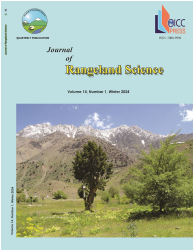

Volume 14, Issue 1, 142409 (1-8)

Journal of Rangeland Science (JRS)

https://dx.doi.org/10.57647/j.jrs.2024.1401.09

Evaluation of Rainwater Harvesting Methods and Its Effect on Vegetation and Soil Characteristics (Case Study: Bolbol Rangelands, Ashkzar, Yazd Province, Iran)

Ali Zare[1], Mohamad Ali Hakimzadeh Ardakani[1]*, Ali Akbar Karimian[2]

[1]Department of Desert Management, School of Natural Resources & Desert Studies, Yazd University, Yazd, Iran.
[2]Department of Rangeland and Watershed Management, School of Natural Resources & Desert Studies, Yazd University, Yazd, Iran.

*__Corresponding author:__ hakim@yazd.ac.ir

Research and Full Length Article

Received:
16 October 2021
Revised:
24 February 2023
Accepted:
18 March 2023
Published online:
15 January 2024

Abstract:

In order to investigate the effect of contour furrow on the vegetation and soil characteristics, a study was conducted at Bolbol rangelands, Ashkazar, Yazd Province, Iran in 2020. The implementation of contour furrow was done previously at the rangeland in the area of 100 ha in 2006. Data were collected at both contour furrow site and outside it (control site). At each site, four transects (300 m) were established at the distance of 100 m from each other. Along each transect, 15 plots (2 m^2) were established at a distance of 12 m from each other. At each plot, the vegetation characteristics (vegetation percent, richness and diversity of species, *Artemisia sieberi* canopy cover) and soil characteristics (soil permeability, soil moisture and carbon stabilization) were measured. The obtained data of sites were compared using independent T test. According to the results, the vegetation percent and canopy cover of *Artemisia sieberi* increased by 29.5 % and 47.7 % than that for control, respectively ($p \leq 0.01$). The effect of contour furrow on species diversity index was significant ($p \leq 0.05$) and the diversity index was increased by 23 % than that for control. The soil moisture was compared in both sites in May, August and November. Result showed that soil moisture increased by 66.4 % ($p \leq 0.01$) in May. An increase of 12.5 % of carbon storage was observed in the soil at the contour furrow site as compared to the control site ($p \leq 0.01$). It was concluded that the implementation of contour furrow coupled with planting of *Artemisia sieberi* was successful in combating desertification in this research area.

Keywords: Soil permeability; Soil moisture; Contour furrow; Vegetation

1. Introduction

Rapid urbanization, population explosion, and climate change have threatened water security globally, regionally, and locally. While there are many ways of addressing these problems, one of the innovative techniques is the employment of rainwater harvesting systems (Zabidi et al., 2020). Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, land surfaces, road surfaces, or rock catchments using simple techniques such as pots, tanks, and cisterns as well as more complex techniques such as underground check dams (Guo and Guo, 2018; Matos et al., 2013). Rainwater harvesting for domestic uses is widely regarded as an economic and ecological solution in water conservation and storm management programs (Canales et al., 2020). Also, Kuntz Maykot and Ghisi (2020) assessed rainwater harvesting system in a multi-story residential building in Brazil.

Harvested rainwater is a renewable source of clean water ideal for domestic and landscape uses. Water harvesting systems provide flexible solutions that can effectively meet the needs of new and existing sites, as well as of small and large ones. More significant attraction of the rainwater harvesting system is its low cost compared to other water supply systems (Siddiqui et al., 2020). Accordingly, Struk-

Sokołowska et al. (2020) assessed the quality of rainwater stored for washing purposes. Fayez (2019) provided updated information on the potential of rainwater-harvesting systems in different climatic zones in Jordan.

Nowaday, the threat and intensification of natural resource constraints are the significant challenges in the sustainable management of these resources (Ardakani and Vahdati, 2018). In this regard, more serious attention to the issue of management, remediation and restoration of natural resources, especially in the vast expanse of pastures in desert ranges is needed more than ever. One of the most enormous constraints on vegetation growth in arid and semi-arid regions is limited access to water (Fathizad et al., 2017). Dealing with the desertification phenomenon requires the restoration of vegetation and an increasing in the potential of soil to plant production efficiency (Hakimzadeh et al., 2014).

