RAINWATER HARVESTING SYSTEM FOR DORMITORIES OF METU-NORTHERN CYPRUS CAMPUS

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ABSTRACT

Water scarcity in the Mediterranean islands has become an important issue to be addressed due to inadequate water supplies and low precipitation in the region. Rainwater harvesting system (RWHS) is one of the promising solutions to overcome the water shortage which not only conserves water resources but also reduces the overall carbon foot print of water collection and distribution cycle. This paper presents the theoretical potential of rainfall in Northern Cyprus for constructing a Rainwater Harvesting System for the dormitories of Middle East Technical University – Northern Cyprus Campus. Instead of introducing RWHS in each of the three dormitories ineffectively, it is found to be realistic for non-potable uses in only one dormitory with an overall collected volume of 2831 m^3 and a volumetric reliability of ~93%. The results of this study provide an opportunity for water scarce regions to use their limited resources in an efficient manner.

Keywords: Rainwater Harvesting System, Volumetric Reliability, Rainfall, Northern Cyprus

1 INTRODUCTION

Cyprus is the third largest island in the Mediterranean Sea located at 35°N latitude. According to 1978-2009 rainfall data, the island experiences majority of its rainfall during winters months between December and February, with almost no rainfall from May to September. Precipitation in the mountainous range of Kyrenia is around 470 mm at an elevation of 1000 m, whereas the Karpaz Peninsula region located at the east of the island produces 460 mm of annual average rainfall. The west coast of the island where the study area is located as shown in Figure 1 receives the minimum annual average rainfall of 270 mm. Thus, the water resources within the island are scarce, which poses challenges in terms of efficient water usage. The over exploitation of water resources is a main barrier towards its sustainability especially in the limited water resources regions like Cyprus. A good solution for this problem such as rainwater harvesting system (RWHS) should be viewed as a mean to deal with the scarcity problem in future.

A RWHS collects and stores the rainwater for direct use or for recharging the ground water. The RWHS is not a new idea; instead a lot of work has already been done in this regard. These systems are now identified as an integral component of sustainable water consumption. Normally, the university campuses are found to have significant impacts on the total water consumptions by using RWHS. However, the empirical assessment of the performance of a RWHS has always been in question. Ward et al., 2012 studied the longitudinal empirical performance assessment of a non-domestic RWH system located in an office building in the UK. The actual performance of the system was compared with the estimated performance based on two methods: the intermediate (simple calculations) and detailed (simulation-based) method. The results of the study indicated 87% saving in water consumption over an 8-month period due to an over-sized system for the actual number of occupants in the building. However, the same analysis was done for a small sized tank to achieve a similar level of performance. Economic analysis of the project was done and the payback of capital costs for both the over-sized and smaller-sized tanks were found to be 11 and 6 years, respectively. The study concluded a significant reduction in water and cost savings by employing a RWHS in an office building.

