Bolu Abant İzzet Baysal University Rainwater Harvesting Project

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1. Introduction

City centers are growing in our world and the world population is increasing rapidly with the 20th century. With the effect of global warming, water resources become insufficient. Water quality is rapidly declining due to overuse and pollution, and more than 1 billion people today do not have access to safe and clean water, according to World Wide Fund for Nature (WWF) data. Although 70% of the earth is covered with water, only ~ 3% of it is drinkable and 2/3 of this part is in glaciers, so we can only access 1% of our water. With these ratios, we can understand how valuable our water actually is. Today's water resources management approaches are insufficient. Rainwater harvesting systems are an important alternative.

2. Status of Water Resources in Turkey

UNEP 2010: Water per capita
<1700 m^3: Area experiencing water stress
<1000 m^3: Region facing drought
<500 m^3: Absolute Drought

Table 1. Estimated amount of water per capita by years

Year	Population	Water Per Capita (m^3)
2013	76,667,864	1450
2035	100,000,000*	1100
2050	106,000,000*	970

*Hoşgör (2010) ''2050'ye doğru Nüfusbilim ve Yönetim"

According to the results, Turkey "Area experiencing water stress" is located in 2013. Turkey's population would be 106 million in 2050 and "Region facing drought" will significantly in the area.

3. Turkey and Bolu Characteristics of Water Use

According to TurkStat 2018 Municipal Water Statistics 6.2 billion m^3 of water was drawn from sources in Turkey. 224 liters of water consumed per capita in Turkey, Bolu been spent an average 158 liters of water per person per day.

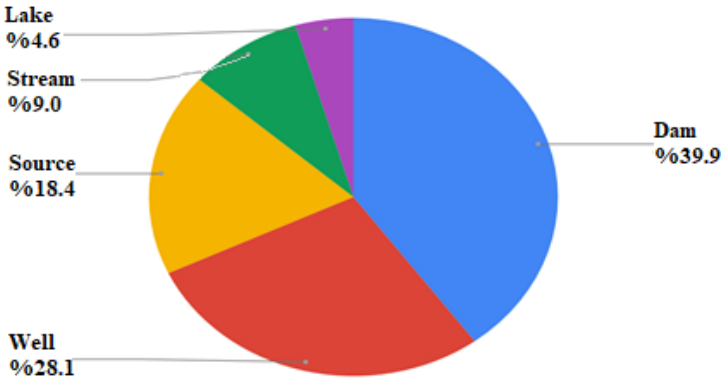


Figure 1. Water usage rates according to sources in Turkey

4. Examples of Rainwater Collection Systems

Table 2. Rainwater Collection Systems

Source	Region Average Precipitation Height (mm / year)	Purpose of the study	Rate of Increase (%)	Duration of Earnings to Cover the Investment (Year)
Liaw and Tsai (2004)	3 cities of Taiwan	Determination of optimum rainwater tank volume	5	15
Roebuck et al. (2010)	West Yorkshire, England (700)	Total cost of use of YST systems	3,5	5
Tam et al. (2010)	4 cities of Australia	Comparison of YST systems with alternative water sources	3	20
Ghisi and Mengotti de Oliveira (2007)	Florianopolis, Brazil (1706)	Combining YST systems with gray welds	1	-
Zhang et al. (2009)	4 cities of Australia	Usability of YST systems in multi-storey buildings	6,5	-
Rahman et al. (2010)	Sydney, Australia (1200)	Determining the most suitable scenario for the use of YST systems in multi-storey buildings	5	60
Farreny et al. (2011)	Granollers, Spain (650)	Application of YST in dense residential areas to meet the need for non-potable water	0	27

Swinburne University of Technology: The rainwater accumulated in the tanks placed in the North and South Campuses was used only for the irrigation of green areas and covered the cost of YST gain in 19 and 21 years.

With the YST system created for Tokyo, Fukuoka and Nagoya domes, the water collected in the toilets and green areas were used, and $ 120,000 was earned from the roof of the Fukuoka Dome alone.

YST foreseen for Tancredo Neves International Airport in Brazil can collect more than 87000 m^3 of rainwater annually. This amount is more than the total non-potable water requirement of the airport and the return on investment varies between 2-19 years with different tank options.

5. Need for Rainwater in Public Buildings

USA: It shows that 29% of the water used in schools is used only for irrigation.

Brazil: Tancredo Neves International Airport, 65% of the water used to meet non-potable water demands.

Japan: The water used in Fukuoka Dome, siphon and irrigation facilities is 59% of the total water used.

