	222 (28.8%)	127 (16.5%)	20 (2.6%)	1 (0.1%)
There are sufficient free playgrounds on the campus	2.49	129 (16.8%)	261 (33.9%)	260 (33.8%)	110 (14.3%)	10 (1.3%)	3 (0.4%)
I find the lighting elements on the campus sufficient	2.89	96 (12.5%)	179 (23.2%)	244 (31.7%)	218 (28.3%)	33 (4.3%)	3 (0.4%)
I have easy access to open areas within the campus	3.28	66 (8.6%)	100 (13.0%)	201 (26.1%)	362 (47.0%)	41 (5.3%)	3 (0.4%)
Green and Environmental Features							
The variety of flora (plants) in the outdoor spaces of the campus is sufficient	1.99	270 (35.2%)	287 (37.4%)	161 (21.0%)	45 (5.9%)	5 (0.7%)	5 (0.6%)
The diversity of fauna (animals) in the outdoor areas of the campus is sufficient	2.49	214 (27.7%)	214 (27.7%)	168 (21.8%)	105 (13.6%)	71 (9.2%)	1 (0.1%)
The amount of open-green space on the campus is sufficient	2.36	181 (23.4%)	280 (36.3%)	181 (23.4%)	112 (14.5%)	18 (2.3%)	1 (0.1%)
The green areas on the campus are suitable for people of all ages and physical characteristics	2.68	110 (14.3%)	227 (29.4%)	254 (32.9%)	159 (20.6%)	21 (2.7%)	2 (0.3%)
The open-green areas within the campus have a natural appearance	2.67	133 (17.3%)	211 (27.4%)	230 (29.8%)	171 (22.2%)	26 (3.4%)	2 (0.3%)
Comfort and Belonging							
It is a pleasure to spend time alone or with my group friends in the outdoor areas of the campus	3.11	74 (9.6%)	116 (15.1%)	272 (35.4%)	267 (34.7%)	40 (5.2%)	4 (0.5%)
I can take a walk in the outdoor areas of the campus	3.07	95 (12.4%)	144 (18.8%)	187 (24.3%)	296 (38.5%)	46 (6.0%)	5 (0.6%)
I feel safe in the outdoor spaces of campus	3.25	68 (8.9%)	119 (15.5%)	207 (27.0%)	299 (39.0%)	74 (9.6%)	6 (0.8%)
I feel comfortable in the outdoor areas of the campus during the winter months	1.97	296 (38.4%)	271 (35.1%)	142 (18.4%)	58 (7.5%)	4 (0.5%)	2 (0.3%)
I feel comfortable in the outdoor areas of the campus in summer	2.63	168 (21.7%)	183 (23.7%)	214 (27.7%)	182 (23.5%)	26 (3.4%)	0
The outdoor spaces of the campus relax me	2.68	133 (17.2%)	188 (24.4%)	269 (34.8%)	158 (20.5%)	24 (3.1%)	1 (0.1%)
The campus' outdoors help me feel belonging to this university	2.57	170 (22.0%)	181 (23.4%)	260 (33.6%)	135 (17.5%)	27 (3.5%)	0
I am satisfied with the general quality of life on campus	2.51	135 (17.5%)	243 (31.5%)	268 (34.8%)	112 (14.5%)	13 (1.7%)	2 (0.3%)
I find the security of the places in the immediate vicinity of the campus sufficient	2.75	110 (14.3%)	198 (25.7%)	261 (33.9%)	176 (22.9%)	25 (3.2%)	3 (0.4%)
Environmental Management and Green Campus identity							
I am satisfied with the outdoor air quality of the campus	2.70	163 (21.2%)	174 (22.6%)	194 (25.2%)	209 (27.2%)	29 (3.8%)	4 (0.5%)

Table 4 (continued)

