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Evaluation the Western Canal of Al- Ishaqi Irrigation Project

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ABSTRACT

The water scarcity that Iraq suffers from and the low irrigation efficiency in irrigation projects, therefore, it was necessary to evaluate the performance of the irrigation system of the western canal for the Ishaqi irrigation project in Salah al-Din Governorate to determine the water management strategies that can be used to improve the irrigation efficiency in the project. The performance of the field irrigation system was evaluated on two fields of different crops and irrigation methods according to the agricultural reality of the study area in the Western canal for the Al-Ishaqi Irrigation Project in Salah Al-Din Governorate. The fieldwork included measurements of the moisture content before and after irrigation, field capacity, and measuring the inflow of each field using a venturi flume to find the discharge inside the field and measuring the depth of the root during the growing season. The field measurements showed that the actual average water application efficiency for field W1, which is irrigated with the Border irrigation system is 36.1%, and in field W2, which is irrigated with the furrow irrigation system is 26.8%. As for the water distribution efficiency, the average distribution efficiency for fields W_1 and W_2 was about 98.8% and 98.4%, respectively. Field measurements showed that the actual conveyance efficiency of the western canal is 93.1%. The overall project efficiency for the western canal was 28.3%. The results of this evaluation conducted in the western canal t revealed that farmers are using more water than required, resulting in a large amount of water loss in the fields by deep permeation observed in this study due to inefficient use, poor irrigation schedule, and lack of knowledge and skills sufficient farmers have in managing water.

Keywords: Irrigation, Water application efficiency, Water losses, Overall Efficiency

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تقييم الجدول الغربي لمشروع ري الاسحاقي

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الخلاصة

أن ندرة المياه التي يعاني منها العراق بسبب نقص المياه الواردة من مصادر الانهار وقلة الامطار وتدني كفاءة الارواء في مشاريع الري لذلك توجب اجراء تقييم لأداء منظومة الري لجدول الغربي لمشروع ري الاسحاقي في محافظة صلاح الدين من أجل تحديد استراتيجيات ادارة المياه التي يمكن استخدامها لتحسين كفاءة اداء نظام الري. تم تقييم اداء منظومة الري الحقلي على حقلين لمحاصيل وطرق ري مختلفة حسب الواقع الزراعي لمنطقة الدراسة في الجدول الغربي للمشروع . تضمن العمل الميداني تحديد المحتوى الرطوبي قبل وبعد الري والسعة الحقلية وقياس التدفق الداخل للحقل باستخدام مجرى فنشوري لمعرفة عمق المياه المطبقة داخل الحقل وقياس عمق الجذر خلال موسم النمو. أظهرت القياسات الحقلية ان متوسط كفاءة تطبيق المياه الفعلية للحقل W_1 الذي يروى بمنظومة الري الشريطي هي 36.37 % و في الحقل W_2 الذي يروى بمنظومة الري بالمروز هي 26.3 % . كما بلغ متوسط كفاءة التوزيع للحقول W_1 , W_2 98.8% و98.4% على التوالي . وبينت القياسات الحقلية ان كفاءة النقل الفعلية لجدول الغربي هي 93.1%. وكانت كفاءة المشروع الاجمالية لجدول الغربي هي 28.3 %. كشفت نتائج هذا التقييم الذي تم إجراؤه في مشروع ري الإسحاقي أن المزارعين يستخدمون مياهًا أكثر مما هو مطلوب ، مما أدى إلى فقد كمية كبيرة من المياه في الحقول عن طريق التغلغل العميق بسبب الاستخدام غير الفعال وسوء جدولة الري ونقص المعرفة والمهارات الكافية لدى المزارعين في ادارة المياه .

الكلمات الرئيسية: الري , كفاءة تطبيق المياه , خسائر المياه الري , الكفاءة الاجمالية .

