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EFFECT OF GRAVEL FILTER ON RUNOFF, SEDIMENT CONTROL AND VEGETATION ENHANCE IN RAINWATER CATCHMENT SYSTEM (DAREH-MORID BASIN, BAFT)

EFEITO DO FILTRO DE CASCALHO NO RUNOFF, CONTROLE DE SEDIMENTOS E MELHORIA DE VEGETAÇÃO NO SISTEMA DE CAPTAÇÃO DE ÁGUA CHUVA (BACIA DE DAREH-MORID, BAFT)

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ABSTRACT

In this study gravel filter were used to control runoff and sediment to enhance vegetation in Dareh Morid Basin of Baft, Kerman.This research was conducted in a completely randomized block design with four treatments and three replications.Treatments included natural system as a control, natural system with gravel filter, im permeable system without gravel filter, and impermeable system with gravel filter. The effect of gravel filter on reducing sediment and increasing vegetation was measured at depths of 25, 50 and 75 cm using TDR device after each rainfall.The results of this study revealed that at all three mentioned depths in the impermeable system with gravel filter, the moisture was significantly higher than in other treatments.The performance of the gravel filter along with making the system surface impermeable reduced sediment erosion and increased vegetation. As a result, it can be claimed that the rainwater harvesting through impermeable surfaces using gravel filter will be a good solution to control runoff plus sediment and a significant contribution to the water supply of plants in arid and semi-arid regions.

Keywords: Water haversting; Rainfall; Gravel filter; Runnof reduction; Rainwater catchment surfaces system.

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RESUMO

Neste estudo, filtros de cascalho foram usados para controlar o escoamento e os sedimentos para realçar a vegetação na Bacia de Dareh Morid de Baft, Kerman. Esta pesquisa foi conduzida em um delineamento de blocos completamente casualizado com quatro tratamentos e três repetições. Os tratamentos incluíram o sistema natural como controle, natural sistema com filtro de cascalho, sistema impermeável sem filtro de cascalho e sistema impermeável com filtro de cascalho. O efeito do filtro de cascalho na redução de sedimentos e aumento da vegetação foi medido em profundidades de 25, 50 e 75 cm usando dispositivo TDR após cada chuva. Os resultados deste estudo revelaram que em todas as três profundidades mencionadas no sistema impermeável com filtro de cascalho, o a umidade foi significativamente mais alta do que em outros tratamentos. O desempenho do filtro de cascalho junto com a impermeabilização da superfície do sistema reduziu a erosão de sedimentos e aumentou a vegetação. Com isso, pode-se afirmar que a captação de águas pluviais por meio de superfícies impermeáveis com filtro de cascalho será uma boa solução para o controle do escoamento mais sedimento e uma contribuição significativa para o abastecimento de água de plantas em regiões áridas e semi-áridas.

Palavras-Chave: Captação de água; Chuva; Filtro de cascalho; Redução do escoamento; Sistema de superfícies de captação de água da chuva.

INTRODUCTION

According to the official statistics of the World Food Organization in 2003, the area of arid and semi-arid regions of the world was about 61 million square kilometers, which is equivalent to 46% of the Earth's area. In terms of continental distribution, it covers 14% of the Americas plus the periphery of Europe, 13% of Africa, 10% of Australia, and 11% of the Asian continent (Akhtar et al. 2010). In sloping lands, sediment erosion usually increases with increasing slope and hencd sediment retention in these lands is very important (Zhang et al. 2015). One of the salient features of such areas is low and irregular rainfall with relatively high air temperatures, which leads to limited water resources, thus complicating sustainable agriculture (Musyoki et al. 2014). As such, it can be stated that the first factor limiting the establishment of vegetation in arid and semi-arid regions is the amount of water in the root zone of the plant (Gardi, Sconosciuto, 2007; Lal 2001). Sediment erosion can cause gradual degradation of hills, especially in sloping agricultural landscapes (Pijl et al. 2020). Today, natural factors such as floods affect sedimentation in the region (Frings et al. 2019). A study compared the runoff increase due to the use of asphalt with plastic coating, oil mulch coating, plastic coating, soil compaction, plastic coating with gravel at the slope surface against its level at the natural slope surface. It found a significant effect of these materials and methods on increasing runoff, such that sometimes the runoff has increased to 91% (Huang, 2002).

