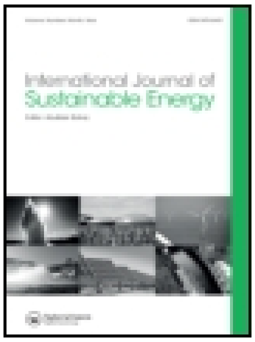

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Design of a passive rainwater harvesting system with green building approach

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ABSTRACT
In this study, a passive rainwater harvesting system was designed. The system is planned to be installed on the roof of the building of Engineering Faculty of Yalova University. The meteorological rain data of Yalova province was analysed and the most suitable rainwater silo dimensions were determined accordingly. A suitable location for the silo was recommended considering the statics of the building. The passive rainwater harvesting system requires no additional pump power and no complex filtration systems. A rainwater delivery system is designed from the roof to the reservoirs for flushing without any additional energy consumption according to the storage location. The minimum height between the tank and the floor was determined to compensate the pressure losses along the critical length. The results of the economic analysis showed that this system can save about 8.5 tons of water/year and 2900 €/year water costs from one building.

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Rainwater; passive rainwater harvest; water sustainability; sustainable buildings; green campus; green buildings

1. Introduction

Over the past decade, there is an increasing concern about environmental problems, energy and resource consumption. In order to cope with the challenges associated with these problems, the focus is first on sustainable development on a global scale. For example 6th Action Plan for the Environment draws attention to sustainable management of resources (Tsoutsos et al. 2008). From this point of view, it would be appropriate to start the sustainability researches by studying overall performances of buildings using environmental aspects (Giama and Papadopoulos 2012), the places where human beings perform their vital activities the most (Shah and Edwards 2013).

For the implementation of sustainability philosophy on the buildings, the concept of green building is revealed. The main purpose of the sustainability concept in green buildings is to reduce the negative effects of housing on life and the environment during the life cycle (Anastaselos et al. 2016). Many studies have defined the green buildings as ‘a high-performance building that considers and reduces environmental and human health effects’ (Rashidi et al. 2015). The most common aims of Green buildings are; energy, land, water and material saving, environmental sensitivity and reducing all kinds of pollution (Zuo and Zhao 2014; Berardi 2013). Some studies, point out more detailed framework for sustainable buildings or green buildings with a versatile design strategy. The main idea of the strategy is to reduce energy consumption and maximises the daylight usage, to improve indoor air quality and thermal comfort, to protect water, to allow the reassessment of the recycled

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materials. These are often referred to as green constructions that provide the maximum benefit and ease of use (Robichaud and Anantatmula 2011; Zannis et al. 2006).

Some of the environmental problems that arise with unplanned urbanisation and the conversion of all consumption to wastage are the risk of water pollution, a decrease in groundwater reserves and the threat of extinction of wetlands. In recent years, the procurement of agricultural, industrial, drinking and potable water has become increasingly difficult for all countries (Durmus 2013; Nižetić et al. 2019). Therefore, sustainable water management work is very important in the understanding of green buildings.

In sustainable water management, processes are being carried out to ensure the efficient use of water in accordance with the criteria such as selection of in-building equipment for minimisation of water consumption through the life cycle, maximum utilisation of rain water, irrigation of the water and use in toilets, purification and reuse of grey water. For example, grey water can be used in residences gardens, toilet reservoirs or washing machines. Black water can be used in gardens, landscapes or flushing after a proper treatment (Alkhatib, Roesner, and Marjoram 2007; Ghisi and Ferreira 2007; Furumai 2008; Li, Boyle, and Reynolds 2010; Kayaga and Smout 2011).