It is understood that the amount of water used in toilet and irrigation in public buildings varies between 30% and 70% of the total consumption.

6. Average Annual Precipitation in Turkey

The average annual precipitation amount between 1970 and 2015 in our country was determined to be 624.6 mm. This value shows significant differences according to the regions. In Turkey, annual rainfall varies between 260 mm and 2300 mm.

The most rainy place in our country is the Eastern Black Sea coast. The main reasons why this section receives a lot of rainfall is that the mountains start from the coast, extend parallel to the shore and have a high altitude.

Western Black Sea, Menteşe Region and Taurus Mountains are also among the places with high rainfall in our country. Here, the mountains extend parallel to the coast.

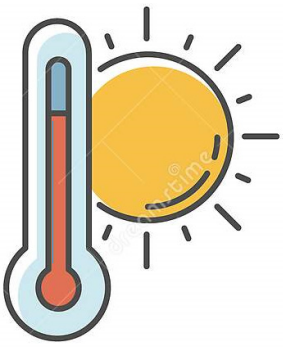
In the inner parts, mountainous areas receive more rainfall than places with less altitude. Accordingly, the effect of the mountains on the distribution of rainfall in our country is high.

Central Anatolia, surrounded by mountains, is one of the least rainy places in our country. Igdir and southern plains of Malatya in Turkey's Southeastern Anatolia There are also at least wettest places.

Figure 2. Turkey average annual precipitation map

7. Bolu Province Temperature and Precipitation Charts

The climate is warm and temperate in Bolu, 734 m above sea level. There is significant rainfall throughout the year in Bolu. The is a great deal of rainfall, even in the driest month. According to Köppen-Geiger, the climate is Cfb. The annual average temperature of Bolu province is 10.9 ° C. The average annual rainfall is 573 mm.



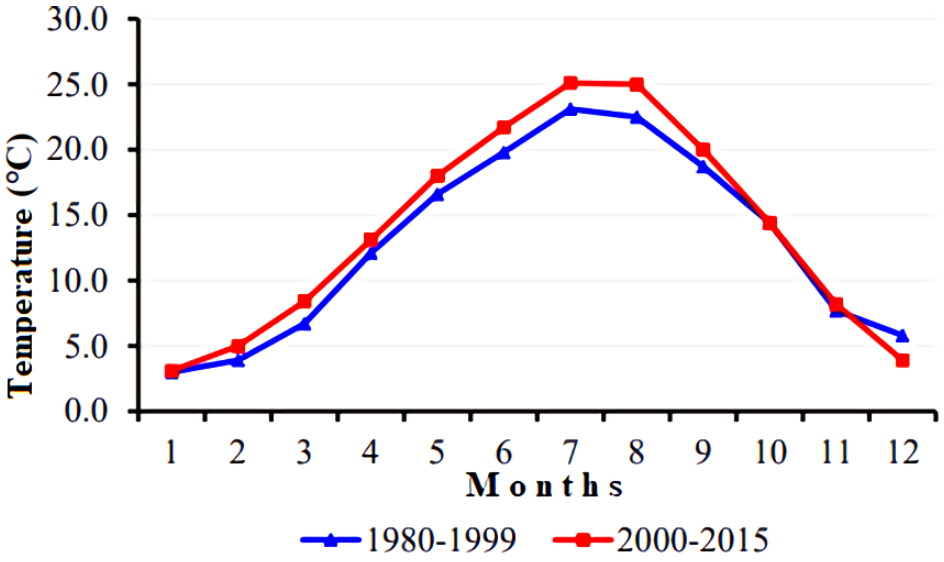


Figure 3. Bolu province monthly average temperature values between 1980-1999 and 2000-2015

