Anbar Journal of Engineering Science (AJES)
P-ISSN: 1997-9428; E-ISSN: 2705-7440

Vol. 12 , No. 1 (2021) , pp. 76 ~ 82
DOI: 10.37649/aengs.2021.171200

Univiersty of Anbar

Anbar Journal Of Engineering Science©

journal homepage: http:// www.uoanbar.edu.iq/Evaluate/

Minimizing Evaporation Losses from Small Reservoirs (Wadi Houran-case study)

Rasha I. Naif [a]*, Isam M. Abdulhameed [b]

[a] *Dams and Water Resources Engineering Department, College of Engineering, Al-Anbar, Iraq*
[b] *Upper* Euphrates Basin Developing Center, University of Anbar, Iraq

PAPER INFO

Paper history:
Received 10/ 1/ 2021
Revised 13/2/2021
Accepted 28/3/2021

Keywords:
Evaporation Losses
Wadi Houran
Agriculture
Surface Area
Water Level

ABSTRACT

Current paper proposed a new technique to reduce evaporation from small dams reservoirs by minimizing the surface area of a reservoir during maximum evaporation losses period. A mathematical relationship linking the depth of water with the surface area of the reservoir has been formulated, and its integration can be used to estimate conservable water quantities. Reducing the water level in the reservoir to the minimum permissible level before the dry months has reduced the evaporation losses by 65% and 51% for the two scenarios. These two scenarios have been conducted by assuming that the dry months start with the presence of the water level in the reservoir at a height of 14 and 12 m, respectively. On the other hand, evaporation losses during drought months have been decreased by 24%. By this technique, it can be possible to obtain wide areas suitable for agriculture, contributing to the economic and social development of the region. Also, Depth index(DI) suggested in this study and defined as the ratio of volume of the water in the reservoir to corresponding surface area, to compare the location of the best dam among the 13 proposed dams in Wadi Houran by reducing evaporation losses. The results of this index showed the best location was at DI=10.901 in DM 7, and the worst is at DI=2.425 in DM 8.

1. Introduction

Water is a crucial element for the survival of life and as a result of the increasing demand for it and great development of civilization, water scarcity issues have been significantly increasing. It is worth mentioning that evaporation losses are the greatest challenge on water harvesting in arid zone. This is due to the wide bare soil area, lack of vegetation and the frequency of small rainfall events that allow bare soil to return water to the atmosphere **[1].**

One of the basic components of the hydrologic cycle is evaporation, which is essential to water balance studies, water resources management and irrigation system design **[2].** Evaporation is considered a main requirement for planning and designing any water project in this region. Taking into account the actual values of evaporation would reduce massive water wastes **[3]**. The evaporation process from dams reservoirs and lakes establish a great loss in water resources, especially in arid and semi-arid regions, such as the Iraqi Western Desert. In arid regions, evaporation can represent up to 25 to 30% of the total consumption use of surface water because evaporation is a large part of the water budget in these regions **[4].** High temperature and irregular rainfall create threats on small dams. Due to the evaporation phenomenon, water losses about 40% of stored water in existing dams all the times **[5].** The evaporation losses from Mousl dam and Had-

* Corresponding author. Rasha I. Naif: rasha2020@uoanbar.edu.iq ; +9647823461289

itha dam account to more than 2 billion m^3 per year **[6]**.

The evaporation volume is varied linearly with the surface area of the reservoir, that mean a reducing of reservoir surface area by 20% is followed by reduction in evaporation volume by the same ratio. **[7].** Many methods were proposed to reduce evaporation losses from reservoirs by managing one of the evaporation causes as reducing the wind impact and the water temperature. Several techniques were suggested to control evaporation losses last decades, as wind breakers or using of floating synthetic mono-layers on the surface of the water **[8].** The use of floating material is of high cost and may affecting the water quality **[9]. [10]** Presented a review of published researches from 2014 to 2018 in which it was focused on the used techniques for evaporation reduction from water surfaces. These techniques include; the physical methods, chemicals methods and Biological methods. In Algeria, presented a study to evaporation reduction from water reservoirs by a thin chemical film are placed on the surface water and know the effect of this technique under arid conditions. The results indicated that evaporation rate was reduced overall up 16 and 22%**[11]. [12]** Presented a study to reduce evaporation losses from 16 Tishreen dam reservoir. The results show that the most environmentally friendly and it do not affect the composition of water, and suitability for different uses is the air bubbles method or water bubbles, which reducing the annual water loss by 7.6%. Recharging ground water by 31.54 cm/year means feeding aquifers by 28 Mm3/year, and therefore these Recharging will sustain the water resource quantity and quality in the Wadi Houran**[13].**Current research is proposed some ideas to minimize evaporation losses from small dams reservoirs, and managing utilizing this saved water.