The rapid consumption, contamination and shortage of fresh water resources has leaded us to develop water demand management policies (Butler and Memon 2006; Thivet and Fernandez 2010; Deverill, Herbertson, and Cotton 2001) and to find alternative sources such as desalination systems (Kabeel and El-Said 2013) or rainwater harvesting in sustainable water method studies (Rahman, Keane, and Imteaz 2012). Utilisation of rainwater is an economic, environmental, public and environmentally friendly technology (Domènech and Saurí 2011). Collecting and storing rainwater with zero emission can increase the amount of available water resources in the city and reduce the city floods, pollution and improves the urban water issue. On the other hand, the use of rainwater can contribute to reduce the amount of piping needed for water networks. Collected rainwater can be used in the building for laundry washing, house cleaning, irrigation with fire extinguishing, pool or ponds, toilet flushes or car wash etc. (Villarreal and Dixon 2005; Ekinci 2015). It is very important for water conservation to collect rainwater from buildings with large roof space and use with simple treatment (Villarreal and Dixon 2005; Eroksuz and Rahman 2010). The use of rainwater can mitigate the adverse environmental effects of urban life and reduce energy burden by using these methods (VanWoert et al. 2005; Karahan 2009).

Among alternative water sources, rainwater harvesting systems have a lower cost and less risky option for human health (Farreny, Gabarrell, and Rieradevall 2011; Ibrahim 2009; Ghisi 2006; Sturm et al. 2009; Beal et al. 2012; Palla et al. 2012). The structure of the rainwater harvesting system varies depending on the climatic conditions of the location, the reliability of rainfall, consumer demand, and the quality of the required rainwater. The rainwater harvesting systems are divided into five main subsystems: (i) collection, (ii) treatment, (iii) storage, (iv) distribution and (v) water backup systems. The structure of each subsystem varies according to the availability of the components and local applications (Ward, Barr, et al. 2012; Theodosiou, Aravantinos, and Tsikaloudaki 2014).

Vieira et al. investigated the energy intensity situations of the rainwater harvest. In the study, they examined the energy intensity values of rainwater harvesting systems first and set out strategies to improve the energy performance of rainwater harvesting systems applied to buildings (Vieira et al. 2014). Vo et al. outlined the consequences of climate change on wastewater rehabilitation and reuse in the review (Vo et al. 2014). These studies summarise the modern methodologies and their purposes of water re-use. Liu and Ping described the innovative solutions for water-saving and proposed a comprehensive water-saving assessment system for existing residential building (Liu and Ping 2012).

Eren et al. investigated the potential of rainwater to be collected from roofs of buildings on the Sakarya University campus. Within the scope of the study, the amount of green areas in each region, the required rainwater and the ratio of satisfaction were calculated (Eren et al. 2016). Similarly, Amr et al. have identified a checklist for sustainable landscape water-related measures on university campuses, based on examples of international practices. Within the scope of the study, some of the contemporary campuses in Egypt examined and the situation of campus landscapes and sustainability measures are analysed (Amr et al. 2016).

Sahin and Manioglu have examined the indoor and outdoor use of rainwater in the buildings and how rainwater usage is handled in Green Building Certification Systems (Şahin and Manioğlu 2011). Through the water conservation strategies, they have recommended to increase the utilisation of rainwater technology in order to reduce water consumption at the buildings.

As it is seen, different solutions and different methods have been proposed in the literature. The amount of water that could be collected with rainwater harvesting from a building was calculated with a statistical method. In order to minimise the initial investment cost according to the calculated amount of storage, the volume of the silo was selected from the standard sizes available the market. A suitable rainwater drainage system was designed between the silo and the toilette reservoirs. The entire collected rainwater was planned to be evaluated. Attention has been paid to all materials used in the installation during design are standard and made of recyclable materials.

The main objective of this study is to develop a passive rainwater harvesting system with a simple physical filtration. The passive rainwater harvesting system is novel for the field. Unlike the other rainwater harvesting systems investigated through the searched literature, our system will not consume energy for purification or pressurisation.

Utilisation of the rainwater instead of mains water is not a conventional concept in the region. Because of this, the study is expected to start the applications to harvest and use the rainwater around the location. This paper offers a new, easy to install, user friendly system for sustainable use of potable water.

2. Material and method

The aim of this paper is the investigation of the rainwater potential to be harvested to meet the water requirements of the toilet reservoirs from the roof of the Energy Systems Engineering (ESM) Department building planned to be built in Yalova University campus. The appropriate silo volume was selected, designed and the cost of the system was analysed. For this purpose, a method has been disclosed for the design of sustainable water management and passive water recycling system with in the line of the Green Campus Approach.

As seen in Figure 1, the precipitation data, measured pointwise from the stations, were calculated spatially for the provinces using the Kriging Method under Geographic Information Systems.