In the past, people, especially occupants of arid lands whose access to water was limited invented different ways to collect and conserve water. Today, many of these methods are reclaimed and introduced as indigenous knowledge. In such conditions, in order to use rainfall and surface runoff to improve the vegetation and create ecological balance, the implementation of a series of rainfall storage operations with planting or sowing is essential in the natural resource ranges. Rainwater storage is one of the effective remediation methods that has been implemented or is being implemented in recent years in some pastures of arid regions of the country to store rainfall and strengthen groundwater aquifers while preventing water waste and water loss in pastures (Abdollahi et al., 2016). Types of water storage protection methods include dams, earthen dams, stone-mortar dams, pitting, gourds, flood spreading, contour furrow, and instance. Due to the variety of methods for storing rainfall reserves, their high cost, and other performance, there is need for a plan to find a better and more appropriate method in arid climates (Bahmadi and Shahryari, 2016).

Tesfa Gebrie et al. (2020) in the assessment of rainwater harvesting potential for non-potable use in urban ranges concluded that an enormous amount of water for non-potable could be obtained. Hence, the use of rainwater harvesting systems in urban ranges is an appropriate method and plays an excellent role in resolving the water scarcity problem.

Sayl et al. (2020) used a GIS-based approach with remote sensing to identify the optimal sites, for rainwater harvesting. Four indices: evaporation, cost benefit sediment, and hydrology were evaluated. Results showed that the variance inverse and rank order method affected the ranking priority and considered all of them as the sensitive criteria, compared to the methods of AHP[1] and FAHP[2].

Aghaloo and Chiu (2020) identified optimal sites for a rainwater-harvesting agricultural scheme in Iran using the fuzzy logic in a GIS-based decision support system. Saghari et al. (2019) suggested that the implementation of rainfall storage had significantly increased the indicators of species evenness, richness and diversity, and the percentage of vegetation in the project range, compared to the control range. The percentage of vegetation in the range of holes has increased about twice and in the range of crescents about 1.5 times more than the control range. Instance and contour furrow had significant effect on regenerating and increasing vegetation than the control increasing by increasing soil moisture, production and vegetation percentage, (Rostami et al., 2017). Instance operation has a more favorable and efficient effect to increase vegetation (Bahmadi and Shahryari, 2016). Zare et al. (2021a) by the implementation of ripping operations along the Haloxylon planting in the Ashniz Meybod rangeland, Iran found an increase of 1.87 % and 1.68 % for vegetation and canopy cover of Haloxylon, respectively.

Increased vegetation due to runoff collection was reported by contour trenching, contour furrow, ripping, and pitting with 79.7 %, 75 %, 72.7 %, and 65 % which were higher than that for control, respectively. In comparison, soil moisture content, different treatments of contour furrow, cereal trenching, ripping, pitting and control with an average of 11.56 %, 11.1 %, 10.53 %, 10.03 % and 7.05 % were reported, respectively (Khazaei and Shahrivar, 2017).

Esfandiari and Hakimzadeh Ardakani (2014) in the Bakhtegan basin, Iran found that surface water had improved the quantitative and qualitative condition of vegetation in this region. Zare et al. (2021) in the study of different methods of planting of *Haloxylon Aphyllum* Iljin (crescent watering, ripping, and planting in arid rivers) in the Myibod rangeland, Iran reported the highest increase in vegetation (5.15 %), rooting (more than 3 m), and permeability (8.03 cm/h) obtained for planting in ephemeral streams, respectively. Jafari et al. (2013) in furrowing remedial operations in the Ivaneki range of Semnan, Iran had led to an increase of 32 % in carbon reserves and 37 % in nitrogen of the whole ecosystem, respectively

Shahrokh et al. (2017) found a higher carbon sequestration increase of plant biomass and the increased soil moisture in the contour furrow operation than the control site.

Improvement and development rangeland projects using rainwater harvesting are costly, for this reason; evaluating their success and impact of particular is important. A lot of research has been done in this field, but the effect of the contour furrow combined with seed sowing on the establishment of plants and the soil moisture in Bolbol rangeland, Yazd province, Iran has not been studied. It is expected to have different plant and soil parameters in the implementation of biomechanical operations in the region. The purpose of this research was to investigate the impact of rainwater harvesting on vegetation and soil indicators in Bolbol range with annual rainfall less than 110 mm per year.