1. INTRODUCTION

Water scarcity and global climate change are issues that most countries are dealing with today. As for Iraq, the country is currently experiencing a catastrophic water deficit due to the lack of water from river sources and rainfall, and this problem is likely to become more severe in the future, especially in areas where the flow of the Tigris and Euphrates rivers . This problem will certainly worsen in the future, (**Almasraf and salim**). It is necessary to take good and fast steps to achieve a strategic vision for water management and to improve water use through the use of modern irrigation systems, technologies, methods, and agricultural processes, (**AL Mosawi and Al Thamiry, 2022**). The evaluation of water use efficiency has become very important to determine the amount of water lost and the actual need for water, especially in irrigation projects to determine its efficiency. Many irrigation projects, particularly large-scale irrigation projects, are performing far below their potential performance, (**Murray-Rust and Snellen, 1993; Alcon et al., 2017**). This is mostly because of ineffective resource management, a lack of anticipated benefits, and negative effects on human health and the environment**,** (**Biswas, 1990**). The necessity of analyzing irrigation systems to determine their efficiency, consistency, and sufficiency to other performance metrics **(Latif and Ahmad, 2008)**. More emphasis is being placed on guaranteeing effective irrigation water utilization for optimum economic profit and the long-term sustainability of water supply. To continuously expand and maintain agricultural productivity, optimal crop water management is required for greater sustainability **(Webster, 2014)**. The objective of evaluating irrigation system performance is to ensure that resources are used more efficiently and effectively by providing appropriate feedback to management at all levels **(Small and Svendsen, 1992)**. Performance indicators are quantifiable factors that show how irrigation systems currently function and how they have changed over time and space **(Dumanski and Pieri, 2000; Mayer, 2008)**. Water distribution standards and irrigation efficiency have recently become critical for modern agricultural activities. Irrigation systems with high efficiency are better when compared to those with lower efficiency. Evaluating irrigation performance illustrates a practical education to stakeholders on how things work and what the system can do effectively to enhance the effectiveness of irrigation systems. Thus, it should be an assessment of the performance of irrigation schemes to check the status of systems and the level of water use efficiency **(Clemmens and Molden, 2007)**. Improving water use efficiency for irrigation and increasing productivity through different systems is one of the economically feasible alternatives to overcoming water shortage. Creating irrigation systems that use water and energy resources more effectively for various crops and agricultural operations is one of the top objectives in agriculture today. Thus, evaluating existing design rules and standards is essential for effective designs. Evaluating the effectiveness of an irrigation system is critical in improving long-term farming water management.

This work aims to determine the overall irrigation efficiency of the canal and provide the correct recommendations to increase the irrigation efficiency in the project and its effective management.

2. METHODOLOGY AND METHOD

2.1 The Study Area

Al-Ishaqi Irrigation project is situated within the central region of Iraq and the administrative borders of the governorates of Salah al-Din and Baghdad. as represented in **Fig. 1.** study area is situated inside 34⁰04'50" and 33⁰29'38"N latitude and 44⁰27'13" and 43⁰58'28"E longitude. The project's total area is 171,750 hectares, and the irrigated area is about 94,764.5 hectares. The mean annual rainfall of the project is 161.8 mm, with the maximum rainfall amount occurring in Jan. The mean daily minimum and maximum temperature vary between 4.1–25.6 °C and 13.7–46.5 °C, respectively. The relative humidity of the study area varies between 27.8 and 78.5%. The wind speed is lowest in December (1.27 m/s) and highest in March (3.1 m/s). The sunshine hour shows a large variation (6–12.5 h/day). The soil of the agricultural lands in the project is silt loam, loam, and sandy loam. The irrigation methods used in the project are surface, pump, drip, and sprinkler irrigation. The main irrigation network in the Al-Ishaqi irrigation project consists of the main canal and the eastern and western canals, from which secondary canals branch.

2.2 Fields Selected under Study

The evaluation of the Al-Ishaqi irrigation project needs to find the actual irrigation efficiency in many farms. Two farms are chosen to evaluate the irrigation performance inside them as accomplished by the farmer (he practices it in the current reality without guidance or change in the irrigation process). The selected fields, W1 and W2, are located within the lands irrigated by the western canal at the beginning and mid of the canal. **Fig. 2.** shows the locations of the selected fields in the study area, and **Table 1**. gives the details of the fields listed.