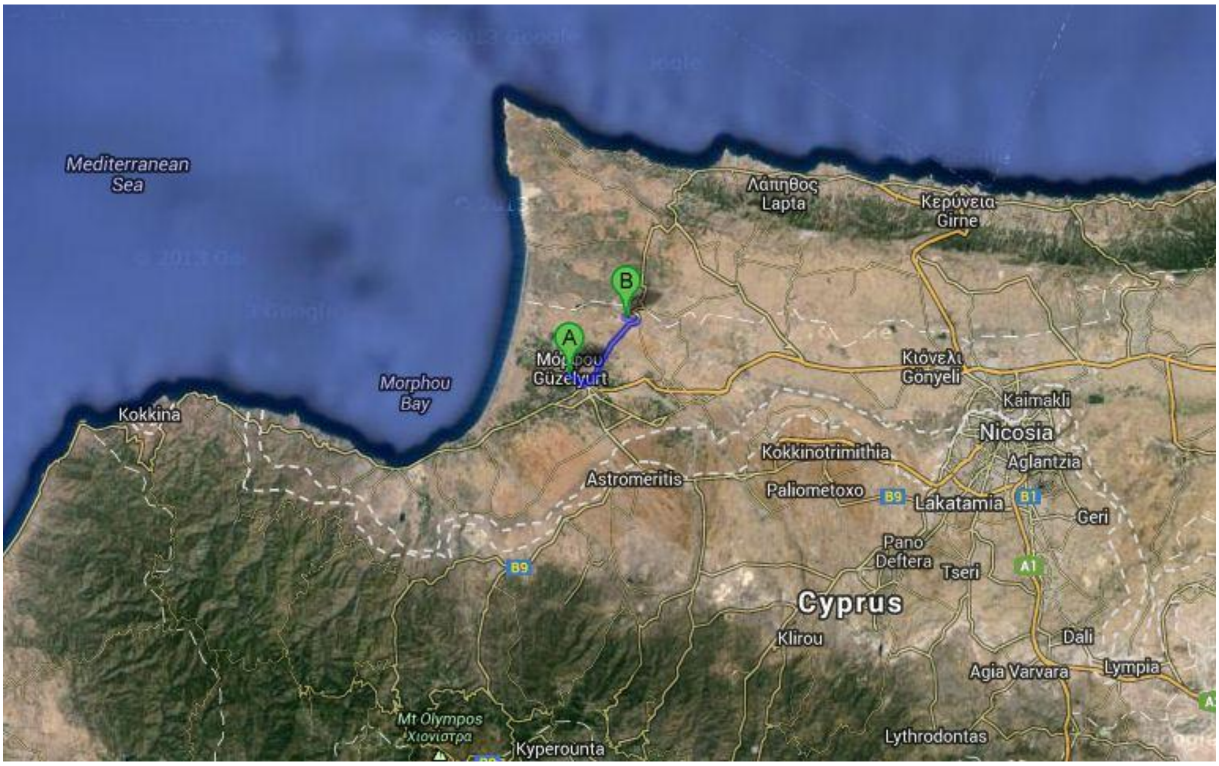


Figure 1: West coast of North Cyprus indicating the locations of Guzelyurt Region and Middle East Technical University-Northern Cyprus Campus as A and B respectively

Patel and Patel, 2012 demonstrated the efficient water resource management by RWHS in Claris, one of the largest pharmaceutical companies in India. At Claris, approximately 223,000 liters of rain water can be harvested within an area of 223 m^2. In addition to the RWHS, Claris also have 13 recharge wells and a storm water drainage channel system for preserving the groundwater and for maintaining the ground level. These systems are of utmost importance owing to the fact that there are no large water bodies near to the Claris and no other external water supply is available, therefore, the groundwater is the only source to meet the water requirements of the whole Claris Campus.

Aladenola and Adeboye, 2009 proposed a rainwater harvesting system for Abeokuta region where the annual mean precipitation is 1,156 mm with an intra and inter annual variability between 0.7-1 and 0.2, respectively. The study was focused on non-potable water uses in households where the estimated annual water demands of laundry and flushing were 21.6 m^3 and 29.4 m^3. It was concluded that 74.0 m^3 of rainwater can be harvested by RWHS which can easily fulfill the laundry and flushing demands of households in all months except November, December, January, and February. However, an adequate storage facility can make up for the dry months by storing the excess water in September and October. June and September were found to be with highest potential of water saving owing to the two rainfall peak periods in the vicinity.

Hamid and Nordin, 2011 studied the reliability of installing the RWHS by doing a case study for Kolej Perindu 3, which is one of the male residential colleges in Universiti Teknologi MARA (UiTM) Malaysia. The average rainfall in Malaysia, as reported by the author, is 3000 mm which provides an opportunity to exploit this natural resource at its best in serving the needs of local population by solving the water supply problems. The study concluded that the installation of RWHS could be 90% reliable based on the available rainfall area and the roof catchment area of the college. The economic appeal of the RWHS installation was also studied which resulted in an annual savings of RM 10460 from the water bill of the campus.

This paper aims to analyze constructing a RWHS for the dormitories of Middle East Technical University – Northern Cyprus Campus (METU-NCC). Locations of dormitories I and II are indicated in Figure 2 while Dormitory III is situated in front of Dormitory I across the road and on the right side of Dormitory II. Methodology to harvest rainwater is discussed in Section 2. The necessary data required for the study is collected from the university records and expressed in the same section. Results and discussions of the study are presented in the later section. Section 4 proposes a design and strategy that can be applied to achieve the prime objective. Finally, the conclusions are given in Section 5.

