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ARTVIN ÇORUH UNIVERSITY
GRADUATE EDUCATION INSTITUTE
DEPARTMENT OF NATURAL RESOURCE MANAGEMENT

ANALYSIS OF RAINWATER HARVESTING IN THE CONTEXT OF SUSTAINABLE WATER MANAGEMENT: ARTVIN ÇORUH UNIVERSITY

MASTER THESIS

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Supervisor

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ARTVIN-2025

THESIS DECLARATION

This study titled “Analysis of Rainwater Harvesting In The Contex Of Sustainable Water Management: Artvin Çoruh University” under the responsibility of my advisor Assoc. Prof. Dr. Elanur ADAR YAZAR from beginning to end, that I have shown the information I received from other sources in the text and bibliography completely, and that I have acted in accordance with scientific research and ethical rules during the study process. I declare that I accept all kinds of legal consequences in case the contrary occurs.

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I hope that the research will be useful to practitioners in terms of scientific and technical aspects.

Esra ATAK ÇELEBI
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ABSTRACT

ANALYSIS OF RAINWATER HARVESTING IN THE CONTEXT OF SUSTAINABLE WATER MANAGEMENT: ARTVIN ÇORUH UNIVERSITY

Water is the source of life and living things. It is a continuous value in a cycle between oceans, atmosphere and soil. Approximately 71% of the Earth's surface is covered with water. Around 97.5% of the earth's water resources are seas and oceans, while glaciers, groundwater and surface water make up 2.5%. Among these, only 0.3% freshwater resources suitable for ecosystem and human use. Recognizing the vital role of water, a precious natural resource, it is crucial that individuals use it responsibly and avoid waste. The scarcity of freshwater and the expensive processes required to purify it have prompted innovative solutions. Consequently, many nations are exploring and prioritizing alternative water sources as a strategy for the sustainable management of their natural resources.

Countries around the world should consider rainwater as an alternative to conserve water and make maximum use of it. Rainwater harvesting involves capturing and storing rainwater, along with any water that flows off surfaces during rainfall. Collecting water from collection areas such as roofs in urban buildings to meet domestic, industrial, agricultural and environmental demands is an extremely necessary saving measure due to the scarcity of water resources or simply to save water. In this way, water resources will be protected.

In this thesis, the feasibility of rainwater harvesting for Artvin Çoruh University Central and Seyitler Campuses was investigated. The calculations and results show that when the rainwater harvesting system is applied for both campuses, the project pays its initial cost in 19 years, which means that the project is efficient.

Keywords: Water saving, Rainwater harvesting, Sustainability, Natural resource, Cost analysis, SWOT analysis, Efficiency

ÖZET

SÜRDÜRÜLEBİLİR SU YÖNETİMİ KAPSAMNDA YAĞMUR SUYU HASADININ ANALİZİ: ARTVİN ÇORUH ÜNİVERSİTESİ

Su; hayatın ve canlıların yaşam kaynağıdır. Okyanuslar, atmosfer ve toprak arasında bir döngüde sürekliliği olan bir değerdir. Dünya yüzeyinin yaklaşık %71'i sularla kaplıdır. Yeryüzündeki su kaynaklarının yaklaşık %97,5'ini deniz ve okyanuslar; %2,5'lik kısmını ise buzullar, yer altı ve yer üstü suları oluşturmaktadır. Bunun da yalnızca %0,3'ü ekosistem ve insan kullanımına elverişli tatlı su kaynaklarından oluşmaktadır. Değerli bir doğal kaynak olan suyun hayati rolünü kabul ederek, bireylerin onu sorumlu bir şekilde kullanması ve israftan kaçınması çok önemlidir. Tatlı su kıtlığı ve onu arıtmak için gereken pahalı süreçler yenilikçi çözümleri teşvik etmiştir. Sonuç olarak, birçok ülke doğal kaynaklarının sürdürülebilir yönetimi için bir strateji olarak alternatif su kaynaklarını araştırmakta ve önceliklendirmektedir.

Dünya ülkeleri suyu tasarruflu kullanıp, sudan maksimum faydalanabilmek için yağmur suyunu bir alternatif olarak düşünmelidir. Yağmur suyu hasadı, yağmur suyunu ve yağmur sırasında yüzeylerden akan suları yakalamayı ve depolamayı içerir. Su kaynaklarının az olmasından dolayı ya da sadece su tasarrufu sağlamak amacıyla; evsel, sanayi, tarım ve çevresel amaçlı talepleri karşılamak için kentsel yapılardaki çatı gibi toplama alanlarından suyun toplanması son derece gerekli bir tasarruf önlemidir. Bu sayede su kaynakları korunmuş olacaktır.

Bu tezde Artvin Çoruh Üniversitesi Merkez ve Seyitler Yerleşkeleri için yağmur suyu hasadının uygulanabilirliği incelenmiştir. Yapılan hesaplamalar ve sonuçlar göstermiştir ki yağmur suyu hasat sistemi her iki yerleşke için uygulandığında 19 yılda proje ilk maliyetini ödemekte bu durum da projeden verim sağlandığı anlamı taşımaktadır.

Anahtar Kelimeler: Su tasarrufu, Yağmur suyu hasadı, Sürdürülebilirlik, Doğal kaynak, Maliyet analizi, SWOT analizi, Verimlilik

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LIST OF ABBREVIATIONS

DSI	Devlet Su İşleri
FAO	Food and Agriculture Organization
H_2O	Water
HDPE	High Density Polyethylene
ISKI	İstanbul Su ve Kanalizasyon İdaresi
ITU	İstanbul Teknical University
LEED	Leadership in Energy and Environmental Design
MGM	Meteroloji Genel Müdürlüğü
MIT	Massachusetts Teknoloji Enstitüsü
NPV	Net Present Value
OECD	Organisation for Economic Cooperation and Development
OGM	Orman Genel Müdürlüğü
RWH	Rainwater Harvesting
TOB	Tarım ve Orman Bakanlığı
USA	Unıted States Of Amerıca
WTA	Withdrawal-to-Availability Ratio
WWAP	World Water Assessment Programme
$	Dollar

1. INTRODUCTION

Water is the source of life and living things. It is a continuous value in the cycle between oceans, atmosphere and soil. Approximately 71% of the Earth's surface is covered with water. Approximately 97.5% of the earth's water resources are seas and oceans, and 2.5% are glaciers, groundwater and surface water. Of this, only 0.3% consists of freshwater resources suitable for ecosystem and human use. Responsible water usage by individuals is paramount, given that it's a vital natural resource; waste should be avoided. Over the years from ancient times to the present day, water resources have started to decrease for various reasons. With the industrial revolution, the increasing consumption and population density in the world has increased the use of water, and at the points where sufficient precautions are not taken about wasting water, it has entered the process of depletion before completing the water cycle. Limited freshwater availability and the costly nature of obtaining potable water have compelled a search for alternative solutions. This has made finding alternative water resources a pressing need for sustainable resource management, increasingly adopted worldwide. In the future, countries that do not pay attention to the importance of water, do not incorporate water saving measures into life, do not consider rain, which is a natural resource, as an alternative, and do not follow awareness-raising policies for their citizens on this issue will definitely have problems.

Countries around the world should consider rainwater harvesting as an alternative to conserve and maximize the use of water. Rainwater harvesting involves capturing and retaining both rainwater and the water that flows off surfaces. Collecting water from collection areas such as roofs in urban buildings to meet domestic, industrial, agricultural and environmental demands is an extremely necessary saving measure due to the scarcity of water resources or simply to save water. In this way, water resources will be protected and floods that will be encountered in excessive rainfall will be eliminated when excess water is stored with the necessary measures.

Since the protection and sustainability of each natural resource is inevitable in the technologically rapidly developing world, it is absolutely necessary to make the necessary investments in rainwater harvesting, not to create reservations on this issue, and to raise awareness of the society by making the necessary legal regulations. Countries that invest in their natural resources are favorable for faster growth and development. As people see and evaluate their countries in this development, they will ensure that they leave a better country to their future generations by saving water.

1.1 Thesis Purpose and Importance

In an age where resources are becoming scarce and many countries are experiencing water scarcity, the economical use of water, which is the most valuable natural resource, is an extremely important issue. Although Turkiye is perceived as a country with abundant water resources, the reality is different when climate change and diminishing natural resources are considered. Turkiye has started to enter the class of countries experiencing water stress and will experience water scarcity in the next 50 years if necessary measures are not taken. For all these reasons, the rainwater harvesting to be calculated based on Artvin Çoruh University Central and Seyitler Campuses in Artvin province and its contributions to water saving express the importance of this thesis. The aim of this thesis is to see the contribution of rainwater to sustainability, to witness that it reduces costs when it is saved, and to clarify this issue objectively with the calculations made. The water consumption data for Artvin Çoruh University Central and Seyitler Campuses for the year 2023 and the values to be calculated with the precipitation data of Artvin province will contribute to the results of this study.

1.2 Literature Review

1.2.1 Water Resources and Distribution

Water is one of the most important natural resources for all living things. In other words, water is the source of life and living things (Aksungur & Firidin, 2008). Water, which is the main cause of life on earth, is a valuable environmental resource that can be found in solid, liquid or gaseous form. It is a continuous value in a cycle between oceans, atmosphere and soil. Developing and managing water resources to ensure water security in response to increasing demand is essential for growth and sustainable development. This is true not only for developing countries but also for developed countries (Hakyemez, 2019).

The main sources of water on earth are oceans, seas, lakes, glaciers, rivers and groundwater. The waters on earth are in a continuous cycle. Some of the water enters the atmosphere as water vapor through evaporation caused by the energy coming from the Sun and the perspiration of plants. Water vapor descends back to the earth as precipitation as a result of some activities it undergoes in the atmosphere. While some of the precipitation that lands on land seeps underground and forms groundwater, some of it passes into surface flow and reaches lakes and seas with rivers. This movement of water is called the water cycle (hydrological cycle). Through the water cycle, the world's available water potential is constantly replenished in a perfect way. However, excessive consumption and pollution cause the available water resources to decrease day by day (Anonymous1, 2022).

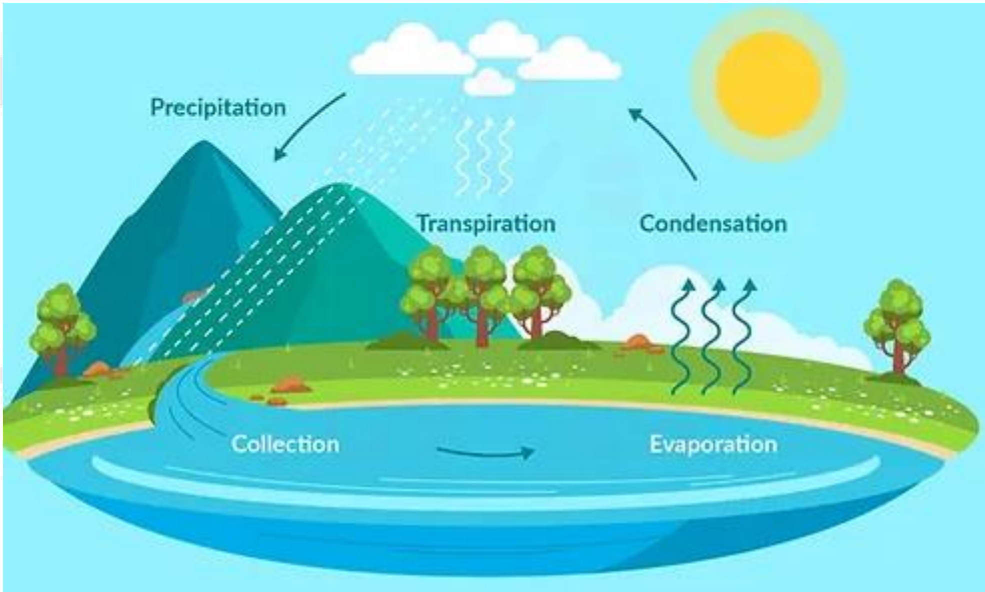

Figure 1. The water cycle (Anonymous 1, 2022)

Approximately 71% of the earth's surface is covered with water and 97.5% of the earth's water resources are salty seas and oceans and 2.5% are glaciers, ground and surface waters (Shiklomanov, 2003). Although three quarters of the Earth's surface is covered with water, the amount of fresh water available for human use is very limited. The total amount of freshwater on Earth is about 35 million km^3 (i.e. 2.5% of the total water on Earth), of which only 0.3% (about 105000 km^3) consists of freshwater resources suitable for ecosystem and human use. The remaining freshwater is mostly preserved in the poles, high mountain glaciers and underground reserves (Muluk et al., 2013).

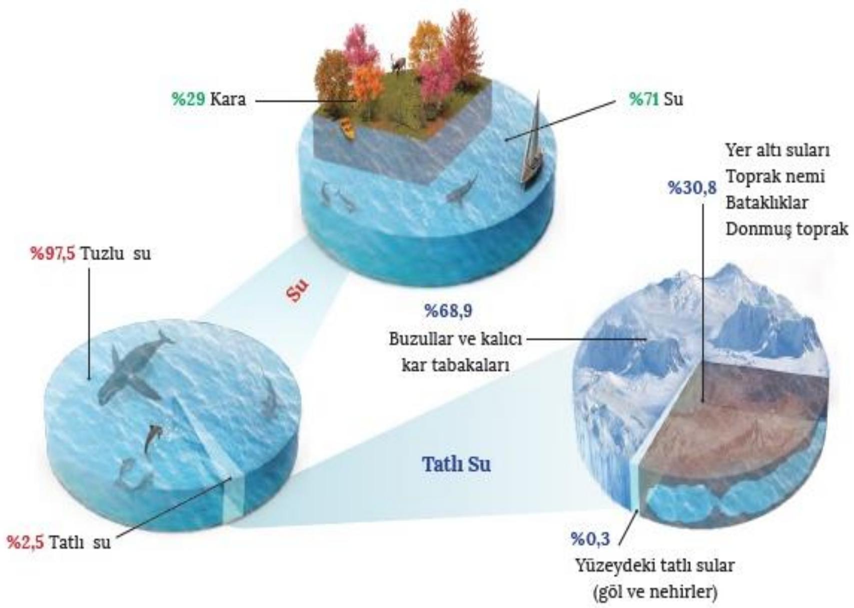

Figure 2. Distribution of water resources in the world (Anonymous 2, 2024)

Today, while the world population is increasing rapidly, potable and usable water resources are decreasing. Very few of the world's water resources are potable and usable. Due to reasons such as population growth, environmental pollution, unconscious water consumption, global warming and changes in climatic conditions, water is consumed before completing its cycle. This situation causes the need for water to increase day by day and increases the strategic importance of water day by day. Water resources are unevenly distributed throughout the world. While America, North Asia, Australia and Central Europe stand out in terms of water resources, North Africa, the Middle East and Southeast Asia face water scarcity (Alpaslan et al., 2008). Many countries are already facing water scarcity. This situation forces countries to take compulsory measures. Global water consumption has increased six times in the last 100 years (Üstün et al., 2020). According to the Risk Report prepared for the World Economic Forum in 2014, water scarcity is among the top three risks in the world. Currently, about one-fifth of the world's population (1.2 billion people) live in places with water shortages, while 1.6 billion people cannot access healthy water due to lack of infrastructure and economic reasons (Eren et al., 2016). Water demand, which increases by approximately 1% per year due to population growth, economic developments and changes in consumption habits, will continue to increase significantly in the next two decades (WWAP, 2018).

1.2.2 Uses of Water

Water is the main element that forms the network of relationships with energy, food and environment (Muluk et al., 2013). There are many sectors where water is required, including human use, ecosystem use, economic development, energy production and national security (Aksungur and Firidin, 2008). Agriculture, energy, food, industry, social dynamics and environmental rights are the main areas that need to be addressed in this process (Figure 3).

Water use can be categorised under four main headings;

1- Food and agriculture (the most water-intensive sectors globally),

2- Energy and industry,

3- Domestic use (use for drinking and potable water),

4- Ecosystems

Each water use area is driven by many different factors (such as demographic changes, technological developments, economic growth and prosperity, changes in eating habits and social and cultural values) and as a result, current and future water demand plans are made in line with these changes. However, it is difficult to predict how all these factors will affect water demand in the coming years due to uncertainties.

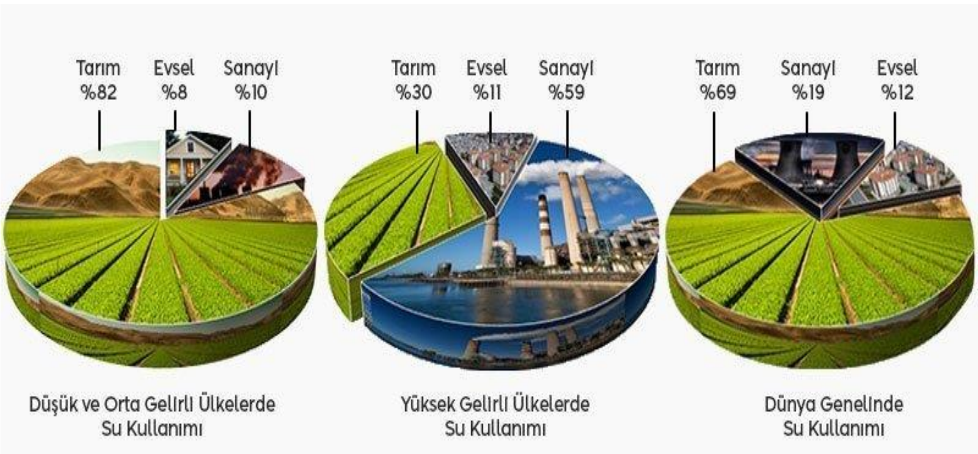

Figure 3. Sectoral use of water in the world (Anonymous 3, 2022)

The need for water in the future requires forecasting how to utilize limited water resources with growing population and changing socio-economic structure as well as food, energy and industrial needs (Muluk et al., 2013).