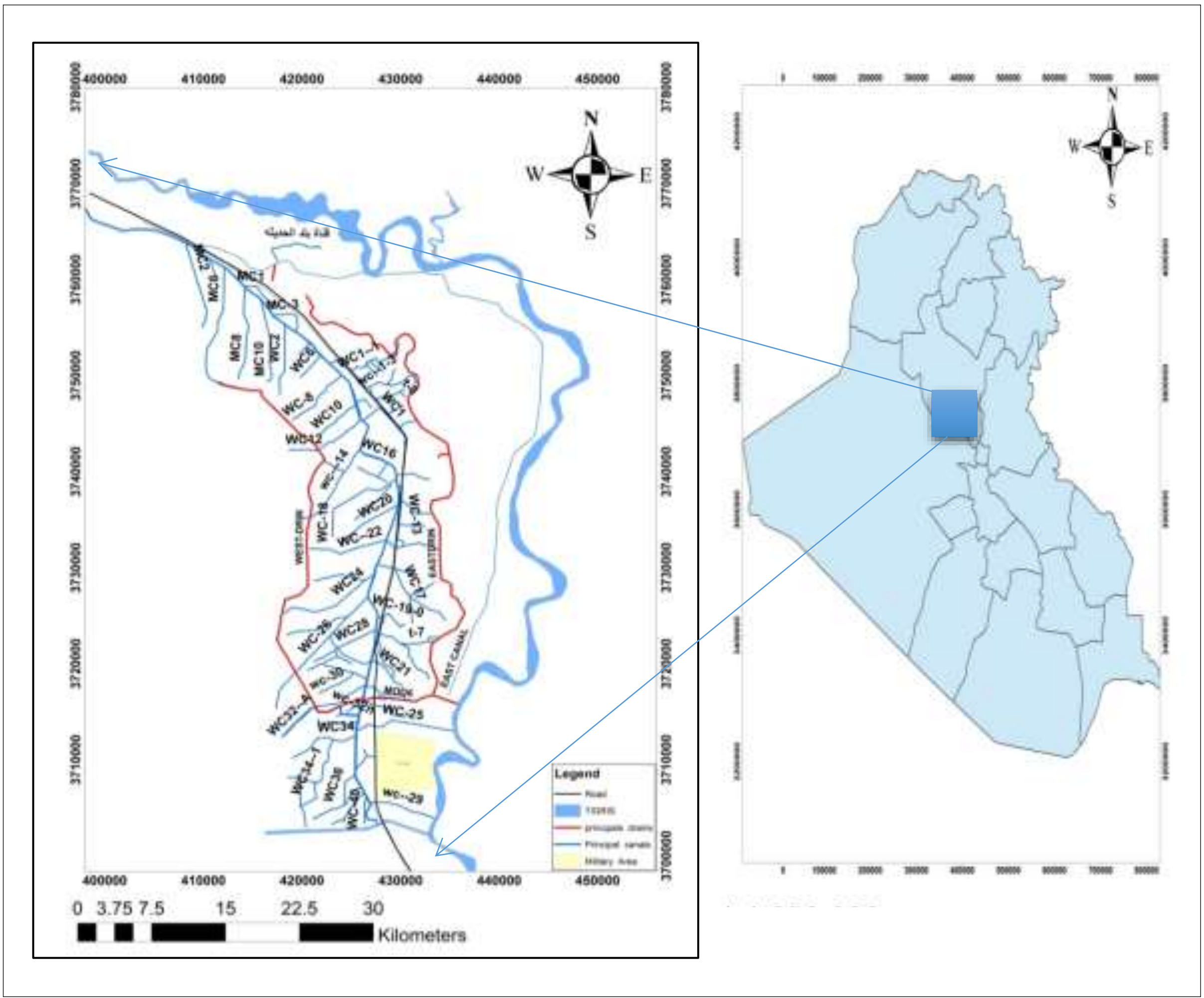

Figure 1. Location map of Al-Ishaqi irrigation project for the Western canal. (**Directorate of Al-Isahqi irrigation project, 2022).**

Table 1. The information of the fields selected study area

Fields selected	Station km	Crop	Irrigation method	Fields size(don)	No. of Irrigation under observation
W1	05+640	Wheat	Border	6	4
W2	29+800	Garlic	Furrow	1	5