Variables	Mean	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Non-response
I am satisfied with the environmental management of the university	2.34	211 (27.3%)	221 (28.6%)	225 (29.1%)	100 (12.9%)	16 (2.1%)	0
Garbage is collected regularly in and around the campus	3.37	55 (7.2%)	89 (11.6%)	208 (27.2%)	342 (44.8%)	70 (9.2%)	9 (1.2%)
Transportation facilities (traffic. public transportation. etc.) are sufficient on the campus	1.94	353 (45.8%)	211 (27.4%)	123 (16.0%)	68 (8.8%)	16 (2.1%)	2 (0.3%)
Lessons and social activities related to environmental education are sufficient	2.26	196 (25.7%)	247 (32.3%)	253 (33.1%)	59 (7.7%)	9 (1.2%)	9 (1.2%)
Green Campus status is an important preference criterion in my university selection	3.26	100 (13.1%)	112 (14.7%)	194 (25.4%)	207 (27.1%)	151 (19.8%)	9 (1.2%)
'Green Campus' practices in universities support high quality of life	3.59	77 (10.0%)	91 (11.8%)	137 (17.8%)	233 (30.3%)	231 (30.0%)	4 (0.5%)
The indoor and outdoor areas of campus have unique (architectural, landscape, historical, etc.) identity values	2,39	183 (23.8%)	233 (30.3%)	237 (30.8%)	102 (13.2%)	15 (1.9%)	3 (0.4%)
The open and closed areas of the campus are arranged to reduce the amount of energy use within the campus	2.65	121 (15.7%)	183 (23.8%)	329 (42.7%)	121 (15.7%)	16 (2.1%)	3 (0.4%)
Renewable energy sources (wind, sun) are used adequately within the campus	2.58	134 (17.4%)	213 (27.7%)	281 (36.5%)	124 (16.1%)	18 (2.3%)	3 (0.4%)

Discussion

University campuses hold a significant place in urban environments due to their substantial spatial coverage within cities and the important roles that universities play. To address existing challenges in adapting to climate change and bolster resilience against potential future issues, it is imperative to reevaluate campus development plans and landscape designs. This involves transforming campus areas into climate-compatible urban spaces that align with user preferences. Colding and Barthel (2017) emphasize that the campus areas, including their structural components and lands, can be regarded as shared community spaces within the city.

This study highlights the critical role of user-centered ecological design strategies in enhancing the sustainability and climate resilience of university campuses. The findings emphasize the significance of pedestrian paths and bicycle lanes, aligning with previous research that underscores their role in reducing carbon footprints, promoting physical activity, and improving microclimatic conditions (Saklı, 2019; Fadhil & Waheeb 2021). However, unlike previous studies, this research extends the discussion by proposing shaded pedestrian pathways and an integrated cycling network as primary tools for sustainable urban mobility and carbon reduction (Yerli & Özdede, 2017).

Prior studies have highlighted the demand for green spaces and social areas on university campuses (Hami & Abdi 2021; Larson et al. 2016). The survey results of this study confirm that this demand is also high among İzmir Katip Çelebi University users. The proposed design interventions—including shaded seating areas, green corridors, and biodiversity-focused planting strategies—are directly aligned with these preferences. Similar strategies have been implemented at Politecnico di Torino University and Eskişehir Technical University (Genta et al. 2022; Çetin et al., 2021). However, this study differs by incorporating context-specific strategies tailored to the Mediterranean climate of İzmir, emphasizing water efficiency and thermal comfort solutions.

Globally, sustainable campus design has been linked to initiatives such as rainwater management systems and renewable energy integration (Amr et al. 2016; Fachrudin 2020). This study aligns with these efforts by integrating solar panels and rainwater collection systems to reduce resource dependency and enhance climate resilience. However, the Mediterranean climate presents unique challenges that require optimized water conservation and heat mitigation strategies, setting this research apart from previous models.

Nature-based solutions (NbS) and biophilic design principles offer holistic approaches that integrate ecological and user-centered strategies into urban campuses (Scott et al. 2016; Pauleit et al. 2019). Previous research has demonstrated that shaded seating, tree canopy coverage, and adaptive user behaviors improve outdoor

