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Assessing Xeriscaping as a Retrofit Sustainable Water Consumption Approach for a Desert University Campus

Esam M. H. Ismaeil [1,2,*] and Abu Elnasr E. Sobaih [3,4,*]

1 Civil and Environmental Department, College of Engineering, King Faisal University, Al-Ahsaa 31982, Saudi Arabia
2 Architecture and Urban Planning Department, Faculty Of Engineering, Port Said University, Port Said 42526, Egypt
3 Management Department, College of Business Administration, King Faisal University, Al-Ahsaa 31982, Saudi Arabia
4 Hotel Management Department, Faculty of Tourism and Hotel Management, Helwan University, Cairo 12612, Egypt
* Correspondence: emohamed@kfu.edu.sa (E.M.H.I.); asobaih@kfu.edu.sa (A.E.E.S.)

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Abstract: Assessing water usage associated with urban green infrastructure is crucial for water resource management and sustainable planning of desert campus areas. A public university campus layout in the desert region is considered an urban city subject to urban water consumption (UWC) of significant intensity and extent, even though the urban layout is essential to all campus occupants' comfort and environmental sustainability needs. Hence, there is a need to reduce its detrimental effects through sustainable methods for campus water content. This study focuses on assessing urban xeriscaping landscape quantities as a practical potential approach to support university campus decision-makers in reducing urban water consumption and preserving the urban campus water content as asset management and life quality. Four selected landscape field experiments were undertaken by adopting xeriscaping landscape design instead of existing conventional urban design at King Faisal University's (KFU) campus layout, Al-Ahsaa, Eastern Province, Saudi Arabia. The study built a specific practical sustainability retrofit approach in water conservation from conventional to xeriscaping method inside the existing public desert campus area. Applying the study approach framework considering xeriscaping layout design provided sustainability requirements, retrofit approach, and pathway to effective landscape mapping, based on reasonable and accurate quantities of xeriscaping landscape items, to convert the KFU campus layout as a low water consumption campus with an average reduction of 41% water consumption within the remaining campus layout. The results of this study contribute to the water conservation and management in university desert campus and opens the door for other studies on the use of this approach for thermal reduction, economic and environmental benefits beside its value for water reduction.

Keywords: xeriscaping; water consumption; water management; water conservation; desert campus; Saudi Arabia

1. Introduction

Population growth, economic development, and dietary shift (toward more animal products) have resulted in ever-increasing water demand and, consequently, pressures on water resources. Water is one of the most essential natural resources and is the backbone of life. It is included in many human activities such as agriculture, medicine, construction, spinning and weaving, and various industries. Water is the backbone of life on our planet, albeit this precious resource is increasingly in demand and under threat. Water covers about 70% of the planet; however, only 3% of the world's water is freshwater. Additionally, two-third of that is tucked away in frozen glaciers or unavailable for our use [1]. Many water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes, and aquifers are drying up or becoming more polluted for human use. More than half the world's wetlands have disappeared [1]. Agriculture consumes more water than other source and wastes much of that through inefficiencies [2]. Climate change is altering weather and water patterns worldwide, causing shortages and droughts in some areas and floods in others. At the current consumption rate, this situation gets worse. By 2025, two-thirds of the world's population may face water shortages [2].

Furthermore, ecosystems around the world suffer even more. Agriculture uses 70% of the world's accessible freshwater, but 60% of this is wasted due to leaky irrigation systems [2–4]. Even groundwater is not safe from pollution, as many pollutants can leach into underground aquifers. Reducing the number of people suffering from water scarcity is also one of the main goals set in the Sustainable Development Goals (SDGs) as highlighted by the United Nations [2]. A key to creating a sustainable landscape is to include native plants to the area or well adaption to similar growing conditions [5]. The main aim of sustainability is to reduce the consumption of resources and reach the limit of the production of resources to a better extent. For water, this could apply through processes such as water reuse and water harvesting [6]. There is a persistent need for sustainable landscapes in public campuses using recent software like virtual reality to ensure that workplaces are productive and healthy [7]. Furthermore, the hedonic price method (HPM) and the contingent valuation method (CVM) are two valuation techniques used to estimate and report the benefits of public and private environmental goods.

There are several approaches or examples of applying water sustainability to the university campus. First, maximizing on-site storm-water management by focusing on filtering runoff resulting from rainfall events equal to or less than 1 (about 80% of all rainfall events in Eugene). Second, limiting off-site drainage whenever possible. Third, using plant materials and terrain to slow and absorb runoff, filter sediments, and facilitate infiltration. Fourth, maximizing pervious surfaces to permit water infiltration where possible. Fifth, minimizing the need for landscape irrigation. Sixth, using weather-based irrigation controls to minimize runoff and excess water use. Seventh, using natural drainage ways wherever possible [8]. Eights, using grey-water and water-saving devices. Ninth, using plantings that can tolerate low summer watering. According to the American Society of Landscape Architects (ASLA), the principles of a sustainable landscape design include: rainwater/greywater harvesting—88%, native plants—86%, native/adapted drought-tolerant plants—85%, low maintenance landscapes—85%, permeable paving—77%, firepits/fireplaces—75%, food/vegetable gardens (including orchard, vineyards)—75%, rain gardens—73%, drip irrigation—72%, and reduced lawn area—72% [9,10]. The main goals of sustainable landscape design are to conserve water and energy, reduce waste and decrease runoff. Residential gardens should treat water as a resource, value soil, preserve existing plants, and conserve material resources to achieve these goals as well as treat water as a resource, value the soil, preserve existing plants, and conserve material resources [9,10].

Xeriscape is a contemporary landscape maintenance term coined from the Greek xeros, meaning dry and scape, and from the Anglo-Saxon term sc-hap meaning view [11]. The practice of xeriscape encompasses many landscape styles and materials, from lush gardens to desert-like landscapes [11]. Xeriscape can be defined as specific landscaping that works with the principle of protecting the water resources and the environment [12]. It is the process of landscaping, or gardening, that reduces or eliminates the need for irrigation and maintenance. It can also be defined as a water-efficient landscaping and natural landscaping that aims to protect the water resources and environment by using the least amount of water in general [13–15]. It is also known as arid landscaping worldwide, a landscaping scheme that adopts the principle of protecting the water resources and the environment with a minimum of water use [16]. With current climate conditions, fresh drinking water is becoming a scarce commodity globally as droughts rise [17]. The landscape is easy to maintain, capable of withstanding drought, and conserving and retaining water; xeriscaping is different from natural landscaping or local landscaping in that, i.e., the concentration is on water conservation. Planting non-native plants that are drought-resistant or can survive without additional water is more important than plants that are part of the ecosystem already [18].

Xeriscaping or xerigrending is promoted in regions that do not have accessible, plentiful, or reliable freshwater supplies and is gaining acceptance in other regions as access to irrigation water is becoming limited. Xeriscaping may be an alternative to various types of traditional gardening; in some areas, terms such as water-conserving landscapes, drought-tolerant landscaping, or intelligent scaping are used instead [19,20]. The xeriscaping method produces and utilizes vegetation as greenspaces with native/indigenous/natural plants, gravel, wood chips, and natural solid material, appropriate to the local climate [21]. Therefore, with current climate conditions, fresh drinking water is becoming a scarce commodity on a global scale as the frequency of droughts rapidly rises [18]. Zero-scaping or zero-scaping is sometimes substituted for xeriscaping due to phonetic similarity [22].

Xeriscapes can reduce water consumption by 60% or more compared to regular lawn landscapes [23]. In Turkey, one of the first large-scale xeriscaping evaluations was conducted and found that switching an average city park to more native vegetation in the region lowered irrigation usage by 30–50%. The city with a water usage reduction of 30% can save roughly $2 million annually; however, the exact value depends on location [24]. Applied research [25] has recognized xeriscaping as an effective water reduction approach. It reduces outdoor water use and irrigation [25] to encourage and incentivize xeriscaping for greenspace development [26]. Xeriscaping requires far less time and effort to maintain, saves money because there is little or no need for cutting lawns, reducing landscape water usage and waste by 50 to 75%, reduce pollution by 75%, save 10–30% on utility bills. No need for daily organizing xeriscaping items, protect the landscape from wildfires, preserve native plants, which depend on little water and reduce pesticide use, reduce costs between cutting down on maintenance and water usage, reduce fertilizer usage, little need for soil amendments and help local wildlife [27,28].

Xeriscaping is theorized to help offset the urban heating island (UHI); it was found that dry areas that utilized xeriscaping with shade trees mitigate UHI effects during the day and night with an average temperature difference of roughly 2.5 °C (4.5 °F) cooler [29]. The use of xeriscaping water within ecological sustainability is essential for the design stage [30]. Xeriscape creates healthy and environmentally sound landscapes that use less fertilizer and pesticides, which has become a vital implementation issue in today's conditions and compatible nature landscapes in arid areas with limited water resources. Xeriscape approach includes environment protecting and water-efficient landscape implementations [31]. Urbanization is a natural and social process involving simultaneous changes to the Earth's land systems, energy flow, demographics, and the economy. Understanding the spatiotemporal pattern of urbanization is increasingly essential for policy formulation, decision making, and natural resource management [32]. Assessment of the water usage associated with urban green infrastructure is crucial for water resource management and sustainable planning of the desert area [11,33].

The xeriscaping practice also contributes to vegetation loss, an increasingly heterogeneous landscape, and water efficiency through mulching, appropriate plant selection, and landscape design. The xeriscape feature goal is to submit opportunities for urban regions to enhance future water conservation and landscape conversions from mono-culture grass lawns to the xeriscape concept [23,32]. Landscape architecture applications improve environmental quality and repair the corrupted environmental conditions; wise usage of water and aridity-resistant vegetal applications came forward with global warming and some concerns connected to the climate change; different scenarios produced for the coming years of climate change [23,31]. Several cities' "xeriscaping" policy involve landscape conversion of water-intensive plants to low-water-demand, drought-resistant vegetation [34]. Water-efficient landscaping is the fundamental approach for water conservation in arid and semi-arid regions. Therefore, intensive landscaping of mixed plant materials consumes a massive amount of water, whereas xeriscaping minimizes water-use landscaping because of its environmental and financial benefits. The environmental aspect of xeriscaping is choosing vegetation appropriate for the climate, called drought-tolerant vegetation. Xeriscaping often replaces grassy lawns with soil, rocks, mulch, and drought-tolerant native plant species. Trees flowers, specially adapted to arid climates, are called xerophytes and can reduce water use by 50 up to 75% and saves water and money [25,26].

Xeriscape approach is one of the landscaping methods where water is used effectively by including plants with low water requirements. In addition, natural plant species should be used in the design because natural plants require less watering after the completion of regulation work or do not require additional irrigation, except for natural rainfall [35–38]. The arid landscape (xeriscape) has become an important application issue in today's conditions. The main aim of the xeriscape landscape design approach is to protect water resources by minimizing water use. In current conditions, in which water is important, the right landscape design and applications begin with a well-done survey analysis of natural and cultural data [39–43]. Green spaces (GSs) are significant, nature-based solutions to climate change and have immense potential to reduce vulnerability to heat waves while enhancing the resilience of urban areas in light of climate change. However, in the Saudi context, the availability of GSs across cities and their perceived role in climate change mitigations and adaptation strategies remain unexplored and challenging due to limited water resources. Planning and design are essential in landscape architecture arrangements and must be determined clearly and fit for sustainability goals and principles [40–42].