2. Materials and methods

2.1 Study area

The Bolbol range is located at a distance of 40 km from Yazd, (53°48′55″ to 53°48′20″ E, and 31°55′39″ to 31°55′42″ N) (Fig. 1). According to the long-term rainfall statistics of Khamsian station and Khezrabad watershed studies, 73.7 % of rainfall occur in the first three or four months of the wet year. Most of the rainfall in the region occurs almost from February to April. The dry and wet

1. Analytic Hierarchy Process
2. Fuzzy Analytic Hierarchy Process

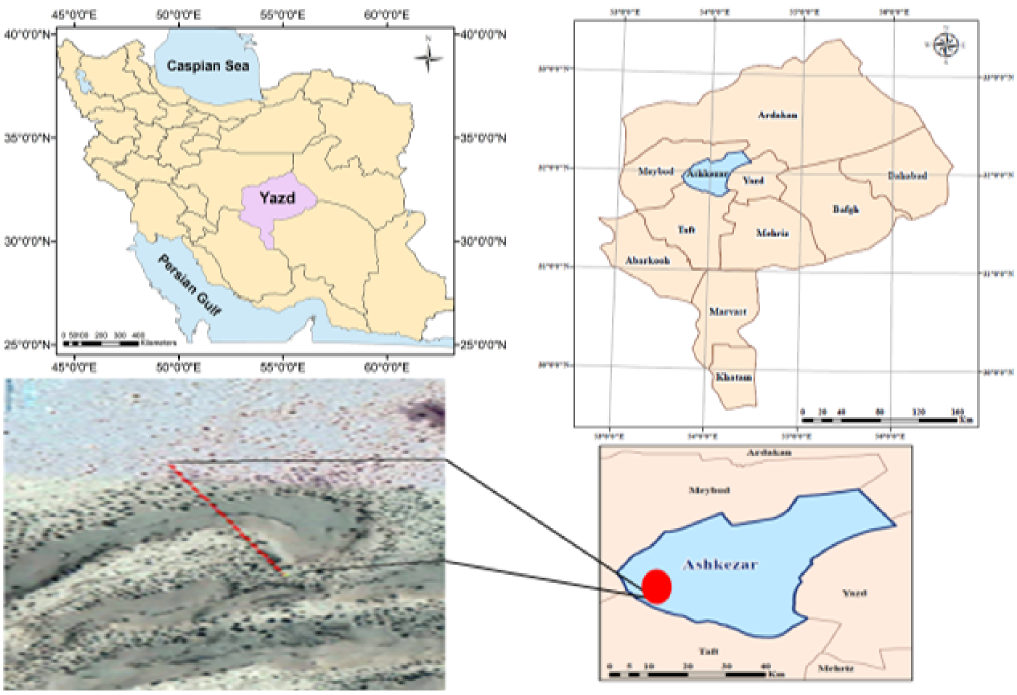

Figure 1. The location of the study area

periods of the region in the return periods of 100 years are possible with a probability of rainfall of 15.8 and 283.3 mm, respectively. The wettest period is from mid-December to late March and the rest of the year is dry (Zare et al., 2021a). Its climate is arid in Dumbarton climate classification system with the aridity index of 3.9. The average annual rainfall is 108 mm and the average annual temperature is 18 °C according to the long term data.

The dominant plant type of area is *Artemisia sieberi*. Considering the watershed studies of the Khezrabad basin, the region is a part of the upper plateaus and terraces with different slopes and low slopes on Quarternary period, short and young terraces, and alluvial fan (Zare et al., 2021).

Contour furrow is the creation of small and shallow streams of level lines on the surface of pastures, which is done to penetrate water into the soil, prevent from its surface flow, increase vegetation, and forage production and avoid the formation of surface runoff and soil erosion.

In the study range in 2006, the implementation of contour furrow was done at a range of 100 ha. The average length of furrows was 560 m/ha, with dimensions of depth and width of 30 cm. The characteristics of vegetation and soil were investigated in the ranges of contour furrow and control (ranges without operations, which are edaphically and climatically like the project ranges). Past software was used to evaluate numerical indicators of diversity and species richness.

2.2 Methodology

2.2.1 Vegetation parameters

Vegetation characteristics including the percentage of vegetation in the region, the number of plant (density) and vegetation cover of the species, richness and diversity of species were measured using the transect-plot method in both control and contour furrow sites. The total number of 60 plots was considered for each site. The length of transects was determined based on the conditions of the planting range, at each site, four transects (300 m) were established at a distance of 100 m from each other in each site, the first transect was established randomly and the rest were placed parallel to it at a distance of 100 m. Along each transect, 15 plots (2 m^2) were established at a distance of 12 m from each other (Baghestani, 2008).

After identifying the plant species and counting the shurbs, the canopy percent of the species in the plots was measured for each site, and based on the data obtained from the plots, the percentage of total vegetation, canopy, and the number of plants (density) of species per hectare was calculated.

The diversity of the species consists of two parts, the richness of species and uniformity. The number of species in a given unit of society is called species richness, which includes all species. The distribution of all individuals among these species is called uniformity, and by combining these two components, species diversity, which means measuring the richness of a species by uniformity, was obtained. Margalef's (1957) index (Equation 1) was used to determine the species richness.

$$R = S - 1/\ln(N) \tag{1}$$

Where
R = the amount of Margalef index,
S = the number of species,
N = the frequency of species.