Water Use in Food and Agriculture

Water is essential for the production of income-generating agricultural services. The agricultural sector is one of the most intensive and inefficient water users. According to World Bank data, more than 69 per cent of fresh water is used for agriculture in many parts of the world. However, this rate varies significantly from country to country (Hakyemez, 2019).

Nevertheless, irrigated agriculture yield is about 2.7 times higher than dry agriculture (rain-fed). This situation strengthens the possibility of opening more areas to irrigated agriculture in the future. The amount of land under irrigated agriculture in the world increased from 170 million hectares in 1970s to 304 million hectares in 2008 (FAO, 2011). This figure is expected to increase to 330 million hectares in 2025 with the opening of areas with high agricultural potential to irrigated agriculture worldwide. Today, agricultural water use worldwide is approximately 3100 km^3 (69% of total use). Unless various measures are taken for effective utilisation, this amount is estimated to be 4500 km^3 in 2030 (65% of global water use). Therefore, water-related problems are closely linked to agricultural production, food supply and trade (Muluk et al., 2013).

According to the Organisation for Economic Cooperation and Development (OECD) report, the agricultural sector will face the challenge of meeting the increasing food demand in the coming decades; global food consumption is estimated to increase by 50% in 2030 and 100% in 2050 compared to today (OECD, 2012). It is predicted that this increase cannot be met with the existing water potential and that the increase in agricultural water demand can be kept at 14% by increasing productivity in agriculture. In this case, the agricultural sector will need to produce more agricultural products using less water (WWAP, 2006).

There is a different relationship between agriculture and climate change. Agricultural activities cause climate change by releasing methane and greenhouse gases into the atmosphere. However, at the same time, agriculture is one of the sectors that will be most intensely affected by the effects of climate change. Another issue that has gained importance in recent years is agricultural activities for biofuel production. With the increasing demand for biofuels, agricultural activities for biofuel production have increased considerably in many countries. Therefore, crop production for biofuels has started to create additional pressure on water resources (Muluk et al., 2013).

Water Use in Energy and Industry

The second largest water consumption activity in the world takes place in the commercial and industrial sectors. Approximately 20 per cent of water use worldwide takes place in these sectors. Although the amount of water used in industry is less than that used in agriculture, the need for accessible and sustainable water resources in industrial use is increasing (Muluk et al., 2013). This situation varies from country to country. In developed countries, water use in the industrial sectors is around 50 per cent, while water use in the agricultural sector is relatively lower. The energy sector, which is located between the commercial and industrial sectors, consumes approximately 75% of the total amount of water used by these sectors alone. In 2016, the energy sector withdrew about 340 billion cubic metres of water and consumed about 50 billion cubic metres of it. More than one third of the total water withdrawn in the energy sector is used as cooling water in coal-fired power plants. Worldwide, primary energy production accounts for more than two thirds of water consumption. Most of this amount is used in fossil fuel and biofuel production.

The textile industry is another water-intensive sector. According to the United States Environmental Protection Agency, the production of a single pair of jeans requires 10000 litres of water. Another water-intensive sector is meat production and the soft drink industry. The Water Footprint Network estimates that the production of ingredients for a single coffee cup requires roughly 130 liters of water. The global automotive industry is another sector that consumes significant amounts of water as it uses water in various production processes. According to some estimates, more than 39 thousand gallons of water is consumed to produce a car (Hakyemez, 2019).

Domestic Water Use

Domestic water use is assessed on the scale of daily water consumption per capita. In households, water is mainly used for eating and drinking and cleaning. This situation varies greatly between regions and countries: While 20 litres of water per person per day is used in rural and arid areas of the African continent, the average water use in the United States is 300 litres per person per day (Hakyemez, 2019). For example, in Asia, Africa and Latin America, daily water withdrawal per capita varies between 50-100 m^3. In water-scarce regions, this figure drops to 20-60 m^3 per person per day. Global population growth projections predict that the human population will increase by 2.2 per cent to 9.2 billion by 2050. At the same time, the urban population is expected to increase by 2.8 billion, reaching 70% of the total population. As a result, urban population growth will be a serious problem in the next 40-50 years. The majority of this projected population increase is expected to take place in areas that are either developing or underdeveloped (Muluk et al., 2013).

Compared to other sectors, domestic water use is quite low. Increasing water demand with population growth leads to overuse and depletion of groundwater resources. The current domestic water use rate of about 11 per cent is generally assumed to remain unchanged (Muluk et al., 2013). Table 1. shows water withdrawals and sectoral utilisation in different countries.

Table 1. Freshwater withdrawals and sectoral freshwater use by country (Muluk et al., 2013)

Country	Total freshwater withdrawal (km^3/year)	Freshwater withdrawal per capita (m^3/person/year)	Domestic use (%)	Industrial utilization (%)	Agricultural use (%)	2010 population (million)
Angola	0.4	18	23	17	60	19
Egypt	68.3	809	8	6	86	84
Somalia	3.3	352	0	0	99	9
Canada	45.1	1330	20	69	12	34
USA	482.2	1518	13	46	41	318
Brazil	58.1	297	28	17	55	195
China	578.9	425	12	23	63	1362
India	761.0	627	7	2	90	1214
Israel	2.0	268	36	6	58	7
Japan	88.4	696	20	18	62	127
Turkiye	40.1	530	15	11	74	76
France	33.2	529	16	74	10	63
Russia	76.7	546	19	63	18	140
England	11.8	190	22	75	3	62
Avustralia	59.8	2782	15	10	75	22

Sectoral water use by country also reflects the level of development. Although agricultural water usage averages around 82% in developing and less developed nations, this figure decreases significantly to 30% in developed nations (Muluk et al., 2013). For example, the water used for irrigation in Spain is 70% of the total water used, in Greece 80%, in Portugal 80% and in Italy about 50%. In high-income countries, agricultural water use is replaced by the industrial sector.

Utilization of Water in Ecosystems

All freshwater resources require continuous and healthy ecosystems, so ecosystems (forests, wetlands and grasslands) are always at the centre of the global water cycle. Understanding the water cycle as a biophysical process is essential for sustainable water use. Ecosystems have historically been perceived as non-productive water users, but this is a misconception. Ecosystems do not use water, but rather recycle it. All ecosystem services, such as climate regulation, soil fertility, food production, flood control and nutrient recycling are supported by the presence of water. The availability and quality of water is an ecosystem service for direct human use, such as flood prevention and mitigation of extreme droughts. One ecosystem service should not be favoured over another (Muluk et al., 2013).

1.2.3 Water Scarcity

Water is an essential and important resource for economic development and the maintenance of healthy ecosystems. An ecosystem encompasses all organisms and their interrelationships, as well as their interactions with the non-living world. Water, a critical component and often considered the lifeblood of the ecosystem, faces increasing pressure. As human populations grow, and with rising agricultural and industrial water demands, the strain on water resources intensifies. This imbalance between water availability and needs generates a global challenge known as water scarcity. Defined internationally, water scarcity is characterized by the inability to fully meet the demands of all water users, whether in terms of volume or quality, under current institutional frameworks (Falkenmark et al., 1989).

The concept of water scarcity can be divided into two: physical water scarcity and economic water scarcity. While physical water scarcity refers to the insufficiency of natural water resources to meet the demand of a region, economic water scarcity occurs as a result of poor management of natural water resources that are sufficient. Although water scarcity usually occurs in regions with low rainfall, it can create serious problems in different regions due to human activities, population density, intensive agriculture and water-intensive sectors (Figure 4) (Hakyemez, 2019).

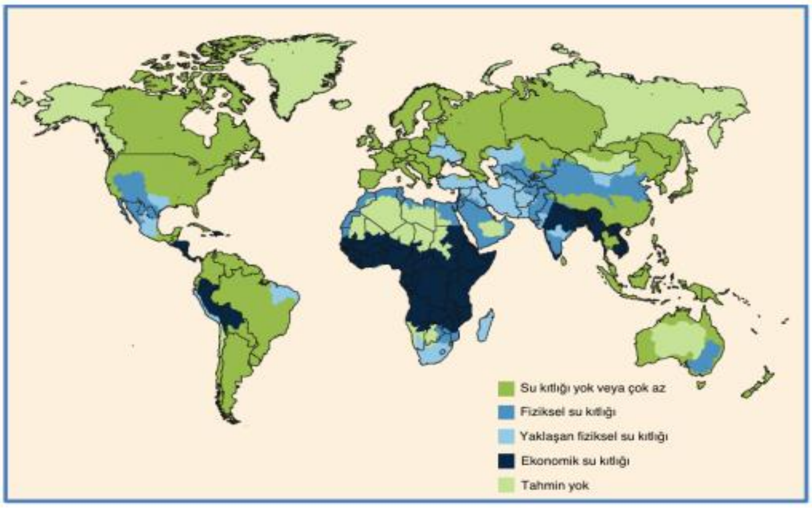

Figure 4. World water scarcity map (WWAP, 2012)

A study conducted by researchers at the Massachusetts Institute of Technology (MIT) (Schlosser et al., 2014) projects that by 2050, about half of the world's anticipated population of 9.7 billion will experience moderately stressed water supply situations.

In a study by Padowski et al. (2015), water vulnerability is often caused by water resource shortages and management problems, but can be mitigated by a number of economic investments (e.g. desalinization, transporting water from distant locations). In addition, Padowski et al. (2015) show that in 40% of low-income countries, it is noteworthy that institutional problems (especially corruption) are among the most important drivers of water vulnerability. This is not just a concern but a reality in 119 low-income countries. Twenty-five countries identified water vulnerability as a major problem.

How to Measure Water Scarcity

Water scarcity is becoming a major issue in the world and is expected to become widespread and affect a larger population. For this reason, both the public and private sectors have increased research on water scarcity in the last decade. Within the framework of these studies, there are various indicators developed to show the state of water scarcity in the world.

a. Falkenmark Indicator

In 1989, Swedish water expert Malin Falkenmark introduced the Falkenmark Indicator, a widely recognized tool for assessing water stress. This indicator is determined by measuring the yearly per capita availability of water within a given country or region. The Falkenmark Indicator is calculated by dividing a country's or region's total water resources by its population, as represented in Equation 1. Falkenmark also established classifications, shown in Table 2, to characterize varying levels of water stress and scarcity.

$$\text{Falkenmark Indicator} = \frac{\text{Available water resources}}{\text{Population}} \qquad (1)$$

Table 2. Falkenmark indicator classes

Falkenmark Indicator (m^3/person/year)	Class name
>1700	No Stress
1000-1700	Water Shortage
500-1000	Scarcity
<500	Absolute Scarcity

Water availability of more than 1700 m^3/person/year is defined as the threshold below which water scarcity occurs only sporadically or locally. If the indicator is below this amount, water scarcity is classified into different degrees of severity. At less than 1700 m^3/person/year, water stress occurs regularly, but below 1000 m^3/person/year, water scarcity is the limit of water scarcity for economic development, human health and well-being. Less than 500 m^3/person/year is a fundamental constraint to life (Falkenmark et al., 1989).

b. Withdrawal-to-Availability Ratio

The Withdrawal-to-Availability (WTA) index is another metric employed for assessing water scarcity. The WTA is calculated as the proportion of a region's total yearly water withdrawals to its annual water supply (Equation 2) (Table 3).

$$\text{WTA} = \frac{\text{Total Available Withdrawals}}{\text{Annual Water Supply}} \qquad (2)$$

Table 3. Withdrawal-to-availability ratio classes

Index (%)	Class name
<10%	Minimal Risk
10% -20%	Moderate Risk
20% - 40%	Medium Risk
>40%	High Risk

Using a regional approach, areas are classified as facing "Medium Risk" when their yearly water withdrawals constitute 20% to 40% of their annual water supply. A "High Risk" designation is assigned if this ratio surpasses 40% (Hakyemez, 2019).

1.2.4 Water Stressed Countries

While the Falkenmark Indicator generally decreases as population increases, some densely populated countries surprisingly exhibit high Falkenmark Indicator values. As evidenced in Table 4, nations such as Russia, the United States, and Brazil, despite their large populations, possess high indicators and therefore do not suffer from water stress. Canada, noted for its extensive forests, has the highest Falkenmark Indicator owing to its relatively small population. In contrast, China, which possesses the world's largest supply of renewable freshwater, has a low indicator because of its immense population. Despite having moderate renewable freshwater, Algeria faces absolute water scarcity due to its substantial population. Malta, a Mediterranean island nation, also faces absolute scarcity because of its limited renewable water resources. Furthermore, Table 4 reveals that Israel has the lowest Falkenmark Indicator among the countries listed. Although possessing more renewable water than Malta, its relatively large population places it at the bottom of the list (Hakyemez, 2019).

Table 4. Falkenmark indicators of selected countries (Hakyemez, 2019)

Country	Renewable Freshwater Resources (milion m^3)	Population (milion)	Falkenmark Indicator (2015)
Canada	2902000	35832513	80988

Table 4 (Continued) Falkenmark indicators of selected countries (Hakyemez, 2019)

Norway	289927	5166493	56117
Brazil	8233000	205962108	39973
Russia	4525000	144096870	31402
Croatia	114550	4225316	27110
Sweden	222833	9747355	22.861
Serbia	159185	7114393	22375
Congo	1283000	76196619	16838
Ireland	71786	4677627	15347
Bulgaria	105982	7202198	14715
Slovakia	66601	5421349	12285
Albania	30818	2885796	10679
USA	3069000	321039839	9560
Hungary	91697	9855571	9304
Bangladesh	1227000	161200886	7612
Switzerland	51173	8237666	6212
Nigeria	950000	181181744	5243
Netherland	81802	16900726	4840
Spain	162392	46449565	3496
France	196846	66456279	2962
China	2840000	1371000000	2071
Romania	34827	19870647	1753
Germany	132000	81197537	1626
Turkiye	111990	78741053	1422
Polond	40797	38005614	1073
Czech Republic	10020	10538275	951
South Africa	51350	55291225	929
Algeria	11670	39871528	293
Malta	98	439691	223
Israel	1800	8380100	215

Despite being surrounded by water on three sides, Turkiye can be said to be a “water stressed” country. In 2015, the amount of water per capita was calculated 1422 m^3, while this figure was 1386 m^3 in 2017. Considering Turkiye's annual water potential, assuming a population of 83.6 million in 2020, the amount of available water per capita is 1347 m^3/year. According to Falkenmark index values, Turkiye is not a country rich in water potential, it is a country suffering from water stress (water shortage). According to the Falkenmark Water Stress Index, and considering the effects of population growth and climate change, it may be among the water-constrained countries in the coming years (TOB, 2021a). Turkiye will have water-stressed country and water potential of 1120 m^3 in 2023 (Hakyemez, 2019).

1.2.5 Water Resources and Distribution in Turkiye

Turkiye is not a country rich in fresh water. Turkiye has an area of 783562 km^2 and its average height above sea level is 1132 m. Turkiye has a semi-arid climate. The only source of surface and groundwater is rainfall. According to the data of the General Directorate of Meteorology, when precipitation, which is the most important source of water, is analyzed, Turkiye's average precipitation is 574 mm and the average annual precipitation across the country is below the world average (800 mm) (TOB, 2021a). Although there are regional differences depending on the precipitation regime, climate characteristics and seasonal characteristics, the annual precipitation amount is calculated as 450 billion m^3 (DSİ, 2020). The highest precipitation is observed in the Eastern Black Sea Region and the lowest in the central parts of Central Anatolia (Figure 5) (TOB, 2021a).

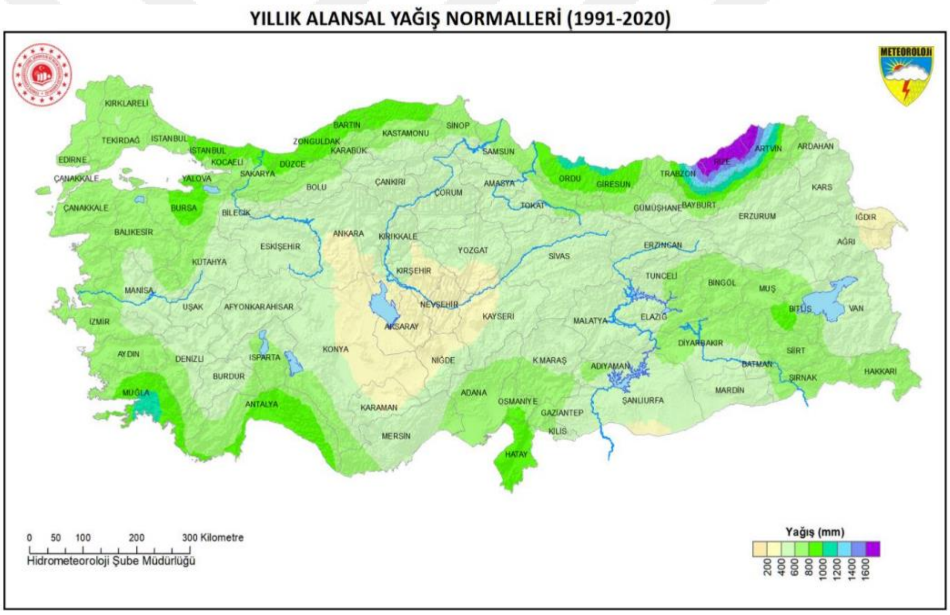

Figure 5. Areal rainfall normals for Turkiye (1991-2020) (MGM, 2022)

Topographical differences cause climatic differences. The average altitude in Turkiye is approximately 1100 - 1200 meters. While the average altitude is lower in the western regions, it is higher in the eastern and interior regions. Therefore, the Central Anatolia and Eastern Anatolia regions with high plateaus and mountain ranges receive much more snowfall. The coastal areas have a Mediterranean climate with long, hot and dry summers and short mild, rainy winters. However, on the Central Anatolian plateau, where winters are cold and summers are extremely hot, precipitation rates are very low. As a result, rainfall varies greatly in the country, ranging from 250 mm in the southeastern regions to over 3000 mm on the Black Sea coast. The distribution of total annual precipitation in Turkiye is given in Figure 6.