Table 5 Expectation level frequency table

Variables	Mean	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Non-response
Green and Natural Events							
Flora (plant) diversity	4.08	30 (3.9%)	31 (4.0%)	79 (10.3%)	336 (43.7%)	293 (38.1%)	4 (0.5%)
Fauna (animal) diversity	3.26	103 (13.4%)	91 (11.9%)	219 (28.6%)	209 (27.2%)	145 (18.9%)	6 (0.8%)
Roof gardens	3.74	43 (5.6%)	69 (9.0%)	159 (20.8%)	265 (34.6%)	229 (29.9%)	8 (1.0%)
Increasing green spaces	4.24	23 (3.0%)	26 (3.4%)	61 (7.9%)	293 (38.2%)	365 (47.5%)	5 (0.6%)
Woodlands (Forested areas suitable for small-scale passive use)	3.84	48 (6.3%)	56 (7.3%)	117 (15.3%)	292 (38.1%)	254 (33.1%)	6 (0.8%)
Biological pond	3.32	78 (10.2%)	107 (13.9%)	222 (28.9%)	210 (27.3%)	151 (19.7%)	5 (0.6%)
Pond	3.28	91 (11.9%)	116 (15.1%)	198 (25.8%)	210 (27.4%)	151 (19.7%)	7 (0.9%)
Landscapes with high aesthetic value	3.69	57 (7.4%)	62 (8.1%)	161 (21.0%)	265 (34.6%)	221 (28.9%)	7 (0.9%)
Visual element of water	3.35	87 (11.3%)	91 (11.8%)	170 (22.1%)	309 (40.2%)	112 (14.6%)	4 (0.5%)
Artistic and Cultural Features							
Artistic items (sculpture, etc.)	3.55	72 (9.3%)	75 (9.7%)	136 (17.6%)	330 (42.8%)	158 (20.5%)	2 (0.3%)
Areas suitable for artistic activities	3.82	37 (4.8%)	59 (7.7%)	126 (16.4%)	330 (42.9%)	218 (28.3%)	3 (0.4%)
Amphitheatre	3.84	33 (4.3%)	52 (6.8%)	149 (19.5%)	304 (39.7%)	227 (29.7%)	8 (1.0%)
Festival/gathering areas	3.90	42 (5.5%)	39 (5.1%)	112 (14.6%)	332 (43.2%)	243 (31.6%)	5 (0.6%)
Accessibility and Use							
Walking paths	4.03	28 (3.6%)	32 (4.2%)	92 (12.0%)	352 (45.8%)	265 (34.5%)	4 (0.5%)
Bicycle paths and parks	3.88	34 (4.5%)	42 (5.5%)	129 (16.9%)	333 (43.6%)	225 (29.5%)	10 (1.3%)
Rest areas	4.16	21 (2.7%)	26 (3.4%)	49 (6.4%)	383 (49.8%)	290 (37.7%)	4 (0.5%)
Furniture that will allow studying in open spaces	4.07	33 (4.3%)	37 (4.8%)	76 (9.9%)	321 (41.8%)	301 (39.2%)	5 (0.6%)
Free play areas	3.73	40 (5.2%)	64 (8.3%)	171 (22.3%)	284 (37.0%)	209 (27.2%)	5 (0.6%)
Personal private space	3.74	42 (5.5%)	62 (8.1%)	159 (20.7%)	294 (38.2%)	212 (27.6%)	4 (0.5%)
Infrastructure and safety							
Charging stations	3.71	44 (5.8%)	75 (9.8%)	146 (19.1%)	294 (38.4%)	206 (26.9%)	8 (1.0%)
Increasing lighting elements	3.75	34 (4.4%)	54 (7.0%)	196 (25.5%)	275 (35.8%)	210 (27.3%)	4 (0.5%)
Increasing security	3.64	50 (6.5%)	67 (8.7%)	183 (23.9%)	273 (35.6%)	194 (25.3%)	6 (0.8%)
Recreational and Social Activities							
Ability to take nature photos	3.52	66 (8.6)	83 (10.8%)	191 (24.8%)	244 (31.7%)	185 (24.1%)	4 (0.5%)
Bird watching	3.00	126 (16.4%)	126 (16.4%)	256 (33.2%)	148 (19.2%)	114 (14.8%)	3 (0.4%)
Picnic units	3.33	89 (11.6%)	96 (12.5%)	205 (26.7%)	230 (29.9%)	149 (19.4%)	4 (0.5%)
Areas suitable for activities such as yoga/Pilates in open spaces	3.17	104 (13.5%)	114 (14.8%)	224 (29.1%)	202 (26.3%)	125 (16.3%)	4 (0.5%)
Activities such as skating, skateboarding	3.16	100 (13.1%)	122 (15.9%)	234 (30.6%)	170 (22.2%)	139 (18.2%)	8 (1.0%)

Table 6 Reliability analysis of scales

Scale	Cronbach's alpha	Number of propositions	Mean	St. deviation
Current usage habits	0.83	20	2.02	9.79
Satisfaction	0.93	32	2.63	19.13
Expectations	0.95	27	3.66	20.06

thermal comfort (Huang et al. 2019). The findings of this study similarly indicate that users prefer shaded areas during summer and sunlit spaces in winter, highlighting the importance of microclimate-responsive design interventions.

A study conducted in Santa Catarina, Brazil, found that while students exhibited high awareness of sustainability goals, there were gaps between this awareness and campus infrastructure (Ribeiro et al. 2021). The present study confirms this trend, showing that while users support sustainability initiatives, infrastructure development must actively facilitate sustainable behaviors.

