



Sustainable Development of Wadi Houran- Western Iraqi Desert

Isam M. Abdulhameed^a, Ahmed S. Mohammed^a, Ammar Hatem Kamel^a, Kamal Y. ALmafrchi^b, Isam Kh. Alhadeethi^a, Abed S. Fayyadh^a, Muthanna K. Ibrahim^a, Hasan A. Mutar^a, Rasmi. M. Hamad^a, Rasha I. Naif^c, Emad T. Abdel Ghani^a, Waleed H. Hamed^a, Muneer N. Ahmed^a, Jabbar Sh.E. Al-Esawi^a

^aTeaching Staff, University of Anbar. ^bGIS & BIM Administrator, URN Inc, Toronto, Canada. ^cMSc. Student, Water Resources Engineering, University of Anbar.

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ABSTRACT

Wadi Houran is one of the largest valleys in Iraq. Although it is discharging billions of rainfall water over/during many years to Euphrates river, it's almost devoid of agricultural investment. The current study aims to focus on this important valley water resource and study the possibility of constructing a series of small dams to store rainfall water and planting forestry and establishing a natural reserve that is able to sustain and improve ecology system.

Target area of 4000 km² is selected in the midstream of the valley. In general, it is about one billion m³ of rainwater flowing to Euphrates River during some years with yearly average values about 400 Mm³. Four dams were constructed to store about 46 Mm³ of rainwater. It is possible to construct small-dam-series of optimal height and location to expand the rainwater harvesting and groundwater recharging. A Current study was done and aimed to establish of oases and natural reserves in order to improve climate conditions, minimize the dust and CO₂, mitigation of summer high temperature and decrease the soil erosion due to torrents. This study recommended constructing 13 optimal height dams that store about 303 Mm³ of water, and increase the water surface area of reservoirs in this valley from 15 to 90 km² which leads increase the water volume that is recharging ground water from 4.7 Mm³ to 28 Mm³ per year.

1. Introduction

Water scarcity is a global problem caused by the climatic change, the policy neighboring countries and the policy and plans of the country with/of managing water resources. Iraq is one of the Middle East countries that is experiencing water crisis due to the expansion in water project implementations in Turkey and Syria especially with the absence of a bilateral agreement upon water shares distribution of international rivers[1].

Effective planning and management of water resources is necessary to provide fresh water and improve the quality of life especially in arid and semi-arid areas such as Iraqi Western Desert since rainfall is extremely

limited and spatially distributed with poorly available groundwater supply [2]. The western desert contains valleys that receive large quantities of torrents water such as Houran, Al-Ghadaf, Tabletc. [3]. Also, they contain several small dams constructed during the 1970s and 1980s with different heights and storage capacities [4]. There are twelve small dams constructed in western desert [5].

Wadi Houran is discharging huge water quantities as surface runoff during rainy seasons and it has only four small dams as shown in Table (1) and Figure (1). Therefore , many studies were published to cover this important natural phenomena aiming to save as much rainwater as possible.

[6] suggested appropriate sites for water harvesting in Wadi Houran by using (GIS) and Multi Criteria Evaluation (MCE) as a tool for decision support. The results served to organize the subsequent field surveys thus

* Corresponding author. Rasha I. Naif.

E-mail address: rasha_ded@uoanbar.edu.i

considerably reduce the time and cost of the survey.

[7] studied the rainwater harvesting of Houran valley by using remote sensing techniques. Digital Elevation Model (DEM) was applied to determine the suitable sites of small dams, where small lakes along Wadi Houran will lead to increase the agriculture and develop artificial forests to decrease the desertification phenomenon.

[8] studied the ability to predict the best water harvesting sites in Houran valley using Model Builder in Arc GIS10.2, which combines various biophysical factors are the slope, runoff depth, land use, soil texture, and stream order. While [9] used Analytical Hierarchy Process (AHP) and pairwise comparison method to predict the best harvesting locations.

[10] developed the (Optimal Height And Location Model (OHALM)) and combining it with DEM to design small dam series with optimal heights and locations in this valley.

Table 1 – Small dams in Houran valley [5]

No.	Name	Completion date	Height of dam m	Storage capacity Mm ³
1	Rutba Dam	1981	19	32
2	Al-Ubailah Dam	1973	11.5	4
3	Horan 2 Dam	2007	15	5
4	Horan 3 Dam	2003	15	5.3