This study submits one of the urban landscape methods that address the issue of the reasonable and adopted quantities of xeriscaping landscape items through using field experiments assessment method to support decision-makers in a public desert university project, using King Faisal University (KFU) campus as the case study, to achieve a crucial requirement goal in water content conservation. The study opens the door for various studies on the value of xeriscaping as a practical approach to water conservation in urban desert regions and similar urban regions. Therefore, the main research questions are: to what extent does the xeriscaping approach conserve water in an urban desert campus? What is the most appropriate approach of xeriscaping for water conservation? What are reasonable quantities per square meter of xeriscaping landscape items can support decision-makers in a public desert university project to achieve a crucial requirement goal in water content conservation? The structure of next sections of this paper will be as follows: it is started by reviewing the related literature, then exploring the methods and materials adopted in the study. It then followed by presenting the results of the four undertaken experiments and discussing these results. The paper ends by highlighting the conclusion and limitations of the research as well as opportunities for future research.

2. Literature Review

Applying a new method in water demand consumption in all life aspects is an international and vital requirement, especially in irrigation work in agriculture and soft landscape field. The use of xeriscaping water within ecological sustainability is an essential form of design [16,17]. It illustrated high-ranking design in landscape irrigation application in water consumption reduction using xeriscaping landscape concept in construction campus project, even in a small private construction project, which started ascending in use recently [13–17]. Explaining the benefits of using xeriscaping in construction projects like universities focuses on landscape discipline and the essential factors and elements used in this field as practical solutions to the current regional crises such as the water crisis, energy crisis, and global warming [17–19]. A full explanation is given to the fundamental principles of xeriscaping, design, and influences [20–26]. Saudi Arabia is the biggest country in the gulf area. Many studies were undertaken on the Saudi Arabian context to highlight water resources and consumption for all life activities, e.g., agriculture and landscape activity [23–26]. The KFU campus is one of the biggest university campuses in Saudi Arabia. Several references [30–35] have explained the detail for all planting types, water consumption and all landscape component areas inside the campus [40–43].

A review of literature [44–50] focused on xeriscaping method as an applied approach in landscape layout to achieve several goals like water-saving and thermal reduction. On the other side, some other literature [27–34] focused on economic and environmental benefits like heat island influence from applying xeriscaping method in specific construction projects using recent software like GIS and environmental measures [51]. Other literature [52–54] explained with narrative and figures the seven xeriscaping layout principals, feasibility, and benefit for each principle. The literature also focused on the procedure to achieve practical xeriscaping layout landscape in a construction project like irrigation network type used for this approach and material type for the irrigation network. The majority of the case of this literature study was applied spatially, theoretically, and practically in private residential areas. Nonetheless, few of them were undertaken on a public campus like a university campus [41,42,47–55]. Despite the value of literature review, there was no explanation or mention of a comprehensive method to apply xeriscaping landscape approach in qualitative and quantitative based on realistic and practical field experiments in specific mega-projects or big public spaces, e.g., university layout landscaped campus, such as KFU.

This study examines a specific retrofit approach of water conservation in a public desert campus area based on practical numerical technical assessment results by applying four experimental areas xeriscaping design instead of existing conventional urban design in KFU's campus layout. This study investigates, based upon the knowledge arising from literature review work as well as applied solid urban planning and design landscape architecture arrangements, the xeriscaping methods fit for sustainable water conservations through partnerships between several agencies (such as the university's team, the national water service, private agriculture firms, and municipal governments).

3. Materials and Method

Saudi Arabia is ranked third in the world in terms of daily per capita water consumption at 286 L per day, after the United States of America and Canada [55]. Saudi Arabia has a limited stockpile of non-renewable groundwater that can exploit low replenishment rates (2.8 billion cubic meters in the Arabian shield) [56]. Saudi Arabia's water requirements, estimated in 2015 at about 24.8 billion cubic meters, with a constant annual increase of 7%, are witnessing the agriculture sector in which the largest consumer of water in Saudi Arabia is 84% of the total water demand [57,58]. Water use in the agricultural sector reflects an environmental challenge due to its dependence on non-renewable resources, which represent 90% of the total water supplied to the sector. The high use of water in the agricultural sector is due to gaps in water sector policies, legislation, and general shortcomings. Where the feed alone consumes 67% of the water requirements in the agricultural sector, while the irrigation efficiency is 50% at present compared with more than 75%, and the water loss reaches about 25% in different areas and buildings, by setting price indicators and incentives for conserving water [57,59].

Al-Ahsa has an area of 379,000 km^2, equivalent to 20% of Saudi Arabia's lands [47]. Al-Ahsa is famous for its abundance of palms date that covers vast areas of its land. It exceeds three million palm trees, and it produces more than one hundred thousand tons of dates annually, equivalent to 10% of Saudi Arabia's production. In June 2018, Al-Ahsa Governorate was considered a significant settlement over the past 500 years. With its classification in the UNESCO World Heritage List and 2019, Al-Ahsa was nominated as the capital of Arab tourism, and in 2020 Al-Ahsa Oasis entered the Guinness Encyclopedia Record as the most significant stand-alone oasis in the world. It was qualified to cultivate the usual crops grown in hot and temperate regions, on 10 thousand hectares of agricultural land, with 30 thousand holdings.

Al-Ahsaa region, like the rest of Saudi Arabia, depends mainly on groundwater to cover the required consumption of water in all areas, and given that Al-Ahsa is one of the regions that record the highest temperatures in Saudi Arabia, where the temperature reaches 50 degrees Celsius, which works on the speed of water evaporation and losses.

The water sources in Al-Ahsa also depend on triple treated wastewater for irrigation. The corporation benefits from the output of the triple treated sewage plants of the Ministry of Environment, Water and Agriculture. There are also agricultural drainage water reused for irrigation and groundwater. It currently accounts for about 10% of the total irrigation water in the Al-Ahsa project. The treated sewage transfer project and water sources depend on the desalination of an estimated 60% of the total water supply in the civil sector [48,49]. Table 1 shows water resources quantity in the eastern province, which explains the latest ministry of water statistics for the water consumption quantity from the two essential water resources in whole Saudi Arabia regions within 2017, 2018 and 2019. The table shows the different irrigation systems and water drainage rates. The water quantity consumption in the Eastern province, with an area of 778,479 square kilometers, represents 36.2% of the total area of Saudi Arabia of 2400 million square kilometers. The eastern province consists of 11 cities; one of them is Al-Ahsa, including KFU's study area [50,60–64].

Table 1. Water resources quantity in the eastern province.

Year	**2017**			**2018**			**2019**		
Region	**Underground Water**	**Sweet Water**	**Total**	**Underground Water**	**Sweet Water**	**Total**	**Underground Water**	**Sweet Water**	**Total**
Riyadh	444	626	1070	441	638	1079	454	635	1089
Makka	5	745	750	43	741	784	29	798	827
Al-Medina	11	190	201	26	213	239	15	237	253
Qassim	57	8	65	155	12	167	165	13	178
Eastern	246	436	682	265	417	682	226	434	660
Aseer	8	93	101	29	75	104	33	76	109
Tabouk	41	11	52	58	12	70	58	15	73
Hail	58	0	58	64	0	64	65	0	65
Northern borders	30	0	30	39	0	39	33	0	33
Jazan	6	53	59	53	34	87	58	33	90
Najran	22	0	22	32	0	32	30	0	30
Al-Baha	19	13	32	20	13	33	22	15	37
Al-Jouf	28	0	28	48	0	48	49	0	49
Total	975	2175	3150	1273	2155	3428	1237	2256	3493

Water is a significant concern in Saudi Arabia and the university in particular. The problem lies in the limited water resources, as Saudi Arabia's geographical location is in desert areas with no rivers or lakes with little rain. It may be exposed to evaporation quickly due to high temperatures, as the temperature may reach 50 degrees or more in the spring and summer semesters, that is, from April to September. There are also evaporation losses.

KFU's campus is located in the eastern province of Saudi Arabia and relies on three sources that make the university semi-independent in providing water and covering all demands. The KFU water resources include production and consumption resources; Production resources include rainfall, wells, municipality network, and sanitary drainage with treatment. Consumption resources include construction buildings, fire systems, types of equipment, swimming pools, sanitary fixtures, irrigation networks, and losses; Figure 1 shows the University KFU water resources diagram. The main source inside King Faisal University of water groundwater is fifteen artesian wells distributed around the university. Figure 2 shows their locations, and these groundwater wells decrease their productivity of water day after day as the rate of production of some wells decreased from 370 gallons/min to reach 80 gallons/min with little production; approximately eight wells are operated [51,63,64]. The average water productivity in the university is underground through suitable pumps of 4500 cubic meters per day. Irrigation works for agriculture in green spaces consume about 3000 cubic meters, while general and domestic purposes in the university buildings consume about 1500 cubic meters [63,64].

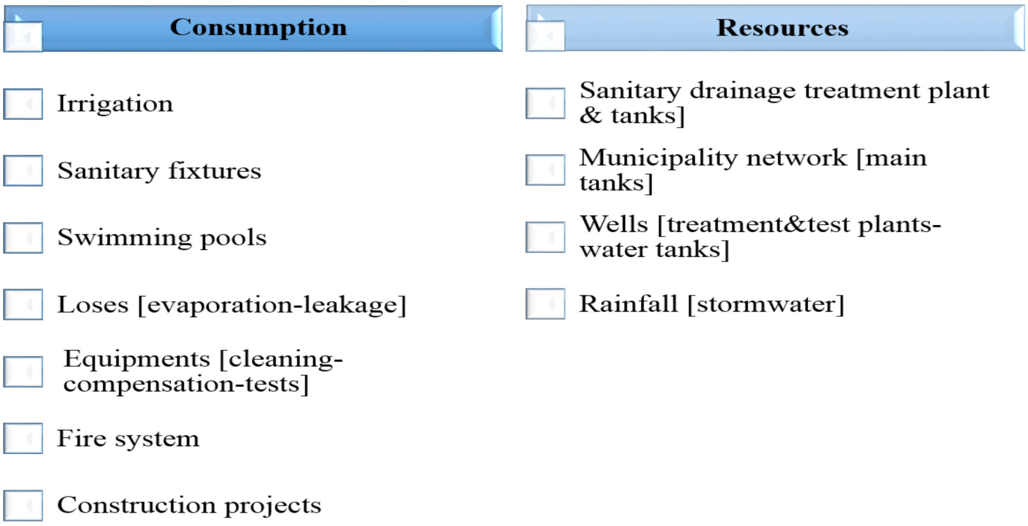


Figure 1. KFU water resources and consumption.

Figure 2. Groundwater artesian wells locations inside King Faisal University layout.

Figure 2 shows the underground wells' locations on KFU's campus general layout plan. The university has three desalination plants for reverse osmosis to supply all university buildings with water suitable for domestic use; a treatment unit of 550 cubic meters per day on the old campus; a treatment unit with a capacity of 5000 cubic meters per day on the new campus to serve all employees, associates, students, residents, and visitors. The number of individuals and users of the university is approximately 7000. Moreover, the number of students is about 30,000 students, and residents and visitors to the university are approximately 5000. With the limited resources, the daily consumption of water in the buildings of the university increases, especially with the increase in expansions and new projects at the university. Daily consumption at approximately 250–280 L per person.

Furthermore, a growing number of university students increases the gap between the amount of water produced daily and the total consumption volume at the university. The university's irrigation networks contain two parts of nutrition from well water: the university campus irrigation network (male and female students' housing) and the old university, and the irrigation network housing the faculty members from treated wastewater. The university's irrigation networks operation automatically uses the central control system (SCADA system), the latest modern operating methods for university academic areas, and the housing of faculty members. In contrast, the old university operates the network manually, and a table shows the water needed for the types and quantities of plants cultivated in the university gardens. The consumption quantities are calculated based on the operating schedules for irrigation. The terms of operating time (10 min for palms, trees and shrubs, soil and flower coverings, and 15 min for green spaces) as well as when operating pressure according to the approved irrigation companies' schedules, so that in the event of low pressure, the actual consumption of water decreases. Calculate the amount of water consumption for green spaces based on the quantities of sprinklers and the amount of water discharged per minute and palms, trees, and shrubs, based on the discharge of bulers and drops.