Figure 1. Annual total areal precipitation normal in Turkey for 1981–2010 years.

According to Köppen-Geiger CS climate type effects on %65.1 of Turkey. Yalova province is in the northern region of Turkey and has the Cs type of climate. In Yalova, winters are mild, summers are very hot and dry. According to 29 years, annual total areal precipitation data from Turkish State Meteorological Service, the climate of Yalova is similar to the city of Thessaloniki in Greece (Figure 2).

The required local rainfall data to calculate the cost and payback periods are obtained from the Yalova Meteorology Provincial Directorate. The probability of precipitation is calculated with a similar way that was used in Eren et al. (2016). Monthly mean, mode, median, rainfall frequency values were obtained by statistical analysis and the last eleven years rainfall data were evaluated in terms of rainwater harvesting. Setting Y to be yearly average rainfall (kg/m^2 year) and D to average daily precipitation amount the potential of annual rainwater can be determined from:

$$Y = D\ x\ 365 \tag{1}$$

However, it is not possible to collect the whole available rainwater. In order to calculate the usable amount, the roof condition and the filtration values have to be taken into account. In this case the potential of daily rain harvest from a building (B) can be calculated by Fewkes (1999); Ghisi, Bressan, and Martini (2007):

$$B = R\ x\ F\ x\ A\ x\ D \tag{2}$$

This equation is in (kg/day). In order to calculate in (m^3/day) Equation (3) can be used (Aladenola and Adeboye 2010; Abdulla and Al-Shareef 2009):

$$B = \frac{R\ x\ F\ x\ A\ x\ D}{\rho} \tag{3}$$

Here, according to DIN 1986/ISO 1438 standards, (R) is the roof run-off coefficient. It was accepted as 0.8 (Ghisi, Tavares, and Rocha 2009; Vaes and Berlamont 2001). This coefficient means that all the rain falling on the roof cannot be used because of the physical properties such as the roof structure. According to DIN 1986/ISO 1438 standards, F is the filter efficiency coefficient and it was accepted as 0.9 (Ward, Memon, and Butler 2012). The coefficient expresses the efficiency of the filter that is used for the separation of the collected rainwater from the visible solid matter. The annual precipitation is described similar ways in the literature (Liaw and Chiang 2014; Imteaz, Matos, and Shanableh 2014; Bocanegra-Martínez et al. 2014). The annual harvest that can be collected from a building (ΣY) can be calculated by Equation (4):

$$\Sigma Y = B \times 365\ (m^3/year) \tag{4}$$

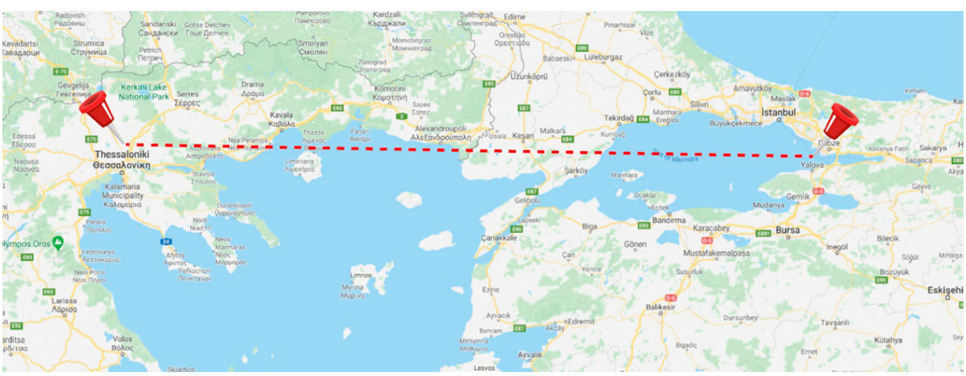

Figure 2. Latitude relationship between Thessaloniki and Yalova cities.

