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# Rainwater Harvesting and System Design in Livestock Farms

## Hayvancılık İşletmelerinde Yağmur Suyu Hasadı ve Sistem Tasarımı

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**Abstract:** The most critical threat that global warming poses is undoubtedly water scarcity. Especially in the agricultural sector, water is an indispensable component. Therefore, it is essential to develop alternative water resources and methods against water scarcity that threatens our future. In this study, rainwater harvesting potentials on the roofs of livestock barns were determined, and system designs were made. The study was carried out at Bursa Uludag University Faculty of Veterinary Medicine Animal Health and Animal Production, Research and Application Center. According to the study results, the most rainwater was harvested in December, and the least was harvested in August. While the required water requirement in the examined poultry farms can be supplied at 71.5% in December, 13.3% can be completed in August. In the sheep farms, 90.4% of the need can be supplied with 216.9 $m^3$ of water collected in December, while water can be transferred to other months. While it is possible to supply 57.4% of the cattle in the winter months, this rate drops to 16.4% in the summer months. In dairy cattle farms, on the other hand, while the need can be supplied in winter with rainwater harvesting, the requirement can be supplied by storing the existing water and transferring it to different periods. Rainwater harvesting systems designed for livestock farms can pay for themselves in 7 years at the latest.

**Keywords:** Bursa, depreciation period, livestock, storage design, rainwater

**&**

**Öz:** Küresel ısınmanın dünyamızda oluşturduğu en önemli tehdit şüphesiz ki su kıtlığıdır. Özellikle tarım sektöründe su vazgeçilemez bir bileşendir. Bundan dolayı geleceğimizi tehdit altına alan su kıtlığına karşı alternatif su kaynakları ve yöntemleri geliştirmek çok önemlidir. Bu çalışmada, hayvan barınaklarının çatılarından yağmur suyu hasadı potansiyelleri belirlenmiş ve sistem tasarımları yapılmıştır. Çalışma Bursa Uludağ Üniversitesi Veterinerlik Fakültesi Hayvan Sağlığı ve Hayvansal Üretim, Araştırma ve Uygulama Merkezinde yürütülmüştür. Çalışma sonucuna göre, işletmelerin genelinde Aralık ayında en fazla, Ağustos ayında ise en az yağmur suyu hasadı yapılmıştır. İncelenen kümes işletmelerinde Aralık ayında gerekli su ihtiyacı %71.5 oranında karşılanabiliyorken, Ağustos ayında %13.3'ü karşılanabilmektedir. Koyun işletmesinde ise Aralık ayında toplanan 216.9 $m^3$ su ile ihtiyacın %90.4'ü karşılanabiliyorken diğer aylara da su transferi yapılabilmektedir. Besi sığırı işletmesinde kış aylarında %57.4'ünü karşılamak mümkün iken yaz aylarında bu oran %16.4'e kadar düşmektedir. Süt sığırı işletmelerinde ise yağmur suyu hasadı ile kış aylarında ihtiyacın tamamı karşılanabilirken var olan suyun depolanarak diğer dönemlere de aktarılmasıyla ihtiyacı giderebilmektedir. İşletmeler için tasarlanan yağmur suyu hasadı sistemleri ise en geç 7 yılda kendini amorti edebilmektedir.

**Anahtar Kelimeler:** Bursa, amortisman süresi, çiftlik hayvanları, depolama tasarımı, yağmur suyu

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## INTRODUCTION

In recent years, global warming's severity has increased considerably and seriously threatens our future. It is seen that this situation increases the need for water in factors such as increasing population, industrialization, and food supply, but it gradually decreases the power to provide it. Water is the most essential need for living things to survive. It constitutes 2/3 of the human body and is vital for physical and psychological health. Although the human body can survive for a long time without food, it can only survive 3-5 days without water (Akın and Akın, 2005). The importance of water for people is not only a necessity for their health, but it is also vital for them to continue their lives in daily life. Although water is used in many different areas such as cleaning, food, textile, and energy production in daily life, besides industry, the most consumer of water in our country is the agriculture sector, with a rate of 70% (Aydın, 2019).

While water is essential for all living things, it also has particular importance for animals. The hardness, quality, and amount of water to be used in the care of animals must be in the appropriate ratio. In addition, the animal's environmental conditions and physical and physiological characteristics should be considered in water consumption. In cases where the animals are not given water of sufficient quality and quantity, it causes them to become ill, reduces their feed consumption, and decreases the yield. For this reason, inadequate water and faulty methods cause health problems in animals, and they also cause economic damage to the enterprise.

Only 3.5% of the total water in the world is usable. The fact that resources are depleted or become unusable daily poses a severe threat to the next generation. The increasing human population, damages caused by domestic and industrial wastes in existing water resources, and current political and environmental problems cause rapid depletion and pollution of water resources. One of the methods that can be applied to prevent water shortages and water scarcity problems that may occur in the future is to reuse the used, dirty water by treating it. However, this creates very high costs. Because of this situation, it becomes necessary to turn to alternative water recovery methods.

