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RESEARCH ARTICLE

Water conservation criteria in green building evaluation systems and estimation of possible water savings in the case of application of these criteria on a detached house

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Abstract

In Turkey, which is still classified as a water-stressed country, the amount and proportion of water consumed as drinking and sanitary water in buildings is increasing day by day. This situation not only threatens water resources, but also leads to additional infrastructure investments and high energy costs for the treatment, supply, and removal of water to and from buildings. The aim of this study is to look at the issue in a holistic way, to identify all the measures that can be taken to save water in a building, and to estimate how much water can be saved assuming that they are applied to a real house. For this purpose, the water saving measures developed in the most well-known green building rating systems LEED, BREEAM and CASBEE systems and in the National Green Certification System YeS-TR, have been examined. The study investigated how much water could be saved if a house with a garden on a 780 m^2 plot of land in the province of Sivas was built according to the specified measures. The study showed that the annual water consumption of the house, which is 800 tonnes, can be reduced to 414 tonnes through appropriate landscaping, rainwater harvesting, grey water harvesting and the use of water-saving devices. The study can be a guide for efforts to construct new buildings in a water-saving manner, which can make a significant contribution to solving the water shortage in Turkey and reducing the costs caused using water in buildings.

1. Introduction

While Turkey's available water resources were about 4,000 m^3 per capita per year in the 1960s, this amount decreased to 1,652 m^3 in 2000, 1,544 m^3 in 2009 and 1,346 m^3 in 2020 with the increasing population [1]. These figures are quite low compared to Europe, and Turkey is the most threatened European country in this respect. Even if water availability in the 21st century is assumed to remain unchanged, according to the projection of the Turkish Statistical Institute (TÜİK-Türkiye İstatistik Kurumu), the population will be 93 million in 2050 and the amount of water per capita will decrease to 1,200 m^3 in 2050 [2]. Moreover, these calculations do not take into account the millions of immigrants and the millions of tourists that are hosted in the country, especially during the summer months. According to the Falkenmark indicator, available water potential between 1700-1,000 m^3 per capita means water stress, between 1000-500 m^3 water scarcity and less than 500 m^3

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absolute water scarcity [3]. Accordingly, Turkey is still among the countries experiencing water stress. On the other hand, while the amount of water resources per capita is decreasing with increasing population, the total amount of water resources is decreasing due to the increase in temperature and decrease in precipitation associated with climate change. While 1,300,000 hectares of wetlands have lost their ecological and economic function in the last 40 years, it is estimated that 60 per cent of the nearly 300 natural lakes, which are among the most important freshwater resources, have dried up. Akşehir Lake, which used to be the fifth largest freshwater lake, has lost its natural lake function; the water level of Beyşehir Lake has dropped from 26 metres to 6 metres and that of Eğirdir Lake from 14 metres to 5 metres [4]. According to the drought assessment of the State Meteorological Service (MGM-Meteoroloji Genel Müdürlüğü) for the last three months, a large part of the country experienced severe drought, as shown in Fig. 1 [5]. The World Bank stated in 2022 that "without reform, a 10% reduction in water supply in Turkey could reduce GDP by 6%" [6].

As it is known, the name of the Ministry of Environment and Urbanisation was changed to the Ministry of Environment, Urbanisation and Climate Change (ÇŞİDB-Çevre, Şehircilik ve İklim Değişikliği Bakanlığı) on 29 October 2021 and a draft law on climate change was prepared in October 2022. MGM has developed climate projections with 3 different global models for the period 2016-2099 to show the impact of climate change on our country. According to the most moderate of these models, the average annual temperature in Turkey is projected to increase by 1.5-2.6°C and the average temperature anomaly is projected to be between -0.9 and 4.1°C in the period 2016-2099. According to the same model, total annual precipitation in Turkey is projected to decrease by an average of 3-6% during this period [7]. It has been reported that surface water in Turkey's basins could decrease by 20%, 35% and 50% for 2030, 2050 and 2100 respectively, and that there could be an expansion of arid areas by 2100, which could lead to increased water stress in the southern Mediterranean regions of Turkey [8]. The Euphrates-Tigris basin is of critical importance to both Turkey and neighbouring countries. As a result of the projections about the basin, it is revealed that there will be a 26-57% decrease in annual surface runoff in Turkey [9]. The decrease in water resources along with the decrease in precipitation indicates that the per capita water supply may fall below 1,000 m^3 in the 2070s, which would place Turkey in the category of countries experiencing water scarcity, despite TÜİK's projection that the population will decrease after 2050 [2].