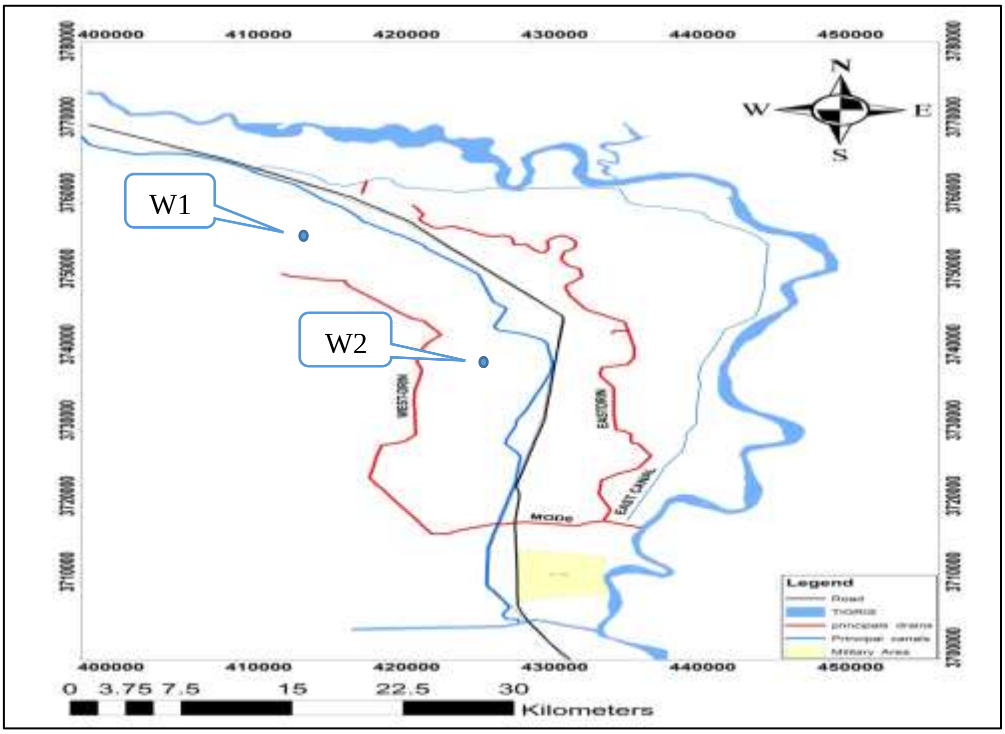

Figure 2. Show the location of the selected field within the Al Ishaqi irrigation project.

2.3 Soil Characteristics of Fields

Soil samples were taken from the selected fields with a 0-50 cm depth and 50-100 cm to cover the expected depth of the root zone. The test of water content at field capacity (FC), permanent wilting point (PWP) (by volume), and Soil texture was conducted at the laboratory of Tikrit University, College of Agriculture. The bulk density test was in the field using the core**. Table 2.** Shows Laboratory results for soil (soil texture, field capacity, permanent wilting point, bulk density**)**.

Table 2. Soil characteristics of the selected fields within the study area.

Fields selected	Depth of soil (cm)	Soil texture	Bulk density (g/cm^3)	FC (%)	PWP (%)
W1	0-50	Loam	1.58	48.7	12.12
	50-100	Loam	1.63	43.22	13.04
W2	0-50	Silt Loam	1.46	46.59	10.15
	50-100	Silt Loam	1.45	47.35	12.69

2.4 Inflow Measurement

Due to the absence of gates and weirs at the outlets of the fields and the difficulty of knowing the pump discharge to know the volume of water entering the fields, a Venturi Flume is placed at the entrance of the channel entering the field. A Venturi duct is an open, critical-flow duct with a confined flow that creates critical depth by causing a drop in the hydraulic gradient line. Discharge was measured using Venturi Flume by measuring the height of the water in the source and the other in the throat. The coefficient for the used Venturi Flume device was found by measuring the discharge in an experimental field by volume method and Venturi flume, and the coefficient was 0.98. Flow rates were measured in each irrigation. The irrigation rate for the field (W1) irrigated by the pump was 20.02 lps, Equal to almost every irrigation. The flow rates in the field (W2) irrigated by Surface irrigation were varies between (14.8-22.1 lps). **Fig. 3**. Shows the measurement of the discharge using a Venturi Flume. The discharge is calculated from Eq. (1) (**Cone, 1917**):

$$Q_{c}= CB_2y_2\sqrt{\frac{2gH}{1-(\frac{B_2y_2}{B_1y_1})^2}} \tag{1}$$

where

Q_c is the discharge (m^3/sec) .