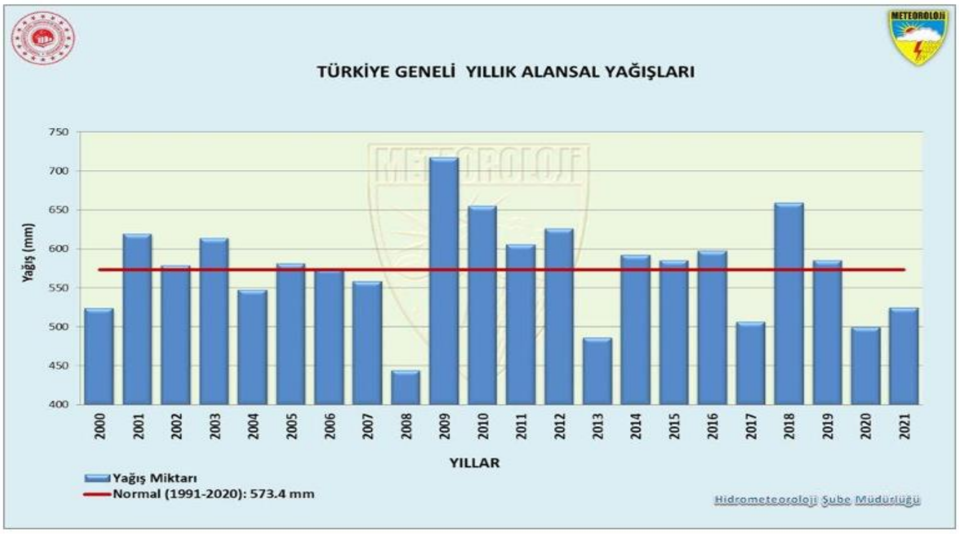

Figure 6. Distribution of total annual precipitation (MGM, 2022)

Turkiye's water resources are composed of natural lakes, rivers, dams, and groundwater reserves. The nation is home to over 120 lakes, with Lake Van being the most expansive. Furthermore, Turkiye boasts more than 700 dams, with the Atatürk, Keban, and Karakaya Dams among the largest (DSI, 2020).

Considering the amount of precipitation falling on Turkiye, 274 km^3 of this water returns to the atmosphere through evaporation from soil, water surface and plants, 69 km^3 of it feeds the groundwater, and 158 km^3 of it flows and discharges into the seas and lakes in closed basins through rivers of various sizes. 69 km^3 of water that feeds the groundwater, 28 km^3 of it rejoins the surface water through springs. In addition, there is an average of 7 km^3 of water coming from neighboring countries annually. Thus, Turkiye's gross surface water potential is 193 km^3. Taking into account the 41 km^3 that feeds groundwater, the total renewable water potential is calculated as 234 km^3 gross. However, the surface water potential that can be consumed within the framework of today's technical and economic conditions is 95 km^3 from domestic rivers and 3 km^3 from rivers coming from neighboring countries, totaling 98 km^3 on average per year. Together with 14 km^3 of groundwater potential, Turkiye's consumable surface and groundwater potential is 112 km^3 per year on average. With the studies carried out to date, only 44 km^3 (39%) of this reserve can be utilized (DSI, 2018). (Figure 7 and Table 5)

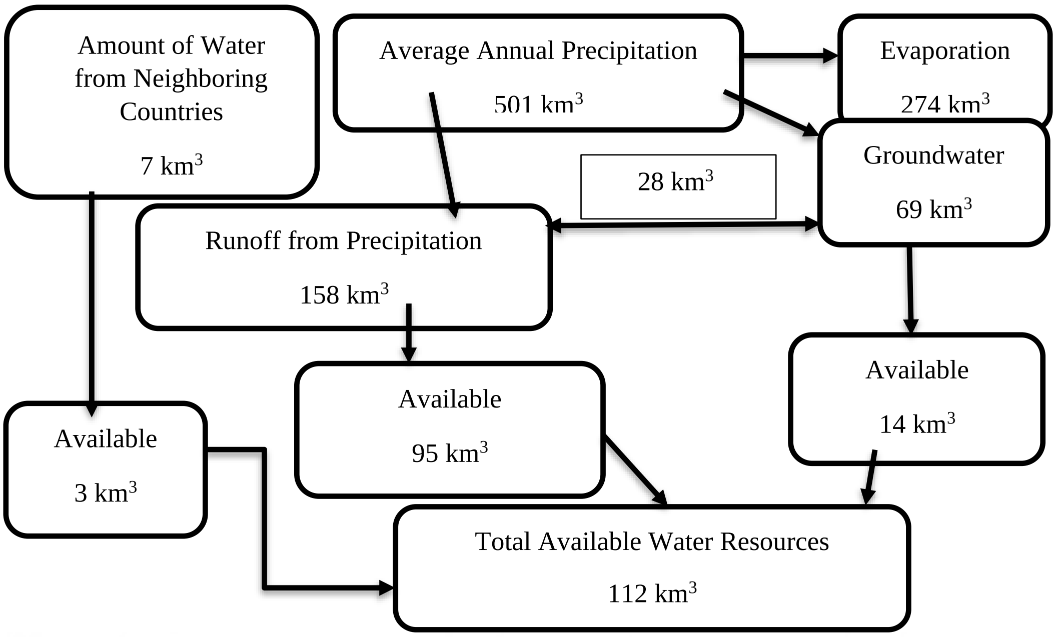

Figure 7. Turkiye's water potential (Kalkınma Bakanlığı, 2018)

Table 5. General information on precipitation, population and water potential of Turkiye (TOB, 2021a)

Total annual rainfall	450 km^3
Average annual area rainfall	574 mm
Annual average runoff amount (natural runoff)	185 km^3
Annual available surface water amount	94 km^3
Groundwater safe reserve amount	18 km^3
Total annual available water amount	112 km^3
Country population	83.6 milion
Annual water amount per capita	1347 m^3

Hydrologically, Turkiye consists of 25 large basins (Figure 8 and Table 6) where average annual precipitation, evaporation and surface water flows vary greatly (DSI, 2018). Annual precipitation amounts and intra-annual precipitation amount distributions in the basins vary greatly.

Figure 8. Map of Turkiye's water basins (DSI, 2018)

Table 6. Annual average water potential by basins (DSI, 2020)

Basin No	Name of Basin	Average Natural Flow (hm^3)	Average Annual Yield ($I/s/km^2$)
1	Meriç – Ergene & Marmara	1657	3.6
2	Marmara	7442	10.2
3	Susurluk	4963	6.5
4	Kuzey Ege	1985	6.4
5	Gediz	1776	3.3
6	Küçük Menderes	624	2.8
7	Büyük Menderes	3047	3.7
8	Batı Akdeniz	6499	9.8
9	Antalya	12944	20.3
10	Burdur	234	1.2
11	Akarçay	375	1.5
12	Sakarya	6487	3.2
13	Batı Karadeniz	10797	11.9
14	Yeşilırmak	7046	5.6
15	Kızılırmak	7004	2.7
16	Konya Kapalı	2407	1.5
17	Doğu Akdeniz	7559	11.3
18	Seyhan	6183	8.9
19	Asi	1782	7.2
20	Ceyhan	7734	11.5
21	Fırat	31133	8.1
	Dicle	25183	14.6
22	Doğu Karadeniz	16426	22.8
23	Çoruh	6981	10.9
24	Aras	4480	5.1
25	Van	2602	4.6
Total		185352	7.66

As is the case in the world, there is a disproportionate distribution of water quantity and population in Turkiye. There is an unbalanced distribution between the flow potential of the basins and the population benefiting from these basins. On average, 186 billion cubic meters of water flows annually in river basins (DSI, 2016). While the Çoruh, Western Mediterranean and Antalya basins are water rich, the Marmara, Küçük Menderes and Asi basins are water poor. On the other hand, the situation in the Meriç-Ergene Basin borders on water scarcity. The Marmara region, home to 28% of the nation's population, gathers only 4% of the total runoff. Furthermore, the utilization of surface and groundwater in the Meriç, Ergene, Gediz, Büyük Menderes, Burdur Lake, Akarçay, Konya, and Asi River basins has surpassed the natural replenishment rates of the water resources. This has increased the pressure on the basins and posed a great danger to the natural ecosystem (TOB, 2021a).

The Dicle-Fırat Basin, the largest basin in terms of water potential, is located between Turkiye and the Middle Eastern countries and consists of many large rivers. All of these rivers originate within the borders of Turkiye. The Burdur and Akarçay closed basins stand out as the basins with the lowest water potential compared to the other 23 basins (Hakyemez, 2019).

As a result of the different amounts of precipitation falling on the basins, the uneven distribution of population density, industrialization and urbanization, the inefficient and unsavory application of agricultural activities, the negative effects of sectoral activities on clean water create problems in the context of usage and consumption needs. After all the Falkenmark indicators defining the water stress of the basins were created as in Table 7.

Table 7. Regional Falkenmark indicators for 2015 (Hakyemez, 2019)

Basin Name	Population 2015	Water Potential (billion m^3/year	Falkenmark Indicator (m^3/person/year)	Defination
Meriç – Ergene	749510	0.76	1.014	Water Shortage
Marmara	17608408	2.84	161.06	Absolute Scarcity
Susurluk	3793746	2.57	677.43	Scarcity
Kuzey Ege	1112098	0.88	791.3	Scarcity
Gediz	1588561	0.79	497.31	Absolute Scarcity
Küçük Menderes	4168415	0.46	109.15	Absolute Scarcity
Büyük Menderes	1346490	1.7	1262.54	Water Shortage
Batı Akdeniz	908877	3.87	4258	No Water Stress
Antalya	3341962	7.03	2103.55	No Water Stress
Burdur	680105	0.17	244.08	Absolute Scarcity
Akarçay	709015	0.31	437.23	Absolute Scarcity
Sakarya	7262833	4.03	554.88	Scarcity
Batı Karadeniz	1879209	5.09	2705.93	No Water Stress
Yeşilırmak	2721221	3.1	1139.19	Water Shortage
Kızılırmak	3715291	3.95	1063.17	Water Shortage
Konya Kapalı	3105368	4.9	1577.91	Water Shortage
Doğu Akdeniz	1745221	4.8	2747.50	No Water Stress
Seyhan	2183167	3.55	1626.08	Water Shortage
Asi	1533507	1.18	769.48	Scarcity
Ceyhan	1609483	3.81	2367.22	No Water Stress
Fırat-Dicle	12646409	37.48	2963.81	No Water Stress
Doğu Karadeniz	2404480	9.36	3892.73	No Water Stress
Çoruh	246920	4.46	18064.15	No Water Stress
Aras	584360	3.28	5609.62	No Water Stress
Van Lake	1096397	1.65	1504.93	Water Shortage
Turkiye (2015)	78741053	112	1422.23	Water Shortage

In line with the Falkenmark indicators showing water stress, the current situation in the basins (for 2021) and the water stress that will be experienced in 2050 with the prediction studies are shown in Figure 9. and Figure 10 on the country map (TOB, 2021a).

Figure 9. Current status of water potential per capita in basins (TOB, 2021a)

Figure 10. Water potential per capita in basins projected situation for 2050 (TOB, 2021a)

1.2.6 Uses of Water in Turkiye

In parallel with world, water is mostly consumed in agricultural irrigation (Figure 11). Regarding agricultural irrigation, Turkiye employs conventional techniques that hinder the effective utilization of water. Specifically, traditional surface irrigation is utilized in 94% of the irrigated lands across Turkiye, while sprinkler and drip systems account for the remaining 6% (Muluk et al., 2013). Most water loss is caused by the traditional surface irrigation system. As a method, it is necessary to abandon the traditional irrigation system and significant water can be achieved. In Turkiye, close monitoring and implementation of these developments by the agriculture-based industry will facilitate the transition to modern irrigation systems (Alpaslan et al., 2008).

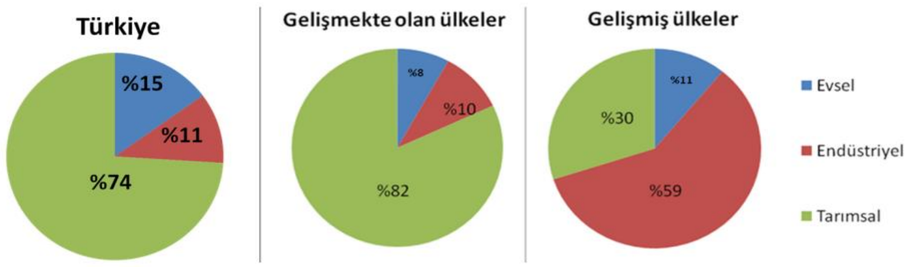

Figure 11. Comparison of Turkiye with developed and developing countries in water use (Kınacı, 2017)

Another major area of water use is urban uses. Today, many cities are experiencing significant water problems. The most important reason for the emergence of these problems is that the need for water has not been sufficiently investigated and analyzed in the planning of development processes. In developed countries, losses in urban networks are below 20%, while in Turkiye this value varies between 40% and 60% (Alpaslan et al., 2008).

Similar to global trends, water use for energy production is increasing in Turkiye along with the rising energy demand. The share of water use has been increasing over the years in industry in Turkiye. The share of water use in industry increased from 4.3% in 2004 to 22% in 2023 (Table 8) (Hakyemez, 2019).

Table 8. Percentages of water use in Turkiye (Hakyemez, 2019)

Year	Irrigation (billion m^3)	Households (billion m^3)	Industry (billion m^3)	Total (billion m^3)
1990	22.0	5.1	3.4	30.5
2004	29.6	6.2	4.3	40.1
2008	33.8	5.8	6.0	45.6
2010	38.2	5.8	6.0	49.9
2012	41.6	6.0	8.4	56.0
2014	35.9	5.7	9.1	50.7
2016	43.1	6.2	11.1	60.4
2023	72.0	18.0	22.0	112.0

Turkiye's 2023 targets include using all 112 billion cubic meters of water potential. In addition, the shares of total water use are targeted at 64% for agriculture, 20% for industry and 16% for households. Including the use of new irrigation techniques, agricultural irrigation is projected to consume 72 billion cubic meters of water. Considering population growth, urbanization and rapidly developing tourism sector, household water use is estimated to be around 18 billion cubic meters in 2023. In the industrial sectors, total water consumption in 2023 is expected to be 22 billion cubic meters (Hakyemez, 2019). If population growth and economic and industrial growth continue, the pressure on Turkiye's water resources is expected to increase in the future (TOB, 2021a). Therefore, it is imperative for Turkiye to protect and efficiently utilize its water resources in order to transfer healthy and sufficient water to future generations.

Considering the vital importance of water, saving and efficient use of the water used, preventing loss and leakage are among the human measures to be taken, while the accumulation of rainwater and its use in necessary places should also be considered within this effective use network.

2. RAINWATER HARVESTING

Rainwater harvesting is the collection and accumulation of rainwater and runoff water. In this way, it is the provision of water required for crop, animal production and domestic consumption (Kantaroğlu, 2009). To make an alternative definition; rainwater harvesting can be defined as the collection of water from collection areas such as roofs in urban buildings to meet domestic, industrial, agricultural and environmental demands in order to save water due to the scarcity of water resources (Üstün et al., 2020).

It is very important that water, which is a natural resource, is used consciously and without waste by people. The limited amount of fresh water resources and the costly methods of obtaining clean water have led people to different searches. It is technically and economically impossible to increase the amount of clean water resources despite the increasing demand for water with the population. This situation has necessitated the search for alternative water resources for the sustainable management of natural resources. Rainwater harvesting has been practiced and emphasized in many countries in recent years (Yalılı Kılıç and Abuş, 2018). By collecting and storing rainwater and using it for different purposes, both water resources are protected and economic gains are provided in water bills.

Even though rainwater harvesting systems are being implemented in many countries of the world today, it cannot be said that developments on this subject are not yet sufficient in Turkiye, which is in the category of countries with water shortage. It is known that solutions such as collecting rainwater in traditional buildings in appropriate seasons and using it when needed have been widely applied in the past. There are definitely water wells around historical buildings. In addition to water wells, the use of cisterns to collect rainwater is quite common in traditional houses. The rainwater method includes regional and in-building rainwater management. Regional rainwater management can reduce water use through agricultural irrigation and water harvesting techniques on a larger scale. With in-building rainwater management, the use of network water can be reduced by collecting rainwater from the roofs of buildings (Tanık, 2017).

Rainwater harvesting potential varies from region to region across Turkiye as it is directly proportional to rainfall (Himat, 2018). The off-grid nature of the harvesting system makes it suitable for dispersed settlements and individual use. Designing rainwater harvesting systems in buildings during the construction of buildings instead of renovating them later will accelerate the widespread use of rainwater harvesting applications (Üstün et al., 2020).

2.1 Characteristics of Rainwater

Water is an odorless and tasteless chemical compound that is abundant on Earth and indispensable for the life of all living things. In nature, water is seen in solid, liquid and gaseous forms. Its chemical formula (H_2O) consists of 2 hydrogen and 1 oxygen atom. It is formed by a neutralization reaction between a substance containing H+ ion and a substance containing OH- ion.

H_2O represents pure water and its compound, the closest example of pure water is rainwater. Pure water is not potable water for living things, it is of no use to humans. Apart from the fact that water is fluid, the minerals it contains are very important for humans and living things. There must be various minerals in the water that living things need to drink. Rainwater, that is, pure water, collects the minerals in the structure of the soil when it falls to the ground after it rains, these rainwater form a stream on the earth, this is a drinkable water (Anonymous 4, 2022).

2.2 History of Rainwater

Rainwater has been the main source of water throughout antiquity. Since very early civilizations, rainfall collection and water storage have been very important for people, especially those living in arid and semi-arid regions. Archaeological findings in many parts of the world show that since prehistoric times, people have been collecting and storing rainwater in low permeability soil or simple cavities in rocks to meet their water needs for irrigation, domestic use and livestock breeding. Rainwater harvesting (RWH) was practiced by the people of the city of Ur in Sumer about 4500 years ago and later by the Nabataeans and other tribes of the Middle East. There is evidence that the same process was practiced in China 6000 years ago, even in Jordan 9000 years ago and in Israel around 4000 BC. The collection and storage of rainwater in earthen tanks for domestic and agricultural uses has been practiced in India since 3000 BC and in rural Thailand for more than 4000 years (Yannopoulos et al., 2019).