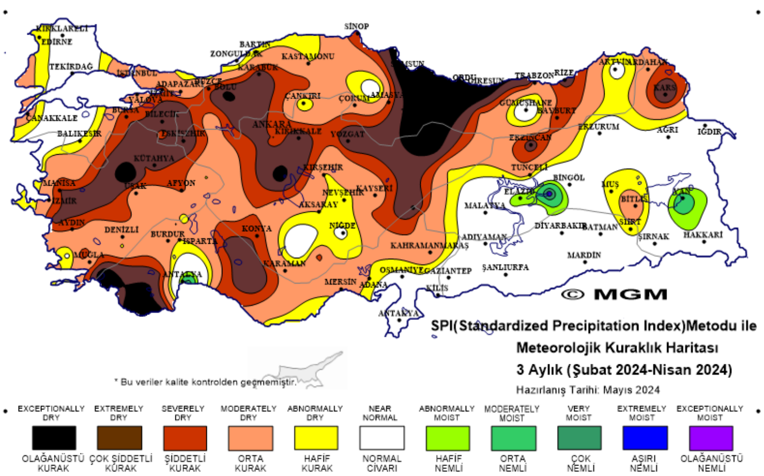

Fig. 1. Turkey's drought map from February 2024-April 2024 [5]

Another important issue to consider is that the population in Turkey is concentrated in certain regions and water resources are distributed differently from region to region. Almost a fifth of the population lives in Istanbul and half of the population lives within the boundaries of 10 metropolitan cities [10]. According to the 2015 Regional Falkenmark Indicators, the Marmara, Gediz, Küçük Menderes, Burdur and Akarçay basins are in a state of absolute scarcity [3]. It is certain that these regional differences will aggravate the impact of possible droughts in certain regions.

Buildings, where 16% of the annual usable water is used for drinking and service purposes, are one of the major areas of water consumption in Turkey and therefore one of the areas where savings can be achieved [11]. Conservation of drinking and domestic water is important for the protection of water resources. However, it is also important in terms of reducing the costs of delivering water from the source to the user and returning the used water to nature with the required qualities, the costs of required investments for infrastructure and reducing the energy used for these processes [12].

There are many studies in the literature that have examined one or more of the water saving measures in buildings and their cost-benefit analyses separately. These studies reveal that water conservation measures are generally cost effective [13-18]. Unlike the literature, this study aims to identify how much water can be saved in a building through holistic measures covering the design, construction, and use period.

For this purpose three of the most widely used green building rating systems and the criteria included in the YeS-TR rating system, which has recently been implemented in Turkey, were examined to determine the water saving measures that can be taken. The amount of water that can be saved with each measure is shown if a two-storey detached house with a garden is built according to the specified measures.

2. Water Conservation Criteria in Green Building Rating Systems

One of the important goals of green buildings is water conservation and it is argued that water use can be reduced by 40% in these buildings [19]. The US Environmental Protection Agency defines green building as the practice of creating environmentally responsible and resource-efficient structures and utilising processes throughout the life cycle of a building, from its siting to its design, construction, operation, maintenance, renovation and demolition [20]. Green Building Rating Systems (GBRSs) are third-party, voluntary and market-oriented standards that measure the sustainability level of buildings through multi-criteria assessment and encourage the adoption of economically, environmentally and socially sustainable practices in the design, construction and operation of buildings [21]. In this study, the criteria for water conservation of LEED, BREEAM, and CASBEE, which are the most widely used rating systems, and national YeS-TR rating system, which was put into practice by ÇŞİDB on 12.06.2022, are examined. Although water conservation is considered as a separate category in these four systems, some criteria under other categories may indirectly serve water conservation. In this study, only the main category for water conservation is analyzed for clarity.

2.1. LEED

In the LEED (Leadership in Energy and Environmental Design) rating system introduced by the US Green Building Council (USGBC) in 1995, the "Water Efficiency" category includes 7 criteria, 3 of which are mandatory (Table 1), and can receive 11 of the total 110 LEED points. LEED requires alternative water sources to include reclaimed wastewater provided by the municipality (purple pipe water), grey water, rainwater, treated seawater, water recovered from condensation, etc.

Table 1. LEED water efficiency category [22]

Criteria	Cr.	Objective
Reducing Outdoor Water Use	M	Reduce outdoor drinking water consumption and protect zero and low cost drinking water sources.
Reducing Indoor Water Use	M	Reduce indoor drinking water consumption and maintain zero and low-cost drinking water sources.
Water Measurement at Building Level	M	Support water management and track water consumption to identify additional water saving opportunities.
Reducing Outdoor Water Use	2	Reduce outdoor drinking water consumption and protect zero- and low-cost drinking water sources.
Reducing Indoor Water Use	6	Reduce indoor drinking water consumption and protect zero- and low-cost drinking water sources.
Optimization of Process Water Use	2	Protect potable water sources used for mechanical processes while controlling corrosion in the condenser water system.
Water Measurement	1	Identify water saving opportunities.

