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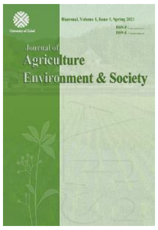

Watershed management by identifying suitable places for water storage, a way to ecological compression (case study: Talandasht district, Kermanshah-Iran)

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ABSTRACT

This study aims to determine the optimal locations for rainwater harvesting in the Talandasht region of the province of Kermanshah. As a multivariate analysis, the Analytic Hierarchy Process (AHP) was used to determine the optimal sites. GIS identifies the optimal locations for the Talandasht region based on the biophysical characteristics taken into account. In this study, slopes between five and fifteen percent were given the highest score, while slopes below five and above sixty percent received the lowest score. The soil permeability was measured using soil hydrological groups, with hydrological groups 4 (D) and 1 (A) receiving the highest and lowest scores, respectively. Over 10,000 hectares of Talandasht's total area have a slope greater than five percent, and runoff is flowing in it. If the average annual rainfall is 400 mm, there will be 34285714 cubic meters of precipitation. By determining the optimal storage location, water can be stored and used for additional purposes, including supplemental irrigation and the creation of rainfed gardens. In various regions of the country, rainwater collection has a high executive potential. Conservation and integrated agriculture are excellent opportunities for conserving and storing rainwater in the region and reducing the region's yield gap.

Highlights

- This study determines Kermanshah's Talandasht region's best rainwater harvesting sites.
- Runoff flows in over 10,000 ha of Talandasht's slopes greater than 5%.
- Water can be stored for irrigation and rainfed gardens by finding the best storage location.
- Conservation and integrated agriculture can store rainwater and reduce the region's yield gap.

1. Introduction

Dry areas are areas with an aridity index (average ratio of annual precipitation to potential evapotranspiration) less than 0.65. As the world's largest biome, these regions cover about 45% of the earth's surface (Prăvălie, 2016). They support and feed approximately 38% of the world's human population (Ray-Shyan et al., 2018). Dry areas have difficult conditions for agriculture in terms of climate and soil because the annual water balance is negative, the rainy season is short and variable, the content of soil organic matter is low, and soil erosion and salinity are high (Kassam et al., 2012). However, due to population growth and climate change scenarios, the long-term sustainability of rain-fed agriculture in dry areas is critical to global food security (García-Palaciosa et al., 2019). The yield gap (difference between potential and actual yields) is high in dry areas, especially in dry farming. The water -holding capacity of the soil, a key regulatory system in dry farming, is strongly related to the soil structure (Maestre et al., 2016).

The world today faces many challenges, including poverty, environmental degradation, climate change, and ensuring food security. At the same time, there is a lot of competition for land, water, energy, and other inputs in food production. The entry of humankind into a new historical period called the Anthropocene (climate change

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caused by human activities) has exposed the universe to the biggest drivers of change; Agriculture is one of the main factors that cause these changes. As a result, food insecurity and climate changes in a region can have wide political and economic effects. These challenges require action through a transformation in the food production system. Increasing food production per unit area in a way that creates less pressure on the environment and maintains production capacity in the future can be a suitable response to these factors. Sustainable compression in this framework seeks to increase the achievements of the agricultural sector while keeping the ecological footprint low. Sustainable compaction is the result of two technological and socio-economic approaches. Among these, there are two technological principles: one is the use of agro-environmental processes, such as sustainable or ecological compression, and the other is the use of plant and animal breeding (genetic compression). Therefore, policymakers for food production systems should consider multiple objectives from multifunctional perspectives, including biodiversity, sustainable development, rural economy, etc.

Sustainable compression is a method of production in which crop production is improved without negative environmental effects or cultivating new lands. The FAO also recently defined ecological compaction or sustainable compaction in the organic farming complex as an increase in primary production per unit area without compromising the system's ability to maintain its productive capacity (Ray-Shyan et al., 2018).

Rainwater harvesting, which has gained renewed attention since the 1980s, has been a rational approach to water scarcity for thousands of years (Ray-Shyan et al., 2018). Increasing the efficiency and productivity of water depends on the identification of rainwater collection sites. Every year, about 413 billion cubic meters of water enter the country as a result of precipitation, of which about 283 billion cubic meters reenter the atmosphere through evaporation and transpiration. Only 130 billion cubic meters of it are renewable and are either stored behind dams or used to feed underground water tables. The purpose of implementing rainwater collection projects is actually to use the 283 billion cubic meters of water that are lost every year in the form of evaporation and transpiration. It should be noted that the generalization of this plan on a wide scale can lead to a lack of serious attention to the category of natural nutrition. The underground water tables and aquifers will be destroyed. As a result, it will have adverse effects on the environment.

Moving towards a sustainable compression model requires some operational strategies. The following can be mentioned:

1) Planning and applying on-farm practices in the fields of watersheds, ecosystems, and landscapes, and maximizing productivity by increasing ecological activities and actions

2) Combining ecosystem-based strategies with beneficial practices in which natural capital (soil, biodiversity, water, etc.) and multifunctional ecosystems are used as tools for developing productive and resilient agricultural systems.

3) Development of agricultural practices based on systems thinking in which land, water, food, livestock, and crop management are integrated.

4) Using the cyclical system to manage natural resources (for example, food recycling),

5) Controlling agroecological processes, such as the food cycle, biological nitrogen fixation, metamorphosis, etc.

6) Helping farmers to accept barriers to sustainable compaction and creating motivation for its sustainable adoption by addressing long-term profitable ecological practices.

7) Creating strong organizations consisting of smallholder farmers by taking advantage of the role of women, who are recognized as intermediaries between the markets and the government.

Sustainable intensification can provide more food and better ecosystems and transform agriculture into a major contributor to global sustainability (Foley et al., 2011).

Ameri Ekhtearabadi et al. (2011) conducted a study with the aim of determining suitable water harvesting locations using the Analytical Hierarchy Process (AHP). They used the river, slope, vegetation, land use, and road profiles digitally. After the relative weighting of the layers in the GIS† environment, suitable catchment locations were divided into five areas based on priority. In a similar way to the results of Jalili et al. (2007) in Sarab Niloufer Plain of Kermanshah, it was showed that the parameters of permeability, texture, and thickness of the critical layer had the highest importance. An important parameter for suitable areas for rainwater harvesting is rainfall. In this case, factors such as the number of days when the rainfall exceeds the basin threshold, the minimum and maximum rainfall probability, and the annual average rainfall probability are important. Land use or vegetation is another important parameter that affects surface runoff (Ameri Ekhtearabadi et al., 2011). It has been proven that the density of vegetation will increase infiltration and thus reduce the share of runoff. The type of soil and environmental issues are also important (Jalili et al., 2014).