With the pre-acceptance of 'The entire harvested rain from a building can be used in sinks. That leads the more rainwater is used in the reservoirs, the more water is saved from the network water.' the maximum annual savings potential from a building (S) can be calculated by Equation (5):

$$S = \Sigma Yx\ C_W \tag{5}$$

Here C_W is the price of water in €/m^3. It should be noted that the calculation of the amount of rain harvest in the first part of this paper is a statistical method to predict for the future. On the other hand, the calculations in the economic analysis give clear results as the water used in the reservoirs is taken into consideration. The net amount of the water used in the system can be calculated in terms of reservoir volume (litre). Simplifying the pay-back calculations in (Khastagir and Jayasuriya 2011) The payback period (PP) of the designed harvesting system can be calculated by:

$$PP = \frac{C_S}{S} \tag{6}$$

In this equation C_S is the cost of the silo. A similar method is also used in (Campisano and Modica 2012). Finally, we've introduced an additional information about number of use reservoirs (U):

$$U = \frac{B}{RC\ x\ Nof}(\text{times}) \tag{7}$$

Here RC is the reservoir capacity and Nof is the number of flush. This number is introduced in order to ease the measure of utilisation. With 'U', the flush quantity can measured by installing a simple counter device to the reservoirs for validation of the saving potential.

Passive Rain Water Harvest and Recovery System (PRRS) was designed considering the architectural structure of the building according to the silo dimensions. The system is designed as a silo next to each floor, standing on its own foundation besides the building (Figure 3). It is planned that the

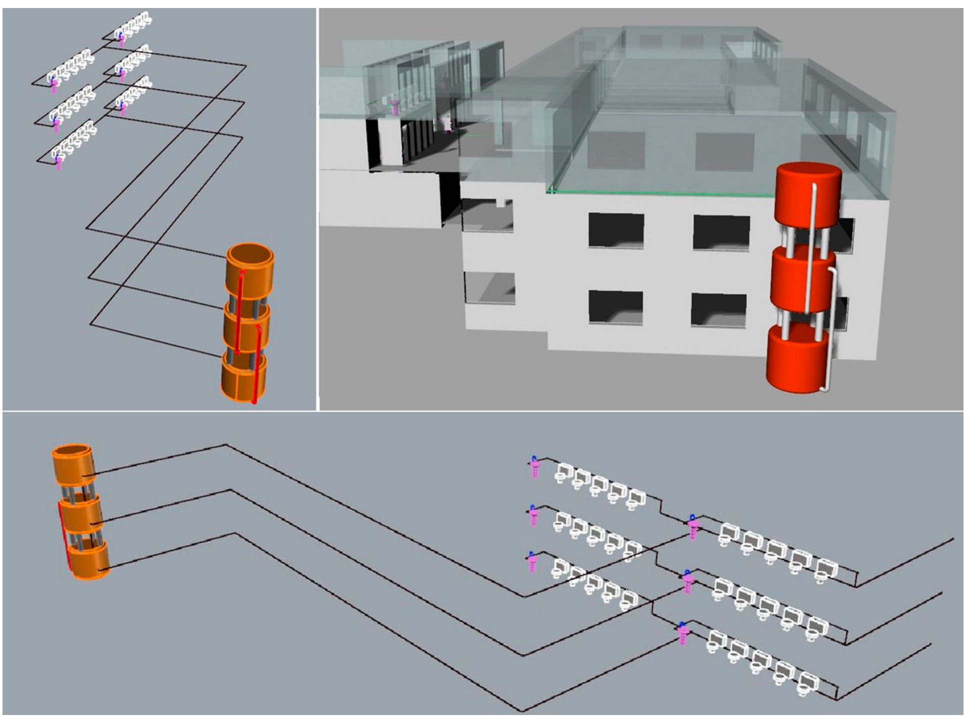

Figure 3. PRRS installation layout.

weight of the rainwater will not be carried by the building that is located in the earthquake zone (Yalova). If the dynamic load that generated by oscillating rainwater in the silo during the earthquake is considered, standing the silo on its own foundation without charging the building becomes extremely important.

The designed system does not require energy any consumption or additional equipment while filtrating and collecting the rainwater to the silos. The flow of the water from the silos to the reservoirs is achieved by gravitational force. Thus, the system is evaluated as passive system. Also, no chemical filter treatment was required because the system planned to be installed in a non-industrial environment that would cause pollution. The only physical filter is the first flush system to prevent unwanted particles.