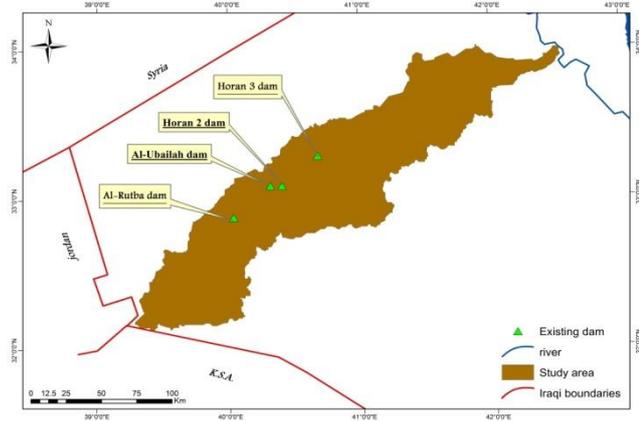


Fig. 1 Existing small dams in the study area

2. Description of the study area

2.1. General Description

Wadi Houran is extending for 458 km from the Iraqi-Saudi borders to Euphrates river south of Haditha city as shown in Figure (2). The geographical location of the valley is between the longitude 39°00' 00" to 43°00'00" East and the latitude 32°00'00" to 43°30'00" North [11]. The valley catchment area is around 13,370 km² and the difference in elevation from the beginning to the end is around 600 m. Wadi Houran region is classified as an arid region characterized with hot summer and cold winter [8]. The average annual rainfall is 115 mm. The annual average of relative humidity ranges between (19%-82%) which varies largely from month to another during the year. Wadi Houran is characterized by considerable temperature ranges between (0-48) ° C [6]. The annual evaporation value for the study area ranges between (1600-1900) mm as shown in Figure (3). The highest evaporation value occurs in July and August [12].

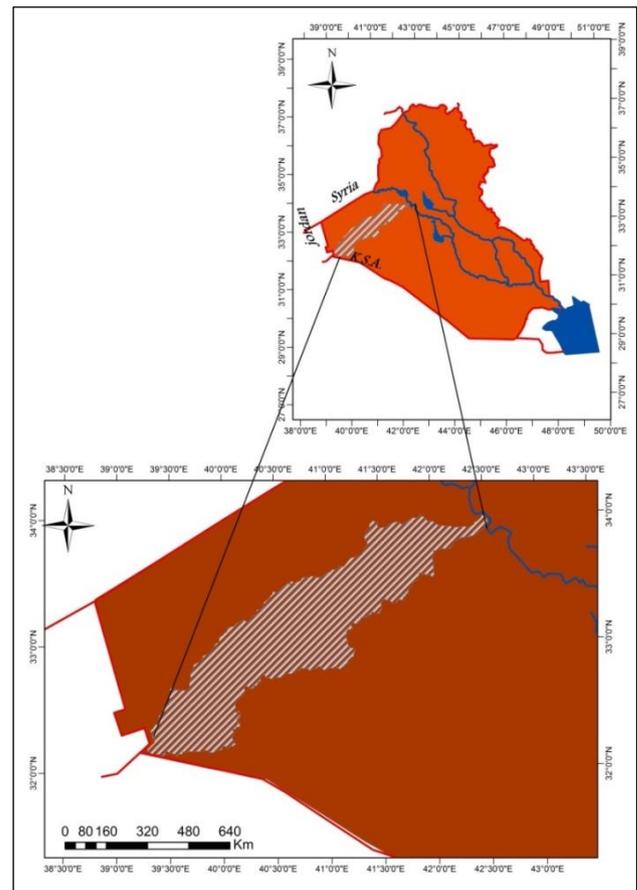


Fig. 2 The study area

Table 2 – Average climatic factors from Rutbah Station, period (1971 2010)[7]

Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rainfall (mm)	22.7	21.2	24.6	23.9	7.2	0.01	0.0	0.0	0.01	6.7	13.0	24.0
Evaporation (mm)	55.6	81.6	121.6	202.1	295.5	377.5	420.7	402.0	353.5	233.5	115.9	61.3
T(C°)Max	13.2	15.3	19.4	25.9	31.6	35.7	38.3	38.1	35.8	29.4	20.7	14.6
T(C°)Min.	1.9	3.1	6.5	11.8	16.6	20.2	22.8	22.4	19.2	14.1	7.6	3.6
Wind speed (m/s)	3.0	3.7	4.0	3.9	3.6	3.9	4.1	3.5	2.7	2.6	2.5	a.

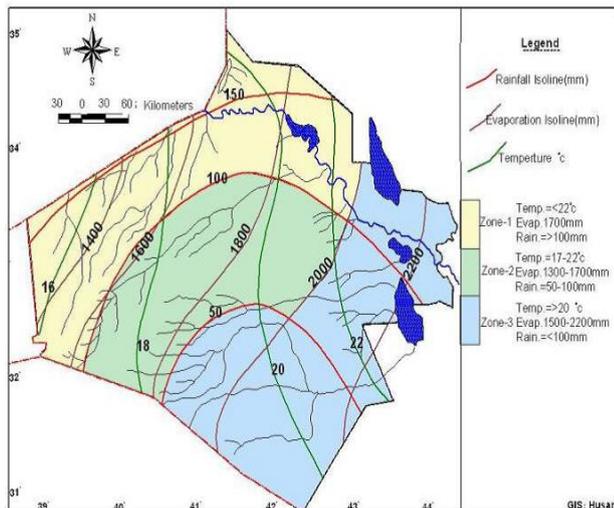


Fig. 3 Distribution of Rainfall, Evaporation & Temperature [12]

2.2. Geological Description

The whole course of Wadi Houran is located in the Western Desert Subzone within the Inner Platform of the Arabian Plate. The subzone is generally characterized by simple tectonic scheme and almost no structural geological features apart from faults of different types. Some of those faults reached the course of the valley and had caused displacements of some geological formations. The displacement ranges within magnitude of few tens of meters; majority of them are strike slip faults. Few of the existed faults shifted the course of the valley. From reviewing the geological maps and the existing faults, it is clear that the majority of the large and acute meanders of wadi Houran are not related to tectonic activities. The exposed rocks along the course of wadi Houran range in age from Upper Triassic to Middle Miocene with many large unconformities.