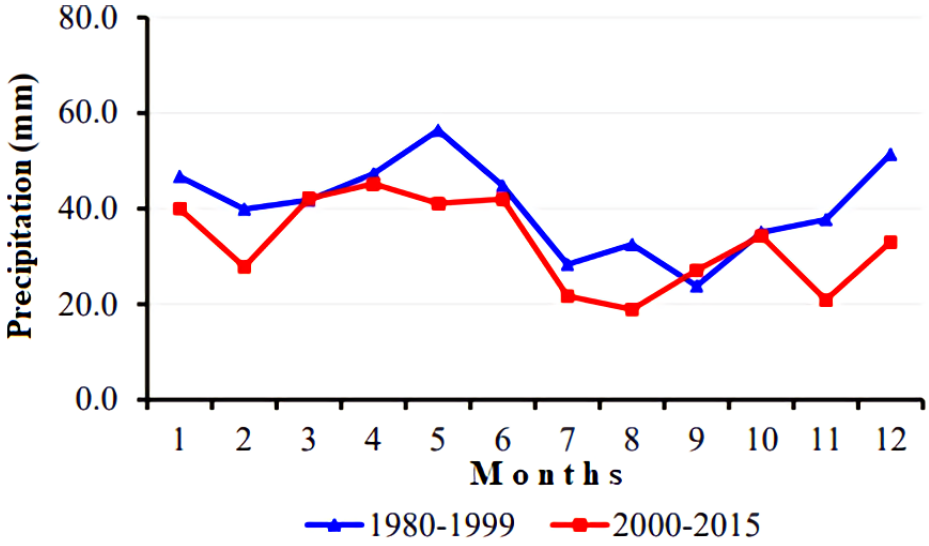


Figure 4. Bolu province average rainfall values between 1980-1999 and 2000-2015

8.Seasonality Index (SI)

Seasonality Index (SI) (Walsh & Lawler 1981) determines the relationship between monthly precipitation changes in a year and the lowest value indicates that monthly precipitation is equal to each other in 0 years.

In regions with regular rainfall, the amount of water that needs to be collected for a rain-free period decreases and makes the YST systems more economical.

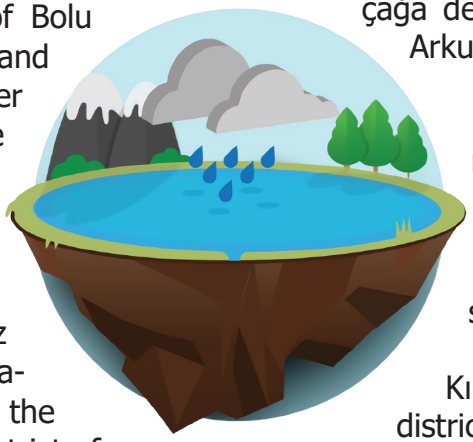
R is the annual median precipitation and the monthly median precipitation value in month Xj j. The seasonality index for Bolu is calculated as 0.22. This value is classified as climate with conjugate precipitation regime with rainy season.

$$\overline{SI} = \frac{1}{\overline{R}} \sum_{n=1}^{12} \left| X_n - \frac{\overline{R}}{12} \right|$$

9. Bolu Water Resources

According to TUIK 2018 data, the average daily amount of water consumed per person in Turkey in Bolu is 158 liters, while 224 liters.

Bolu Central District: The drinking water of the central district of Bolu is obtained from Gölköy Dam and purified in the Drinking Water Treatment Plant located on the Salıbeyler District of our city. Bolu's most famous natural spring water is Kokez. Kökez Spring emerges from Aladağ Ormanı Gölcük locality. Kokez water spring flows in 87 fountains as a fountain. In addition, the drinking water of the central district of Bolu is supplied from Bayramışlar and Değirmenözü Springs and from deep wells at 10 points.



Dortdivan: The water requirement of the district center is met by the deep well located in Yazi Mevkii and Köroğlu spring waters 35 km from the center by gravity system. The flow rate of the deep well is 21 lt / sec, and the gravity water flow is 5 lt / sec.

Gerede: The water requirement of the district is supplied from the woolen plateau and deep wells of Yeniçağa and the spring water of Arkut Mountain. The flow rate of the Yünlü highland deep well is 20 lt / sec, the Yeniçağa deep well is 20 lt / sec, and the Arkut Mountain source is 10 lt / sec.

Göynük: There are three natural spring waters in the district. The names and flow rates of these resources are as follows: Rod 11 lt / sec, Ilıcaksu 8 lt / sec, Örencik 8 lt / sec.

Kıbrıscık: The water need of the district is met from the natural resources located in the Kurds Çayırı Mevkii of Karlık and Yazıcı Plateau. Its flow rate is 12 lt / sec.

Mengen: The drinking water of the district is met from three sources. Two of these are natural resources and one is a well. The flow of the Kavacık Locality İnanç natural resource is 11 lt / sec, the flow rate of the Hızır Creek natural source is 12 lt / sec, and the flow of the Akbükeson Well is 15 lt / sec.