Simpson index was used to determine species diversity (Magurran, 1988). The Simpson index was obtained by Equation 2.

A B C

Figure 2. A: measuring soil permeability, B: profile drilling and measuring the root depth of *Artemisia sieberi*, C: Contour furrow images

$$1-D = 1-\sum (P_i)^2 \quad (2)$$

Where
$1-D$ = the numerical value of the Simpson index,
P_i = the ratio of all the cases in the sample that belongs to species i. (The value of this index varies from zero to one).

To measure the root depth of *Artemisia sieberi*, trench digging and soil profile observations were performed. During the transect, two *Artemisia sieberi* stems and a total of 8 bushes were selected for each site, and trench digging and root depth measurements were performed (Fig. 2).

2.2.2 Soil parameters

In the present study, a soil profile was excavated and described on each site. Soil moisture in different seasons, permeability, and soil carbon storage at the control and contour furrow sites were measured. Two points were randomly selected throughout each transect and soil sampling was taken at a soil depth of 0 – 30 cm. Water infiltration in the soil was measured using the double cylinder method and soil moisture percent measured by the TDR[3] (Roth et al., 1990). In total, 8 and 16 cases of water infiltration, soil carbon and soil moisture measured at each site and the whole region, respectively. The soil moisture was measured three times in May, August and November months. The amount of soil carbon storage was calculated in t/ha as Equation 3. (Magurran, 1988):

$$Cs = 100 \times OC\,(\%) \times Bd \times e \quad (3)$$

Where:
Cs = organic carbon (t/ha),
OC = percentage of organic carbon,
Bd = soil bulk the number of plant (density) of soil (g/cm^3),
e = sampling depth (m).

The clump method was used to determine the soil bulk the number of plant (density) (Dianati et al., 2010). In relation to carbon emission control, the amount of soil carbon at a depth of 30 cm was selected as the standard in the Kyoto Convention (McKenzie et al., 2000).

3. Time Domain Reflectometry

Soil permeability is one of the main characteristics of soil for storing moisture from rainfall and transfer to the aquifer. One of the best methods for measuring and determining the permeability of water in the soil is to perform a double-cylinder test (Mousavi et al., 2005).

The model was used to calculate the water infiltration into the soil (Mousavi et al., 2005). This model is one of the experimental equations for water infiltration into the soil and as presented in Equation 4.

$$\mathrm{I} = \mathrm{at^b} \quad (4)$$

Where
I = cumulative penetration,
t = time (minute),
a and b = regression coefficients.

To measure water infiltration in the soil by the double cylinder method, water infiltration was measured in the soil in cm at 2, 4, 6, 11, 16, 21, 31, 41, 51, 66, and 80 minutes (Fig. 2). Then, the cumulative calculation of time and the amount of infiltration was performed, and the logarithm was taken. After drawing the diagrams, the amount of a and b was determined and replaced in the formula (Equation 4) and the amount of water infiltration in one hour was calculated.

After collecting vegetation and soil data and calculating the desired indices. For normalization of data, the Shapiro-Wilk test and for analyzing data T-test were used (Bihamta and Zare Chahouki, 2011).

3. Result

The result of means comparison using independent T test showed that the mean values of vegetation percent were 4.47 % and 5.79 % in control and contour furrow sites, respectively (Table 1). The execution of the furrow has increased the vegetation of the region by 29.5. Also, the effect of contour furrow on the *Artemisia sieberi* cover was significant ($p \leq 0.01$). Plants canopy increased by 47.7 % more than that for control. The effect of contour furrow on species richness was significant ($p \leq 0.01$) and the value of the richness index was decreased by 32 %, due to high

Table 1. Results of the evaluation of vegetation parameters in in Bolbol sites

Vegetation characteristics	Control	Contour furrow	AS %	T value	*P*
Vegetation	4.47 ± 0.46	5.79 ± 1.02	29.5 %	4.63	**
Richness of species	0.37 ± 0.21	0.25 ± 0.16	−32.4 %	2.92	**
Diversity of species	0.435 ± 0.23	0.535 ± 0.54	23.0 %	20.78	*
Artemisia sieberi canopy cover	2.22 ± 0.83	3.28 ± 0.98	47.7 %	3.16	**
Artemisia sieberi root depth (cm)	92.75 ± 5.29	84.00 ± 6.32	−9.4 %	2.52	ns
Artemisia sieberi density	2081 ± 28.36	2220 ± 31.43	6.7 %	0.78	ns

*, **: Significantly different at 5 and 1 % probability level, respectively, ns = non-significant.

uniformity of plants. Also, the effect of contour furrow on species diversity index was significant ($p \leq 0.05$) and its values were increased by 23 % than that for control (Table 1). The effect of contour furrow on the plant density and root depth of *A. sieberi* was not significant. *A. sieberi* density at the control and contour furrow sites were 2081 and 2220 shurb/ha, respectively. *A. sieberi* density at the contour furrow site had increased by 6.7 % more than that for control site. The root depth at the contour furrow site had decreased by 9.4 % compared to the control. It seems that it is due to higher soil moisture in the furrows and the plants in farrow did not develop their roots for water absorption.