2.2. BREEAM

The BREEAM (Building Research Establishment Environmental Assessment Method) System, developed in England in 1990, is known as the first building environmental certification program. The weight of the "Water" category, which is one of the 10 categories of the system, is 6.36% for detached houses and 6.73% for flat type houses out of 110. The category, which consists of four criteria, focuses on "identifying methods to promote sustainable water use in the operation of the building and its site and to reduce drinking water consumption (internal and external) throughout the life of the building and minimize losses due to leakage (Table 2).

2.3. CASBEE

Introduced in Japan in 2001, the CASBEE (Comprehensive Assessment System for Built Environment Efficiency) system applies a unique method of evaluation and calculates the built environment efficiency (BEE) by dividing the environmental quality of the building (Quality-Q) by the environmental load of the building (Load-L). "Reducing water load", which is discussed under the heading of Resources and Materials, is expressed under two subheadings in the system (Table 3).

2.4. YeS-TR

There are 6 categories in the YeS-TR system, and the "Water and Waste Management" category, which includes criteria for water conservation, can receive 24 credits out of 110.

Table 2. BREEAM water category [23]

Subject	Cr.	Credit Summary
Wat 01 Water consumption	5	Reducing demand for drinking water by providing efficient plumbing, rainwater harvesting and water recycling systems.
Wat 02 Water monitoring	1	Water meters at the main water supply to promote water consumption management and monitoring to reduce the effects of inefficiencies and leaks.
Wat 03 Water leakage detection and prevention	3	Identification of leak detection systems, installation of flow control devices and easily accessible leak isolation valves.
Wat 04 Water efficient equipment	1	Determining and reducing water demand arising from uses other than domestic drinking and sanitation components.

Table 3. CASBEE reduction of water load [24]

LR2 Resources and Materials: Water	Evaluation
1. Water Resources	Water saving methods installed in the building's water supply equipment are evaluated.
1.1. Water Conservation	Level 3 Major faucets are equipped with a water saving valve. Level 4 In addition to the water saving valve, equipment is used to save water.
1.2. Rainwater and grey water 1.2.1 Rainwater Usage Syst.	Level 4 Rainwater is used. Level 5 Rainwater usage rate is at least 20%.
1.2.2 Grey Water Usage System	Level 4 Grey water is reused. Level 5 More than two types of wastewaters are used (grey water, sewage water and industrial water are collectively referred to as wastewater)

Half of this credit is intended for Water Management and the other half for Waste Management. Table 4 presents the 6 criteria credited for water management.

In the guide, it is mentioned that various brands of fixtures and equipment that can ensure effective water use can be installed in buildings. In this way, the amount of water they consume at various water use levels is presented in Table 5.

3. Method

The study aims to determine the water saving measures that can be used in a house and to determine the possible amount of water savings that can be made with these measures. As a result of examining the water saving criteria of green building rating systems, the measures that can be taken in the house selected as the application project are grouped under 5 headings.

Table 4. YeS-TR water management module [25]

Theme	Cr.	Method	
SAY 01 WATER MANAGEMENT	30	Credit given acc. to reduction rate compared to the reference value.	
SAY 01 K1 Selecting app. fixtures and equipment	20	Reduction Rate in water use (pers/time/month/year)	Credit/20
		%5- %15	5
		%16 - %25	10
		%26 - %35	15
		> %36	20
SAY 01 K2 Preventing losses and leaks in water distribution / taking necessary precautions	10	Water loss/leakage can be expressed as a percentage (%) and the maximum achievable rate is taken as 15%. Full credit (10) is received for water loss and leakage rate below 20%.	
SAY 01 K3 Monitoring and recording water usage	M	The purpose of this criterion is to monitor and record water use with meters.	
SAY 01 K4 Control of water quality	5	It is given if the tank cleaning and water distribution lines in a new residential building will be checked periodically, records will be kept and a contract is made with the company to work with.	
SAY 01 K5 Rainwater collection, treatment, and use	7,5	Ensuring the use of rainwater by making the necessary calculations. Full credit (7.5) is received for rainwater utilization rate over 80%.	
SAY 01 K6 Reuse of waste water (grey water)	7,5	Preparing a feasibility report for the grey water collection, treatment and reuse system and ensuring the use of grey water. Full credit (7.5) is received for grey water utilization rate over 40%.	

Table 5. YeS-TR indoor armature and outfit water consumption [25]

Indoor fixtures and fittings	Ref.	Lev.1	Lev.2	Lev.3	Lev.4	Lev.5	Unit
WC	6	5	4,5	4	3,75	3	Effective reservoir volume (lt)
Sink	12	9	7,5	4,5	3,75	3	Volume (lt/min)
Shower	14	10	8	6	4	3,5	Volume (lt/min)
Bath	200	180	160	140	120	100	Volume (lt)
Urinal (single)	10	8	4	2	1	0	Volume (lt/dish/hour)
Grey water/rainwater	0	0	0	0	25	50	Savings rate for use in toilet (%)
Kitchen sink	12	10	7,5	5	5	5	Volume (lt/min)
Kitchen sink: restaurant	10,3	9	8,3	7,3	6,3	6	Volume (lt/min)
Dishwasher	17	13	13	12	11	10	Volume (lt/rev)

"Detection and Prevention of Losses and Leaks in Water Distribution", which are mentioned in the rating systems but are not under the control of the contractor or user, and "Optimization of Process Water Use", which would not be effective for a single residence, were not included in the measures.

