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Impproving the performance of Hurriya-Dagharah Irrigation project using Aqua-Crop Model

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Abstract— Iraq has experienced a depletion of water mainly because of climate change, and decrease for water. There is for instance the Daghara/Huriyh Irrigation Project, which is an agro centric, large-scale project involving Qadisiyah Governorate to solve issues of water management. Several objectives of the study were established, namely evaluating the application of the currently installed irrigation system, the storage and distribution in the fields, and canals and the overall performance of the project. Nine fields were assessed, Three (A1, A2, A3) in the first, (B1, B2, and B3) in the second and (C1, C2, C3) in the third phase respectively. This entailed the measurement of water potential concerning moisture content, field capacity and discharge was done. There was thus a poor irrigation efficiency, which was estimated to range from 36%. 768% and 42. Nine percent for the different tools while the evaluated storage efficiency ranges from 50. 17% and 77. 47%, while the anti-inflation target is set at 15%, import price level at 26% and distribution efficiency at between 93%. 9% and 97. 6%. This revealed that conveyance efficiency of water was 86. 38 % while the overall efficiency towards the project completion was only 32 %. 39 % for high wastage from irrigation. Therefore, using AquaCrop model, the virtual irrigation efficiency was estimated using the overall 80% sprinkler irrigation and 20% drip irrigation allocation. Among all the irrigation techniques, Sprinkler was found to be most efficient, second to that was drip Irrigation (90. 36 %). The tested virtual efficiency with sprinklers was 68. 39% and with drip irrigation it 77. 25 %, which is close to two and the respondents reported half times the actual efficiency. This improvement could lift the ratio in cultivated area from 107000 to 239000 dunums for the same water volume.

Keywords— Irrigation, water application efficiency, overall efficiency, aqua crop.

1. Introduction

Water is an important yet scarce global commodity which is required for everybody's daily needs and for crop growing. Irrigation is pivotal in the utilization of water hence they should be used efficiently to help increase production and food security. But impossible situations appear due to the growth of water consumption and climate changes influencing the irrigation process. Greater emphasis on precise and symbiotic techniques can contribute to assessing the efficiency and cutting down on excessive use of water due to changing climates and increased population [3, 4]. Lack of management leads to a lot of wastage of water in this process and therefore efficiency testing of water usage utilizing recognized gadgets for irrigation projects that can be termed efficient [4, 5, 6]. Organizational performance is measured by applying a framework based on field-based water diversion, transportation, and distribution assessments [7, 8]. Water resources should be used wisely and properly especially concerning farming to reduce water scarcity [9, 10, and 11]. Another of the efficiency appraisal is also the long-term water availability to the agricultural produce, which serve as the reference for enhancing on projects such as Dagarah-Huriyh Irrigation project. Research that has been done earlier covers different irrigation schemes and the level of efficiency. This is from Checkol et al [13] conducted the Geray irrigation scheme assessment in Ethiopia with concern to the canal conveyance and maintenance. Korkmaz and Avci carried adequacy, effectiveness and reliability treatment in the Menemen Left Bank irrigation district [14]. Dessalew et al. [15] used the Bedene Alemtena small-scale irrigation scheme to quantify the application efficiency, distribution efficiency, and water productivity. In their paper, Tesfaye et al. [16] looked into the environmental effects in relation to Wosha and Werka Irrigation system leading to improved agricultural yields and water resource provision. For instance, Geleto et al. [17] assessed five spate irrigation systems of different scales in Ethiopia in terms of, A, B, and C. Abera et al., [18] have analyzed the Dirma small-scale irrigation programme and found out the results in terms of conveyance, application, storage and overall efficiencies are assessed. Al Mosawi and Al Thamiry [19] on the Elaj irrigation project in Iraq made an assessment on the total suitability index and water use efficiency besides the economic value of water. Based on the findings of Al Thamiry et al. [23], the researchers recognized that the increased availability of water leads to higher wetted diameters and depths and demonstrated that the saturated hydraulic conductivity had positively correlated with wetted diameter as well as wetted depth. From the study conducted by Al Masraf and Salim [24], it was established that SWRT membranes which has the ability in increasing the water and crop production in the difficult soil. In the study that was conducted by Al Masraf and Abdullah went further and provided the evidence that through the management of the watrer retention technology, crops production is boosted through the underground water retention. Later, Hameed and Al Thamiry [26] highlighted the distribution and the conveyance efficiency of the projects concerned which signifies that the projects are using significant quantity of water and leaking. Mushab and Almasaf [27] posited that enhancement of the SWRT membranes has increasing impact on yield productivity and rationalised water utilisation in arable farming. Shatt Al-Diwaniya canal Al Saadi and Al Thamiry [28], the current high discharging canal construction upgrade for the highest discharging capacity. Al Mosawey and Abed [29] utilized WaterGEMS to model the water network variables and chlorine residual concentration levels. Explaining the changes to the discharge and the removal or deposits and also the improvement which Moshtagian, Al Thamiry and AlSafar [30] have identified. Case study: Concerning water, field water, and distribution efficiency, Al-Hameed, and Al Thamiry [20] responded the Al-Ishaqi irrigation project. Portable and local equipment used in moisture content determination in the field, field capacity and wilting point can also be used to make an assessment of the irrigation project to identify some problems and make some adjustments for plant improvement.