Rainwater harvesting as an alternative water recovery method has become more important recently. While only 30% of the precipitation in the world is mixed with groundwater, the remaining significant amount of rainfall cannot be used and is lost. Thanks to the rainwater harvesting method applied in buildings, a significant amount of lost rainwater can be stored. The stored water can be used as drinking water and using water in houses and operations and water savings can be achieved. To obtain maximum efficiency from rainwater harvesting, it is necessary to pay attention to the precipitation characteristics of the place where the system will be installed, how much water the system can provide, and the initial costs (Üstün et al., 2020). At the same time, the warehouse selection should be made according to the seasonal precipitation scale of the region where the system will be installed. It should have the capacity to store rainwater during the periods when the precipitation is the highest, and it should be able to be used during periods when the rainfall is low (Çaylı, 2021).

This study determined the rainwater harvesting capacity of the livestock farms in Bursa Uludag University Faculty of Veterinary Medicine, Animal Health and Animal Production, Research and Application Center, and the system design was created. The payback period of this system and the possible water savings are evaluated.

## MATERIAL AND METHOD

### *Study Area*

The study was carried out at Bursa Uludag University Faculty of Veterinary Medicine Animal Health and Animal Production, Research and Application Center. The study aims to determine the amount of water that can be saved by selecting the ratio of the water obtained by rainwater harvesting method in the beef cattle, dairy cattle, sheep barn, and poultry roofs in the application center to supply the water needed in the livestock farms. Since the livestock farms examined in the study are far from each other, all the farms were evaluated, and a separate calculation and design were carried out for each.

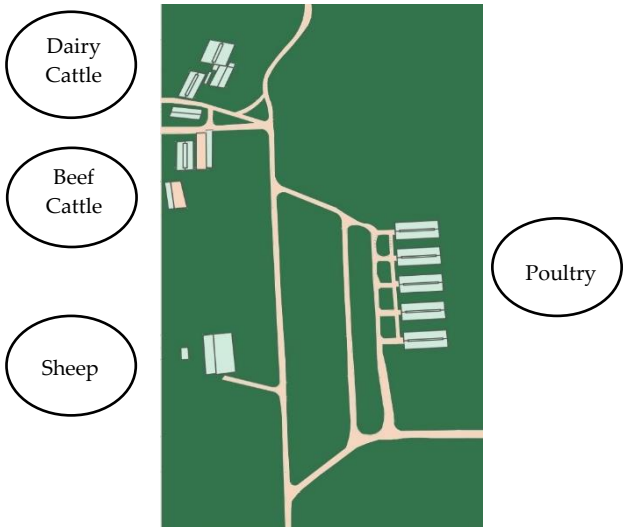


**Figure 1.** Top view of the research center where the study was conducted.
*Şekil 1. Çalışmanın yürütüldüğü araştırma merkezinin üst görünüşü.*

The dimensions of the barns examined in the study were obtained by visiting the farms and making measurements in the barns with the help of a laser meter (Extech DT300, USA) (Figure 2). In the dimensions, the areas of the roofs were calculated by measuring the barns' length, width, and ridge height. The calculated roof areas are 3359 $m^2$, 1145 $m^2$, 1336 $m^2$ and 2720 $m^2$ for poultry, sheep, beef, and dairy cattle processing, respectively. Since five houses belong to the poultry farm, the maximum roof area is calculated for the poultry farm. The sheep barn is the farm with the smallest roof area.


**Figure 2**. Extech DT300 Laser meter.
*Şekil 2. Extech DT300 Lazermetre.*

***Rainwater Harvest Calculation***

In the study, Equation (1) was used for rainwater harvest calculations of livestock farms (TEMA, 2017; Yalılı Kılıç and Abuş, 2018; Temizkan and Kayılı, 2021; Çakar, 2022).

$$\text{Rainwater Harvest} = A \times P \times RC \times FEC \quad (1)$$

A: Roof area of buildings to be harvested ($m^2$)

P: Precipitation (L $m^{-2}$)

RC: It is the roof coefficient that indicates that all precipitation reaching the roof cannot be reused. It is the coefficient specified by German standards as 0.8 in DIN1989.

FEC: It is the efficiency coefficient of the first filter passed to separate the rainwater collected from the roof from the visible solids. It is a coefficient given by calculating that not all water can pass through here. It is specified as 0.9 in DIN1989.

Monthly precipitation amounts (P) for Bursa were obtained from the official website of the General Directorate of Meteorology (MGM, 2021). Rainfall averages of the last thirty years of precipitation are taken into account.