Among the important factors with a key role in increasing soil moisture retention are the combined use of insulation surfaces to produce more runoff on the one hand and the utilization of plant mulch or sand filters on the other hand to penetrate the harvested runoff, which could improve the soil moisture conditions. The use of sand filters in catchment surface systems is possible due to easier implementation and availability of required materials and has a key role in faster infiltration of runoff and increase of soil moisture in the root zone (Ghaderi 2004). Milkias et al. (2018) while emphasizing the role of rainwater catchment systems in water supply, found that these systems increase soil moisture at the depth of 60 cm in a maize farm in Ethiopia.

Yazar et al. (2014) evaluated water harvesting techniques with emphasis on micro-catchments in the form of an experimental design with five different treatments (control treatment, nylon coating, gravel coating, treatment with dry forage and compacted surface) in Turkey. By analyzing data on rainfall, runoff, basin area, soil moisture storage and plant evapotranspiration, they monitored the water balance in the pistachio root region.They determined the overall efficiency of the rainwater harvesting system by comparing the ratio of water stored and used by the plant to the rainwater of the system surface. Their results revealed that the overall efficiency of rainwater harvesting systems varied from 2.9% to 79% depending on their surface area and the capacity of the plant root region and the plastic coating system has the highest efficiency compared to other treatments. Emphasizing the above and as a large part of Iran is in arid as well as semi-arid conditions and its population is growing, attention should be paid to the use of rainwater on a small scale. Accordingly, in this research, the effects of impermeable system with gravel filter in runoff and sediment control and vegetation increase are considered as the objectives of this study.

The study area in Kerman province was located in the central part of Baft city, Kiskan district, Darreh Morrid village. Darreh Morrid village is located in 12 km northwest of Baft. In terms of geographical location, this region has the coordinates of 56/31/54 to 56/37/56 east longitude and 22/20/29 to 29/25/41 north latitude at an altitude of 2780 meters above sea level. The average rainfall of the basin is 320 mm and the absolute maximum air temperature is 38°C, while the minimum temperature is -20 °C. The average slope of the studied Basin is 20% with the general slope of the north-south Basin (figure 1).