C is the coefficient of discharge .

B_1 is the width upstream (m)

B_2 is the width throat (m) .

$y_1$is the depth upstream (m)

y_2 is the depth throut (m) .

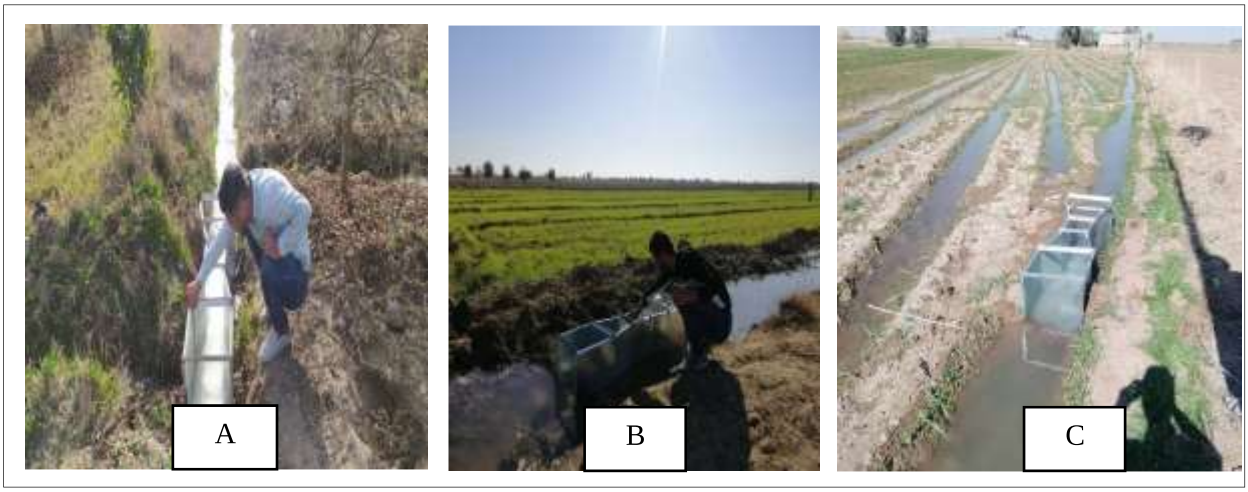

Figure 3. Measurement of the discharge using a Venturi Flume in the study area. (A) The Experimental field, (B) W1, and (C) W2

2.5 Sample Collection

Soil samples were taken immediately before irrigation from three locations, one in the first third, the second in the middle third, and the third in the last third. A hand auger and core bore to varying depths; 0-25, 25-50, and 50-100 cm. It was taken according to the depth of the root zone. To keep the samples of damp soil moist, they were put in a bag and tightly sealed. The samples were measured and dried in an oven. The moisture content was determined before irrigation. On the next day after irrigation, soil samples were taken from the same locations and previous depths to determine the moisture content after irrigation.

For better usage in the water application equation, moisture content % measurements are translated to depth units **(Egharevba, 2009).**

2.6 Measuring the Depth of the Plant's Root

Because accurate measurement of the root zone is difficult due to various variables, it is often assumed or inferred. The root zone of selected crops (wheat, garlic) is measured practically in the experimental field by cutting randomly selected plants considering the expected depth and radius. Each irrigation's root depth is measured using tape **(FAO, 1989).**

3. Evaluation of Various Efficiencies

3.1 Moisture Content and Depth of Water Stored

The moisture content was calculated using the following mathematical formula (**Musa et al., 2016):**

$$P_w=\frac{W_w}{W_s}\times 100 \qquad (2)$$

Where P_w is Moisture content (by weight), W_t is the weight of moisture soil, W_s is the weight of solid soil, and $(W_t\text{-}W_s) = W_w$ is the weight of water.
The amount of moisture can be transformed from weight ratios to volume ratios P_v, such as:

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

where, As, the soil's specific gravity (This differs depending on the categorization of the soil's texture).
The calculated moisture content was translated into water depth so that the numbers in Equation 2 could be used. The soil moisture content was calculated based on the depth by multiplying the percentage volume (Pv) by the soil depth (D) extracted by the auger.
Thus:

$$d =\frac{p_w}{100}\times A_s\times D \qquad (4)$$

where **, d** is the depth of moisture in the root zone before and after irrigation, **D** is the depth of a root zone.
Similarly, the depth total of water held in the root zone was determined by adding the proportion of crop consumptive consumption until the time to take a soil sample after irrigation, as shown below:

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

where dn is the total depth of water stored in the root zone, Etc is the consumptive use of the crop for the period between sample time before and after irrigation **(Israelson et al., 1944).**

3.2 Depth of Water Applied

The following equation was carried out to calculate the average depth of applied water from the irrigation system which was used in the fields:

$$Q * T = d_g * A \tag{6}$$

Where:
Q is the flow rate (m^3/min),
T is the time of irrigation (min),
d_g is the average depth of applied water (mm),
A is the area of the field (m^2).

3.3 Application Efficiency

The following relationship was used to compute the water application efficiency, according to (**FAO, 1989)**:

$$E_a = \frac{d_n}{d_g} \times 100 \tag{7}$$

Where $\mathbf{E_a}$ is Application efficiency (%), $\mathbf{d_n}$ is the root zone's depth where water is stored (mm), and $\mathbf{d_g}$ is the Total depth of water applied in the field (mm).

3.4 Distribution Efficiency

The efficiency of water distribution refers to the uniformity and consistency of the water distribution within the root zone. It is used to evaluate a single irrigation system by studying the consistency of water distribution. The mathematically efficient distribution is as follows:

$$Ed = \left(1 - \frac{Y}{d}\right) \tag{8}$$

where:
E_d is water distribution efficiency,
d is the depth of water stored in the soil, and **Y** is the average deviation (the numerical mean of deviation) from the average depth of soil-stored water.

3.5 Water Storage Efficiency

Storage efficiency refers to the efficiency of water storage in the root zone relative to the water that this area is needed, and it is expressed mathematically as:

$$Es = \left(\frac{d_n}{d_s}\right) \times 100 \tag{9}$$

where:
Es is the water storage efficiency (%),
ds is the water depth the root zone needs during one irrigation (mm) (**FAO,1989).**

3.6 Conveyance Efficiency

It is the ratio between the amount of water leaving the canal to the amount of water entering the canal, and the following relationship gives it:

$$Ec = \frac{Q2}{Q1} * 100 \quad (10)$$

where:
Ec is the conveyance efficiency (%),
Q_1 is the amount of water entering the system (m^3/s),
Q_2 is the amount of water leaving the system (m^3/s) at the source (**Hansen, 1960).**

4. RESULTS AND DISCUSSION

4.1 Moisture Content

Moisture content is an important input for evaluating irrigation efficiency, where has calculated change in the moisture content of irrigations of the selected farms within the study area and during the period from 1st of Nov. 2021 to 20th of Apr. 2022, **Figs. 4 and 5** show the change in moisture content before and after irrigation for all irrigations for each farm and also shows the (FC) and (PWP) levels and the allowed depletion management (AD). The (AD) was used as a benchmark for determining whether the applied water was sufficient based on (FAO,1989) guidelines for each category. The farmers in the study area are not familiar with (AD) but rely on their experience and the availability of water in the project to determine the irrigation times. The water accessible to the crop is indicated by the difference between (FC) and (PWP), and when the moisture content is less than PWP, the soil becomes dry, and the crop can no longer draw water from the soil. The level of moisture content before irrigation for field W1 was below the allowed depletion level (AD) during the monitoring period, as shown in **Fig. 3.** As for farm W2, the level of moisture content before irrigation was below too the allowed depletion level (AD) and near the permanent wilting point (PWP) during the observation period of 6 months as shown in **Fig. 4**. This means that the plant was under the pressure of moisture which is expected to negatively affect the yield. It was noted that there is a variation in the moisture content as it was applied at different levels during the study period, which means that the farmer used water without specific calibration or irrigation scheduling, and also because of the lack of water constantly to adopt the Rotational system in the project.