The result of independent T test showed that the amount of soil moisture in May was increased significantly at the furrow compared to the control site ($p \leq 0.01$). Soil moisture at the furrow site increased by more than 66 % in May compared to the control site (Table 2). However, the effect of contour furrow was not significant for soil moisture in August and November. (Table 2). The results showed that the effect of contour furrow on soil permeability and carbon storage was not significant. The average water infiltration in the soil at the control and furrow sites was 3.45 cm/h and 2.75 cm/h, respectively. These values are in the category of average water infiltration in surface soils (Rajaie et al., 2013). Soil permeability at the furrow site decreased by 25 % as compared to the control site. The average soil carbon storage at control and furrow sites was 8.82 and 9.92 t/ha, respectively, indicating that carbon storage in the soil had increased by 1.1 t/ha at the furrow site as compared to control site (equal to 12.5 % increase).

4. Discussion

This study was conducted on watershed operations such as contour furrow coupled with seed sowing for rainwater harvesting in soil and thier effcts on plant cover and soil carbon storage in Bolbol rangelands located in Ashkazar, Yazd, Iran in 2020. Results showed that the contour furrow increased vegetation up to 29.5 %. The increase in vegetation on the furrow site was due to the moisture stored in the furrows. Surface water accumulates inside the furrow and creates more suitable conditions for vegetation in it. The results of this research were in agreement with the results of the research (Mahmoodi Moghadam et al., 2016; Souri et al., 2017; Zarekia et al., 2018; Bahmadi and Shahryari, 2016; Delkhosh and Bagheri, 2012; Zarekia et al., 2021) on the increase of vegetation products. Soil moisture in the second half of May in the furrows was 66 % higher than that for control. Therefore, the furrow plant had more canopy due to receiving more moisture. Also, the increase in humidity had caused the growth of newer plants in the furrows. The species (*Pteropyron aucheri*), which usually grew in streams and canals of area, grew significantly in the furrows. Also, tillage had created suitable conditions for the species (*Salsola yazdiana*) which had a higher plant density than that for control site. Seed sowing had also increased the plant density in the furrow region; so, vegetation percent diversity of species at the furrow site had increased. Rainwater storage and increased soil moisture had caused the roots of the *Artemisia sieberi* plant to spread superfi-

Table 2. Results of the evaluation of changes in soil parameters in Bolbol sites

Soil characteristics	Control	Contour furrow	%	T value	*P*
Soil moisture in May %	31.25 ± 0.23	52.00 ± 0.85	66.4 %	5.17	**
Soil moisture in Agust %	11.25 ± 0.21	11.25 ± 0.65	0.0 %	0.00	ns
Soil moisture in November %	13.00 ± 0.18	13.25 ± 0.32	1.9 %	0.297	ns
Soil permeability (cm/h)	3.45 ± 0.24	2.75 ± 0.45	−25.3 %	1.079	ns
Carbon storage in soil (t/ha)	8.82 ± 0.25	9.92 ± 0.58	12.5 %	0.847	ns

*, **: Significantly different at 5 and 1 % probability level, respectively, ns = non-significant.

cially on the floor of the furrows instead of deep growth. The roots of plants outside the furrow, deprived of stored water, grew more profound and could use the soil moisture in the lower layers. Other studies had shown that instance stores about 52 – 104 m^3/ha of rainwater during the rainy season and increases vegetation and plant diversity in the range so that vegetation indices in the remedied range have increased (Delavari et al., 2017). Also, our results were consistent with most of the studies in this field (Bahmadi and Shahryari, 2016; Ebrahimi et al., 2014; Rad et al., 2008; Saghari et al., 2019).

Although the soil permeability at the furrow site has decreased compared to the control site, both are in the medium permeability class (Rajaie et al., 2013). The decrease in permeability is due to the deposition of clay on the floor of the furrow, which reduces the permeability and increases evaporation. The study of Zaremehrjardi et al. (2013) also showed that the rate of water permeability in the range of remediation operations in the second year had decreased as compared to the first year, which was the most important reason for reducing the permeability of sediment accumulation on the soil surface.