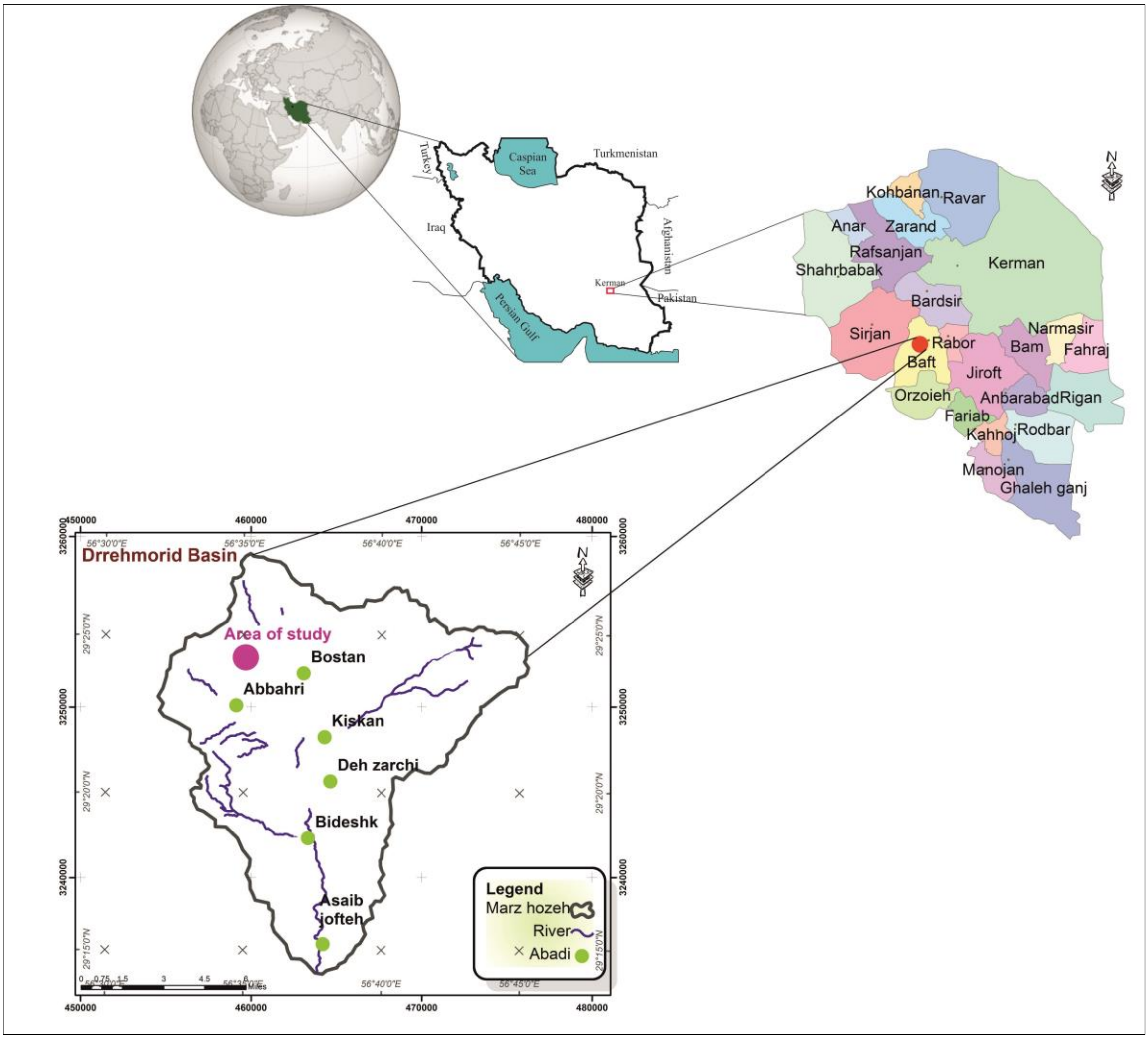

Figure 1. Geographical location of Dareh Morid Basin in Kerman province, southeast Iran.
Source: Authors (2021).

MATERIALS AND METHODS

To make this research operational, in the first step, the dimensions of catchment surface systems were calculated using equation (1) based on the factors of plant water requirement, annual rainfall of the project, root area, runoff coefficient and efficiency fator.

(Relationship 1) MC = RA * (WR-DR) / (DR * K * EFF)

Where,

MC = catchment area in square meter;
RA = average root growth of the plant used in square meter;
WR = annual water requirement of the plant in millimeter per year;
DR = rainfall in millimeter;
K = runoff coeficiente;
EFF = water holding capacity in soil in percent.

Then, the catchment surface systems based on equation (1) have been considered in the form of a completely randomized block statistical design in four treatments including 1- natural treatment as control, 2- natural treatment with gravel filter, 3- impermeable treatment without gravel filter 4- impermeable treatments with gravel filter. Accordingly, the systems were determined in square shapes with dimensions of 7 x 7, 49 square meters. A total of 12 plots were constructed at the project site.

Next, in order to measure the volumetric soil moisture and compare its variation in each of the treatments, two sensors were installed as vertical bars at the depths of 25, 50, and 75 cm in the downstream holes of each system. The volume moisture content of each of the treatments at depths of 25, 50, and 75 cm was measured by TDR device through connecting it to vertical sensors 24 hours after each rainfall or each time of supplementary irrigation. Banquettes were also designed around each hole to direct runoff from the surface of the systems into the hole. Arrangement of treatments and repetition of rainwater catchment systems have been presented in Table 1. Figure 2 outlines a view of the banquette established after the rainfall.

Repetition 1	Control
	Natural with filter
	Impenetrable
	Impenetrable with filter
Repetition 2	Control
	Natural with filter
	Impenetrable
	Impenetrable with filter
Repetition 3	Control
	Natural with filter
	Impenetrable
	Impenetrable with filter

Table 1. Arrangement of treatments and repetition of rainwater catchment systems on the sloping slope.
Source: Authors (2021).

Figure 2. View of the banquets established after the rainfall.
Source: Authors (2021).

DISCUSSION

RUNOFF MEASURING IN DIFFERENT PRECIPITATION EVENTS

Table 2 presents analysis of rainfall events leading to runoff production in catchment surface systems (runoff has occurred in at least one of the repetitions of one of the treatments) during 2016 to 2017. The maximum and minimum rainfall leading to runoff production in the catchment surface systems during the research period was 31.5 mm and 0.9 mm, respectively. Rainfall of 0.9 mm led to runoff production only in impermeable systems.