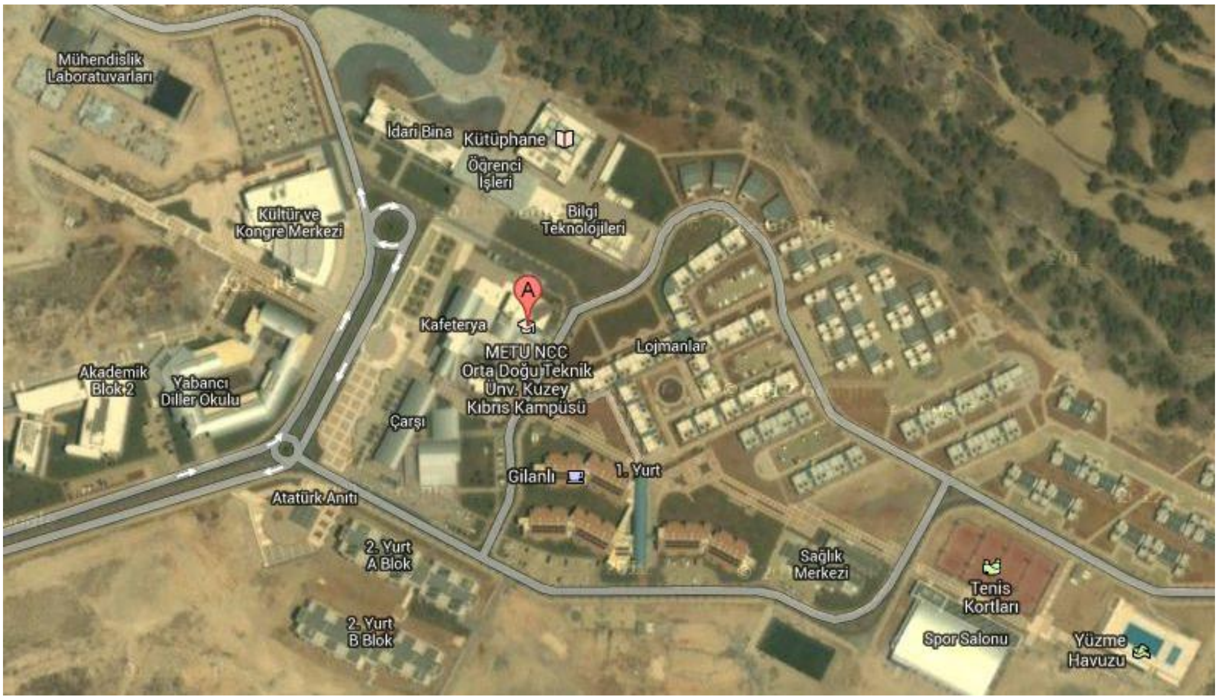


Figure 2: View of Middle East Technical University - Northern Cyprus Campus Dormitories

2 RAINWATER HARVESTING SYSTEM

2.1 Methodology

2.1.1 Rainwater Collection

RWHS is the collection of rainwater from the man-made built catchments especially roofs or other natural surface catchments to use for domestic, agricultural, environmental or industrial purposes (Gould, 1999). Rainwater harvesting for non-potable uses has four major components in the system; catchment area, gutter and downspout, storage facility and distribution system. In this case study, roof of the dormitories serve as the catchment area. Usually the available rainfall in the region and the roof catchment area determines the size of the RWHS (Mohammed et al., 2007). The following equation by (Australian Government Department of Health and Ageing, 2004) can estimate the maximum rainwater runoff that can be collected;

$$\text{Runoff} = \text{A} \times (\text{Rainfall} - \text{B}) \times \text{Roof Area} \tag{1}$$

where A is the runoff coefficient and B is the loss due to wetting of surfaces and absorption.

It is essential to identify the water consumption on the micro level to set the standards which ensure the demand to be fulfilled all the time. Non-potable uses in an academic building such as water closet (43%), washing (27%), flushing toilets (20%), and cafeteria use (9%) and cleaning (1%) can be satisfied by using rainwater (Leggett et al., 2001). Also, more than 20% of household water is responsible for just toilet flushing (Metropolitan Planning Council, 2013). Rainwater can be collected, filtered and directed to these toilets, creating a recyclable resource. A value of 20% of total water supply for flushing is approximated for this study as well.

2.1.2 Volumetric Reliability

Volumetric Reliability also called water saving efficiency (ET) is measured as a percentage of mains water conserved. It gives a clear picture of how much rainwater can satisfy the demand of water coming from the fresh source. In this study, volumetric reliability (ET) of flushing toilets is considered only and is calculated by dividing the amount of rainwater consumed by the total quantity of water asked for flushing. ET can be calculated by using the following relation (Ward et al., 2012);

$$\mathrm{ET}\ (\%) = \left(\frac{\mathrm{V}}{\mathrm{D}}\right) \times 100 \qquad (2)$$

where V is the amount of rainwater provided by the RWH system (m^3) and D is the total quantity of water demanded (m^3).

2.2 Data Collection

2.2.1 Technical Data

Table 1. Monthly Water Consumption by Dormitories in 2012

Month	Water Consumption (m^3)		
	Dormitory I	**Dormitory II**	**Dormitory III**
Jan	1565	1972	1628
Feb	893	1402	869
Mar	1880	2526	1564
Apr	2046	1769	1423
May	1855	1660	1463
Jun	681	859	1259
Jul	0	0	26
Aug	0	0	5
Sep	1250	1043	860
Oct	1453	979	1666
Nov	1453	1526	3959
Dec	1453	1526	1967
Total	**14529**	**15263**	**16689**

Table 2. Technical Data for RWHS Analysis

Runoff coefficient	0.85 (Usul, 2009)	
Loss due to absorption and wetting of surfaces	2 mm/month (Hamid and Nordin, 2011)	
Price of water supplied to campus	1.5 TL per m^3	
Roof Catchment Areas	Dormitory I	4156 m^2
	Dormitory II	3943 m^2
	Dormitory III	2834 m^2

The first logical step towards the potential applicability of RWHS at METU NCC is to collect the data regarding monthly water demands in the dormitories. Since, monthly water consumption in all dormitories is monitored, the data is provided by the university administration for the year 2012 as shown in Table 1. However, the monthly consumption of some months such as October to December for Dormitory I, November and December for Dormitory II and October for Dormitory III was missing in the provided data. Therefore, these values are estimated by taking the average of monthly water consumption of other months except July and August, because, these two months represent summer break in the university and most of the students are off-campus. A little water consumption of about 31 m^3 in Dormitory III is observed during the summer break due to the maintenance activities in that dormitory. Next, the typical data for RWHS analysis such as run-off coefficient, loss due to absorption and wetting of surfaces, and price of water supplied to the campus are obtained. In addition to that the roof catchment areas for all dormitories are measured by using Planimeter from the drawings provided by the administration. A summary of technical data for RWHS analysis is presented in Table 2.