In the study, the amount of water that can be harvested with the rainwater harvesting system to be installed on the roofs of the barns was compared with the water requirement of the enterprise. The daily drinking and potable water needs of livestock are given in Table 1 (Chapagain and Hoekstra, 2003). According to the rate of meeting the water requirement, the financial gain and water savings provided by the system were calculated using the Bursa Metropolitan Municipality's water charge tariff. Appropriate rain harvesting system designs were made for the livestock enterprises examined in the study.

**Table 1.** Daily water consumption required for livestock.
*Çizelge 1. Hayvanlar için gerekli günlük su tüketimleri.*

| Livestock | Drinking water consumption of livestock (liter head$^{-1}$ day$^{-1}$) | Amount of water used for livestock (liter head$^{-1}$ day$^{-1}$) |
|---|---|---|
| Beef cattle | 38 | 11 |
| Calf | (5-23) 14 | 0 |
| Dairy cattle | 70 | 22 |
| Goat | 3.79 | 5 |
| Sheep | 7.57 | 5 |
| Poultry | 0.3 | 0.15* |

* It is half of the daily water consumption requirement of chickens.

## RESULTS AND DISCUSSION

### *Water Consumption in Livestock Farms*

According to the species of animals, their need for water and their sensitivity may differ. Cows' body consists of 56% water; they need 3-4 liters of water to produce 1 liter of milk. Therefore, water consumption in cows is high. Otherwise, lack of water in cows causes health and mental problems such as decreased feed consumption, reduced productivity, and more nervous behavior of livestock (Göncü et al., 2008). Poultry, on the other hand, consists of 70% of their body water, and they consume twice as much water as the feed they consume. Water facilitates the digestion of poultry, the work of their joints, and their blood circulation (Anonymous, 2019). In addition to using drinking water in animal breeding, domestic water for animal care and the barn constitute an essential part of water consumption. The livestock's daily total water consumption needs are given in Table 2, considering the number of farm animals and the everyday drinking and domestic water needs of the livestock.

**Table 2**. Daily water consumption of the livestock in the monitored farms.
***Çizelge 2**. İncelenen işletmelerdeki hayvanların günlük su tüketimi.*

| Livestock | | Daily Drinking Water Consumption (liter day$^{-1}$) | Daily Consumption of Water Used for Animals (liter day$^{-1}$) | Total Water Consumption (liter day$^{-1}$) |
|---|---|---|---|---|
| Species | Number | | | |
| Beef cattle | 100 | 3800 | 1100 | 4900 |
| Calf | 12 | 168 | 0 | 168 |
| Dairy cattle | 52 | 3640 | 1144 | 4784 |
| Goat | 65 | 246.35 | 325 | 571.35 |
| Sheep | 125 | 946.25 | 625 | 1571.25 |
| Poultry | 25000 | 7500 | 3750 | 11250 |

### *Rainwater Harvest Amount of Monitored Farms*

There are five poultry hens, three beef and dairy cattle barns and three sheep barns in the farm yard where the study was carried out. In the study, calculations related to rainwater harvesting of the roof areas of all barns were made.

There are 25 thousand chickens in total, 5000 in each of the five chicken coops in the farm. Since each house has a large roof area, there is the potential to harvest a significant amount of water from five house roofs. The highest amount of water gathered in the henhouses was calculated as 241.3 $m^3$ in December when the rainfall was the most, while the lowest water harvest was realized with 44.9 $m^3$ in August when the rain was the least (Table 3).

There are three barns in the sheep farm where rainwater harvesting can be done. According to the rainwater harvest calculation made in the barns, the highest water harvest will be realized in December with 82.2 $m^3$, and the minor water harvest will be recognised in August with 15.3 $m^3$ (Table 3).

Rainwater harvesting is planned in seven barns on the dairy cattle farm. Due to the high number of buildings in the enterprise and the data obtained from the General Directorate of Meteorology, a high amount of rainwater can be collected in the Bursa region due to the high average precipitation in winter. While the most water is collected in December, with 195.4 $m^3$, the least is collected, with 30.4 $m^3$ in summer (Table 4).

**Table 3.** Amount of water to be collected monthly and seasonally in poultry houses and sheep farms.
*Çizelge 3. Tavuk ve koyun işletmelerinde aylık ve mevsimsel toplanacak su miktarları.*

| | Poultry | Sheep | | Poultry | Sheep |
|---|---|---|---|---|---|
| Months | Amount of rainwater collected on the roof ($m^3$) | Amount of rainwater collected on the roof ($m^3$) | Seasons | Amount of rainwater collected on the roof ($m^3$) | Amount of rainwater collected on the roof ($m^3$) |
| December | 241.3 | 82.2 | | | |
| January | 212.3 | 72.3 | | 636.9 | 216.9 |
| February | 183.3 | 62.4 | Winter | | |
| March | 168.3 | 57.3 | | | |
| April | 149.7 | 51 | | 441.5 | 150.4 |
| May | 123,5 | 42.1 | Spring | | |
| June | 83.1 | 28.3 | | | |
| July | 53.9 | 18.3 | | 181.9 | 61.9 |
| August | 44.9 | 15.3 | Summer | | |
| September | 106.6 | 36.3 | | | |
| October | 161.3 | 54.9 | Autumn | 453.1 | 154.3 |
| November | 185.2 | 63.1 | | | |

Due to the high number of chickens in the poultry houses, monthly water consumption is high (337.5 $m^3$). However, since the amount of harvested water is high, most needs can be supplied, especially in winter. While 71.5% of the required water need can be supplied with the rainwater harvested in December, 13.3% of the necessary condition can be provided in August, when the little water is collected (Table 5-6).