Identifying potential sites for rainwater harvesting is an important step toward maximizing water and land productivity in arid regions. In addition to identifying the appropriate location, their technical design is also a key factor in the success of rainwater harvesting systems (Al-Adamat et al., 2012). The suitability of rainwater harvesting sites depends on several criteria (Mahmoud and Alazba, 2014), technique, and method (Winnaar et al., 2007). Analysis of the main factors to decide and choosing the best method and location size depends on the target area (Ray-Shyan et al., 2018). One group of studies on biophysical parameters such as rainfall, drainage system, slope, land use, and soil type (Kumar et al., 2008: Kadam et al., 2012) and another group on socio-economic parameters (land ownership, distance to residential areas, streams, roads, agricultural area, population density, and

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†. Geographic information system

associated cost) (Bulcock and Jewitt., 2013: Hobbs et al., 2008: Kahinda et al., 2008; Krois and Schulte., 2014). The most common biophysical criteria used in arid and semi-arid regions to identify suitable sites for rainwater harvesting (as a percentage of all reviewed studies) are slope (83%), land use/cover (75%), soil type (75%), and rainfall (56%). Distance to settlements (25%), distance to streams (15%), distance to roads (15%), and cost (8%) were also the most important socio-economic criteria, which are discussed in another category.To identify suitable sites using biophysical criteria, tools, and methods such as GIS and remote sensing (Bamne et al., 2014), hydrological modeling with GIS and remote sensing (Mahmoud and Alazba., 2014), the multi-criteria analysis combined with modeling Hydrological, GIS and remote sensing (Khan and Khattak, 2012) and multi-criteria analysis with Shamiri GIS (Shamiri and Ziadat, 2012) have been used. All methods and tools used in research studies related to site selection for rainwater harvesting have limitations. However, the GIS/remote sensing tool is the first practical tool to identify suitable locations. While to achieve more accurate results and multi-criteria areas, the integration of multi-purpose analysis methods and tools and GIS-based hydrological modeling is highly recommended. A study was conducted in the western part of Iraq in Anbar province. The catchment area of this region is 13370 square kilometers, and it has a dry climate with dry summers and cool winters. The average annual temperature is 21°C, July is the hottest, and January is the coldest month of the year. The average annual rainfall is very low (75 to 150 mm). About 49% of the rain falls in winter, 36% in spring, and 15% in fall. The average annual potential evaporation is 3200 mm (Adham et al., 2016). This watershed is dry most of the year, but during the rainy season, severe flooding occurs in a short time. Therefore, dams are one of the methods of storing rainwater in the rainy season for use in the dry season and are effective structures for the proper use of water in Iraq. This study focuses on choosing a suitable place for rainwater harvesting in the Talandasht region of Kermanshah. In this area, most of the people are engaged in agriculture and animal husbandry. In this article, the results of the design, management, and implementation of a rainwater harvesting pilot project in Kermanshah with the aim of supplemental irrigation of rain-fed crops and garden development have been examined. In fact, the study of a vast watershed with limited data to choose a location can be complicated considering all factors, but using GIS and remote sensing is easy in the location selection process.

2. Materials and methods

2.1. Study area

Talandasht study area, with an area of about 12,685 hectares, is located at the geographical position of 46°52' to 47°3' east longitude and 24°1' to 24°6' north latitude. Talandasht district is located in the northwest of Hasanabad Plain (Islamabad West) and the south of Mahidasht in Kermanshah county. Talandasht district has nine villages, including Akhundi, Talandasht, Taghtaq, Taviran Olia, Taviran Sofla, Anjirak, Toh Ruileh Olia, Toruileh Sofla, and Tawalegah. Figure 1 shows the geographical location of the Talandasht watershed in the political divisions of the province. The maximum height above sea level is 2100 meters, and the minimum height at the outlet of the basin is 1600 meters. Fan alluviums of connected form, cut plateaus and alluvial plains form the physiographic ranges of this region (Jalili et al., 2007).

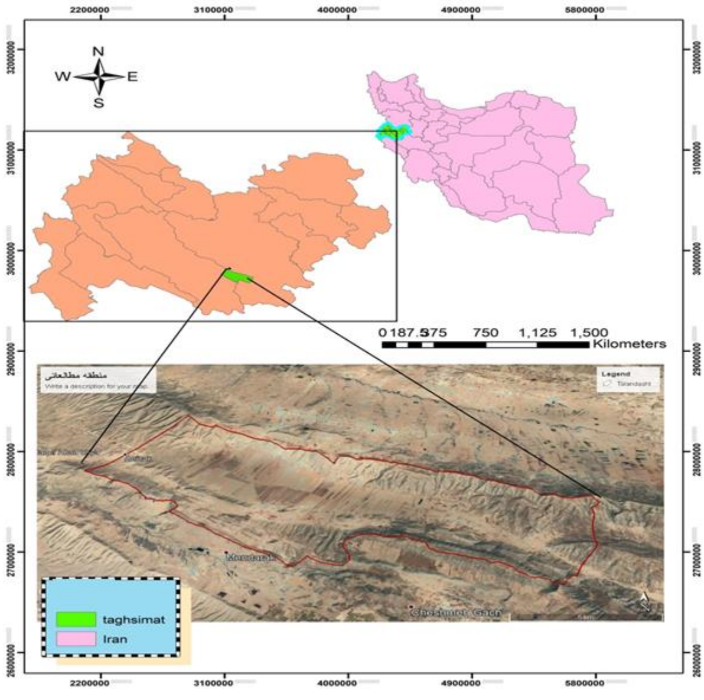

Figure 1. Geographical location of the study basin

Table 1. Monthly of climatic data of Mahidasht station from(1986-1996)

Climatic data	Month											
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Absolute minimum air temperature (℃)	-2	-9.5	-12.5	-25	-24	-24	-9	-4	0	0	3	4
Absolute maximum air temperature (℃)	38	35	28	12	20	26	32	32	39	43	42	40
Average maximum air temperature (℃)	0.4	20	12	7.8	7.7	11.8	16.8	20.9	30.3	26.5	32.2	24.6
Average air temperature (℃)	2.65	10.5	1.8	1.3	1.2	4.4	9.2	12.8	19.1	19.5	22.8	18
Average minimum air temperature (℃)	4.9	1	-1.5	-5.1	-5.2	-2.9	1.7	5.1	7.9	12.5	13.4	11.4
Potential evapotranspiration (mm)	0.2	45	27.9	24.8	23.6	65.1	90	120.9	152	64.3	151.9	123
ET_0 Talandasht	0.5	42	27.2	0.3	0.2	0.9	78	108.5	142	0.2	0.8	123
Rainfall (mm)	0.1	55.2	69.2	66.8	62	95.6	62.9	22.9	1.2	0.2	0.4	0.7

2.2. Climatic characteristics of the study area

The average annual rainfall is about 450 mm, the annual evaporation from the evaporation pan is 2000 mm, and the annual potential evapotranspiration are estimated to be about 1000 mm. Average, absolute minimum, average minimum, absolute maximum, and average maximum air temperature in the Talandasht region were reported as 14, -21, 6, 44, and 22 degrees Celsius, respectively. According to Selyaninov's classification, the climate of the region is semi-arid. Mahidasht meteorological station is adjacent to the Talandasht study area. Therefore, in order to check the monthly distribution of climatic data in the study area, the 30 years average data of this station, which is available in Table 1, was considered representative.