The construction and use of cisterns to store rainwater dates back to the Neolithic Age. Cisterns are one of the key features of a well-designed city and a method of collecting rainwater. It is known that these systems, especially in the Mediterranean region, were built to collect rainwater from hillsides, open gardens and roofs and were mostly used for domestic purposes (Mays et al., 2013). Towards the end of 4000 BC, it is seen that cisterns were not only used as water storage techniques for households, but also as the basic elements of water management techniques used in agriculture. Throughout antiquity, cisterns were excavated in sand or loose rock and then covered with waterproof plaster. They ranged in design from irregularly shaped holes to highly complex structures such as those built in Crete (Mays, 2007).

In southern Jordan, early water harvesting structures were built more than 9000 years ago. In Yemen, findings dating back to at least 1000 BC show that runoff water was diverted to irrigate an area covering 20000 ha, enough to meet the food needs of up to 300000 people. In Morocco and Tunisia, rainwater harvesting using water harvesting systems that utilize hillsides and walls, and in Egypt, rainwater harvesting using cisterns and valley bed runoff in the northern Sinai regions are ancient traditions (Figure 12).

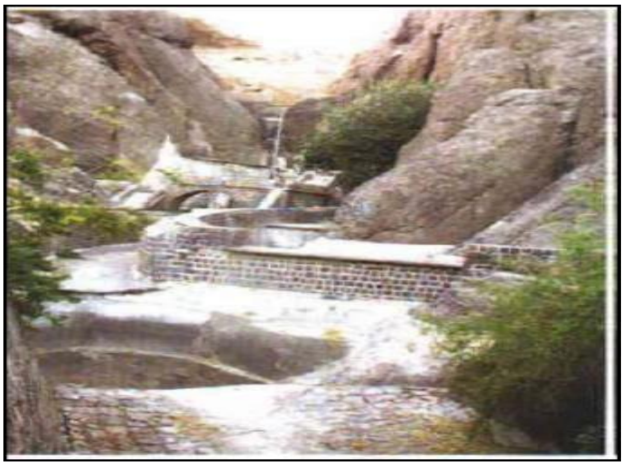

Figure 12. Rainwater harvesting system in Yemen for 3000 years (Incebel, 2012)

Since Classical and Hellenistic Crete, the small Aegean islands and other semi-arid settlements on the mainland lacked surface water sources or usable groundwater, cisterns were constructed to collect rainwater during the rainy season to guarantee the water supply of the inhabitants. The techniques employed include circular or rectangular storage systems, as well as cisterns carved entirely or partially into the rock (Figure 13) (Yannopoulos et al., 2019).

Figure 13. Rural rainwater cisterns and the main cistern, Greece (Yannopoulos et al., 2019)

The ancient Maya inhabited a large area of what is now Guatemala, Mexico, Belize and the western regions of Honduras and El Salvador, and although there was no drought, artificial reservoirs were built for irrigated agriculture in a rainforest environment. An important source of water in the region was water collected in depressions or when soil was removed for house construction. The Maya also constructed cisterns in limestone rock beneath buildings and ceremonial plazas, and developed bottle-shaped underground cisterns and drainage systems dug into limestone bedrock and plastered with cement (Figure 14) (Mays et al., 2013).

Figure 14. Entrance to a water storage in Guatemala (Mays et al., 2013)

In later times, cisterns became a key feature of a well and properly designed city. Increased water demand during the Roman period with increasing population and growth of residential areas; increased size of the cisterns, as well as the development of the structures where the water was transported with cisterns (Mays et al., 2013). The Romans made extensive use of cisterns. According to the findings, cities often had a comprehensive water distribution system that included both surface water and rainwater diverted through aqueducts, as well as well groundwater. It is known that rainwater flowing from the roofs of houses is stored in cisterns for domestic use.

Roman villas are known to have had shallow, rectangular, open-top tanks on the ground where rainwater was collected from the ceiling and especially from a rectangular hole in the roof; these were used for domestic use and for irrigation of small gardens (Figure 15) (Yannopoulos et al., 2019)

Figure 15. Imprivium structure used in the Roman Empire (Yannopoulos et al., 2019)

The Minoan Civilization, the first European Civilization, existed on the island of Crete during the period 3200 BC-1150 BC and developed a system of terracotta canals to collect rainwater and transported surface water and rainwater from the mountains through canals (Angelakis and Spyridakis, 2010). These canals set an example for the further development of the transportation of water from one place to another. During the Hellenistic period, rainwater was usually collected by surface runoff and stored in cisterns. Collecting rainwater at high points for hilltop settlements far from water sources was considered one of the best solutions and rainwater was collected in open cisterns (Mays et al., 2013). Although settlements were built far from water sources, societies found ways to bring water to the settlement, store it and use alternative sources. Roman cisterns were built throughout Greece, Spain, southern Italy, Asia Minor and North Africa (Yannopoulos et al., 2019). Hydraulic systems that have changed and evolved over time reveal once again how important water is for societies.

The fall of the Roman Empire was followed by radical changes in water supply systems (Mays et al., 2013). In the eastern part of the empire, Constantinople and much of the eastern Mediterranean, Roman traditions in irrigation systems were maintained for several centuries and these techniques declined over time (Selimoğlu et al., 2022). Although the techniques of water supply have changed, the issue of water supply has always been important.

During the Venetian period (1204-1668), rainwater collected by surface runoff was good filtered and used. Venetian hydraulic technologies were highly developed and many of these technologies were used in the famous castles built during that period (Mays et al., 2013). Figure 16 shows a schematic representation of a filtered cistern application.

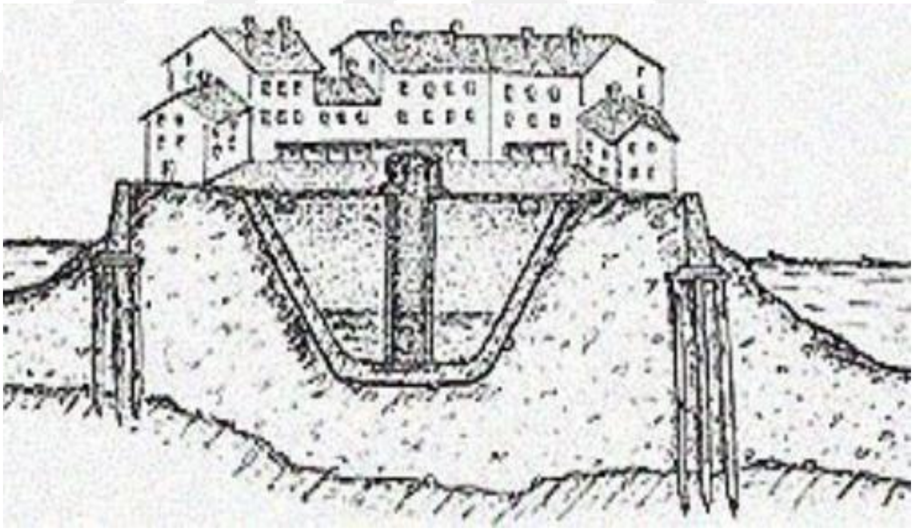

Figure 16. Filtered cistern application in Venice (Yannopoulos et al., 2019)

During the Byzantine period, which is now known as the Fatih district of Istanbul, cisterns were built to provide solutions to the water problem needed by the people as a result of increasing human population. An example of the Yerebatan Cistern is the largest known closed cistern (total capacity of 80000 m^3). The Yerebatan Cistern was built in the 6th century under the Basilica of Stoa. The water of the cistern was supplied by an aqueduct from the springs in the Marmara Basin in the Belgrade forest. In addition to cisterns, it is known that the basements of houses and palaces were also used as cisterns in the historical peninsula in the past (Kılıç and Abuş, 2018).

Figure 17. Yerebatan Cistern (Kılıç and Abuş, 2018)

The Roman construction tradition in Europe gradually declined over the centuries, but some of the surviving techniques were developed and continued in the Ottoman state (TOB, 2023). Looking at the history of Turkish culture, “water culture” has taken its place among the most fundamental values of the pre-Islamic and post-Islamic society (Şahin and Manioğlu, 2011). For this reason, various water systems, from the fountains available in every mosque to meet the need for ablution to Turkish baths, played an important role in Ottoman culture and served as social gathering. The water supply to these structures was provided by large hydraulic installations developed during the Ottoman period.

The role of cisterns in Istanbul diminished during the Ottoman period due to centralized water systems, but continued in remote areas not served by water systems. In contrast to the rectangular plan of Byzantine cisterns, circular cisterns emerged in rural areas during this period (Figure 18).

Figure 18. Ottoman Cistern near the Bodrum (Oziş, 1987)

Dating from the 16th century, many of these cisterns were found in southwestern Anatolia and served the military logistical purposes of the Ottoman army. Many of these cisterns are still used today for the water needs of animals (Oziş, 1987).

They are thought to have been reshaped with the emergence of water technologies and later at the beginning of the industrial revolution. By the 19th century, distribution cisterns had been developed in technological efforts to meet water supply needs. Networks now also required water pressure for multi-storey buildings. It is known that some cisterns were built on the tops of cities during this period and were also intended to provide tap pressure. The first examples of the period mostly applied historical technologies. The gradual introduction of reinforced concrete provided the most suitable technique and material for the construction of cisterns or water tanks almost all over the world, creating a global approach in this field (Mays et al., 2013). As can be seen, cisterns have been an important part of water supply throughout history to ensure the sustainability and prosperity of water resources. Their simplicity and ease of use have led to their sustainable use (Mays, 2010).

In the 20th century, although the revival of water harvesting techniques began in the early 1930s, activities in both construction and research are recorded to have started in Australia in the 1950s (FAO, 1989).

As a result, cisterns, canals, wells and aqueducts have transported, stored and distributed the water needed by humanity. While the first rainwater harvesting techniques were domestic and small-scale, the techniques of collecting, transporting, storing and filtering water have developed and changed depending on the increasing needs with the increasing population over time. It is possible to see this change and development in the structures that have survived to the present day.

2.3 Uses of Rainwater

The rapid depletion and pollution of fresh water resources has brought alternative resources such as rainwater to the agenda. In this way, rainwater is collected during times of high rainfall and used during dry times (Alpaslan et al., 2008). Incebel (2012) presents the areas where rainwater can be used together in Table 9.

Table 9. Where rainwater can be used (Incebel, 2012)

Place of use	Application/Purpose
City	• Irrigation of parks, landscape areas and other green areas, • Commercial use (car washing, etc.), • Decorative use (urban pools, fountains, waterfalls, etc.), • Dust control, • Concrete production, • Fire fighting and fire protection, • Toilets of business centers and workplaces
Industry	• Cooling water, • Boiler feed water, • Process water, • Irrigation of gardens of industrial facilities • Personal use by employees,
Personal use	• Toilet, • Bathroom, • Drinking water when filtered,
Agriculture	• Irrigation,
Restoration/Rekreation	• Improvement and development of wetlands, • Recreational use (water sports, fishing, etc.), • Feeding of rivers, • Other (fish production, artificial snow, etc.),
Groundwater recharge	• Installation of barriers to prevent salt water intrusion into shoreline wells • Ensuring advanced treatment, • Increasing the water capacity of aquifers • Storing reclaimed water, • Control or prevention of ground subsidence
Drinking water source	• As a direct source of drinking water, • As an indirect source of drinking water

In addition to these, it would be very useful in today's conditions to collect rainwater in airports, military zones, stadiums, touristic facilities and buildings with a large enough roof area, where there are large impermeable areas, and to put it into use after simple treatment (Alpaslan et al., 2008).

When daily domestic water use is analyzed, the information in Figure 19 is noteworthy.

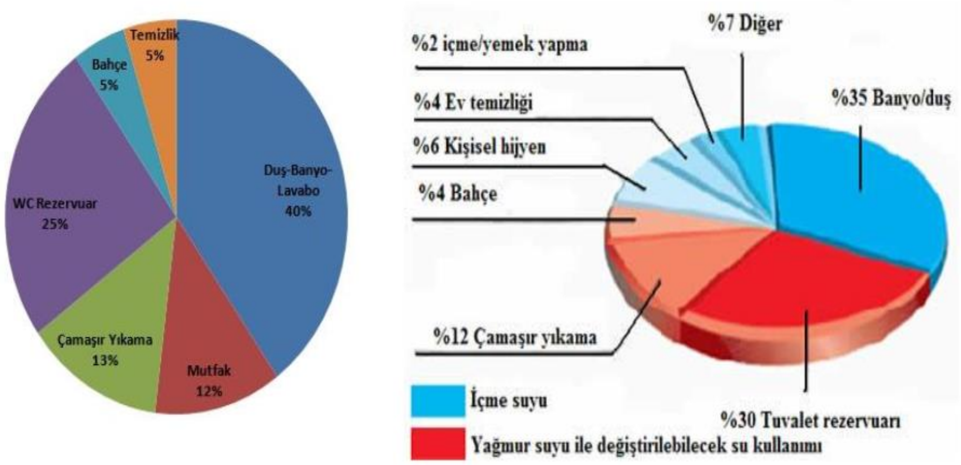

Figure 19. Percentages of domestic water use (Tanık, 2017)

2.4 Advantages and Disadvantages of Rainwater

Advantages

The systems needed to collect rainwater are based on simple technology. This is an indication that they are easy to maintain. The water collected in the rainwater system can be used for different purposes and functions. This provides economic benefits. While the invoice amount is reduced in small businesses and workplaces, the reduction of water resources on an industrial scale can be prevented.

Rainwater does not contain many chemicals found in groundwater and surface water. For this reason, it is suitable for irrigation. At the same time, water stored in large volumes is useful in areas where forest and bush fires are common.

In response to the increasing demand for water with population growth, many societies meet their water needs from groundwater. Rainwater prevents this, preserving groundwater reserves while reducing the risk of running out of water.

Rainwater stored during active rainfall helps reduce flooding in low-lying areas and prevents pollution caused by erosion that meets surface water.

Collecting and using rainwater also reduces the water and energy footprint as it reduces the use of other water and energy resources (Can, 2020).

Disadvantages

This can be considered a disadvantage as rainfall is difficult to predict. In arid regions with relatively little rainfall, it is not enough to rely only on water from rain. Rainwater harvesting is more suitable for regions with heavy rainfall (Can, 2020). In this sense, it can be said that the most feasible region in Turkiye is the Eastern Black Sea Region.

Depending on the level of technology to be used and the dimensions of the system, the figures to be spent vary. When the initial cost is deducted, the amounts to be spent can be high according to the technology.

The tanks or areas required for storing rainwater have certain capacities. In a time of more rainfall than expected, these tanks may not be able to hold all the rainwater (Can, 2020). In addition, it may be difficult to find and place large capacity tanks in a suitable location.

2.5 Collection, Storage and Distribution of Rainwater

2.5.1 Rainwater Collection

- **Cistern System**

Cistern applications are presented as an ideal solution for places where underground and surface water resources are not sufficient, but rainfall is sufficient.

Figure 20. Example of cistern (Anonymous 5, 2024)

The water needs of cities, towns and villages are supplied from rainfall, surface and groundwater. Cisterns are usually buried in the ground and are constructed in such a way that they do not leak water. Water collected from roofs, terraces and clean concrete courtyards is given to the cistern. The rainwater supplied to the cistern needs to be filtered through sand and silica sand is used for this purpose.

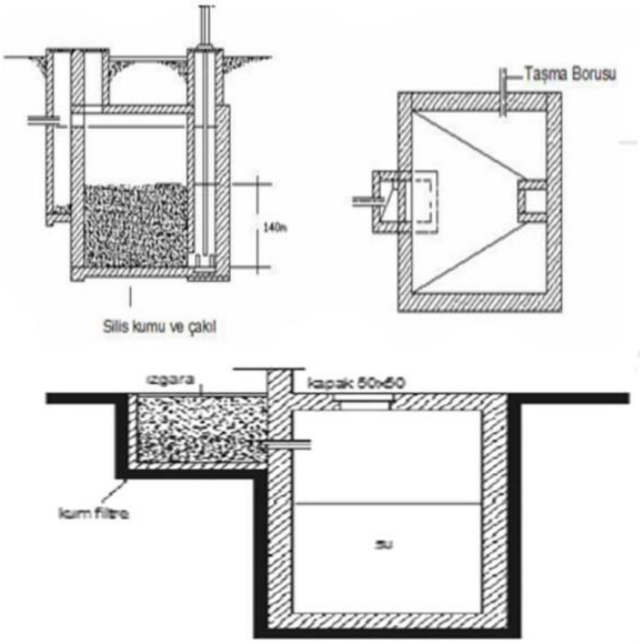

Figure 21. Cistern system (Tanık, 2017)

A sand filter of approximately 1 m in height with the bottom 1/3 of gravel and the top 1/3 of fine sand gives good results. In more sophisticated cisterns, rainwater undergoes a process of resting and filtering. A 1.40 m high sand filter made of gravel and fine sand filters suspended impurities and floating matter from the water and allows cleaned water to pass into the water intake well. In order to keep the water clean, it is better to take water from the cistern with a pump, not with buckets (Tanık, 2017).

- **Tank Method**

This storage method is based on placing harvested rainwater in an external tank, usually above ground or underground, and storing the collected water in these tanks. A typical storage system consists of 4 components (Tanık, 2017). These include;

- ✓ Collection of rainwater from the roofs or ground of buildings,
- ✓ Ensuring transmission through the gutter system,
- ✓ Collecting rainwater in the rainwater tank,
- ✓ Purification and transmission into the building.

Figure 22. Example of a storage tank located underground (Tanık, 2017)

The sizing of a storage tank can be determined in relation to several variables.