Date of storm	rainfall duration (hours)	Rainfall rate (mm)	Average rainfall (Mm per hour)	Maximum rainfall intensity (Mm per hour)
95.7.25	2	8.1	1.8	**4.2**
95.8.1	0.5	0.9	1.7	**4.2**
95.8.3	1	4.2	3.3	**6**
95.8.9	1	1.6	1.1	**3.6**

Date of storm	**rainfall duration (hours)**	**Rainfall rate (mm)**	**Average rainfall (Mm per hour)**	**Maximum rainfall intensity (Mm per hour)**
95.8.23	3.5	9.4	1.4	**4.8**
95.8.25	9.5	16	1.6	**4.8**
95.8.28	2	1.3	0.7	**1.8**
95.8.30	4	7.7	4.8	**4.8**
95.9.3	15	25.6	1.6	**5.4**
95.9.10	6.5	17.2	2.2	**4.8**
95.9.16	2.5	6.1	1.4	**3**
95.9.20	10	22.1	1.9	**6.6**
95.10.1	5	11.4	1.7	**5.4**
95.10.5	10	14.8	1.4	**4.2**
95.11.8	2.5	4.7	1.6	**3**
95.11.11	2.5	10.6	3.2	**7.8**
95.11.17	6	9.3	1.3	**3**
95.12.14	3.5	5.1	1.4	**3**
95.12.16	10.5	31.5	2.5	**6.6**
95.12.20	3	4.8	1.1	**2.4**
96.1.13	2	7.9	2.4	**4.8**
96.1.15	1.5	2.2	1.4	**4.2**
96.1.23	10.5	26	2.3	**6.6**
96.2.10	2	9.6	2.5	**10.2**
96.2.13	1.5	6.9	2.1	**9.6**
96.2.15	0.5	0.9		**3**

Table 2. Results of analysis of storms leading to runoff production in catchment surface systems
Source: Authors (2021).

COMPARISON OF SOIL MOISTURE CONTENT IN NATURAL TREATMENTS WITH AND WITHOUT FILTERS

The comparison of the average soil moisture content at the studied depths in natural treatments with and without filters was performed using Duncan's test with the results presented in Table 3. These results indicate that at the depth of 25 cm of seedling pits, although there is no significant difference in soil moisture percentage between natural treatments with and without filters, the natural treatment with gravel filter had a higher moisture content at that depth (15.82%). At the soil depth of 50 cm, there was a significant difference between natural treatments with filter and without filter at 5% probability level. There was a significant difference between natural treatments with and without filters (at the level of 5% probability) at the depth of 75 cm of seedling soil (Figures 3- 5).

Natural treatment	Depth of 25 cm	Depth of 50 cm	Depth of 75 cm
With filter	15.82a	16.28a	14.41a
Without filter	15.48a	15.85b	14.00b

Table 3. Comparison of the average soil moisture percentage at the studied depths in natural treatments with and without filters (Common letters in each column represent lack of significant difference (at the probability level of 0.05)).
Source: Authors (2021).

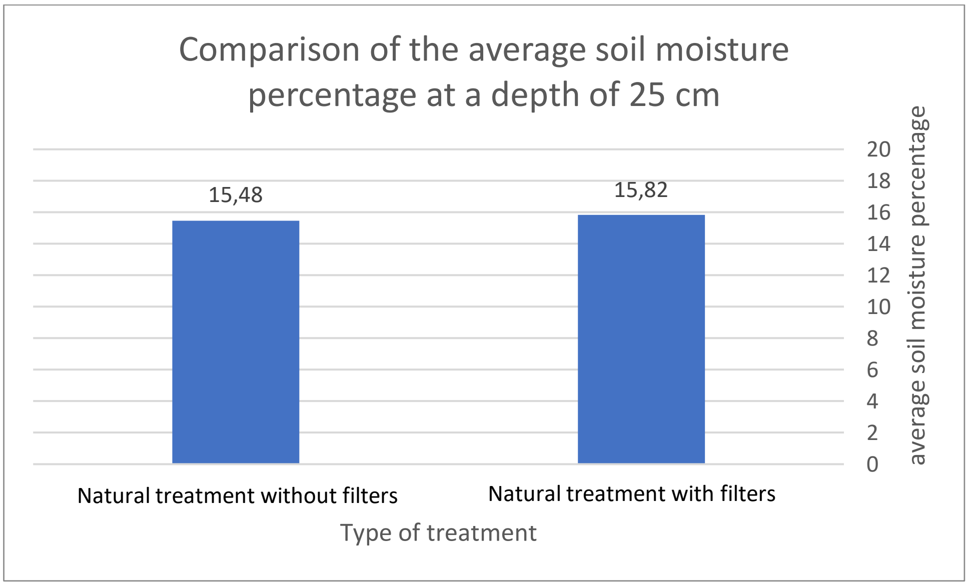

Figure 3. Comparison of the average soil moisture percentage at the depth of 25 cm. Source: Authors (2021).