In the Bolbol range, carbon storage in the furrow site was 0.94 t/ha higher than that for control site, this increase in carbon storage which is not statistically significant was due to the 12.5 % increase in vegetation at this site. In other studies, it was shown that carbon storage was higher in the contour furrow operation than the control site (Roth et al., 1990; Jafari et al., 2013; Gholami et al., 2020).

Contour furrow in the Bolbol range at the rate of 560 m/ha with an average width of 30 cm about 280 m^2/ha tillage was done. In case of 100 % success of the project, according to the affected range, the collected rainwater has the potential to develop vegetation by 29 % of the canopy in the range. In general, the contour furrows had a capacity of 34 m^3 of rainwater in which some of the collected rainwater evaporates after rainfall. Most of the rainfall in the region occurs in February to April and the dry season of the region was more than 8 months per year. Therefore, with all the above conditions, achieving total vegetation as about 29 % can be considered as a success. In Ethiopia, water harvesting techniques had significant impact on improved soil moisture, runoff and ground water recharge and increased agricultural production (Tolossa et al., 2020).

5. Conclusion

This study was conducted on watershed operations such as contour furrow coupled with seed swoing, for rainwater harvesting in soil and plant cover and soil carbon storage in 2020 in Bolbol rangelands located in Ashkazar, Yazd, Iran. Results showed that the effect of contour furrow on vegetation, species richness, plant coverage was significant ($p \leq 0.01$). An increase of 1.1 t/ha (equal to 12.5 % increase) of carbon in the contour furrow site compared to the control site was observed. According to the obtained results, the maximum ecological potential of the region for the development of vegetation with the contour furrow was 29.5 %, which should be considered during the implementation of the contour furrow projects in desert areas with climatic and physical conditions similar to the study area.

In arid and desert areas such as the study area due to low rainfall, poor distribution and frequent droughts, high density compaction operations were based solely on rainfall in the region whose maximum ecological capacity with climatic and adaptive conditions of the study area was 29.5 % increasing of vegetation. Due to the obtained results in this research, the selection of contour furrow method and planting of *Artemisia sieberi* could be successful in combating desertification.

Ethical approval:
This manuscript does not report on or involve the use of any animal or human data or tissue. So the ethical approval does not applicable.

Funding:
No funding was received to assist with conducting this study and the preparation of this manuscript.

Authors Contributions:
All authors have contributed equally to prepare the paper.

Availability of data and materials:
The data that support the findings of this study are available on request from the corresponding author.

Conflict of Interests:
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abdollahi V., Zolfaghari F., Jabbary M., Dehghan M. R. (2016) Effect of crescent pond on soil and vegetation properties in Saravan Rangelands (Sistan and Baluchestan Province) *Iranian Journal of Range and Desert Research* 22 (4): 658–671. (In Persian)

Aghaloo K., Chiu Y. R. (2020) Identifying Optimal Sites for a Rainwater-Harvesting Agricultural Scheme in Iran Using the Best-Worst Method and Fuzzy Logic in a GIS-Based Decision Support System *Water* 12 (7): 1913.

Ardakani M. A., Vahdati A. R. (2018) Monitoring of organic matter and soil salinity by using IRS-LissIII satellite data in the Harat plain, of Yazd province *Desert* 23 (1): 2008–0875.

Baghestani M. N. (2008) Determining Of An Optimum Sample Size For Annual Yield Estimation In The Steppic Rangeland Of Yazd Province *Journal of Rangeland* 2:162–171. (In Persian)

Bahmadi M. H., Shahryari A. R. (2016) Effects of different rainfall storage methods on vegetation restoration (Case study: Romeh and Dehno watershed, Nehbandan city) *Iranian Journal of Range and Desert Research* 23 (1): 51–57. (In Persian)

Bihamta M. R., Zare Chahouki M. A. (2011) Principle of Statistic for the Natural Resources Science University of Tehran Press. (In Persian)

Canales F. A., Gwoździej-Mazur J., Jadwiszczak P., Struk-Sokołowska J., Wartalska K., Wdowikowski M., Kaźmierczak B. (2020) Long-term Trends in 20-Day Cumulative Precipitation for Residential Rainwater Harvesting in Poland *Water* 12 (7): 1932.