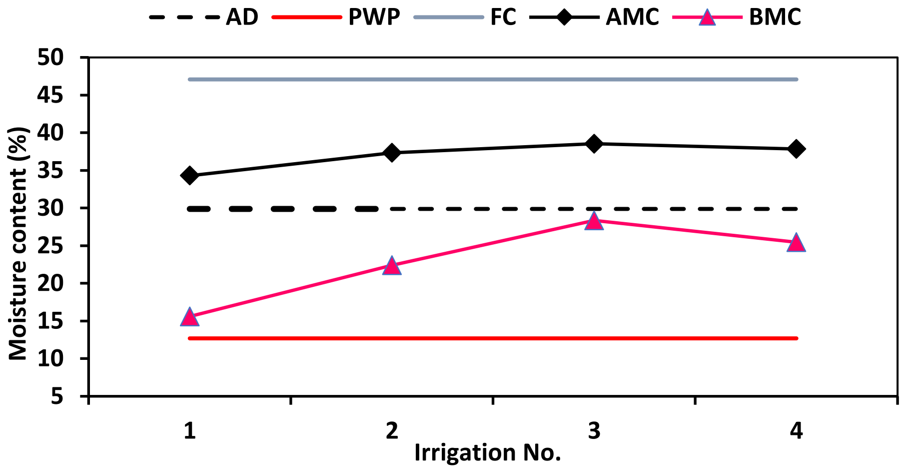

Figure 4. Relationship in moisture content before and after irrigation (by volume) for the effective root zone in field W1 (12th of Nov. 2021 to 8th of Apr . 2022).

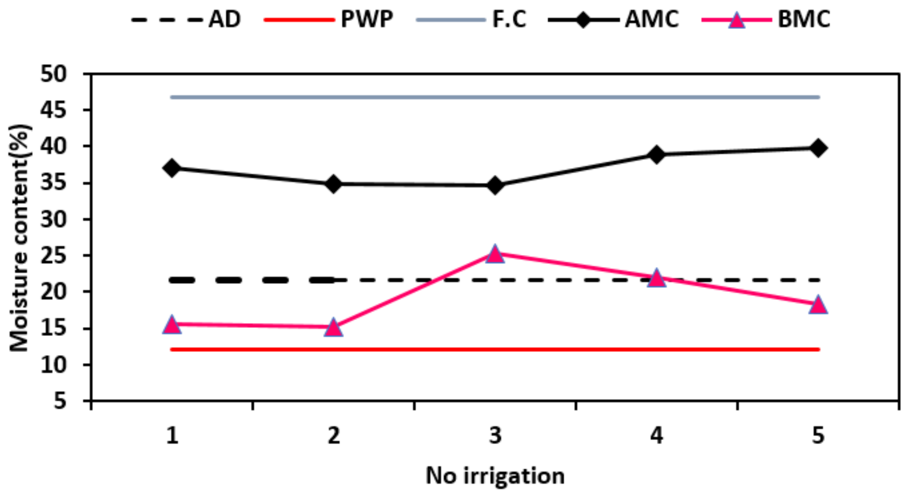

Figure 5. Moisture content variation before and after irrigation (by volume) for the effective root zone in field W2 (1st of Nov. 2021 to 20th of Apr. 2022).

4.2 Depth of Applied Water

The applied water results conducted in the selected farms show that the water farmers use is higher than the needed water. The average depth of water applied in field W1 was 93.9 mm, and the stock in the effective area was 39.05 mm, while 54.84 mm was deep percolation, which is about 58.4% of the amount of water lost in this field. As for field W2, a large percentage of water was lost, especially in the first irrigations of plant growth, by about 72.8 %. All of this can be attributed to the excessive application and unwise use of farmers' insistence on filling the border and furrow to the upper edge and the expectation. More water means more productivity and the effect of soil texture, land slope, and type of border and furrow used by the farmer in the study area. Another reason is that the farmer in each irrigation applies water in approximately the same quantities, which indicates that the farmer is not aware of the water requirements of the cultivated plants. **Figs 6 and 7**.

show the applied water depth, stored depth, and water losses for the selected farms W1, and W2 within the study area.

