Water Savings in Sustainable Campuses: Example of KTU Kanuni Campus

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ABSTRACT
Due to population growth, built environments in urban areas increased and open green areas decreased in the early 20th century. As a result of this situation, sudden climatic changes and natural disasters occurred in the cities. The quality of life of the people affected negatively and the ecosystem was damaged as a result of the change in the cities. And also cities have become fragile. Especially in recent years, planners have started to develop new approaches to these negative results depending on technology and environmental impacts. The most effective of these studies is 'sustainable rainwater management' for controlling rainwater.

The research was carried out on campuses, which are also described as small urban models from urban open green areas. In this context, it has been made to develop solutions by using natural landscape elements as urban infrastructure systems. In this study data analysis and synthesis methods are studied within the boundaries of the campus area of Karadeniz Technical University. The areas where water protection can be provided in the study area were determined in accordance with the analyses. Using rainfall data, rainwater that can be collected from each building in the regions is calculated and determined how much water meets the campus water need within the context of sustainable campus. Recommendations have been made regarding the functional and aesthetic use of water in water collection areas.

Keywords: permeable surface, rainwater harvesting, rainwater management, sustainable campus

1. INTRODUCTION

Water is the source of life necessary for living beings to survive. It maintains the biological life activities of all living beings, from the smallest to the largest. It is not possible for a life to live without water ([1]. One of the most important reasons separating the world from other planets and living environments is the existence of water. From this point of view, water is an indispensable opportunity for the continuity of ecosystems [2]. According to the United Nations Committee on Economic, Social and Cultural Rights, necessary measures should be taken to meet the water needs of nature and living things [3]. The United Nations Millennium Summit stressed the need for sustainable environmental provision for environmental development [4].

In 2050, with the change from day to day with 1,200 m^3 of water-poor climate conditions of the falling amount of water per capita in Turkey it is anticipated that we will be a country. Turkey's potential of 98 billion m^3 of surface water and ground water potential was determined to be 14 billion m^3. According to the report on countries experiencing water scarcity will be available water in Turkey [5]. Despite these values, per capita water consumption in the world is 800 m^3. Given that human potential is 1.2 billion people, 2.4

billion people cannot reach healthy water conditions. DPT (2007) [6] According to SPO (2007) reports, more than 3 billion people will suffer water shortages by 2025 [7-6].

In this context, the gradual depletion of water resources disrupts humanity and its ecological balance [8-9-10]. It is necessary to take new measures and measures in this sense by using natural resources in a balanced way. For this purpose, especially in recent years, important steps have been taken towards the struggle for living with water. Urban and regional planners have developed new planning approaches to rational use of water due to climate change and unconscious water use [11]. Planners organize effective green spaces for practices that mitigate and successfully tolerate the negative impacts of the city [12]. Water Efficient Landscape (WEL), Water Wise Garden (WWG), Low-Water Use in Landscape (LWUL) and Xeriscape" studies have emerged in this sense [13]. The common aim of all planning approaches is to use water rationally to save water in open green spaces [14-15].

This study was carried out with the aim of developing solutions by using natural landscape elements as urban infrastructure systems in the campuses which are also described as small urban models from urban open green areas. The KTU Kanuni campus is divided into 4 regions and the roof areas of the buildings of each region are calculated. With the help of 2018 meteorological data, the annual rainfall values and the amount of rainwater from each building were calculated. In this context, rainwater was calculated on the roofs of the buildings with rainwater harvesting method. According to the calculations, the amount of green area and the water requirements of the green areas were calculated for 4 regions and the amount of water collected by rain harvesting was evaluated. In addition, the use of the waters collected in the designated areas for recreational purposes was determined and visuals were developed for these areas and recommendations were presented. Water collection methods using rain gardens, planned wetlands, landscape canals, vegetation covers, guides and permeable surface materials are proposed as naturalistic landscape approaches.