2. Study Area

Dagharah-Huriyh is an abandonment irrigation project that is half complete and lies in Qadisiyah Governorate in Iraq, and neighbors the Dholmiya Canal to the north; the Hilla-Diwaniyah irrigation project to the south; the Diwaniyah-Shaafeyah irrigation project to the west with desert to the east. There are two major canals called Daghara, Huriyh, Dholmyia, and Sharifiya. The project covers six sectors: Aftak, Daghara, Somer, Sanya, and Al Bdair, boasting an area of 63500 dunum of which 20700 dunum can be irrigated. Its characteristics include good drainage, flat and level with fine to medium soil coverage, without soil slips. Shatt Al-Daghara is sub-river of Shatt Al-Hilla which has nineteen branches and, different head regulators control the flow also. It is a very important undertaking especially for irrigation in the region considering that Iraq falls under the arid desert with little and irregular rainfall for rain fed agriculture.

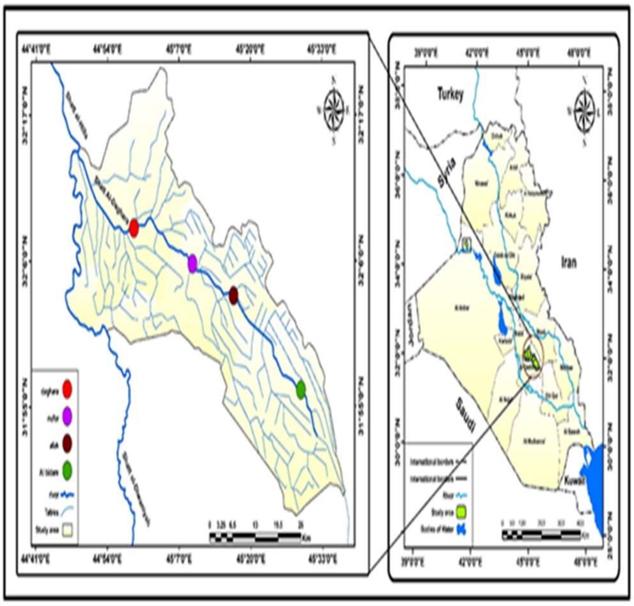

Figure 1: Location map of the Dagharah/Huriyah irrigation project.

3. Material and Method

3.1 *Field selected*

Thus, as part of the evaluation of the Al-Daghara/Huriyh irrigation project, an assessment of irrigation efficiency was made on nine farms which constitute a sample of all the farms in the project area. The fields selected for completion were chosen based on distances those fields were from the main project canal. This was done with the intention of comparing the overall irrigation approach that was implemented by the farmers with the methods currently in use and without making any alterations to the approach. They include only those farms that were located within the region influenced by the given main channel and its branches, and thus the assessment is done in a systematic manner. The latitude and longitude of each farm are captured in Table 1 below to display the exact location in the event of any controversy.

Table 1: The fields coordinates.

NO.	The name of the canal	The selected fields	UTM Coordinates(m) Easting Northing
1		A1	445456 320843
2		A2	445451 320841
3		A3	445450 320836
4		B1	450824 320621
5	Shatt Al-Daghara	B2	450719 320528
6		B3	450716 320520
7		C1	452247 320020
8		C2	452247 320019
9		C3	452247 320018

3.2 *Sample collection*

The soil samples were purchased at both pre and post irrigation process by using a hand auger and core. These samples were collected from varying depths, that is, the first layer of 0–25 cm, the second layer of 25–50 cm and the deepest layer being 50–100 cm as per the root zone guidelines of FAO. These soils were collected only during the morning time. Measures of both soil moisture content the soil samples containing different levels of moisture was meticulously collected, weighed and then dried using the oven method. To determine the moisture status, the pre-irrigation assessment of the soils was done before getting to the irrigation exercise. The next day same kind of samples and at the same depths were taken after the irrigation event had occurred to determine the moisture content at the particular time of sampling.

3.3 *Field soil characteristics*

The samples of the soil were collected at two horizons 0-50 cm and 50 -100 cm, so as to obtain three samples covering the root zone of the plant. Soil samples were periodically collected from the College of Agriculture, Baghdad University for conducting tests in order to find out the Field capacity, permanent wilting point and soil texture. The texture of the soil was also assessed before the survey using a triangular rating scale with sand, silt and clay. Field capacity was determined by saturating the soil and then taking an excess water in order to determine the amount remaining in the soil. Recalculation of the apparent soil porosity allowed for the examination of the permanent wilting point, which was assessed by reducing the amount of moisture in the soil. Table 2 displays the information on soil texture, field capacity and permanent wilting point which are are important parameters for any fertile type.

Table 2: The laboratory Results.

Field selected	Depth of soil (cm)	Soil texture	AV. FC. (cm)	AV. P.W.P (%)
A1			0.43	24
A2			0.39	27
A3			0.35	23
B1	0-50	Sandy loam	0.37	15
B2	50-100		0.41	29
B3			0.34	21
C1			0.36	17
C2			0.33	12
C3			0.31	17

3.4 *Measurement of the root zone*

In order to find out the specific depth of the root zone of the wheat crop in the experimental field, systematic approaches were used. The procedure was a random choice of three plants with regards to the projected depth and the radius estimates and accurate measurement of the depth of the root every time irrigation took place using a measuring tape. This approach was used because the process of defining the exact depth of the root zone is rather problematic, especially with regard to possible impacts of numerous factors and variables. In this way, the chosen systematic approach allowed the researchers to collect credible and representative data on the depth of the wheat crop's root zone within the experimental field.