These are;

- ✓ Area of the collecting surface,
- ✓ Local precipitation and weather conditions,
- ✓ Volume of water needed (demand),
- ✓ Maximum amount of rainwater collected (supply),
- ✓ Availability of a backup water supply,
- ✓ Availability of the settlement,
- ✓ Budget

In the installation of above-ground tanks, the area where the tank will be installed should be smooth and hard, free of piercing and damaging materials such as stones and metal that can damage the tank, in order to prevent regional collapses over time. The location of the tank depends on its size, shape, available space, climate and soil conditions. The tank can be installed underground, partially underground or above ground and should preferably be located at the shortest distance to minimize piping and pumping requirements (Temizkan and Kayılı, 2020).

Figure 23. Example of above ground storage (Anonymous 6, 2024)

While a proposed underground storage tank has advantages such as protection from direct sunlight and keeping the water cool, the cost of installation and construction can increase, especially in hard and rocky soil or if the site has high groundwater levels (Temizkan and Kayılı, 2021). In addition, underground tanks are more difficult to maintain and repair.

2.5.2 Advanced Rainwater Collection Systems

- **Infiltration**

Infiltration is the easiest way to use rainwater. Underground infiltration is one of the methods used to replenish and protect groundwater. It is also the easiest way to restore groundwater to its original level. Natural regeneration of groundwater relies on 20-50% rainwater. First, it must be established that the soil is naturally permeable. The main condition for the use of rainwater collected in tanks is the absence of substances that impair the purity of the water.

Figure 24. High permeability stones (Tanık, 2017)

These stones are permeable and allow rainwater to percolate into the groundwater, even during heavy rains. An important prerequisite for ensuring the permeability of the stones is the use of "clean" production techniques. The ground should never be covered with concrete and rainwater should infiltrate into the ground. The advantages of infiltration are that it reduces the load on the sewerage system. The costs of the network and the sewerage system are therefore reduced, so there is no need to take safety measures against random infiltration of water into the sewerage network. The advantages of using rainwater and infiltration systems are the reduction of wastewater treatment costs, the easy construction of rainwater tanks, and the reduction of damage caused by floods and overflows (Tanık, 2017).

- **Surface Water Collection According To Roof Types**

There are technical issues and types of construction (pitch roof-asbestos concrete roof-metal platform roof) for rainwater harvesting from the surface.

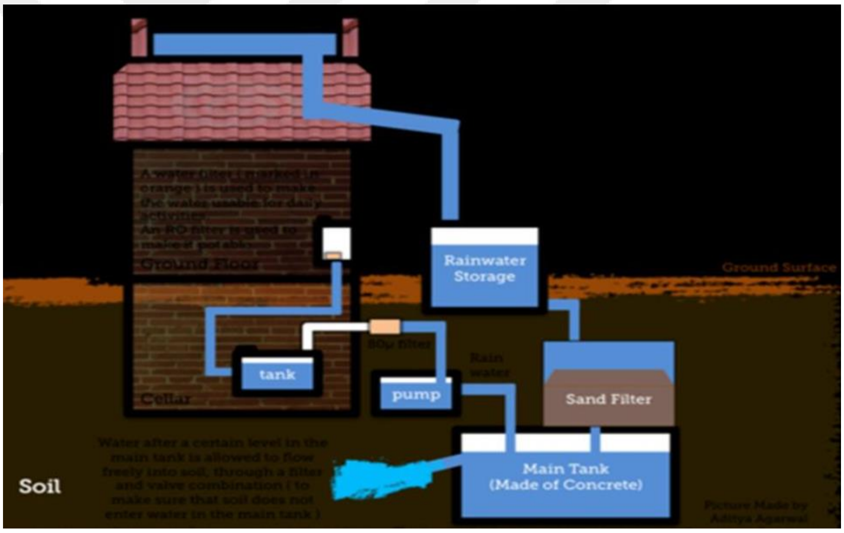

Figure 25. Water collecting from the roof surface (Anonymous 7, 2023).

The water collected from pitch roofs is usually yellow in color and has a specific odor that makes it recommended for use in toilets and garden irrigation. It has been proven by various tests to be bacteriologically harmless. The asbestos-concrete roof is prone to thawing. In this case, the collected water can only be used for toilets, depending on the percentage of asbestos. Water collected from metal platform roofs, especially mixed metal roofs, is not suitable for laundry or garden irrigation. This water can only be used for toilets (Temizkan and Kayılı, 2021)

- **Filtration System**

Filtration is an important process that removes large quantities of pollutants from the water for the use of rainwater. It is very important to install the filtration system in an accessible location so that it can be periodically maintained and cleaned. Gravel filters do not require any maintenance costs. Cleaning once or twice a year is sufficient. Rainwater passed through mechanical filters can be used for toilet cleaning, washing machines and garden irrigation. It is recommended to use filters that can be easily cleaned but prevent contaminants such as leaves and sand from entering the water tank (Tanık, 2017).

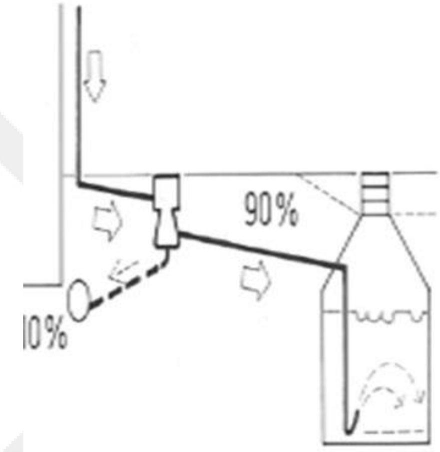

Figure 26. Filter example

Figure 27. Example of a filtered tank (Tanık, 2017)

- **Modular Structure**

Whereas years ago individual parts were assembled in a complex way, now only two pre-assembled parts need to be joined together. Thanks to modular systems, easy assembly and low costs, the maintenance of the system has become easier and more reliable than other known services required for building maintenance. The first module contains the filter, tank and collection pipes. The second module includes the pressure control and collection pipes.

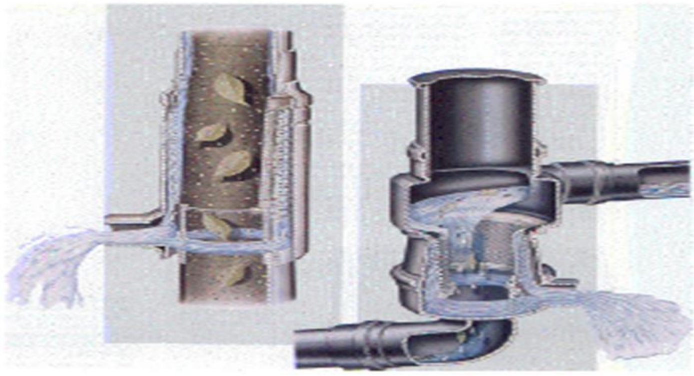

Figure 28. First module filter, tank and collection pipes, second module pressure control and collection pipes (Tanık, 2017)

2.5.3 Advanced Rainwater Distribution Systems

In a simple rainwater harvesting system within the dwelling (single system), rainwater collected from the roof is passed through a filter that retains large particles and then into a rainwater tank. From the rainwater tank, the water is pumped to the areas of the house where it is needed, such as the washing machine or the toilet tank.

In this system, there is no charge for the rainwater collected, except for the initial installation cost of the system. However, the weakness of this system is the water shortage in the building when rainwater is scarce or when there is a problem with the rainwater collection system (Tanık, 2017).

a. Direct supply of the network with rainwater system

The mains and rainwater system are connected to each other. When rainwater is scarce, the rainwater system is fed into the mains and used for washing machines and toilet reservoirs inside the building. As shown in Figure 29, the advantages of this system are that there is no need for an additional space inside the building, but the weaknesses of the system are the energy cost of the pump to pump the water from the mains when rainwater cannot be used, pump maintenance costs, more expensive and complicated control mechanism, and pump operation whenever there is water use in the building.

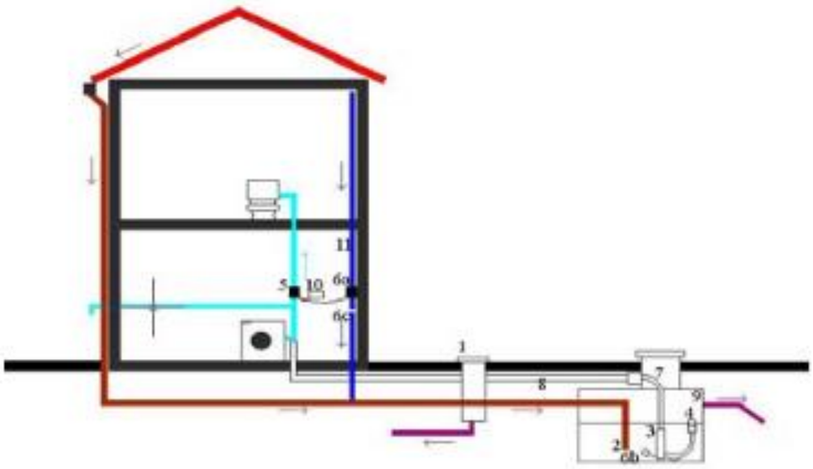

Figure 29. Use of rainwater inside the building with direct feed system (Şahin and Manioglu, 2011).

Advantages of the system:

- ✓ There is no need for additional space inside the building.
- ✓ Rain water is pumped with the help of a specific pump.

Disadvantages of the system:

- ✓ When rainwater is not used, the water in the mains is pumped, creating an unnecessary energy deficit.
- ✓ If the pump fails, the water cannot be used to supply the rainwater pavement.
- ✓ The control mechanism is expensive and complex (Şahin and Manioglu, 2011).

b. Combining mains water and rainwater in a tank inside the building (distribution by gravity system or roof tank system)

In this system, both rainwater installation and mains water come to the tank located in the attic. In Figure 30, the system is such that rainwater is filled into the tank and then gravity fed to the washing machine and toilet reservoirs without the need for a pump inside the building.

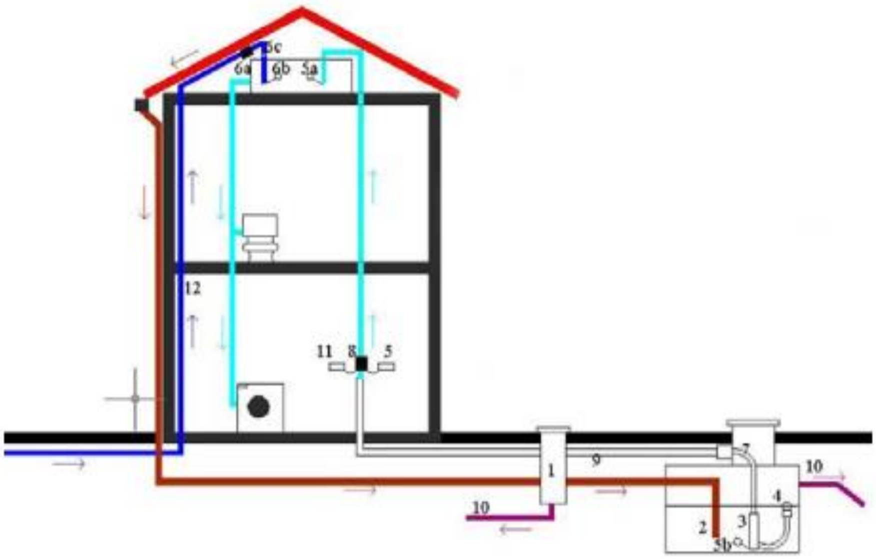

Figure 30. Distribution by gravity (Şahin and Manioglu, 2011)

Advantages of the system:

✓ Simple control system and low pump cost

✓ When there is no water in the rainwater tank, with the help of the control panel, water is added to the roof tank from the main network floor with the soleid valve (6a).

✓ Energy saving is also ensured as the distribution is provided by gravity.

Disadvantages of the system:

✓ The pressure can be low, which slows down the filling of toilet cisterns.

✓ There is a need for space for storage between the roof and the building.

✓ In the "Regulation on Buildings to be Built in Earthquake Zones 2007", under the title 7.10. Reinforcement of Reinforced Concrete Structures, the article "7.10.7. Reducing the Mass of the Reinforced Concrete System" states that the weights of installations such as water tanks on the roof should be lowered to the ground (Şahin and Manioglu, 2011).

c. Systems where rainwater installation and network are used independently of each other (double system)

In this type of system, the rainwater installation is not fed by the mains, instead both systems (rainwater installation and mains) are used independently in the toilet cistern or washing machine within the dwelling. As shown in Figure 31, there is no additional cost as both systems are extended to the toilet tank or washing machine (Tanık, 2017).

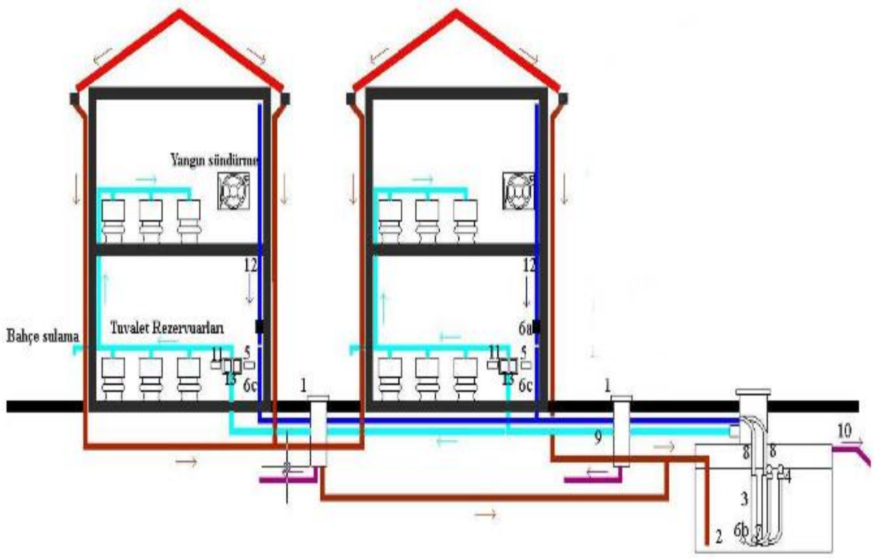

Figure 31. Double System (Şahin and Manioglu, 2011)

2.6 Cost-Benefit Analysis of Rainwater Harvesting

Costs

The region-specific initial investment cost of the collection, transmission, storage, distribution and treatment components of the RWH system and operating costs such as electricity, maintenance and repair are taken into account (Anonymous 8, 2024)

Benefits

The economic benefit of the system is considered as the reduction in the use of municipal water through the use of rainwater and the consequent reduction in the cost paid for water.

Cost-benefit analysis of the rainwater harvesting system to be implemented is performed to analyze the profitability of the system. Net Present Value (NPV) is one of the cost-benefit analysis methods that shows the economic value of the investment. By using the NPV method, payback periods of the systems can be compared in terms of investment. NPV is the difference between the present value of the return provided by the rainwater harvesting system investment over its economic life minus the present value of the investment costs. When the NPV is positive, it means that the rainwater harvesting system is profitable.

Scenarios should be created in cost-benefit analyses; it should be considered that rainwater collected from the roofs of micro-areas and/or the surface in recreational areas can be used in toilet reservoirs; outdoor garden irrigation, car washing, fire extinguishing, ornamental pools, filling artificial ponds (TOB, 2023).

In cost-benefit analysis scenarios for RWH, attention should be paid to the following elements. These are:

- ✓ Roof/area size in micro-area,
- ✓ Long-term monthly (minimum last 10 years) rainfall data,
- ✓ Purpose of water use (irrigation, recreation, domestic water, etc.),
- ✓ Average consumption of water.

The following cost elements should be examined during the cost-benefit analysis of RWH. These include:

- ✓ Tank, gutter and roof assembly,
- ✓ Material (fiberglass, concrete, metal, wood, welded steel, polypropylene, vinyl),
- ✓ Size,
- ✓ Pressure tanks and pumps,
- ✓ Filter systems and chemicals,
- ✓ Labor force

Precipitation Analysis

One of the most important criteria for the design of a RWH project is the amount of rainwater to be collected (Üstün et al., 2020). For this reason, in order to determine the feasibility of the RWH, the precipitation regime in the study region and the system components to be used in the RWH should be examined in detail and the precipitation potential specific to each region should be revealed. With the increasing effects of climate change, precipitation regimes in cities have started to change. Rainfall regimes that were previously characterized by normal intensity and long duration have been replaced by high intensity and short duration rainfall. Therefore, the impacts of climate change should also be taken into consideration.

The payback period calculated within the scope of cost-benefit analyses is considered as an important criterion in the evaluation of the investment. The threshold value of the payback period of systems for the use of rainwater in micro-areas is considered to be 20 years with expert opinion, and in cases where the payback period is less than 20 years, it is accepted that these systems are rational (TOB, 2023).

2.7 SWOT Analysis of Rainwater Harvesting

SWOT analysis is a strategic technique used to identify the strengths and weaknesses of a project or any initiative, technique, process, situation or person. Also it can identify opportunities and threats arising from the internal and external environment. This technique requires determining the objectives of the project or initiative and identifying the internal and external factors that are positive or negative for achieving the objective.

An environmental factors are examined, opportunities are identified, and activities that may pose a threat are recognized in advance and measures are taken with SWOT analysis. It includes strategic and planning approaches such as revealing strengths, identifying weaknesses and taking precautions, analyzing the difficult situations of weaknesses in the face of possible threats, etc.

- **Strenghts**

✓ Water is a natural, clean and spontaneous resource (water cycle)
✓ Rainwater can be easily used in many areas and for different functions
✓ Reducing the damage caused by floods and overflows
✓ Ensuring less use of municipal water
✓ Ensuring that water is underpaid
✓ The fact that Turkiye has a non-arid climate type and that the average rainfall in some regions is suitable for rainwater collection and storage
✓ The RWH system is easy to build, easy to operate and does not require complex control
✓ The availability of specialized engineers for the RWH system and the ability to produce the necessary materials locally
✓ The rainwater content should be clean and can be treated with simple methods such as filtration and sedimentation when necessary.
✓ Continuous increase in environmental awareness and education level
✓ Managers prioritize environmental issues such as water conservation
✓ RWH has been done and used in the past

- **Weaknesses**

✓ Areas where industry and/or population is dense do not receive much precipitation

✓ Lack of widespread use of rainwater harvesting

✓ Not realizing that rainwater is a good source of water

✓ The fact that a holistic water policy has not yet been implemented in Turkiye and the framework of basic principles and methods related to water management has not been fully determined.