2. Study Area

Wadi Houran is the greatest valley in the western Iraq desert, about 450 km from Baghdad **[14].** It extends from the Iraq-Saudi borders to the point where it meets the Euphrates River near Haditha city between the longitude 39°00"00' to 43°00"00' East and the latitude 32°00"00' to 43°30"00' North **[15]** [Figure (1)]. Its catchment area is 13,370 km^2, but there is only one weather station at Al-Rutba city located in midstream of the valley average annual rainfall is about 115 mm **[16].** Evaporation depth for Wadi Houran is ranging between (1600-1900) mm per year and more than half evaporation value occurs in summer months, June, July and August **[17]** as shown in Table (1). A small dams series (SDS) in Wadi Houran was designed to store the largest amount of rain water **[18].** In current study, first dam in the series (dam number 1) is located in Downstream and chosen as a case study, as shown Figure (2).

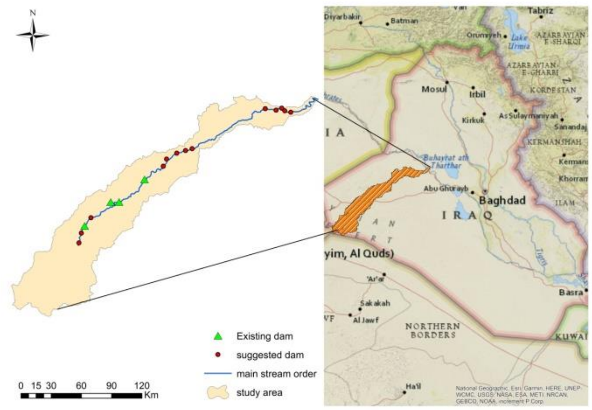

Figure 1. Location of study area

Table 1. Evaporation depth in dry months

Dry month	Evaporation depth (mm)
June	377.5
July	420.7
August	402
Total	1200.2

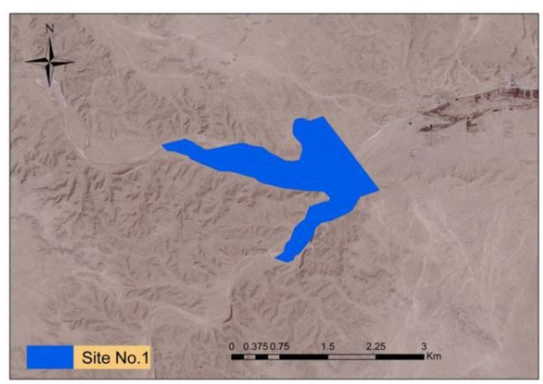

Figure 2. Location of Dam No.1

3. Methodology

Two scenarios were adopted on the assumption that the dam reservoir contains different water level before the beginning of the dry months, which are 14m, and 12 m, and a set of low-cost methods was proposed to reduce evaporation losses from reservoirs by decreasing the surface area of the reservoir at summer months. The surface area of the reservoir can be reduced by reducing the water height in the reservoirs to minimum possible elevation and using this water by planting summer crops. This is done with the following steps:

1. Reduction the water level in the dam reservoir to the permitted level before the drought months (June, July and Aug.), the planting summer crop is done through the following steps:

1.1. Formulating the relationship connects between the water level and the surface area of the reservoir as shown in the figure (3)