3.5 *Inflow measurement*

To quantify field inflow and regulate the open outlets without gates or weirs, a Venturi flume was placed at the beginning of the canal. This device thus provides a critical depth by cutting the hydraulic grade line and thus allowing for the estimation of the discharge. Head loss at both the source and throat of the flume was recorded while the determined coefficient value was 0. 98. Other devices such as orifice plates or weirs can also be used but results in less accuracy, reliability, and much more head loss to deal with if the flow rates range from low to high. It also does not fluctuate a lot of performance when it comes to water quality and sediment content thus improving the chances of data collection. To calculate the discharge accurately, an equation proposed by Cone, V.M. in 1917 (21) is employed, ensuring robust and reliable calculations:

$$Q = CB_2Y_2\sqrt{\frac{2gH}{1-(\frac{B_2Y_2}{B_1Y_1})^2}} \qquad (1)$$

Where Q represents the discharge, C denotes the coefficient of discharge, B1 represents the width upstream (in meters), B2 represents the width throat (in meters),y1 signifies the depth upstream (in meters),y2 signifies the depth throat (in meters), H represents the depth difference (y1 - y2), and g denotes the acceleration due to gravity.

4. Evaluation of the moisture content, storage of applied water, application distribution, and effectiveness of storage

4.1 *The evaluation of moisture content and the determination of water storage depth.*

The following equation conducted the moisture content by (Musa et al, 2016)

$$P_w = \frac{w_w}{w_s} * 100 \qquad (2)$$

The degree of saturation (Pw) was defined by the following formula by using the weights of the moist soil (Wt.), the solid mass of soil (Ws.), and water (Ww.). These weight ratios were then converted into volume ratios and given as Pv **:**

$$P_v = P_w\, A_s \qquad (3)$$

Soil moisture content (Pw) was calculated using soil's specific gravity (As), which varies with soil texture. The computed moisture content was then converted into water depth for use in Equation (2). Moisture content at specific depths was determined by extracting soil depth (D) with an auger and multiplying it by the volume percentage (Pv).

$$d = \frac{PW}{100} * A_s * D \qquad (4)$$

In the root zone, the water depth before irrigation (‘d’) was determined, as well as the depth of the root zone ‘D’. Hydration status at the microscopic root zone level was evaluated by calculating the cumulative fraction of crop consumptive use right up to the time of soil sampling after irrigation.

$$d_n = d + E_{tc} \qquad (5)$$

The amount of water that resides in the root zone is described by ‘dn’, whereas the ‘Etc’ represents the quantity of water consumed by the crop between the pre- and post-irrigation sampling. Soil moisture reveals whether the soil is sufficiently moist for plant growth: it helps to avoid over-watering and, consequently, to avoid water waste, and under-watering, which decreases crop yields (Israelson et al., 1944).

4.2 *Depth of water applied*

The following equation shows the average applied depth used in the irrigation system in each field.

$$Q * T = d_g * A \qquad (6)$$

Where Q is the convertion rate of water in cubic meters per minutes, T is the time taken in minutes to do the irrigation, A is the area of the field in square meters and dg is the effective depth of water applied in millimeters. Correct measurement of the amount of water placed at the plants’ disposal is a very central aspect in horticulture since it determines whether the crops are to be provided adequate water to support their growth or not.

4.3 *Water application efficiency*

Through the following formula, the efficiency of water application was conducted by FAO [5]:

$$E_a = \frac{d_n}{d_g} * 100 \qquad (7)$$

The water application efficiency (Ea) was estimated as the ratio of the water stored in the root zone (dn) to the total depth of water applied in the field (dg), in percentage. Yield notes the availability and effectiveness of irrigation water in the delivery or reception to the fields and thus, the crops consequently, water application efficiency increases, in water-scarce areas reducing the losses through irrigation water.

4.4 *Water distribution efficiency*

Based on FAO, the means of determining the level of uniformity of water application along the irrigation run is the examination of the uniformity of water application to the land.

$$E_d = (1 - \frac{Y}{d}) \qquad (8)$$

There are factors that influence the Ed; the average water penetration (d), and deviation from the required depth(y). This efficiency determines how equitably irrigation water is provided ideally under different conditions that determine the rate of growth of crops as well as their quality. Therefore, assessing this parameter may need modifications to be made to the irrigation system.

4.5 *The efficiency of water storage*

Storage capacity defines the receptiveness of the root zone to water storage and how water necessary to meet the water deficit in a given area is stored. It has been mathematically described by the FAO (5) as:

$$E_s = \left(\frac{d_n}{d_s}\right) * 100 \qquad (9)$$

Soil water storage efficiency (ES), in percentage, depicts water stored in the root zone during a single irrigation event (ds). This reduces how often the plants are watered and promotes crop germination and growth.

4.6 *Conveyance Efficiency*

It is defined as the flow rate of water out of the canal divided by the flow rate into the canal and can be described by this relationship:

$$E_c = \frac{Q_2}{Q_1} * 100 \qquad (10)$$

Where, Ec is the conveyance efficiency (percentage), Q1 is the amount of water entering the system (m3/s), Q2 is the amount of water leaving the system (m3/s) at the source (Hansen, 1960).

4.7 *Assessing the overall efficiency*

The irrigation efficiency of the system is a product of field application efficiency, distribution efficiency, and transportation efficiency. This is the numerical calculation is carried out according to the following formula:

$$E_o = Ec \times Ed \times Ea / 10^4 \qquad (11)$$

Where Eo the Overall Project Efficiency (%) is, Ec is the conveyance efficiency of the main network up to a minor level (%), Ed is the distribution efficiency (%), Ea is the field application efficiency (%), (Rai et al., 2017).

