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Evaluation of the Dagharah-Huriyh Irrigation Project

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ABSTRACT

This research evaluates the performance of the Dagharah-Huriyh irrigation project in Iraq and proposes managerial methods to enhance its operation. The study area is located in the Qadisiyah (formerly Diwaniyah) Governorate, along the Dahghara stream. The Dholmiya Canal, Hilla-Diwaniyah Irrigation Project, Diwaniyah-Shaafeyah Irrigation Project, and desert stretch along its north, west, and east borders. Fieldwork involved measuring water inflow, soil moisture content, and root zone depth. Nine fields were selected for the project, and their water application efficiency ranged from 37.33% to 67.12%. The average efficiency is approximately 56.45%, and the median efficiency is 57.9%. Field B2 and field C3 had low water application efficiencies of 37.33% and 46.45%, respectively. This indicates that farmers over-irrigated or mismanaged water in these areas, causing crops to lose a lot of water. Storage efficiency varied between 31.68% and 98%, while distribution efficiency exceeded 90% for all fields. Infrastructure upgrades, water management optimisation, and modern equipment and technologies are needed. These adjustments aim to reduce water losses, improve water use, and promote sustainable agriculture in the Dagharah-Huriyh irrigation project.

1. INTRODUCTION

The Daghara Project is a major agricultural project in Iraq's Al-Qadisiyyah Governorate. It is one of the region's main agricultural projects to improve water resource use and agricultural growth. This project helps grow several crops on thousands of acres. The Daghara area has a dry desert environment. Thus, irrigation is vital to farming. The facility gets its water from rivers and canals. The Daghara Project aims to improve local farmers' livelihoods, provide agricultural jobs, and boost crop production. The regional agricultural development plan relies on this initiative to achieve agricultural self-sufficiency. The Daghara Project, a regional landmark, conducts agricultural development and sustainable water resource management research. Understanding its history, goals, and limitations helps explain efforts to promote agriculture in dry places and handle water shortages. Water scarcity is a critical issue faced by many industries, including agriculture, water supply, and manufacturing. The rising global population and food demand have intensified competition for this limited resource [1]. Iraq, like other nations, is struggling with water scarcity caused by reduced river water, rainfall, and inefficient irrigation practices. To address this, the Al-Daghara/Huriyh irrigation project's performance must be evaluated to improve water management and efficiency [2]. Evaluating irrigation systems' efficiency, uniformity, and appropriateness is necessary, considering factors like climate change, population growth, and competing industries [3, 4]. Inadequate management leads to significant water losses, emphasising the need to assess water usage efficiency, especially in irrigation projects [4-6]. Effective performance evaluation considers water diversion, transport, application, and uniformity in the field [7, 8]. Optimizing water application efficiency is crucial for sustainable agricultural productivity and addressing water stress [9-11]. Assessing irrigation system efficacy is vital for long-term water management in agriculture. The findings can inform improvements for the Dagarah-Huriyh irrigation project [12]. Previous studies have highlighted various irrigation schemes and evaluated their performance indicators. For instance, Checkol and Alamirew [13] assessed the Geray irrigation scheme in Ethiopia, revealing canal conveyance efficiency and maintenance issues. Korkmaz and Avci [14] examined the water supply and irrigation performance of the Menemen Left Bank irrigation district, emphasising sufficiency, efficiency, dependability, and equity. Dessalew and Dar [15] evaluated the Bedene Alemtena small-scale irrigation scheme, focusing on application efficiency, distribution efficiency, and water productivity. Tesfaye et al. [16] assessed the Wosha and Werka irrigation systems, addressing agricultural production, water availability, and physical indicators. Geleto et al. [17] compared two community-managed small-scale irrigation systems in terms of conveyance efficiencies, application efficiencies, and irrigation uniformity. Kibret et al. [18] evaluated the Dirma small-scale irrigation programme, highlighting conveyance efficiency, application efficiency, storage efficiency, and total efficiency. Mosawi and Al Thamiry [19] examined the Elaj irrigation project in Iraq, considering overall effectiveness, water consumption efficiency, the economic productivity of water, and water application efficiency. Abbass and Al Thamiry [20] find out that higher water contents lead to larger wetted diameters and depths. The wetted diameter shows an inverse relationship with the saturated hydraulic conductivity, whereas the wetted depth displays a direct correlation with the saturated hydraulic conductivity. Al Masraf and Salim [21] highlighted the potential of SWRT membranes for optimizing crop productivity and water management in challenging soil conditions. Abdullah and Almasraf [22] demonstrated that subsurface water retention technology enhanced crop production by effectively storing rainwater. Sadeq Hameed and Al Thamiry [23] evaluated project efficiency, distribution, and conveyance. Excessive water consumption caused deep penetration and water loss. In a field experiment, Mushab and Almasaf [24] demonstrated that SWRT membrane troughs below the root zone enhance agricultural production and water efficiency. Al-Saadi and Al-Thamiry [25] assessed and improved Shatt Al-Diwaniya and its diversion canal, boosting discharge capabilities and water management. Al-Mosawey and Abed [26] used WaterGEMS to simulate and evaluate water network parameters and chlorine levels. Alsaffar and Al-Thamiry [27] descaling boosts discharge. A good system reduces deposits. Hydraulic models and gate closures help the pumping system overcome buildup, low flow, and climate. Lastly, Hameed and Al-Thamiry [28] assessed the Al-Ishaqi irrigation project in Salah al-Din Governorate, Iraq, focusing on water application efficiency, field water use efficiency, and distribution efficiency. This study aims to evaluate irrigation project effectiveness by analyzing factors such as moisture content, allowed depletion, field capacity, and wilting point. By comparing results across fields, success in providing adequate water while minimizing waste will be determined. The evaluation aims to identify issues, improve irrigation practices, optimize water usage, and ensure optimal plant growth conditions.