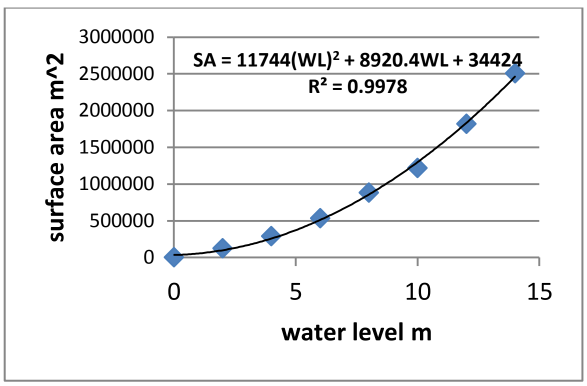

Figure 3. Location of Dam No.1

1.2. Integrating the relationship extracted from the previous step to obtain the saved volume of water and as follows:

$$dv = \int_{h_i}^{h_f} (S.A).dh \quad (1)$$

The integration result is:

$$VS = \frac{a}{3}\left(h_f^3 - h_i^3\right) + \frac{b}{2}\left(h_f^2 - h_i^2\right) + c\left(h_f - h_i\right) \quad (2)$$

Where:

VS: the saved volume of water (m³)
$S.A$: the surface area of reservoir (m²)
h_f: the final water level of the reservoir (m)
h_i: the initial water level of the reservoir (m)
a, b, c: constants

- Planting summer crops:

The irrigated area is calculated by the formula:

$$AI = \frac{VS}{GDI} \quad (3)$$

$$P.C(ton) = AI(ha) * RPC\left({}^{ton}/_{ha}\right) \quad (4)$$

Where:
AI: the irrigated area (m²)
VS: the saved volume of water (m³)
GDI: the gross depth of irrigation (m)
$P.C$: the productivity of crop
RPC: The rate productivity of a crop

2. As for the drought months (June, July and Aug.) , the area that can be planting is found as follows:

$$Y = H_{storage} - H_{min} \quad (5)$$

$$H_{min} = H_D + \beta \quad (6)$$

$$AI = \frac{V_Y}{GDI} \quad (7)$$

Where:
Y: the water level between $H_{storage}$ & H_{min} (m)
$H_{storage}$: the level of water at the end of May month (m)
H_{min}: the minimum level of the water in the reservoir (m)
H_D: the level of dead storage in the reservoir (m)
β: the coefficient for irrigation (m)
AI: the irrigated area (m²)
V_Y: volume of storage between $H_{storage}$ & H_{min} (m³)
The value of V_Y is calculated by interpolation from reservoir volumes data based on the value of Y.

- **Depth Index (DI)**

This index introduced in this study and defined as the ratio between the volume of potential storage (V) generated by the realization of dam to corresponding surface area at a certain elevation. These parameters (storage capacity, water surface area) are used to generate this index as shown in the following equation:

$$DI = \frac{V}{S.A} \quad (8)$$

Where:
DI: depth Index (m)
V: Volume of water storage (m³)
$S.A$: Surface area of the reservoir (m²)
The main factor associated with the evaporation process from the reservoir are the water surface area and the depth of water, so this index was taken into account when evaluating the present research.

4. Results and Discussions

The first step in the methodology is to reduce the reservoir level to the permissible limit (8m) before the months of drought (June, July and Aug.) and find the saved volume of water. This is done through two scenarios that were imposed in this study, which are A and B on the assumption that the dam reservoir contains the water at a height of 14 and 12m, respectively as shown in Figure (4). Using the equation (2), the saved volume of water is determined after determining $\boldsymbol{h_f}$, $\boldsymbol{h_i}$ for each scenario. For example, Scenario A, the value $\boldsymbol{h_i}$= 14m and $\boldsymbol{h_f}$= 8m. By applying equation (2) we get the saved volume of water ($\boldsymbol{VS}$).

When performing this step, the surface area of reservoir is reduced by different percentages. These percentages are found by dividing the surface area at height h_f by the surface area at height h_i and subtracting it from 100%. The table (2) shows the results of reducing the surface area of two scenarios.