5. Simulation of the Aqua-Crop model

The management of irrigation and field is taken into consideration by the Aqua-Crop simulation software that simulate plant-soil interactions. It is connected with the atmosphere through the upper boundary, (ETo and CO2,) and to the groundwater through the lower boundary. The model proposes the root zone as a water supply, subsequent to rain, irrigation, capillary action, robbery as well as evapotranspiration. They divide the soil profile into 12 substrate parts and record water stress on a daily basis. No stress occurs if water levels are higher than the depletion threshold (Ks = 1); no more stress accumulation when at the permanent wilting point (Ks = 0) (Raes et al., 2018a).

5.1 *Implementation of Aqua-Crop Model*

Calibration of the AquaCrop model is a process that has the following procedures. First, nonadjustable data like climate, net applied water depth, specific soil parameters, and irrigation frequency are fed in. The climate file consists of the average maximum and minimum temperatures, the amounts of rainfall, rainfall intensity, and potential evaporation during the growing season of 2022/2023. Six basic soil parameters, namely, texture, field capacity, wilting point, initial water content, and saturated hydraulic conductivity are provided for the main root zone layer. Crop parameters are defined into constant or commonly important parameters and non-conservative parameters that depend on the sowing time, local climate, and irrigation technique. In the irrigation file there are given the types of irrigation (sprinkler or drip) and its frequency as well as water salinity. One about water balance/salinities: Desired water levels are more than 4 meters at the project area with no effects on water balance or salinity issues identified. They found that in biomass development estimates in field management files, such factors influence water productivity parameters: soil fertility. Mulch cover is not applied and the soil is slightly above average in fertility and applicable weed control. After configuration, the program is executed, and computer translates the inputs into numerical results that are analyzed. Among the four parameters of the root zone soil water content profile, the profile that best represents application efficiency is chosen through a least squares method, represented as Application Efficiency = [Wr (Zx)] / WCTot.

6. Result and Discussion

6.1 *Moisture conent*

Determination of pre and post irrigation soil moisture level is important in measuring irrigation effectiveness and as check up for the state of soil and its suitability to the plant. Moisture content deter-mines the amount of water that is in the soil and available for plant uptake. Therefore, the analysis of these results is beneficial in decision-making processes related to the agriculture and the environment. Indeed, concerning the duration of the growing season for winter wheat, and for this study, winter wheat was planted in November 2022 and harvested in May 2023, making a growing period of 140 days. Before and after irrigation, soil moisture was determined at several depths of the root at Nutrient Plots from November 1, 2022 to May 10, 2023. Figures 4-1 to 4-9 exhibit the moisture content, and the AD, FC, and PWP levels of the soil texture classes. AD was computed according to FAO using the guidelines for assessment of water availability. Irrigation activities among farmers were always on the assumption of previous performance and projected water supply in the project. The difference between FC and PWP reveals the quantity of water exploitable by plants; once FC is exceeded, soil dries up for crops.

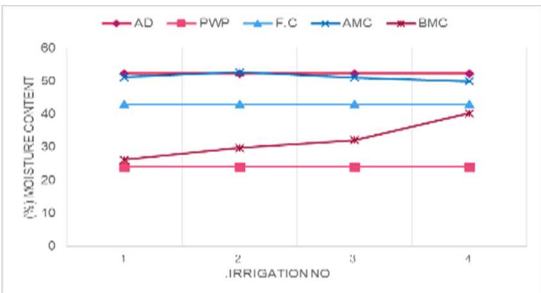

Figure 2: Pre and post-irrigation of the moisture content (by volume) in a field (A1) (11, 1-202 2to 5, 1-2023).

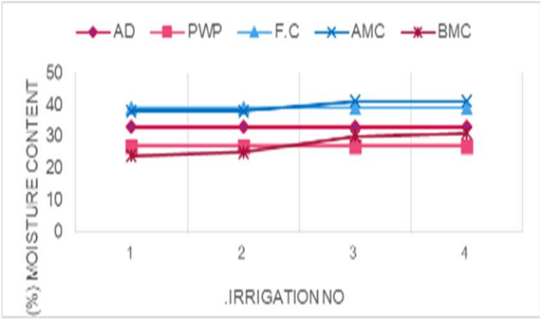

Figure 3: Pre and post-irrigation of the moisture content (by volume) in a field (A2) (11, 1-202 2to 5, 5-2023).

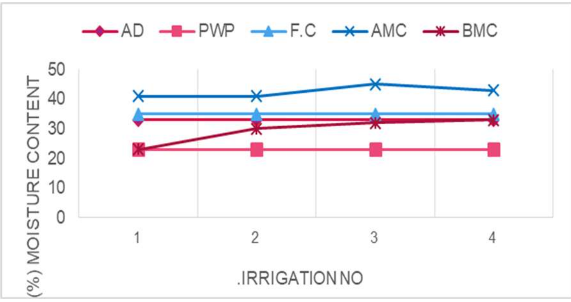

Figure 4: Pre and post-irrigation of the moisture content (by volume) in a field (A3) (11, 6-202 2to 5, 7-2023).

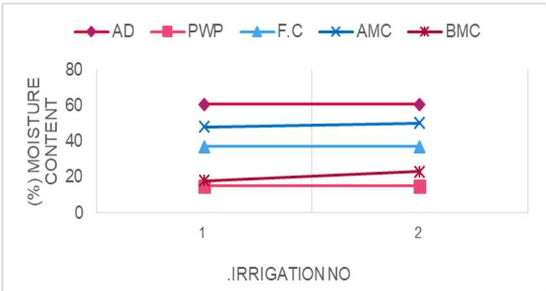

Figure 5: Pre and post-irrigation of the moisture content (by volume) in a field (B1) (11, 22-202 2to 5, 12-2023).