2. STUDY AREA

Dagharah-Huriyh is a partially developed irrigation project located in Qadisiyah Governorate, Iraq. It is bounded by the Dholmiya Canal to the north, the Hilla-Diwaniyah Irrigation Project to the south, the Diwaniyah-Shaafeyah Irrigation Project to the west, and a desert area to the east. The main conveyance sources for the project are the Daghara and Huriyh canals, along with the Dholmyia and Sharifiya canals. The project area is divided into six sectors, each with a different length and discharge capacity for its main canal. The project covers the Afak, Daghara, Somar, Sanya, and Al-Bdair districts, with a total area of 635,000 dunum and a developed irrigated area of 207,000 dunum. The area has flat topography and fine to medium soil characteristics, with no evident signs of erosion. Shatt Al-Daghara, a branch of Shatt Al-Hilla, runs through the project area, with 19 streams branching from it. The Daghara regulators, Huriya means head regulator, Sharifia means head regulator, and various cross regulators control the flow of water within the system. The project is widely regarded as a highly significant irrigation development endeavor, embracing several dimensions, including economic and social elements. The aforementioned statement delineates the agricultural aspect of the region situated in the floodplain area, which is distinguished by an arid desert environment. In this particular geographical context, the practice of rainfed agriculture is impractical owing to the limited and unpredictable precipitation patterns. Hence, the project functions as the fundamental basis for facilitating agricultural activities inside Iraq.

3. MATERIAL AND METHOD

3.1 Field selected

To assess the irrigation efficiency of the Al-Daghara/Huriyh project, a comprehensive evaluation was conducted on a sample of nine farms. The selection of these fields was based on their distance from the main project canal. The objective was to analyze the actual irrigation practices employed by the farmers without any intervention or modification to the existing irrigation methods. These selected farms were strategically located within the area irrigated by the main channel and its associated branches, ensuring a representative assessment. The specific coordinates of each farm are detailed in Table 1, providing precise information for reference and analysis purposes.

Table 1. The farm's location

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

3.2 Sample collection

Soil samples were procured both prior to and after the irrigation process using a hand auger and core for collection. These samples were obtained at different depths, namely 0-25 cm, 25-50cm, and 50-100cm, as per the recommended root zone depth guidelines provided by FAO. The soil samples were collected during the morning period. The soil samples containing varying moisture levels were carefully extracted, weighed, and subsequently subjected to controlled drying in an oven. In order to evaluate the moisture content, the initial assessment of the soil samples was carried out before the commencement of irrigation. Following the irrigation event, the same sampling locations and depths were revisited the subsequent day to measure the moisture content at that particular point in time.

3.3 The characteristics of the soil of the fields

Samples of soil have been procured from designated regions, with a focus on two depth ranges (0-50cm and 50-100cm) to ensure a complete representation of the root zone. Within the soil depth spanning 0-100cm, noticeable variations in soil characteristics were observed, indicating differences in moisture levels and organic composition. To analyze these properties comprehensively, a series of rigorous laboratory tests were conducted at the College of Agriculture, Baghdad University. These experiments entailed quantifying the water content at the permanent wilting point (PWP) and field capacity (F.C.) in terms of volume and assessing soil texture. Soil texture was assessed using the triangular method. This approach determines soil texture based on the proportions of sand, silt, and clay. These proportions are depicted on a triangular diagram, and the soil type is determined by the point representing the soil content. To determine field capacity, soil samples are saturated with water and then gently drained. Field capacity represents the soil's water retention after complete drainage and is typically expressed as a percentage. The permanent wilting point is the soil moisture level at which plants stop growing and are unable to extract any more water. This value is also determined experimentally by drying the soil and monitoring its moisture content. The outcomes derived from these tests are presented in Table 2, which provides a detailed overview of the results obtained in order to improve soil texture, field capacity, and permanent wilting point.