2.2.2 Rainfall in Guzelyurt Region, Northern Cyprus

A significant variation in rainfall can be observed between winters and summers in Northern Cyprus. Figure 3 represents the average monthly rainfall for Guzelyurt region based on the period of 1978-2009. It was found that the average precipitation during winters reached to a maximum of 66 mm in December contrary to what is experienced in summers when there is almost no rainfall between June and September. Thus, the period between June and September can be fairly termed as dry months for this region. A cumulative total value of rainfall in Guzelyurt is calculated and found to be 326.7 mm for an entire year. This low value of precipitation poses challenges in terms of constructing RWHS in the region owing to the fact that RWHS is a promising option for water saving in the regions with higher precipitation values between 1000-3000 mm (Aladenola and Adeboye, 2009; Hamid and Nordin, 2011).

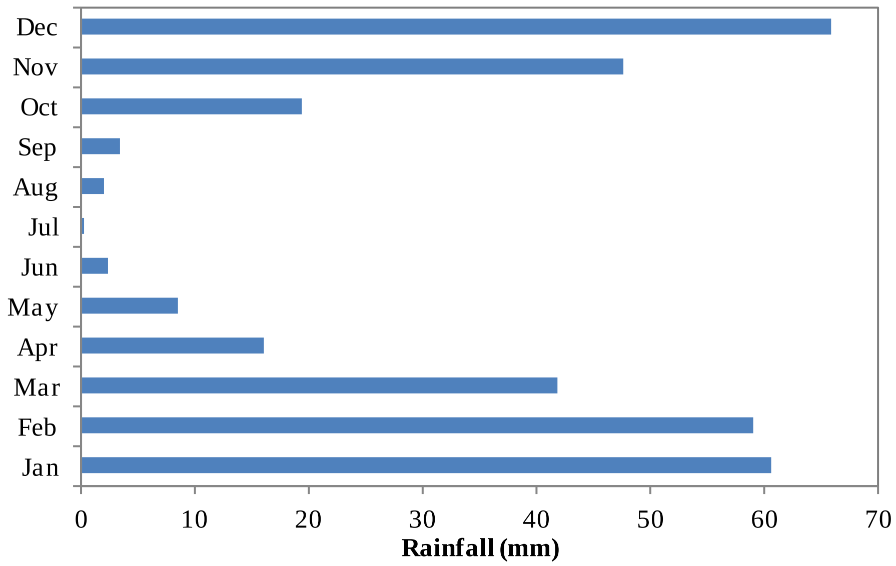


Figure 3. Monthly Average Rainfall in Guzelyurt Region, North Cyprus

3 RESULTS AND DISCUSSION

The results obtained for volume of rainwater harvested based on roof catchment areas, cost savings and reliability for Dormitories I, II and III are presented in Table 3, 4 and 5, respectively. Figure 4, 5 and 6 depict the share of harvested rainwater in total water consumption. Based on the available rainfall and roof catchment areas, it is observed that the amount of harvested rainwater shares very little contribution in the total water consumption of each dormitory throughout the year. The same is observed in flushing needs where the results are found to be promising for only one month i.e. February in Dormitory I. In all other months, the amount of harvested water is found to be quite lower than the estimated demand in flushing, thus, resulted in a low reliability value throughout the year in each dormitory. The volumetric reliability for dormitories 1, 2 and 3 are found to be 37%, 33% and 22%, respectively for an entire year, which does not afford to construct a separate RWHS for each dormitory.

The separate RWHS for dormitories I, II and III are also not found to be economically appealing in terms of cost saving from the water bills. It is estimated that an annual saving of 1614 TL, 1531 TL and 1104 TL is possible by constructing a separate RWHS for each dormitory, which accounts for 7.4%, 6.6% and 4.4% of total billing amount of dormitories I, II, and III, respectively. A cost saving of less than 10% completely forfeited the purpose of separate RWHS for each dormitory and suggested that it is impossible to make each and every dormitory a water efficient building due to less precipitation and limited roof catchment areas.