The total green areas within the university academic area are 73,110 m^2. The total green area within the residential area is 45,530 m^2, and its types are palms, trees, shrubs, soil coverings, and green spaces; all of these types consume approximately 3911 m^3/day. The green areas constitute the most significant proportion, reaching 2940 m^3/day. Table 2 shows plants type, required operation pressure, water drainage, and network type inside the KFU as a case study. Table 3 shows water requirements for the types and quantities of plants cultivated in the university layout, which reach a total of 3,910,530 (L/day) 3911 (m^3/day) [64–68].

Table 2. Different irrigation network systems and water drainage rates.

Plants Type	Required Operation Pressure	Water Drainage	Network Type	Notices
Ground cover and seasonal flowers	2 bar	4 L/h	Drippers	
Palms	2 bar	7.6 L/m	Bubbler	
Trees	2 bar	3.8 L/m	Bubbler	
Shrups	2 bar	1.9 L/m	Bubbler	
Shrups	2 bar	4 L/h	Drippers	
Grass	3 bar	6.5 L/m	Sprinklers (rotary)	Big areas
Grass	2.1 bar	0.95–7.6 L/m	Sprinklers (fixes)	Medium & small areas

Table 3. Water requirement for the types and quantities of plants in the university layout.

Plant Type	Unit	Actual Irrigation Consumption L/Day Summer	Quantity	Irrigation System	Water Need L/Day Summer	Water Need L/Day Water	Irrigation Consumption/Day
palms	No.	80	2250	Bubbler	100 L	50 L	180
trees	No.	40	15,500	Bubbler	80 L	40 L	620
shrups	No.	5	11,327	Bubbler	12 L	7 L	56.635
shrups	No.	0.6	26,600	Drippers	12 L	7 L	15.96
Ground cover	M2	0.6	163,225	Drippers	7 L	3.5 L	97.935
grass	M2	49	270,560	sprinklers	12 L	6 L	2,940,000
					total water (L/day)		3,910,530

3.1. Fundamental Principles and Benefits of Xeriscaping

As centers for knowledge transfer and development in different areas, universities have a pivotal role in society and are deemed as reference institutions for developing cultural and environmental activities. In addition, environmental issues are intertwined with sustainability and applying all relevant systems [54]. The xeriscaping format is one of the types of modern design of sites. As discussed earlier it is a practical solution to the crises of the modern region, such as the water crisis, energy crisis, and global warming. Several xeriscaping principles could be explained as follows [22–28]:

a. Plan and design the areas and zones for an appropriate variety of plants with different heights, colors, and textures to create exciting and beautiful plants such as turf, perennial beds, trees, shrubs, and perennials views, screens, slopes, the development

of a planting plan that integrates with hard materials and water network, the amount of light per day, wind, and moisture.
b. Water conservation amount, applied water reduction, and evaporation amount.
c. Soil improvement helps drain the landscape quickly and stores water simultaneously; some desert plants prefer gravel soils instead of well-amended soils.
d. Using mulch- locally derived from helping retain moisture in the landscape. Mulch keeps plant roots cool, prevents soil from crusting, minimizes evaporation, and reduces weed growth. Organic mulches include bark chips, pole peelings, or wood grindings.
e. Suitable and saving irrigation, with proper drip systems and irrigation clocks to avoid overwatering by hand or an automatic sprinkler.
f. Limited turf areas like native grasses such as buffalo grass and blue grama can survive with a quarter of the water that bluegrass varieties need.
g. Maintain landscape with low maintenance process cost in regular fertilization, cutting, clippings, occasional pruning, removing dead stems, promoting blooming, maintenance waste, and height and spread controlling.

The benefits of xeriscaping discussed earlier can be summarized in the following:

- Reducing water waste; over 50% of residential water usage goes towards landscaping and lawns. Xeriscaping can reduce landscape water usage by 50 to 75%.
- Using minimum efficient irrigation.
- Reducing maintenance time in cutting the grass, mowing, and weeding the lawn.
- Water requirements are low, and only occasional pruning and weeding are necessary.
- Reducing costs in the long term with xeriscaping.
- Reducing fertilizer usage since using advantage of native plants will not have to use chemical supplements, but only simple organic soil is the only supplement needed to help maintain a healthy xeriscaped landscape.
- Reducing pollution and make a healthy environment by removing acres of sod; gas-powered mowers will not require the moisture.
- Reducing heat islands to improve sustainable requirements.
- Using native softscape items require less maintenance and survival in the climate conditions.
- Improve the community's overall look by planting items that thrive in the climate.

3.2. Xeriscaping Items

KSA is distinguished by its vast area of diverse geographical landscapes and climates. Consequently, there is enormous variation in the distribution of plants across the Kingdom. A total of 24 species of 471 plant species belonging to 89 families selected in the present review from the KSA, which used in several uses like medicinal plants; the most dominating families are Asteraceae, Fabaceae, Lamiaceae, Euphorbiaceae, Solanaceae, Apiaceae, Brassicaceae, Chenopodiaceae, Poaceae, Amaranthaceae, Boraginaceae, Apocynaceae, Convolvulaceae, Asclepiadaceae, Capparaceae, Polygonaceae, and Zygophyllaceae [53]. Within the four study field experiments used in this study, the xeriscaping items used in this study reach about 24 items as illustrated in Figure 3 mixed; 20 items are selected native softscape types, and 4 items; all are compatible with sustainable requirements focusing on water consumption reduction according to sustainable requirements.

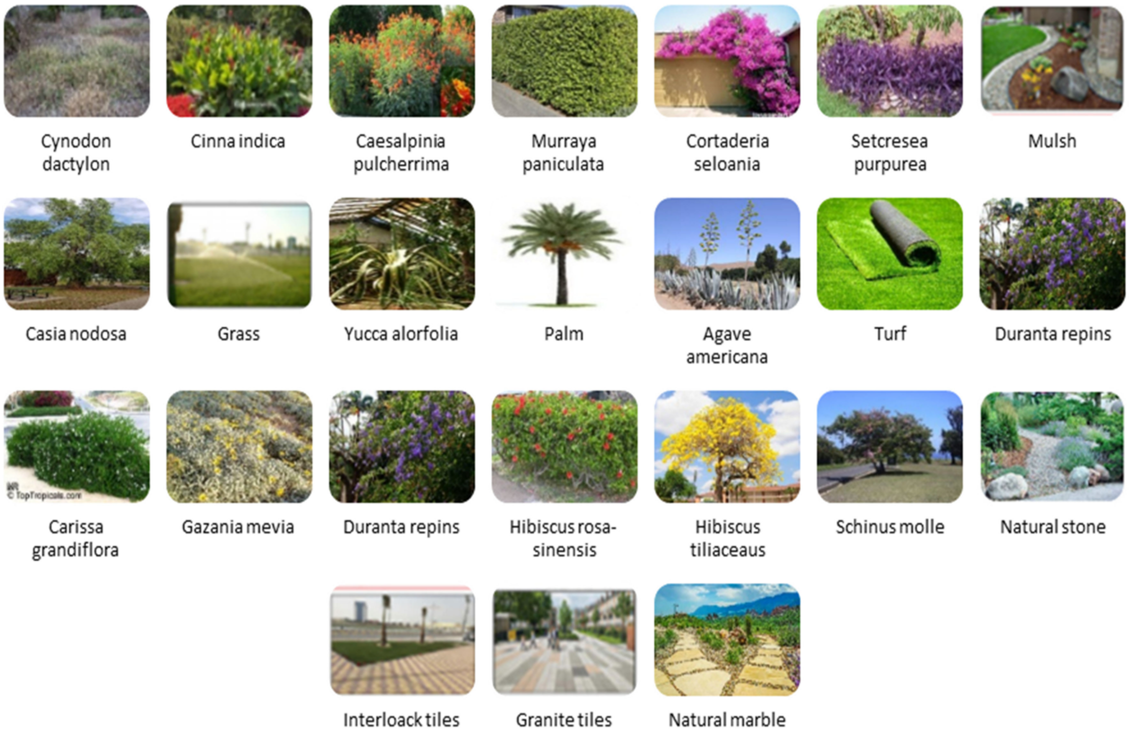


Figure 3. The soft scape and hardscape types used in the study case.

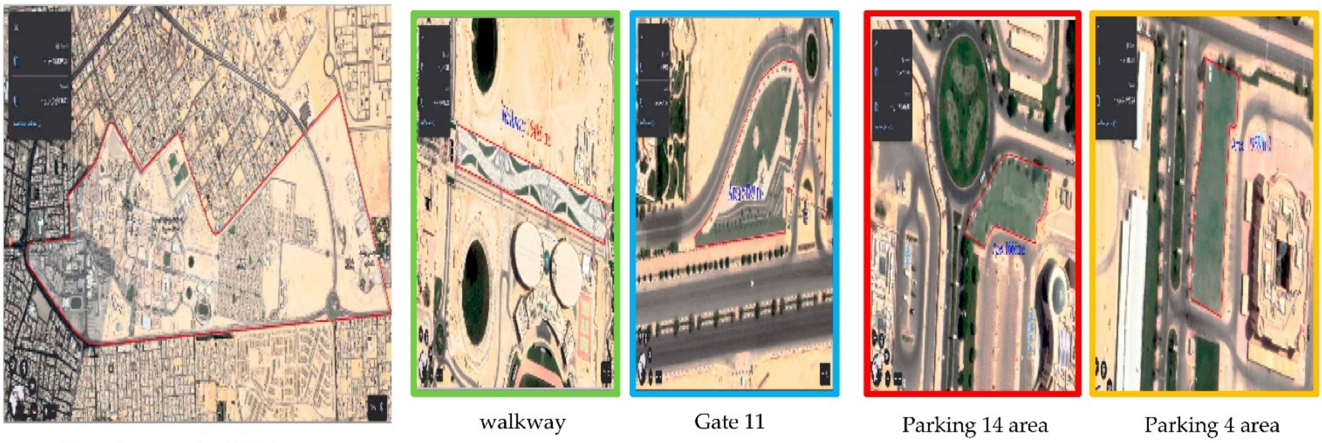
3.3. Adopted Methodology

This research adopted an experimental research methodology. Four different experiments were undertaken to examine different approaches of xeriscaping for their possibility of water reduction in a university dessert campus using the KFU's campus as a case study. Each experiment was monitored by specialized team. Data of each experiment was recorded in a sheet for analysis. The research adopted numerical technical assessment for four selected landscape field experiments. Different types of xeriscaping landscape designs instead of existing conventional urban design at KFU campus layout, Al-Ahsaa, Eastern Province, Saudi Arabia. The study adopted a practical retrofit approach in water conservation from conventional to xeriscaping method inside the existing public desert campus area of KFU. The research team organized and classified all available comprehensive data and information about xeriscaping (before and after xeriscaping, which presented in Appendices A–C) as urban landscape layout sustainability method; water resources and consumption inside KFU campus and open landscape layout; and native soft landscape for the case study area.