Table 2. The results of two scenarios to reduce surface area

scenarios	$\boldsymbol{h_i}$ m	$\boldsymbol{h_f}$ m	$\boldsymbol{a}$	$\boldsymbol{b}$	$\boldsymbol{c}$	$\boldsymbol{VS}$ m^3	$\boldsymbol{S.A}$m^2 Reduced	S.A reduction ratio %
A	14	8	11744	8920.4	34424	9,532,901	1,622,224	65
B	12	8				5,254,787	933,943	51

From the above table, the percentage of surface area reduction ranges between (51% - 65%), which is a good percentage to reduce evaporation losses to the maximum level possible. This saved water (VS) is used for for planting Summer crops.

- **Planting Summer crops:**

The benefit that can be obtained from using the saved volume of water (VS) from the previous step by planting Summer crops before the drought months. For example, the Maize crop grow between 1-April and 23-August and the gross depth of irrigation (GDI) of this crop is (1325)mm **[19].** Using the equation (3), the irrigated area is calculated by dividing the saved volume of water *(VS)* for each scenario by GDI for the Maize crop and to find the Maize productivity. The equation 4, is used where the rate of productivity Maize *(RPC)* = 13 ton/ha **[20]**. Table (3) shows the results of irrigated areas for the two scenarios before drought months.

Table 3. The results of three scenarios to irrigated area

scenarios	$\boldsymbol{VS}$ m^3	$\boldsymbol{AI}$ m^2	$\boldsymbol{AI}$ ha	*Maize productivity ton*
A	9,532,901	7,194,642	719.4	9352
B	5,254,787	3,965,877	396.6	5158

The resulting irrigated area ranges between 396.6 and 719.4ha and the amount of Maize that can be produced ranges from 5158 to 9352 tons. If this method is applied to the 13 proposed dams, assuming that a little difference between reservoirs areas and storage volumes exists, annual Maize production can range between (67000 – 120000) tons. It is a huge quantity needed to develop the region economically.

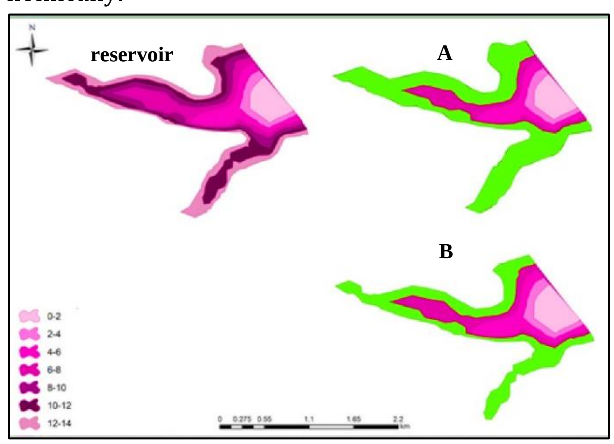

Figure 4. Contour map of the reservoir to irrigation with the two scenarios, A-scenario A, B-scenario B

The second step in the methodology is to reduce evaporation volume in the drought months, crops are grown that extend from 1st June to 1st September such as growing a cucumber crop with a GDI = 682 mm **[19].** The irrigated area and the crop productivity during these months is calculated by using equations from (4) to (7), as below:

1. The minimum level of the water in the reservoir (H_{min}) was calculated by using the equation (6), which depends on the (H_D)

value, that is equal to (6m) and the value of (β) assumed in this study is about (0.8m).

2. The value of the water level between $H_{Storage}$ & H_{min} (Y) was calculated by using equation (5), which depends on the level of water at the end of May month ($H_{Storage}$) and the minimum level of the water in the reservoir (H_{min}).
3. The value of the volume of storage between $H_{Storage}$ & H_{min} (V_Y) was found by interpolation for the data of reservoir based on the value of (Y).
4. Using equation (7), the irrigated area (AI) was calculated by dividing (V_Y) by (GDI).
5. To find the crop (cucumber) productivity, use equation (4), where the rate of productivity cucumber = 9.5 ton/ha **[21].**

The table (4) shows the results of irrigated area and to reduce the surface area for the reservoir during drought months.