Table 3. RWHS Analysis for Dormitory I

Month	**Rainfall (mm)**	**Volume of Water (m^3)**	**Total Water usage (m^3)**	**Water used in Flushing (m^3)**	**Savings (TL)**	**Reliability (%)**
Jan	60.6	207.0	1565	313.0	310.5	66.1
Feb	59.1	201.7	893	178.6	302.6	112.9
Mar	41.9	141.0	1880	376.0	211.4	37.5
Apr	16.1	49.8	2046	409.2	74.7	12.2
May	8.5	23.0	1855	371.0	34.4	6.2
Jun	2.4	1.4	681	136.2	2.1	1.0
Jul	0.2	0.0	0	0.0	0.0	0.0
Aug	1.9	0.0	0	0.0	0.0	0.0
Sep	3.3	4.6	1250	250.0	6.9	1.8
Oct	19.3	61.1	1453	290.6	91.7	21.0
Nov	47.6	161.1	1453	290.6	241.6	55.4
Dec	65.8	225.4	1453	290.6	338.1	77.6
Total	**326.7**	**1076**	**14529**	**2906**	**1614**	**37**

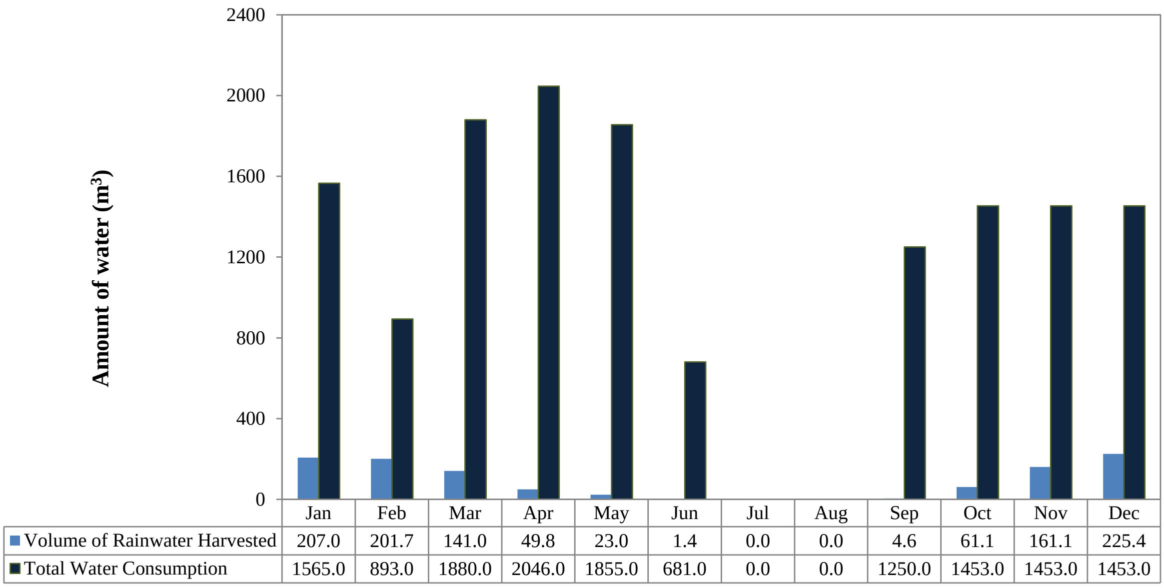


Figure 4. Total Water Consumption and the amount of Rainwater Harvested by Dormitoy I

The results obtained from the analysis presented in Table 3, 4 and 5 and in Figure 4, 5 and 6 revealed the insights of obstacles in constructing individual RWHS for each dormitory building. A holistic approach of making a practical design of RWHS could be utilizing the annual precipitation and roof catchment areas of all dormitories under consideration so that at least one of the dormitories can be made water efficient. For this purpose, Dormitory II is selected due to its downslope location in the campus. The location is promising because it allows the flow of rainwater under the action of gravity from Dormitory I and II to Dormitory II. In this way no energy is input to the system in pumping the water, which contributes to the sustainable aspects of the design.

Table 4. RWHS Analysis for Dormitory II

Month	Rainfall (mm)	Volume of Water (m^3)	Total Water usage (m^3)	Water used in Flushing (m^3)	Savings (TL)	Reliability (%)
Jan	60.6	196.4	1972	394.4	294.6	49.8
Feb	59.1	191.4	1402	280.4	287.1	68.3
Mar	41.9	133.7	2526	505.2	200.6	26.5
Apr	16.1	47.3	1769	353.8	70.9	13.4
May	8.5	21.8	1660	332.0	32.7	6.6
Jun	2.4	1.3	859	171.8	2.0	0.8
Jul	0.2	0.0	0	0.0	0.0	0.0
Aug	1.9	0.0	0	0.0	0.0	0.0
Sep	3.3	4.4	1043	208.6	6.5	2.1
Oct	19.3	58.0	979	195.8	87.0	29.6
Nov	47.6	152.8	1,526	305.3	229.2	50.1
Dec	65.8	213.8	1,526	305.3	320.7	70.1
Total	**327**	**1020.9**	**15263**	**3053**	**1531**	**33**

