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# Stormwater Management and Green Infrastructure Suggestions for Sustainable Campus; Example of Yozgat Bozok University Campus

Melek KAPLAN [1]*, Kübra YAZICI [2]

**ORCID 1:** 0000-0003-4667-0328, **ORCID 2:** 0000-0002-6046-1648

[1] *Yozgat Bozok University, Graduate Education Ens., Department of Agricultural Sciences/ Directorate of Construction Works, 66100 Merkez, Yozgat, Türkiye.*

[2] *Yozgat Bozok University, Faculty of Agriculture, Department of Landscape Architecture, 66100 Center, Yozgat, Türkiye.*

**** e-mail**: k-yazici-karaman@hotmail.com*

**Abstract**

*Due to concrete structures, transportation networks, and impermeable surfaces, the overpopulation of cities makes it difficult for water to filter through the soil. Cities, in particular, disrupt the natural cycle of rainwater, leading to surface runoff. As a result, the soil skips the stages of water filtering, feeding the groundwater, evaporating, and returning to the atmosphere, leading to an increased frequency of floods that are not part of the hydrological cycle. One of the alternative solutions to global warming is the green infrastructure system. Practices such as rainwater collection systems, water recovery technologies, and the development of irrigation systems ensure efficient use of water resources and prevention of water pollutiYozgat Bozok University Campus has planned for a sustainable campus from a green infrastructure perspective, and has presented a master plan that addresses issues like rainwater management, wastewater recovery, solid waste recycling, and the qualities and quantities of campus open-green areas. The study involved landscape planning, the identification of rain harvesting areas for the campus, which is currently facing a water shortage, and the presentation of plant preferences and water-efficient solution suggestions for the region.*

***Keywords:*** *Landscaping,stormwater management, planning.*

# Sürdürülebilir Kampüs için Yağmursuyu Yönetimi ve Yeşil Altyapı Önerisi; Yozgat Bozok Üniversitesi Kampüsü Örneği

**Öz**

*Kentlerde aşırı nüfus artışıyla birlikte beton yapılar, ulaşım ağları ve geçirimsiz yüzeyler sebebiyle suyun toprak içerisinde süzülmesi zorlaşmaktadır.Özellikle kentlerde yağmur suyunun doğal döngüsü bozulmakta ve yüzey akışı gerçekleşmektedir. Bu nedenle suyun toprak tarafından filtrelenerek yeraltı suyunun beslenmesi ve buharlaşıp atmosfere geri dönmesi aşamaları atlanarak hidrolojik döngüde yeri olmayan sel vb. taşkınlarla artık daha çok karşılaşılmaktadır. Küresel ısınma ile alternatif çözümlerden biri de yeşil altyapı sistemidir. Yağmur suyu toplama sistemleri, suyu geri kazanma teknolojileri ve sulama sistemlerinin geliştirilmesi gibi uygulamalarla, su kaynaklarının verimli bir şekilde kullanılması ve su kirliliğinin önlenmesi sağlanmaktadır. Bazı mevcut uygulamaların yer aldığı Yozgat Bozok Üniversitesi Kampüs'ünde yeşil altyapı perspektifinden sürdürülebilir bir kampüs için planlama yapılmış, yağmur suyu yönetimi, atık suların geri kazanılması, katı atıkların geri dönüştürülmesi, kampüs açık-yeşil alanların nitelikleri ve miktarları gibi konularının ele alan master planı ortaya konulmuştur.Çalışmada peyzaj planlama yapılmış, mevcutta su sıkıntısı yaşan kampüs için yağmur hasadı yapılacak alanlar belirlenmiş, az su isteyen bölgeye uygun bitki tercihi ve çözüm önerileri sunulmuştur.*

***Anahtar kelimeler:*** *Peyzaj, planlama, yağmur suyu yönetimi.*

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## 1. Introduction

Since the beginning of time, humans have been focusing on development, change, and consumption, which they have accelerated over time to meet the increasing needs of themselves and their environment. Rapid population growth has led to an imbalance in the scales of development, change, and consumption, resulting in unconscious consumption. Initially, this imbalance did not appear to pose a threat. Then it has become increasingly evident for a more comfortable life, the activities of individuals, and nations due to their selfish desires. For example, various problems such as environmental pollution, global warming and climate change, unconscious consumption of water resources, floods, drought, epidemics, wars, urbanization, migration, and noise pollution have made the world more dangerous (Malkoç True & Kılıçarslan Deniz, 2012; Benison & Payne, 2022; Çon & Polat, 2020). These circumstances have prompted contemplation on the necessary steps to mitigate and avert these issues. These problems could affect human life and the continuity of ecological life. Therefore, the concept of sustainability has gained importance worldwide.