Table 7 Normal distribution tests of scales

Variables	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	*df*	Sig	Statistic	*df*	Sig
Current usage habits	0.58	654	0.00*	0.98	654	0.00*
Current usage areas satisfaction level	0.04	654	0.05	0.99	654	0.05
Expectations from the open-green areas of the campus	0.69	654	0.00*	0.95	654	0.00*

*Significant at the $p < 0.05$ level

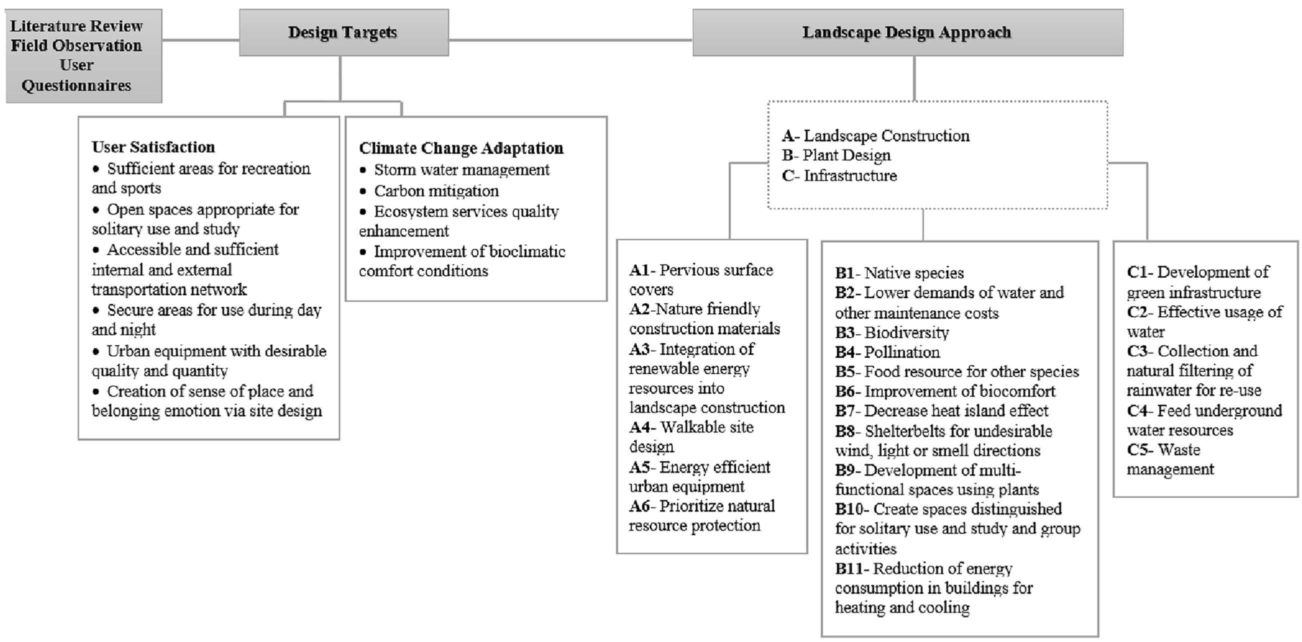


Fig. 4 Landscape design approach developed in scope of climate change adaptation and user expectations

Biophilic design principles have been shown to enhance student well-being by incorporating natural light, green spaces, and water elements into campus design (DeLauer et al. 2022). The results of this study reinforce these findings, demonstrating that tree-shaded walkways, green areas, and sensory gardens contribute to improved mental well-being and stress reduction. This suggests that in hot climates like İzmir, increasing bioclimatic comfort through strategic landscape interventions can significantly enhance the user experience.

The proposed planting strategies in this study focus on mitigating the urban heat island effect, enhancing carbon sequestration, and improving the aesthetic and ecological quality of the campus. Prior research has emphasized that native plant species require minimal maintenance and are more resilient to heat stress (Susilowati et al. 2021). The findings of this study support this perspective, demonstrating that broadleaf plant species can reduce water consumption while improving thermal comfort.

To further enhance sustainability, the study avoids large grass surfaces and instead recommends ground cover species that require less irrigation. Additionally, vegetative screening along the highway is proposed to mitigate noise and dust pollution, while denser tree planting within the campus enhances shade coverage. The selection of fruit-bearing plant species contributes not only to campus biodiversity but also to the creation of a self-sustaining ecological system.

Sustainable landscape design principles emphasize energy efficiency, bioclimatic comfort, and resource conservation (Alpay et al., 2013). The current study incorporates these principles by integrating shading structures, bike paths, and low-heat-absorption materials, while also promoting water conservation through rainwater harvesting and wastewater reuse strategies.