2.3. Water resources of the region

Talandasht is very poor in terms of water resources, and generally, there is no reliable water source on this plain. Few of springs that do not have an appreciable water supply and are not important from the point of view of agriculture and the wells dug in the settlements of this plain for the daily use of the people are the only sources of water available in this plain. The small amount of annual rainfall, unsuitable physiographic conditions, lack of suitable places to build water storage facilities, and the poverty of the aquifer in the region have all caused the lack of access to programmable water resources in this plain. Since rainfall, even in small amounts, occurs almost everywhere, it can be collected and used with the help of water harvesting methods before it becomes a flood or becomes polluted in the flow path. Unlike large centralized systems, such as dams, that require investment and advanced technology, water harvesting systems have simple technology and can be implemented on a small scale. For this reason, this method can be used without location restrictions. Rainwater harvesting restores the underground water reserves of the region. It not only increases access to water but also increases employment opportunities and improves socio-economic conditions in dry areas (Ammar et al., 2016: Ray-Shyan et al., 2018). After the successful implementation of the watershed project in the Talandasht area by Gol Nasar Agricultural Engineering Technical Services Company, which focused on the creation of Chinese dry dams (by stones in small waterways), gabion dams (in larger waterways with fences), and earth dams (to control water pollution and nutrition) artificially concentrated in seasonal watercourses (generally non-condensing with a height of 3-5 m), huge changes were made in water resources, especially groundwater. The result of these changes was the digging of four wells (one for drinking and three for agriculture) and the conversion of 80 hectares of dry land to irrigated land. If the irrigation system is converted to a drip irrigation system, the water level of the fields can be increased to about 200 hectares. In order to choose the best place, the socio-economic, physical conditions, and characteristics of the target area should be taken into account (Al-Adamat, 2008). Due to the lack of access to the soil hydrological groups of the Talandasht basin, this information was estimated by an innovative method by Di Paola et al. (2017) based on the slope of the area and geomorphological features.

2.4. Statistical analyses

Analytic Hierarchy Process (AHP) is multivariate analysis. AHP facilitates the decision-making process by providing a structure for organizing and evaluating the importance of different criteria and the preference of options for decision-makers.

In the AHP process, the stages of analysis include creating a hierarchical model, giving the model the ability to make group decisions, comparing two by two criteria and sub-criteria to determine their importance in decision-making, combining and integrating to determine the best options, and performing sensitivity analysis (Ameri Ekhtearabadi et al., 2011). This process is a suitable decision-making method for identifying GIS-based rainwater harvesting sites (Salavati et al., 2017). The method adopted to develop such a system includes criteria selection, data acquisition criteria classification, AHP development, relative weights calculation, sensitivity analysis and water quantity estimation. One of the indicative examples of AHP application is helping to locate underground water resources in the geographic information system (GIS) environment. Based on the review of sources and opinions of experts and professors, the influencing factors on the infiltration and storage of rainwater in the soil profile in the Talandasht watershed, in order of importance and priority, include slope percentage, hydrological groups, vegetation/land use, elevation classes, and Euclidean distance. It was considered from waterways (Table 2). Then the selected biophysical criteria were extracted using the digital model of the area's height with a resolution of 30 meters and entered into the process of hierarchical analysis. In the hierarchical approach, the most weight is assigned to the layer that has the most impact in determining the goal. In other words, the weighting criterion for each information unit is also based on the role it plays within that layer (Lopez and Zinck, 1991). Using the expert choice software, their importance coefficients were extracted, and the obtained coefficients were used in the geographic information system. They were determined into four classes: very suitable, suitable, average, and unsuitable. Finally, based on the considered physical characteristics, the optimal sites were identified by a geographic information system and using a hierarchical analytical process for the Talandasht region.

3. Results and discussion

3.1. Slope

In this study, slopes of 5 to 15% were given the highest score, and slopes below 5% and above 60% were given the lowest score (Table 2). One of the effective factors in the amount of runoff and rainwater infiltration in the soil is the slope. The amount of sediment, the speed of water flow, and the materials needed to build dams depend on the amount of runoff (Adham et al., 2016). In order to investigate the land use characteristics of Talandasht, the extent of each slope class is given in Table 3. Figure 2 shows the slope layers of the study area. In Khairkhah's study (Khairkhah Zarkesh et al., 2015), a slope of 18 to 30% was given the highest score, and a slope of 0 to 2% and more than 30% was given the lowest score. Ammar et al. (2016) have recommended terracing as a suitable technique for rainwater storage for slopes of 5-30%.

Table 2. Effective layers in rainwater harvesting in the Talandasht region

Criterion valuation of layers	Euclidean distance from waterways	Altitude classes (meters above sea level)	Land use	Hydrological groups	Slope	Layers
4	0-1032	1456-1626	Forest lands	loamy sand-clay sand	5-15	very suitable
3	1032-2140	1626-1723	Pasture lands	loam-clay loam- hard layer deep in the soil	15-30	Appropriate
2	2140-3409	1723-1839	Scattered rainfed lands	Clay	30-60	medium
1	3409-5548	1839-2106	Drayland land	Salty soils - stone - asphalt road - concrete	<5 and >60	Unsuitable
	0.12	0.16	0.17	0.24	0.31	Coefficient obtained from AHP for each layer