This valley’s range of age includes 20 geological formations with wide variety of rocks within the formations and locally within the same formation. The course of wadi Horan is tectonically controlled, in its uppermost reach its trend is almost S – N; following Nabtah Fault system. Farther on, it changes its trend towards the northeast following the main transversal fault and lineament system. Along its course, tens of

normal and abnormal large meanderings occur. Those which are abnormal are controlled tectonically as revealed from the existing lineaments of NW – SE trend. Figure (4).

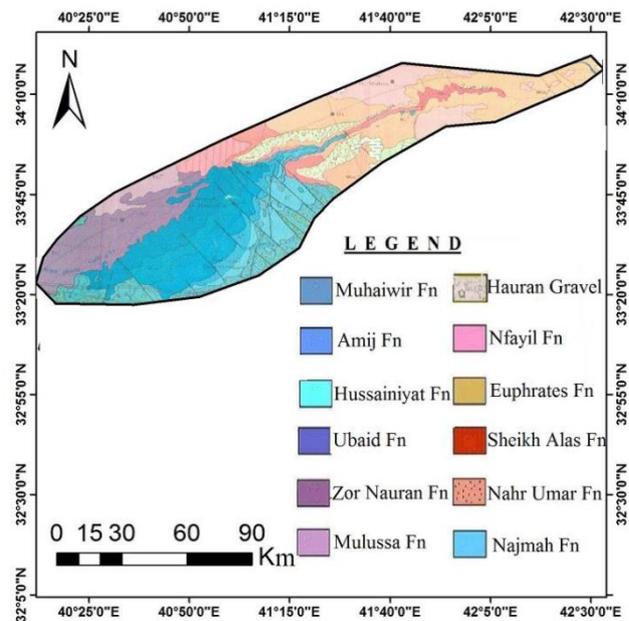


Fig. 4 Geological map of the study area [7]

2.3. Hydrological Description

Groundwater plays a major role in human’s life and land development in desert regions especially in areas that are remote from freshwater sources. The direction of groundwater discharge in the Western Desert is mostly to the east and northeast to the drainage area represented on the western (right) bank of the Euphrates River, but there are different local directions for flowing through the region depending on the geological setting of the region and their topographical and structural characteristics [13]. Several depressions exist in the western Iraqi desert which receives water from large valleys. The Ga’ara aquifer is one of the main aquifers in the region due to its width and deep water content. Most of the aquifers are recharged from rainfall and runoff of the intermittent valleys [14]. The groundwater level varies according to the geological formation of the area, whereas it is extracted by well drilling and this is the most widespread in Al-Anbar province. These wells located at depths ranging

between 10m to 700 m. The wells located in high areas source their water through the marine sediment or the remaining of ancient saline ponds. The figures (5, 6) describe the geographical distribution of the depth of the wells and the groundwater flow directions.

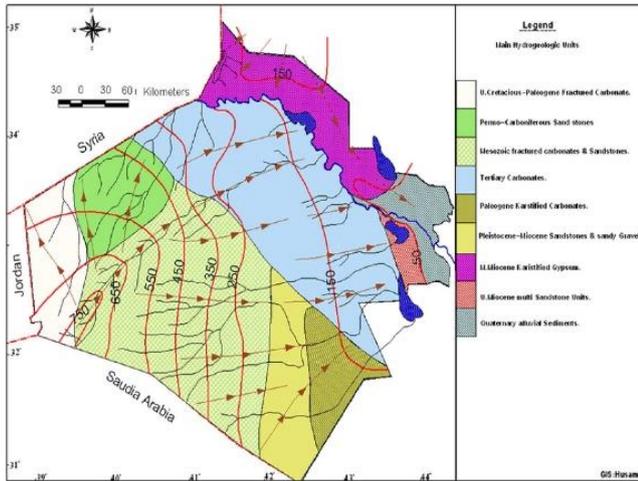


Fig. 5 The hydrological system distribution over Anbar province [12]

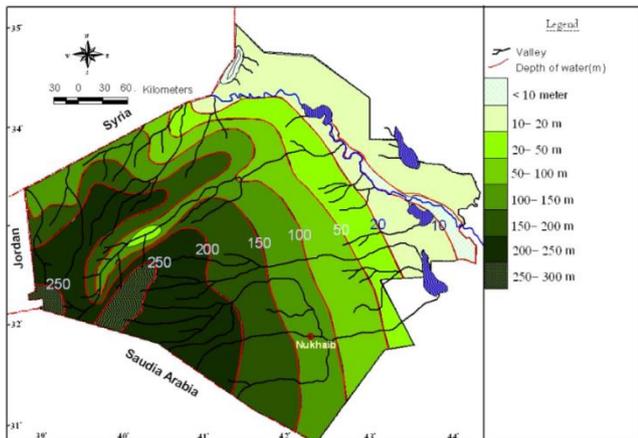


Fig. 6 Groundwater depths [12]

About billion m³ of rainwater may be discharged in rainy seasons to Euphrates river in some years with average yearly value of 400 million m³ [15], [16]. The catchment area of Wadi Houran with its large tributaries like Hussainiyat, Mihzam, Saqqar, Amij is about 16550 Km². Infiltrating of one mm of rainwater means feeding aquifers by 16.55 million m³. The best locations of rainwater harvesting are shown in Figure (7), while the best locations of small dams are shown in Figure (8).