- The amount of water that can be saved with each of the following measures was determined based on literature and making necessary calculations: Appropriate landscaping to reduce outdoor water use,
- Selection of appropriate fixtures and fittings to reduce indoor water use,
- Installation of rainwater harvesting systems,
- Installation of grey water harvesting systems,
- Monitoring and recording of water use.

The determined amount was deducted from the appropriate water use, such as the use of rainwater in the garden. As a result of all measures, the total water saving potential was determined.

4. Application

A two-storey detached house with a garden in Sivas was chosen for the application (Figure 2). Water consumption data of the house used by a family of four was obtained. The distribution of domestic water use was made according to the literature. Since garden irrigation takes place during the summer months, the average amount of irrigation water was easily determined, and a water use table was created. The table was updated by determining how much water could be saved with each measure.

Fig. 2. The house and its garden selected for the application

Sivas is one of the cities in Central Anatolia that has experienced severe drought in recent years. Due to a lack of water in the 4 Eylül Dam, which supplies the city with water, the city experienced large-scale water cuts in the last months of 2022. The problem was solved by laying a transmission line of up to 50 km to another dam in Sivas. However, this required the construction of pumping stations and the consumption of large amounts of energy as it occurs in similar applications [26].

The examined house is located on approximately 780 m^2 of land. There are 4 pines, 4 dwarf pines, 11 fruit trees, 1 large and 2 small Japanese maple trees in the garden. There is a 280 m^2 hard ground area on the land, including the house, a 50 m^2 greenhouse, and approximately 450 m^2 of lawn area. A water system with card is used at home. Monthly water consumption in winter months is around 30 tons on average. With the start of garden irrigation in summer, water consumption increases. The amount of water used was determined according to the loadings made by the homeowner to the card. Although there are some changes in domestic water use from month to month, since it is not possible to follow this exactly in the card system and it does not affect the total water consumption, domestic water use was taken as 30 tonnes throughout the year.The distribution of 30 tons of water consumption in the house was made considering the rates suggested by [27], as shown in Fig. 3. Considering the loadings made to the card for garden irrigation, the average consumption amounts given in Table 6 were found.

Measures that can be taken to reduce water use are discussed under the following headings.

4.1. Appropriate landscape design for reducing outdoor water use

One of the most important issues in landscape architecture is water conservation, and "xeriscape" design has become a prominent approach. Xeriscape can generally be defined as landscaping that aims to use the least amount of water possible, thus protecting water resources and the environment [28]. The basic principles of xeriscape landscaping have been identified as comprehensive planning and design, proper soil preparation, appropriate planting, design of easy to maintain and practical lawn areas, efficient irrigation, use of mulch and appropriate maintenance [17]. An important application of xeriscape studies is the replacement of lawn with xeriscape plants and the installation of a more efficient irrigation system. In a pilot study conducted by the North Marin Water District, the estimated annual water savings was 125 litres per square metre of lawn removed. Albuquerque, New Mexico has implemented a lawn to xeriscape programme. By replacing sprinkler irrigation systems with more efficient irrigation methods, they saved an average of 172 litres of water per square metre of lawn. The Southern Nevada Water Authority estimated annual water savings of 234 litres per square metre of lawn removed in Las Vegas [29].

Fig. 3. Distribution of domestic water consumption (Referring to [27])

Table 6. Estimated water consumption according to usage areas

	WC	Laundry	Kitchen	Cleaning	Bathroom	Garden	Total
Month/Rate	0,26	0,14	0,13	0,06	0,41	-	1,00
January	7,80	4,20	3,90	1,80	12,30	-	30,00
February	7,80	4,20	3,90	1,80	12,30	-	30,00
March	7,80	4,20	3,90	1,80	12,30	-	30,00
April	7,80	4,20	3,90	1,80	12,30	-	30,00
May	7,80	4,20	3,90	1,80	12,30	-	30,00
June	7,80	4,20	3,90	1,80	12,30	80,00	110,00
July	7,80	4,20	3,90	1,80	12,30	120,00	150,00
August	7,80	4,20	3,90	1,80	12,30	120,00	150,00
September	7,80	4,20	3,90	1,80	12,30	80,00	110,00
October	7,80	4,20	3,90	1,80	12,30	40,00	70,00
November	7,80	4,20	3,90	1,80	12,30	-	30,00
December	7,80	4,20	3,90	1,80	12,30	-	30,00
Total	93,60	50,40	46,80	21,60	147,60	440,00	800,00

It can be seen that a significant proportion of the water consumption of the home chosen as the application project is for the garden. It has been assessed that the landscape design shown in Fig. 4 can be applied to save water used for the garden.