Delavari A., Bashari H., Tarkesh M., Mosaddeghi M. (2017) Effects of small micro-catchment semi-circular bands on the diversity indices and frequency distribution models in Narron rangelands (Sistan & Baluchistan Province) *Journal of Rangeland* 11 (3): 331–341. (In Persian)

Delkhosh M., Bagheri R. (2012) Investigating the effect of mechanical project crescent on production, canopy cover percentage, plant composition and soil moisture in Gurik Range management project in *The First National Conference on Rainwater Levels Systems,* December 22–23, 2012 Mashhad, Iran (In Persian)

Dianati Gh., Naghipour A., Tavakoli H., Heydariyan Aghakhani M., Afkhami M. (2010) Influence of enclosure on carbon sequestration of soil and plant biomass in semi-arid Rangelands of North Khorasan *Journal of Rangeland* 3 (4): 679–668. (In Persian)

Ebrahimi M., Arab M., Ajorloo M. (2014) Effects of Enclosure on Ecological Indexes of Rangeland Health Using Landscape Function Analysis Method (Case Study: Jiroft Jbalbarez Rangeland) *Journal of Rangeland* 8 (3): 261–271. (In Persian)

Esfandiari M., Hakimzadeh Ardakani M. A. (2014) Evaluation of active desertification with emphasis on the soil degradation by IMDPA model (Case study: Abadeh-Tashk, Fars) *Iranian Journal of Range and Desert Research* 17 (4): 624–631. (In Persian)

Fathizad H., Hakimzadeh M. A., Fallah Shamsi S. R., Yaghobi S. (2017) Watershed-level Rainfall Erosivity Mapping Using GIS-based Geostatistical Modeling *Journal of Earth Science Research* 5 (1): 13–22.

Fayez A. (2019) Rainwater harvesting in Jordan: potential water saving, optimal tank sizing and economic analysis *Urban Water Journal* 17 (5): 446–456.

Gholami A., Sadoddin A., Ownegh M., Hossein Alizadeh M., Yari A. R. (2020) Soil Erosion Reduction by Implementing a Carbon Sequestration Project in East of Iran *Journal of Rangeland Science* 10 (1): 1–15.

Guo R., Guo Y. (2018) Stochastic Modelling of the Hydrologic Operation of Rainwater Harvesting Systems *Journal of Hydrology* 562:30–39.

Hakimzadeh M. A., Kousari M. R., Esfandiari M. (2014) Assessment and mapping of desertification sensitivity in central part of Iran *International Journal of Advanced Biological and Biomedical Research* 2 (5): 669–681.

Jafari H. J., Azarnivand H., Zarechahouki M. Z., Jafari M., Kargari E. (2013) Effects of contour furrow on carbon sequestration and nitrogen fixation in Artemisia sieberi rangelands of Semnan province *Iranian Journal of Range and Desert Research* 20 (2): 298–308. (In Persian)

Khazaei M., Shahrivar A. (2017) Effects of integrating biological and mechanical practices on vegetation cover, soil moisture, runoff and sediment yield (Case Study: Margon region of Kohgiloyeh va Boyerahmad province) *Journal of Rangeland* 11 (1): 16–26. (In Persian)

Kuntz Maykot J., Ghisi E. (2020) Assessment of A Rainwater Harvesting System in A Multi-Storey Residential Building in Brazil *Water* 12:546.

Magurran A. E. (1988) Ecological diversity and its measurement 179. Princeton University Press. Princeton, NJ.

Mahmoodi Moghadam G., Saghari M., Rostampour M., Chakoshi B. (2016) Effects of constructing small arc basins system on rangeland production and some soil properties in arid lands (case study: Steppic rangelands of Sarbishe, South Khorasan Province) *Journal of Rangeland* 9 (1): 66–75. (In Persian)

Margalef R. (1957) Diversidad de species en las commundades naturals *Publications del Instituto de Biological Aplicatae* 6:59–72.

Matos C., Santos C., Pereira S., Bentes I., Imteaz M. (2013) Rainwater Storage Tank-sizing: Case Study of a Commercial Building *International Journal of Sustainable Built Environment* 2 (2): 109–118.

McKenzie N., Ryan P., Fogarty P., Wood J. (2000) Sampling measurement and analytical protocols for carbon estimation in soil, litter and coarse woody debris *National Carbon Accounting System, Technical Report* 14 (1): 1–17.