The monthly water requirement for the animals in the sheep farm is 64.4 $m^3$. More water can be harvested than the amount of water needed, especially in winter. While the required water need can be supplied with 216.9 $m^3$ in winter, water transfer can be provided in the following months. Thus, even though water is harvested much lower than the need in the spring months, 90.4% of the total market can be supplied. In summer, there is a potential to supply 32% of the required need (Table 5-6).

**Table 4.** Amounts of water to be collected monthly and seasonally in dairy cattle and beef cattle farms.
*Çizelge 4. Süt sığırı ve besi sığırı işletmelerinde aylık ve mevsimsel toplanacak su miktarları.*

| Months | Dairy Cattle | Beef Cattle | Seasons | Dairy Cattle | Beef Cattle |
|---|---|---|---|---|---|
| | Amount of rainwater collected on the roof ($m^3$) | Amount of rainwater collected on the roof ($m^3$) | | Amount of rainwater collected on the roof ($m^3$) | Amount of rainwater collected on the roof ($m^3$) |
| December | 195.4 | 96 | | | |
| January | 171.9 | 84.5 | | 515.8 | 253.4 |
| February | 148.4 | 72.9 | Winter | | |
| March | 136.3 | 66.9 | | | |
| April | 121.2 | 59.5 | | 357.6 | 175.5 |
| May | 100 | 49.1 | Spring | | |
| June | 67.3 | 33.1 | | | |
| July | 36.4 | 21.4 | | 134.1 | 72.4 |
| August | 30.4 | 17.9 | Summer | | |
| September | 72 | 42.4 | | | |
| October | 109 | 64.2 | Autumn | 306.2 | 180.3 |
| November | 125.2 | 73.7 | | | |

The average water requirement for the animals in the beef cattle farm is 147 $m^3$ per month. The water consumption in beef cattle is high. However, less water can be harvested due to the small number of barns with closed areas on the farm and the small roof areas of the closed barns. For this reason, while it is possible to supply 57.4% of the average water need in winter, this rate drops to 16.4% in summer (Table 5-6).

**Table 5.** The rate of supplying the monthly water needs of the livestock farms with rainwater harvesting.
*Çizelge 5. İşletmelerde aylık su ihtiyaçlarının yağmur suyu hasadı ile karşılanma oranı.*

| Months | Poultry | | Sheep | | Beef cattle | | Dairy cattle | |
|---|---|---|---|---|---|---|---|---|
| | Amount rainwater collected ($m^3$) | Absorption rate (%) | Amount rainwater collected ($m^3$) | Absorption rate (%) | Amount rainwater collected ($m^3$) | Absorption rate (%) | Amount rainwater collected ($m^3$) | Absorption rate (%) |
| December | 241.3 | 71.5 | 82.2 | 100 | 96 | 65.3 | 195.4 | 100 |
| January | 212.3 | 62.9 | 72.3 | 100 | 84.5 | 57.5 | 171.9 | 100 |
| February | 183.3 | 54.3 | 62.4 | 100 | 72.9 | 49.6 | 148.4 | 100 |
| March | 168.3 | 49.8 | 57.3 | 100 | 66.9 | 45.5 | 136.3 | 100 |
| April | 149.7 | 44.3 | 51 | 100 | 59.5 | 40.5 | 121.2 | 100 |
| May | 123.5 | 36.5 | 42.1 | 72 | 49.1 | 33.4 | 100 | 88 |
| June | 83.1 | 24.6 | 28.3 | 44 | 33.1 | 22.5 | 67.3 | 45.3 |
| July | 53.9 | 15.9 | 18.3 | 28.5 | 21.4 | 15.6 | 36.4 | 24.5 |
| August | 44.9 | 13.3 | 15.3 | 23.8 | 17.9 | 12.2 | 30.4 | 20.5 |
| September | 106.6 | 31.5 | 36.3 | 56.5 | 42.4 | 28.9 | 72 | 48.5 |
| October | 161.3 | 47.8 | 54.9 | 85.4 | 64.2 | 43.7 | 109 | 73.4 |
| November | 185.2 | 54.9 | 63.1 | 98.1 | 73.7 | 50.1 | 125.2 | 84.3 |

In dairy cattle farms the monthly average water requirement is 147.5 $m^3$ and the seasonal average is 445.5 $m^3$. The fact that there are many closed barns in the farm ensures a high rate of water harvesting. This situation can supply all the average water needs in the spring months due to providing all the requirements for the operation in the winter months and transferring the excess water to be stored in the following months. The water harvest to be carried out on the farm is very important in terms of cost and in terms of providing water savings (Table 5-6).