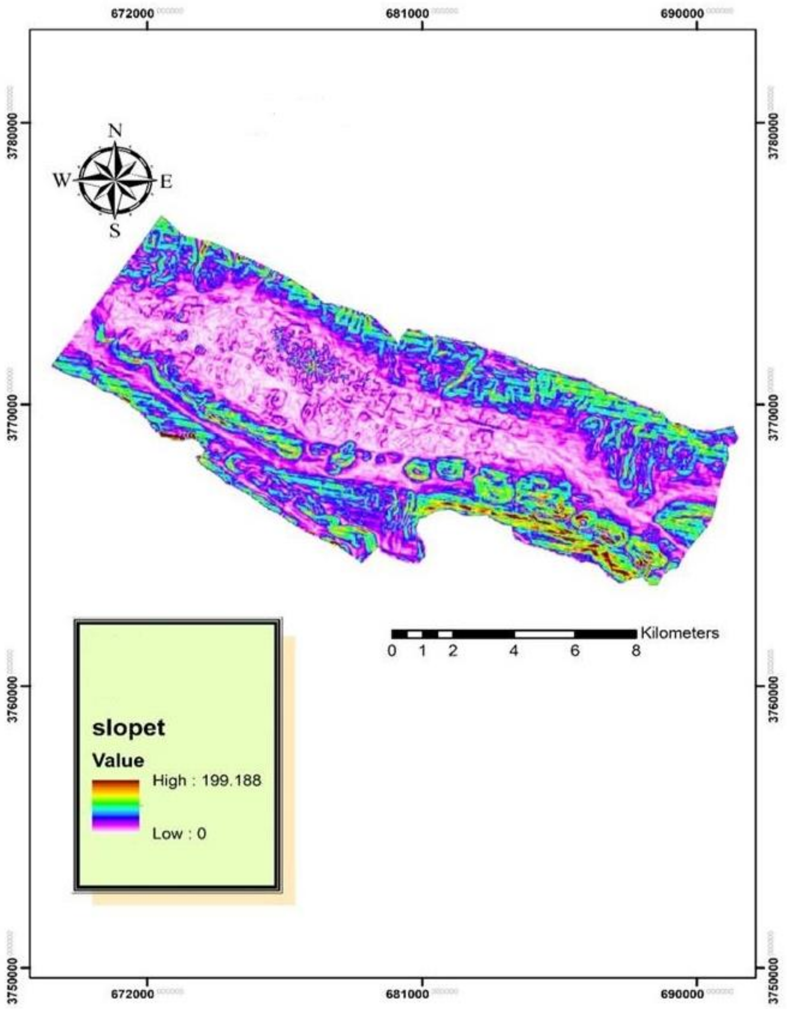

Figure 2. Slope layers

Table 3. Class and percentage of slope of Talandasht region

Slope classes	Area (ha)	Percentage (%)
0-2	1514	11.9
2-5	994	7.8
5-8	824	6.5
8-12	2330	18.3
12-15	97	0.8
15-30	3034	24
30-60	2483	19.6
>60	409	3.2
Total	12685	100

Soltani (2017), in the study of the Mekhoran and Khosroabad Sanghar watersheds of Kermanshah, concluded that in addition to the rainfall factor, which is one of the main factors in the discussion of rainwater storage, the slope and texture of the soil are more effective than other factors. Low slopes tending to zero disrupt the mechanism of runoff production and movement and increase the number of puddles and surface water retention, which prevents the collection of runoff in one place to the extent that maintains the rational-economic justification of the implementation of rainwater collection plans. It causes problems. On the other hand, the high slope is also considered an undesirable phenomenon. The high slope has caused land erosion and the loss of good soil in the catchment area, and it is not possible to create mechanical structures in places with a high slope (Keshavarz, 2012). Adham et al. (2016) recommend rainwater collection in areas with a slope greater than 5% because these areas are subject to high erosion due to the irregular distribution of runoff.

3.2. Hydrological groups

After preparing the soil hydrological maps and obtaining the user map, the infiltration curve related to the basin was prepared in the ArcGIS software environment. Figure 3 shows the hydrological groups of the study area. Soil hydrological groups were used to measure soil permeability, and hydrological groups 4 (D) and 1 (A) were given the highest and lowest points, respectively. Hydrological group D has the lowest permeability and the highest potential for runoff production, so it gets the highest score. Hydrological group A has the highest permeability and the lowest potential for runoff generation, so it gets the lowest score (Khairkhah et al., 2015: Sadeghi, 2011).

3.3. Land cover/use

Land use plays an important role in the infiltration and storage of precipitation (Keshavarz, 2012). In Talandasht, in addition to forest and pasture lands, out of a total of 12,685 hectares, 4,363 hectares (34.4% of the total area) are allocated to rainfed lands, and 1,636 hectares (12.9%) are allocated to scattered rainfed lands (Figure 4). Scattered rainfed lands are a part of non-agricultural lands that have been cultivated by carrying out agricultural operations. Therefore, from the total area of 5999 hectares to rainfed agriculture and vegetation in the study area of Talandasht, it includes forest and pasture cover with 5736 hectares (45.2%) of forest and 950 hectares (7.5%) of pasture. Examining the slope classes of the region and based on the principles of agriculture shows that slopes above 12% are not suitable for agriculture. Therefore, 1200 hectares of the land under rainfed cultivation should be changed and allocated to rainfed trees. Rainfed and irrigated gardens and agriculture have potential for rainwater harvesting, but residential areas are not prone to rainwater harvesting due to private ownership and permeable bed and due to the inability to collect runoff.

3.4. Pasture

Astragalus Euphorbia is the only grassland type in the Talandasht range. This type has been destroyed due to the overexploitation of vegetation. The dominant species of the type are self-expressing the intensity of destruction in the pasture type. Stable and high-quality species, such as *Dactylis glomrata*, *Agropyron spp*., and *Bromus tomentellus*, are few. *Stipa barbata* species at lower altitudes and *Festuca ovina* species at higher altitudes appear in spots. Among the shrub species, *Daphne mucronata* is relatively more abundant than the others.

After mounding and seeding operations, during the management operations of the Talandasht watershed, restoration was carried out on the level of degraded pastures and sloping lands of the region, which had poor coverage. The pastures were enriched by using the seeds of pasture species, such as clover and alfalfa, and grazing management was done by reducing pressure. Livestock was moved to pastures (Gol Nasar Consulting Engineers).

3.5. Forest

The forest types in the Talandasht area mainly include Iranian oak and Iranian-barnet oak, which has a coppice growth form. The areas that are located in the vicinity of the residential areas and generally have a relatively low slope and semi-deep soil have been destroyed and encroached, and wheat cultivation has been started under Ashkob. Since the power of the asexual life of the Iranian oak (*Quercus persica*) is strong and it reproduces in different ways (stem, root, and root), its complete removal is not easily possible, and even after a fire, root activity does not stop. In recent years, due to the replacement of oil, gas, and LPG fuels instead of firewood and the migration of villagers, and the implementation of the water management plan in the Talandasht watershed, the forest has been restored.