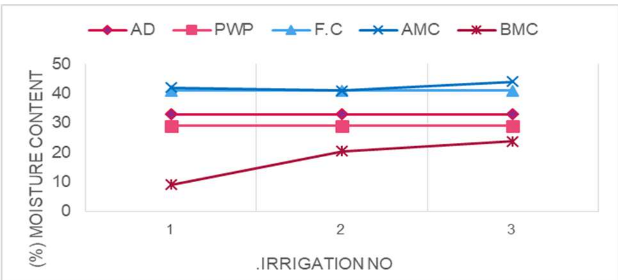

Figure 6: Pre and post-irrigation of the moisture content (by volume) in a field (B2) (11, 15-202 2to 5, 5-2023).

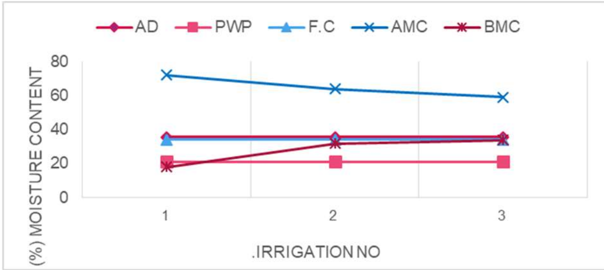

Figure 7: Pre and post-irrigation of the moisture content (by volume) in a field (B3) (11, 22-2022 to 5, 10-2023).

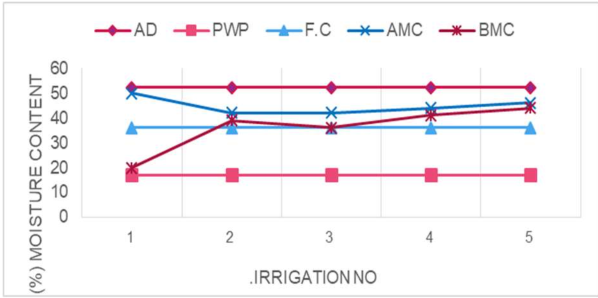

Figure 8: Pre and post-irrigation of the moisture content (by volume) in a field (C1) (11, 25-2022 to 5, 3-2023).

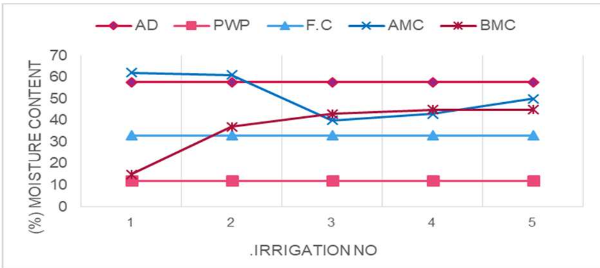

Figure 9: Pre and post-irrigation of the moisture content (by volume) in a field (C2) (11, 22-2022 to 5, 3-2023).

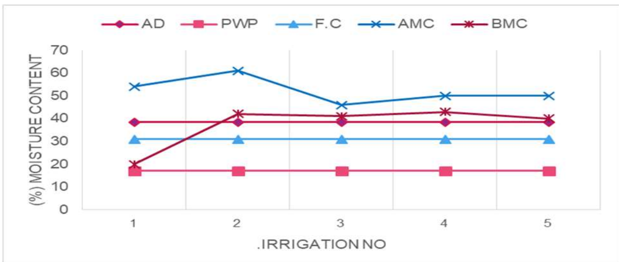

Figure 10: Pre and post-irrigation of the moisture content (by volume) in a field (C3) (11, 25-202 2to 5, 6-2023).

In all the fields, the moisture content before irrigation in fields A1 to C2 was below AD meaning the plants need water and irrigation cannot be deferred. Before irrigation, the parameter was higher than the AD starting from the second irrigation, which also indicates the fact that the farmer used more water than the plants required in field C3.

6.2 *Depth of Water Application, Retention, and Losses*

Irrigation management encompasses the measurement of applied depth, storage, and losses that one intends to make. That is, applied depth is the total water that is placed on the ground by irrigation. Storage as defined here is the water in the profile physically contained by the soil and chemically accessible to plant roots and utilizable in transpiration processes in leaves. Irrigation losses are water that is unavailable to plants including runoff, deep percolation, and evaporation losses. Effects on the quality of irrigation and sustainable farming can be minimized by paying more attention to these factors and putting in place the right means of controlling them. Stored depths are presented in figures 11, to 19 alongside the applied water and losses.

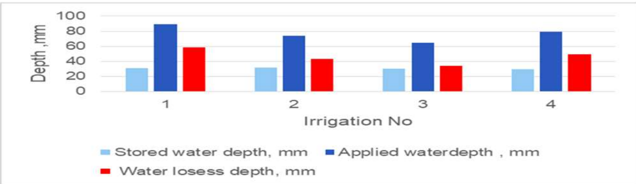

Figure 11: Depth of Water Application, Retention, and Losses for A1.

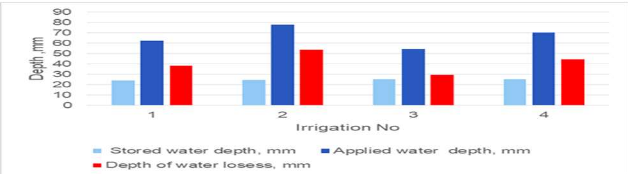

Figure 12: Depth of Water Application, Retention, and Losses for A2.