✓ The fact that the regulation at the level of law containing details on the co-management of waters in terms of quantity and quality has still not been made

✓ In the use of water in agriculture, some of the soils have become barren due to the unconscious excessive use of water by farmers. In addition, due to the inadequacy of drainage channels in irrigated fields, the ground water level rises and swamps are formed in many places.

✓ The fact that agricultural irrigation has reached the level of waste due to wild methods

✓ Due to global climate change, the available water potential per capita has decreased to around 1300 m^3 per year and Turkiye has started to be among the countries that are not water-rich according to the index of available water.

- **Opportunities**

✓ Prioritizing water saving in agricultural areas

✓ Using rainwater in the agriculture sector, which consumes the most water worldwide

✓ Meeting the need for water in dry times

✓ Increased environmental awareness

✓ Being a sustainable alternative and achieving maximum benefit from it

✓ The fact that it is not a country with high air pollution, and that regions receiving rainfall have particularly low emissions

✓ Water can be used economically through the use of artificial intelligence technologies with development

✓ Innovative rainwater harvesting systems can be developed through the use of artificial intelligence technologies with development

- ✓ Rehabilitation of water networks and reduction of loss and leakage rates through effective management and monitoring
- ✓ In order to reduce the problems caused by water scarcity, new resources in basins where there is a disparity between population and water resources should be put into use, and dams and ponds under construction should be completed.
- ✓ Investment plans of private enterprises for the use of water resources
- ✓ Being a resource that can be used in emergencies such as war, fire, etc.

- **Threats**

- ✓ In parallel with rapid population growth, increasing urbanization and industrialization, the rate of water use changes, pollution and decrease in water per capita
- ✓ Increase in environmental pollution as a result of imbalance between production and consumption
- ✓ Climate change and the resulting increase in global warming-related problems
- ✓ Disruption of ecological balance
- ✓ Increasing air pollution with increasing population and developing technology
- ✓ Lack of control and management in the use of groundwater and the related increase in inefficient use
- ✓ The threat of facing transboundary waters and water shortage with the Middle Eastern countries in the future and in this context, the threat that water cannot be properly defended in the international platform as a political value for our country
- ✓ Unconscious irrigation practices and old irrigation networks, excessive use of water in agriculture and consequent environmental problems such as salinization, eutrophication and pollution
- ✓ The fact that the mechanisms that can supervise the investments to be made by private enterprises for the use of water resources have not yet been established by the state.

2.8 Studies on Rainwater Harvesting

2.8.1 Studies on Rainwater Harvesting in the World

Technologies for water conservation have been developed and widely used in the world many years ago. Especially developed countries protect their drinking water resources by reducing water consumption. Although the rate of water potential available in Europe or Japan is considerably higher than the rate in our country, water is used more economically by managing it in different ways through the use of gray water by treatment, the collection and use of rainwater and measures that can be taken in health equipment systems. In addition, in the Gulf countries, where water shortages are widespread, the decrease in costs with the technologies developed in the last 20 years has made it more common to obtain drinking water from seawater. In many countries, some of the examples of different applications of water conservation in buildings with different functions ranging from residences to health or education buildings have been discussed.

The use of rainwater is quite common in the USA. Although the incentives developed for these systems, which have been used since the 1970s, are still limited, there are different financial incentives determined by each state (Şahin, 2010; Ekinci, 2013). An average of 250000 households in the USA use rainwater harvesting systems (Alparslan et al., 2008). In Santa Fe, New Mexico, it is mandatory to use rainwater harvesting systems in new buildings over 232 m^2.

In the Solaire building in Manhattan, different methods of water conservation are applied. No potable water is consumed outside the building (use for irrigation on green roofs). Inside the building, 50% less potable water is consumed compared to traditional high-rise buildings. Rainwater is collected in a 38 m^3 underground tank and used for landscape irrigation of green roofs on the 1st, 17th, and 27th floors after sedimentation and treatment.

In Texas, real estate loan assistance has been provided for industrial and commercial facilities in buildings with rainwater systems since 1993, and tax reductions were implemented in 2001 for buildings with rainwater systems.

In Austin, in 2008, the state covered $500 for the installation of rainwater systems in residential buildings and $5000 for installation in public buildings or non-profit organizations. In the state of Virginia, a tax deduction of up to 2000 dollars can be made, provided that it does not exceed half of the system cost.

In Japan, which started to grow rapidly with the economic development in the 1960s, a dual distribution system was developed in order to make maximum use of the limited water resources. In 1984, a dual distribution system was installed in new buildings larger than 3000-5000 m² by the Tokyo Government and the recycled water was started to be used in toilet reservoirs and urinals. The use of gray water treatment systems or rainwater collection systems in buildings larger than 30000 m² has been made mandatory by law by the Japanese Ministry of Public Works.

The use of rainwater has gradually begun to become widespread in some parts of England, for reasons such as the initial investment and maintenance cost, the effects of rainwater quality on public health, despite many incentive programs. The strategy developed for the effective use of water at the University of Southampton in the Administration and Student Affairs Building, completed in 2005, is the use of rainwater in the building. rainwater collected from the roof area of 1000 m²' is collected in the underground tank of 15000 liters and used by about 21 people in the structure with 3 toilet reservoirs in 150 urinal (Şahin, 2010; Ekinci, 2013).

The Daimler-Chrysler building in Berlin is one of the best examples of the effective use of rainwater. The complex consisting of 19 buildings has a roof area of 48000 m² and provides a collection of 23000 m³ of rainwater. Rainwater management in the building; on the green roofs of 19 buildings, collected rainwater is provided in toilet reservoirs and landscape irrigation in the form of an artificial lake for rainwater collection.

Germany has pioneered "DIN 1989" many countries with its standards in rainwater collection systems. This standard addresses issues relating to rainwater, planning, installation, application and maintenance, rainwater filtration, rainwater reservoirs and their additional components (Şahin, 2010; Ekinci, 2013).

In different cities of India, legal obligations have been introduced regarding the use of rainwater in new buildings. In New Delhi all new buildings with a roof area of greater than 100 m² and new buildings with a construction area greater than 1000 m, Gujaratda is in all official buildings, Indoreda 250 m² in all new buildings with construction area, Hyberebadda in all new buildings with over 300 m² of space, Chennaiide in all new buildings with 3 floors, Mumbaide in all buildings with parcel area of 1000 m², In urban areas with infrastructure in Rajasthan with a parcel area greater than 500 m^2, the use of rainwater has been made compulsory by law (Şahin, 2010).

In the Fiji islands, rainwater collected from the roofs of schools and buildings belonging to state institutions, airports and etc. places with large surfaces are used. A large number of concrete cisterns have been made in Thailand since eighties, where the collected waters are evaluated for drinking and use (Yalılı Kılıç and Abuş, 2018).

The study in Brazil found that rainwater harvesting saves about 12–79% in the amount of potable water, depending on the size of the roof and storage tank (Üstün et al., 2020).

2.8.2 Studies on Rain Water Harvesting in Turkiye

The Regulation on Rainwater Collection, Storage and Discharge Systems in Turkiye was put into force in the Official Gazette by the Ministry of Environment Urbanization with the number 30105 and the date 23.06.2017.

Information on the types of rainwater harvesting systems is included in the Regulation EK-1. In this section, recommendations are presented on the design, installation, testing and maintenance of stormwater harvesting systems applied for the purpose of using water, in the subjects included in the BS 8515 (2009) standard. The BS 8515 (2009) standard specifies that domestic waters such as wash water, toilet water and garden irrigation water that are not expected to meet drinking water quality standards (domestic, commercial, etc, water needs in industrial and public places) include issues related to the provision of rainwater. The standard in question; drinking, food preparation and cooking, dishwashing and personal hygiene related water needs are not included in the provisions to be met. Although there are no specific provisions regarding the use of rainwater as firewater or commercial irrigation water, these areas are not excluded from the standard scope (Official Gazette, 2017).

The principles of application regarding rainwater harvesting and recycling water obtained from grey water were published on 22.02.2020. ISKI has introduced a requirement for grey water project in buildings with a total construction area of more than 30000 m^2 and rain water harvest project approval for parcels above 1000 m^2, starting from 1 March 2021 (TOB, 2021b).

The use of rain water in the collection and elimination of alternative water needs is of great importance for the protection and sustainability of water resources. In Turkiye, there are various examples of rainwater harvesting usage technologies from building roofs.

Siemens Gebze Organized Industrial Zone “Green Building Concept, many technologies related to water conservation have been developed. In order to maintain underground water resources and quality, the use of perforated stones and green space in the parking lot has been increased in order to ensure that rainwater coming to the site is passed to the soil and absorbed by the soil. Again for the same purpose, after the roof rainwater is stored, it is foreseen that it will be reused in the building. In order to maintain and improve water quality, rainwater that comes to the areas of hard landscaping (especially asphalt roads) is directed to the soil instead of rain channels and filtered here. Rainwater collected from the roof is evaluated as use water in the fire irrigation system and softened in the whole area and used in landscape irrigation outside the building (Yaman, 2009).

In Diyarbakir Solar House, rainwater from the roofs and water from the water tank and the water from the domestic wastewater treatment are used in garden irrigation and toilet reservoirs by passing carbon filters (Anonymous 9, 2022).

Rainwater collected from roofs in Borusan Auto-Inspection Facilities is collected and treated in separate tanks and used in toilet reservoir, car wash and garden irrigation and fire storage (Şahin and Manioglu, 2011).

The rainwater on the terrace of Bursagaz, which is designed with the Green Building Concept, and the drainage water around the building are accumulated and filtered through the filters and 20 m3 rain water is stored and this storage water use in the toilet reservoirs with the irrigation of these green areas (Anonymous 10, 2022).

Bursa Hilton Hotel is a model hotel with the Green Star Concept, which increases energy efficiency and is located in environmentally friendly hotels. This concept also includes the use of rainwater or treated wastewater in garden irrigation and/or toilet reservoirs (Anonymous 11, 2022).

Konya Science Center project has been implemented in Konya, the largest city in Turkiye in terms of surface area, and LEED NC Gold certified is the first and only scientific center of Turkiye. The construction process of the project is finished and opened in April 2014. The project, which was implemented with the support of TUBITAK, is in a land of about 100000 m²; 26250 m² closed area, 14000 m² open parking area and vehicle routes, 11000 m² walkways, etc. So it has a green area of 47000 m². These are thematic exhibitions, outdoor exhibitions, observation and viewing tower, planetary, conference rooms, laboratories and library. In Konya Science Center where rainwater management is carried out, rainwater collected from the roof is transferred to two separate tank using the rain channels around the building and is reused in the building (Yanar, 2015).

Istanbul Technical University (ITU) Ayazaga campus in 2013 within the scope of green campus works, water harvest project, concrete applications and rain garden applications were used for collecting rainwater. It is ensured that the waters entering the rain gardens are filtered by the plants placed in it. This is not a mechanical filter. It is scientifically stated that this process is called “fitoremediation”, that is, improvement with plants. It is stated that this technique costs less than one-third compared to systems using gray infrastructures. In practice, the rainwater that is cleaned using the phytoremediation technique is collected by the pipes at the base of the rain gardens and directed to the pond with rainwater lines for the revival of the ITU pond, which is suffering due to the dense construction in the Istinye region. It can be said that the rain harvesting technique is an application that can be implemented in many other points in Istanbul, squares, parks and the application in ITU is an example. The research, which points out that the ITU pond, which is revived by the rainwater harvest, is now home to many bird species and other species, in an urban environment like Maslak, where skyscrapers and hard floors dominate, it underlines that the pond operates in a “oasis” natüre.

Kadikoy Municipality Environmental Management and Climate Change Manager, which describes the studies carried out about five years about the rain harvest in Kadikoy Municipality, these works are used for "the protection of groundwater and the use of healthier projects they developed. The first of these can be summarized in agricultural irrigation, the second in the printing of collected rainwater siphons, and the third in the form of the integration of rainwater collection system in street washing vehicles”. Through the rain harvest, the knowledge that they save about 750 tons of water as an institution is shared. It is obvious that all three projects implemented by the Municipality of Kadikoy are intended to encourage citizens to collect rainwater (Anonymous 12, 2022).

3. MATERIALS and METHODS

This thesis study was prepared to examine the applicability of the rainwater collection system for the Artvin Coruh University Central Campus and the Seyitler Campus. Many communities around the world have developed various rainwater harvesting systems. A number of factors are taken into account when selecting the appropriate water sources or specific rainwater collection system. Climate, precipitation regime, technology, socio-economic factors play an important role in the final election. When considering a rainwater harvesting system for water supply, the first stage should be to determine its environmental, technological, social and economic feasibility. After analyzing these factors and examining the precipitation data of the past years, this system will be investigated for the applicability of Artvin Coruh University Central Campus and Seyitler Campus buildings. Studies have shown that; rainwater collection projects are mostly successful if they go through an efficient storage process. The water storage tank can be found in various sizes, shapes and material types. The main element for these tanks is the volume of water that they can hold. The size and capacity of the water tank can be calculated by determining the volume of water requirement and the rainwater harvested.

3.1 Artvin Coruh University Central Campus and Seyitler Campus

3.1.1 Central Campus

On the edge of the Çoruh River, 70 acres of land established on the Coruh University Central Campus, along with some departments affiliated to the Rectorate and Faculty of Education, Faculty of Arts and Sciences, Faculty of Arts, Faculty of Science, The Faculty of Health Sciences and Vocational School of Health Services provides education services. Nihat Gökyigit Congress and Culture Center and Central Library are also located in this campus (Anonymous 13, 2024).

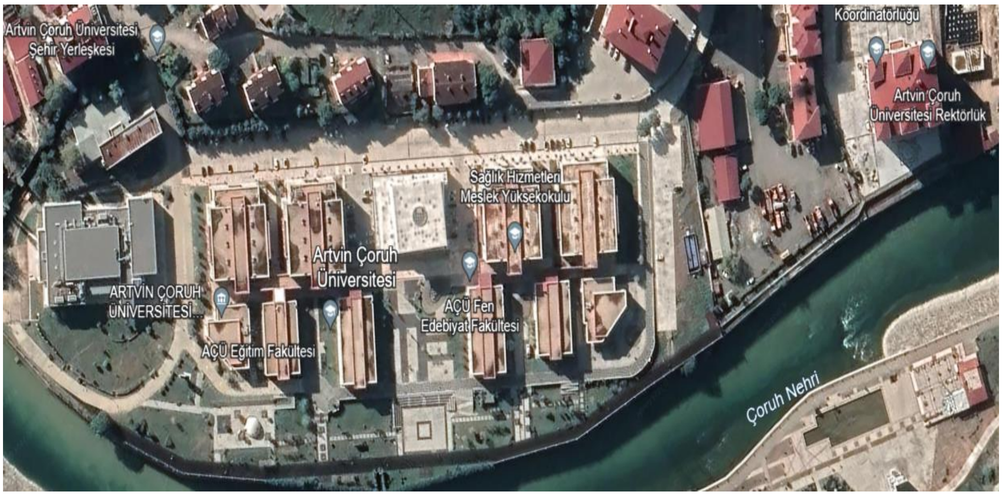

Figure 32. Artvin Çoruh University Central campus

Water Consumption Data in the Central Campus

Water consumption within buildings located at the Central Campus of Artvin Coruh University refers to the use in toilets and lavatory. The water required for irrigation of the university green areas is provided by underground water extraction from wells. The data were obtained from the University's Information Processing unit.

Table 10. Year water consumption analysis of Central campus in 2023

2023 Year Water Consumption															
Number	Water Meter No	Building	Consumption(m^3)												
			January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
1	948	Congress Cultural Centre	21	16	23	20	26	21	30	27	26	31	36	51	328

Table 10 (Continued) Year water consumption analysis of Central campus in 2023

2	946	Faculty of Arts and Sciences	856	561	681	231	341	342	351	260	253	589	921	669	6.055
3	949	Faculty of Education	687	186	301	302	492	461	450	890	433	1184	956	646	6.988
4	1022	Central Library	270	49	240	118	186	24	30	9	0	97	176	97	1.296
TOTAL			1.834	812	1.245	671	1.045	848	861	1.186	712	1.901	2.089	1.463	14.667

3.1.2 Seyitler Campus

The Seyitler Campus is located approximately 3 km from the city and is located on 187 acres of land. This campus includes the Faculty of Forestry, School of Business, Faculty of Tourism and Faculty of Sport Sciences and Graduate Science Institute. In the two educational blocks completed in 2011 and opened for educational service, Artvin Vocational School and Engineering Faculty carries out education services. Central Research Laboratories, which were opened in 2011 and subsequently gathered under the roof of Science-Teconology Application and Research Center, are also located in this campus. At the same time, the Medical and Aromatic Plants Specialization Coordinator and the Medical and Aromatic Plants Application and Research Center and Technology Transer Office are also units located in the Seyitler Campus. Also this campus includes the Sports Hall with a closed area of about 3500 m^2, Center for Social and Cultural Activities, Furniture and Decoration Application Workshop (Anonymous 13, 2024).

