Selection of water harvesting sites in Horan valley

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Abstract: Geographic techniques were used to select the sites of water harvesting systems within the Horan basin. Analytical Hierarchy Process (AHP) and pairwise comparison were used to determine the importance of selected traits for water harvesting (soil texture area, runoff, Land cover,). A total of 96 water harvesting sites were identified, of which 11 were found to be the most important. The results showed that the use of AHP to compare the pairs of traits affecting water harvesting. There are several promising areas for harvesting, totaling 96 sites, distributed between sandy and loamy sand and sandy clay loam. With 11 sites characterized by sandy clay soil and high surface runoff. The site 41 has the highest weight in the selected traits 0.557, while the site 84 was the lowest weight and reached 0.339 in terms of importance. The total area of the 96 study sites reached 35402.48 ha, which constitutes 19.7% of the area of the valley, while the area of the most important sites for harvesting, which amounted to 11 sites (633.49) ha, which constitutes (0.35%) of Total area of the valley and 1.7% of the total area of the water harvesting sites. The volume of water collected at all harvest sites (96 sites) was 20288131.92 m³, 567159.58 m³. The correlation between the different characteristics, the derivation of a mathematical equation that reflects the values of the best sites using a program, and then a map of calculated values, is calculated to determine their suitability in the application.

1. Introduction

Due to climate changes in the planet Earth and the drought in the region in addition to the lack of water incomes in the Tigris and Euphrates rivers in last years, and also due to the aridity and dams established by Syria and Turkey on the streams of these rivers, It is important to find alternative water resources.

Water resources is one of the most important criteria for societies building and their development. Evaluation, planning, and management of water resources are raised to be one of important subjects in the humans’ life, particularly in arid and semi-arid regions like Iraqi western desert, since precipitation is extremely limited, with poorly available ground water supply.

The problem of water shortage in arid and semi-arid regions is one of low rainfall and uneven distribution throughout the season, the average annual rainfall in "Iraqi western desert" area is about 115 mm, such a matter makes rain-fed agriculture is a risky enterprise. Therefore new interest came up in recent decades to evaluate traditional rainwater management techniques most of them being simple, sure to implement and of low capital investment.

The classical sources of irrigation water are often at the break of overuse and therefore untapped sources of (irrigation) water have to be sought for increasing agricultural productivity and providing sustained economic base. Rainwater harvesting is an effective means of water conservation. It also helps to reduce the excessive use of water in the irrigation of land, especially when it is associated with the cultivation of local plants with little water consumption and adapted to the desert conditions. Rain
water is available naturally and there are no additional taxes for Private wells or processing by the municipality [1]. Water harvesting for dry-land agriculture is a traditional rainwater management technology to ease future water scarcity in many arid and semi-arid regions of world [2].

This technology is gaining new popularity nowadays. As an appropriate technique depends on the amount of rainfall and its distribution, land topography, soil type and soil depth and local socio-economic factors, these systems tend to be very site specific. The water harvesting methods applied strongly depend on local conditions and include such widely differing practices as bounding, pitting, micro catchments water harvesting, flood water and groundwater harvesting [3] and [4].

Until the last few years, GIS applications to hydrology, flood routing and water harvesting modeling have been relatively limited. With the rapid advances in GIS in the 1980s, this technology began to be used to simulate the flow of water on the land surface [5],[6] and [7].

Incorporating remote sensing results into a GIS environment has improved harvested water analysis in recent years.

This study aims to Identification of promising regions in Horan valley in western desert of Iraq for water harvesting installations.

2. Location of the study area
Horan Valley is the largest valley in Iraq. It is located in Anbar province, west of Iraq, extending 485 km from the Iraqi-Saudi border to the Euphrates River near Haditha Between latitudes (39° 00'00'') and (42° 30' 00'') and (42° 00'00'') and (34° 00' 00''). The catchment area of the basib is (20000 km²), (Figure 1).

3. Materials and methods

Images and Reports:
- Digital Elevation Model (DEM), 30*30 m resolution of the Shuttle Radar for Topographic Missions (SRTM) for the year 2010.
- Climatic data for the years 1981-2017 from Iraqi Directorate of Meteorological and Seismic Monitoring.
- Soil survey report from National Center for Water Resources Management.

Geographic Information System Programs:
- ArcGIS V.10.2
- ERDAS V.2014

4. Work procedure

The method of hierarchical analysis of the factors influencing water harvesting has been used, and this method involves weighing each factor influencing the water harvesting by importance, and then calculating the accumulated weights for each site.