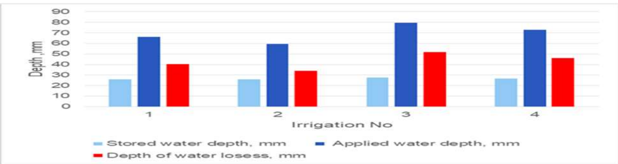

Figure 13: Depth of Water Application, Retention, and Losses for **A3.**

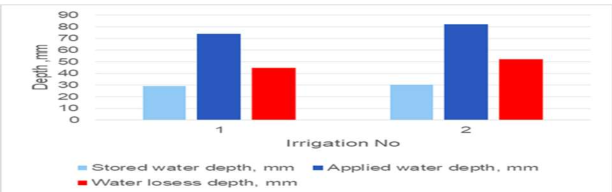

Figure 14: Depth of Water Application, Retention, and Losses for **B1.**

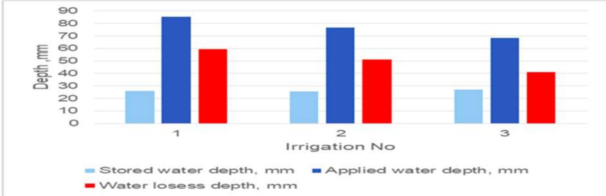

Figure 15: Depth of Water Application, Retention, and Losses for **B2.**

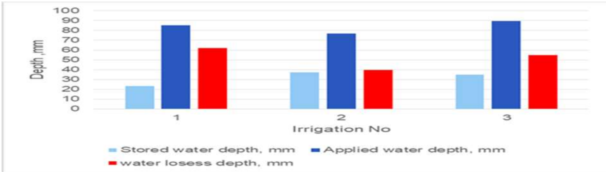

Figure 16: Depth of Water Application, Retention, and Losses for **B3.**

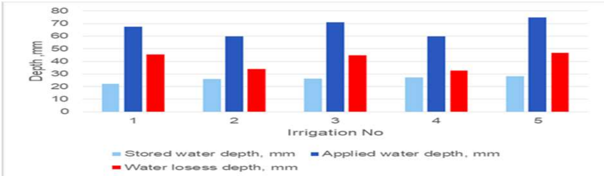

Figure 17: Depth of Water Application, Retention, and Losses for **C1.**

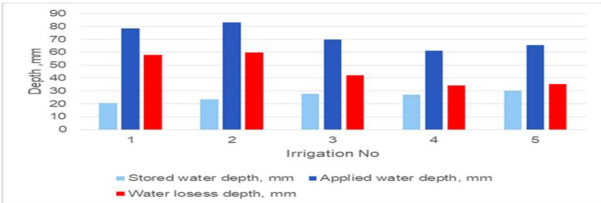

Figure 18: Depth of Water Application, Retention, and Losses for **C2.**

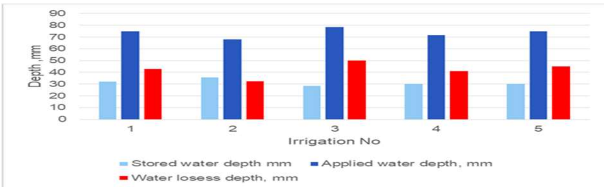

Figure 19: Depth of Water Application, Retention, and Losses for **C3.**

The losses varied between 50. 12 % and 64 % because of the differences in soil texture or because of the steepness and irrigation standards of the land. Regarding field B1, B2, and B3, the losses were closely estimated at 61 % and hence the similairity in soil and irrigation management. Fields C1, C2, and C3 lost from 57. 4 to 64%, thus, while slightly more variable, proved to have high deep percolation losses. Such high water losses indicate wastage of water, of which most of the water that is supplied to the crops is not utilized.

6.3 *Application Efficiency of Water*

Application efficiency in the Al-Daghara/Huryah farms was determined as the ratio of the depth of water at the root zone to the depth of water in the field from FAO, (1989). The mean efficiencies of each irrigation varied between 36.768% and 42.9%, which is appreciably low, thus meaning that just below half the supplied water is consumed by the crops effectively. Of particular inferential value is that the farmers are either over-irrigating or using water ineffectively as evident by high deep percolation, runoff, and evaporation losses. The individual application efficiency, which was calculated as the ratio of the required amount of water to the amount of water that was applied averaged 38.97 %, thus, confirming the need to enhance the irrigation practices among the farmers. It is possible to achieve the mean efficiency of application of 77.94% if the time needed for irrigation is reduced two times. Figure 20, 21, and 22 provide the application efficiency trends during various times of the irrigation.

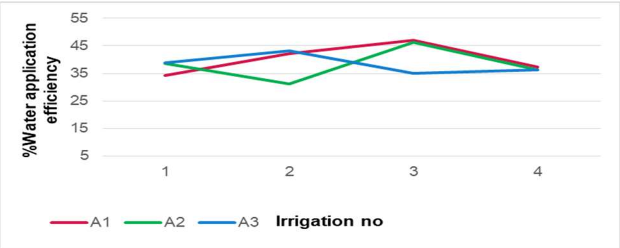

Figure 20: The direction of application efficiency curves for field A1, A2, and A3.

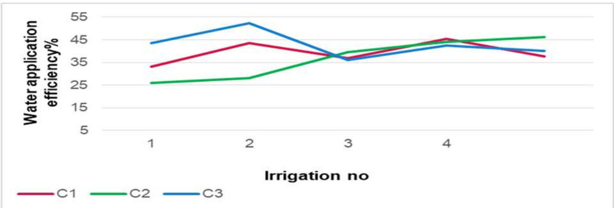

Figure 21: The direction of application efficiency curves for field C1, C2, and C3.