The heights and locations of the silos are calculated high enough to meet the required flow pressure from the silos to the reservoirs by satisfying the pressure losses throughout the installation. The pressure losses are calculated by Equation (8). Accepted values and loss coefficients along the critical line are given in Table 1.

$$h_k = h_{k,total} = h_{k.continious} + h_{k,local} = \left(f\frac{L}{D} + \sum K_K\right)\frac{V^2}{2g} \tag{8}$$

3. Results and discussion

In this study, a method of harvesting and passive storage of rainwater for the Engineering Faculty Building of Yalova University was investigated. The local rainfall data required for the analysis were provided by the Provincial Directorate of Meteorology of Yalova. The monthly rainfall average is given in Table 2 for Yalova between the years 2006 and 2016. A total of 4015 data of 11 years were analysed to determine the daily average rainfall potential. It was seen that the maximum monthly mean rainfall was 11.38 kg/m^2 in October 2010 and the minimum monthly mean rainfall was 0.01 kg/m^2 in August 2008. The lowest annual average rainfall was recorded as 1.32 kg/m^2 in 2008 and the highest amount of precipitation was recorded as 3.55 kg/m^2 in 2010. The average precipitation was calculated as 2.06 kg/m^2. The deviation of the monthly minimum and maximum rainfall of the 11-years average rainfall was calculated as 0.64 and 0.73 respectively.

The analysis showed that the most frequent daily precipitation (mod) and the median value of precipitation data were ‘0’. Note that zero mod and median do not lead to a decision ‘there is no need to set up a passive rain harvest system’. Contrarily, the rainfall data of the province alerts a shortage of water resources and thus the studied kind of harvest systems is a necessity. The frequency distribution (frequency of occurrence of precipitation) is illustrated in Figure 2. The amount of daily precipitation above 30 kg/m^2 is negligible so they are not included in the graph.

Table 1. Accepted characteristics of the water for the critical line pressure loss accounts and local loss coefficients.

	Element	Unit	Magnitude
1	Density (ρ)	kg/m^3	999,7
2	Dynamic viscosity (μ)	kg/ms	1,307.10^{-3}
3	Roughness (ε) for commercial steel pipe	μm	0,045
	Installation Element		Loss Coefficient
1	Elbow		0,3
2	Sharp entry		0,5
3	Branch flow		1
4	Flat flow		0,2
5	Full flow ball valve		10
6	Sharp exit		1,06

Table 2. 2006–2016 Monthly Average Rainfall Amounts (kg/m^2).

Months Years	1	2	3	4	5	6	7	8	9	10	11	12	Average
2006	*2.86*	*3.71*	*2.23*	*0.42*	*0.54*	*2.97*	*0.06*	*0.20*	*2.02*	*1.01*	*4.37*	*0.98*	*1.78*
2007	*3.92*	*0.41*	*1.02*	*1.35*	*0.82*	*0.49*	*0.54*	*1.08*	*0.77*	*2.59*	*3.69*	*4.60*	*1.77*
2008	*1.55*	*1.39*	*3.66*	*0.46*	*1.17*	*0.65*	*0.90*	*0.01*	*4.81*	*2.44*	*2.61*	*2.08*	*1.81*
2009	*3.59*	*5.29*	*3.57*	*1.04*	*0.44*	*0.47*	*0.37*	*0.18*	*1.47*	*1.96*	*3.44*	*4.89*	*2.23*
2010	*5.35*	*5.77*	*2.75*	*1.83*	*1.18*	*7.37*	*0.07*	*0.02*	*2.17*	*11.38*	*0.57*	*4.19*	*3.55*
2011	*2.29*	*0.50*	*1.38*	*1.92*	*1.13*	*0.80*	*0.73*	*0.20*	*0.20*	*3.43*	*0.44*	*2.85*	*1.32*
2012	*3.96*	*3.17*	*1.87*	*2.83*	*1.56*	*0.55*	*0.92*	*1.12*	*1.10*	*1.43*	*2.76*	*5.17*	*2.20*
2013	*2.04*	*2.79*	*3.18*	*1.11*	*0.61*	*1.26*	*0.05*	*0.10*	*0.32*	*2.80*	*1.60*	*1.50*	*1.45*
2014	*0.94*	*0.65*	*2.58*	*1.02*	*2.18*	*1.59*	*2.32*	*0.37*	*6.28*	*2.75*	*2.29*	*4.27*	*2.27*
2015	*3.81*	*2.97*	*1.51*	*3.01*	*1.19*	*1.73*	*0.00*	*0.76*	*2.81*	*5.78*	*0.68*	*0.28*	*2.04*
2016	*4.40*	*2.70*	*3.00*	*1.10*	*1.80*	*1.00*	*0.10*	*1.70*	*1.30*	*1.10*	*3.20*	*4.90*	*2.19*