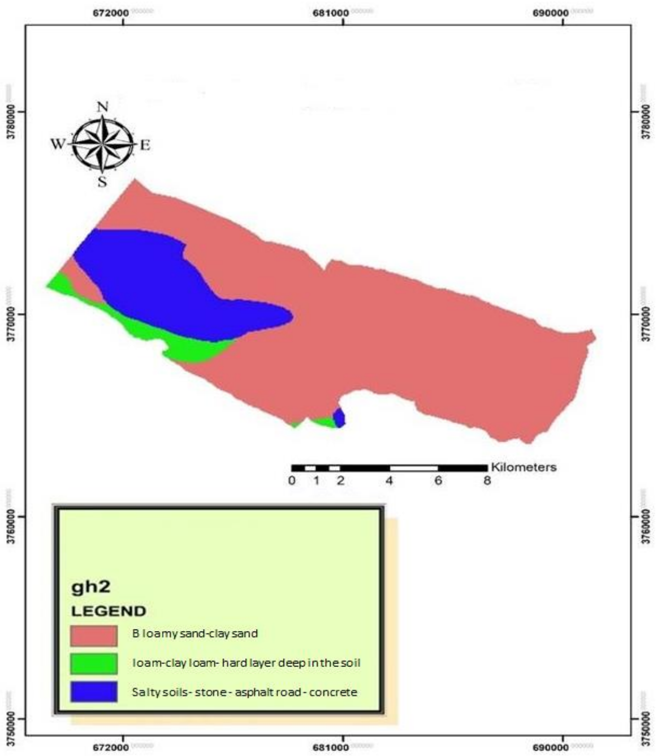

Figure 3. Hydrological groups

3.6. Agricultural landscape

The lack of reliable water sources in the region has caused agriculture in this plain to rely on seasonal rains, and rainfed cultivation of cereals and legumes is the only common agriculture in this plain. Rainwater harvesting by collecting and managing runoff increases water availability for domestic and agricultural use, as well as ecosystem capacity (Mekdaschi and Liniger, 2013). Table 4 shows the composition of crop cultivation in two periods before 1975 and after the implementation of the watershed project in 1985. By looking at Table 4 and comparing the two time periods before and after the implementation of the watershed project in Talandasht district, the magnitude of the project and its impact on biodiversity and crop diversity are determined. Cultivation of water crops, which was far from the mind, is signed, up to 80 hectares.

Also, the unprecedented cultivation of 20 hectares of saffron is extremely important from an economic point of view. Due to the increase in the area under the cultivation of legumes during the implementation of the ICARDA food security project in the west of the country, Talandasht, as one of the target areas, has caused the stability of production and increased production of protein and fodder (especially cowpea). The existing records of rainwater harvesting in the world show that this method was performed for the first time in the desert of occupied Palestine with an average rainfall of 90 mm and has greatly contributed to the production of fodder in the region.

3.7. Height

Creating a digital elevation model (DEM) of each region is an example of the spatial analysis of that region. Water resources management is a spatial problem. Water projects and especially the management and planning of droughts need to estimate locally available water (Hesari, 2013). Figure 5 shows the digital layers of the investigated area.

3.8. Euclidean distance from waterways

The distance from the waterway in the basin is the next effective factor in choosing suitable places for rain collection. This network expresses the direction of the runoff that is caused by rainstorms and flows on the surface of the basin (Sadeghi, 2011). The most basic method for creating a map of the distance to the waterway in GIS is the Euclidean distance tool. This tool shows the distance of each point in the area to the nearest river or waterway. Figure 6 shows well the distance of each point to the waterway. The map of the distance from the waterway was prepared in meters and divided into 0-1032, 1032-2140, 2140-3409, and 3409-5548classes. The floor of 0-1032 meters was given the highest score, and the floor of 3409-5548 meters was given the lowest score. The depth of runoff is an important criterion for choosing suitable sites for rainwater collection. The depth of runoff to evaluate the source of water during runoff is affected by the amount of rainfall and the distance from waterways. In this study, the rainfall were similar for the entire study area, and the same conditions were considered for the entire basin. Therefore, the runoff depth was more influenced by the Euclidean distance from the waterway. The longer the distance from the waterway is (for example, on the fourth floor, 3409-5548 meters), the amount and depth of the runoff increases and care must be taken in the construction of the channel or dam to control and store the runoff and prevent erosion.Therefore, more than 10,000 hectares of the total area of Talandasht have a slope of more than 5%, and the runoff flows in it. By determining the appropriate storage location, it can be stored and used for further uses, especially supplementary irrigation and the development of rainfed gardens. Dense vegetation is associated with higher rates of absorption and infiltration, and therefore, lower runoff. The relationship between the order of the flow and the distance from the waterway is such that the greater the distance from the waterway, the more sub-branches join together, the volume of runoff increases and more care is needed in the management of the construction of the Chinese dry channel, gabion dam or earthen dam. It reduced the volume of runoff and minimized erosion and wastage of water (Khairkhah Zarkesh et al., 2015).

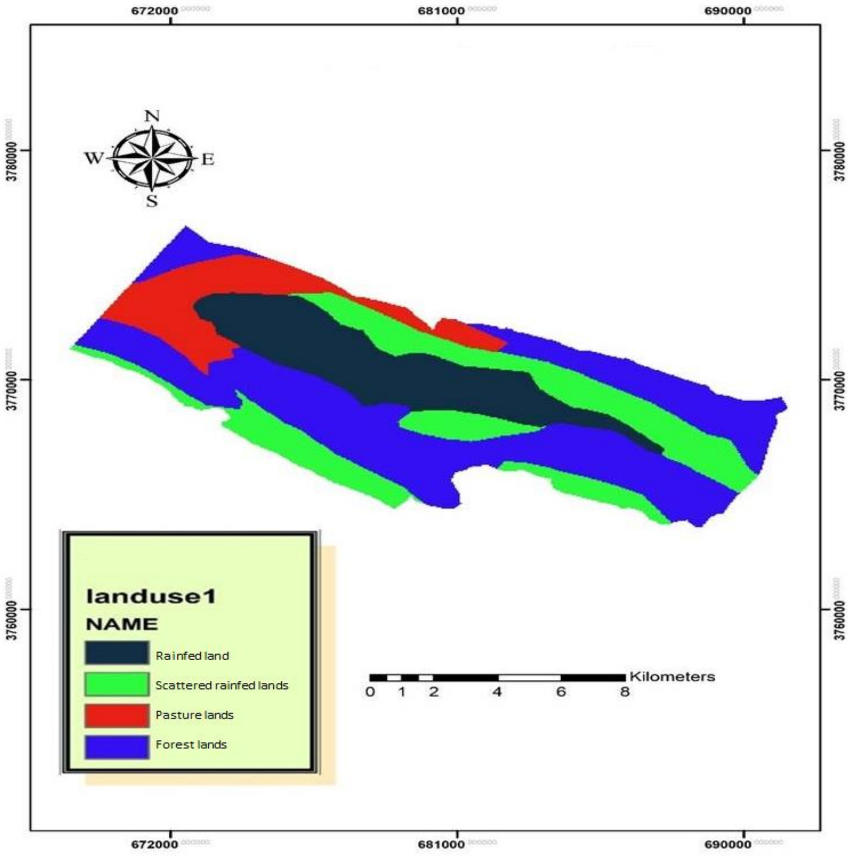

Figure 4. Land use / land cover

Table 4. Crop composition of the Talandasht region before (the year 1996) and after the implementation of watershed management project (the 90s)