**Table 6.** Rates of supplying seasonal water needs with rainwater harvesting in farms.
*Çizelge 6. İşletmelerde mevsimsel su ihtiyaçlarının yağmur suyu hasadı ile karşılanma oranı.*

| Seasons | Poultry | | Sheep | | Beef cattle | | Dairy cattle | |
|---|---|---|---|---|---|---|---|---|
| | Amount rainwater collected ($m^3$) | Absorption rate (%) | Amount rainwater collected ($m^3$) | Absorption rate (%) | Amount rainwater collected ($m^3$) | Absorption rate (%) | Amount rainwater collected ($m^3$) | Absorption rate (%) |
| Winter | 636.9 | 62.9 | 216.9 | 100 | 253.4 | 57.4 | 515.7 | 100 |
| Spring | 441.5 | 43.6 | 150.4 | 90.4 | 175.5 | 36.8 | 357.6 | 96 |
| Summer | 181.9 | 17.9 | 61.9 | 32 | 72.4 | 16.4 | 134.1 | 30 |
| Autumn | 453.1 | 44.7 | 154.3 | 80 | 180.3 | 40.9 | 306.2 | 68.7 |

### *Design of Rainwater Harvesting System in Monitored Livestock Farms*

A rainwater collection system has been designed for the farms examined to save both water and the economy at the maximum level and to collect and benefit from the precipitation falling in the region at the top level.

The galvanized steel water tank with a total capacity of 250 tons supplies the amount of rain in the poultry farm examined in the study (Figure 3). In case of more precipitation than expected in the water tank used in the system or claim of a systemic problem, two discharge pipes from the pipeline and the tank are added to the system to drain the excess water. In the system, it is planned that the rainwater collection line will pass above the ground surface, and the tanks will be buried under the surface. The preference for underground buried tanks was planned as underground storage systems due to the advantages such as space-saving, water can be filled into the tank by its gravity, the possibility of mossiness is reduced due to low light transmittance, maintenance is easy, and the case of damage is lower.

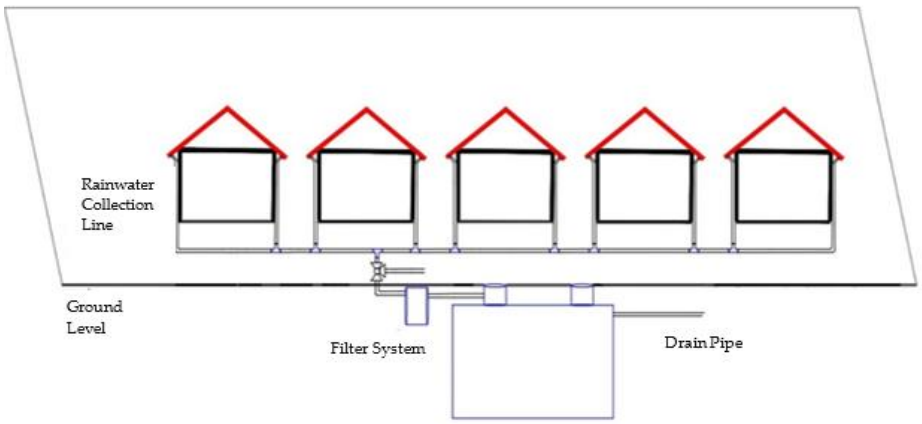


**Figure 3.** Rainwater harvesting system design of poultry houses.
*Şekil 3. Tavuk işletmesi yağmur suyu hasadı sistem tasarımı.*

It is planned to use a galvanized steel water tank with a capacity of 85 tons for the systematic design to supply the amount of rain that will fall in the examined sheep farm. The system design is given in Figure 4.