Table 4. The results of irrigated area and to reduce the surface area for the reservoir during drought months

V_Y m³	$S.A$m² Reduced	S.A reduction ratio %	AI m²	AI ha	Cucumber *productivity ton*
223,582.7	209,398	24%	327,833	32.8	311.6

From the above table, The percentage of surface area reduction = 24%, which is a good percentage for the production of cucumber crop during the dry months in an amount equal to (311.6 tons). If this method is applied to 13 proposed dams in the study area, assuming a few differences between reservoir areas and storage volumes, the production of cucumber crop is about (4050.8 ton).

Planting summer crops results showed is very suitable for use, in addition to huge reduction in evaporation losses, and a large area for agriculture is obtained, resulting in a distinctive appearance of the dam. On the other hand, the cost of pumping is taken into account, so we suggest using solar pumps and putting them on boats to adapt to the water level variation in the reservoir.

Depth Index (DI)

In this study, the Depth Index (DI) was suggested to find the best location for the dam. This index was applied to 13 proposed dams distributed 5, 5 and 3 on Down-stream, Mid-stream and Up-stream respectively, by dividing the maximum storage volume by corresponding surface area of the reservoir at a certain elevation.

As shown in Table (5). The best location is the maximum DI ratio because increasing this ratio is followed by minimizing relative surface area because the inverse relation between DI and surface area. That mean maximizing DI is minimizing relative evaporation losses.

The best location is at DI index 10.901 in SDM7 and the worst one is at DI 2.425 in SDM8 and the value of this index ranges between (3.517-5.436), (2.425-10.901) and (2.653-6.605) in Down-stream, Mid-stream and Up-stream respectively.

Table 5. Dams sites classification by using Depth Index DI

Zone	dam	Location X	Location Y	DI	The best location
Down-stream	DD1	801589.42	3751862.87	5.3	6
	DD2	795696.36	3753254.76	4.2	10
	DD3	792641.59	3755930.26	4.4	9
	DD4	787030.84	3753892.00	3.5	11
	DD5	776271.95	3755417.36	5.4	5
Mid-stream	DM6	703665.45	3715753.51	5.1	7
	DM7	697148.83	3713864.72	10.9	1
	DM8	688448.86	3711313.10	2.4	13
	DM9	678287.45	3705445.63	5.03	8
	DM10	675037.20	3698392.33	8.1	2
Up - stream	DU11	603172.71	3647335.19	5.9	4
	DU12	593659.41	3632095.23	6.6	3
	DU13	591303.88	3622364.95	2.7	12

5. Conclution

1. The saved water volume can be estimated by integrating the proposed nonlinear relationship between the water level and the

surface area of the reservoir (SA = a(WL)^2 + b(WL) + c).

2. Minimizing water level in summer months can reduced the evaporated water volume by about (51 – 65)%, that help in developing the region.
3. Proposed method can optimize the water level to minimize evaporation losses since the Western desert contains 12 small dams by different storage volumes.
4. The optimal small dam location can be selected using depth index that introduced in this study because minimizing evaporation losses. The best location is at DI index 10.901 and the worst one is at DI 2.425

References

[1] Pilgrim D.H., Chapman T.G. & Doran D.G.(1988), problems of rainfall-runoff modeling in arid and semiarid regions. Hydrological Sciences Journal, 33(4), 379-400.

[2] Sammen S.S.(2013), FORECASTING OF EVAPORATION FROM HEMREN RESERVOIR BY USING ARTIFICIAL NEURAL NETWORK. Diyala Journal of Engineering sciences. Vol.06, No.04, pp.38-53.

[3] Abdullah S.S., Malek M.A., Mustapha A. & Aryanfar A.(2014), Hybrid of Artificial Neural Network-Genetic Algorithm for Prediction of Reference Evapotranspriation ($ET_\circ$) in Arid and Semiarid Regions. Journal of Agricultural Science, 6(3), p191.

[4] Dawood A. K.(2013), "Reduce Evaporation Losses from Water Reservoirs," *IOSR J. Appl. Phys.*, vol. 4, no. 6, pp. 13–16, doi: 10.9790/4861-0461316.