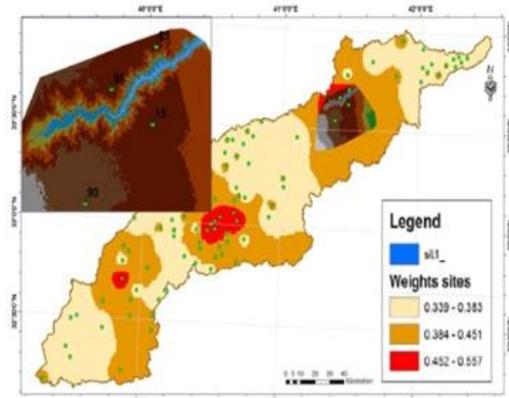


Fig. 7 Best rainwater harvesting locations [9]

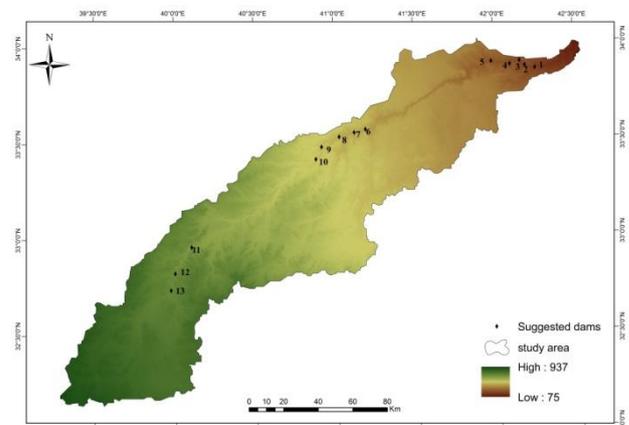


Fig. 8 proposed small dams series (13 dams) [10]

2.4. Biological Description

There are many oases in Wadi Houran. [17] studied the vegetation species in this valley and compared it with those indicated by Guest (1966). They found disappearance of some species due to variations in the physical environment within these oases, therefore; it is very important to construct natural reverse to protect the valley's environment. Most plants in this valley are Haloxylon salicornicum, Helianthemum aegypticum, Artemisia scoparia, Centaurea sinaica, Salsola barysoma, Ducrosia anethifolia, Gundelia tourneforti, Avena barbata, Hordium spontanium, Avena wiestii and Iagonychium farctum. Trees like Date palms, Olive, Opuntia spp, and Eucalyptus spp.

In 1970, a deer sanctuary was established in Wadi Houran. The gazelles have historical significance in Iraq through their drawings were found in the monuments of Babylon especially the Dama - dama species which became extinct and forced the government to import the gazelles from Bulgaria and breeding it as they adapted to the Iraqi conditions and multiplied because their origins was Iraq. Due to its importance to the Arabs, it was mentioned in Arabic literature and poetry, and it gained distinction in the poems of many poets. In addition to the dama - dama species, there is the Iraqi reem, which is a wild deer characterized by the

beauty of shape and agility and its color is tilted to bright red. Furthermore, many other types found in Iraq and some Arab countries, including the Arabian oryx, red ibex, antelope, deer and mountain deer. Iraqi Ministry of Agriculture was requested from the International Union for Conservation of Nature and some countries concerned with Wildlife have been contacted to supply these reserves with new and rare species and develop the Al-Masad nature reserve near Rutbah city. Other animals live in western desert like Camel, Deer (*Gazella subgutturosa*), Rabbit, wolf, Wild Rabbit, Gray wolf, Goat, Sheep, Brown Fish, Jackal, birds like Pterocles, Deer Falcon, Al-Shaheen, and Houbara.

3. Future goals for developing the study area

This research focuses on developing the study area by achieving the following goals:

3.1. Environment and ecology improvements:

- a. Harvesting rainwater by constructing small-dam-series leads to improve the climate, increase the recharge of groundwater, and improve its quality. About 90 km² of water surface area of reservoirs behinds 4 dams and 13 proposed additional small dams. Bird and fish with trees surrounding reservoirs will create a very healthful environment.
- b. Planting forests around reservoirs and shallow wells using renewable energy pumps will create good environment habitations to the plants and animals that live in the desert conditions.
- c. Establishing renewable energy stations due to the presence of sufficient sunny hours in general, and high wind speed in areas with a height more than 700 m above sea level around Rutbah city.

3.2. Security aspects:

- a. Creating job opportunities in agricultural and pastoral sectors, without violating the valley environment.
- b. Planning to increase the population density per unit area within the region's ecosystem.
- c. Engaging the valley by oases and surrounded and/or open reserves.

3.3. Desert tourism:

- a. Establish tourist resorts near the valley's oases.
- b. Construct semi-open zoos surrounded by natural reserves.
- c. Establish stadiums and sports such as golf courts, horse and camel riding fields.