Table 2. The laboratory results

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

where, AV. FC is the average field capacity and AV.P.W.P. is the average permanent welting.

3.4 Measurement of a root zone

To ascertain the optimal root zone depth for the wheat crop in the experimental field, a systematic methodology was employed. The approach involved a randomized selection of three plants, considering the anticipated depth and radius parameters, followed by meticulous measurements of the depth of the root during every irrigation occurrence, employing a precise measuring tape. This methodology was chosen due to the inherent complexities associated with accurately determining the root zone depth, which can be influenced by a multitude of factors and variables. By adopting this systematic approach, the researchers aimed to obtain reliable and representative data regarding the wheat crop's root zone depth within the experimental field.

3.5 Inflow measurement

To accurately quantify the inflow into the field and address outlets without gates and weirs, a Venturi flume was deliberately positioned at the onset of the canal. This specialized device operates by inducing a critical depth through the manipulation of the hydraulic grade line, thereby facilitating the estimation of discharge. By carefully measuring the water levels at both the source and throat of the Venturi flume, the discharge can be precisely determined. Experimental measurements were conducted to determine the coefficient specific to the Venturi flume device, resulting in a coefficient value of 0.98. The selection of the Venturi flume as the primary measurement tool was a result of a meticulous evaluation process. In contrast to several alternative measurement devices, such as orifice plates or weirs, the Venturi flume offers distinct advantages in terms of precision and reliability. Its capacity to accurately measure water flow across a wide spectrum of flow rates, coupled with minimal head loss, rendered it the most suitable choice for our specific research requirements. Furthermore, the Venturi flume exhibits consistent performance even in the presence of varying water quality and sediment content, thereby ensuring the utmost reliability in our data collection process. The provided illustration visually represents the process of measuring the inflow into the field using the Venturi flume. Figure 1 shows venturi flume. In order to calculate the discharge accurately, an equation proposed by Cone in 1917 [29] is employed, ensuring robust and reliable calculations:

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

where, Q represents the discharge, C denotes the coefficient of discharge, B_1 represents the width upstream (in meters), B_2 represents the width throat (in meters), Y_1 signifies the depth upstream (in meters), Y_2 signifies the depth throat (in meters), H represents the depth difference (Y_1-Y_2), and g denotes the acceleration due to gravity

Figure 1. Measuring study area discharge via a Venturi flume

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 determination of moisture content was conducted through the utilization of the mathematical equation posited by Musa et al. [30]:

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

Moisture content (P_w) was ascertained by considering the weights of both moist soil (W_t) and solid soil (W_s), as well as the weight of water (W_w), utilizing the specified formula. Furthermore, the weight ratios of moisture content values were transformed into volume ratios, which were represented as P_v:

$$P_v = P_w A_s \quad (3)$$

The calculation of soil moisture content (P_w) was based on the consideration of the soil's specific gravity (A_s), which is known to exhibit variations based on the soil texture. The moisture content that was computed was subsequently converted into a water depth with the intention of utilizing it in Eq. (2). To ascertain the moisture content at particular depths, the depth of soil (D) was extracted using an auger and subsequently multiplied by the volume percentage (P_v).

$$d = \frac{P_W}{100} * A_s * D \quad (4)$$

The water depth within the root zone, denoted as 'd', was measured both before and after irrigation, while 'D' represents the depth of the root zone itself. To determine the total water depth present in the root zone, the cumulative fraction of crop consumptive intake was computed until the time of soil sample collection following irrigation.

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

The accumulation of water within the root zone is expressed as 'd_n', while 'E_{tc}' denotes the consumptive water use by the crop during the time between the pre-irrigation and post-irrigation sample times.

Thus, soil moisture is its water content. It is important because it tells if the soil is wet enough for plant development. Monitoring moisture content prevents over-irrigation (which wastes water and leaches soil) and under-irrigation (which lowers crop production).

4.2 Depth of water applied

The average depth of water applied to the irrigation system was determined by the following equation:

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

where, Q represents the flow rate of water (in cubic meters per minute), T is the duration of irrigation (in minutes), A is the area of the field (in square meters), and d_g is the average depth of applied water (in millimeters).

Applied water depth measures irrigation water delivery. This characteristic directly affects crop growth and production, making it critical. Accurate measuring ensures crops receive enough water for maximum development without waste.

4.3 Water application efficiency

As recommended by FAO [5] the efficiency of the application was determined using the following formula:

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

The water application efficiency (E_a) is calculated as the ratio of the water stored in the root zone (d_n) to the total depth of water applied in the field (d_g), expressed as a percentage.