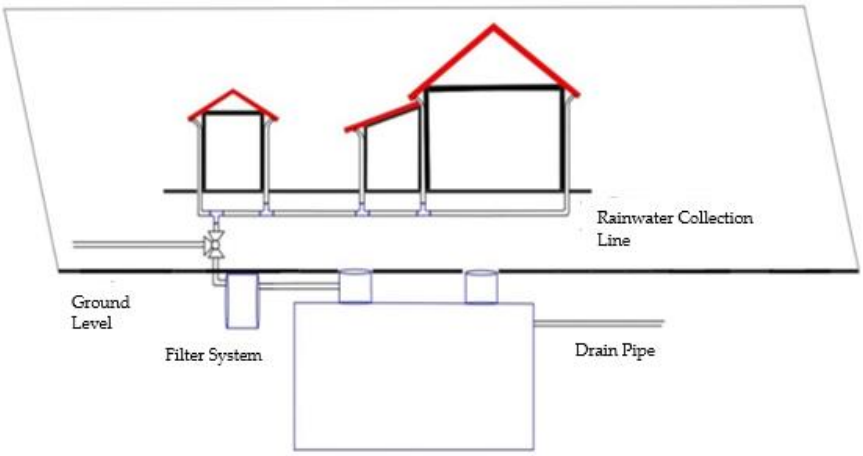


**Figure 4.** Sheep farm rainwater harvest design.
*Şekil 4. Koyun işletmesi yağmur hasadı tasarımı.*

Considering the amount of water that can be harvested in the farm, the cost, and the required water requirement while designing the rainwater harvesting system and choosing the tank for the beef cattle farms, the use of a galvanized steel water tank with a capacity of 100 tons in both farms supplies they need (Figure 5).

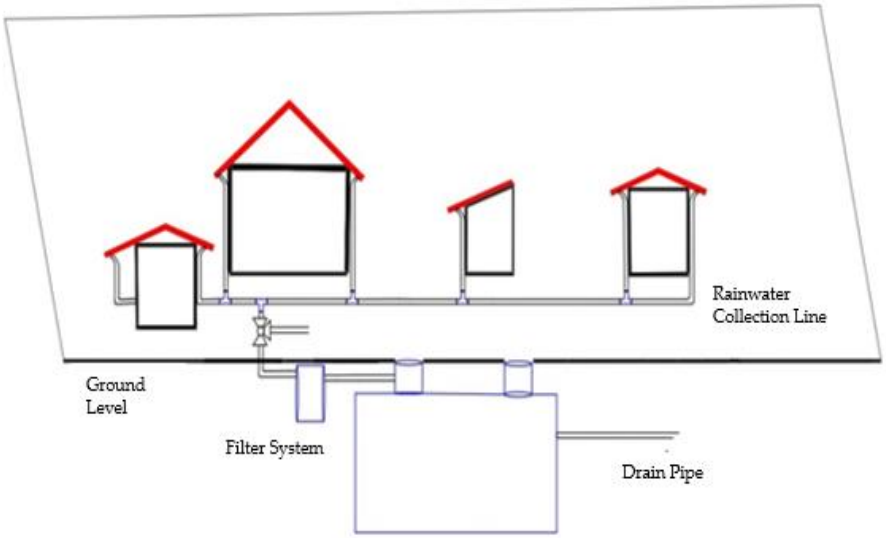


**Figure 5.** Beef cattle farm rainwater harvest design.
*Şekil 5. Besi sığırı işletmesi yağmur hasadı tasarımı.*

The dairy cattle farm decided to use a galvanized steel water tank with a total capacity of 200 tons due to the high potential of water to be harvested (Figure 6).

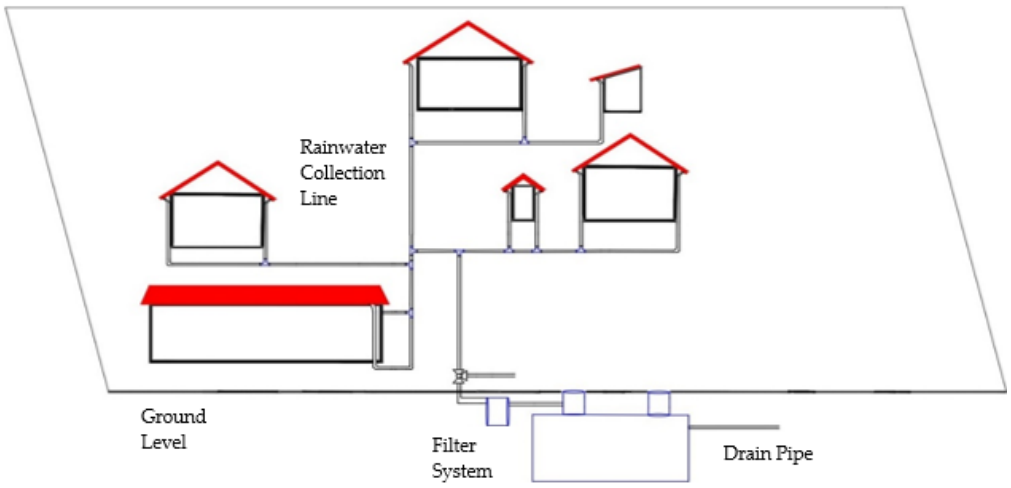


**Figure 6.** Dairy farm rainwater harvest design.
*Şekil 6. Süt sığırı işletmesi yağmur hasadı tasarım.*

The costs of the material list required for installing the rainwater harvesting system in the farms are given in Table 7 in detail.