The landscape for each field experiment was designed to convert existing conventional landscapes in the KFU's campus layout to a xeriscaping landscape concept, including 24 native plants, trees, shrubs, and five native hardscape materials, different types of xeriscaping materials from special agriculture agent. The total four areas are 31,750 m^2, representing 22% of the total area of KFU landscape. These areas consume 3,910,530 L (3911 m^3), the remaining KFU landscape with an area of 86,890 m^2. The field numerical technical assessment results supervised according to experts' physical realization like farmers, researchers, engineers, and required international and local standards in water consumption inside university campus and maintenance discipline submeter in periodical time within 2019–2020. The experimental field of the four areas was monitored by the SCADA system. Field observation and assessment (before and after xeriscaping) for converting the existing four landscape areas and results evaluated by experts in the campus landscape field are practical. The assessment results supported the authors to logically prove the study results and feasibility for applying specific quantities type of xeriscaping landscape, as well as convenience practically decision-maker to apply the proposed approach on all remaining landscape areas, representing 78% of the total traditional landscape in the university campus.

4. The Study Experiments

The research team, with the official technical team and two particular landscape suppliers, made an applied study of four areas within the KFU campus border. As discussed earlier, the campus is located in Al-Al-Ahsa city with a total area of 4.5 km^2. The four cases reach approximately 31,750 m^2, representing 22% of the total area. Figure 4 shows the KFU location layout and the four field experimental locations as actual cases from the Google map before applying the study's xeriscaping method. The green spaces are at the level of the KFU layout site. These study cases can be clarified as follows [60–63,66].



walkway Gate 11 Parking 14 area Parking 4 area

Google mape for KFU campus

Figure 4. King Faisal University general location and applied case study areas locations.

4.1. Study Field Expermint 1: Parking 14 Landscape

4.1.1. The Previous Situation for Parking 14 Landscape Area

This study field experiment location is beside the campus male and female student dormitories with an area 1371 m^2. It finishes in tender design containing terrazzo tiles. The hardscape for pavement and softscape items were: palms: phoenix dactylifera; trees: tabebula ayrea, cassia indosa, and schhinus molle; shrubs: hibiscus rosa-sinensis; muraya panuclaya, canna indica, caesalpennia pulcherrima, durantya rebins; succulents: agave americana, yucca aloforia prostrata; groundcover and climber: carissa grandiflora, gazanianivea, bougainyilla glabra mixed color, citecressa purpurea, and grass: cynodon dactylon; with total 45.814 L (45.8 m^3) of water consumption. Figure 5 shows the consumption water quantity for each softscape item, the tender design for this area, and the photo before applying this study (more details in Table A1).

4.1.2. Applying Xeriscape for Parking 14 Landscape Area

In this study field experiment, the layout design contains palms: phoenix dactylifera; trees: tabebula ayrea, cassia indosa, and schhinus molle; shrubs: hibiscus rosa-sinensis; muraya panuclaya, canna indica, caesalpennia pulcherrima, durantya rebins; Succulents: agave americana, yucca aloforia prostrata; groundcover and climber: gazania nivea, bougainyilla glabra mixed color, citecressa purpurea, and carissa grandiflora; grass: cynodon dactylon; hard material: mulch, natural gravel, natural stone, and interlock, with total/day 33.478 L (33.5 m^3) of water consumption with around 27% water consumption reduction. Figure 6 shows the area after applying xeriscaping for the activity walkway landscape (more details in Table A5).

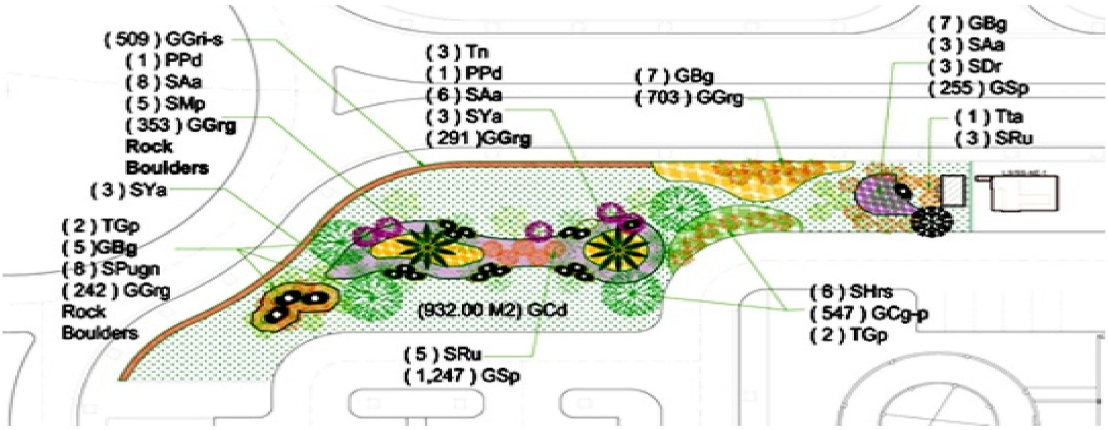


Figure 5. The previous situation for Parking 14 landscape area. Previous tender softscape design (Details of water consumption is shown in Table A1).

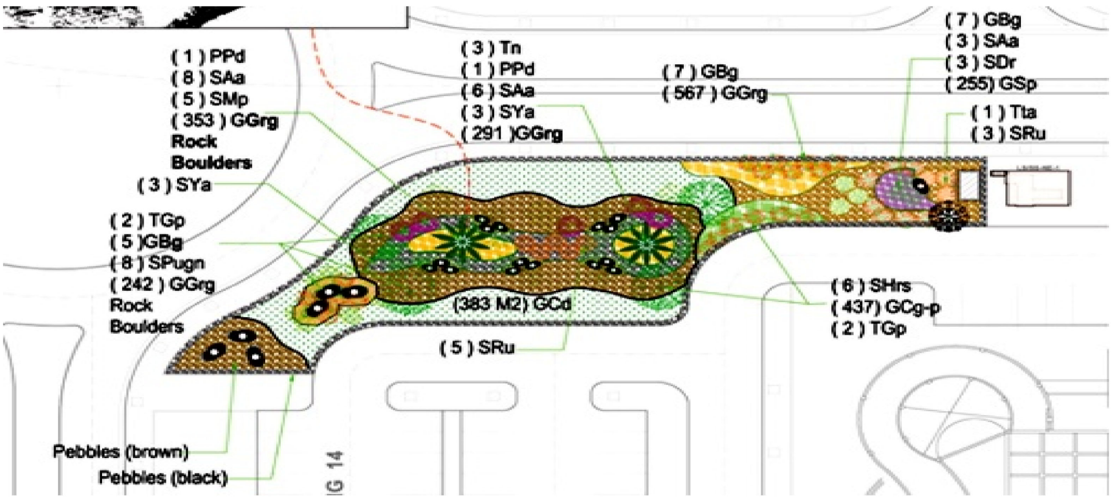


Figure 6. Applying to xeriscape for Parking 14 landscape area. Xeriscaping softscape design (Details of water consumption is shown in Table A5).

4.2. Study Field Experiment 2: Parking 4 Landscape

4.2.1. The Previous Situation for Parking 4 Landscape Area

This study field experiment location is in the front of the research center building inside the campus with an area 1720 m^2, and finishes in tender design containing terrazzo tiles as hardscape, and softscape items were: trees: callistemon viminalis, cassia indosa, hibiscus tiliaceaus, plumeria obtuse, and cassia fistula; shrubs: hibiscus rosa sinensis, tecomaria capensis, vitex agnus castus, saesalpinia pulcherrima, and myrtus communis; succulents: agave americana; groundcover and climber: rosmarinus officinalis, gazania nivea, and cortaderia seloania; grass: cynodon dactylon. Figure 7 shows the consumption water quantity for each soft scape item, the tender design for this area, and the photo before applying this study (more details in Table A2). The total was 48,600 L (48.6 m^3) of water consumption.

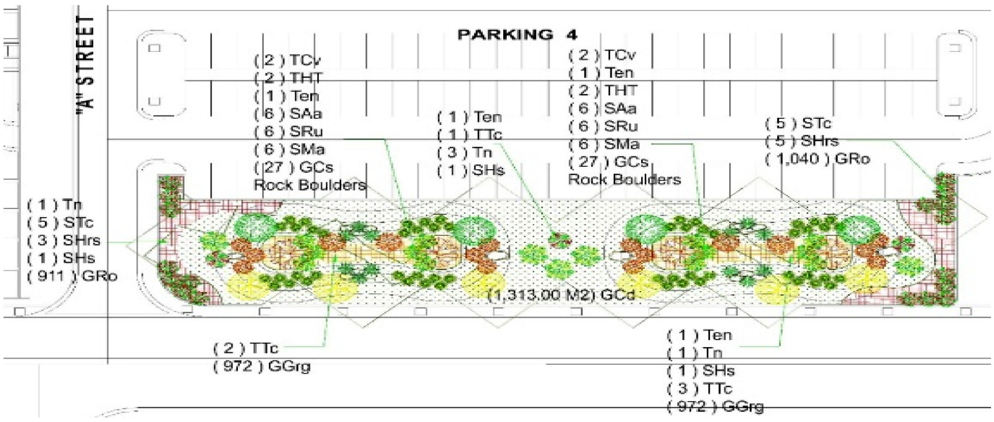


Figure 7. The previous situation for Parking 4 landscape area. Previous tender softscape design (Details of water consumption is shown in Table A2).

4.2.2. Applying Xeriscape for Parking 4 Landscape Area

Figure 8 shows the area after applying xeriscaping for the activity walkway landscape (More details in Table A6). In this study field experiment, the layout design contains trees: callistemon viminalis, cassia indosa, hibiscus tiliaceaus, plumeria obtuse, and cassia fistula; shrubs: hibiscus rosa sinensis, tecomaria capensis, vitex agnus castus, saesalpinia pulcherrima, and myrtus communis; succulents: agave americana; groundcover and climber: rosmarinus officinalis, and cortaderia seloania; grass: cynodon dactylon; hard material: mulch, natural gravel, natural stone, and interlock; with total/day 21,636 L (21.6 m^3) of water consumption with around 55.5% water consumption reduction.

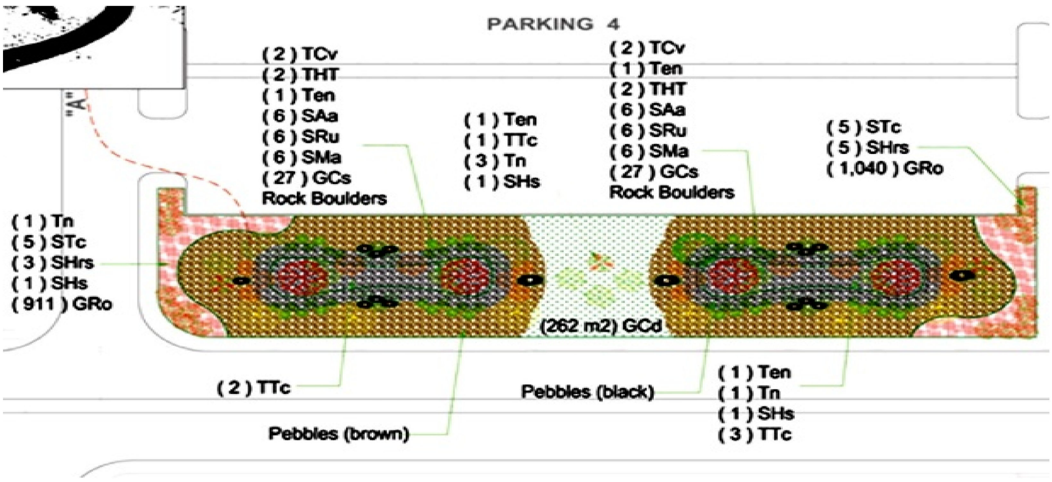


Figure 8. Applying xeriscape for Parking 4 landscape area. Xeriscaping softscape design (Details of water consumption is shown in Table A6).