Table 3. Daily average rainfall distribution and representative capabilities of Yalova.

Rainfall Amount (kg/m^{2}day)	Frequency	% Frequency	Representation Capability (%)
0	2719	67,72	67,72
1	409	10,18	77,9
2	162	4,03	81,93
3	106	2,64	84,57
4	89	2,22	86,79
5	70	1,74	88,53
6	64	1,6	90,13

Table 2 and Figure 2 show that the most common daily average rainfalls of Yalova province and daily average rainfall distribution are as shown in Table 3. The appropriate rainfall values of Yalova province that can be used for water management are determined between 0 and 6 kg/m^2 day. The rainfall amounts above 6 kg/m^2 are not included in Table 3 since they are rare.

According to the information given in Table 3, approximately 68% of the 4015 days have no precipitation. This result is one of the indicators that Yalova is not rich in water and should be emphasised on water management. This conclusion agrees with the data given in Table 2. The results indicate that the highest rainfall of Yalova province is 1 kg/m^{2}day. The frequency of occurrence of this precipitation is 10.18%. Noting that 68% of the days of a year have no precipitation, 1 kg/m^{2}day represents the 78.18% of the total rainfall regime of the province. The constant parameters those were used in the representative ability calculations of the most common precipitation are shown in Table 4.

The capacity of each reservoir was accepted as 5 lt. Table 5 was obtained by using the daily average precipitation values and the values given in Table 3.

Figure 5 illustrates daily collectable rainfall volume and the closest standard silo volumes depending on the average daily rainfall of 1–6 kg/m^{2}day (the highest frequency in the rainfall regime of

Table 4. Constant parameters and values.

Constant Parameter	Value
Roof area of the building (m^2)	*2941.80*
Number of floors	3
Roof coefficient (DIN 1986/ISO 1438)	*0.80*
Filter coefficient (DIN 1986/ISO 1438)	*0.90*
Density of rainwater (kg/m^3)	*999.97*
Potential number of storage	3
Reservoir capacity (litres)	5
Number of washbasins per floor (pieces)	4
Number of reservoirs per floor (pieces)	20
Total one time water consumption in reservoirs (litres)	300
Cost of water (€/liter)	0,58

Table 5. Design parameters, costs, savings and payback period for daily rainfall values 1–6 kg/m^{2}day values.

GO	1	2	3	4	5	6
Ability to Represent Rainfall	*77,9*	*81,93*	*84,57*	*86,79*	*88,53*	*90,13*
Y (kg/m^2)	*365,00*	*730,00*	*1.095,00*	*1.460,00*	*1.825,00*	*2.190,00*
B (kg)	*2.118,10*	*4.236,19*	*6.354,29*	*8.472,38*	*10.590,48*	*12.708,58*
B (m^3)	*2,12*	*4,24*	*6,35*	*8,47*	*10,59*	*12,71*
B (litre)	*2.118,16*	*4.236,32*	*6.354,48*	*8.472,64*	*10.590,80*	*12.708,96*
ΣY (kg)	*773.105*	*1.546.210*	*2.319.315*	*3.092.420*	*3.865.525*	*4.638.630*
ΣY (m^3)	*773,13*	*1.546,256*	*2.319,39*	*3.092,51*	*3.865,64*	*4.638,77*
U (No)	*7,06*	*14,12*	*600,00*	*28,24*	*35,30*	*42,36*
C_D (€)	*320,00*	*600,00*	*21,18*	*800,00*	*900,00*	*900,00*
ΣC_D (€)	*960,00*	*1.800,00*	*1.800,00*	*2.400,00*	*2.700,00*	*2.700,00*
S (€)	*3.339,91*	*6.679,83*	*10.019,74*	*13.359,66*	*16.699,57*	*20.039,48*
PP (year)	*0,29*	*0,27*	*0,18*	*0,18*	*0,16*	*0,13*