As part of the proposed new landscaping;

• The amount of water used can be greatly reduced by the types of plants used in the garden. The following were planned in this respect;

- Preferring coniferous species in the garden, such as spruce, pine and thuja, which require less water than deciduous species,
- Selecting fruit trees that require the least amount of water, such as cherry, sour cherry, apricot and almond,

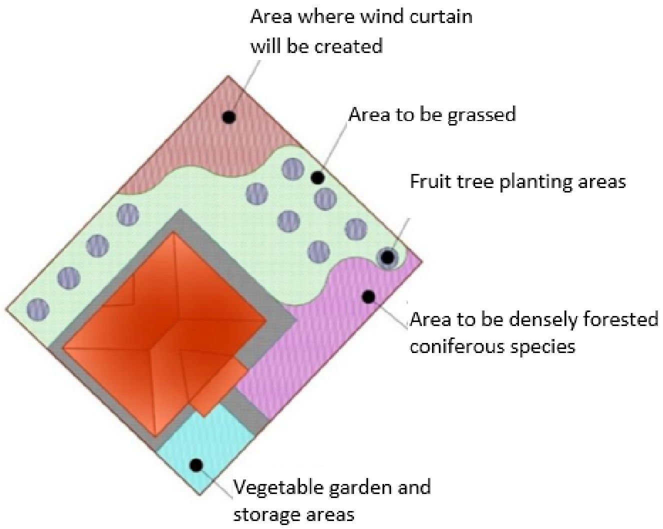

Fig. 4. New landscape layout proposed for the garden

- Prevention of the evaporation and protection of the soil moisture by creating a wind curtain on the north side of the garden, since that side is the dominant wind direction,
- Planting tall trees on the south side of the garden and protection of soil moisture by shading the soil surface,
- Not planting lawns under the trees to help the trees reach the water in the soil easy and to reduce water used for watering the lawns by reducing the amount of lawn by 40% compared to the current situation,
- Mulching the soil surface under the trees to improve the visual quality of the garden and prevent evaporation of water from the soil surface in hot weather.

• 60% water savings can be achieved by watering lawns with subsurface drip irrigation and integrating it with moisture sensors.

• Soil moisture is retained for long periods by organic water-retaining polymers applied underground in the garden. When the soil is watered, the polymers retain the water and as the soil dries out, it gradually releases the water it has stored, saving a large amount of water.

• The water-holding capacity of the garden soil structure can be increased naturally by adding mixtures such as perlite, vermiculite and leonardite.

It has been estimated that the amount of water used to irrigate the garden can be reduced by 50% in the worst case scenario with the new landscaping of the garden and other measures to be taken. In this case, the total annual water use will be will be reduced from 440 to 220 tonnes.

4.2. Selection of suitable fittings for reducing indoor water use

There are many studies in the literature showing that significant savings in indoor water use can be achieved by choosing the right fixtures and appliances [18, 30-32]. From these appliances, thermostatic bathroom faucets not only reduce water and energy consumption by preventing wasted water flow, but also increase comfort by relieving users of the need to adjust the water temperature.

YeS-TR system claims that it is possible to achieve high savings with appropriate fixtures and equipment, as shown in Table 5. Stave (2003) revealed that right fixtures and appliances can reduce water consumption by 0.1 m^3 per person per day, from the current estimate of 0.29 m^3 to 0.19 m^3 [32]. Another study conducted in USA found that water-efficient appliances could reduce per capita water use by up to 49.7% [33]. Inman & Jeffrey (2006) reported that widespread replacement of household appliances with water-efficient devices can reduce household water consumption by 35-50% [16]. Another study found average savings of 20% with a thermostatic mixer and 27.3% with a shower head with a stop button [30]. In the kitchen, one study found savings of 29.1% with a spray nozzle, 8.3% with a foot-operated shut-off valve and 5.2% with a sensor shut-off valve [31].

The house we examined has a total of three bathrooms, one on the ground floor and two on the upper floor. Each bathroom has a shower, a sink and a toilet, and the shared bathroom upstairs has a bathtub. There is also a sink in the kitchen. It has been observed that there is no equipment that can save water in these areas, other than medium quality mixed batteries. To save water; It has been evaluated that thermostatic faucets and economical shower heads with start-stop buttons can be used in bathrooms, more economical models can be used in sink and kitchen faucets, and lower capacity and double-stage flushes can be used in toilets. Thanks to these measures, a very conservative estimate of 30% water saving in bathrooms, 20% in WCs and 10% in the kitchen is envisaged.