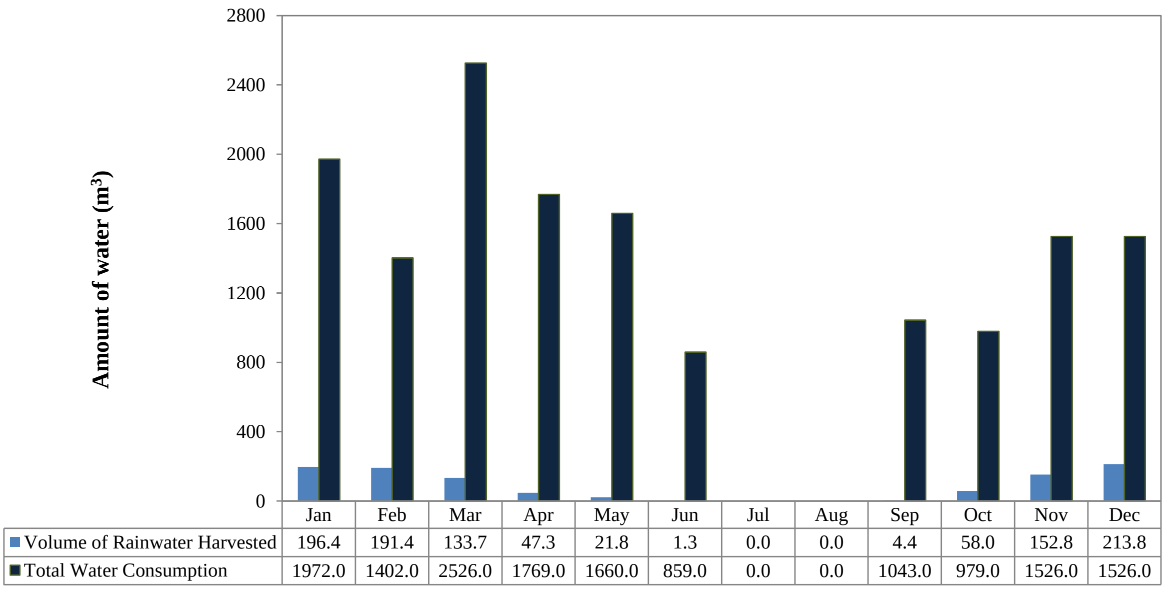
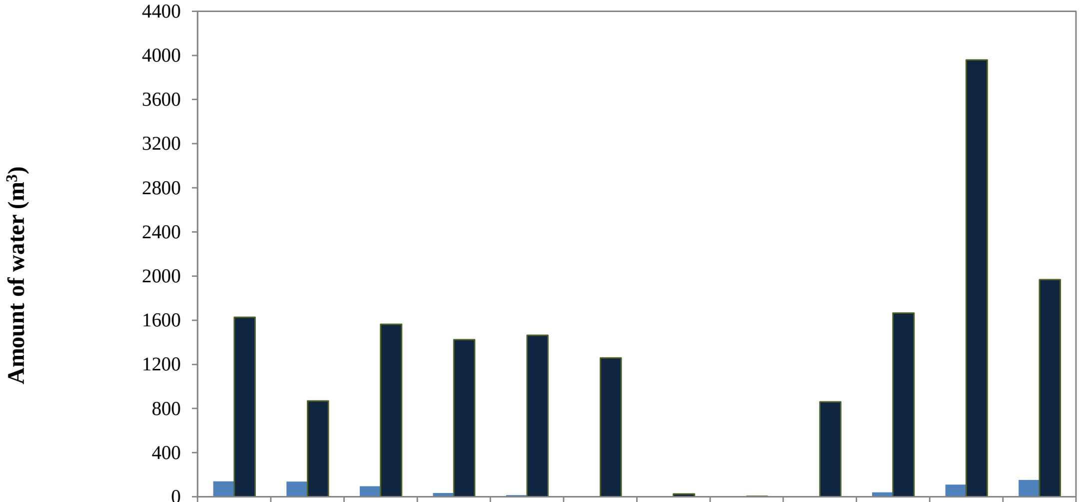


Figure 5. Total Water Consumption and the amount of Rainwater Harvested by Dormitory II

The results of the analysis of RWHS for Dormitory II based on the rainwater collected in all three dormitories are presented in Table 6 and Figure 7. It is evident from Figure 7 that the RWHS is now significantly contributing to the water demands of Dormitory II, especially in December and February, where its share is recorded to be ~64% and 61%, respectively. This overall RWHS design qualified with a water reliability of ~93% for an entire year and an annual cost savings of 4246 TL which amounts to 19% of savings in water bills of Dormitory II. The water reliability on a monthly basis is found to be more than 100% from November to February, making the flushing system completely independent of any other external water supply beyond RWHS, and in other months such as October and March, it is also scaled up to 82.1% and 73.4% from 29.6% and 26.5%, respectively. Invigorated by the encouraging results of this RWHS analysis for Dormitory II, a complete design of collection and distribution of the harvested rainwater is proposed, the details of which are presented in the forthcoming section.