Sustainability is a type of system created against the threats of the decrease and disappearance of the resources used by all living things interacting with each other in the ecosystem in the world today and in the future (Gülgün et al., 2014; Öktem, 2016; Özdal Oktay & Özyılmaz Küçükyağcı, 2015; Aşur et al., 2022; Altuğ & Malkoç True, 2021). Sustainability plays an important role in protecting natural resources, improving the damaged ecosystem by conserving energy, creating social and economic welfare, and social participation (Qadis et al., 2019; Yazici et al., 2018; Gülgün & Yazici, 2016; Gülgün & Akça, 2020; Bertiz et al.,2019; Yazici & Gülgün, 2017). With the roles it has assumed, the importance of sustainability has increased and become a goal of many reports, conferences, agreements, institutions, and organizations aimed at sustainability by real and legal persons. Green infrastructure systems serve the protection, development, and support of urban ecosystems by connecting green areas in the city, reducing flood risk through natural drainage, promoting climate quality, and addressing various other issues. In recent years, green infrastructure has become a widely used strategic approach in sustainable land use, providing alternative solutions to ecological, social, and environmental problems worldwide (Ak & Güneş Gölbey, 2021; Ak, 2022). This approach refers to a holistic system of natural, semi-natural, and artificial functional ecologic factors at all spatial scales in and around urban areas (Tzoulas et al. 2007).

According to Benedict and McMahon (2002), green infrastructure is a system of interconnected natural areas and open spaces that could protect ecosystem values and help maintain clean air and water for people and wildlife. Derse (2023) defined the green infrastructure system as a network that enhances human welfare and quality of life, strategically planning the environmental characteristics of outdoor green spaces to provide ecosystem services. The green infrastructure system supports the ecosystem in many ways. Urban streams are basic green infrastructures that form the ecological backbone within the urban fabric, protect biodiversity and species movements, and create green corridors and connections with natural systems in the urban periphery. Individually, they serve as the green veins of the city, but when combined with an integrated approach, they create ecological corridors that connect the green infrastructure units surrounding them to the natural systems in the city's periphery. Green infrastructure offers many advantages in terms of being ecologically based, practical and applicable, innovative, multidisciplinary, and protecting public health. However, it also presents certain challenges, such as the need for coordinated efforts with all stakeholders and the inability of different professional groups to demonstrate the same level of sensitivity towards the subject from a multidisciplinary standpoint. This study developed a landscape master plan for a campus, taking stormwater management into account. Due to the intense increase in urbanization, cities are facing significant challenges in protecting and effectively using water, a basic natural resource essential for the continuation of vital activities. Compared to rural areas, cities have impervious surfaces that reduce water infiltration. Therefore, groundwater and soil recharge are significantly reduced (Vanwoert et al., 2005; Ekşi et al., 2016).

When the precipitation passes through the surface runoff, it carries various pollutants to the receiving environment. Urban designs based on the current understanding of urbanism either prevent or

incompletely disrupt the hydrological cycle of water (Vanwoert et al., 2005). Depending on the type of receiving environment, precipitation, which should move in the hydrological cycle, reaches the gutters from the roofs, from there to the sewage system and concrete channels, and then to the water basins such as rivers, lakes, and seas (Figure 1).