4.3. Study Field Experiment 3: Gate 11 Landscape

4.3.1. The Previous Situation for Gate 11 Landscape Area

This study field experiment location is beside residential campus gate no. 11, with an area of 3700 m^2. Before the study, the gate layout finishes contained stamped concrete, interlock as hardscape, and finishes in tender design contained terrazo tiles. The hardscape for pavement and softscape items were: palms: phoenix dactylifera, and american palm; trees: pithecellobium dulce, hibiscus tiliaceaus, vitex agnus castus, nerium oleander, and cassia glauca; groundcover and climber: rosmarinus officinalis, cortaderia seloania; grass: cynodon dactylon. Figure 9 shows the consumption water quantity for each soft scape item, the tender design for this area, and the photo before applying this study (more details in Table A3). The total was 72,045 L (72.5 m^3) of water consumption.

Figure 9. The previous situation for Gate 11 landscape area. Previous tender softscape design (Details of water consumption is shown in Table A3).

4.3.2. Applying Xeriscaping for Gate 11 Landscape Area

In this study field experiment, the layout design contains palms: phoenix dactylifera, trees: hibiscus tiliaceaus; succulents: agave americana; groundcover and climber: rosmarinus officinalis; grass: cynodon dactylon; hard material: mulch, natural gravel, and natural stone; with total/day 47,780 L (47.8 m^3) of water consumption with around 39% water consumption reduction. Figure 10 shows the area after applying to xeriscape for the activity walkway landscape (more details in Table A7).

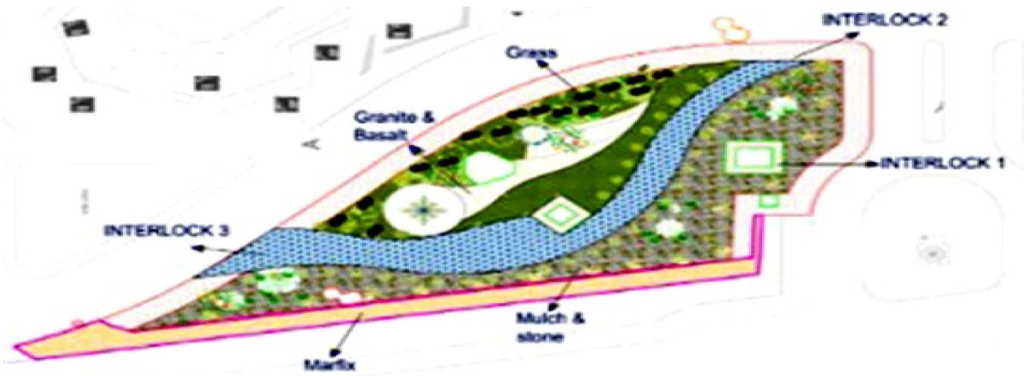


Figure 10. Applying xeriscape for Gate 11 landscape area. Xeriscaping softscape design (Details of water consumption is shown in Table A7).

4.4. Study Field Experiment 4: Activity Walkway

4.4.1. The Previous Situation for the Activity Walkway Landscape Area

This study field experiment location is beside residential gate no. 11 for all campus gates with an area of 24,960 m^2. The walkway is 520 m in length and 43 m in width. The palms include phoenix dactylifera and american palm; trees: hibiscus tiliaceaus, vitex agnus castus, nerium oleander, and cassia glauca; Shrubs: hibiscus rosa-sinensis; Succulents: agave americana; groundcover and climber: rosmarinus officinalis, cortaderia seloania; grass: cynodon dactyl with 4 circle fountain; with total 237,330 L (237.3 m^3) of water consumption. Figure 11 shows the consumption water quantity for each soft scape item, the tender design for this area, and the photo before applying this study (more details in Table A4).

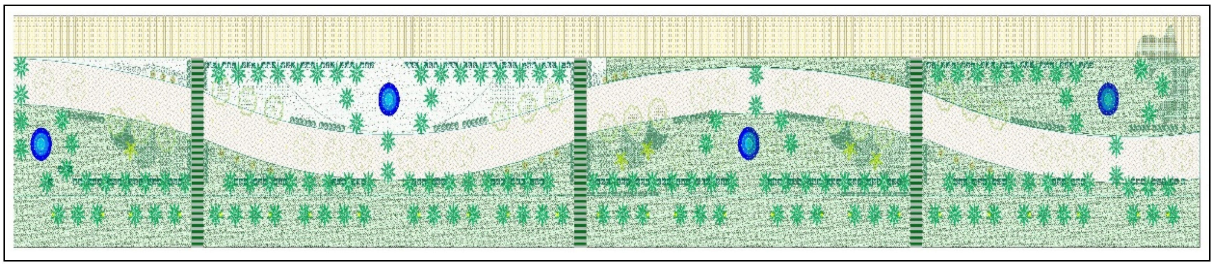


Figure 11. The previous situation for the walkway landscape area. Previous tender softscape design (Details of water consumption is shown in Table A4).

4.4.2. Applying Xeriscaping for Activity Walkway Landscape Area

In this study experiment, the layout design contains palms: palm date; trees: ziziphus spina, albizia lebbeck, and tamarindus indica; Shrubs: moring indica, and aloe vera; groundcover and climber: bougain vililea; grass: grass cl2000; hard material: mulch, natural gravel, natural stone, and Interlock with 6 circle fountain with total/day 138,450 L (138.5 m^3) of water consumption with around 42.1% water consumption reduction. Figure 12 shows the area after applying to xeriscape for the activity walkway landscape (more details in Table A8).

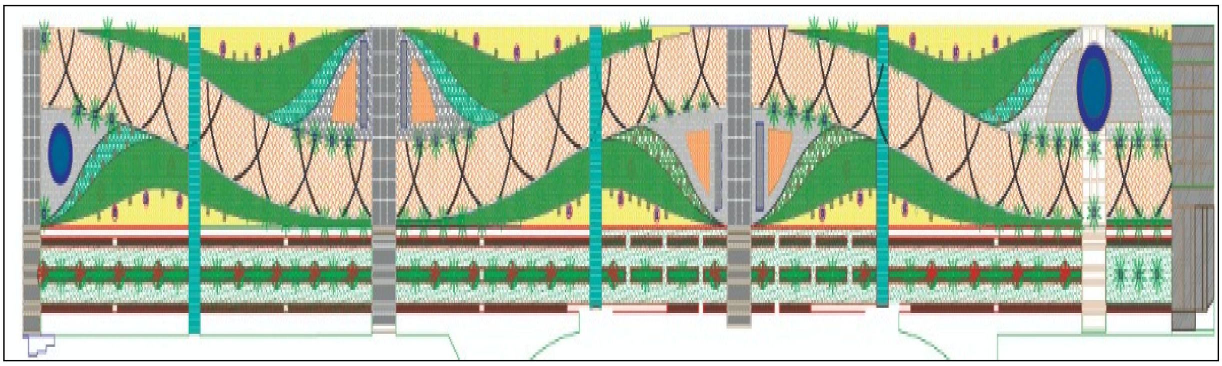


Figure 12. Applying xeriscape for walkway landscape area. Xeriscaping softscape design (Details of water consumption is shown in Table A8).

5. Results and Discussion

Through the study field experiment, the research team with the technical and engineer team proved the validity of applying urban xeriscaping landscape as a practical potential approach to conserve water resources content inside the KFU campus. The study field experiment used 24 urban native softscape types and four hardscape items available in Saudi Arabia in four areas. The total four experiment areas, 31,750 m^2 represent 22% of the total KFU campus green landscape layout. Using numerical assessment through experts' physical monitoring supported by maintenance discipline SCADA system, each selected four areas achieved a significant rate in water consumption reduction after converting conventional landscape with xeriscape landscape as follows [64,68].

5.1. Thw Study Field Experiment 1

Parking 14 landscapes in the previous situation for an area of 1371 m^2, and finishes in tender design contain 2 hard landscape items and 16 urban native softscape items with a total of 45,814 L (45.8 m^3) of water consumption. Applying xeriscaping landscape design contains four hardscapes and 16 urban native softscape with a total/day of 33,478 L (33.5 m^3) of water consumption. That means a 27% water consumption reduction. Figure 13 shows the water consumption quantity for each softscape item for the previous status and Figure 14 shows the water consumption quantity after applying for xeriscaping status.

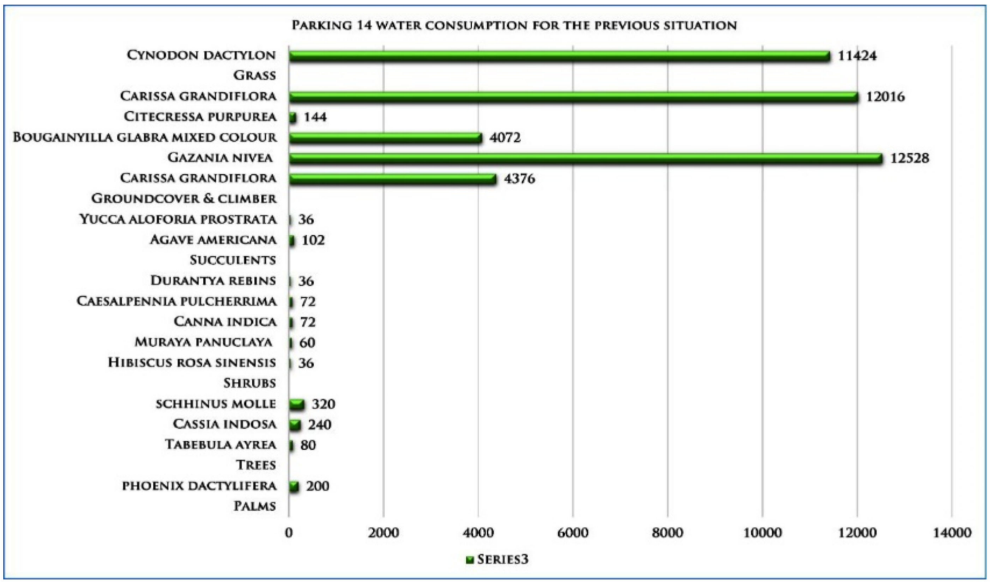


Figure 13. Experiment 1 water consumption quantity for previous status. Previous tender softscape design water consumption (Details in Table A1).

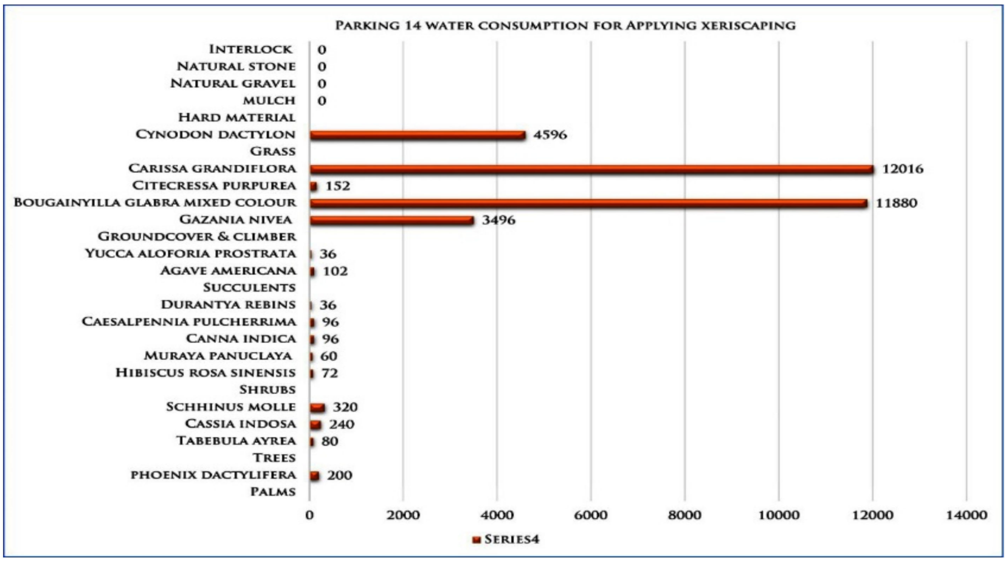


Figure 14. Experiment 1 water consumption quantity after applying for xeriscaping status. Xeriscaping softscape design water consumption (Details in Table A5).