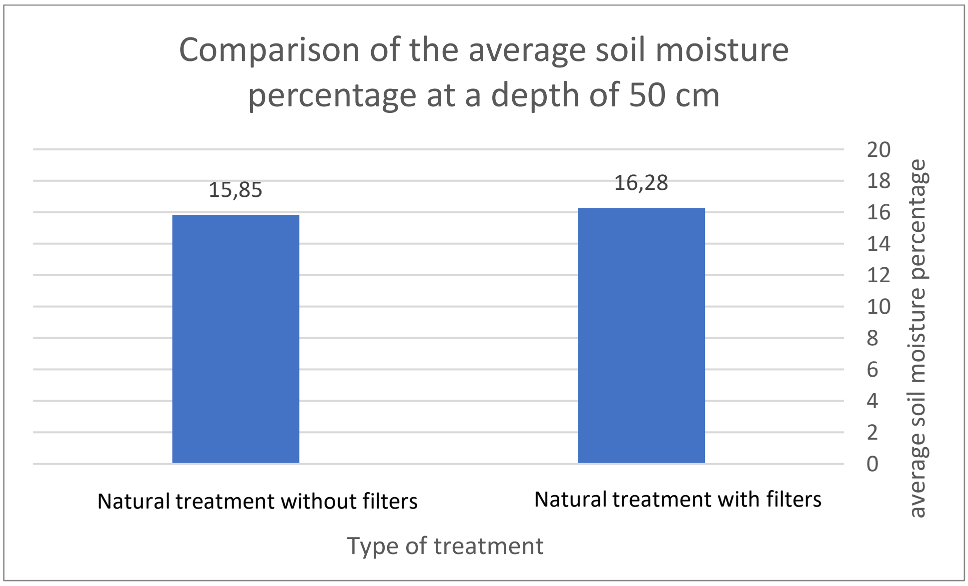

Figure 4. Comparison of the average soil moisture percentage at the depth of 50 cm. Source: Authors (2021).

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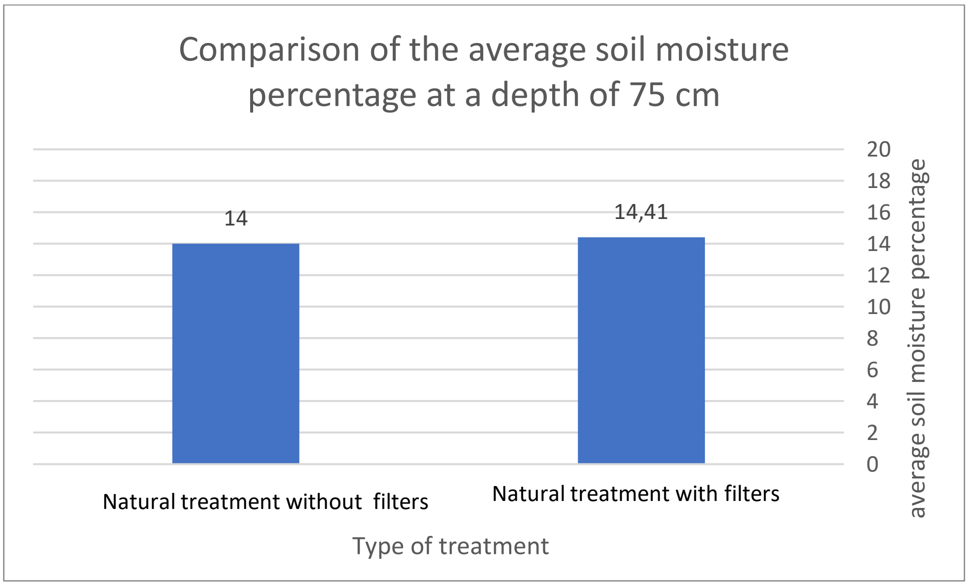

Figure 5. Comparison of the average soil moisture percentage at the depth of 75 cm.
Source: Authors (2021).