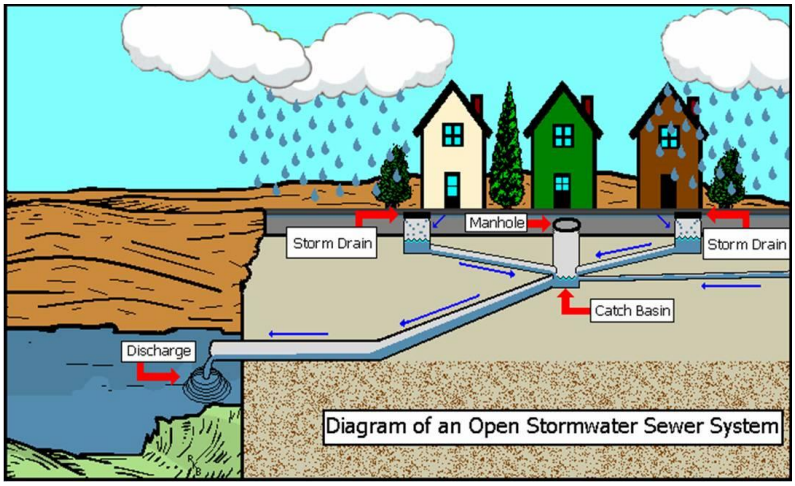


**Figure 1.** An example of stormwater management (Town of Sweden, 2024)

According to Ekşi et al. (2016), the hydrological cycle no longer accommodates the stages of water filtering by the soil, feeding the groundwater, evaporating, and returning to the atmosphere, leading to an increased frequency of floods. In another study, Saygın & Ulusoy (2011) presented a strategy for the use of low-cost and green infrastructure elements that will contribute to the ecosystem and ensure that rainwater is recycled to serve different purposes (toilet reserves, irrigation, recreation corridors, landscaping elements, etc.) on the land where it falls instead of being classified as a waste and produced recommendations that will guide the implementation of these strategies. Coşkun Hepcan & Hepcan (2018) emphasized that in areas with a large extent of irregularly distributed parts and corridors within the urban development area, the continuity in the landscape between them is low. Hepcan & Hepcan (2018) revealed the importance of a green infrastructure system in cities, highlighting specific green areas that can significantly contribute to the urban ecosystem when used appropriately to establish a green infrastructure system in the future. We conducted this study with the aim of fostering a sustainable environment on campuses. The green infrastructure proposals on the Yozgat Bozok University campus provided similar results and recommendations. The topographical structure and ecology of the land are important determinants in planning. Summarizing the findings from this research reveals the absence of a green infrastructure system on campus, insufficient open and green areas in the campus landscape, and no green areas suitable for inclusion in the green infrastructure system on the city's periphery. We provide stormwater management solutions and recommendations based on our examination of Yozgat Bozok University's Central Campus. The university designed and planned its master plan for a sustainable campus, addressing issues such as reducing carbon footprint and climate change, managing rainwater, recycling wastewater, recycling solid wastes, and increasing the number of open-green areas on campus.

## 2. Material and Method

The main material of the study consists of Erdoğan Akdağ East Campus and Bilal Şahin West Campus of Yozgat Bozok University (Figure 2), which was founded within the borders of Yozgat province. Yozgat, where the university is located, is in the Bozok plateau and the Central Kızılırmak section of Central Anatolia. It has neighboring provinces such as Kayseri, Sivas, Nevşehir, and Çorum. It is a city with a surface area of 14.074 km2 and a population of 418,442. In 2006, Yozgat Bozok University officially established its infrastructure; Erciyes University followed suit in 1982, and YOBU began as Yozgat Vocational School. Gazi University established a second vocational school in 1989. Currently, there are 14 faculties, 4 schools, and 8 vocational schools. Additionally, YOBU boasts 23,877 students, 964 academic staff, and 1140 administrative staff (Figure 3).

Erdoğan Akdağ East Campus and Bilal Şahin West Campus currently have 14 Faculties, 1 College, 1 Vocational School, 2 Institutes, 1 Research and Application Hospital, 1 Technopark, 1 laboratory building, 1 Science and Technology Application and Research Center, 1 Career Center building, 1 Guest House, 1 Central Dining Hall, 1 Central Library, 1 Mosque and Complex, 1 Practice Mosque, 1 Cannabis Building, 1 Congress and Culture Center, 1 market, 2 restaurants, 1 café that has not yet been opened, 1 gymnasium, 1 Male Student Dormitory, 1 Female Student Dormitory, 1 gymnasium, sports complex (football field, outdoor tribune, indoor astroturf field, basketball court) affiliated to the Credit Dormitories Institution (Yozgat Bozok University Report, 2022). The campus is located on a 4,070,000 $m^2$ area. Yozgat Bozok University Campüs consists of Erdoğan Akdağ East Campus and Bilal Şahin West Campus because it is divided by highways. The campus is approximately 1300 m above sea level.