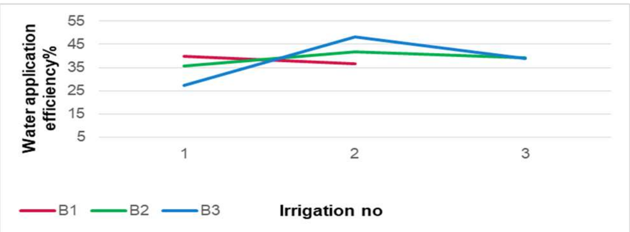

Figure 22: The direction of application efficiency curves for field B1, B2, and B3.

The lowest average application efficiency at the beginning of the project was in field A3 (38. 09%), in the middle at field B3 (38. 05%), and at the end at field C2 (36. 768%), likely due to over-watering. The highest average efficiency at the beginning was in field A1 (40. 21%), in the middle at field B2 (38. 89%), and at the end at field C3 (42. 9%).

6.4 *Water Storage and Distribution Efficiency*

The efficiency stored of the selected fields fluctuated from one project stage to another, whether at the start, mid, or end of a project. The reading also demonstrated that excess water was added to the solution. Initially, the average storage efficiency ratios were 72.19% (A1), 67. 95% (A2) and 74.24% (A3) at the beginning of the project. Moreover, at the middle, were 62.675% at B1, 50. 17% at B2 and 77.27% at B3. Finally, it reached 63.6 % in C1, 58.1 % in C2 and 56.5 % in C3. However, the mean storage efficiency of 64.7 % shows reasonable storage of water better irrigation and water management is still possible. Other distribution efficiency calculated totaled more than 90%, which considered excellent [Hansen, 1960], and, therefore, moisture and nutrients are evenly distributed within the root zones. Distribution efficacies for the items were average of 95. 75% (A1), 94. 75% (A2), 95. 62% (A3), 97. 25% (B1), 96. 6% (B2), 97. 6% (B3), 97. 5% (C1), 93. 9% (C2) and 97.2% (C3). Several aspects of the surface irrigation affected the trend towards the increased irrigation uniformity and they included the irrigation methods used.

6.5 *Conveyance Efficiency*

Conveyance efficiency is important in irrigation management as it indicates how enhanced water gets to the field in question from the source with minimal loses through seepage, evaporation, leakage etc. Thus, the high efficiency of the conveyance means more water is available for crops, and the chance of efficient irrigation is also raised. In the 2023 winter season, conveyance was characterized in the main canal, and the discharges were photographed with 50.195 m^3/sat 0+200 km and 43.36 at 63+000 km. Losses of water over this distance were 6.835 L/s or 0.58 m^3/s, the conveyance efficiency was estimated to be 86.38 % which was regarded as good [Halcrow, 1992]. The collectors revisited show an efficiency of 98% for distribution canals, while that of water courses was 97.5% as estimated by Al Fao for Engineering Consultation 1990.

6.6 *The Overall Project Efficiency*

To evaluate the overall efficiency of the Daghara/ Huriyh Irrigation Project, must be the average results of application, distribution and conveyance efficiencies are calculated.

Table 3. Shows the average irrigation efficiencies for the project in its Main canal as below.

Canal name	Field	Ea %	Av. Ea %	Ed %	Av. Ed %	Ec %	Eo %
Shat al Daghara	A1	40	38	95	96	86	35
	A2	38		94			
	A3	38		95			
	B1	38		97			
	B2	38		96			
	B3	38		97			
	C1	39		97			
	C2	36		93			
	C3	42		97			

The conveys performance level of the project was found to be average and was above 70%. Halcrow, (1992) established that the conveyance efficiency may be 90% – 70% for the lined and the unlined canals. Eisenhauer et al. (1997) argue that distribution efficiency should be greater than 60 percent. The lack of efficiency in resource allocation in the studied fields was not very evident since the distribution efficiency was very good as presented in table 4-2. FAO (1989) has stated that for application efficiency should lie in the range of 55% to 70% but unfortunately it was not so in the context of the project. As noted by Machibya et al. (2004), the efficiency of the surface irrigation in general should be between 50-60% (good), 40% (reasonable), while below 40% (poor). Further evaluating the above parameters, it was realized that the overall project efficiency is weak for the main canal as it is slightly below the acceptable limit. This sign suggests that there is poor water management, and that too much water is being sent to the fields. As for the development of more effective water management to decrease water wastage, it is pertinent that the actual crop water shortage in every plant be ascertained and the water applied should be checked against such amount.

6.7 *Virtual case*

As a result of environmental and climate changes, it is compulsory for the irrigation techniques also to evolve. Aqua Crop version 6 is a model developed by FAO that allows to assess crop yields as well as water possibilities under different irrigation systems. Due to incompetence depicted in border and furrow system of surface irrigation, it is warranted to adopt modern methods of irrigation. The application of these methods could ramp up the outcome of projects that demand such capacity – whether executed inside an organisation or under outsourcing with a third party. This type of irrigation that is deemed to cover eighty percent of the project area lose water relatively lesser and supply water more evenly. The remaining 20 percent must have some other type of soil, crop or some topographical issues that qualifies them to use drip irrigation that targets at eliminating leakage and distribution losses at plant root system. Regarding the expansion of the system, the relation of virtual efficiency and actual efficiency is provided in the table 4.

Table 4: The efficiency comparasion.