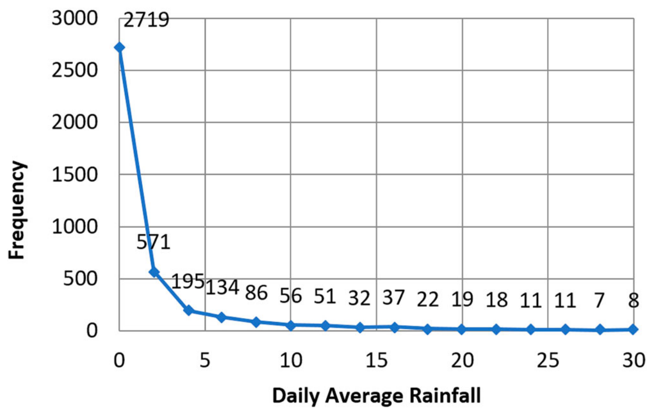

Figure 4. Frequency of daily average rainfall amount for Yalova province (kg/m^2).

Yalova). The amounts of daily rainwater that can be collected from the buildings (BDR) and the values of the payback period are as in Figure 4.

According to Figures 5 and 6, if the silo capacity selected as 3 tons for the most frequent rainfall, which is 1 kg/m^2, then the payback period is 0.29. If the storage volume is selected as 12 tons for a minimum average rainfall of 6 kg/m^{2}day, the payback period becomes 0.13 years. In Figure 3, the back-shaded area represents the selected silo volume. If the back- shaded area is higher than the grey area that means the silo volume is larger than the volume of rainwater to be collected. However, if the grey area is higher than back-shaded area that means the volume of the silo is insufficient. The silos, those selected from standard plastic silo measures on the market, are large enough to collect the total rainfall at 1, 2, 4 and 5 kg/m^{2}day average rainfall values. For 3 and 6 kg/m^{2}day average rainfall values, the standard volume of the silo will be insufficient to store the collected water. The larger volumes correspond to unnecessarily big volumes and considering the frequency of the rainfall, the initial investment will be unnecessarily much. In this case, the silos can be manufactured in the calculated dimensions instead of the standard dimensions. However, the cost of a non-standard production is more expensive than a standard selection. Thus, choosing the most suitable option from the standard silo dimensions seems as the most reasonable method for maximisation of water collection and from the economic aspects. As a result, 6 kg/m^{2}day seems like a good option according to PP but not such attractive in case for representative capacity since is it very low. Therefore, considering the parameters like PP, representative capacity, initial investment and aesthetic the volume of the silo should better be selected as small as it can.

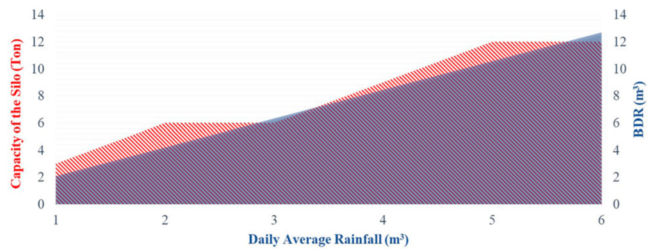

Figure 5. Storage volume- daily average rainfall- BTGY.

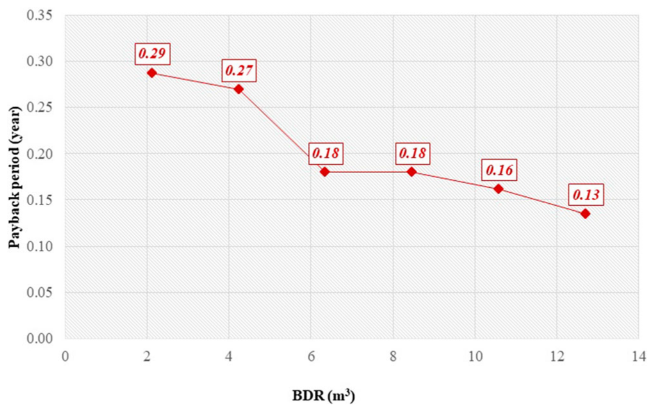

Figure 6. Payback period- BTGY.