Efficiency evaluates how well irrigation water is supplied to fields and used by crops. In water-scarce areas, increased water application efficiency reduces irrigation water losses.

4.4 Water distribution efficiency

According to FAO, the uniformity of water application along the irrigation run can be assessed by evaluating the consistency of water application to the land.

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

The average water penetration (d) and average variation from the required depth (y) determine water distribution efficiency (E_d).

Field irrigation water distribution efficiency measures how evenly irrigation water is distributed. The lack of equal distribution can cause overwatering and underwatering, which in turn affects crop health and output. Evaluating this parameter may necessitate changes to the irrigation system.

4.5 The efficiency of water storage

The concept of storage efficiency pertains to the efficacy of water storage in the root zone in relation to the corresponding water demand within the given region. According to the FAO [5], a mathematical definition is provided as follows:

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

The water storage efficiency (E_S) is expressed as a percentage and is determined based on the root zone's water requirement in the course of a single irrigation event (d_s).

Soil water storage efficiency measures irrigation water retention. Effective soil storage allows the soil to retain water longer, minimizing irrigation and assuring crop development.

5. RESULTS AND DISCUSSION

5.1 Measurement of moisture content

The measurement of moisture content plays a vital role in evaluating the effectiveness of irrigation practices. In this study, an investigation was conducted to examine the changes in moisture content across selected farms within the designated research region from November 1, 2022, to February 1, 2023. Figures 2 to 10 illustrate the disparity in moisture content levels before and after irrigation events, highlighting the field capacity (FC) and permanent wilting point (PWP) thresholds, as well as the available water (AD) parameter. As indicated by Eq. (5), AD was employed as a criterion to determine the adequacy of water supply based on the categorization guidelines recommended by FAO (1989). It is worth noting that farmers in the research area possess limited expertise in assessing AD and often rely on historical knowledge and the water supply provided by the project to make informed decisions regarding irrigation. In instances where the moisture content of the soil falls below the permanent wilting point (PWP), the soil may become arid, thereby hindering the crop's capacity to uptake water. The difference observed between field capacity (FC) and permanent wilting point (PWP) indicates the amount of water that is accessible for the crop's utilization. Figures 2 to 10 present the moisture content pre and after each irrigation by volume in the selected fields.