This method was also applied at the levels of each factor depending on the importance of the level, and multiplied the level value by the weight of the factor to produce a value reflecting the actual weight of the factor influencing the water harvesting. The factors are: soil type, catchment area, Runoff depth, slope and land use, as shown in table 1.

The slope map, the hydrological grid and the catchment area were also derived using the digital elevation model. (Figure 2).

Table 1. Pairwise Comparison Matrix

|          | Soil texture | Aerea | Runoff depth | Slope | Land cover | Weight |
|----------|--------------|-------|--------------|-------|------------|--------|
| Soil texture | 0.438        | 0.49  | 0.439        | 0.38  | 0.333      | 0.42   |
| Area      | 0.219        | 0.245 | 0.292        | 0.285 | 0.266      | 0.26   |
| Runoff depth | 0.145        | 0.122 | 0.146        | 0.19  | 0.2        | 0.16   |
| Slope     | 0.109        | 0.081 | 0.073        | 0.095 | 0.133      | 0.1    |
| Land cover | 0.087        | 0.061 | 0.048        | 0.047 | 0.066      | 0.06   |
Figure 1. study area (Horan Valley)
The calculation of the flux depth was based on climatic data, soil characteristics and land cover. A total of 96 sites were identified, distributed across the study area, as shown in Figures 3, 4 and 5 and the weights for each site were calculated and a map of those weights was derived showing their spatial distribution pattern to determine the best locations for the construction of water harvesting projects.
The correlation values between the different factors, the general weight of the site and the operation of a mathematical equation using the program (SPSS v. 23) are calculated to calculate the importance of the site directly. To make sure the equation is correct, a map is derived based on the calculated values for each site and compared to the predefined map.

5. Results and Discussion

5.1 Water harvesting

5.1.1 Slope

After using the digital elevation model to determine the total slope of the basin, the gradients were grouped into five categories covering the total area of the basin [8]. The map shows 5 categories of pelvic slope and it is clear from the map that most areas of the basin fall into the category (0-2%), which are the best in water harvesting processes, as shown in Figure 6, while the other categories, which are (8-45%) Confined to areas located within the slopes and the valley.

5.1.2 Soil texture

The main soils were determined in Horan valley based on previous survey reports as shown in Fig. 7. The soil was then classified into four groups according to the USDA-SCS-CN Soil Hydrological Group method described by [5] and [6]. It is noted that most of the soil cultivars in Horan valley were in A (sandy loam, loamy sand) and C (sandy clay loam) groups.
5.1.3. Catchment Area
Using the digital elevation model, the land area that feeds each of the proposed water harvesting sites is calculated, as shown in Figure 8, the largest area is (43, 44, 45) with a feeding area estimated at about 4356.29 hectares, the lowest feeding area at the site (82), estimated at 1 ha.

5.1.4. Surface runoff
The runoff rate for each site is calculated by calculating the average rainfall value and using SCS-CN to see the depth of runoff, as shown in Fig. 9, and notes that flux depth values were limited between 56.72 - 89.53 mm.
5.1.5. Land Use
The Horan Valley is located in the dry areas that are free of stream, and the annual rainfall is less than 150 mm, which is reflected in the nature of the land cover. It is noted that all areas of the valley are arid desert lands, with the exception of the area of the Rutba city, which is packed with urban land, as illustrated in Figure 10.

5.1.6. Detection of Water Harvesting Sites in Horan Valley
According to the traits and factors mentioned above, it was used the general weight of magnitude for each factor to calculate the total weight of all factors in all areas to detect the suitability of each site as a water catchment using the equation (1).

\[ S = \sum W_i \cdot X_i \]  

(1)
Where: S is suitability, $W_i$ is the general weight of trait, $X_i$ is the specific weight. For example, the application of this equation on the catchment 15 is like the following:

$$w_{15} = (Sw_1 x Sx_1) + (Aw_2 x Ax_2) + (Rw_3 x Rx_3) + (SLw_4 x SLx_4) + (Cw_5 x Cx_5)$$

$$w_{15} = (0.42 x 0.33) + (0.26 x 0.286) + (0.16 x 0.098) + (0.1 x 1) + (0.06 x 1) = 0.388$$

Where; S is the soil, A is the area of catchment, R is the runoff, SL is Slope, C is the land Use.