COMPARISON OF SOIL MOISTURE IN THE TREATMENTS OF INSULATING A PART OF THE SYSTEM SURFACE WITH AND WITHOUT FILTER

Table 4 compares the average soil moisture percentage at the studied depths in the treatments of insulating a part of the system surface with and without filters which was performed using Duncan's test. These results indicate that at seedling hole depth of 25 cm, although there is no significant difference in soil moisture percentage between treatments of insulating a part of the system surface with and without filters, the treatment of insulating a part of the system surface with gravel filter had a higher percentage of moisture at that depth (16.28%). At the soil depth of 50 cm, there was a significant difference between the treatments of insulating part of the system surface with filter and without filter at a probability level of 5%. At the depth of 75 cm of seedling soil, there was a significant difference between treatments to insulate part of the system surface with and without filters. At this depth, the highest percentage of soil moisture was related to the treatment of insulating part of the system surface with gravel filter (14.59%) (figures 6- 8).

Insulation treatment	Depth of 25 cm	Depth of 50 cm	Depth of 75 cm
With filter	16.28a	16.46a	14.59a
Without filter	15.69a	16.01b	14.28ab

Table 4. Comparison of the average soil moisture percentage at the studied depths in the treatments of insulating a part of the system surface with and without filters (Common letters in each column representlack of significant difference (at the probability level of 0.05)).
Source: Authors (2021).

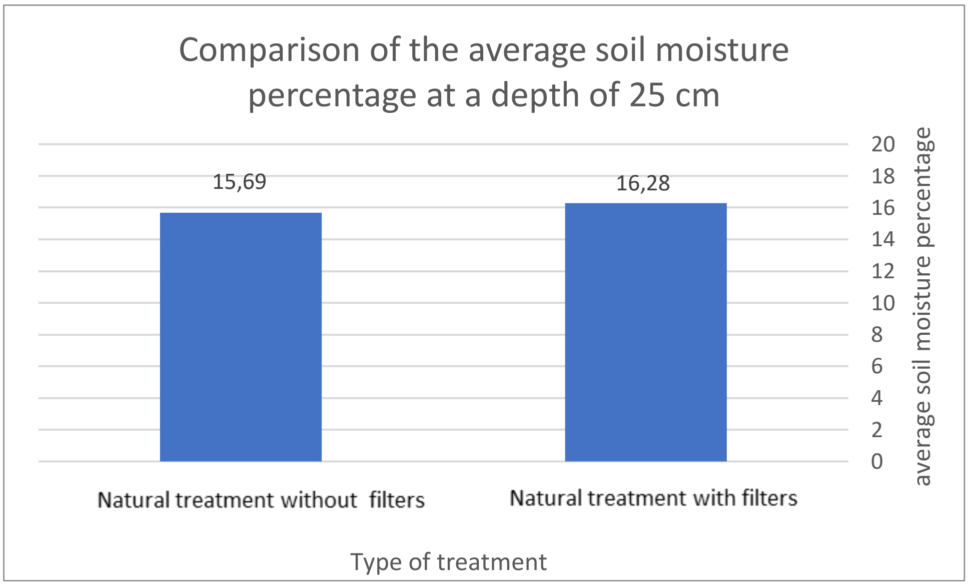

Figure 6. Comparison of the averagesoil moisture percentage at the depth of 25 cm.
Source: Authors (2021).