5.2. Study Field 55.1 Thw Study Field Experiment 2

Parking 4 landscapes in the previous situation for an area of 1720 m^2, and finishes in tender design contain 2 hard landscape items and 14 urban native softscape items with a total of 48,600 L (48.6 m^3) of water consumption. Applying xeriscaping landscape design contain four hard landscape and 14 urban native softscape items with a total/day of 21,636 L (21.6 m^3) of water consumption. That means a 55.5% water consumption reduction. Figure 15 shows the water consumption quantity for each soft scape item for the previous status. Figure 16 shows the quantity after applying for the status of the xeriscaping items.

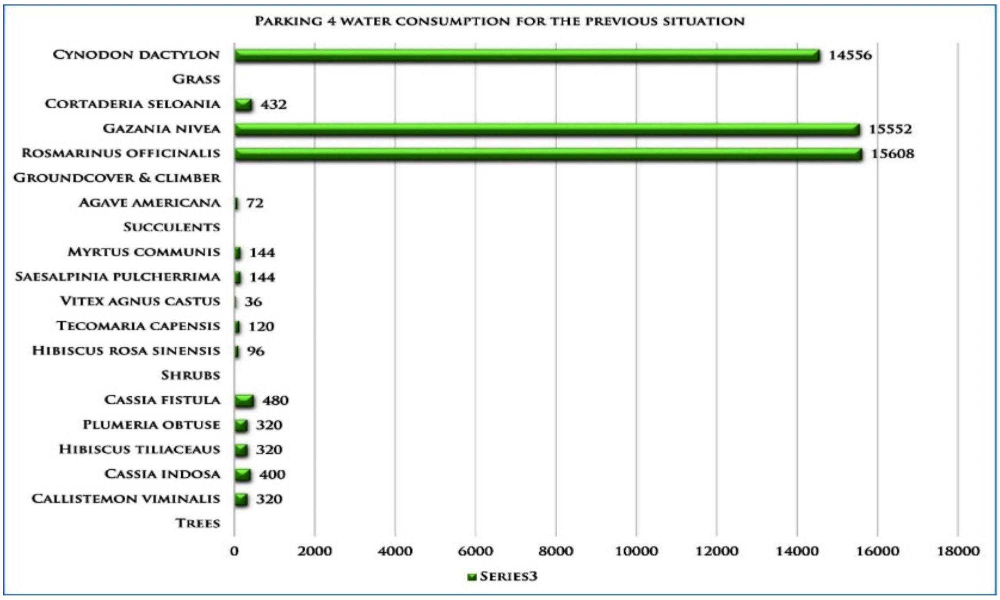


Figure 15. Experiment 2 water consumption quantity for previous status. Previous tender softscape design water consumption (Details in Table A2).

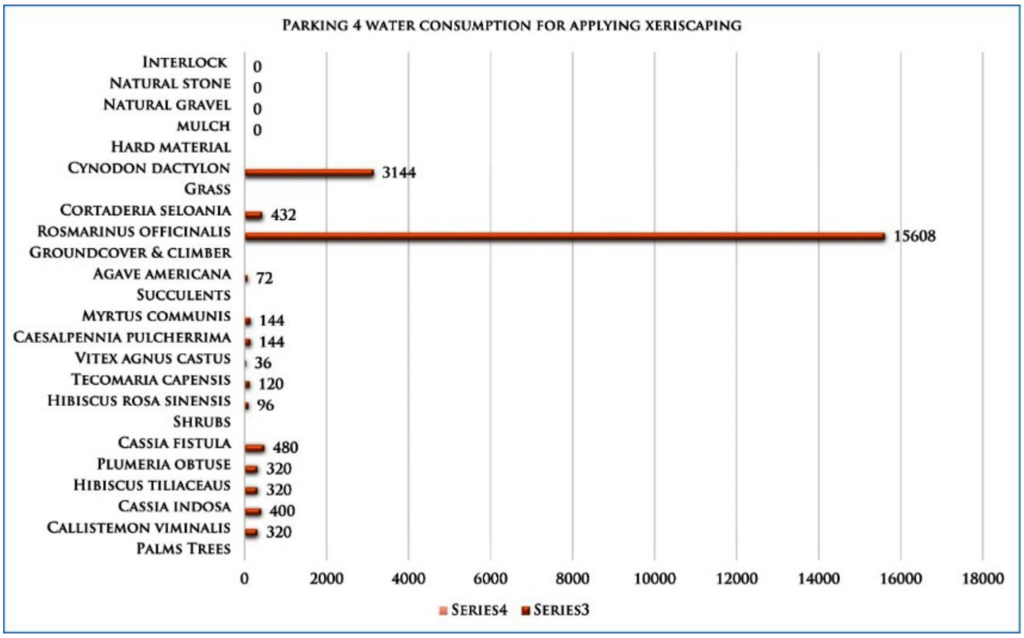


Figure 16. Experiment 2 water consumption quantity after applying xeriscaping items. Xeriscaping softscape design water consumption (Details in Table A6).

5.3. The Study Field Experiment 3

Gate 11 landscape in the previous situation has the area 24,960 m^2, and finishes in tender design contain two hard landscape items and 14 urban native softscape items with 72,045 L (72.5 m^3) of water consumption. Applying xeriscaping landscape design contain four hard landscape and 14 urban native softscape items with a total/day of 47,780 L (47.8 m^3) of water consumption. That means 39% water consumption reduction. Figure 17 shows the water consumption quantity for each softscape item for the previous status. Figure 18 shows the quantity of water consumption after applying xeriscaping items.

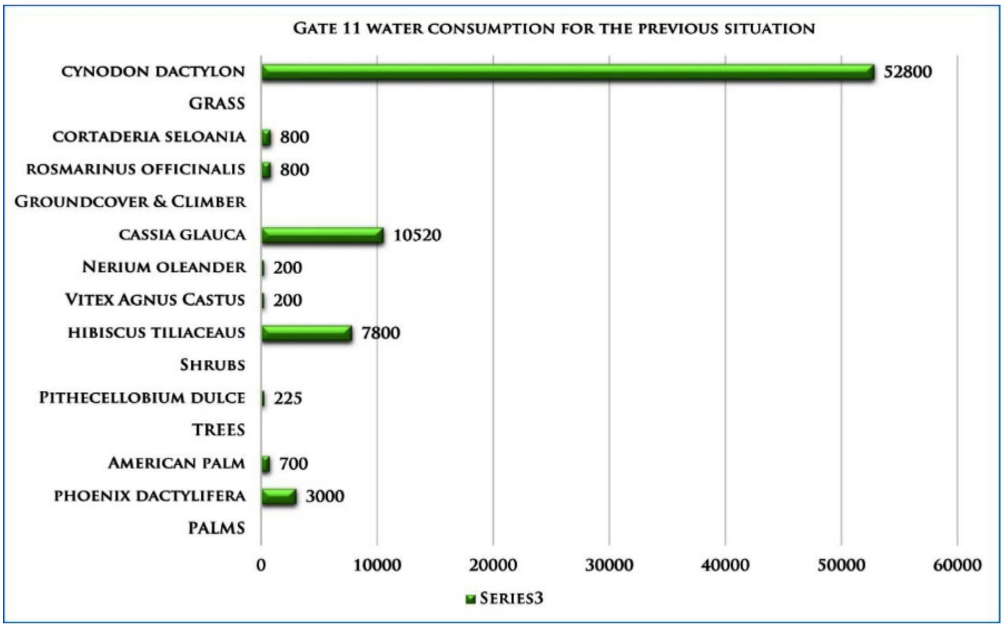


Figure 17. Experiment 3 water consumption quantity for the previous status. Previous tender softscape design water consumption (Details in Table A3).

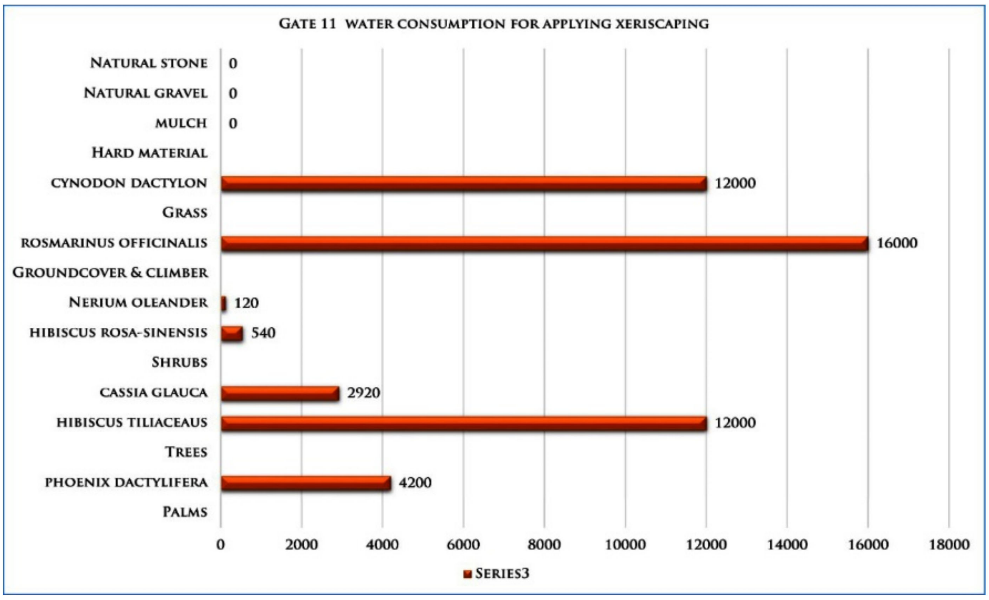


Figure 18. Experiment 3 water consumption quantity after applying xeriscaping items. Xeriscaping softscape design water consumption (Details in Table A7).

5.4. Study Field Experiment 4

Activity walkway in the previous situation has the area 1720 m^2, and finishes in tender design contain two hardscape items and 14 urban native softscape items with a total of 237,330 L (237.3 m^3) of water consumption. Applying xeriscaping landscape design contain four hard landscape and 14 urban native softscape items with a total/day of 138,450 L (138.5 m^3) of water consumption. That means a 42.1% water consumption reduction. Figure 19 shows the water consumption quantity for each softscape item for the previous status. Figure 20 shows the water consumption quantity after applying xeriscaping items.