The combination of crop cultivation before the year 1996	Area (ha)	The combination of crop cultivation after the watershed project (90s)	Area (ha)
Dryland wheat	3100	Dryland wheat	3272
Dryland barley	770	Dryland barly	950
Dryland spring peas	1549	Irrigated wheat	30
Black fallow	580	Spring peas	1420
		Expectational peas	60
		Forage Peas	20
		Lentils	40
		Bitter vetch	10
		Rain-fed Safflower	10
		Saffron	20
		Alfalfa	8
		Vegetables	20
		Vetch	40
		Rosa damascena	4
		Dryland almonds	20
		Dryland grapes	5
		Stubble fallow	70
Total	5999	Total	5999

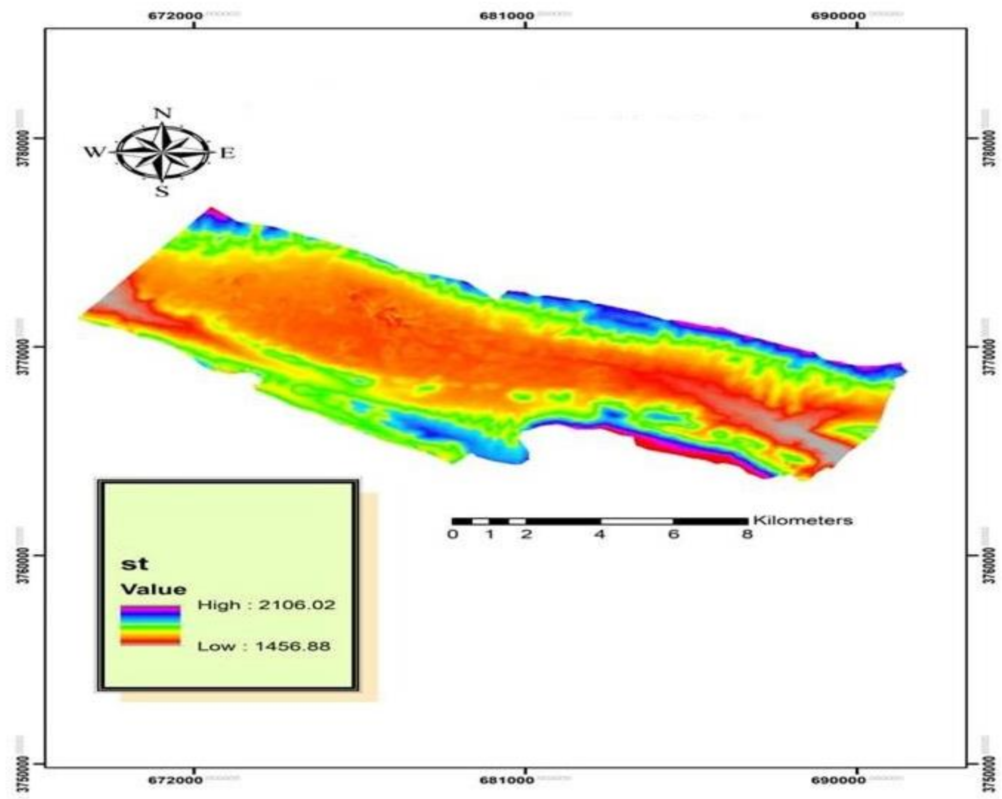

Figure 5. Digital height layer

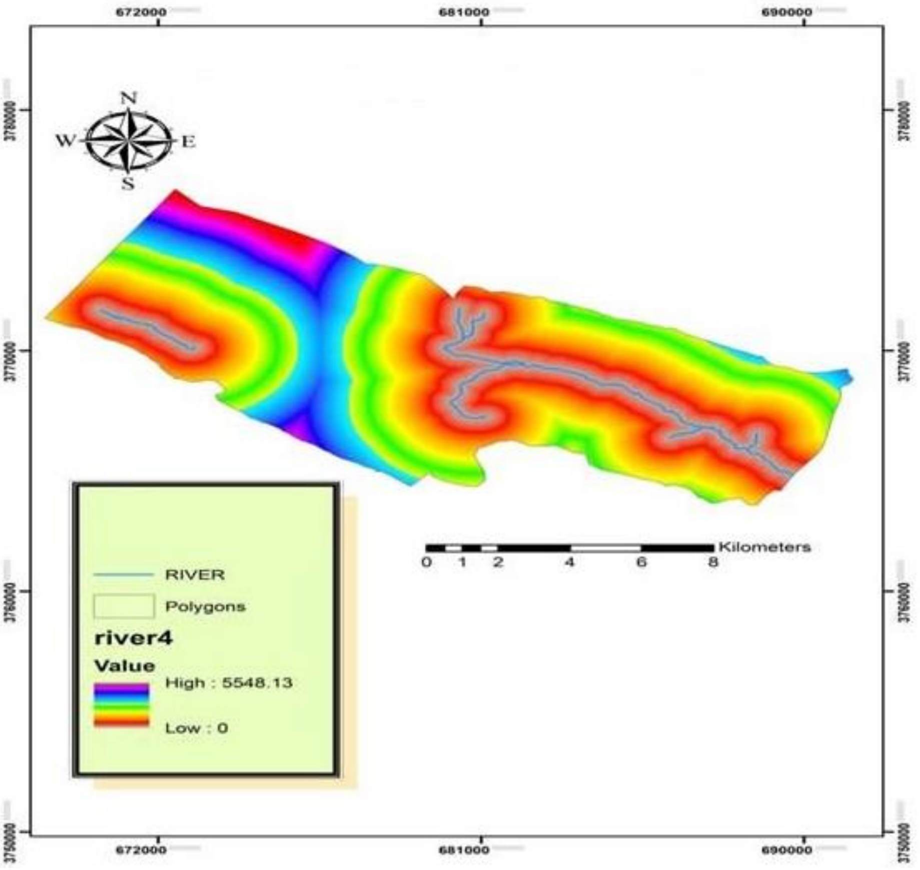

Figure 6. Euclidean distance from the waterway

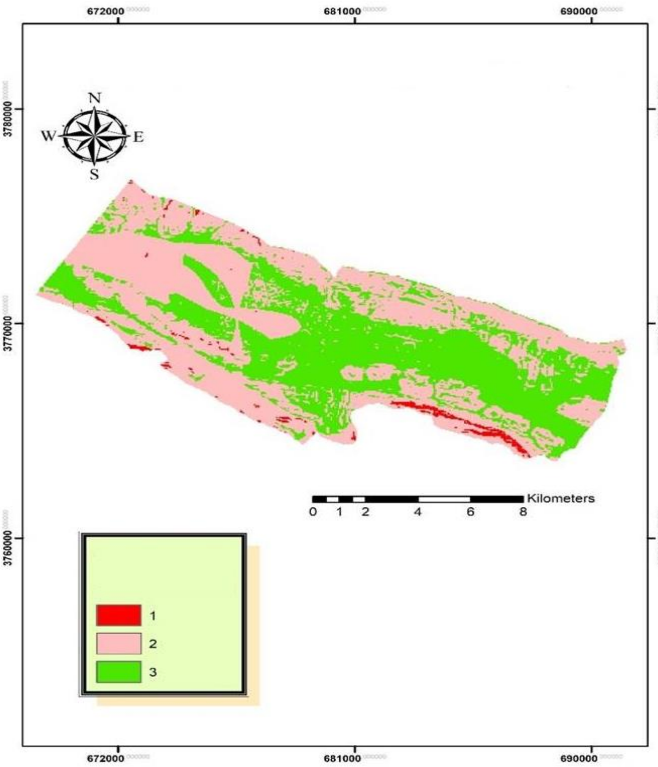

Figure 7. Final zoning of areas prone to storage of ecological compaction streams in rainfed agriculture

3.9. Final zoning of rainwater storage

After using GIS to prepare and classify the layers, the final map of rainwater harvesting potential was prepared (Figure 7). Finally, using the Raster calculator, each of the layers was multiplied by the weight obtained from AHP, and three basins, unsuitable, medium, and suitable for water storage, were determined. All the green spots that are prone to water storage are among the agricultural lands of the region. These lands have the potential to infiltrate and store rainwater, provided that farmers use soil management methods (such as vertical plowing, conservation tillage, conservation of residues, crop rotation, and use of organic fertilizers to increase soil organic matter therefore increasing soil water storage). The water stored with these methods is easily available to the plants. In addition, it costs less than other water storage methods and reduces soil erosion.

3.10. Possibilities of development and improvement and conclusions

Talandasht region has special conditions and great potential in terms of climate, topography, and soil. Especially with regard to the altitude above 1600 meters, which seems to be the best area for implementing watershed and aquifer projects above 1000 meters, and priority is given to areas above 1500 meters (due to low evaporation and the possibility of storing water in pools, canals and basins). Therefore, it seems that if rainwater is stored, the development of rain-fed gardening and supplementary irrigation of the region will be possible. Considering that Talandasht is an isolated area with a length of 30 km and a width of 2 km, the height of the plain is 1600 meters above sea level. Therefore, if a 40 km long canal (ditch) is created on two sides using level lines. At an altitude of 1650 to 1700 meters, an amount of 34300000 cubic meters of water can be collected annually and managed for supplementary irrigation and garden development.

4. Conclusion