4. Materials and Methods

4.1. Data Source:

The results of the present study based on different types of data, which

was collected from different sources to identify the optimal height and location of small dams:

- 1- The Global Digital Elevation Model (GDEM) was obtained from the National Aeronautics and Space Administration (NASA) website (earthdata.nasa.gov), as shown in Figure (9)
- 2- Satellite imagery (Landsat 8) was obtained from the United States Geological Survey (USGS) website (earthexplorer.usgs.gov)
- 3- Satellite image (Quick Bird 60cm) was obtained from the Iraqi General Commission of Survey (IGCSE) .
- 4- Climate data for Al-Rutba station were obtained from the Iraqi Meteorological Organization and Seismology data recorded between 1971 and 2019.
- 5- The hydrological soil group map of Wadi Houran was obtained from previous studies, a soil map based on physical tests conducted on samples of soil obtained from the study site in the soil laboratory- University of Anbar, as shown in Figure (10)

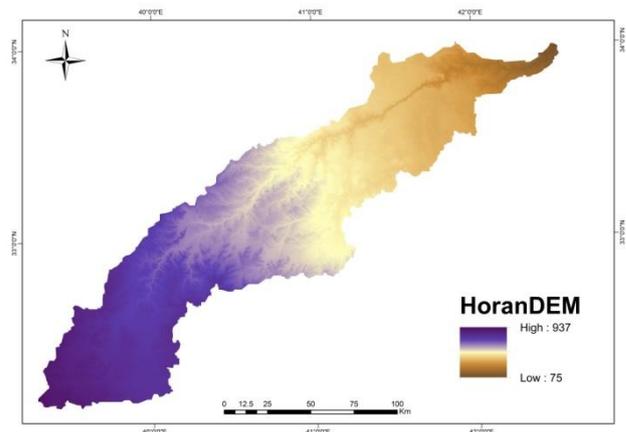


Fig. 9 Global Digital Elevation Model for the study area

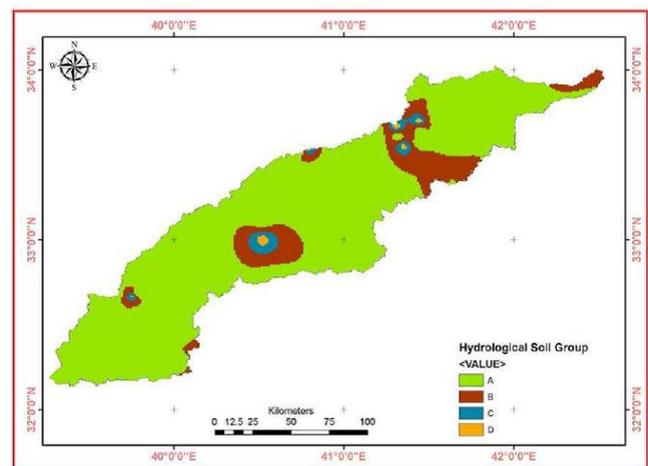


Fig. 10 Hydrological Soil Group map [18]

4.2. Methods:

4.2.1. Rainfall-Runoff Relations:

Wadi Houran area is suffering from lack of hydrological data, where it contains only one weather station at Rutbah city and no hydrometric stations in the valley and surrounded areas. Flooding occurred on certain dates, and no rainfall intensity or any surface runoff was recorded that occurred in 2/12/2019 and 25/11/2018, as shown in Figure (11) & (12).the cross section area of the flow below the bridge shown in Figure 11 is 610 m². It is difficult to estimate the flood velocity because there is no flow meter station. The velocity of wavy flow shown in this figure is very larger than the allowed velocity in lined channel, which is 1.2 m/sec. In Jordan valley discharging to Albahr-Almayet, the flood velocity is 10 m/sec [19], it is very high velocity, so it may be logical to guess the flow velocity below the bridge in Figure 11 is about 3m/sec. that means the discharge is about 1800 m³/sec. so the volume discharged per one hour is 6.48 million m³. That means all reservoirs in this valley are completely filled (if they are empty before this storm) at only 7 hours of this discharge. The duration of Wadi Houran discharge in heavy storms is not less than 10 days or more. The peak flood value will occur early then decreases gradually during one or two days of the flooding time.



Fig. 11 Flooding in study area (2/12/2019) [20]



Fig. 12 Flooding in study area (25/11/2018)[21]

It is very difficult to predict the rainfall-runoff relation in western desert of Iraq because of the lack of hydrological data.

Land cover, land use and soil properties lead to predicting runoff by using hydrological models. So the Watershed Modeling System (WMS) is used to estimate the runoff using remote sensing data. Multiple steps are required to produce the necessary layers in WMS Tools [22]. Wadi Houran has the largest value of surface runoff and water harvesting volumes among other valleys in western desert as shown in Table 3.

Table 3 – The physical characteristics and harvesting volumes of western desert valleys [22]

Valleys	Area (km ²)	Length (km)	Slope (%)	Yearly harvesting (m ³ / km ²)
Houran	13,340	490	0.162	15,355.36
Al-Abeith	6515	340	0.169	4582.31
Al-Ghadaf	5900	165	0.236	7098.64
Ameg	5399	170	0.223	6405.22
Al-Awaj	1246	60	0.28	4782.34

4.2.2. Groundwater Recharging:

As the sediment loads was disposed in the reservoirs behind small dams, the fine particles will decrease the hydraulic conductivity of the soil in the reservoir bed. The conductivity will decrease and approach to the minimum value of 1*10⁻⁸ meter/second [23]. That means about 31.54 cm of water will be infiltrated to ground water every year. Multiplying this depth by reservoir bed area is equal to the volume of water that is recharging the aquifers every year from small dams reservoirs which is

about 4.7 million m³/year from the existing 4 dams, and extends to 28 million m³/year if the proposed small dams series are constructed. Other recharging volumes due to infiltration of rainwater and surface runoff among 16,000 km² (the global valley's area). It is very important to establish weather station network in this strategic valley in order to collect more representative data that enable to study its hydrological features.