A notable contribution of this study is its focus on renewable energy integration within the campus landscape. The design for the Faculty of Engineering and Architecture building (Focal Area 2, Table 7) incorporates solar

Table 8 Landscape design suggestions produced in line with user survey results

Structural design suggestions	Plant design suggestions	Managerial suggestions
Defining walking and cycling paths within the campus, Designing open space uses with thermal comfort features in summer and winter seasons, Creating areas suitable for being alone and working/studying in the open area, Creating areas suitable for artistic activities, Designing meeting, festive and free play areas, Defining picnic areas, Increasing the accessibility levels of campus exteriors, Increasing the quality of urban equipment elements, designing ergonomic, energy efficient equipment suitable for use as a charging unit, Collecting and storing rainwater, using it for irrigation of landscape areas within the campus, Installing gray water treatment and storage systems in buildings, using them for appropriate needs (irrigation, reservoir, etc.), The use of permeable and semi-permeable pavement types in structural landscape areas, Increasing the use of renewable energy sources, Creating a common design language throughout the campus, Designing items that will add identity value to the campus, Creating areas that will strengthen the sense of belonging of campus users and increase their perception of quality of life	Increasing the presence of green areas and ecological service quality on the campus, Increasing the diversity of flora and fauna, including edible plants that will provide food for animals in appropriate areas, Roof gardens design in suitable areas, Creating wind-break with plants in the necessary areas of the campus, Screening the borders of the campus in the direction of the highway with suitable plant species for the retention of traffic-induced dust, particles and heavy metals, Preferring native species with low maintenance costs and low water needs in plant species selection, Creation of carbon sink areas	Solving the transportation problem to the campus, Developing educational policies that will create environmental awareness, Ensuring the participation of users in the process of increasing the environmental development and quality of the campus through student clubs, social activities and similar projects