2. MATERIAL METHOD

Trabzon Karadeniz Technical University is designated as the legal field of study. In the study area, 4 regions identified within the campus boundaries and the faculty building structures and the green areas included. The main purpose of the determination of the regions has been evaluated by considering the areas where rainwater accumulation is possible in terms of water conservation. For this purpose, on-site observations were made on rainy days and the boundaries of the study area were marked on the maps.

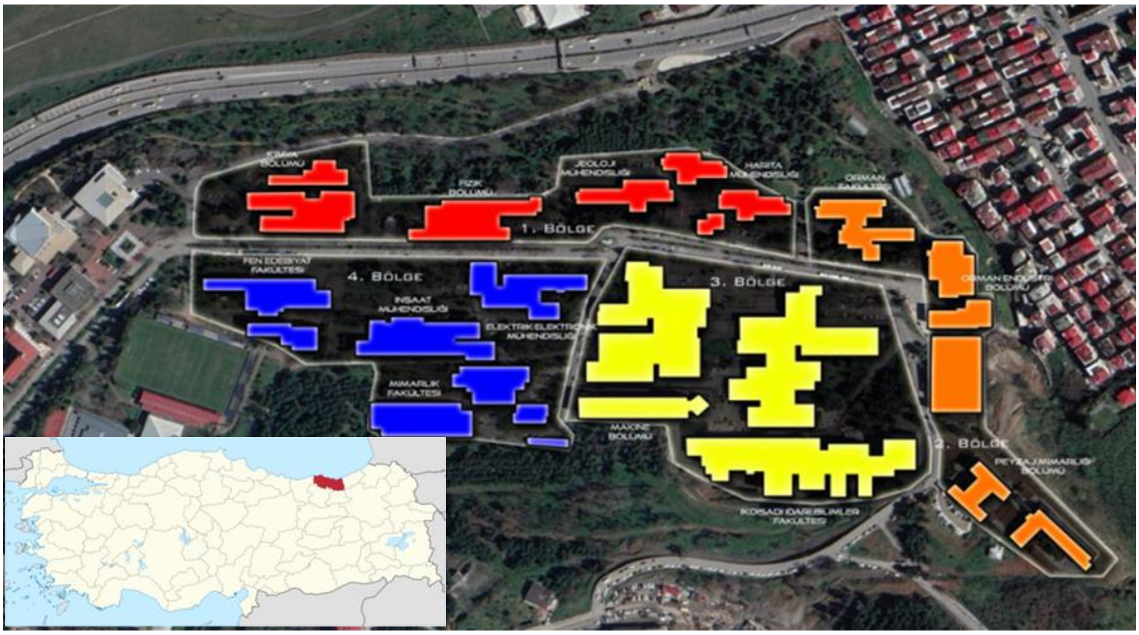

Figure 1. *Study area location*

In the first region; Physics Department, Chemistry Department, Geological Engineering Department, Surveying Engineering Department and they have 13082 m^2 roof areas.

- In the second region; Forest Engineering Department, Forest Industry Workshop Building, Forest Industry Department, KTU Indoor Parking, Landscape Architecture Department and they have 6667 m^2 roof area.
- In the third region; Faculty of Economics and Administrative Sciences Department, Faculty of Law Department, Faculty of Architecture Department and they have 9430 m^2 roof areas.
- In fourth region; Civil Engineering Department, Mechanical Engineering Department, Electrical and Electronics Engineering Department and they have 23480 m^2 roof areas.

KTÜ Kanuni campus has a slope range of 6-15% and 3-5%, the buildings are in the elevation group between 66-99 m and the campus is between 33-99 m value ranges. The area has rich vegetation and completely reflects the climatic conditions of the Trabzon region. It has a warm and temperate climate and has significant precipitation. Even in the driest months, precipitation occurs. The average annual temperature is 14.4^{0}C. The average annual rainfall in the city is 891 mm. The average temperature was 24^{0}C in July-August, temperature reached the highest temperature in August-July at 30.4 ^{0}C (Table 1).