Mousavi S. B., Neyshaburi M., Feiziasl V. (2005) Infiltrate Bility And Coefficients Of Infiltration Equations Using Double Rings, Rainfall Simulator And Raindrop Methods *Journal Of Agricultural Science (University of Tabriz)* 15 (1): 79–91. (In Persian)

Rad M. H., Mirhosseini S., Meshkat M. A., Soltani M. (2008) Effect of soil moisture on Haloxylon's root development *Iranian Journal Of Forest And Poplar Research* 16 (1): 112–123. (In Persian)

Rajaie S. H., Esmaili K., A. Abbasi A., Ziaei A. N. (2013) Study Of Permeability Changes In Water Spreading Projects.(Case Study: Jajarm Projects) *Iranian Journal of Irrigation and Drainage* 7 (1): 114–121. (In Persian)

Rostami A., Khavaninzadeh A., Bagestani Maybodi N. (2017) The effect of runoff harvesting methods on vegetation condition in arid lands (Case Study: Godar Herisht) *Desert Ecosystem Engineering Journal* 6 (16): 25–34. (In Persian)

Roth K., Schulin R., Fluhler H., Attinger W. (1990) Calibration of time domain reflectometry for water content measurement using a composite dielectric approach *Water Resources Research* 26 (10): 2267–2273.

Saghari M., Rostampour M., Mahmoudi Moghaddam G., Chakoshi B. (2019) Investigation of the Effect of Constructing Small Arc Basins System on Vegetation Composition and Biodiversity in Arid land Ecosystems in the East of Iran (Case study: Rangelands of Sarbisheh, South Khorasan Province) *Desert Ecosystem Engineering Journal* 8 (23): 33–44. (In Persian)

Sayl Kh., Adham A., Ritsema C. J. (2020) A GIS-Based Multicriteria Analysis in Modeling Optimum Sites for Rainwater Harvesting *Hydrology* 7 (51): 1–14.

Shahrokh S., Souri M., Moetamedi J., Eftekhari A. (2017) Effects of contour furrow on soil and biomass carbon sequestration (case study: Khalifan Rangelands, Mahabad) *Iranian Journal of Range and Desert Research* 24 (1): 130–144. (In Persian)

Siddiqui R., Siddiqui S., Javid K., Navaz Akram M. A. (2020) Estimation of Rainwater Harvesting Potential and Its Utility in the Educational Institutes of Lahore Using GIS Techniques *Pakistan Geographical Review* 75 (1): 1–9.

Souri M., Mahdavi K., Tarverdizadeh S. (2017) Effect of mechanical improvement treatments on vegetation performance *Iranian journal of Range and Desert Research* 24 (2): 360–369. (In Persian)

Struk-Sokołowska J., Gwoździej-Mazur J., Jadwiszczak P., Butarewicz A., Ofman P., Wdowikowski M., Kaźmierczak B. (2020) The Quality of Stored Rainwater for Washing Purposes *Water* 12 (1): 252.

Tesfa Gebrie A., Yonas Gebresilasie H., Afera Halefom T. (2020) Rainwater harvesting potential assessment for non-potable use in urban ranges *Sustainable Water Resources Management* 6 (104): 1–8.

Tolossa T. T., Abebe F. B., Girma A. A. (2020) Rainwater harvesting technology practices and implication of climate change characteristics in Eastern Ethiopia *Cogent Food & Agriculture* 6:1724354.

Zabidi H. A., Goh H. W., Chang C. K., Chan N. W., Zakaria N. A. (2020) A Review of Roof and Pond Rainwater Harvesting Systems for Water Security: The Design, Performance and Way Forward *Water* 12 (11): 3163.

Zare A., Hakimzadeh M. A., Karimian A. A. (2021a) Determining Successful Methods of Haloxylon Aphyllum Iljin Planting in Desert and its Effect on Improving Vegetation and Soil Characteristics (Case study: Dosangi, Meybod) *Desert Management* 9 (1): 67–80. (In Persian)

——— (2021) Evaluation of Rainwater Harvesting Methods and its effect on vegetation and soil characteristics (Case studies:Bolbol pastures of Ashkzar) *Journal of Natural Ecosystems of Iran* 12 (44): 16–27. (In Persian)

Zarekia S., Baghestani Maybodi N., Mirjalil A., Ahmadi Roknabadi M. R. (2021) The 18-year impact of rainfall storage projects on vegetation in steppe rangelands (Case study: Rangelands less than 100 mm of rainfall in Yazd province) *Iranian Journal of Range and Desert Research* 28 (1): 69–81. (In Persian)

Zarekia S., Fayyaz M., Zare M. T., abolghasemi M. (2018) Study of Methods of Rain Harvesting and Season Planting in Initial Establishment of Astragalus squarrosus in Yazd Province (Case Study: Kalmand Bahadoran Rangelands) *Desert Management* 6 (11): 39–50. (In Persian)

Zaremehrjardi M., Mahdian M. H., Barkhordari J. (2013) Investigation on the Effects of floodwater spreading on soil infiltration rate (Case study: Floodwater Spreading of Sarchahan, Hormozgan Province) *Iranian Journal of Watershed Management Science and Engineering* 7 (20): 1–8. (In Persian)