Table 4 – Proposed dams in Wadi Houran

5. Results and Discussion

5.1. Water Harvesting:

Wadi Houran is discharging huge amount of rainwater runoff which reaches billion m³ during some observed years [2]. According to the unique Rutbah weather station date, the average yearly runoff in Horan valley could have reached around 400x10⁶ m³ [16], but there are only four small dams were constructed with total storage capacity of 46 Mm³ only. An Optimal Height And Location Model (OHALM) was developed by

No.	Location	Height	Storage volume Mm ³	Surface Area m ²	Ranking
1		14	13.2	2,502,431.6	9
2		13.5	11.4	2,740,177	12
3		13	15.3	3,528,017	10
4	Upstream	12.5	25.8	7,351,076	11
5		13.5	24.3	4,471,927	3
6		13.5	13	2,548,380	8
7		12.5	28.5	2,620,139	1
8	Midstream	13.5	25.5	10,499,504	13
9		13.5	37.9	7,534,638	6
10		13.5	24	2,962,105	2
11		13.5	32.8	5,536,197	4
12	Downstream	13.5	18.2	2,755,617	5
13		14	33.3	12,571,899	7

5.2. Groundwater Recharging:

One of the objectives of constructing a small dam in western desert is to recharge the groundwater and sustain the water resources. The minimum possible recharging quantities can be estimated by considering only the reservoir recharging after decreasing its bed hydraulic conductivity due to the sedimentation of fine particles. Constructing proposed 13 small dams will increase the reservoir area close to 90 km². The water infiltrated volume through this area when assuming the minimum hydraulic conductivity of 31.54 cm/year is about 28 million m³.

[10] to propose the optimal dams series in Houran valley. Table 4 and Figure 7 illustrated 13 small dams that their total reservoir volume is 303.2 million m³. If these dams were constructed, the total harvested volume of all 17 dams is 350 million m³ which is less than the average surface runoff volume recommended by [16].

Many weather stations must be constructed in this valley in order to observe rainfall and surface runoff date. This study recommends constructing these 13 dams and improves the hydrologic information by updating observation of sufficient weather stations in order to study the economic feasibility of constructing other dams.

5.3. The best location of a natural reserve for wild animals:

Target area of 4000 km² is selected in the midstream of the valley, fig. (13) explains this area which shown as green polygon.

There are many constraints affecting the best location to construct the natural reserve.

- 1- The water harvesting capacity. (Figure 6)
- 2- The ground water depth. (Figure 5).
- 3- Groundwater quality. (Fig. 14)
- 4- The distance from the main roads and small dams. (Figure 13)
- 5- Renewable energy aspects.

For 1st constraint, it is clear that both the east and west ends of target area is the best soils to harvest more rainfall water, but the east end is far from the main road, (Figure 13), and the groundwater in this region is very salt, (fig. 14). The west end of target area is better for the nature reserve; it is plotted as a yellow rectangle near Rutbah city as shown in Figure (14). Although the 2nd constraint don't verify the same location because the groundwater depth is decreased as the distance to Euphrates river is decreased, but 3rd constraint is more active because the salinity in east zone is greater than 10,000 ppm, so it isn't suitable only to irrigate high tolerance crops. Water quality is better in the west of the target area, the water quality in yellow rectangular is about 1000-1500 ppm. It is potable water so it is suitable to any sensitive plants and livestock.

It is very important to expand water-harvesting technique and construct the best ranking small dams that closer to this area in order to sustain the groundwater quantity and quality by recharging the aquifers.

4th constraint also verify the selected location, the distance from the main road is about 3 km only as shown in Figure (13).

For the potential renewable energy constraint, There's no variation in sunny hours among the valley's locations, but the best location for high wind speed is nearly to Rutbah city. So the yellow rectangle is verifying this constraint.

The current study recommends selecting the location that verify these active constraints.

The yellow rectangular in fig. 14 is the selected location of the natural reserve. It is must be far from the flood line level in the valley, also it is better to introduce the right side boundary of the valley within the reserve fence. Figure (15) explain the profile of the reserve perpendicular to the valley alignment.

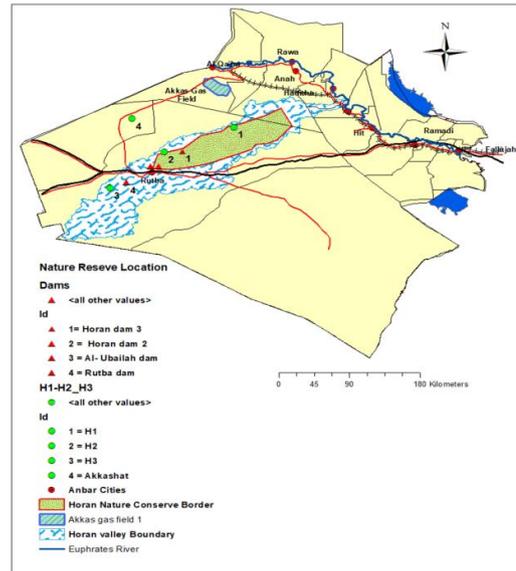


Fig. 14 Groundwater quality in western desert [12]