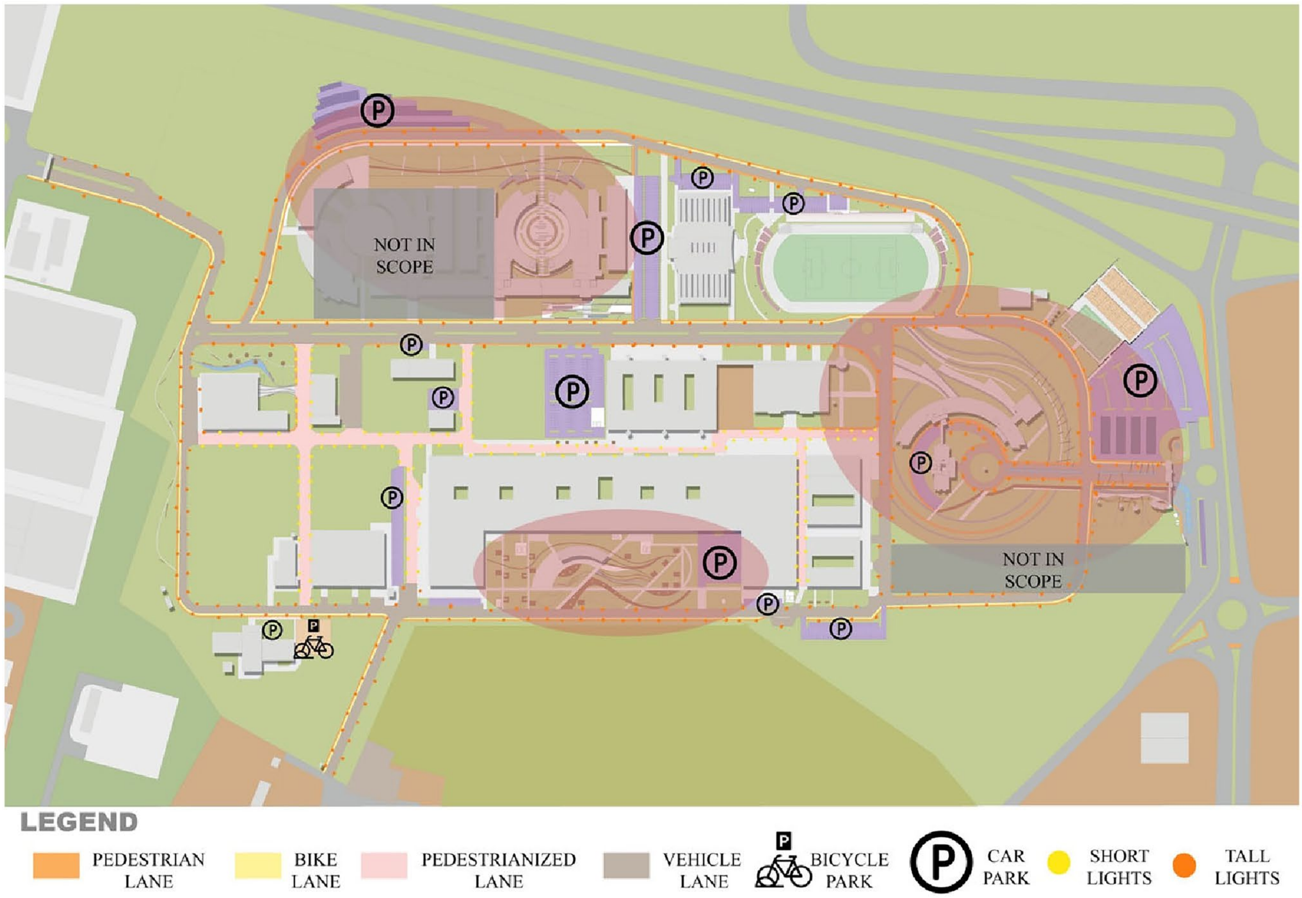


Fig. 5 Focus areas for which ecological design proposals were developed

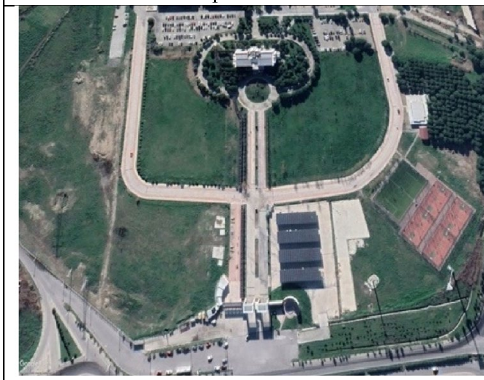
panels, aligning with recent trends in campus sustainability (Rabaia et al. 2021). These interventions are expected to reduce reliance on conventional energy sources, decrease operational costs, and contribute to global carbon reduction efforts (Fachrudin 2020).

Survey data analysis reveals that users prioritize pedestrian paths (mean: 4.03) and bicycle lanes/parks (mean: 3.88) within the campus environment. This preference underscores their significance in enhancing connectivity, safety, and environmental sustainability (Saklı, 2019). The findings align with Fadhil & Waheeb (2021), who emphasize that pedestrian and cycling infrastructure fosters ecological awareness, sensory engagement, and user comfort. These principles have been integrated into the present study's design proposals, ensuring alignment with user expectations.

Designing campus landscapes in response to student preferences is a key consideration. Hami & Abdi (2021) identified greenery, seating areas, and water features as the most critical campus design elements for students. Previous research has demonstrated that factors such as spatial variety, landscape diversity, plant color variation, and social interaction areas contribute positively to campus usage and satisfaction (Eslamirad et al. 2022). This study builds upon these insights by enhancing species diversity and transforming undefined spaces into functional areas. The integration of shade structures, walking paths, seating facilities, and vegetative screening ensures dust and noise mitigation, while fragrant and flowering species improve outdoor sensory experiences. Upon the successful realization of the urban adaptation plan and the implementation of structural landscape interventions for climate change, an increase in the diversity and quality of ecological services within the campus is expected. Simultaneously, a decrease in the consumption of natural resources and energy is anticipated. This comprehensive approach is likely to contribute to higher user affinity and satisfaction levels, reflecting an improved perception of campus life quality. Through these coordinated efforts, the campus environment is expected to undergo a significant evolution towards greater sustainability and an enhanced user experience. In this context, the term 'transformative shift' refers to the gradual yet impactful improvements in environmental resilience, resource efficiency, and user engagement facilitated by these interventions.

Table 9 Recommended landscape design decisions in focal design areas

Focal Area 1: The campus main entrance and the area around the Rectorate building



Current Situation

Landscape Design Suggestion

Design Decisions

This area will be shaded with vegetal elements to provide bioclimatic comfort for pedestrians, especially in summer, and will be covered with ecological surface materials with high heat absorption and precipitation permeability. Studies have shown that urban vegetation significantly reduces surface and air temperatures, enhancing thermal comfort for pedestrians during summer months (Lai et al., 2019). Additionally, creating interconnected green spaces, such as woodland networks with organic-shaped pathways, will support recreational activities while improving microclimates (Iuorio & Harbich, 2019).