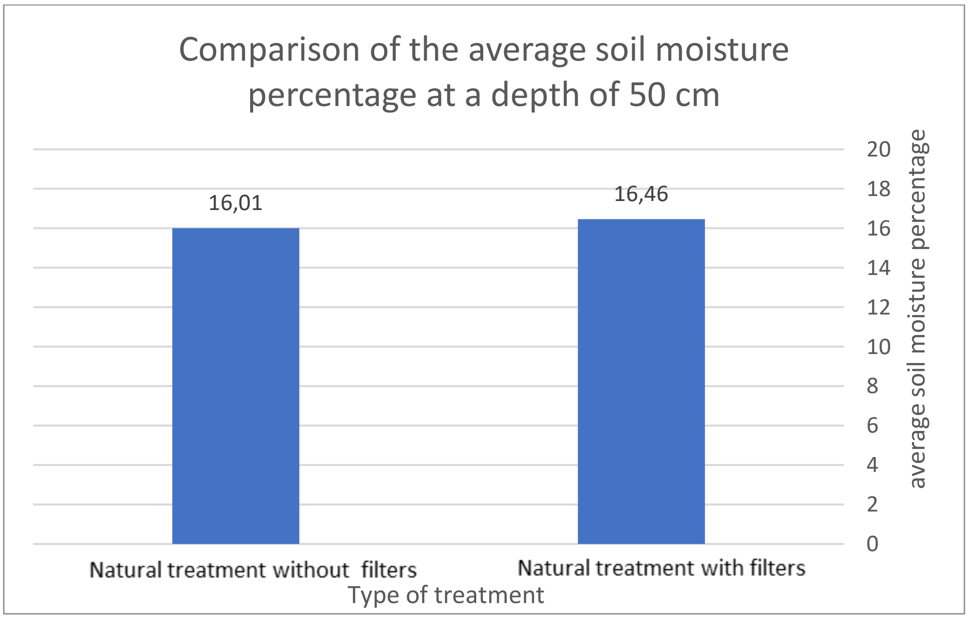

Figure 7. Comparison of the average soil moisture percentage at the depth of 50 cm.
Source: Authors (2021).

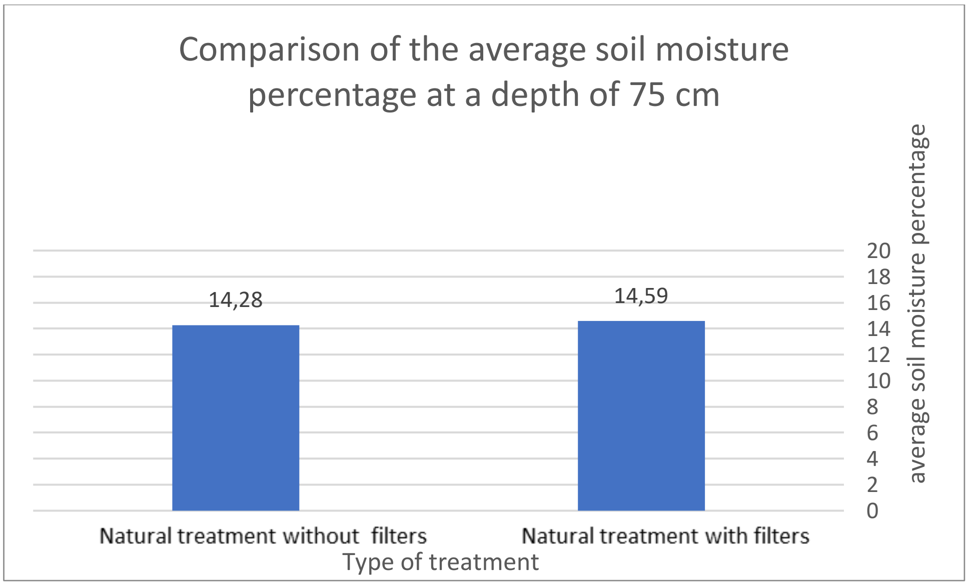

Figure 8. Comparison of the average soil moisture percentage at the depth of 75 cm
Source: Authors (2021).

CONCLUSION

The aim of this study was to use a gravel filter to control runoff and sediment as well as to increase vegetation in the Dareh Morid Basin of Baft. Given the high water consumption in the agricultural sector, research on the use of alternative water resources and methods to save its optimal use is very necessary.The findings of this study showed that: The effect of gravel filter is greater than that of natural surface (control). Presence of insulation surface alone does not significantly increase the soil moisture content; however, the presence of insulation surface along with gravel filter creates a significant difference in the soil moisture content.

Thus, it can be claimed that the use of gravel filter can significantly reduce sediment erosion and sediment control. Also, the moisture content in the root zone of the plant is retained for a longer period of time due to the direct transfer of the extracted water to the root zone of the plant.The result will be an important part of the plant's water supply at times of crisis and increased vegetation. The effect of applying insulation surface, especially at low rainfall rate which is very important in the optimal utilization of low rainfall in the dry season and the reduction of water stress.This is also particularly important in arid and semi-arid regions, especially in areas where the temporal distribution of precipitation is not appropriate and, most of the rainfall occurs in the first few months of the year while in other seasons the plants face water stress. Harvesting rainwater using insulation surfaces with gravel filter and its direct transfer to the root zone of the plant is a good response to deal with this problem.

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