4.3. Rainwater harvesting system

Solomon asked the Queen of Sheba, "Have you seen anything better than water under the sky?" said [34]. If there is something in the world that is identical to water, it is rain. Although the rainwater harvesting system is not a new technology, it has been identified as one of the best ways to promote sustainable water supply in urban areas [35]. The rainwater system is an efficient process in that it is a source of water that is used where it is collected. The quality of the water is typically high, allowing it to be used for a wide range of purposes, including toilet flushing, laundry, garden watering and car washing. In the UK, which has a temperate climate, it is estimated that rainwater harvesting can reduce mains water consumption by up to 80 per cent in commercial applications and around 55 per cent in domestic applications. In other countries, such as Australia, this rate is estimated to be as high as 100 per cent. Thirty-four per cent of Australian households have adopted RWHS. It provides about 177 billion litres of water and accounts for about 9% of residential water use in urban areas [36]. Rainwater harvesting systems are also known to be beneficial in terms of managing the risks of stormwater [37].

The amount of rainwater that can be obtained from rainwater harvesting can be calculated with the following equation [38].

$$\Sigma W = A \times M \times \alpha \times \beta \quad (1)$$

In this equation;

ΣW: Total rainwater harvest (m^3),

A: Rainwater collection area (m^2),

M: Rainfall amount (mm/m^2),

α: Roof run-off coefficient,

β: Filter efficiency coefficient.

The roof area of the house is calculated as 180 m^2. In Sivas, which has a continental climate, precipitation occurs in winter, spring and autumn. Summers are generally dry. The annual average rainfall amount was 430,9 mm in the measurement period (1930-2021) [39]. Precipitation data obtained from MGM are given in Table 7.

Roof run-off coefficient is a coefficient determined according to the roofing material, and since the roofing material in this building is tile, this coefficient is taken as 0,75 [40] and the filter efficiency coefficient is taken as 0,90 [41]. Rainwater amounts calculated using Equation 1 are presented in Table 8.

It is possible to use rainwater for garden irrigation and toilet flushing. In this case, a water tank with a capacity of 5 tons will be sufficient. As a result of deducting rainwater harvest from garden use between June and October and from toilet use in the remaining months, it will be possible to save 38.6 tons of water from water use for toilets and 12.2 tons from water use for gardens.

4.4. Grey water usage system

Grey water refers to all wastewater polluted as a result of various uses other than toilets in the home. In this respect, water coming from sinks, showers, bathtubs, washing machines and dishwashers is classified as grey water, while water coming from toilets is classified as black water. Grey water coming from baths and showers is defined as slightly polluted grey water, while grey water coming from washing machines and dishwashers is defined as highly polluted grey water. Grey water contains no or much fewer pathogens than black water. For this reason, it is possible to purify and use it safely and easily for uses other than drinking and domestic water, especially garden irrigation and toilet flushing.

Table 7. Sivas province precipitation data

SIVAS	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.
Avr. Temperature (°C)	-3.4	-2.1	2.7	8.9	13.5	17.0	20.0	20.2	16.2	10.9	4.7	-0.7	9.0
Avr. Highest Temp. (°C)	0.9	2.6	8.1	15.2	20.1	24.0	27.8	28.5	24.6	18.5	10.8	3.6	15.4
Avr. Minimum Temp. (°C)	-7.3	-6.2	-2.1	3.0	6.9	9.6	11.7	11.7	8.1	4.2	-0.3	-4.4	2.9
Avr. Number of Rainy Days	10.92	8.23	11.69	8.85	12.46	9.92	1.85	1.62	4.62	7.23	6.54	10.38	94.3
Total Monthly Precipitation Amount Avr. (mm)	43.4	39.3	45.5	56.5	60.6	34.1	9.3	6.7	17.6	33.2	40.2	44.5	430.9

Table 8. Amount of rainwater that can be harvested

SIVAS	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.
Rain water (ton)	5,27	4,77	5,53	6,86	7,36	4,14	1,13	0,81	2,14	4,03	4,88	5,41	52,35

The undisputed benefits of using grey water can be listed as reducing the unnecessary use of drinking water and thus reducing water bills, providing diversity in water use and reducing the energy and chemicals spent on wastewater treatment [42, 43]. A wide variety of chemical, physical or biological treatment systems can be used in grey water treatment, depending on the pollution content. Researchers recommend the use of granular filters to purify grey water coming from a single home, a school or a small business [44].

In the house we examined, it was envisaged that only the water used in the bathroom could be recycled with the grey water purification system. Although such systems are not common for single houses in our country, low-cost commercial systems for single houses are available in countries such as the USA and Australia. It is estimated that an average of 8.6 tons of water will be consumed monthly from the bathroom. All of this water can be used for irrigation during the five months of irrigation and in toilet flush reservoirs in the other months.

As a result of taking all measures including grey water usage, the new water usage estimation for the house will be as in the Table 9.