Table 1. 2018 data of climate by months [16]

Months	Average temperature (Cº)	Average relative humidity (%)	Average rainfall (mm)	Max. Precipitation (mm)	Wind Direction
January	8	68	8,7	175,7	W 14.2
February	11	68	59,9	130,9	W 14.5
March	13	71	64,3	118,7	W 14.9
April	15	75	61,4	107,3	W 15.9
May	19	74	52,3	92,5	WSW 17.1
June	21	74	51,4	148,5	W 11.0
July	24	73	35,4	147,4	WNW 11.8
August	24	74	45,5	158,8	W 12.3

September	21	73	84	189,8	W 13.4
October	17	74	128,3	236,2	WSW 14.1
December	13	68	97,5	223,1	SSW 15.2
November	9	67	83,3	226,1	W 14.7

Stage I; Within the scope of literature, survey inventory data collection data analysis and synthesis methods were used in the research. At this stage, conceptual framework has been formed by collecting all kinds of literature data and numerical information.
Stage II; On-site examinations of the Karadeniz Technical University Kanuni Campus were conducted and current digital maps, climate data, flora and fauna data were collected. At this stage the current situation was analyzed.
Stage III; Rainwater harvesting method has been applied in 4 regions. This stage, the amount of water required by the green areas in the regions was also calculated and the water requirement in case of watering once a week and a week was determined. Method of study was calculated to Eren et al., (2016) formula;

$$RWA = RCa\ x\ PA\ x\ RC\ x\ Fe \qquad \text{(Eq.1)}$$

Where, RWA is Roof Rain Water Amount (m^3); RCa is the rain collecting area (roof area (m^2)); PA is precipitation amount; RC is roof coefficient; Fe is the filter efficiency coefficient. Roof coefficient; It is the coefficient specified by German standards as 0.8 in DIN1989 (Deutsches Instititut fur Normung). He states that all rain falling on the roof cannot be recycled.
Filter efficiency coefficient; It is the coefficient specified by DIN standards in DIN1989 (0,9). It states that all rain falling on the roof cannot be recycled.

3. DISCUSSION AND CONCLUSION

3.1. KTU Kanuni Campus Rainwater Findings

The campus has been identified as the most problematic area during the precipitation days. The area, which is defined as the joint point of both vehicle and pedestrian transportation, is also the intersection of the main circulation of the campus. For this reason, the superficial flow formed by rain water along with the slope on rainy days is collected in this area and causes a large puddle. It has a completely impermeable, hard surface due to pedestrian and vehicle usage. The accumulated water creates a challenge for pedestrians crossing the road and adversely affecting the transport line (Figure 2).

Figure 2. KTÜ Kanuni Campus on rainy days

3.2. Rainwater harvesting findings

As a result of the observations, the buildings in the areas where rainwater accumulates are identified and divided into 4 different regions. There are 6 buildings in Zone 1, 6 in Zone 2, 4 in Zone 3 and 7 in Zone 4. Table 2 shows the number of buildings, roof areas (m^2) and the amount of rain water collected per year (m^3) per roof in each region. In the 1st region, there is a roof area of 13082 m^2 and rain water amount of 10466 m^3. In the 2nd region there are 6 buildings, 6667 m^2 roof area and 5334 m^3 rain water amount. In the 3rd there are 4 buildings, 9430 m^2 roof area and 7544 m^3 rain water amount in the region. In the 4th region, there are a total of 7 buildings, a roof area of 23480 m^2 and the amount of rain water collected by 18784 m^3. Herrman and Schmida, (1999), Valentin and Herbes (1999), Scott and Silva-Ochoa (2001), Jaber and Mohsen, (2001) have used water harvesting methods in similar ways [17-18-19-20].

The water requirement of the determined green area amounts was calculated for the total irrigation water requirement for a single irrigation. Accordingly, the first region's 14860 m^2 green area and 13082 m^3 water requirement, the 2nd Region's 4680 m^2 green area and 6667 m^3 water requirement, the 3rd Region's 7590 m^2 green area and 9430 m^3 water requirement, 4th has a green area of 19787 m^2 and a water requirement of 23480 m^3.