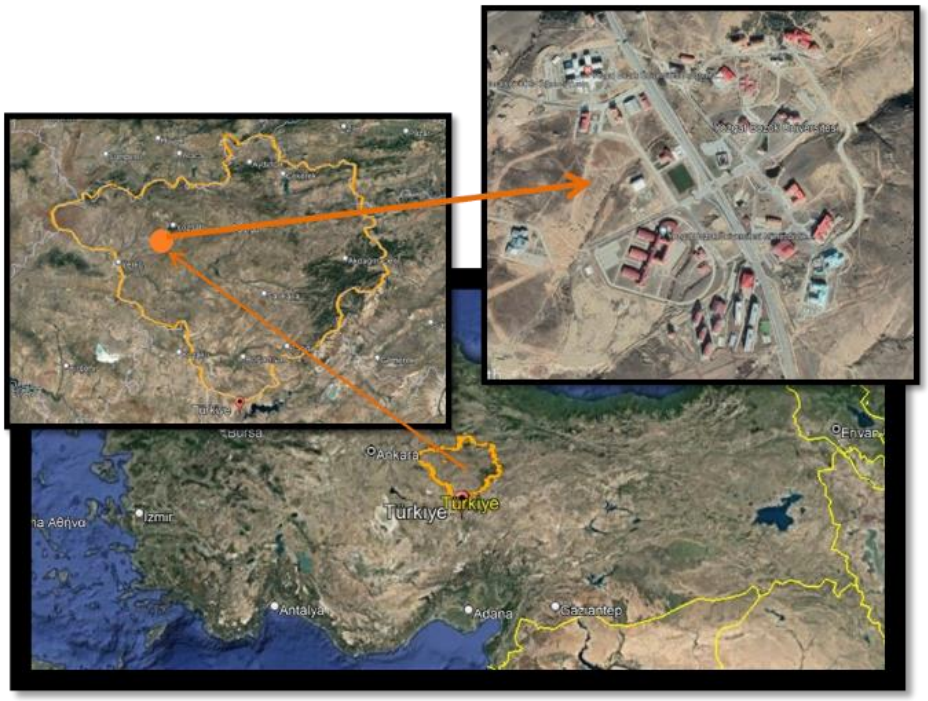


**Figure 2.** Yozgat Bozok University Satellite image (a) (Yozgat Bozok Üniversitesi Report, 2022)

**Figure 3.** General view of Yozgat Bozok University (b) (Yozgat Bozok Üniversitesi Report, 2022)

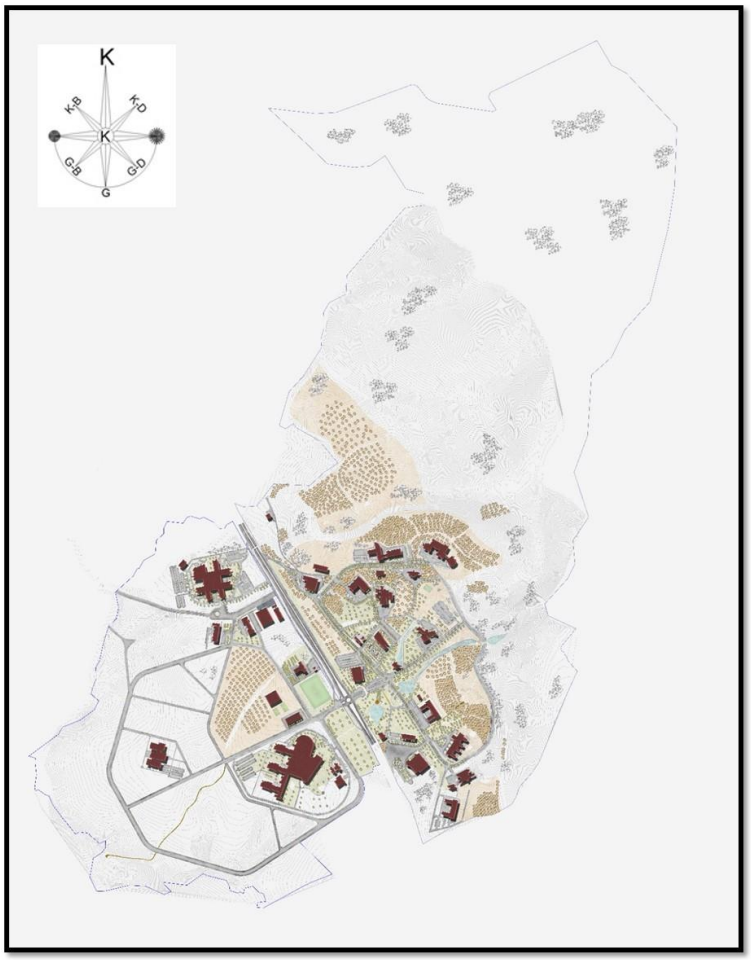


**Figure 4.** Yozgat Bozok University master plan

The other materials of the study consist of photographs of YOBÜ Erdoğan Akdağ East Campus and Bilal Şahin West Campus (Figure 4), as well as plans, various reports, and digital resources including the study area. We conducted the study between 2022 and 2023. Following the theoretical literature research, data on the study area were collected to prepare the landscape master plans of Yozgat Bozok University Erdoğan Akdağ East Campus and Bilal Şahin West Campus. We obtained the necessary data to understand the geographical and environmental conditions of the area. We conducted on-site observations in the study area and took photographs to depict the current situation.

## 3. Findings and Discussion

A water collection pond with a depth of approximately 10 m collects the stream inside the campus. There are two pools and ponds suitable for water storage on the campus. Despite this, the campus lacks a green infrastructure system, and the quantity of open and green areas within the urban landscape remains inadequate. Appropriate use of the area to establish a green infrastructure system will enhance its contribution to the urban ecosystem. This study planned green areas, rainwater storage, and rainwater harvesting, and presented recommendations accordingly. One of the most effective tools for addressing existing issues in ecosystem services in countries like Turkey is a rain garden. In this study, like Özdoğan & Akpınar (2023), it was important to choose a university campus as a study area to show that rain gardens are an important part of life by showing that both young people and academicians live in close contact with these systems and to be the most suitable area for a prototype area. Research should explore the potential for establishing rain gardens on a regional scale in our country, similar to studies conducted abroad. Future studies should also investigate the volumes of rainwater infiltration and redistribution by rain gardens. Considering the deficiencies, the proposed master landscaping plan covering the landscape area is shown in Figures 5 and 8. The Yozgat Bozok University campus area, with its large surface area, divides the proposed master project into layouts, as depicted in the figures. Rocky ground is quite common in the campus area. The project

places rocks in a representative manner to demonstrate their presence. A nature walking path circulation has been designed for the campus users to take a tour of the forest area to be created. In the forest fires experienced in the past years, thousands of hectares of land could not be prevented from burning due to the lack of strips that cut the connection between the plants in the forest areas to prevent fires. The General Directorate of Forestry plans to build fire safety lanes, as specified in their application principles, to prevent and extinguish forest fires in the future.