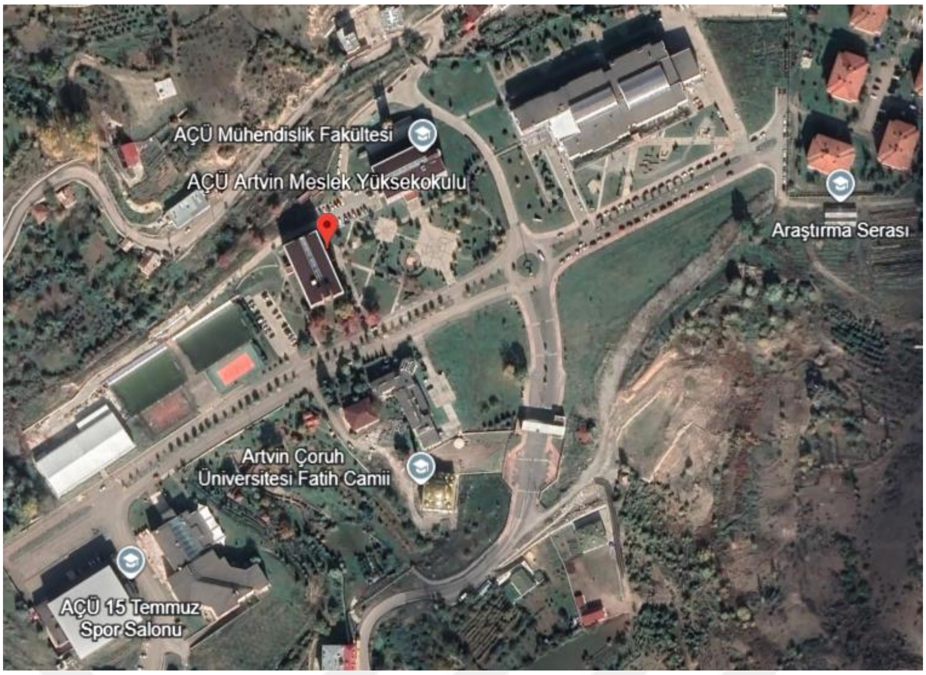

Figure 33. Artvin Çoruh University Seyitler campus

Water Consumption Data in Seyitler Campus

The water consumption in the buildings located at Artvin Coruh University Seyitler Campus refers to the use of toilets and sinks and the use of dining halls. The data were obtained from the University's Information Processing Unit.

Table 11. Year water consumption analysis of Seyitler campus in 2023

2023 Year Water Consumption															
	Water Meter No	Building	Consumption (m^3)												
			January	February	March	April	May	June	July	August	September	October	November	December	TOTAL
1	1614	Seyitler Campus	2.530	2096	2311	1333	1399	1185	1583	2268	2420	1797	2301	2076	23.299

Table 11 (Continued) Year water consumption analysis of Seyitler campus in 2023

2	1895	Seyitler Campus	3	4	7	25	8	11	23	4	3	0	3	8	99
3	1998		0	0	0	0	0	0	174	0	0	0	0	0	174
TOTAL			2.533	2.100	2.318	1.358	1.407	1.196	1.780	2.272	2.423	1.797	2.304	2.084	23.572

3.2 Factors Affecting Rainwater Harvesting

In the projects planned for the collection and use of rainwater, firstly rainwater to be collected and the water needs of the place where this water will be used should be compared. If the rainwater to be collected meets the need or meets the acceptable part, it will be right to carry out such a study.

The issues to be considered in the rainwater harvest; the rainfall characteristics in the region to be studied and the system components to be used in the rainwater harvest can be collected in two headings.

3.2.1 Precipitation Characteristics of Artvin Province

The feasibility of a rain collection system depends on the amount and shape of rainfall in the area, the duration of dry periods and the presence of other sources of water. Year-round rainfall plays an important role in determining whether the rainwater harvest can compete with other water supply systems (Aldavahid, 2022).

Artvin Province is located in the Eastern Black Sea Region, and as the Central district, it is a transition climate characterised by the transition from the Black Sea climate to the Terrestrial climate. The total annual rainfall is 691.6 mm, the month with the highest rainfall is December (85.6 mm), and the month with the lowest rainfall is August (29.1 mm). The average annual temperature is 12.4 C. The wettest season is winter (241.7 mm), while the driest season is summer (109.4 mm). Artvinetin rainfall regime; summer drought is not as severe as in the Mediterranean regime and the wettest circuit coincides with the winter season. The difference between spring and autumn rainfall is less than in the Mediterranean Region, but it complies with the transitional type expression between the Mediterranean and Black Sea regimes. Each season is a transition zone between the rainy Black Sea climate and the land climate (OGM, 2024).

Table 12. Artvin annual precipitation data (MGM, 2024)

ARTVIN	January	February	March	April	May	June	July	August	September	October	November	December	ANNUAL
Measurement Period (1949-2023)													
Average Temperature (ºC)	2.7	3.8	7	11.9	15.9	18.8	20.9	21.2	18.3	14.2	9.1	4.5	12.4
Average Rainy Days	13	12.76	13.56	12.79	14.13	12.79	8.24	8.17	8.61	10.99	11	11.73	137.8
Total Monthly Rainfall Amount (mm)	84.6	71.5	60.8	53.2	53.1	49.2	31.1	29.1	37.9	60.4	75.1	85.6	691.6

3.2.2 Roof Material Coefficient

In the calculations of rainwater harvesting, roofing material is an important factor in determining the harvestable rainwater on the roof. Economic analysis of rainwater harvesting can be done based on the total roof area, the average annual rainfall amount and the flow coefficient which varies according to the roofing material.

In order to determine the amount of water that can be collected from the roofs, it is necessary to calculate the rainwater yield. According to meteorological information, the amount of rainwater collection to be collected can be calculated with the following equivalence (DIN, 1989; Kantaroglu, 2011; Üstün et al, 2020).

Total Rainwater Harvest = Rainwater Collection Area × Annual Rainfall Amount × Roof Coefficient × Filter Activity Coefficient

$$\Sigma W = A \times M \times \alpha \times \beta \tag{3}$$

ΣW: Total rainwater harvest (m^3)

A: Rainwater collection area (total roof area refers to) (m^2)

M: Precipitation amount (the total annual rainfall refers to the amount) (mm/m^2).

Roof coefficient (α): All of the rain falling on the roof surface will be recycled (α=0.8 and α=0.9).

Filter activity coefficient (β): German standards (DIN, 1989) are stated as 0.9
It is the efficiency coefficient of the first filter used for the decomposition of rainwater collected from the roof from solids. It is a determined coefficient taking into account that a certain part of the rainwater cannot pass through the filter (β=0.9) (Yalılı Kılıç ve Abuş, 2018).

In these calculations, the flow coefficient is a dimensionless factor indicating the effect of water collection losses and depends on the nature of the surface slope and the intensity of precipitation. Therefore, since not all the water falling into a roofing area can be collected, it is necessary to take into account the flow coefficient. According to the roofing material, the flow coefficient of the rainwater collection surface is given in Table 13. The flow coefficient for this work is 0.90 for the new metal roof; 0.80 for the concrete pavement roof.

Table 13. Runoff coefficient of rainwater collection surface according to roof material (TOB, 2023).

Roof Material Coefficient	
Water Retention Surface	Flow Coefficient
Tiles	0.75-0.90
Old Tiles	0.75-0.80
New Tiles	0.80-0.90
Metal Roofs	0.70-0.90
Old Metal Roofs	0.70-0.80
New Metal Roofs	0.80-0.90
Coatings Coatings	0.50-0.80
Concrete Coating	0.60-0.80

Table 13 (Continued) Runoff coefficient of rainwater collection surface according to roof material (TOB, 2023).

Brick Coating	0.50-0.60
Floors	0.01-0.30
Sloping ground floor (uncompressed) less than 10%	0.01-0.10
Sloping ground floor (compressed) less than 10%	0.15-0.30
Natural Rock Flooring	0.20-0.50
Green Fields	0.05-0.10

3.2.3 Roof Surface Area

The knowledge of the roof areas for the Central and Seyitler campuses of Artvin Coruh University is given in Table 14.

Table 14. Center and Seyitler Campus roof areas

Central Campus	Roof Area m^2
C1 Block Education Faculty Classroom	1249
C2 Block Faculty of Health Sciences Classroom	1249
C4 Block Faculty of Health Sciences Offices	597
C5 Block Canteen Building	494
C6 Block Education Faculty Offices	713
A1 Block Faculty of Arts and Sciences Classroom	1249
A2 Block Health MYOClassroom	1249
A4 Block Health MYO Offices	597
A5 Block Rectorate Canteen	494
A6 Block Faculty of Arts and Sciences Offices	713
Congress Center	2248
Central Library	875

Seyitler Campus	Roof Area m^2
Forest Faculty	4584
Engineering Faculty	1085
Artvin MYO	1085
Social Indoor Facility	2683
Indoor Gym	2744
Building Works	291
Research Laboratory	967
Furniture Workshop	1720
Greenhouse	252

3.3 Determination of Volume for Storage

After calculating the amount of rainwater that can be collected from the roofs of buildings, the volume of storage tanks should be determined. This is an important stage in the cost of the system. In this study, the required volume of water tanks is considered to be equal to the maximum volume of rainfall that can be harvested throughout the year. The storage volume calculation of the system was made considering the month of December when the maximum rainfall was.

The storage volume of rain to be stored as a result of rain water harvest has been calculated according to Equation 4 (Temizkan ve Kayılı, 2020).

$$V = A \times M_{max} \times \alpha \times \beta \tag{4}$$

Here;

V: Required tank volume (L)

A: Rainwater collection area (m^2)

Mmax : Amount of precipitation for the month with the most precipitation (mm/m^2)

α : Roof coefficient

β : Filter efficiency coefficient

Since the month with the most rainfall in Artvin province is December, data were calculated by taking Mmax = 85.6 mm.

3.3.1 Tank Selection

Rainwater tanks are the part where harvested water is stored for subsequent use. The choice of rainwater tank varies according to the rainfall characteristics of the region, the roof area and the needs of the user. Tanks can be made of various materials. The most commonly used water tanks are polyethylene, polyester (fibreglass) and metal tanks, which can be supplied in different shapes and structures (Anonymous 14, 2024).

- **Plastic tanks**

They are tanks manufactured from high density polyethylene (HDPE), commonly known as polyethylene tanks. These tanks are more cost effective than other tanks and do not require installation, but aesthetically they may not be a good option. Plastic tanks are relatively lightweight and can be easily cut with standard tools and mounted on the body when valves or fittings need to be installed. Models in different colours and capacities for underground and above ground use are readily available.

Figure 34. Example of plastic tank (Anonymous 14, 2024)

- **Fiberglass tanks**

Fibreglass tanks are corrosion resistant, robust and long-lasting products. Fibreglass warehouses are more advantageous products compared to other storage products thanks to their flexible manufacturing, which allows special inputs and outputs to be made at the manufacturing stage according to the demands and needs. Although fibreglass is very resistant to chemicals and temperature, it requires correct design, manufacturing and installation for a suitable application purpose. No special adaptation is required like polyethylene tanks. Fibreglass tanks can be easily repaired when broken or damaged, but it is not possible to say the same for polyethylene or concrete tanks. Thanks to its non-porous structure, it does not cause taste disorders in water. U.V. resistant paint coated products are available in different colours.

Figure 35. Example of fiberglass tank (Anonymous 14, 2024).

- **Metal tanks**

Stainless steel cylindrical tanks, membrane modular cylindrical tanks and stainless prismatic modular tanks are the tanks used in the metal tanks class for water storage needs. Metal tanks, which have advantages over each other according to their usage areas, are a good alternative to create a sustainable resource with their long-lasting use. There are tanks with different capacities from 2000 litres to 200000 litres. Since the tank components are disassembled, it provides convenience in transport, re-assembly and de-assembly stages. Stainless steel tanks are one step ahead of other tanks for domestic use with their resistance to corrosion, dirt and bacteria formation. They are preferred in storage systems where rainwater will be used as drinking water (Figure 36) (Anonymous 15, 2024).

Figure 36. Example of metal tank (Anonymous 15, 2024).

3.3.2 Considerations in Selecting a Suitable Tank

In rainwater storage systems, most of the investment is allocated for water tanks. As a result, when the rainwater to be stored is used, it will be seen in time that it is a self-paying system. In addition, it should not be forgotten that by choosing a tank that can be used in the long term and will cause the least damage to the environment, investment is also made for sustainable life and a clean future.

The following factors should be considered for an optimum tank selection:

- ✓ Stormwater performance: % of rainwater supply
- ✓ Regional rainfall regime: Annual rainfall regime provided by local stations
- ✓ Roof catchment area: Roof area where rainwater will be collected
- ✓ Storage space: Space allocated for storage
- ✓ Mains water: Availability of mains water to be adapted to the system
- ✓ Total water requirement: Amount of water needed for home and garden applications.

3.4 Volumetric Reliability Analysis

Water saving efficiency, also called volumetric reliability, is measured as the percentage of the main water supply that can be saved. Reliability indicates the probability of a tank to provide the required amount of water needed by consumers (Karim et al, 2021).

In this study, the volumetric reliability of water consumption for irrigation of green areas and general use is considered and calculated by dividing the amount of rainwater consumed by the total amount of water needed. Volumetric reliability can be calculated using Equation 5 below.

Rv: volumetric reliability = ratio of available rainwater supply to demand

$$Rv = (\text{Water Supply} / \text{Water Requirement}) \times 100 \tag{5}$$

4. FINDINGS AND DISCUSSION

4.1. Amount of Annual Rainwater Collected

Table 15 and Table 16 show the annual rainwater amounts that can be collected for Artvin Çoruh University Central Campus and Seyitler Campus. When the building roof areas are analysed, it is seen that buildings with larger roof areas are more suitable for rainwater storage. Faculty of Education Classroom, Faculty of Health Sciences Classroom, Faculty of Science and Letters Classroom, Health Vocational School Classroom and Congress Centre are the buildings with the largest roof areas in the Central Campus. This will affect the tank selection and will require the selection of larger tanks in these buildings in terms of volume.

Table 15. Amount of rainwater that can be collected for the Central Campus

Central Campus	Roof Area m^2	Collectable Rainwater (m^3)
C1 Block Education Faculty Classroom	1249	699.68
C2 Block Faculty of Health Sciences Classroom	1249	699.68
C4 Block Faculty of Health Sciences Offices	597	334.44
C5 Block Canteen Building	494	276.74
C6 Block Education Faculty Offices	713	399.42
A1 Block Faculty of Arts and Sciences Classroom	1249	699.68
A2 Block Health MYO Classroom	1249	699.68
A4 Block Health MYO Offices	597	334.44
A5 Block Rectorate Canteen	494	276.74
A6 Block Faculty of Arts and Sciences Offices	713	399.42
Congress Center	2248	1259.32
Central Library	875	435.71
TOTAL	11727	6514.95

In this table, Forest Faculty, Social Indoor Facility and Indoor Gym buildings are the buildings with the largest roof areas in the Seyitler Campus. This will affect the tank selection and will require the selection of larger tanks in these buildings in terms of volume.

Table 16. Amount of rainwater that can be collected for the Seyitler Campus

Seyitler Campus	Roof Area m^2	Collectable Rainwater (m^3)
Forest Faculty	4584	2567.94
Engineering Faculty	1085	607.81
Artvin MYO	1085	607.81
Social Indoor Facility	2683	1503.01
Indoor Gym	2744	1537.18
Building Works	291	163.02
Research Laboratory	967	541.71
Furniture Workshop	1720	963.54
Greenhouse	252	141.17
TOTAL	15411	8633.18

4.2. Suitable Tank Selection According to Storage Volume

After calculating the amount of rainwater that can be collected from the roofs of the buildings, the volume of the tank where the rain will be stored is calculated according to Equation 4. Determining the tank volume is an important step and is one of the most important factors affecting the cost. Considering the initial installation cost of the system, the budget to be spent on tanks will correspond to a large part of the total cost.

The storage volume was calculated according to the maximum rainfall in December (Mmax = 85.6 mm). The storage volumes for each campus are given in Table 17 and Table 18.

Table 17. Tank volumes and selection of suitable tanks for the Central Campus

Central Campus	Tank Volume (m^3)	Available Tank
C1 Block Education Faculty Classroom	86.60	90 tonne
C2 Block Faculty of Health Sciences Classroom	86.60	90 tonne
C4 Block Faculty of Health Sciences Offices	41.39	45 tonne
C5 Block Canteen Building	34.25	35 tonne
C6 Block Education Faculty Offices	49.44	50 tonne
A1 Block Faculty of Arts and Sciences Classroom	86.60	90 tonne
A2 Block Health MYO Classroom	86.60	90 tonne
A4 Block Health MYO Offices	41.39	45 tonne
A5 Block Rectorate Canteen	34.25	35 tonne
A6 Block Faculty of Arts and Sciences Offices	49.44	50 tonne
Congress Center	155.87	160 tonne
Central Library	53.93	60 tonne

Table 18. Tank volume and suitable tank selection for Seyitler Campus

Seyitler Campus	Tank Volume (m^3)	Available Tank
Foresty Faculty	317.84	320 tonne
Engineering Faculty	75.23	80 tonne
Artvin MYO	75.23	80 tonne
Social Indoor Facility	186.03	200 tonne
Indoor Gym	190.26	200 tonne
Building Works	20.18	25 tonne
Research Laboratory	67.05	70 tonne
Furniture Workshop	119.26	120 tonne
Greenhouse	17.47	20 tonne

Storage tanks are usually the most expensive component in any roof collection system and it is important to select the most appropriate type. The shape, size, material or location of the tanks should not cause aesthetic incompatibility. When selecting a storage tank, it may be desirable to reduce the height and increase the area of the tank, increase the height and reduce the area of the tank, or replace one large tank with several smaller tanks.

Considering the amount of rainwater collected, it is considered appropriate to place separate tanks for each building. For buildings with a tank volume exceeding 100 m^3 (100 tonnes), it will be necessary to place more than one tank instead of one. For example, for the Faculty of Forestry located in Seyitler Campus, this means 3 tanks of 100 tonnes and 1 tank of 20 tonnes. The number of tanks to be used is given in Table 19.