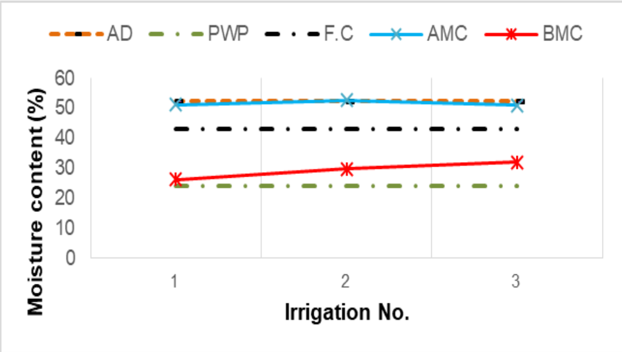

Figure 2. A1 field moisture volume prior to and the following irrigation

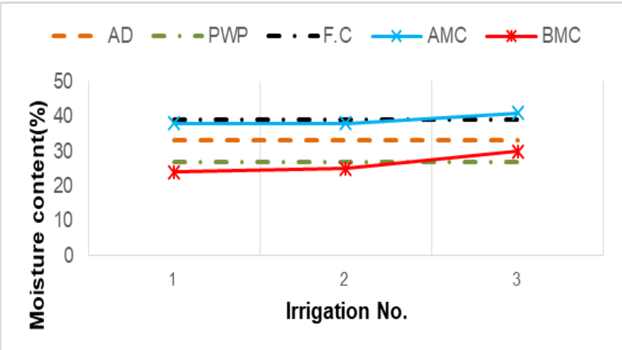

Figure 3. A2 field moisture volume prior to and the following irrigation

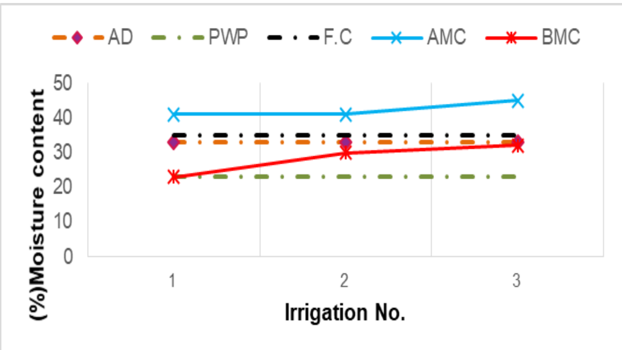

Figure 4. A3 field moisture volume prior to and the following irrigation

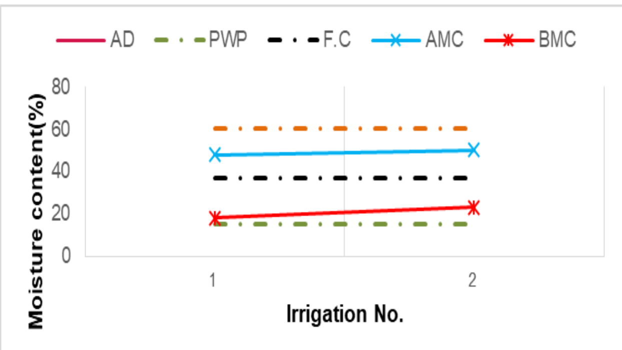

Figure 5. B1 field moisture volume prior to and the following irrigation

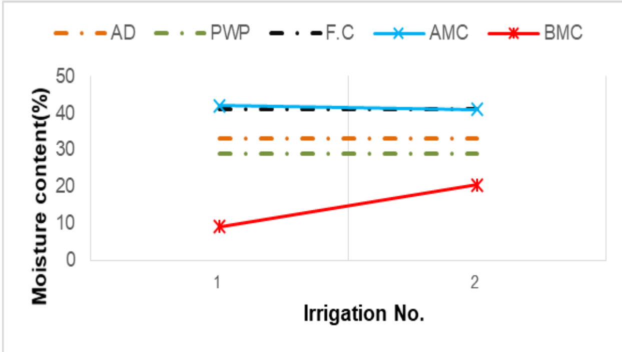

Figure 6. B2 field moisture volume prior to and the following irrigation

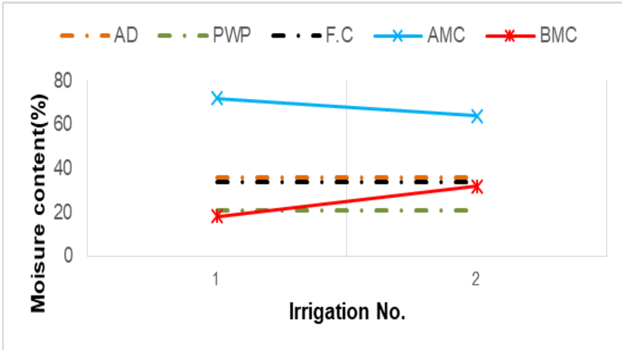

Figure 7. B3 field moisture volume prior to and the following irrigation

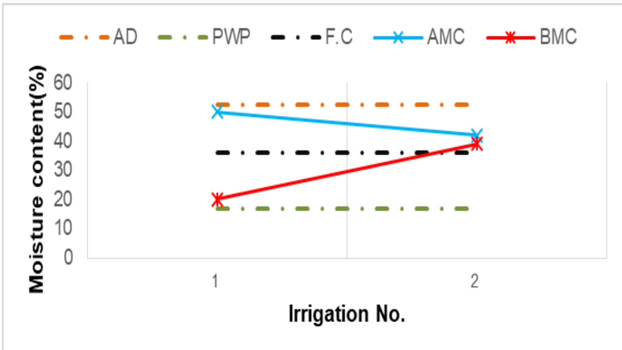

Figure 8. C1 field moisture volume prior to and the following irrigation

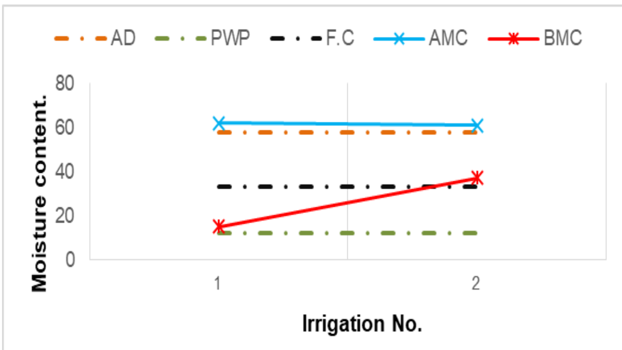

Figure 9. C2 field moisture volume prior to and the following irrigation

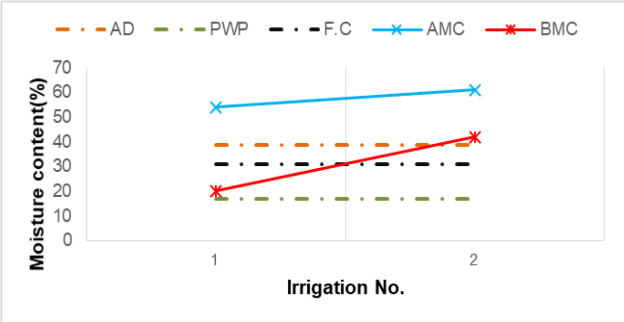

Figure 10. C3field moisture volume prior to and the following irrigation

In this study, the evaluation of irrigation projects revealed the following findings across the nine fields. Fields A1, C1, and C2 have sufficient moisture content, but the allowed depletion is high, indicating potential over-irrigation, meaning that the farmer may be providing more water than the plants require. Field A2 shows generally adequate moisture content, but there is a slight decrease after the third irrigation and Field A3 exhibits appropriate moisture content after irrigation, indicating that the farmer is providing an adequate amount of water for the plants. Fields B1, B2, B3, and C3 indicate sufficient moisture content, but the allowed depletion suggests under-irrigation, meaning that the farmer may not be providing enough water for the plant's needs.