Figures 5 and 8 show the forested areas created with the proposed master plan. We have designed natural areas at specific locations, along with active areas that campus users can utilize. The plan places roads and fire safety lanes in forest areas. The plan also incorporates nature walking paths to access all desired areas on the campus. The planning of natural water collection areas, considering the land's slope, aims to create a campus that is both conducive to living and proficient in battling forest fires. The nature walking paths, fire safety, and road lanes shown in Figures 6 and 7 are located throughout the campus.

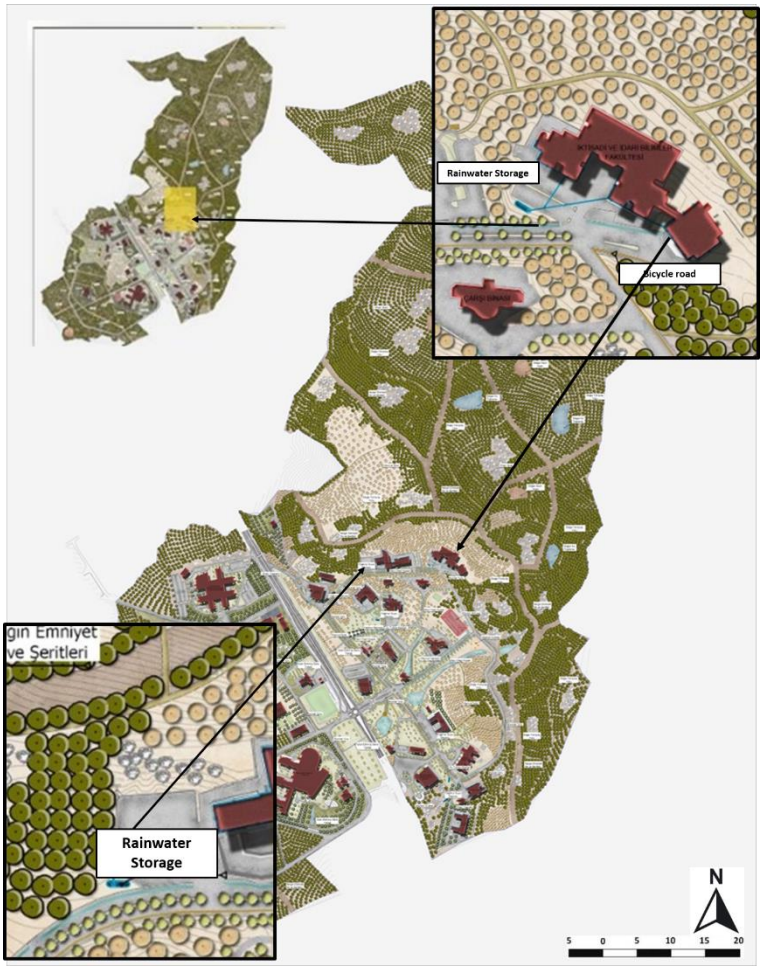


**Figure 5.** An example of stormwater management for Yozgat Bozok University (Layout 1)

Given the impact of global warming on the world, and the imminent end of this period known as the global boiling age, the university campus has planned rainwater collection tanks with sufficient capacity around the buildings to minimize water loss and adapt to the changing times. Leafy and coniferous trees (*Pinus nigra*, *Robinia pseudoacacia,* which grow naturally and do not require maintenance in the region) are planted in areas around the campus where there is no landscaping study. The goal was to observe the impact of the four seasons and provide benefits to the campus residents. Figure 8 shows the transformation of existing unused parking lots into activity workshops, providing campus residents with indoor social spaces for their use. We design observation towers taking into account the land's elevation difference. Saygın & Ulusoy (2011) stated that the problem should be recognized before planning in the area. We carried out planning in accordance with the problem and needs identified in this study. We planned rain gardens in some areas, considering the

land's slopes and on-site observations. The designated areas were determined at the points where the elevation difference of the areas connected to the hard ground where there is a slope affects the surface flow. We used the location of existing coniferous trees, which are suitable for the region. These plants are already present. Due to its low water demand, the project has continued in unplanted areas. We have created water retention areas to collect surface water and enhance the campus's aesthetic appearance. Observations reveal that the existing water in the area has carved out a haphazard path. The master plan aims to rehabilitate these waterways, integrate them into the landscape, and create a habitat for living creatures. Figure 6 depicts the continuation of rainwater harvest, blue-green application, bicycle paths, walking paths, and stream rehabilitation on the university's west campus. Figure 7 shows the planning of a recreational park for hospital users, students, and staff, with careful consideration of its proximity to the research hospital. Another study similar to this study, Artar et al. (2019), emphasized that universities have innovative features and pioneering roles in society. Every year, the Bartun University Kutlubey Campus undergoes development with the addition of new buildings and a changing landscape. Sustainability practices used within the scope of the proposed project will contribute to the spread of a sustainable lifestyle in society. To support this statement, Yozgat Bozok University is also open to development and needs to adapt to climate change. Adaptation of campuses to climate change is easier to plan and implement than in cities. Even though campuses are typically located far from the city center, they still provide the services necessary for the city concept.