Table 19. Tank quantity

Central Campus	Tank quantity		Seyitler Campus	Tank quantity
C1 Block Education Faculty Classroom	1 piece 90 tonne		Forest Faculty	3 pieces 100 tonnes + 1 piece 20 tonnes
C2 Block Faculty of Health Sciences Classroom	1 piece 90 tonne		Engineering Faculty	1 piece 80 tonnes
C4 Block Faculty of Health Sciences Offices	1 piece 45 tonne		Artvin MYO	2 piece 80 tonnes
C5 Block Canteen Building	1 piece 35 tonne		Social Indoor Facility	2 pieces 100 tonnes
C6 Block Education Faculty Offices	1 piece 50 tonne		Indoor Gym	2 pieces 100 tonnes
A1 Block Faculty of Arts and Sciences Classroom	1 piece 90 tonne		Building Works	1 pieces 25 tonnes
A2 Block Health MYO Classroom	1 piece 90 tonne		Research Laboratory	1 pieces 70 tonnes
A4 Block Health MYO Offices	1 piece 45 tonne		Furniture Workshop	1 pieces 100 tonnes + 1 piece 20 tonnes
A5 Block Rectorate Canteen	1 piece 35 tonne		Greenhouse	1 piece 20 tonnes
A6 Block Faculty of Arts and Sciences Offices	1 piece 50 tonne			
Congress Center	1 piece 100 tonne +1 piece 60 tonne			
Central Library	1 piece 60 tonne			

4.3. Volumetric Reliability Analysis Results

Volumetric reliability, also known as water saving efficiency, is the percentage of the main water source that can be saved (Karim et al, 2021). It is obtained by dividing the amount of rainwater consumed by the total amount of water needed. Volumetric reliability was calculated using Equation 5.

The best Rv results were found in December, when rainfall increased, although consumption was relatively higher than in other months.

The amount of water for toilets and general use in the University Centre and Seyitler campuses and the efficiency of monthly water use are shown in Table 20 and Table 21.

Table 20. Volumetric reliability for Central Campus

Central Campus				
Months	Monthly Rainfall Amount (mm)	Collected RWH (m^3)	Total Monthly Water Consumption (m^3)	Volumetric Reliability Rv (%)
January	84.6	856.90	1834	46.72
February	71.5	724.21	812	89.19
March	60.8	615.84	1245	49.46
April	53.2	538.86	671	80.31
May	53.1	537.84	1045	51.47
June	49.2	498.34	848	58.77
July	31.1	315.01	861	36.59
August	29.1	294.75	1186	24.85
September	37.9	383.88	712	53.92
October	60.4	611.78	1901	32.18
November	75.1	760.68	2089	36.41
December	85.6	867.03	1463	59.26
Annual	691.6	7005.13	14667	47.76

Table 21. Volumetric reliability for Seyitler Campus

Seyitler Campus				
Months	Monthly Rainfall Amount(mm)	Collected RWH (m^3)	Total Monthly Water Consumption (m^3)	Volumetric Reliability Rv (%)
January	84.6	1056.05	2533	41.69
February	71.5	892.53	2100	42.50
March	60.8	758.96	2318	32.74
April	53.2	664.09	1358	48.90
May	53.1	662.84	1407	47.11
June	49.2	614.16	1196	51.35
July	31.1	388.22	1780	21.81
August	29.1	363.25	2272	15.99
September	37.9	473.10	2423	19.53
October	60.4	753.97	1797	41.96
November	75.1	937.47	2304	40.69
December	85.6	1068.54	2084	51.27
Annual	691.6	8633.18	23572	36.62

The calculated data show that the amount of rainwater collected decreased due to the decrease in precipitation in August, i.e. in the hot period, and due to this decrease, there was a decrease in volumetric reliability in terms of water saving efficiency due to the increase in consumption compared to the previous month. The resulting values show that; considering the amount of water that can be saved annually, an average of 42.19% volumetric reliability can be mentioned for both campuses, which is a very good and high rate. This means that this amount of water can be saved annually.

4.4. Cost Analysis

Rainwater harvesting systems for Artvin Çoruh University Central and Seyitler campuses have the potential to reduce water bills within the university and provide an additional water source at a reasonable cost. In order to implement this system at Artvin Çoruh University and set an example for the city, it is extremely important that the competent authorities take steps to implement such highly sustainable projects.

4.4.1. Saved Budged

Cost analysis is an important factor in deciding on the implementation of the system. Also, since there is more than one use of water, the cost depends on the desired use of water. In this part of the study, the amount of savings was found using Equation 6 (Aldawahid, 2022). The value of the water tariff determined by the municipality in Artvin varies according to the function of the building. In the tariff used by public institutions in Artvin, the water sales price (mains water fee) is 41.59 TL/m^3 (1.17 \$/m^3) including wastewater fee.

$$S = Vh \times Wt \tag{6}$$

$S = 15148.31\ m^3 \times 41.59\ TL/m^3$

S=630010.73 TL (17746.78 $)

S: Saved cost

Vh: is the amount of rainwater collected in cubic metres (sum of Seyitler and Central Campus),

Wt: Water tariff in m^3 including taxes for institutions in Artvin

Looking at the average of both campuses in the volumetric reliability analysis, the amount of water that can be saved in 1 year shows an average of 42.19%. This means that a budget of 630010.73 TL (17746.78 $) is protected and saved.

4.4.2. System and Installation Cost

In order to determine the cost of the rainwater harvesting system, the equipment and components to be used in the system installation should be determined depending on the purpose of water use of the building. In the university buildings, the use of rainwater for toilets and cleaning is considered, and irrigation is provided from groundwater, i.e. wells, and does not create an additional cost.

For he purpose of to determine the tank prices, Izoplas and Otank companies, which produce tanks in the market, were selected. Polyester, above ground, horizontal water tanks were selected and the cost table is shown in Table 22. Tank prices constitute the most costly item in the cost calculation.

Table 22. Tank cost (Anonymous 14, 2024).

Volume	Quantity	Unit Price (TL)	Total Price (TL)
100	9	500000.00	4500000.00
90	4	460000.00	1840000.00
80	2	400000.00	800000.00
70	1	340000.00	340000.00
60	2	265000.00	530000.00
50	2	215000.00	430000.00
45	2	202000.00	404000.00
35	2	145000.00	290000.00
25	1	126000.00	126000.00
20	3	100000.00	300000.00
TOTAL	28	2753000.00 (77549.29 $)	9560000.00 (269295.77$)

The Regulation on Rainwater Collection, Storage and Discharge Systems was utilised to ensure that the collected rainwater is of a quality to be used in toilets or for cleaning. According to the Regulation, rainwater to be used as domestic water in homes, workplaces and gardens must undergo filtration before entering the storage in order to prevent the accumulation of suspended solids in the tanks. The filter should be placed in the collection pipes. The filter to be selected shall be a filter with a filtration efficiency of at least 90%, which does not allow the passage of solids larger than 1.25 mm (ÇŞB, 2017). In this direction, it is envisaged to place a vortex filter in the piping system between the rainwater collection channel in the buildings and the water tank. 28 stainless steel vortex filters were selected to filter rainwater and separate solids such as leaves, stones, etc. from the water. Vortex filter cost is given in Table 23.

Table 23. Filter cost (Anonymous 16, 2024)

Buildings	Vortex filter quantity	Unit Price (TL)	Total Price (TL)
C1 Block Education Faculty Classroom	1	33150.00	33150.00
C2 Block Faculty of Health Sciences Classroom	1	33150.00	33150.00
C4 Block Faculty of Health Sciences Offices	1	15550.00	15550.00
C5 Block Canteen Building	1	8800.00	8800.00
C6 Block Education Faculty Offices	1	15550.00	15550.00
A1 Block Faculty of Arts and Sciences Classroom	1	33150.00	33150.00
A2 Block Health MYO Classroom	1	33150.00	33150.00
A4 Block Health MYO Offices	1	15.550.00	15550.00
A5 Block Rectorate Canteen	1	8800.00	8800.00
A6 Block Faculty of Arts and Sciences Offices	1	15550.00	15550.00
Congress Center	2	33150.00	66300.00
Central Library	1	15550.00	15550.00
Forest Faculty	4	33150.00	132600.00
Engineering Faculty	1	33150.00	33150.00
Artvin MYO	1	33150.00	33150.00
Social Indoor Facility	2	33150.00	66300.00
Indoor Gym	2	33150.00	66300.00
Building Works	1	8800.00	8800.00
Research Laboratory	1	15550.00	15550.00
Furniture Workshop	2	33150.00	66300.00
Greenhouse	1	8800.00	8800.00
TOTAL	28	493150.00 (13891.5 $)	725200.00 (20428.17 $)

Submersible pumps are the equipment used to raise the water in the tank into the building by pressurising it. In order to transfer the water from the tanks to the building network, 28 stainless clean water submersible pumps will be added to the system. A submersible pump with a delivery capacity of 6000 L/hMax, a delivery head of 45 mMax and a submergence depth of 12 mMax was selected. The cost of the equipment is given in Table 24.

Table 24. Submersible pump cost (Anonymous 17, 2024)

Quantity	Unit Price (TL)	Total Price (TL)
28	13625.00 (383.80 $)	381500.00 (10746.48 $)

Since rainwater will be used for toilets and surface cleaning, sand filter and activated carbon filter will also be integrated into the system to prevent odour that may occur over time since there will be live microorganisms in the water that will wait in the selected tank. Although it requires an additional cost, it is deemed necessary to use it in the applications and examples.

In addition, the inlet flow regulator, overflow siphon and surface suction filter to be placed in the tank also constituted a cost item as a rainwater set. The internal materials of a storage tank are shown in Figure 39 and the cost expense is given in Table 25.

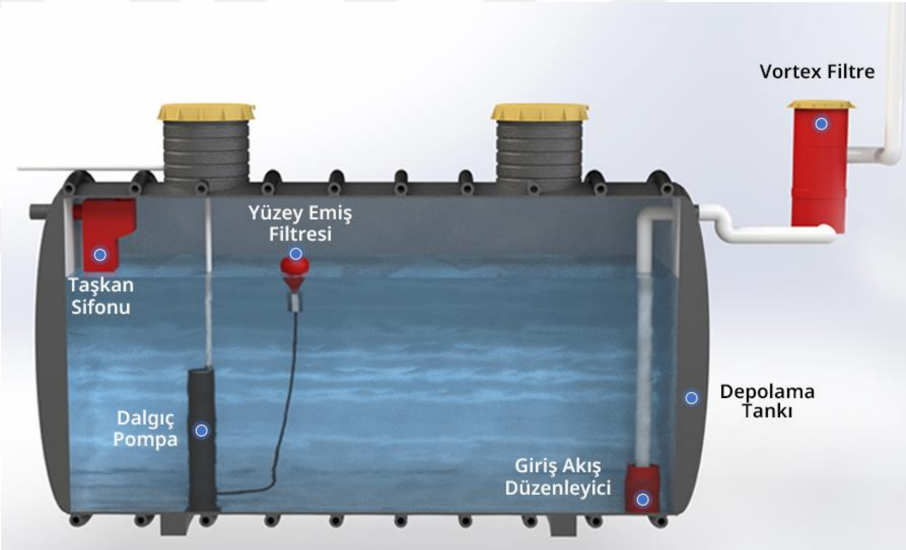

Figure 37. Equipment inside the storage tank (Anonymous 18, 2024)

Table 25. Rain set, sand and active carbon filter (Anonymous 18, 2024)

Model	Quantity	Unit Price (TL)	Total Price (TL)
Rain set 3000	18	17400.00	313200.00
Rain set 0200	6	13100.00	78600.00
Rain set 0150	4	9800.00	39200.00
Sand Filter (100 person)	4	13890.00	55560.00

Table 25 (Continued) Rain set, sand and active carbon filter (Anonymous 18, 2024)

Sand Filter (50 person)	13	12100.00	157300.00
Sand Filter (10 person)	4	11220.00	44880.00
Active Carbon Filter (100 person)	4	15650.00	62600.00
Active Carbon Filter (50 person)	13	12790.00	166270.00
Active Carbon Filter (10 person)	4	11450.00	45800.00
TOTAL	70	117400.00 (3307.04 $)	963410.00 (27138.30 $)

After calculating the amount of savings for the buildings of Artvin Çoruh University Central and Seyitler Campuses, the cost of the system was calculated by adding the cost of each part for the payback period calculation. The total system cost is as shown in Table 26.

Table 26. Total cost

Tank Cost	9560000.00 (269295.77$)
Submersible Pump Cost	381500.00 (10746.48 $)
Vortex Filter Cost	725200.00 (20428.17 $)
Rain Set Cost	963410.00 (27138.30 $)
TOTAL	11630110.00 (327608.73 $)

Finally, in order to determine the economic feasibility of the system, the payback period was taken into account and the implementation cost was compared with the amount of savings. Payback period refers to the time to recover the cost of the initial investment. Payback period as an analysis tool is applied to understand whether the project to be implemented is profitable or not. Since the rainwater harvesting system consists of many different components, the main components that cover most of the initial investment costs of the system were taken into consideration when calculating the payback period.

The payback period can be determined using Equation 7.

$$\text{Payback Period} = \frac{\text{Total System Cost}}{\text{Amount saved per year}} \tag{7}$$

$$\text{Payback Period} = \frac{11630110.00}{630010.73}$$

Payback Period = 18.46 year ~ 19 year

While the continuity of the university and the fact that it will educate students for many years is obvious, the initial cost of the rainwater collection system to be installed may seem high, but the system will pay for itself over the years. The threshold value of the payback period of the systems related to the use of rainwater in micro areas has been accepted to be 20 years and less than 20 years by expert opinion (TOB, 2023). In this sense, it can be said that the rainwater harvesting system considered for this thesis study is rantable, in other words, it is efficient.

5. CONCLUSIONS and RECOMMENDATIONS

All life forms have shown that water is the source of life and the most important indispensable element. Hydrologically, it has always existed as a cycle on earth and will continue to exist in the future. However, unconscious use and consumption of resources damage this cycle. Water is often depleted before it can complete its hydrological cycle. Approximately 71% of the Earth's surface is covered with water, but only 0.3% of it consists of fresh water resources suitable for use. It is very important that water, which is a natural resource, is used consciously and without waste by people. In this context, the sustainability of water, which is a natural resource, is extremely necessary in today's world and is an issue that is emphasised in many countries.

Countries have to take water-related measures themselves and consider rainwater as an alternative in order to use water economically and to make maximum use of water. In regions where water resources are scarce or although water resources are abundant, rain harvesting should be done from the collection areas in urban buildings in order to meet the demands for domestic use, industry, agriculture and environmental purposes. In this way, water resources will be protected.

Studies have shown that rain harvesting has many benefits. A simple technology is applied in the systems required for the collection of rainwater. This provides ease of maintenance. This situation provides economic benefits. While the invoice amount is reduced in homes and workplaces, the reduction of water resources can be prevented on an industrial scale. Rainwater is also suitable for irrigation in parks, gardens and agriculture. At the same time, water stored in large volumes is useful in areas where forest and bush fires are common. Rainwater stored in times of active precipitation helps to reduce flooding in low-lying areas and prevents pollution caused by erosion with surface waters.

The protection of resources in the world, which continues to develop with technology and increasing population, is a human duty to be transferred to future generations and is absolutely necessary. Rain harvesting is a good alternative to serve sustainability.

In this thesis, the applicability of rainwater harvesting has been investigated based on Artvin Çoruh University Central and Seyitler Campuses, and the results have been objectively evaluated with mathematical calculations. 2023 precipitation data and water consumption data in the campuses for the same year were obtained and calculations were requested to be made and information support was provided from the Administrative Affairs unit and the Building Works unit of the University in order to complete these calculations. The Building Works unit shared the ‘roof area and roof material’ information of the university buildings, and the Administrative Affairs unit shared the ‘water consumption data’ information, and the necessary calculations were made in the light of the shared data. The annual rainfall for Artvin is 691.6 mm and the calculations showed that the total amount of consumption data read from the meters is 38239.0 m^3 while the amount of rainwater that can be collected annually is 15148.13 m^3. The volumetric reliability analysis calculated in this context showed an average of 42.19% for both settlements. This means that approximately 42% of water can be saved in a year. The reflection of this rate on the budget corresponds to 630010.73 TL (17746.78 $) annually.

In the rainwater harvesting study within the scope of the thesis, after the budgetary part of the water that can be saved for Artvin Çoruh University Central and Seyitler Campuses was revealed by calculations, the expenditure items to be made for the installation and system were examined and the installation cost was found. Labour force and other costs were ignored. In this context, the most serious cost item was the selected rainwater storage tanks. The total cost of 28 tanks for both campuses is 9560000.00 TL (269295.77$). In addition, since a vortex filter should be placed in the piping system between the rainwater collection channel in the buildings and the water tank, a total of 7252000.00 TL (20428.17 $) for 28 vortex filters, 3815000.00 TL (10746.48 $) for 28 submersible pumps since a submersible pump should be placed in each tank, and 963410.00 TL (27138.30 $) for the inlet flow regulator, overflow siphon and surface suction filter, sand filter and activated carbon filter to be placed in the tank as a rainwater set. The total cost was calculated as 11630110.00 TL (327608.73 $).

When the resulting cost amount and savings amount are compared, if rainwater harvesting, which is the subject of this thesis, is implemented, the system will pay itself back in approximately 19 years. In the Final Report of the Adaptation to Climate Change in Water Resources Project of the Ministry of Agriculture and Forestry, General Directorate of Water Management, it is stated that ‘The threshold value of the payback period of the systems is 20 years with expert opinion and in cases where it is less than 20 years, it is accepted that these systems are rational’. In this context, it can be said that the payback period of 19 years revealed by the calculations made in the thesis study is rantable, in other words, it is efficient.

It is thought that the implementation of rainwater harvesting technology in Artvin province and Artvin Çoruh University Central and Seyitler Campuses will not only contribute to reducing utility bill costs in buildings, but also relieve the pressure on municipalities to provide enough clean water to the public.

Rainwater harvesting, which is analysed in this thesis, is thought to be promising in terms of increasing the availability of usable water in Turkiye, contributing to sustainability, creating a tradition of saving and leaving clean resources for future generations. The existing potential of rainwater, which is a natural resource, should not be ignored. For this reason, it is recommended that the relevant ministries and government agencies should encourage water harvesting in all commercial and public buildings, especially buildings with large roofs, medium-sized houses and detached houses with financial state incentives.

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RESUME

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