It can be concluded that rainwater harvesting methods provide the ability to manage upstream water resources effectively. Stored water can be used as a source for supplementary irrigation in critical periods of water shortage and prevents damage to crop yield. The amount of rainwater harvesting is insignificant compared to building a dam or digging a well. However, these types of projects have more implementation potential in all parts of the country, are more compatible with the environment and attract more people's participation.

Conservative agriculture has good potential in smallholder farms in dry areas, as it is used in different regions of Asia and South America (Jat et al., 2012). In Talandasht, there is potential for conservative agriculture, and it is an opportunity to preserve and store water. Reducing the performance gap in rain-fed agriculture and dry areas to respond to the growing demand for human food, population increase, and climate change is one of the goals of water resources management. In addition, the need to increase food quality and performance stability also shows the need to pay attention to this matter. Also, in dry areas, ecological compression reduces soil degradation, carbon storage, water accumulation, and soil nitrogen binding and availability. Conservation agriculture and livestock-agriculture integration are an opportunity to obtain different agroecosystem services in arid climates.

References

Adham, A., Wesseling, J. G., Riksen, M., Ouessar, M., & Ritsema, C. J. (2016). A water harvesting model for optimising rainwater harvesting in the wadi Oum Zessar watershed, Tunisia. *Agricultural Water Management*, *176*, 191-202. **doi:10.1016/j.agwat.2016.06.003**

Al-Adamat, R. (2008). GIS as a decision support system for siting water harvesting ponds in the basalt aquifer/NE Jordan. *Journal of Environmental Assessment Policy and Management*, *10*(2), 189–206. **doi:10.1142/s1464333208003020**

Al-Adamat, R., Alayyash, S., Amoush, H., Meshan, O., Rawajfih, Z., Shdeifat, A., Harahsheh, A., & Farajat, M. (2012). The combination of indigenous knowledge and geo-informatics for water harvesting siting in the Jordanian Badia. *Journal of Geographic Information System*, *4*, 366-376. **doi:10.1166/jcp.2010.1003**

Ameri Ekhtearabadi, A., Nikpour, M., & Shojaa Talatpa, F. (2011). Determination of proper places for the basin using analytical hierarchy process. Case study: Hamedan province. In *Proceedings of the First International Conference and 3rd National Conference on Dam and Hydroelectric Power Plants*, pp. 1-10. Tehran, Iran.

Ammar, A., Riksen, M., Ouessar, M., & Ritsema, C. (2016). Identification of suitable sites for rainwater harvesting structures in arid and semi-arid regions: A review. *International Soil and Water Conservation Research*, *4*(2), 108-120. **doi:10.1007/978-3-642-15479-9-5**

Bamne, Y., Patil, A., & Vikhe, D. (2014). Selection of appropriate sites for structures of water harvesting in a watershed using remote sensing and geographical information system. *International Journal of Emerging Technology and Advanced Engineering*, *4*(11), 270-275.