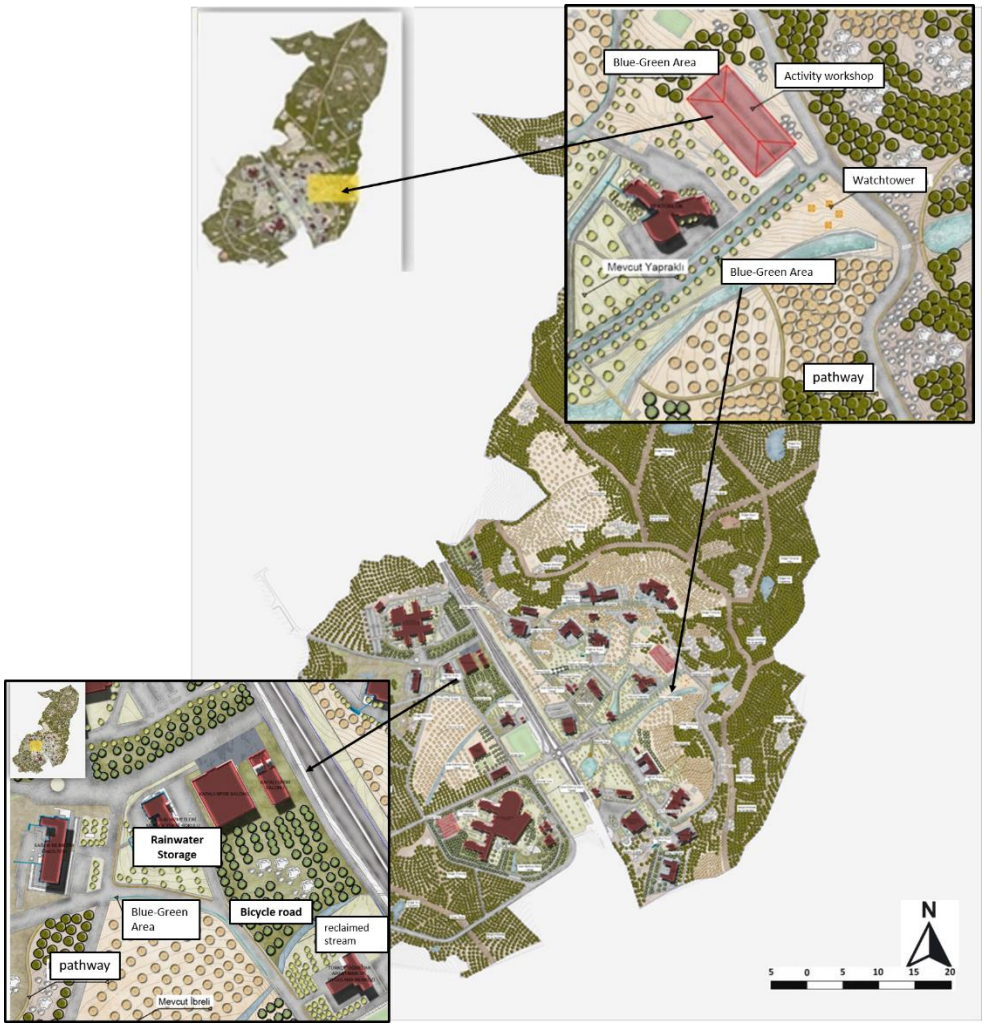


**Figure 6.** An example of stormwater management for Yozgat Bozok University (Layout 2)

In figures 6 and 8 have been shown the planning of bicycle paths, forest nature walkways, fire safety roads and lanes, rainwater storages, a water collection area, a watching tower, and rehabilitated stream beds throughout the campus. The project incorporates both existing and planned plants. Yozgat Bozok University Campus is unique in incorporating the aesthetic appearance of green rocks

into the campus landscape. Figure 6 showed that the placement of the watch tower atop the rocks. Coşkun Hepcan & Hepcan (2018) emphasized the crucial role of planning open and green spaces in implementing environmentalist approaches. Open-green areas produced through planning will be much more functional in terms of many ecosystem services functions, such as wildlife protection and development and rainwater management, and would serve as a backbone in and around the city.