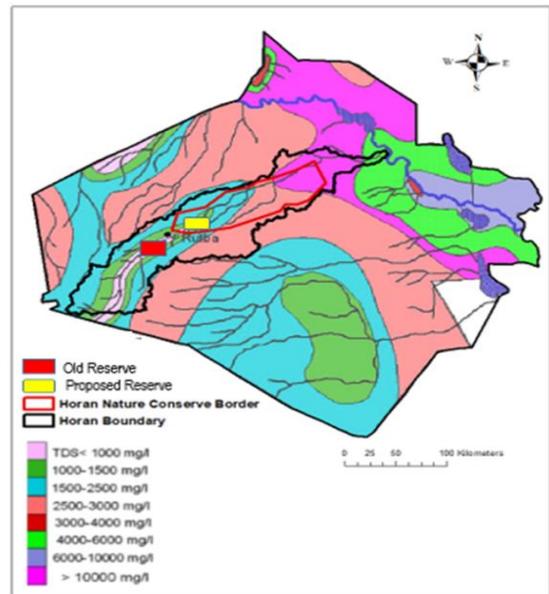


Fig. 15 Elevations of target area

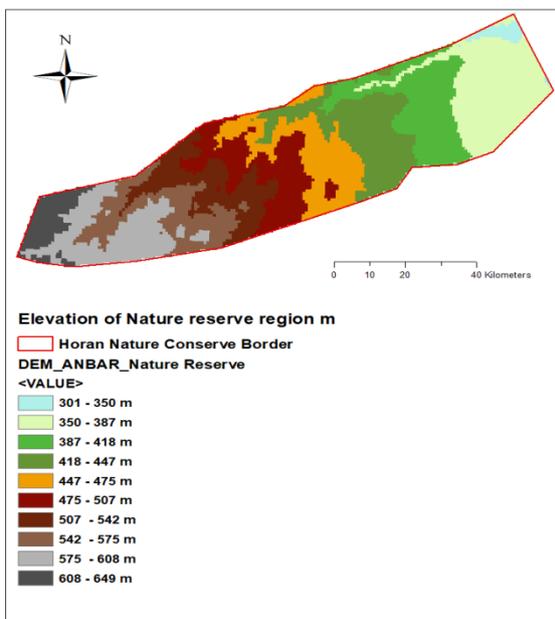


Fig. 13 The target area in Horan valley



Fig. 16 AL-Masad Deer reserve (1974-2014) Google map

The red rectangle south west of Rutbah city is an old Deer reserve that established in 1970 and destroyed by ISIS on 2014, this location is out of the target area in this study, Figure (16). Both neighbor locations (red and yellow rectangles) are verify the constraint of selection the best location. Succession of old Deer reverse is encourage to establish new one in the same region.

6. Project stages

1-First stage (2021- 2025):

- a-Constructing weather station network, 4 stations at H1, H2, H3 and bridge location.
- b-Construct a natural reserve at Al-Misaad near the location of the old reserve.
- c-Construct three small dams at the best sites according to the ranking criteria, and supplying these dams by flow meter stations.
- d-Construct flow meter at the bridge near Al-Baghdadi city.
- e-Planting a wind breaker trees around the small dam reservoirs and at the best rainwater harvesting locations.
- f-Planting many grass plants by airplanes during rainfall season to establish an open reserve for camels.

2- Second stage (2026- 2030):

- a-Expanding the reserve and construct other one near the reservoir of the best small location.
- b-Construct other 3 best location small dams and supply it by weather stations and flow meter stations.
- c-Established an open reserve for camel.

3- Third stage (2031- 2050):

- a-Complete the proposed small dams series of 13 dams by constructing the last 7 among the valley and surrounding all reservoirs by forests.
- b-Expanding the reserves that constructed early.
- c-Monitoring water quantity and quality in aquifers and study the system sustainability.

7. Conclusions and Recommendations

According to the scarcity of hydrological data about Houran valley due to the existence of only one weather station covering the large area (18,000 km²), it is very difficult to predict the surface runoff quantities. therefore, it is very important to establish at least 8 stations. Establishing a natural reserve and planting forests is really important to invest this valley's large area with huge surface runoff quantities to improve the ecology system and climate conditions. About 400 million m³ of harvested high quality water can be used to irrigate millions of several types of trees which are reducing dust, erosion, CO₂ and improving the environment and ecology system.

Small dam series of 13 optimal height and location dams leads to increase the free water area in the valley from 15 to 90 km² which will lead to improve the climate conditions and ecology of the valley. Recharging ground water by 31.54 cm/year means feeding the valley aquifers by 28 million m³/year instead of direct rainwater feeding. These large recharging quantities will sustain the water resource quantity and quality in the oases and reserved regions.

Upper Euphrates Basin Developing Center- University of Anbar is planning to establish an active weather station network and study the rainfall, runoff, infiltration, groundwater aquifer types and its well networks, annually average recharging and safe yield.