In the vicinity of the Rectorate building, efforts will be made to increase vegetative density and facilitate both transitional and recreational activities for pedestrians. For this purpose, the focus will be on the minimal use of structural landscape elements. To both increase the evaporation surface and mitigate the harmful effects of heat islands, ecological materials with high albedo will be utilized. These materials, which effectively reflect solar radiation, have been identified as a key solution for mitigating urban heat islands.

A woodland network be established around the Rectorate building, connecting the area with organic shaped and natural pedestrian axes, allowing for recreational activities. The use of permeable pavements in these areas will further support stormwater management and will help reduce the risk of flooding by enhancing water infiltration into the soil (Ziaeemehr et al., 2023).

The Rectorate car park, on the other hand, will be designed to cover the minimum surface area on the rear facade, taking into account the visual quality around the building, and will be shaded by evergreen trees with high aesthetic value. To contribute to sustainability by generating electricity from renewable energy sources, the parking lot will be covered with solar panels. This dual-purpose design will not only provide shading forparked vehicles but also generate clean energy, aligning with global sustainability goals (Farahmand et al.,2021)

Conclusions

University campuses, resembling miniature cities due to their structural complexity and multifunctional roles, serve as focal points for numerous students and staff members. These spaces must not only provide educational and research facilities but also encompass a diverse range of social amenities to meet the needs of their inhabitants. Beyond their immediate role, campuses can serve as living laboratories, showcasing tangible solutions to prevalent environmental challenges through practical spatial implementations. Crucially, the aspirations and expectations of the campus community must be at the forefront of all endeavors. While campuses contribute to the urban ecosystem, they should concurrently possess the qualities of inviting and comfortable living spaces for their users.

The present study, conducted in the Mediterranean climate context of İzmir, Türkiye, offers insights that are both locally significant and globally relevant. İzmir's Mediterranean climate is characterized by hot, dry summers and mild, wet winters, conditions that pose unique challenges for water management, thermal comfort, and biodiversity preservation in urban and campus landscapes. The Mediterranean climate, specifically the Csa type according to the Köppen-Geiger classification, influences various environmental factors that affect urban planning and management strategies in İzmir (Birim et al. 2023). The hot, dry summers can exacerbate urban heat island effects, leading to increased surface temperatures and reduced thermal comfort for residents (Yavaşli 2017). This phenomenon is particularly critical in urban areas where rapid urbanization has intensified the challenges of maintaining thermal comfort and managing water resources (Akkurt 2024).

Moreover, the interplay between urban vegetation and thermal comfort is significant in Mediterranean climates. Studies have shown that the presence of urban greenery can

Table 9 (continued)

Focal Area 2: The area around the Faculty of Engineering and Architecture building	
	
Current Situation	Landscape Design Suggestion
Design Decisions	
There will be linear plant beds, mirror pools, and linear seating units in front of the Faculty of Engineering and Architecture building. Studies indicate that integrating plant beds and water features, such as mirror pools, can enhance microclimatic conditions by providing cooling effects and improving aesthetic appeal. In order to maintain the structural landscape ratio at a minimum level, the walking paths between the plant beds will be kept at a minimum width and will be designed in the form of a pathway. Permeable pavement the parking area along the surrounding roads to manage stormwater and reduce surface runoff, while the area will be used for will be shaded by trees specifically chosen for car park afforestation. Research demonstrates that permeable pavements combined with strategic tree planting can significantly mitigate urban heat island effects and improve water infiltration rates (Cheela et al., 2021). Planting design will be implemented around the faculty building to provide both bioclimatic comfort and visual privacy for users. Vegetative barriers, such as green cords designed as groves, will be effective in reducing noise and providing natural shading, contributing to the overall comfort of users (Susca, 2022). Additionally, a bike path will be integrated into the design, supported by a green cordon to enhance user safety and ecological connectivity. The walking promenade, continuous in the form of a wooden pier, and seating units will be strategically placed to encourage social interaction and outdoor engagement. Wooden pathways, when sustainably sourced, also reduce heat absorption and align with principles of eco-friendly urban design (Dong et al.,2022). The area between the vehicle road and the highway will be used as a parking lot and will be covered with PV solar panels to provide shade for vehicles and generate energy.	
Focal Area 3: The area around the Central Classrooms building	
	
Current Situation	Landscape Design Suggestion
Design Decisions	
The Central Classrooms building will serve as a hub that includes classrooms and laboratories, a library, a conference hall, a media center, and cafeterias on the campus. This building will consist of multiple blocks, with entrances and exits leading to the designed landscape courtyard. The existing landscape area is currently not preferred by users due to the lack of vegetation and biocomfort. To address this issue, the design will aim to increase the diversity of plant species, enhancing both the visual appeal and functional quality of the area. Research shows that enhancing biodiversity through varied plant species not only supports local ecosystems but also creates more attractive and comfortable environments for users (Xie, 2023). The structural landscape will be designed with pathways and wooden walkways and will be enriched with seating units.	