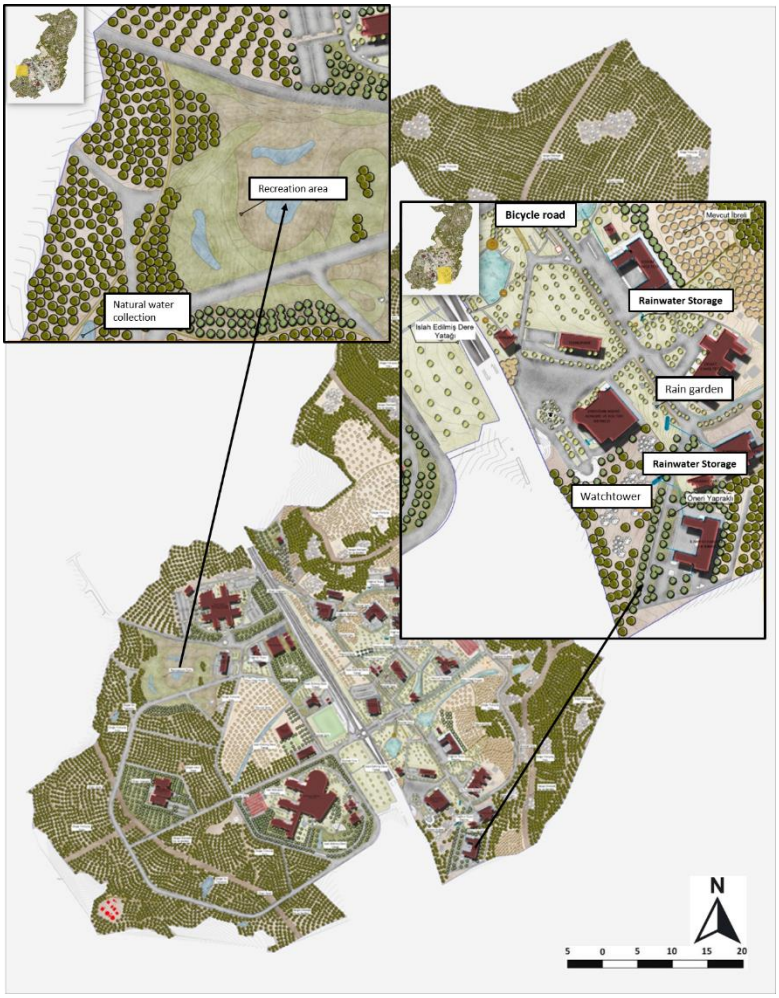


**Figure 7.** An example of stormwater management for Yozgat Bozok University (Layout 3)

The green infrastructure system, which aims to connect large and small open-green areas in the city within an integrated framework, has proven how successful it is with examples of applications in the world. This study aims to provide an evaluative perspective on the concepts of rain harvesting, green infrastructure, and stream rehabilitation, with a focus on the rehabilitation of urban streams using a green infrastructure approach. Figures 6 and 7 show the study area. Figure 8 shows the green infrastructure applications proposed in rehabilitation and restoration projects. Tülek & Ersoy Mirici (2019) Integrating green infrastructure studies that provide ecosystem services into urban planning levels can lead to a more sustainable urban ecology. In this study, rain harvesting areas were planned in areas with high slopes on the campus where water storage areas were created with connected pools. This planning approach is ecologically appropriate for the region. According to Bastian et al. (2012), ecosystem services offer a crucial viewpoint for ensuring the long-term viability of green infrastructure in providing amenities. The examples given are very weak.