5.2 Depth of water applied

The outcomes show that farmer applies varying amounts of water during each irrigation in different fields. Some fields receive substantial amounts of water, resulting in significant water storage in the soil. However, there are noticeable decreases in the water storage depth after irrigations in certain fields, indicating water loss or drainage. In other fields, the water storage depth and application are moderate, suggesting a reasonable amount of water provision. However, there are variations in the water storage depth after irrigations, indicating potential water loss or inefficient water retention. Overall, it is recommended that the farmer assess irrigation practices, implement water conservation measures, and optimize irrigation amounts to minimize water losses and ensure efficient water usage. The following diagrams illustrate the water being used depth, water storage depth, and water losses for the selected fields in the study area. Figures 11 to 13 present the irrigation application, storage and water losses in each field.

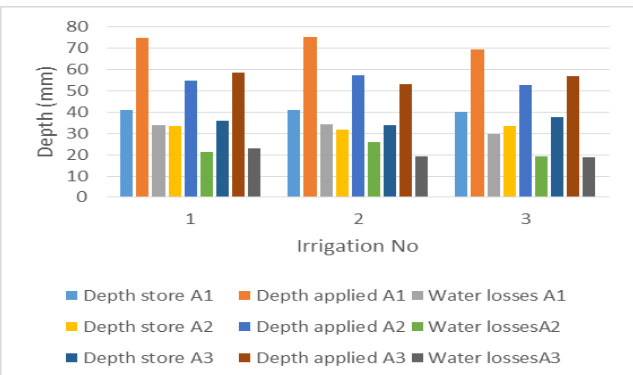

Figure 11. Fields A1, A2, and A3 irrigation application, storage, and water losses

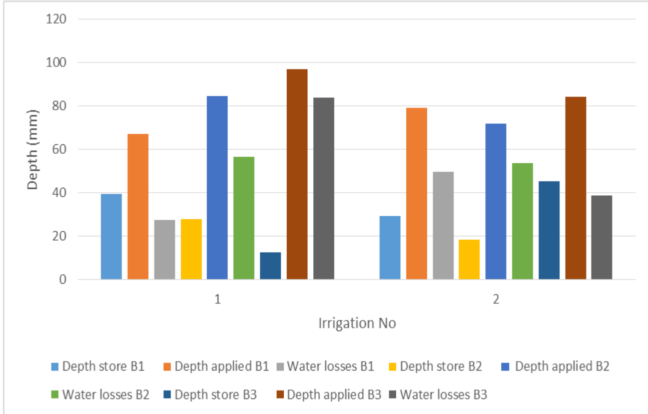

Figure 12. Fields B1, B2, and B3 irrigation application, storage, and water losses

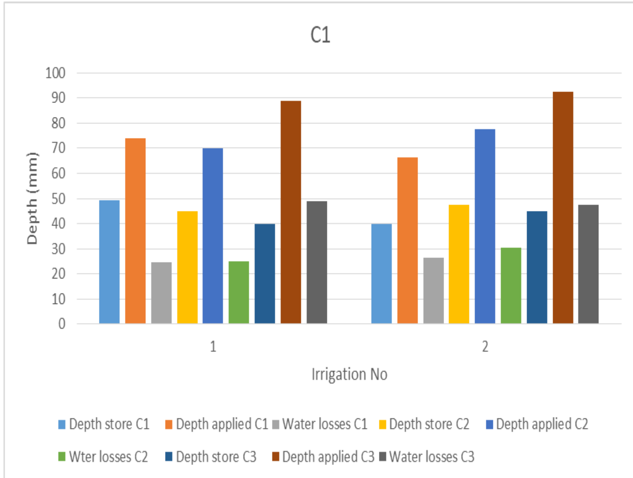

Figure 13. Fields C1, C2, and C3 irrigation application, storage, and water losses