Field	*Actual Ea%*	*Virtual Ea%*		*Difference*
	Surface irrigation (Border)	*Sprinkler*	*Drip*	
A1	40.21	80.45	-	40.24
A2	38.09	79.97	-	41.88
A3	38.4	79.3	-	40.9
B1	38.15	79.75	-	41.6
B2	38.89	80.02	-	41.13
B3	38.05	80.32	-	42.27
C1	39.31	-	90.28	50.97
C2	36.768	-	90.3	53.532
C3	42.9	-	90.5	47.6

Surface irrigation requires a large amount of water for irrigation and it has many drawbacks such as evaporation, leakage and drainage and also it is not water saving because water is distributed unevenly on the fields. This tends to create one or the other extremity in terms of irrigation – over-irrigation or under irrigation. Current techniques of irrigation such as the drip and sprinkler systems make it easy to regulate the amount of water and nutrients to be delivered to crops hence improving their yields. Sprinkling can be less advantageous, as it loses water and allows weed growth, while drip irrigation lets the automated feeding to supplement the plants' nutrition and water supply.
In addition, the irrigated area was compared between the real and the virtual case as shown in Table (5) below.

Table 5: The selected fields area comparison.

Field	Av. time (hr.)	Av. Water vol.	Actual area	Virtual area	Virtual area	Difference
			Surface	Sprinkler	Drip	
A1	15	1534	8	16.4		8.4
A2	17	1493	9	18.5		9.5
A3	10	807	5	10.26		5.26
B1	19	1757	12	24.6		12.46
B2	17	1349	8	16.4		8.4
B3	18	1535	8	16.4		8.4
C1	17	1257	8		18.5	10.5
C2	16	1074	6		13.9	7.9
C3	16	1074	6		13.9	7.9

The findings have revealed that the sprinkler irrigation doubles the area that is irrigated in the same volume of water as surface irrigation while the drip irrigation increases, the agrarian area more than doubles it. Irrigable land extendable through modern irrigation techniques suc h as sprinkler and drip with irrigation water of 50, 196 m3/s can be extended to 237000 ha from the existing 107000 ha. A depiction of the real/not real difference is shown in the figure below.

7. Conclusion

The water application efficiency for fields A1 to C3 in the Daghara/Huriyh Irrigation Project is computed to be 76. 8 to 42.9% average which is about 38. 97 percent percent. These variations were as a result of factors such as, type of soil, methods of supplying water to the crops like irrigation and water quality. Efficiency of water use can be boosted through a better management and maintenance program. The average storage efficiency can be calculated as 64.7% with a range from lowest of 50. 17% to the highest of 77.27% it was established that efficiency was higher in area of better soil structure as well as the extent of efficient irrigation systems practiced. The average distribution efficiency was found to be 93.24% while that of the main canal was 79.41 %. Thus, water loss rates varied considerably, being the highest in fields C1, C2, and C3, while the lowest were in fields A1, A2, and A3. The general efficiency in the main canal in winter and summer was considered at 32.39% and 27.16% respectively or 29.775% on an average. The virtual application efficiency through the AquaCrop model estimated was 79.98% for sprinkler and 90.36% for drip irrigation in which the values are higher than Field application efficiency two times. Thus, sprinkler irrigation makes it possible to double the irrigated area, and drip irrigation – more than double it.

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تحسين أداء مشروع الري الحرية-الدغارة باستخدام نموذج Aqua-Crop

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الخلاصة –شهد العراق استنزافاً للمياه بشكل رئيسي بسبب تغير المناخ، وانخفاضاً في المياه. هناك على سبيل المثال مشروع ري الدغارة/الحرية، وهو مشروع زراعي واسع النطاق يشمل محافظة القادسية لحل قضايا إدارة المياه. تم تحديد عدة أهداف للدراسة، وهي تقييم تطبيق نظام الري المثبت حاليًا والتخزين والتوزيع في الحقول والقنوات والأداء العام للمشروع. تم تقييم تسعة حقول، ثلاثة (A1، A2، A3) في المرحلة الأولى، (B1، B2، B3) في الثانية و (C1، C2، C3) في المرحلة الثالثة على التوالي. وقد استلزم ذلك قياس إمكانات المياه فيما يتعلق بمحتوى الرطوبة والسعة الحقلية والتصريف. وبالتالي كانت كفاءة الري ضعيفة حيث قدرت بـ 36%. 768% و42.9% للأدوات المختلفة، بينما تتراوح كفاءة التخزين المقدرة بين 50.17% و77.47%، في حين تم تحديد هدف مكافحة التضخم عند 15%، ومستوى أسعار الاستيراد عند 26%، وكفاءة التوزيع عند 15%. بين 93%. 9% و97.6%. وكشف هذا أن كفاءة نقل المياه بلغت 86.38% بينما بلغت الكفاءة الإجمالية نحو استكمال المشروع 32% فقط. 39% لارتفاع الهدر من الري. لذلك، باستخدام نموذج AquaCrop، تم تقدير كفاءة الري الافتراضية باستخدام إجمالي الري بالرش بنسبة 80% وتخصيص الري بالتنقيط بنسبة 20%. ومن بين جميع تقنيات الري، وجد أن الرشاش هو الأكثر كفاءة، ويأتي في المرتبة الثانية بعده الري بالتنقيط (90.36%). وكانت الكفاءة الافتراضية التي تم اختبارها مع الرشاشات 68.39% ومع الري بالتنقيط 77.25%، وهي قريبة من اثنين وأبلغ المشاركون عن نصف الكفاءة الفعلية. ومن شأن هذا التحسن أن يرفع النسبة في المساحة المزروعة من 107000 إلى 239000 دونم لنفس حجم المياه.

الكلمات الرئيسية –"الري"، "كفاءة تطبيق المياه"، "الكفاءة الكلية"،" اكوا كروب".