Table 5. RWHS Analysis for Dormitory III

Month	Rainfall (mm)	Volume of Water (m^3)	Total Water usage (m^3)	Water used in Flushing (m^3)	Savings (TL)	Reliability (%)
Jan	60.6	141.2	1628	325.6	211.7	43.4
Feb	59.1	137.5	869	173.8	206.3	79.1
Mar	41.9	96.1	1564	312.8	144.2	30.7
Apr	16.1	34.0	1423	284.6	50.9	11.9
May	8.5	15.7	1463	292.6	23.5	5.4
Jun	2.4	1.0	1259	251.8	1.4	0.4
Jul	0.2	0.0	26	5.2	0.0	0.0
Aug	1.9	0.0	5	1.0	0.0	0.0
Sep	3.3	3.1	860	172.0	4.7	1.8
Oct	19.3	41.7	1,666	333.2	62.5	12.5
Nov	47.6	109.8	3959	791.8	164.8	13.9
Dec	65.8	153.7	1967	393.4	230.5	39.1
Total	**326.7**	**734**	**16689**	**3338**	**1101**	**22**

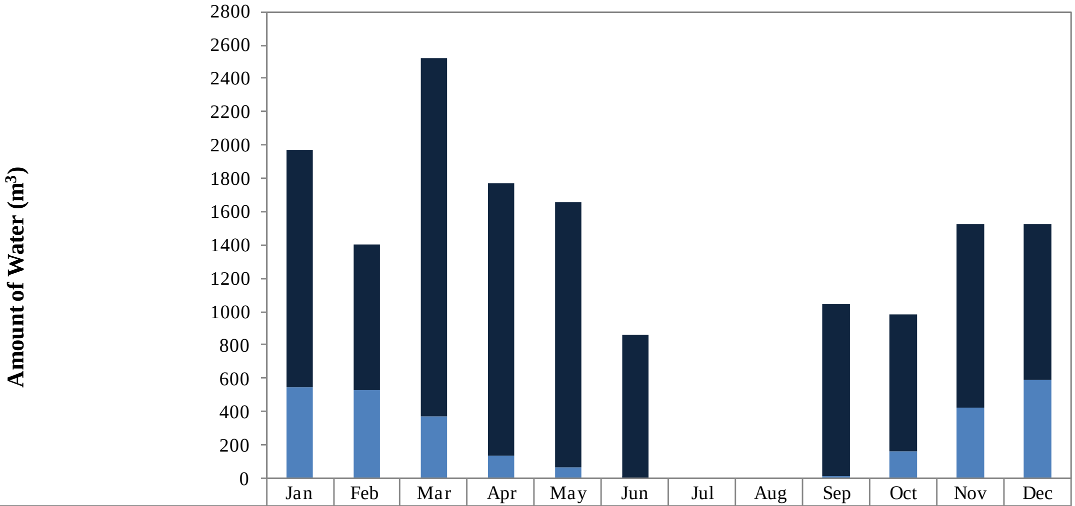


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Volume of Rainwater Harvested	141.2	137.5	96.1	34.0	15.7	1.0	0.0	0.0	3.1	41.7	109.8	153.7
Total Water Consumption	1628.0	869.0	1564.0	1423.0	1463.0	1259.0	26.0	5.0	860.0	1666.0	3959.0	1967.0

Figure 6. Total Water Consumption and the amount of Rainwater Harvested by Dormitory III

Table 6. RWHS Analysis for Dormitory II based on rainwater collected from all three dormitories

Month	Rainfall (mm)	Volume of Water (m^3)	Total Water Usage (m^3)	Water Usage in Flushing (m^3)	Fresh Water Usage (m^3)	Cost Savings (TL)	Reliability (%)
Jan	60.6	544.6	1972.0	394.4	1427.4	816.9	138.1
Feb	59.1	530.6	1402.0	280.4	871.4	795.9	189.2
Mar	41.9	370.8	2526.0	505.2	2155.2	556.2	73.4
Apr	16.1	131.0	1769.0	353.8	1638.0	196.5	37.0
May	8.5	60.4	1660.0	332.0	1599.6	90.6	18.2
Jun	2.4	3.7	859.0	171.8	855.3	5.6	2.2
Jul	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Aug	1.9	0.0	0.0	0.0	0.0	0.0	0.0
Sep	3.3	12.1	1043.0	208.6	1030.9	18.1	5.8
Oct	19.3	160.8	979.0	195.8	818.2	241.2	82.1
Nov	47.6	423.8	1526.0	305.2	1102.2	635.6	138.8
Dec	65.8	592.9	1526.0	305.2	933.1	889.3	194.3
Total	**327**	**2831**	**15262**	**3052**	**12431**	**4246**	**93**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Freshwater Consumption	1427.4	871.4	2155.2	1638.0	1599.6	855.3	0.0	0.0	1030.9	818.2	1102.2	933.1
Volumetric share of Harvested Rainwater	544.6	530.6	370.8	131.0	60.4	3.7	0.0	0.0	12.1	160.8	423.8	592.9

Figure 7. Potential share of rainwater harvested in total water consumption of Dormitory II

4 PROPOSED DESIGN AND STRATEGY

Figure 8 is the proposed design for collection and distribution of the RWHS for Dormitory II. Rainwater collected from the roof catchment areas of all the three dormitories will direct towards the underground storage tank through already existing gutters and pipes. Rainwater will be sent to the flush tanks for removal of any physical contamination caused by pebbles, dirt, leaves, bird droppings, and other materials. This primary treated rainwater will be transferred to the distribution tank from the storage tank via pump. Rainwater from distribution tank will go into the water tank located on the roofs of both the blocks and then circulated to the toilet flushing system of Dormitory II by gravity flow.