5.3 Efficiency in the storage and distribution of water

In fields A1, A2, and A3, the storage efficiency ranged from 51.07% to 89.11%, 54.42% to 90.46%, and 45.9% to 91.39%, respectively. These values suggest that in some cases, the amount of water delivered to these fields exceeds the actual water requirement, indicating a potential for over-irrigation. For fields B1, B2, and B3, the storage efficiency ranged from 57.67% to 85.49%, 81.37% to 95.56%, and 60.36% to 91.3%, respectively. These values indicate a relatively better balance between water delivery and requirement, suggesting a more efficient use of water in these fields. In fields C1, C2, and C3, the storage efficiency ranged from 31.68% to 98%, 42.5% to 97%, and 33.48% to 83.8%, respectively. These values indicate a wider variation in storage efficiency. Some fields may receive more water than necessary (potential over-irrigation), while others may not receive enough water (potential under-irrigation). Field distribution efficiencies on average at the project's beginning, middle, and end were 98.8%, 98.5%, and 98.6%, respectively, indicating successful water distribution using surface irrigation. The water was uniformly distributed, resulting in minimal losses and optimal efficiency. These exceptional efficiencies underscore the effectiveness of surface irrigation in uniformly and efficiently delivering water to the crops according to FAO [5]. The following diagrams depict the efficacy of water retention and dispersal in agricultural areas. Figures 14 to 16 present the water storage and distribution efficiency in each field.

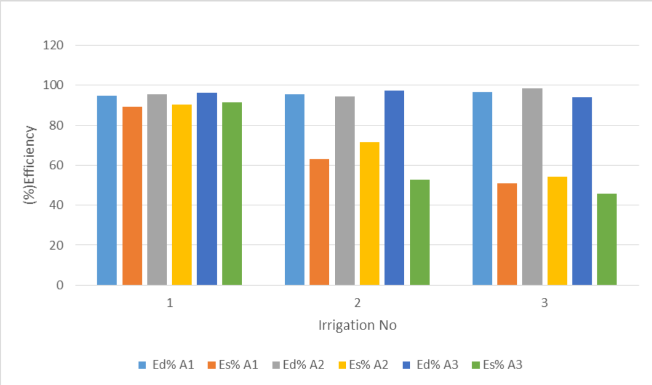

Figure 14. Fields A1, A2, and A3 water storage and distribution efficiency

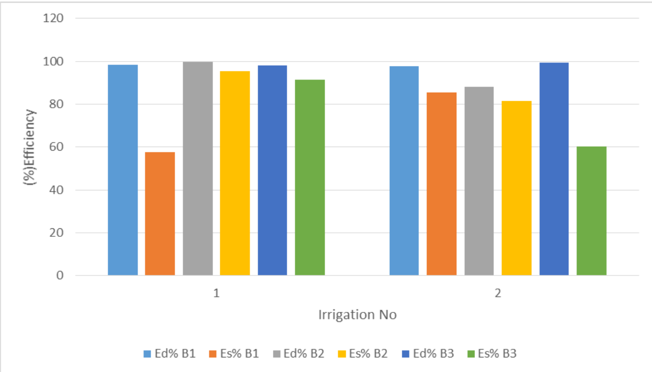

Figure 15. Field B1, B2, and B3 water storage and distribution efficiency

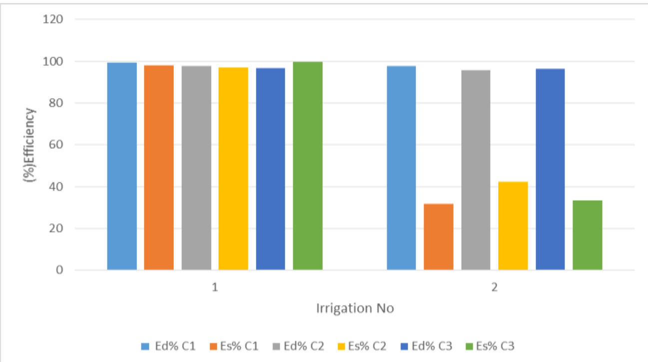

Figure 16. Field C1, C2, and C3 water storage and distribution efficiency

5.4 The efficiency of water application

The effectiveness of water application for the Al-Daghara/Huriyh irrigation project was calculated by comparing the applied water depth to the field with the depth of water introduced into the root zone. Results for fields A1, A2, and A3, B1, B2, and B3, and C1, C2, and C3, which were irrigated using surface irrigation, were approximately 58.44%, 57.9%, and 67.12%, 55.26%, 37.33%, and 51.12%, and 59.09%, 63.8%, and 46.45%, respectively. Fields A1, A2, A3, B1, B3, C1, and C2 demonstrate water use efficiency within an acceptable range for surface irrigation. However, field B2 and field C3 exhibit unacceptable rates, indicating significant water losses in these fields. To enhance water application efficiency, develop a suitable irrigation schedule based on crop needs and soil moisture. This minimizes losses and maximizes efficiency. Employ modern technologies like drip irrigation for precise and controlled water delivery, reducing wastage and improving overall efficiency in agriculture. Application efficiency curve rates sectors are shown from Figures 17 to 19 below.