Kayaga and Smout say utilisation of rainwater and grey water may pave the way for 50% saving for potable water consumption (Kayaga and Smout 2011). The system evaluated within the scope of this paper, 8 tonnes of silo volume that corresponds to 4 kg/m^{2}day rainfall is considered as an example. Here, 4 kg/m^{2}day of rainfall is able to represent 86.79% of the Yalova rainfall regime. Equation (4) allows us to calculate the daily rain water collection amount from the building that is 8.5 tons/year. The monetary provision is calculated as € 2900 annually by Equation (5).

On the other hand, since Yalova province is in the earthquake zone, the harvesting system in this study is designed to be mounted on its own foundation. The silos are planned to be constructed in 3 storeyed next to the building so as not to disturb the existing static balance of the building. The top silo should be placed below the roof to collect the rain water and the bottom of the top silo should be 100 cm above the floor of the upper storey. In this way, the harvested rainwater will not cause an extra burden on the building. The rainwater is planned to flow with its own gravity, so there will be no power consumption since the system does not need a pump.

For rainwater harvesting, active systems are generally recommended in the literature. However, there are many moving parts, complex installation structure and energy consuming pump motors in the active systems. Operating costs and maintenance and repair costs of such parts negatively affect the system's payback period. Generally, their payback period exceeds 7 years. In the passive rainwater harvesting system that we recommend, the installation is quite simple. There are very few moving parts and there are no energy-consuming filtration and pressurisation elements. This significantly reduces operational costs and payback period. From this point of view, the system proposed in this article fills an important gap in the literature and this application contributes the building to achieve the green building criterion.

The purposed system is applicable to the other regions of Turkey. But the payback period should be calculated for each precipitation zone that is given in Figure 1. Yalova is located in the 8th zone. The payback period will be higher in the other regions of Turkey below 8th region and vice versa since the increment of the rainfall has a positive effect on the shortening of the payback period.

The weaknesses of this study are; (i) payback time decreases as tank sizes increase. So, larger tank sized should be investigated for shorter payback periods. (ii) The system itself requires extra construction. Simpler and modular silos should be considered in future studies.

4. Conclusion

In this study, a model was developed to help utilising the rain water effectively for the buildings in University of Yalova, where the province is at the border of being water-poor. The building was chosen to be a model for the Yalova University Green Campus project and it is estimated that € 2900 and 8.5 tons of water can be saved annually (harvested from 2941.8 m^2). The total physical roof area of all the buildings in Yalova University on 2014 is 102,102 m^2, which is about 34 times larger than the model building. Considering all of the buildings in the campus and the saving potential is increasing linearly vs the building roof area, the university has a total saving potential of approximately 442000 €/year.

These results reveal that the method can contribute to the Green Campus goal of University of Yalova. According to the last census which was made by Turkish Statistical Institute (TSI), there are 16,235,830 units and buildings within the municipal borders. It was also reported that the number of buildings are in ascending trend. It was seen that a significant amount of economic savings potential can be achieved in Turkey with this model and similar sustainable water management practices.

State policy is also required together with this kind of designs in order to have an effective and sustainable water management system. The political mechanisms should provide incentives to determine and disseminate the criterion for water conservation in the buildings. The utilisation of waterless urinals, double-flow reservoirs, aquaplaning showers etc. to reduce water consumption in buildings should be encouraged. Regulations must be made to push the use of these water-saving products for new buildings and replacing the sanitary ware and flow elements with water-saving products within a certain period of time for existing buildings as obligatory. States should bring standards and regulations for design and application in the use of rain water treatment systems and treated water (grey water) in buildings especially in public buildings. In this regard, encouragements like tax reductions etc. are required for the dissemination of sustainable water management practices. Financial incentives of state can be provided. In this way, the understanding of sustainable water management will contribute considerably to reduce the environmental, social and economic problems caused by traditional buildings in the aspects of water management. In the continuation of this study, computational fluid dynamics simulation will be used and rainwater will be collected from the roof using a different design with passive system.

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