**Table 7.** List of materials required for the installation of rainwater harvesting system in farms.
*Çizelge 7. İşletmelerde yağmur suyu hasadı sisteminin kurulumu için gerekli malzeme listesi.*

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Poultry houses | Material | Galvanized steel warehouse with a volume of 250 tons | Transport and installation costs | T Pipe | Pipe bend | 11 Ø Pipe | Filter | Three directional Valve |
| | Piece | 1 | 1 | 9 | 2 | 150 m | 1 | 1 |
| | Price | 142500 ₺ | 71485 ₺ | 360 ₺ | 50 ₺ | 2443 ₺ | 18450 ₺ | 2500 ₺ |
| Sheep farms | Material | Galvanized steel warehouse with a volume of 85 tons | Transport and installation costs | T Pipe | Pipe bend | 11 Ø Pipe | Filter | Three directional Valve |
| | Piece | 1 | 1 | 4 | 2 | 75 m | 1 | 1 |
| | Price | 48450 ₺ | 24250 ₺ | 160 ₺ | 50 ₺ | 1221.5 ₺ | 9340 ₺ | 2500 ₺ |
| Cattle farms | Material | Galvanized steel warehouse with a volume of 100 tons | Transport and installation costs | T Pipe | Pipe bend | 11 Ø Pipe | Filter | Three directional Valve |
| | Piece | 1 | 1 | 5 | 3 | 75 m | 1 | 1 |
| | Price | 57000 ₺ | 28500 ₺ | 200 ₺ | 75 ₺ | 1221.5 ₺ | 9340 ₺ | 2500 ₺ |
| Dairy cattle farms | Material | 200 tons galvanized steel warehouse | Transport and installation costs | T Pipe | Pipe bend | 11 Ø Pipe | Filter | Three directional Valve |
| | Piece | 1 | 1 | 10 | 8 | 120 m | 1 | 1 |
| | Price | 114000 ₺ | 57000 ₺ | 400 ₺ | 200 ₺ | 1954.4 ₺ | 18450 ₺ | 2500 ₺ |

***Savings Rate with Rainwater Harvesting***

With the application of the rainwater harvesting system in the henhouses, an economic saving of 5047.6 TL was achieved in December, when the most water harvest was carried out, and 939.2 TL in August, when the minor water harvest was performed (Table 8). Due to the many buildings and the large roof areas, the chicken farm has the highest annual water harvest, with a total of 636.9 $m^3$ and the most financial savings, with a yearly average of 37 846 TL.

**Table 8**. Monthly and annual profit rates (TL) obtained by rainwater harvesting systems in the monitored farms.
*Çizelge 8. İncelenen işletmelerde yağmur suyu hasadı sistemi ile elde edilen aylık ve yıllık kar oranları (TL).*

| Month | Poultry | Sheep | Dairy cattle | Beef cattle |
|---|---|---|---|---|
| December | 5047.6 | 1350 | 3334.1 | 2007.9 |
| January | 4441 | 1350 | 3334.1 | 1767.5 |
| February | 3834 | 1350 | 3334.1 | 1524.8 |
| March | 3525.7 | 1350 | 3334.1 | 1399.3 |
| April | 3131.5 | 1350 | 3334.1 | 1244 |
| May | 2583.4 | 974.8 | 2956.7 | 1027 |
| June | 1738 | 592 | 1630.4 | 692.3 |
| July | 1127.5 | 382 | 1422.9 | 447 |
| August | 939.2 | 320 | 858.5 | 374.3 |
| September | 2229.9 | 759 | 1728.5 | 886 |
| October | 3374.1 | 1153 | 2502.6 | 1342.9 |
| November | 3874 | 1319.7 | 2841.4 | 1541.5 |
| Total Profit | 37846 | 12250.5 | 30611.5 | 14254.5 |

While the absolute average water requirement for the livestock can be supplied for five months with the rainwater system in the sheep farm, a monthly average of 1350 TL is saved (Table 8). Even though most of the year's water needs are supplied on the farm, lower financial gain is achieved compared to other farms due to the low amount of water used and harvested. The average annual income in the sheep farm is 12250.5 TL.

In the beef cattle farms, the highest savings were achieved with 2007.9 TL in December, while 374.3 TL was saved in August (Table 8). The average annual income is 14254.5 TL.

In dairy cattle farms, on the other hand, 3334.1 TL savings were achieved in the months when the need was fully supplied, while 374.3 TL savings were provided in August when the least amount of water was harvested (Table 8). In total, an average of 30611.5 TL is saved throughout the year.

With the implementation of the rainwater harvesting system in all farms located in the Animal Health and Animal Production, Research and Application Center of Bursa Uludag University Faculty of Veterinary Medicine, an annual average of 94962.5 TL financial savings is achieved. When a general evaluation is made, the system can amortize itself in 7 years at the latest (Table 9).