mitigate the adverse effects of high temperatures, thereby enhancing outdoor thermal comfort (Gatto et al. 2020). The integration of nature-based solutions (NBS) has been proposed as a viable strategy to improve urban microclimates, which is essential for promoting biodiversity and ensuring sustainable urban development (Akkurt 2024). The effectiveness of these solutions is underscored by the need for adaptive strategies that consider local climatic conditions, such as the influence of sea breezes that can moderate temperatures in coastal cities like İzmir (Sabatell-Canales 2023).

In terms of biodiversity preservation, the unique climatic conditions of İzmir necessitate careful planning to protect native species and habitats. The Mediterranean climate supports a diverse range of flora and fauna, but urban expansion poses threats to these ecosystems (Kirkan 2019). Effective water management practices are crucial in this context, as they can help maintain the ecological balance while addressing the demands of urbanization (Birim et al. 2023). Overall, the challenges posed by İzmir's Mediterranean climate require a multifaceted approach that incorporates thermal comfort, water management, and biodiversity preservation into urban planning and landscape design. İzmir's Mediterranean climate is characterized by hot, dry summers and mild, wet winters, conditions that pose unique challenges for water management, thermal comfort, and biodiversity preservation in urban and campus landscapes. These climatic features informed the ecological design strategies proposed in this study, such as the selection of drought-tolerant native plants, rainwater harvesting systems, and shading solutions. Similar strategies have proven effective in other Mediterranean regions, such as Spain and Italy, where water scarcity and urban heat island effects are prominent (Pauleit et al. 2019; Amr et al. 2016).

While the findings are particularly applicable to regions with comparable climatic conditions, the broader principles of nature-based solutions, user-centered design, and sustainable resource management are transferable to other climatic contexts. For instance, colder climates may adapt these principles by emphasizing wind-break designs and species selection that supports winter resilience, while tropical regions could prioritize flood management and high-canopy vegetation. This adaptability underscores the potential for generalizing the study's outcomes, provided they are tailored to the specific ecological and climatic needs of the target region. Thus, while rooted in a Mediterranean setting, the study contributes to a universal framework for integrating ecological design into campus landscapes worldwide.

This study highlights the applicability of design strategies tailored to the unique characteristics of the Mediterranean climate, aligning with similar research findings (e.g., Gatto et al. 2020; Sabatell-Canales 2023). The results suggest that these strategies can be adapted to other climatic contexts, such as flood management and the use of high-canopy vegetation in tropical regions, or windbreak designs and winter-resilient plant species in colder climates. Furthermore, the study reinforces the concept of campuses not only as spaces for education and research but also as "living laboratories" where nature-based solutions and biophilic design strategies can be implemented and tested in real-time. Future research can expand on these findings by exploring the applicability of similar strategies across different campus typologies and climatic zones, providing a broader validation of the proposed approaches. In this context, the study contributes to sustainable and resilient campus design both locally and globally.

The present study has forged an approach aimed at aligning ecological design criteria with the preferences and expectations gleaned from a survey conducted within the campus. By formulating ecological design proposals, the study offers a blueprint for campuses encountering similar issues. As such, it holds the potential to guide the enhancement of sustainability and the establishment of resilient campuses that are adaptable to the demands of climate change. This comprehensive study contributes not only to the improvement of campus environments but also to the advancement of urban design practices on a larger scale.

Acknowledgements The authors thank Izmir Katip Celebi University, Scientific Research Projects Coordinator, General Research Project for contributing to the completion of the project. This study was supported by Izmir Katip Celebi University, Scientific Research Projects Coordinator, General Research Project, Faculty of Engineering and Architecture with Project id: 2019-GAP-MUMF-009.

Author Contribution AKO: Conceptualization, Methodology, Software; MC: Data curation, Writing- Original draft preparation. GGS: Visualization, Investigation.; HS: Supervision AKD: Writing- Reviewing and Editing; PO: Software, Validation.

Funding The authors thank Izmir Katip Celebi University, Scientific Research Projects Coordinator, General Research Project for contributing to the completion of the project. This study was supported by Izmir Katip Celebi University, Scientific Research Projects Coordinator, General Research Project, Faculty of Engineering and Architecture with Project id: 2019-GAP-MUMF-009.

Data Availability No datasets were generated or analyzed during the current study.

Declarations

Conflict of Interest The authors declare no competing interests.

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