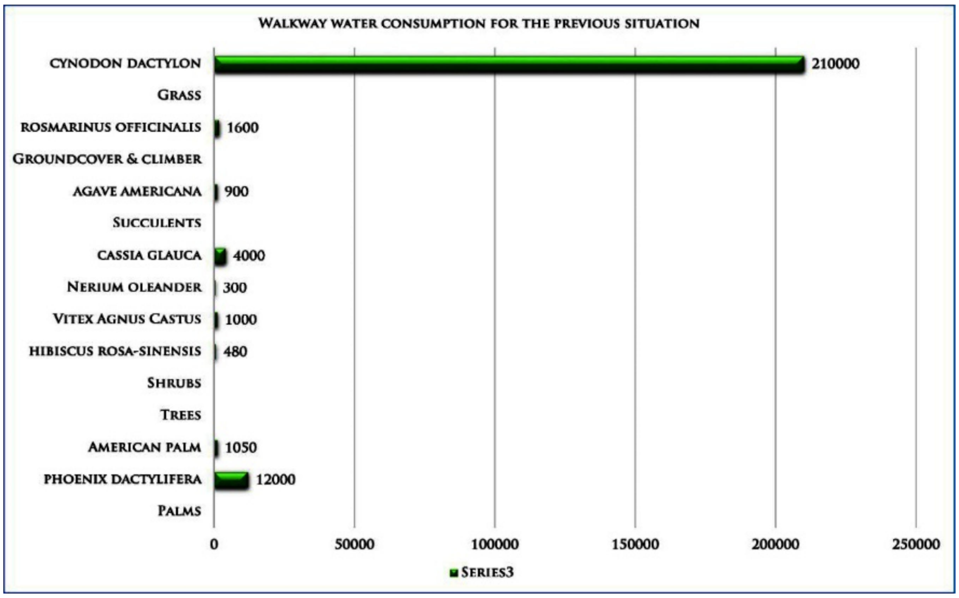


Figure 19. Experiment 4, water consumption quantity for the previous status. Previous Tender softscape design water consumption (Details in Table A4).

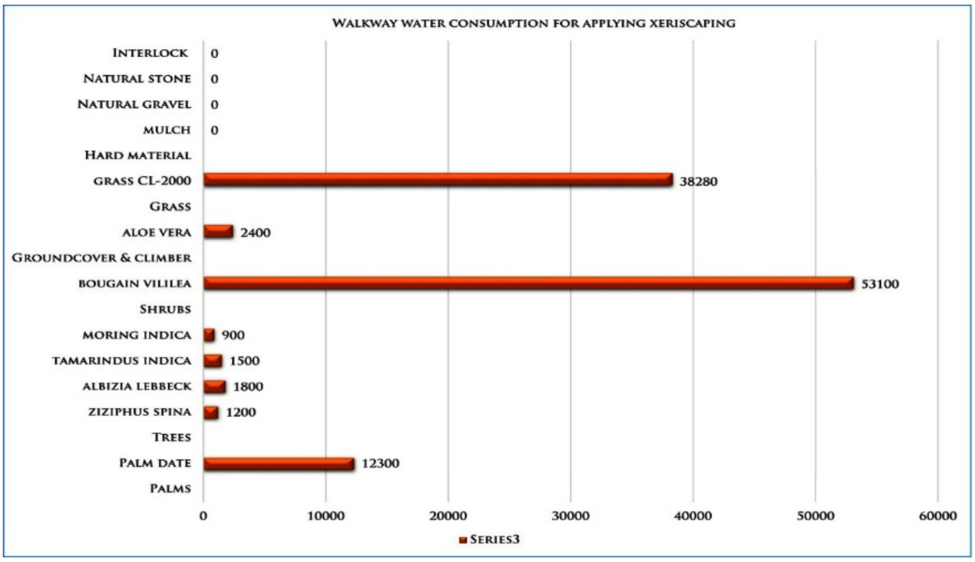


Figure 20. Experiment 4, water consumption quantity after applying xeriscaping items. Xieriscaping softscape design water consumption (Details in Table A8).

5.5. The Study Proposal for Remaining KFU Landscape Area

The total green area within the KFU university landscape layout campus is 118.640 m^2 (university campus 73,110 m^2 and residential area is 45,530 m^2) with water consumption of 3911 m^3/day. The water consumption KFU landscape layout is 3,910,530 L (3911 m^3) from non-renewable 15 artesian wells' water sources. The four study experiments with a total area of 31,750 m^2 representing 22% of the total KFU landscape layout were selected to apply the xeriscaping landscape concept instead of the existing conventional landscape. Monitoring the experiments and the results through physical experts and SCADA system within one year. The landscape items were 10 shrubs types, 11 trees types, 2 palms types, 6 groundcovers and climber types, 2 succulents types, grass types, and 4 hard material types to apply the study. There was obvious water saving in the four experiments of the study (see summary Figures 21 and 22).

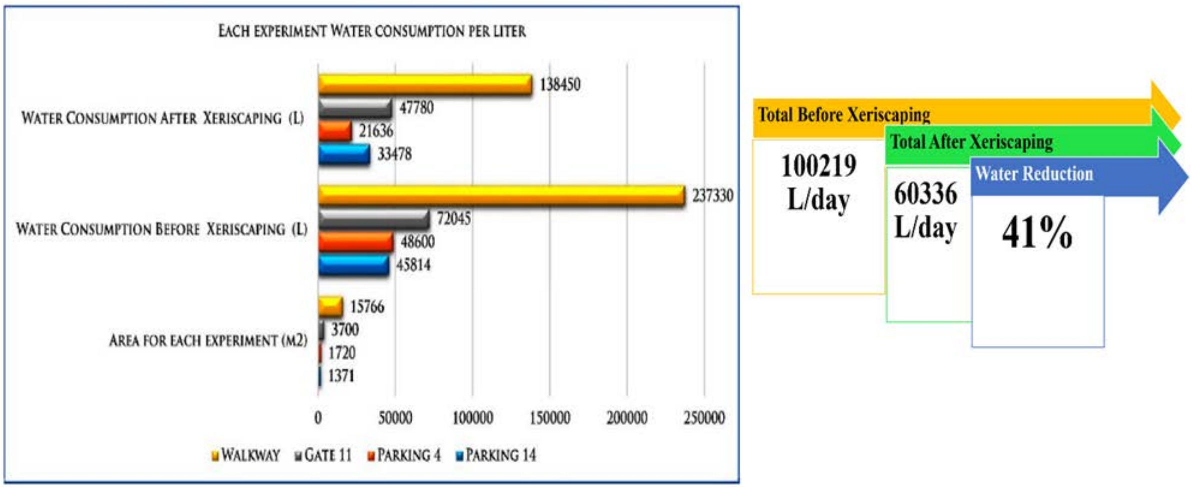


Figure 21. Water consumption comparison before and after applying xeriscaping for each study field experiment.

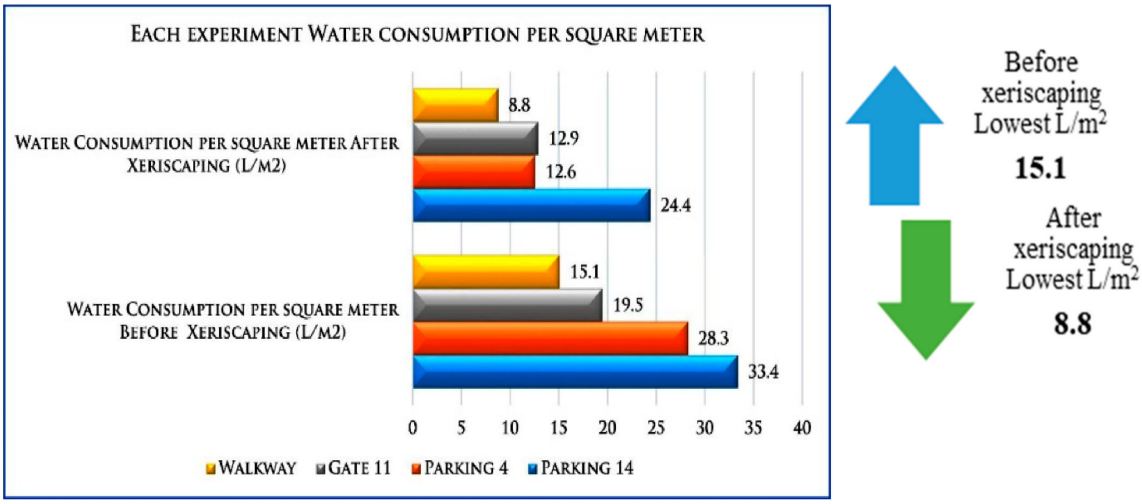


Figure 22. Water consumption comparison before and after applying xeriscaping for each study field experiment and water consumption per square meter L/m^2.

Water consumption before applying xeriscaping landscape (L): Parking 14 45,814 L, Parking 4 48,600 L, Gate 11 72,045 L, Walkway 237,330 L,. Water consumption per liter (L) after applying to xeriscape: Parking 14 33,478 L, Parking 21,636 L, Gate 11 47,780 L, Walkway 138,450 L. The total water consumption for the four experiment areas before the study was 408,789 (408.8 m^3)/day and an average of 100,219 L (100.2 m^3)/day. The water consumption for the four experiment areas after applying the study approach becomes 241,344 (241.4 m^3)/day with an average of 60,336 L (60.3 m^3)/day. This means that the total water consumption reduction is 167,445 L (167.5 m^3), representing 41% of the total selected area. Figure 21 compares water consumption quantity in study field experiments parking 14, park 4, walkway, and gate 11 areas inside KFU in relation to water consumption before and after applying the xeriscaping method, and square meter area for each experiment with the total saved water after applying xeriscaping. Area for each experiment (m^2): Parking 1371 m^2, Parking 1720 m^2, Gate 11 3700 m^2, and Walkway 15,766 m^2. Water consumption per square meter before applying xeriscaping (L/m^2): Parking 14 33.4 L/m^2, Parking 28.3 L/m^2, Gate 11 19.5 L/m^2, Walkway 15.1 L/m^2. Water consumption per square meter after applying xeriscaping (L/m^2): Parking 14 24.4 L/m^2, Parking 12.6 L/m^2, Gate 11 12.9 L/m^2, Walkway 8.8 L/m^2. Figure 22 compares the water consumption before and after applying xeriscaping for each study field experiment and water consumption per square meter for each field experiment.

The study, according to related literature; managing water resources in public organizations in the desert region, especially Saudi Arabia; experts in agriculture and native plants in the eastern province, and results from four case study field experiments for experiment 4 walkway landscape with lowest water consumption 8.8 L/m^2, which monitored for 1 year using experts physical monitoring and the main SCADA system for the demand water for irrigation quantity. Hence, the team managed the significant landscape design quantities for each xeriscaping landscape item according to the lowest water consumption landscape in walkway projects, which the KFU decision-maker can apply for the remaining landscape layout area of 86,890 m^2, with the following percentage for each item. The first is softscape, which includes palms 1%, trees 5%, shrubs and succulents 5%, groundcover and climber 40%, and grass 20%. The second is hardscape, which includes mulch and natural gravel 10%, natural stone and interlock 19%, which can consume 20,300 L (20.3 m^3)/day, compared with the previous four case studies, which consume an average of 60,336 L (60.4 m^3)/day, as well as less than the lowest water.

This study agreed with the literature review (e.g., [23]), which focused on the benefits, principles and some applications of xeriscaping method in the construction field, especially in the landscape discipline. Results in the literature review (e.g., [18,40,52]) were mainly very useful. However, there was a gap in the literature that there is no consistent research approach adopted comprehensively and quantitatively for the xeriscaping items based on several field experiments as a retrofit method inside an existing desert public mega-project campus. The study showed significant results in the landscape layout field supporting natural resources conservation such as water consumption in the coordination of urban landscape design of universities in desert areas. The KFU campus achieved pioneer projects in Saudi Arabia and the Gulf area region in life quality and natural resources conservation.