10. Bolu Abant Izzet Baysal University (BAIBU) Campus

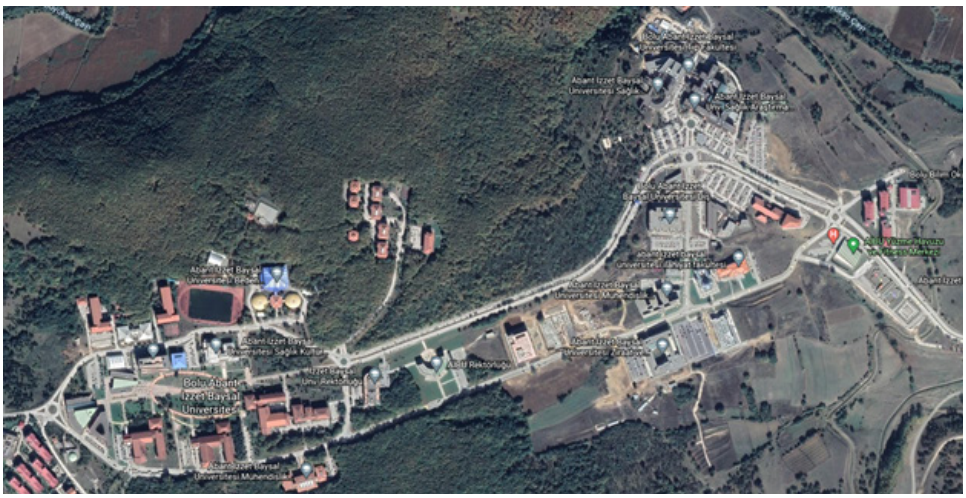


Figure 5. BAIBU campus

11. Number of Staff and Students of BAIBU Campus Buildings

Table 3. Number of Staff and Students of BAIBU Campus Buildings

Building	Number of Personnel (Person)	Number of Students (Person)
Rectorate	163	-
Faculty of Arts and Sciences	156	3295
Faculty of Economics and Administrative Sciences	106	4713
Faculty of Education	162	3220
Faculty of and Architecture	22	841
Faculty of fine arts	35	230
High school of Physical Education and Sports	39	893
Physical Therapy and Rehab. High School	26	513
Bolu School of Health	47	742
Faculty of Dentistry	106	489
Faculty of Engineering	89	1528
Faculty of Theology	64	1339
Faculty of Agriculture	67	2996
Health Services Vocational School	21	511
KYK Student Dormitories	5	5962

12. Campus Buildings Roof Areas

Table 4. Roof Areas

Building	Roof Area (m^2)
Rectorate	1700
Faculty of Arts and Sciences	4370
Faculty of Economics and Administrative Sciences	4370
Faculty of Education	4645
Faculty of Architecture	2180
Faculty of fine arts	2450
High school of Physical Education and Sports	2630
Physical Therapy and Rehab. High School	1376
Bolu School of Health	1400
Faculty of Dentistry	3442
Faculty of Engineering	3333
Faculty of Theology	1538
Faculty of Agriculture and	4740
Health Services Vocational School	805
KYK Student Dormitories	3730

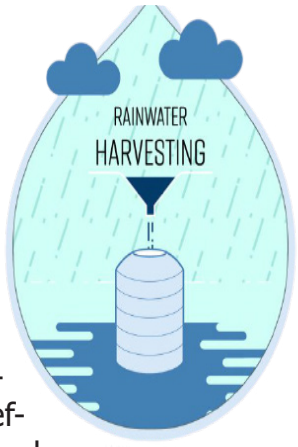
13. Daily and Annual Water Amounts of Campus Buildings

Table 5. Water Amounts of Campus Buildings

Building	Daily Water Expended (L)	Annual water consumption (m^3)
Rectorate	4890	1784,85
Faculty of Arts and Sciences	103530	37788,45
Faculty of Economics and Administrative Sciences	144570	52768,05
Faculty of Education	101460	37032,9
Faculty of Architecture	25890	9449,85
Faculty of fine arts	7650	2792,25
High school of Physical Education and Sports	27960	10205,4
Physical Therapy and Rehab. High School	16170	5902,05
Bolu School of Health	23370	8530,05
Faculty of Dentistry	17850	6515,25
Faculty of Engineering	48510	17706,15
Faculty of Theology	42090	15362,85
Faculty of Agriculture	91890	33539,85
Health Services Vocational School	15960	5825,4
KYK Student Dormitories	179010	65338,65

14. Rainwater Efficiency Calculation

Rainwater efficiency (m^3 / year) = Rain collection area (m^2) * amount of rainfall (mm) * roof coefficient * filter efficiency coefficient



Rain catchment area: It is the total roof area.

Precipitation amount: It is the total annual precipitation amount determined by the General Directorate of Meteorology.

Roof coefficient: It is the coefficient specified by German standards as 0.8 in DIN (1989). The roof coefficient means that all the rain falling on the roof cannot be recycled.