[5] Craig I.P.(2008), "Loss of storage water through evaporation with particular reference to arid and semi-arid zone pastoralism in Australia", DKCRC Working Paper19, The Water Smart™ Literature Reviews, Desert knowledge CRC, Alice Springs.

[6] Danboos A., Jaafar O., and El-shafie A.(2018), "Effect of Evaporation on the Haditha Reservoir on the Euphrates River in Iraq and Recommendations for Reducing Evaporation Losses," vol. 13, no. 2, pp. 929–941.

[7] McJannet D., Cook F., and Burn S.(2008), "Evaporataion reduction by manipulation of surface area to volume ratios: overview, analysis and effectiveness,"

[8] Martínez Álvarez V., Baille A., Molina Martínez J. M., and González-Real M. M.(2006), "Effect of black polyethylene shade covers on the evaporation rate of agricultural reservoirs," *Spanish J. Agric. Res.*, vol. 4, no. 4, pp. 280–288, doi: 10.5424/sjar/2006044-205.

[9] NPSI. Program (2005), "Controlling evaporation losses from farm dams" ,no.4 April.

[10] Youssef Y.W. and Khodzinskaya A.(2019), "A Review of Evaporation Reduction Methods from Water Surface", E3S Web of Conferences 97, 05055, https://doi.org/10.1051/e3sconf/2019970 5044.

[11] Saggai S. and Bachi O.E.K.(2018), "Evaporation Reduction from Water Reservoirs in Arid lands Using Monoluyers:Algerian Expernce", Water Resources, 45, 280-288. https://doi.org/10.1134/S0097807818020 15X.

[12] Hassan I. and Yousuf D.(2019), "Studing the Reducting of the Evaporation in the Dam of 16 Tishreen by Water Bubbles", Tishreen University Journal for Research and Scientific Studies-Engineering Sciences Series, Vol.(11), No.(5).

[13] Abdulhameed I.M., Mohammed A.S., Kamel A.H., Almafrchi K.Y., Alhadeethi I.K., Fayyadh A.S., Ibrahem M.K., Mutar H.A., Hamad R.M., Naif R.I., Abdel Chani E.T., Haaned W.H., Ahmed M.N., and Al-Esawi J.H.(2020), "Sustainable Development of Wadi Houran-Western Iraqi Desert", Iraqi Journal of Civil Engineering, Vol(15).

[14] Sayl K. N., Muhammad N. S., Yaseen Z. M., and El-shafie A.(2016), "Estimation the physical variables of rainwater harvesting system using integrated GIS-based remote sensing approach," *Water Resour. Manag.*, vol. 30, no. 9, pp. 3299–3313.

[15] Ibrahim M. K., Hameed I. M. A. and GhaniE. T. A.(2017), "EVALUATION OF

LAND DEGRADATION FOR HORAN VALLEY BY USING SPECTRAL REFLECTANCE INDICES," Iraqi J .Desert.

[16] Sayl K. N., Shazwani N., Ahmed E., and Dahham A. (2016), "GIS based for Pre-selection of suitable site for Water Harvesting in arid areas case study in the West of Iraq," *ZANCO J. Pure Appl. Sci.*, vol. 28, no. 2, pp. 169–177.

[17] HUSSEIN B. M.(2010), "Hydrogiologic conditions within al-anbar governorate," *J. Univ. Anbar Pure Sci.*, vol. 4, no. 3, pp. 97–111.

[18] Naif R. I. and Abdulhameed I. M.(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.

[19] Ministry of Water Resources (2014), "Strategy for Water and Land Resources in Iraq", Draft Final Report, Appendix F-ReportF.3, Rev000, 16, April, Iraq.

[20] AL-Abodi H. M. K. , and Shati R. K.(2014), "RESPONSE OF MAIZE TO DURATIONOF IRRIGATION, DEPTH AND METHOD OF PLANTING, " The Iraqi Journal of Agricultural Sciences, 54(7):672-684.

[21] http://faostat.fao.org/site/291/default.aspx