**Table 9.** Cost of rainwater harvesting system and payback period of the system.
*Çizelge 9. Yağmur suyu hasadı sisteminin maliyeti ve sistemin amorti süresi.*

| | Poultry | Sheep | Dairy cattle | Beef cattle |
|---|---|---|---|---|
| System Cost (₺) | 237788 | 85971.5 | 98839 | 197000 |
| Annual Earnings (₺) | 37846 | 12250.5 | 14254.5 | 30611.5 |
| Depreciation Period (years) | 6.2 | 7 | 6.9 | 6.4 |

Yalılı Kılıç and Abuş, (2018) carried out a rainwater system design for a house with a garden in their study. The study planned to use a 14.5 $m^3$ tank for gardening and other works, and 47% of the total water need was met by saving 102 $m^3$ of water annually. Thus, an average of 335 TL was held annually.

Temizkan and Kayılı (2021), in their study, planned to provide some of the university's landscape irrigation needs by using the rainwater harvesting system, making use of the roof of the Karabük University Social Life Center. They calculated the cost of four different storage options for harvesting the water. As a result of the study, they stated that 2 766 $m^3$ and 4% of the total water needed for rainwater harvesting and landscape irrigation were supplied and they provided an annual average of 11 644 TL financial savings.

## CONCLUSION

As a result of the study carried out in the sheep, poultry, beef, and dairy cattle farms in the Animal Health and Animal Production, Research and Application Center of Bursa Uludag University Faculty of Veterinary Medicine, the roof areas of the buildings where rainwater harvesting is planned and the average

precipitation for Bursa province, using the average precipitation information the total rainwater to be stored amount has been calculated. As a result of the calculation, it has been seen that the water needs of the sheep and dairy cattle farms are supplied in the other months of the year, except for the summer months when the average water requirement is completed in the winter months when the precipitation is deficient. On the other hand, although the water harvest in the beef cattle farm is not at a high level the amount of water needed is not high because the number of animals is not very high, and most of the need can be supplied. The result of the study shows that the monitored livestock farms save half of their annual average water costs and save a significant amount of water. It has been revealed that the most savings in all farms can be realized in December, which has the highest precipitation. Considering that the world's water scarcity is increasing daily and the importance of water is increasing, it is seen that the amount of savings will contribute to the benefit of people and the environment.

## CONFLICT OF INTEREST

Authors declared no conflict interest.

## DECLARATION OF AUTHOR CONTRIBUTION

The authors contributed equally to the article.

## REFERENCES


Akın, G., & Akın, M. (2005). Suyun insan sağlığı için önemi ve su kirliliği. *Antropoloji*, *21*. https://doi.org/10.1501/antro_0000000295.

Anonymous. (2019). http://uzmantavuk.net/220-tavuklarda-suyun-ve-su-onemi.html. [Access date: November 16, 2022].

Aydın, Y. (2019). Batman ili toprak ve su kaynaklarının tarımsal açıdan değerlendirilmesi. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, 29,* 178-186. https://doi.org/10.29133/yyutbd.511801.

Çakar, H. (2022). İzmir ili koşullarında bahçeli bir sitenin yağmur suyu hasadı potansiyelinin değerlendirilmesi. *Türk Tarım ve Doğa Bilimleri Dergisi*, *9,* 446-452. https://doi.org/10.30910/turkjans.1084095.

Çaylı, A. (2021). Kümeslerin su gereksinimini yağmur suyu hasadından karşılanması üzerine araştırma: Kahramanmaraş örneği. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, *24,* 1048-1058. https://doi.org/10.18016/ksutarimdoga.vi.838619.

Chapagain, A. K., & Hoekstra, A. Y. (2003). Virtual water flows between nations in relation to trade in livestock and livestock products, Value of water research report series No.13, UNESCO-IHE. https://www.waterfootprint.org/media/downloads/Report13.pdf.

Göncü, S., Özkütük, K., & Görgülü, M. (2008). Sığır yetiştiriciliğinde su gereksinmesi ve içme suyu kalite özellikleri. *Hasad Dergisi*, *24,* 44-51.

Yalılı Kılıç, M., & Abuş, M. N. (2018). Bahçeli bir konut örneğinde yağmur suyu hasadı. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, *4,* 209-215. https://doi.org/10.24180/ijaws.426795.

MGM. (2021). Cities & Holiday Resorts. https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=BURSA. [Access date: December 12, 2022].

TEMA. (2017). http://sutema.org. [Access date: November 4, 2022].

Temizkan, S., & Kayılı, M. T. (2021). Yağmur suyu toplama sistemlerinde optimum depolama yönteminin belirlenmesi: Karabük Üniversitesi sosyal yaşam merkezi örneği. *El-Cezeri*, *8,* 102-116. https://doi.org/10.31202/ecjse.778973.

Üstün, G. Ö., Can, T., & Küçük, G. (2020). Binalarda Yağmur Suyu Hasadı. *Uludağ Üniversitesi Mühendislik Fakültesi Dergisi*, *25,* 1593 – 1610. https://doi.org/10.17482/uumfd.765561.