Filter efficiency coefficient: It is the coefficient specified by German standards as 0.9 in DIN (1989). Filter efficiency coefficient is the efficiency coefficient of the first filter that is passed to separate rainwater obtained from the roof from visible solids. It is a coefficient given by calculating that some water cannot pass through here.

Table 7. Rainwater Efficiency

Rain Water Efficiency	Yield (m^3/yıl)
Rectorate	554,472
Faculty of Arts and Sciences	1425319,2
Faculty of Economics and Administrative Sciences	1425319,2
Faculty of Education	1515013,2
Faculty of Architecture	711028,8
Faculty of fine arts	799092
High school of Physical Education and Sports	857800,8
Physical Therapy and Rehab. High School	448796,16
Bolu School of Health	456624
Faculty of Dentistry	1122642,72
Faculty of Engineering	1087091,28
Faculty of Theology	501634,08
Faculty of Agriculture	1545998,4
Health Services Vocational School	262558,8
KYK Student Dormitories	1216576,8

15. Annual Total Water Need

It is known that approximately 10 liters of water is consumed for each flush. This corresponds to an average of 1/3 of the water spent annually. In this case, we can obtain the amount of water we want to collect with the rain collection system by dividing the annual water spent for each building into 3.

Table 8. Annual Total Water Need

Building	**Annual Total Water Need (m^3)**
Rectorate	594,95
Faculty of Arts and Sciences	12596,15
Faculty of Economics and Administrative Sciences	17589,35
Faculty of Education	12344,3
Faculty of Architecture	3149,95
Faculty of fine arts	930,75
High school of Physical Education and Sports	3401,8
Physical Therapy and Rehab. High School	1967,35
Bolu School of Health	2843,35
Faculty of Dentistry	2171,75
Faculty of Engineering	5902,05
Faculty of Theology	5120,95
Faculty of Agriculture	11179,95
Health Services Vocational School	1941,8
KYK Student Dormitories	21779,55

16. Warehouse Volume Calculation

The tank volume of the systems should be calculated considering the month of May when the maximum rainfall occurs.

The amount of precipitation in May: 60.3 mm.

Tank volume = roof square meter * amount of precipitation (mm) * roof coefficient * filter efficiency coefficient

Table 9. Tank volumes

Building	Tank volume (m^3)
Rectorate	73,8072
Faculty of Arts and Sciences	189,7279
Faculty of Economics and Administrative Sciences	189,7279
Faculty of Education	201,6673
Faculty of Architecture	94,64688
Faculty of fine arts	106,3692
High school of Physical Education and Sports	114,1841
Physical Therapy and Rehab. High School	59,74042
Bolu School of Health	60,7824
Faculty of Dentistry	149,4379
Faculty of Engineering	144,7055
Faculty of Theology	66,77381
Faculty of Agriculture	205,7918
Health Services Vocational School	34,94988
KYK Student Dormitories	161,9417

17. Total Cost

Table 10. Total cost

Building	Warehouse prices (Pre galv) (TL)	Filter (TL)	Submersible pump (TL)	Total price (TL)
Rectorate	44000	500	400	44900
Faculty of Arts and Sciences	80000	500	400	80900
Faculty of Economics and Administrative Sciences	80000	500	400	80900
Faculty of Education	80000	500	400	80900
Faculty of Engineering and Architecture	44000	500	400	44900
Faculty of fine arts	55000	500	400	55900
High school of Physical Education and Sports	55000	500	400	55900
Physical Therapy and Rehab. High School	33000	500	400	33900
Bolu School of Health	33000	500	400	33900
Faculty of Dentistry	66000	500	400	66900
Faculty of Engineering	66000	500	400	66900
Faculty of Theology	33000	500	400	33900
Faculty of Agriculture	100000	500	400	100900
Health Services Vocational School	20000	500	400	20900
KYK Student Dormitories	80000	500	400	80900

18. Depreciation Period

Bolu water price (m^3) = 2.7 TL

Table 11. Depreciation periods

Cost calculation	Depreciation Period (Year)
Rectorate	19
Faculty of Arts and Sciences	13
Faculty of Economics and Administrative Sciences	13
Faculty of Education	12
Faculty of Architecture	15
Faculty of fine arts	16
High school of Physical Education and Sports	15
Physical Therapy and Rehab. High School	18
Bolu School of Health	17
Faculty of Dentistry	14
Faculty of Engineering	14
Faculty of Theology	16
Faculty of Agriculture	15
Health Services Vocational School	18
KYK Student Dormitories	15

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