4.5. Monitoring and recording of water use

Another measure recommended in green building evaluation systems is monitoring and recording water use. Meter installation is extremely important as measuring water consumption and charging it on a unit basis, depending on the amount of water used, creates an invoice in the consumer's mind. Two separate studies have shown that measurement has a significant impact on outdoor demand and a significantly lower impact on indoor demand [45, 46]. In the UK, pricing has been shown to achieve a 14 percent reduction in demand [47]. A comprehensive study of over 10,000 multi-family dwellings in the United States found that submetering and price increases resulted in a 15.6% reduction in per capita demand (83 litres/person/day) [33]. It is thought that making the use of potable water, at least for watering gardens, especially lawns, subject to high prices will encourage users to adopt more water-efficient landscaping.

In Turkey, traditional meters or monthly card systems are generally used. Although this is not considered to be a significant problem for Turkey, the accommodation sector in Turkey, with a bed capacity of almost two million, serves domestic and foreign tourism and hosts tens of millions of tourists each year. It is known that the per capita water consumption of those staying in these facilities is up to three times higher than in their homes, where they have to worry about paying the bills [48].

A card system is used in the house studied. Users can track their household and garden expenses based on average values, and it has been observed that the high amount of water consumed for the garden has also become a concern for them. It was assessed that there was no need to install a new smart meter system in the house.

5. Results

Green building rating systems focus on the use of water-saving devices, proper landscaping, rainwater harvesting, grey water recycling and the prevention of losses and leaks in water distribution systems. Except for the prevention of losses and leaks in distribution systems, which is mostly the responsibility of local governments, the potential impact of other measures on water savings was calculated on an application.

More than half of the water consumed in the house studied is used for watering the garden. A significant part of the garden in its current state, 450 m^2, is reserved as a lawn area. With the proposed new landscaping, especially by reducing the amount of lawn by 40%, it is possible to save 50% of the water used in the garden.

Table 9. New water consumption after all measures

	WC	Laundry	Kitchen	Cleaning	Bathroom	Garden	Total
Total	32,2	50,4	42,1	21,6	103,3	164,7	414,3

The examined house has 3 full bathrooms and a kitchen, but there isn't any appliance that could save water other than mixed faucets. Based on YeS-TR system (Table 5) and studies in the literature [18, 31, 32], it was conservatively estimated that water savings of 30% could be achieved in bathrooms, 20% in toilets and 10% in kitchens by using water-saving fixtures and appliances.

It is envisaged that rainwater harvesting will be done from the 180 m^2 roof of the house and it is calculated that a total of 52 tons can be harvested throughout the year. The rainy season and garden watering season naturally do not coincide. Therefore, the harvested rainwater harvesting will be used in garden irrigation in summer and in toilet flushes in winter. In this way, the capacity of the water tank to be installed can be kept to a minimum. With the use of rainwater, the total amount of drinking water to be used in WCs is expected to decrease to 36.5 tons, and the amount of garden irrigation water to 207.8 tons.

Wastewater generated after domestic use is divided as black water, highly polluted grey water, and slightly polluted grey water. It is more suitable to establish a simple and low-cost system to purify slightly polluted grey water for a single residence. For this reason, in our application, it is envisaged to purify an average of 8.6 tons of grey water per month only in the bathroom. It is possible to use this water in the garden during the five months of irrigation and in toilet flush reservoirs in the other months. In this way, it is calculated that the total amount of drinking water to be used in WCs will be reduced to 32.2 tons and the amount of garden irrigation water to 164.7 tons (Fig. 5 and Fig. 6).

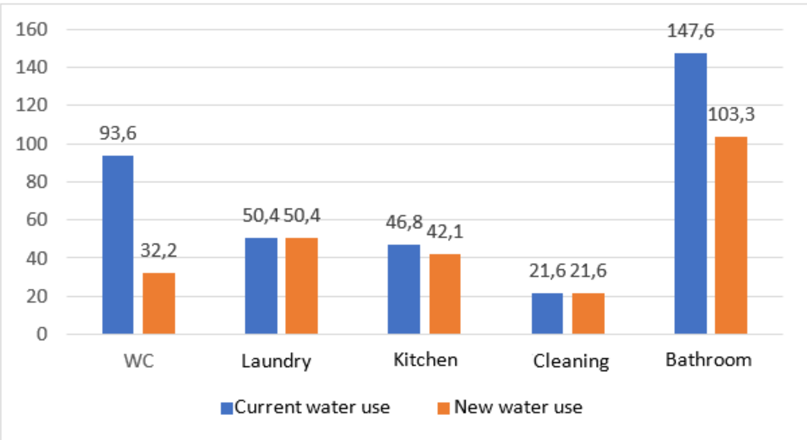

Fig. 5. Projected water savings in domestic water use (ton)