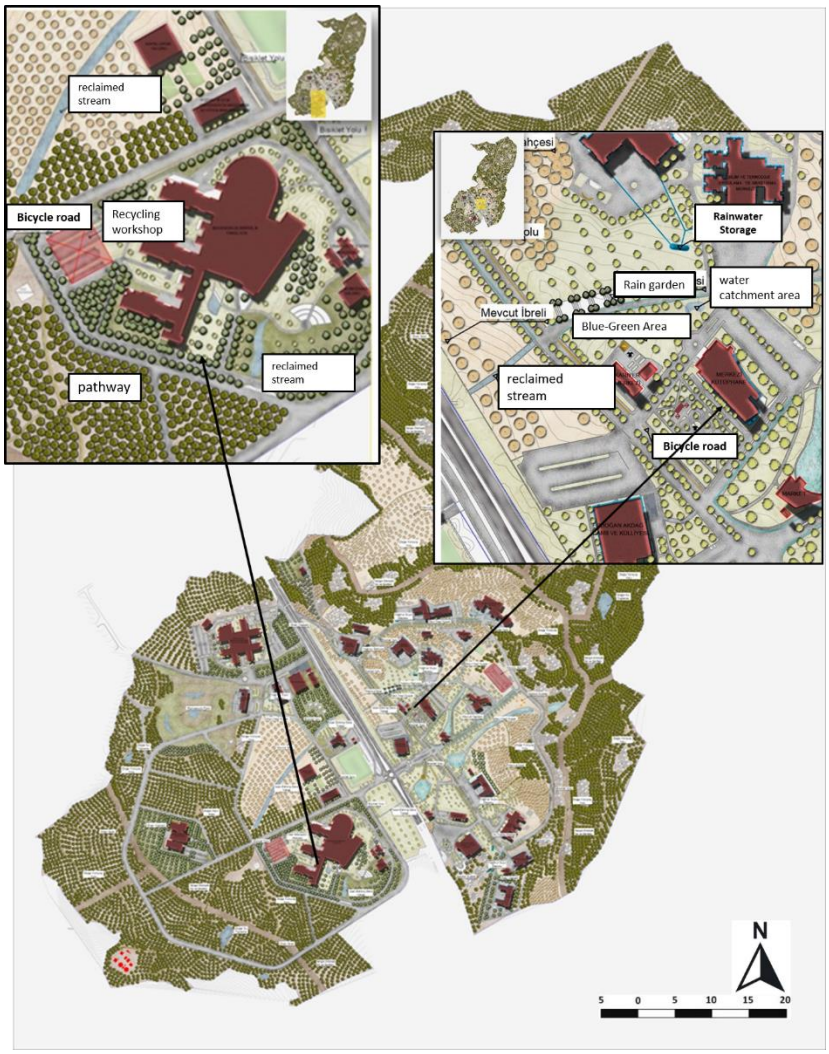


**Figure 8.** An example of stormwater management for Yozgat Bozok University (Layout 4)

Simultaneously, the Yozgat Bozok University was incorporated rain gardens, rain ditches, water retention areas, and green roof applications into its rehabilitation project, despite not currently using them. Aksu (2022) posited that an ecological approach should guide campus management, allowing for an evaluation of the area's features. This study approached planning holistically. Özdoğan & Akpınar (2023) designed a rain garden parking lot. In addition, we designed a car washing station and a greenhouse facility in the area to generate financial resources from the rain garden designs. We have developed systems that rely on rain gardens to supply their water needs. Therefore, the design of rain gardens plays a crucial role in enhancing the university campus's natural appearance, preventing surface runoff, and effectively storing and utilizing rainwater. This study adhered to the planning recommendations from Figure 5 to Figure 8. In addition, Samancı & Karadağ (2024) emphasized that the location of the green areas to be created in the region, where vegetation is important in green infrastructure works, should be compatible with the region and cut cold winds. This study recommends planting plants in open parking lots, as they serve a natural shading function. They emphasized that afforestation can provide permeable surfaces for rainwater on hard surfaces.

## 4. Conclusion and Suggestions

One of the most important factors in climate change is the surface characteristics of cities (Toy & Esringü, 2021). Impervious surfaces increase with urbanizationin urban areas . Impervious surfaces negatively affect the functions and benefits of ecosystems in cities (Pataki et al., 2011). The lack of green spaces disrupts ecosystem balance, leading to the loss of habitats for plant and animal species, reduced biodiversity, and decreased air quality by increasing pollution (McKinney, 2008; Wojnowski et al., 2022). When green areas are not taken and new fields are created, it increases the heat island

effect and the amount of carbon released into nature (Demirbaş & Aydın, 2020). The density of built-up and paved areas, caused by rapid growth, reduces open green areas. Uncontrolled migrations, stemming from various dynamics such as food crises, global warming, disasters, and international developments, continue to occur worldwide. Therefore, it is crucial for local governments, in particular, to enhance the infrastructure of cities to accommodate these migrations. First and foremost, we must prioritize the sustainability of the projects during the planning stage. Creating a balance between environmental and economic values in the planned designs can lead to the emergence of projects that enhance the city's dynamism. These days, when we feel the effects of global warming more closely, designers should be more sensitive to climatic elements while designing.

Green infrastructure designs within the framework of sustainable urban management stand out as a potential solution to many basic problems. We predict that the active role of Xeriscaping, sustainable agricultural production, stormwater management, and sustainable treatment methods in green infrastructure applications in cities will significantly contribute to the creation of an economic, ecological, healthy, and sustainable environment. As a result, this master plan was prepared for Yozgat Bozok University Erdoğan Akdağ East Campus and Bilal Şahin West Campus. We plan to use this study as a guide to create a sustainable, environmentally friendly, and green university. Reporting and evaluating the sustainable and green university is necessary. We could monitor these processes in the short, medium, and long term, and reprogramme and plan in response to change and development. By leaving a livable and sustainable campus for both current users and future generations, the university would gain preference. We should increase green campus areas with local studies, increase the number of local plants, and reduce the water requirement. Given Yozgat's water management issues and its arid climate, it is imperative to adopt more water-saving practices. Buildings can recycle generated wastewater and use it for landscape irrigation. Again, switching to water-saving devices with sensors will reduce irresponsible use of water in buildings. Rainwater management will also be supportive in terms of campus water needs. Additionally, we should encourage local governments to incorporate the quantifiable advantages of rain gardens for sustainable cities and the upcoming generation of Turkish city dwellers. As a result, adaptation of campuses to climate change is easier to plan and implement than in cities. Despite the fact that campuses are typically located far from the city center, they still provide the services necessary for a city. Rather than categorizing rainwater as waste, we have devised a strategy that employs low-cost, environmentally friendly infrastructure components to support the ecosystem and recycle it for various uses such as toilet reservoirs, irrigation, recreation corridors, and landscaping elements. We have also produced recommendations to guide the implementation of these strategies.

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This article, Yozgat Bozok University, Institute of Graduate School of Postgraduate Education Master's Degree, completed in the Department of Agricultural Sciences. The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

**Author Contribution and Conflict of Interest Declaration Information**

All authors contributed equally to the article.

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