The current study confirms that using native plants is crucial due to their potential to develop landscapes in saline and water shortage conditions, leading to a reduction in water consumption for landscaping, which coincidence with previous studies [40]. The study also confirms that landscape design and the xeriscape principles have significant benefits in terms of economic and environmental contributions [18,52], which are worth further research investigation. The main aim of the xeriscape landscape design approach is to protect water resources by minimizing water use. The water-efficient landscape design (xeriscape) includes water-demanding crop plants and water-saving alternative irrigation methods, mulching, etc. [49]. Xeriscape (low-water-use landscaping) has held the promise of significant water savings for several years. The purpose of xeriscaping is to achieve low garden maintenance measured by less watering, less fertilizer and pesticides, less weeding, and less mowing [11,15]. The benefits of xeriscaping include reducing water waste; using minimum efficient irrigation and fertilizer usage; reducing maintenance time; water requirements being low; reducing pollution; making a healthy environment by removing acres of sod; gas-powered mowers will not require the moisture; reducing heat islands to improve sustainable requirements; and improving the community's overall look [13–17].

6. Conclusions

Applying sustainable standards in government construction projects landscape in desert region campuses by adopting sustainability approaches, which support the organization to preserve its natural resources, is a growing concern. This study confirms that applying the xeriscaping landscape concept as a sustainable approach can support rationalizing water consumption rather than traditional landscape methods. The water consumption quantity for the whole KFU landscape layout is 3,910,530 L (3911 m^3) from non-renewable 15 artesian wells water sources. The selected four study experiments with a total area of 31,750 m^2 represented 22% of the total KFU landscape layout. Total water consumption reduction is 167,445 L (167.5 m^3), representing 41% of the total selected area. The lowest water reduction experiment per square meter was a walkway experiment with 8.8 L/m^2, which led to estimating the xeriscape landscape quantity for each item to design and apply for the remaining area in the case study KFU landscaped campus. The KFU campus has adopted a pioneer project in Saudi Arabia and the Gulf area region concerning natural resources conservation. This study opens the way to conduct further studies on the same topic and scope of the xeriscaping method as an environmentally sustainable approach to public projects based on sustainable criteria.

7. Limitations of the Study and Directions for Future Research

The current study focused on adopting xeriscaping as a retrofit approach for water conservation and asset management inside public organizations layout, i.e., university campus layout using experimental research approach of different four case studies. The results may be limited to other public spaces of the same context. The study also opens the door for future research studies on public organizations layout in relation to the use of xeriscaping environmental aspects like heat island reduction. Additionally, the economic impacts of xeriscaping landscape layout design can be another interesting area of research.

Author Contributions: Conceptualization, E.M.H.I. and A.E.E.S.; methodology, E.M.H.I.; software, E.M.H.I.; validation, E.M.H.I. and A.E.E.S.; formal analysis, E.M.H.I.; investigation, E.M.H.I. and A.E.E.S.; resources, E.M.H.I. and A.E.E.S.; data curation, E.M.H.I.; writing—original draft preparation, E.M.H.I. and A.E.E.S.; writing—review and editing, E.M.H.I. and A.E.E.S.; visualization, E.M.H.I.; supervision E.M.H.I.; project administration, E.M.H.I.; funding acquisition, E.M.H.I. and A.E.E.S. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Data available upon request from the first author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Water consumption for each softscape item: previous situation for PARKING 14 landscape area.

Plant List/Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Palms				
phoenix dactylifera	nos.	2	100	200
Trees				
Tabebula ayrea	nos.	1	80	80
Cassia indosa	nos	3	80	240
schhinus molle	nos	4	80	320
Shrubs				
Hibiscus rosa sinensis	nos.	6	12	36
Muraya panuclaya	nos.	5	12	60
Canna indica	nos	8	12	72
Caesalpennia pulcherrima	nos	8	12	72
Durantya rebins	nos	3	12	36
Succulents				

Table A1. *Cont.*

Plant List/Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Agave americana	nos	17	6	102
Yucca aloforia prostrata	nos	6	6	36
Groundcover & climber				
Carissa grandiflora	nos	547	8	4376
Gazania nivea	nos	1566	8	12,528
Bougainyilla glabra mixed colour	nos	509	8	4072
Citecressa purpurea	nos	18	8	144
Carissa grandiflora	nos	1502	8	12,016
Grass				
Cynodon dactylon	m^2	952	12	11,424
				TOTAL/DAY 45.814 L

Table A2. Water consumption for each softscape item: previous situation for PARKING 4 landscape area.

Plant List Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Trees				
Callistemon viminalis	nos.	4	80	320
Cassia indosa	nos	5	80	400
Hibiscus tiliaceaus	nos	4	80	320
Plumeria obtuse	nos	4	80	320
Cassia fistula	nos	6	80	480
Shrubs				
Hibiscus rosa sinensis	nos.	8	12	96
Tecomaria capensis	nos.	10	12	120
Vitex agnus castus	nos	3	12	36
Saesalpinia pulcherrima	nos	12	12	144
Myrtus communis	nos	12	12	144
Succulents				
Agave americana	nos	12	6	72
Groundcover & climber				
Rosmarinus officinalis	nos	1951	8	15,608
Gazania nivea	nos	1944	8	15,552
Cortaderia seloania	nos	54	8	432
Grass				
Cynodon dactylon	m^2	1213	12	14,556
				TOTAL/DAY 48,600 L

Table A3. Water consumption for each softscape item: previous situation for GATE 11 landscape area.

Plant List/Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
PALMS				
phoenix dactylifera	nos.	30	100	3000
American palm	nos	10	70	700
TREES				
Pithecellobium dulce	nos.	15	15	225
Shrubs				
hibiscus tiliaceaus	nos.	130	60	7800
Vitex Agnus Castus	nos	10	20	200
Nerium oleander	nos	10	20	200
cassia glauca	nos	263	40	10,520
GROUNDCOVER & CLIMBER				
rosmarinus officinalis	m^2	100	8	800
cortaderia seloania	m^2	100	8	800
GRASS				
cynodon dactylon	m^2	4400	12	52,800
				TOTAL/DAY 77,045 L

Table A4. Water consumption for each softscape item: previous situation for WALKWAY landscape area.

Plant list/Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Palms				
phoenix dactylifera	nos.	80	150	12,000
American palm	nos	15	70	1050
Trees				
Shrubs				
hibiscus rosa-sinensis	nos.	45	12	480
Vitex Agnus Castus	nos	50	20	1000
Nerium oleander	nos	15	20	300
cassia glauca	nos	100	40	4000
Succulents				
agave americana	nos.	150	6	900
Groundcover & climber				
rosmarinus officinalis	m^2	2000	8	1600
Grass				
cynodon dactylon	m^2	14,000	15	210,000
				TOTAL/DAY 237,330 L

Appendix B

Table A5. Water consumption for each softscape item: Applying xeriscaping for PARKING 14 landscape.

Plant List/Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Palms				
phoenix dactylifera	nos.	2	100	200
Trees				
Tabebula ayrea	nos.	1	80	80
Cassia indosa	nos	3	80	240
Schhinus molle	nos	4	80	320
Shrubs				
Hibiscus rosa sinensis	nos.	8	12	72
Muraya panuclaya	nos.	5	12	60
Canna indica	nos	8	12	96
Caesalpennia pulcherrima	nos	8	12	96
Durantya rebins	nos	3	12	36
Succulents				
Agave americana	nos	17	6	102
Yucca aloforia prostrata	nos	6	6	36
Groundcover & climber				
Gazania nivea	nos	437	8	3496
Bougainyilla glabra mixed colour	nos	1453	8	11,880
Citecressa purpurea	nos	19	8	152
Carissa grandiflora	nos	1502	8	12,016
Grass				
Cynodon dactylon	m^2	387	12	4596
Hard material				
mulch	m^2	150	0	0
Natural gravel	m^2	120	0	0
Natural stone	m^2	145	0	0
Interlock		150		
				TOTAL/DAY 33.478 L

Table A6. Water consumption for each softscape item: Applying xeriscaping for PARKING 4 landscape.

Plant List Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Palms				
Trees				
Callistemon viminalis	nos.	4	80	320
Cassia indosa	nos.	5	80	400
Hibiscus tiliaceaus	nos.	4	80	320
Plumeria obtuse	nos.	4	80	320
Cassia fistula	nos.	6	80	480
Shrubs				
Hibiscus rosa sinensis	nos.	8	12	96
Tecomaria capensis	nos.	10	12	120

Table A6. *Cont.*

Plant List Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Vitex agnus castus	nos	3	12	36
Caesalpennia pulcherrima	nos.	12	12	144
Myrtus communis	nos	12	12	144
Succulents				
Agave americana	nos.	12	6	72
Groundcover & climber				
Rosmarinus officinalis	nos	1951	8	15,608
Cortaderia seloania	nos	54	8	432
Grass				
Cynodon dactylon	m^2	262	12	3144
Hard material				
mulch	m^2	160	0	0
Natural gravel	m^2	210	0	0
Natural stone	m^2	280	0	0
Interlock	m^2	300	0	0
				TOTAL/DAY 21,636 L

Table A7. Water consumption for each softscape item: Applying xeriscaping for GATE 11 landscape.

Plant List/Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Palms				
phoenix dactylifera	nos.	42	100	4200
Trees				
hibiscus tiliaceaus	nos.	200	60	12,000
cassia glauca	nos	73	40	2920
Shrubs				
hibiscus rosa-sinensis	nos.	35	12	540
Nerium oleander	nos.	20	6	120
Groundcover & climber				
rosmarinus officinalis	m^2	2000	8	16,000
Grass				
cynodon dactylon	m^2	1000	12	12,000
Hard material				
mulch	m^2	150	0	0
Natural gravel	m^2	200	0	0
Natural stone	m^2	250	0	0
				TOTAL/DAY 47,780 L

Table A8. Water consumption for each softscape item: Applying xeriscaping for WALKWAY landscape.

Plant List/Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Palms				
Palm date	nos.	123	100	12,300
Trees				
ziziphus spina	nos.	20	60	1200

Table A8. *Cont.*

Plant List/Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
albizia lebbeck	nos	30	60	1800
tamarindus indica	nos	25	60	1500
moring indica	nos.	15	60	900
Shrubs				
bougain vililea	nos	3540	15	53,100
Groundcover & climber				
aloe vera	nos.	40	6	2400
Grass				
grass CL-2000	m^2	3190	12	38,280
Hard material				
mulch	m^2	120	0	0
Natural gravel	m^2	65	0	0
Natural stone	m^2	45	0	0
Interlock				
				TOTAL/DAY 138,450 L

Appendix C

Table A9. Study proposal for applying Xeriscaping concept in area 30 m × 30 m.

Plant List Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Palms				
Phoenix dactylifera	No.	5	100	500
Trees				
Albizia lebbeck	No.	10	60	600
Azadirachta indica	No.	10	60	600
Ziziphus spina	No.	10	60	600
Hibiscus tiliaceus	No.	10	60	600
Pithecellobium dulce	No.	10	60	600
Shrubs				
Cassia Glauca	No.	100	15	1500
Bougainvillea	No.	100	15	1500
V itex agnus	No.	100	15	1500
Plumeria obtusa	No.	100	15	1500
Succulents				
Aloe perfoliata var. vera	No.	75	6	450
Agava-Americana	No.	75	6	450
yucca	No.	50	6	300
Groundcover & climber				
Alternanthera.	m^2	2000	8	2400
Gazania Grandifloura	m^2	2000	8	2400
Wedelia florida	m^2	2000	8	2400
Grass				
Grass-C2000	m^2	200	12	2400

Table A9. *Cont.*

Plant List Botanical Names	Unit	Quantity	Daily Water Requirements/Day	Total Requirements/Day
Hard material				
mulch	m^2	50		0
Natural gravel	m^2	75		0
Natural stone	m^2	75		0
Interlock	m^2	190		0
				TOTAL/DAY 20,300 L

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