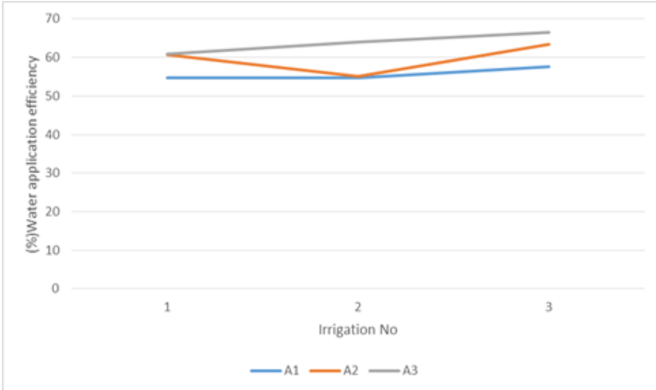

Figure 17. A1, A2, and A3 application efficiency

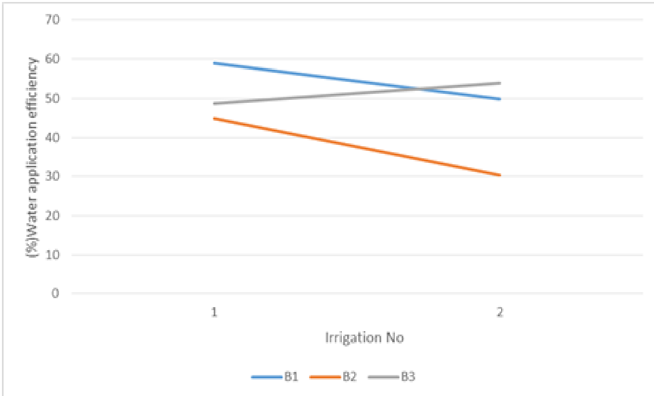

Figure 18. B1, B2, and B3 application efficiency

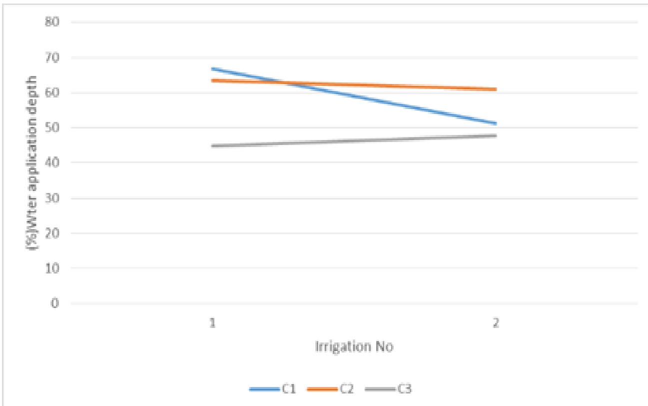

Figure 19. C1, C2, and C3 application efficiency

6. CONCLUSION

The following are the key findings derived from measuring and analyzing all the fieldwork and study outcomes:

i. Tailored Irrigation Practices: The wide variation in water application efficiency, ranging from 37.33% to 67.12%, highlights the need for tailored irrigation practices. Farmers should be provided with guidance on optimizing water usage, ensuring that neither over-irrigation nor under-irrigation occurs.

ii. Improved Water Management: Fields A1, A2, and A3 demonstrate potential over-irrigation, while Fields B1, B2, B3, and C3 indicate more efficient water usage. Fields C1, C2, and C3 display variations in storage efficiency, suggesting a need for improved water management strategies. Implementing better water management practices can help optimize water use.

iii. Moisture Monitoring: Continuous monitoring of soil moisture content is recommended to provide real-time data on soil conditions. This will enable farmers to make informed decisions regarding irrigation scheduling and water application rates.

iv. Distribution Efficiency: The consistently high water distribution efficiency, averaging 98.6%, indicates the success of surface irrigation methods. This method should continue to be employed and possibly expanded to further optimize water distribution.

v. Educational Outreach: Farmers in the project area should receive educational outreach on modern irrigation techniques and best practices. This can help them make more informed decisions about water usage and irrigation scheduling.

Future research can delve deeper into the economic and environmental impacts of implementing recommended improvements. Additionally, investigating the feasibility and benefits of transitioning to alternative irrigation systems, such as automated and sensor-based approaches, could be a valuable area of study.

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NOMENCLATURE

F.C	Field capacity (% by volume)
P.W.P	Permanent wilting point (% by volume)
BMC	Moisture content before irrigation (%)
AMC	Moisture content after irrigation (%)