REFERENCES

- [1] I. Jongerden (2010), "DAMS AND POLITICS IN TURKEY: UTILIZING WATER, DEVELOPING CONFLICT", Middle East policy, 17(1), 137-143.doi:10.1111/j.1475-4967.2010.00432.x.
- [2] A. H. Kamel and A. S. Mohammed (2010), "DETERMINATION OF WATER HARVESTING REGIONS IN IRAQI WESTERN DESERT USING GIS SYSTEM" , IJDC. Vol 2,2, pp 33-42.
- [3] M. Abdullah, N. AlAnsari & J. Laue (2020), "Water Harvesting in Iraq: Status and Opportunities. Journal of Earth Sciences and Geotechnical Engineering, Vol.(10), No.1, 199-217.
- [4] M. Abdullah, N. AlAnsari & J. Laue (2019), "Water Resources Projects in Iraqi Medium and Small Storage Dams. Journal of Earth Sciences and Geotechnical Engineering, Vol.9, No.4, 283-289.
- [5] Ministry of Water Resources(2015), General Authority for Dams and Reservoirs, Water Resources Department in Al-Anbar Governorate. (unpublished data).
- [6] K. N. Sayl, N. S. Muhammad & A. Dahham (2016), "GIS based for Pre-Selection of suitable site for water Harvesting in

- arid areas case study in the West of Iraq", ZANCO Journal of pure and Applied Sciences, 28(2): s169-177.
- [7] A.A. Alhadithi & A.A. Alaraji (2016), "Rainwater Harvesting of Hauran Valley, West of Iraq", Iraqi Journal of Science, vol.57, No.1B, pp:456-468 .
- [8] A. Adham, K.N. Sayl, R. Abed, M.A. Abdeladhim, J.G. Wesseling, M. Riksen, L. Fleskens, V. Karim & C.J. Ritsema (2018), "A GIS-based approach for identifying potential sites for harvesting rainwater in the Western Desert of Iraq", International Soil and Water Conservation Research , doi:10.1016/j.iswcr.2018.07.003.
- [9] A.D. Ahmed, I.M. Abdulhameed, E.T. Abdel Ghani & M.K. Ibrahim (2020), "Selection of water harvesting sites in Horan valley", IOP Conf. Series: Materials Science and Engineering 881-012183, doi:10.1088/1757-899X/881/1/012183.
- [10] R.I. Naif and I.M. Abdulhameed (2020), "Optimal Height And Location Model (OHALM) for rainwater harvesting small dams (Iraqi western desert- case study)", Iraqi Journal of Civil Engineering, University of Anbar, Iraq. Vol.14, No.2.
- [11] M.K. Ibrahim, I.M. Abdel Hameed & E.T. Abdel Ghani (2017),"EVAPORATION OF LAND DEGRADATION FOR HORAN VALLEY BY USING SPECTRAL REFLECTANCE INDICES", Iraqi J. Desert, 7(1), pp.56-63.
- [12] B.M. Hussien (2010), "HYDROGEOLOGIC CONDITIONS WITHIN AL-ANBAR GVERNORATE", Journal of Anbar University for pure science, Vol.4, No.3, pp.97-111.
- [13] S.A. Saleh, N. Al-Ansari & T. Abdullah (2020), "Ground water Hydrology in Iraq", Journal of Earth Sciences and Geotechnical Engineering, vol.10, No.1, 155-197.
- [14] H.K. Al-Jiburi & N.H. Al-Basrawi (2007), "Hydrogeology of the Iraqi Western Desert", Iraqi Bulletin of Geology and Mining, special is (1), 125-144.
- [15] A.H. Kamel (2012), "Evaluation of Potential Water Harvesting in Arid Region (Case Study: Iraqi Western Desert)", The International Journal of the Environment and Water, Vol.(1), Issue 1.
- [16] S.B. AL-Jawad S and N. AL-Ansari (2017), " EVALUATION OF STORM RUNOFF IN WADI HAURAN, WESTERN IRAQ", JOURNAL OF ENVIRONMENTAL HYDROLOGY, Vol.(25) paper. 6.
- [17] A.H. AL-Bayati and A.A. AL-Alwani (2012), "Analytical Study for the Ecosystem of Some Iraq's Western Desert Oasis for Period from 1966 - 2009", The Arab Journal for Arid Environments 6 (2). pp 25-41.
- [18] K.N. Sayl, H.A. Afan, N.S. Muhamad & A. Elshafie (2017), " Developing of a Spatial Hydrologic Soil Map Using Spectral Reflectance Band Recognition and a Multiple-Output Artificial Neural Network Model", Hydrol. Earth Syst. Sci. Discuss., doi: 10.5194/hess-2017-13.
- [19] AL-Naser (2018), " Rapid surface runoff flowing at wadi Zarqaa Maaeen, Hala Journal, Jordan", (In Arabic) <http://www.hala.jo/2018/11/02> (الناصر: جريان ومضي عالي السرعة)نتيجة الأمطار
- [20] Bmmagazine(2019), <https://bm-magazine.com>
- [21] Beladi today news(2018), http://beladitodaynews.blogspot.com/2018/11/blog-post_91.html
- [22] S.O. Sulaiman, A.H. Kamel, K.N. Sayl & M.Y. Alfadhel (2019), "Water resources management and sustainability over the Western desert of Iraq", Environmental Earth Sciences, 78:495, <https://doi.org/10.1007/512665-019-8510-y>.
- [23] H.a. Mortezaei, M.a. Karimpour-Fard. (2017), "Variation of the Hydraulic Conductivity of Clayey Soils in Exposure to Organic Permeants", Civil Engineering Journal Vol. 3, No. 11, pp 1036-1047.