The general weight of each site was calculated from 96 locations and the weights were divided into three categories according to the calculated values, as shown in Figure 11, and the 0.33-0.39 was the least suitable for water harvesting, followed by the 0.39-0.45, which is of a medium shelf life, while the latter category is 0.45-0.55, the most appropriate for the harvest. E, fell into the last category 11 locations and as shown in figures 12, 13, and 14. that the site (41) was higher weight than the rest of the sites (0.55), while the lowest site was the site (84) (0.33) In terms of importance, the difference between sites with the maximum weight and minimum weight (0.55 - 0.33 = 0.22). The devision of the difference on the minimum weight of the sites (0.22 / 0.33) indicates that there is an important value (67%) among the water harvesting sites in terms of importance weight of traits.

![Figure 11. Categories of water harvesting Areas in Horan Valley](image1)

![Figure 12. Area Occupied by the site 77.](image2)
5.2. Statistical data processing

The general weight value of the site is calculated using the SPSS program in a forward way to exclude items that have limited their effect on the weight value. The derivation of the multilinear deflection equation, and the results, showed that the overall weight of the site was associated with both the soil type factor and the catchment area, excluding the remaining factors. The value of $R^2$ was 0.92, and the following equation (2):

$$Sw = 0.226 + 0.897S + 0.26A$$  

(2)

It is noted from the figure 15, that the nature of the weight distribution calculated by the equation above is that there is a slight variation in the lower and upper limits of the weights, as for the pattern of spatial distribution of those weightings that the average type suitable for water harvesting operations differed in terms of spatial distribution pattern and area. It is also noted from the figure 15, that 11 sites that have been designated as the most suitable for water harvesting operations are the same in Figure 11.
5.3. Harvested water volume in selected locations:

The amount of water that can be harvested in 11 selected locations is calculated through the following equation (3):

\[ \text{Volume} = \text{Area} \times Q \]  

(3)

Note from the table 2. that the area of those sites 633.49 hectare, about the amount of total water was 567159.58 m$^3$, as for the sites it was the biggest area is the site 41 and an area estimated 297.90 h. Thus it is best in terms of the amount of accumulated water estimated at 266707.70 m$^3$. The lowest of these sites is the site of 89, with an estimated volume of 3271.34 m$^3$.

This large variation in the catchment area of the sites compels us to prioritize the establishment and design of water harvesting systems for large-scale sites to increase the chance of obtaining more water and thereby increase the efficiency of those projects.

Table 2. Quantity of harvested water in selected locations

| No. Site | Area hectares | Q mm  | Volume m$^3$ |
|----------|---------------|-------|--------------|
| 41       | 297.90        | 89.53 | 266707.70    |
| 77       | 110.92        | 89.53 | 99308.73     |
| 88       | 13.95         | 89.53 | 12485.42     |
| 89       | 3.65          | 89.53 | 3271.34      |
| 90       | 16.77         | 89.53 | 15017.15     |
| 91       | 33.50         | 89.53 | 29988.73     |
| 92       | 23.80         | 89.53 | 21309.06     |
| 93       | 12.01         | 89.53 | 10748.80     |
| 94       | 86.47         | 89.53 | 77420.46     |
| 95       | 17.27         | 89.53 | 15459.69     |
| 96       | 17.25         | 89.53 | 15442.51     |
| Total    | 633.49        |       | 567159.58    |

6. Conclusions

- There are sites suitable for water harvesting operations with an area of 633.49 hectares. is considered a development factor for the region it properly invested
• Calculating the weight of the sites using the mathematical equation reducing the factors that can be included in the study to only two factors depending on the nature and strength of the correlation
• The use of geographic information systems (GIS) programs associated with satellite images is of great benefit in the vast areas that are difficult to access and provides a great deal of effort, cost and time to reach the desired objectives of any study, especially studies related to water harvesting or environmental degradation.
• The process of AHP has a clear effect in the Horan valley. The decision maker can take many useful measures to harvest the rainwater within the vast untapped area of the valley

7. Recommendations
• Establishment of new gauge stations network within the valley or the western region of the country in order to calculate the depth of rain water that covers the valley more accurately when conducting future research.
• Expanding the research on the possibility of using the soil of Horan valley and its use in agriculture.
• Expanding the use of remote sensing and GIS in studies of water harvesting in the desert of Iraq, especially in light of extreme climatic changes, the expansion of deserts and the expansion of agricultural research and green belts, which reduce soil degradation to a large extent and in actual application.
• Expanding research on trying to find future prospects for exploiting the many underground aquifers in the desert of Iraq for agriculture, drinking, settlement and other purposes.
• We recommend the construction of concrete floor tanks that save water for use in the summer season.

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