Bulcock, L. M., & Jewitt, G. P. W. (2013). Key physical characteristics used to assess water harvesting suitability. *Physics and Chemistry of the Earth*, *66*, 89–100. **doi:10.1016/j.pce.2013.09.005**

Di Paola, A., Rulli, M. C., & Santini, M. (2017). Human food vs. animal feed debate. A thorough analysis of environmental footprints. *Land Use Policy*, *67*, 652-659. **doi:10.1016/j.landusepol.2017.06.017**

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K., West, P. C., & Balzer, C. (2011). Solutions for a cultivated planet. *Nature*, *478*, 337–342. **doi:10.1038/nature10452**

García-Palaciosa, P., Alarcónb, M. R., Tenorioc, J. L., & Morenoc, S. S. (2019). Ecological intensification of agriculture in drylands. *Journal of Arid Environments*, *167*, 101-105. **doi:10.1016/j.jaridenv.2019.04.014**

Hesari, B. (2013). Investigation of upstream and downstream hydrological effects of supplementary irrigation development in rainfed areas in Karkheh basin. Doctoral dissertation, Ahvaz University. [In Persian]

Hobbs, P. R., Sayre, K., & Gupta, R. (2008). The role of conservation agriculture in sustainable agriculture. Philosophical Transactions of the Royal Society B: *Biological Sciences*, *363*(1491), 543-555. **doi:10.1098/rstb.2007.2169**

Jalili, J., Hesadi, H., & Hadidi, M. (2014). Artificial recharge of groundwater aquifers by surface drainage canals using AHP method. *Iranian Journal of Watershed Management Science and Engineering*, *8*(24), 29-36. [In Persian]

Jalili, K. H., Sadeghi, S. H. R., & Nikkami, D. (2007). Land use optimization of watershed for soil erosion minimization using linear programming (a case study of Brimvand watershed, Kermanshah province). *Journal of Water and Soil Science*, *10*(4), 15-27. [In Persian]

Jat, R. A., Craufurd, P., Sahrawat, K. L., & Wani, S. P. (2012). Climate change and resilient dryland systems: experiences of ICRISAT in Asia and Africa. *Current Science*, *102*(12), 1650-1659.

Kadam, A. K., Kale, S. S., Pande, N. J., Sankhua, R. N., & Pawar, N. J. (2012). Identifying potential rainwater harvesting sites of a semi-arid, basaltic region of western India, using SCS-CN method. *Water Resources Management*, *26*(9), 2537–2554. **doi:10.1007/s11269-012-0031-3**

Kahinda, J. M., Lillie, E., Taigbenu, A., Taute, M., & Boroto, R. (2008). Developing suitability maps for rainwater harvesting in South Africa. *Physics and Chemistry of the Earth*, *33*, 788–799. **doi:10.1016/j.pce.2008.06.047**

Kassam, A., Friedrich, T., Derpsch, R., Lahmar, R., Mrabet, R., Basch, G., González-Sánchez, E. J., & Serraj, R. (2012). Conservation agriculture in the dry Mediterranean climate. *Field Crops Research*, *132*, 7-17. **doi:10.1016/j.fcr.2012.02.023**

Keshavarz, A. (2012). Appropriate location of drinking water harvesting using fuzzy hierarchical analysis (FAHP) Case study: Birjand plain, Master's thesis, Birjand University. [In Persian]

Khairkhah Zarkesh, A., Mohammadi, F., & Meamarian, E. (2015). Determine areas prone to harvesting and storing rainwater using hierarchical analysis in the GIS environment. *Journal of Rainwater Basin Systems*, *14*(21), 3480.

Khan, M. D., & Khattak, M. (2012). Siting of rainwater harvesting locations in district Haripur using geographic information techniques. *Journal of Himalayan Earth Sciences*, *45*(2), 81-81.

Krois, J., & Schulte, A. (2014). GIS-based multi-criteria evaluation to identify potential sites for soil and water conservation techniques in the Ronquillo watershed, northern Peru. *Applied Geography*, *51*, 131–142. **doi:10.1016/j.apgeog.2014.04.006**

Kumar, M. G., Agarwal, A. K., & Bali, R. (2008). Delineation of potential sites for water harvesting structures using remote sensing and GIS. *Journal of the*

Indian Society of Remote Sensing, *36*(4), 323–334. **doi:10.1007/s12524-008-0033-z**

Lopez, J. H., & Zinck, J. A. (1991). GIS-assisted modelling of soil-induced mass movement hazards: A case study of the upper Coellop river basin, Tolima, Colombia. *ITC Journal*, *4*, 202-220.

Maestre, F. T., Eldridge, D. J., Soliveres, S., Kéfi, S., Delgado-Baquerizo, M., Bowker, M. A., García-Palacios, P., Gaitán, J., Gallardo, A., Lázaro, R., & Berdugo, M. (2016). Structure and functioning of dryland ecosystems in a changing world. *Annual Review of Ecology, Evolution, and Systematics*, *47*, 215–237. **doi:10.1146/annurev-ecolsys-121415-032311**

Mahmoud, S. H., & Alazba, A. A. (2014). The potential of in situ rainwater harvesting in arid regions: developing a methodology to identify suitable areas using GIS-based decision support system. *Arabian Journal of Geosciences*, *8*, 5167-5179. **doi:10.1007/s12665-014-3249-y**

Mekdaschi, R., & Liniger, H. (2013). *Water Harvesting: Guidelines to Good Practice*. Centre for Development and Environment.

Prăvălie, R. (2016). Drylands extent and environmental issues. A global approach. *Earth Science Reviews*, *161*, 259-278. **doi:10.1016/j.earscirev.2016.08.003**

Ray-Shyan, Wu, Molina, G. L. L., & Hussain, F. (2018). Optimal sites identification for rainwater harvesting in northeastern Guatemala by analytical hierarchy process. *Water Resources Management*, *32*(12), 4139-4153. **doi:10.1007/s11269-018-2050-1**

Sadeghi, S. H. (2011). Determining places prone to rainwater collection using DIS-based GIS support system Master's thesis, Birjand University. [In Persian]

Salavati, P., Fakheri fard, A., Asadi, A., & Asadi, S. (2017). Rain-runoff frequency analysis for designing reservoirs in order to collect surface water for the development of urban green space (case study: city of Tabriz). *Irrigation Sciences and Engineering*, *4*(2), 113-117. [In Persian]

Shamiri, A., & Ziadat, F. M. (2012). Soil landscape modeling and land suitability evaluation. The case of rainwater harvesting in a dry rangeland environment. *International Journal of Applied Earth Observation and Geo information*, *18*, 157-164. **doi:10.1166/jcp.2010.1003**

Soltani, A. (2017). Feasibility of susceptible areas for rainwater harvesting, based on AHP in GIS environment (a case Study: Khosroabad watershed, Iran). *Journal of Rainwater Catchment Systems*, *5*(2), 65-76. **doi:10.1007/978-3-642-15479-9-5**

Winnaar, G., Jewitt, G. P. W., & Horan, M. (2007). A GIS-based approach for identifying potential runoff harvesting sites in the Thukela River basin, South Africa. *Physics and Chemistry of the Earth*, *32*(15), 1058-1067. **doi:10.1016/j.pce.2007.07.009**

Ziadat, F., Bruggeman, A., Oweis, T., Haddad, N., Mazahreh, S., Sartawi, W., & Syuof, M. (2012). A participatory GIS approach for assessing land suitability for rainwater harvesting in an arid rangeland environment. *Arid Land Research and Management*, *26*(4), 297–311. **doi:10.1080/15324982.2012.709214**