This RWHS is proposed for non-potable use i.e. flushing toilets only in Dormitory II as discussed earlier. Therefore, the rainwater collected in the underground storage tank will be guided through a separate piping system connecting toilet flushing system with the rainwater storage tank. Distribution tank will be equipped with a level controller which automatically switches to the main water supply either fully or partially when the tank starts running out of water to ensure firm water supply to the residing students. All internal reinforcements that will come in contact with water are of stainless steel while those surfaces which will not interact with water should be of hot dipped galvanized type. This will prevent the tanks from corrosion and increase the durability of the tank. Also these tanks will be easy to maintain.

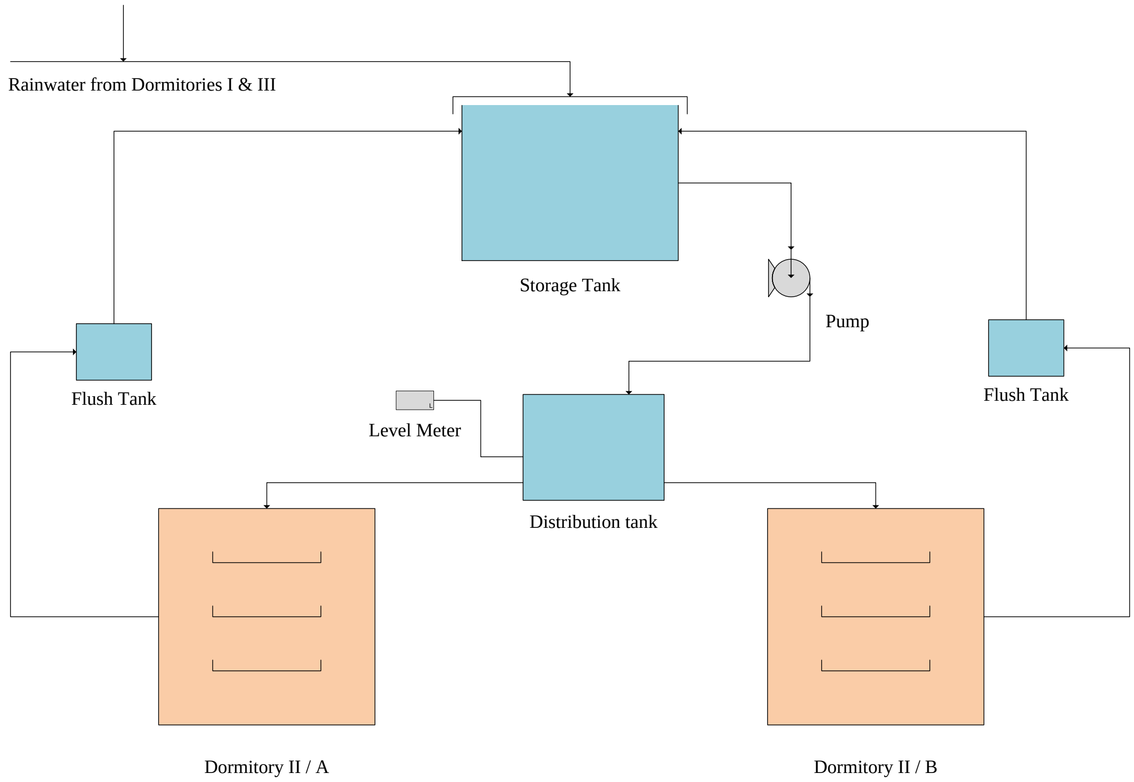


Figure 8. Proposed design for collection and distribution of RWHS in Dormitory II

5 CONCLUSION

The results of this study show that RWHS is realistic for non-potable uses in only one of the dormitories with an overall collected volume of 2831 m^3 and a volumetric reliability of ~93%. The RWHS at the campus depends on the available rainfall and roof catchment area. A suitable strategy has been proposed to harvest and distribute the rainwater into Dormitory II which will contribute to a cost saving of about 4250 TL per year from the water bill. Also, saving water resources will lead to saving energy consumption. In order to implement and associate the idea with the green campus initiative; rainwater needs to be harvested from multiple locations of the campus to satisfy the demand of maximum possible number of buildings. With limited water resources in Northern Cyprus, such systems can greatly contribute to the water sustainability on the island.

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