Table 2. The number of buildings for each region, building roof areas (m^2) and the amount of rainwater that can be collected annually on the roofs, the water requirement of the green area, the total irrigation water requirement for a single irrigation (m^3)

Region	Num. of building	Roof area (m^2)	Roof rainwater amount (annual, m^3)	Green area (m^2)	Water requirement of green area (m^3)
1st Region	6	13082	10466	14860	13082
2nd Region	6	6667	5334	4680	6667
3rd Region	4	9430	7544	7590	9430
4th Region	7	23480	18784	19787	23480
Total	23	31519	42128	24467	52659

Irrigation water requirement has been calculated twice a week, once a week, and every day according to the irrigation status. According to the calculation result, when irrigation is done twice a week, the water collected from the roof areas meets 147% of irrigation water needs in the 1st Region, 237% in the 2nd Region, 207% in the 3rd Region and 198% in the 4th Region.

When irrigation is done once a week, the water collected from the roof areas meets 293% of the irrigation water requirement in the 1st Region, 475% in the 2nd Region, 414% in the 3rd Region and 396% in the 4th Region. Kılıç and Abuş (2012) [21] concluded that they meet 14% of their water needs when they irrigate every day, 49% when irrigation is done twice a week and 98% when irrigation is done once a week. When irrigation is done every day, the water collected from the roof areas meets 39% of the irrigation water needs in the 1st Region, 62% in the 2nd Region, 54% in the 3rd Region and 52% in the 4th Region. Wanjiru and Xia (2018) [22] saved between 30-35% of water use with gray water transformation and rainwater harvesting from buildings and structures in urban areas.

Table 3. Irrigation water needs by region (once a week, twice a week and every day)

	Roof rainwater amount (annual, m^3	Water requirement of green area (m^3)	Once a week		Twice a week		Every day	
			Water requirement (m^3)	Water Required (%)	Water requirement (m^3)	Water Required (%)	Water requirement (m^3)	Water Required (%)
1st	10466	74,3	3566	293%	7133	147%	27120	39%
2nd	5334	23,4	1123	475%	2246	237%	8541	62%
3rd	7544	38,0	1822	414%	3643	207%	13852	54%

4th	18784 98,9	4749	396%	9498	198%	36111	52%

4. RESULTS

Water is an indispensable and most valuable resource throughout human life. It is considered as the most basic food source for all living creatures. However, especially in recent years due to global warming, irregular and sudden precipitation, extreme hot periods have affected the cities and the quality of life of the people living in it negatively. In recent years, Water Conservation and Management in Smart Cities have been widely used under many professional disciplines. The cities do not resist and surrender due to the untimely and irregular precipitation in the cities. This situation has become more noticeable with the reduction of green areas and the increase of impermeable surfaces.

In the study, the roof areas of the buildings of the 4 regions were calculated, with the help of meteorological data, the annual precipitation values of 2018 and the amount of rainwater to be collected from each building were calculated. The amount of green area and the water needs of the green areas were calculated and how much of the amount of water that could be collected with the rain harvest was met. When irrigation is done twice a week, the water collected from the roof areas meets 147% of the irrigation water requirement in the 1st Region, 237% in the 2nd Region, 207% in the 3rd Region and 198% in the 4th Region. When irrigation is done once a week, the water collected from the roof areas meets 293% of the irrigation water requirement in the 1st Region, 475% in the 2nd Region, 414% in the 3rd Region and 396% in the 4th Region. When irrigation is done every day, the water collected from the roof areas meets 39% of the irrigation water needs in the 1st Region, 62% in the 2nd Region, 54% in the 3rd Region and 52% in the 4th Region.

Especially in the Eastern Black Sea Region, rainfall waters should be directed, accumulated and re-evaluated at the level permitted by the slope. Priority should be given to studies on water saving and water management, and should be included in planning and design studies. Collecting and reusing water, which is considered as rainwater harvesting method, is inevitable for arid ecosystems. However, it is required to be applied in areas with high precipitation. Natural vegetation should be evaluated and emphasis should be given to the use of these species and legal arrangements should be made as a necessity in planting.

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