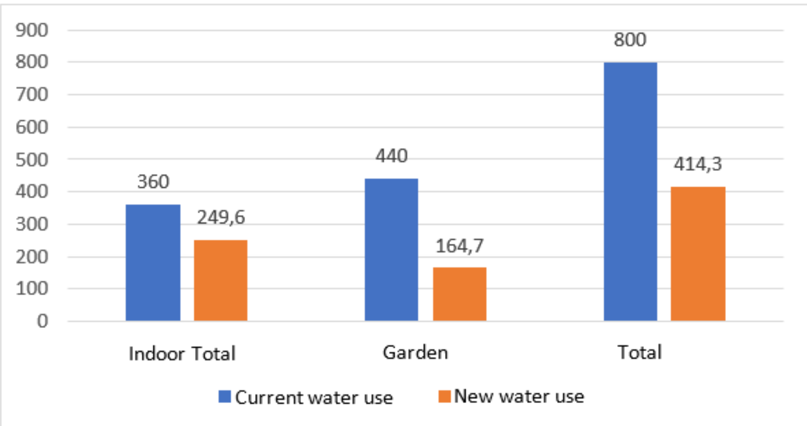

Fig. 6. Projected water savings in total water use (ton)

The current water usage rates of the house and after water saving measures are collected in Table 10. According to this table, 30.7% savings can be achieved from domestic use, 62.6% from garden use and 48.2% from total use. As mentioned before, cost benefit analysis was not included within the scope of this study. However, previous studies and experiences show that all these measures are cost-effective if implemented at the design and construction phase.

6. Conclusion and Recommendations

There are many studies in the literature on water conservation methods ranging from rainwater harvesting to grey water use, from landscaping to the use of water saving equipment and fittings. On the other hand, the general tendency of these studies is to determine the water savings that can be achieved by a single measure and the cost effectiveness of this measure. In this study, contrary to the general trend in the literature, it is aimed to reveal how much water savings can be achieved with the holistic application of water saving measures. In order to determine which measures will be applied, LEED, BREEAM and CASBEE systems as well as the recently introduced YeS-TR system in Turkey were analysed. Although the study does not go into detail, it is possible to see the similarities and differences of the systems' approaches to water conservation. The study revealed that with the holistic application of the methods, which are generally agreed to be cost-effective by each of the researchers, a water saving of nearly 50% can be achieved in a detached house. In this respect, it is considered that it will be a guide for general and local administrations, policy makers, decision makers, sector professionals such as contractors, architects, engineers, and citizens.

It is possible to mention that the study on water conservation is of particular importance for Turkey. Turkey's limited water resources are under great threat due to population growth, urbanization, increased water consumption in residences, and both the decrease in precipitation and the change in the precipitation regime in parallel with global warming. Moreover, Turkey has a very unbalanced regional distribution of water resources. All these requires urgent measures to be taken to save water. In this study, based on the criteria of green building evaluation systems, the real data of a detached house was studied, and it was revealed how much water can be saved. Although the interest in green buildings in Turkey is increasing day by day, the share of green buildings is almost non-existent, and it seems not possible for Turkey to gain benefit from green buildings for water conservation. It is important to include water conservation criteria in the legislation, to impose legal obligations and encouragements. Considering the results of this study, the following points can be suggested:

- Encouraging xeriscaping, especially in regions with dry summers,
- Taking measures such as limiting the amount of water or increasing the price of water that can be used in gardens,
- Making rainwater harvesting mandatory for residences with gardens and buildings with a large roof area usage area ratio,
- Incorporating measures into construction projects such as dividing clean water lines into two branches as domestic and drinking water lines, and installing wastewater lines as two separate lines, black and grey water lines, which allow water to be used a second time in the building,
- Promoting technologies and practices that use water efficiently,

Table 10. Comparison of current and new water consumptions

	WC	Laundry	Kitchen	Cleaning	Bathr.	Indoor Total Toplam	Garden	Total
Current Water Cons. Consumption	93,60	50,40	46,80	21,60	147,60	360	440,00	800,00
New Water Cons.	32,2	50,4	42,1	21,6	103,3	249,6	164,7	414,3
Savings Rate (%)	65,6	0,0	10,0	0,0	30,0	30,7	62,6	48,2

- Paying attention to the use of water-saving fixtures and equipment when giving occupancy permits to new buildings,
- Providing consultancy services to citizens on xeriscaping, rainwater collection systems and grey water treatment systems,
- Applying incentives such as increasing or decreasing water prices and property taxes for residences where water consumption is significantly more or less than reference residences,
- Imposition of legal obligations by the state to prevent losses and leakages in the distribution system, which is the responsibility of local governments.

Another important issue regarding water saving is personal water usage habits. Although these are not directly addressed by green building evaluation systems [49, 50] because they are not measurable, it is known that some simple habits and responsible citizenships lead to significant water savings [51, 52].

The most important limitation of this study is that no real application has been made, but estimates have been made based on calculations and literature. These estimates can only be verified by applications to be realised in the field.

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Author Contributions

S Yıldız: Conceptualization, Methodology, Validation, Formal analysis, Writing- Original Draft, Writing-Reviewing and Editing.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

Not applicable.

Conflict of Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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