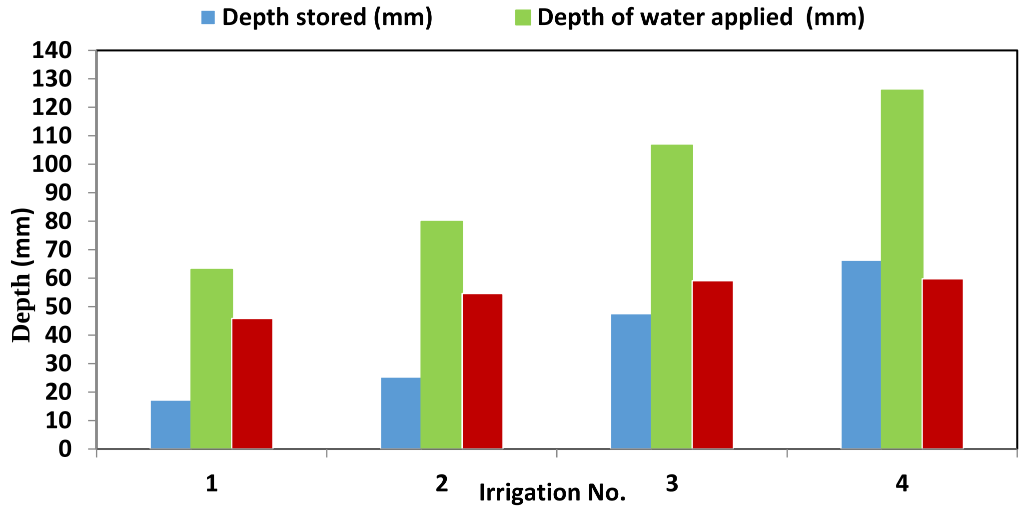

Figure 6. Depth of applied water, depth stored, and water losses for all irrigation in farm W_1 (12th of Nov. 2021 to 8th of Apr. 2022).

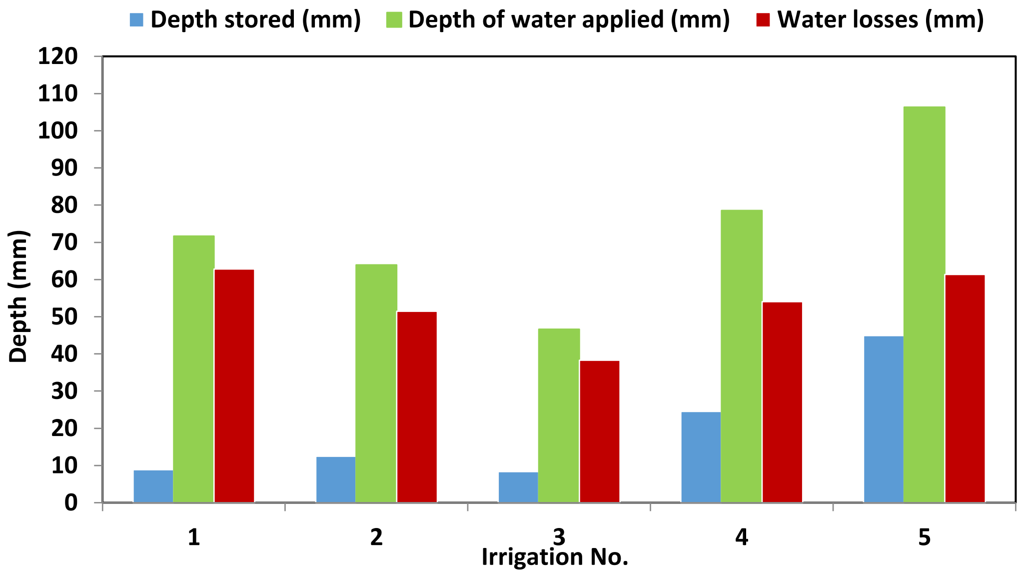

Figure 7. Depth of applied water, depth stored, and water losses for all irrigation in field W2 (1st of Nov. 2021 to 20th of Apr. 2022).

4.3 Water Storage and Distribution Efficiency

Calculation of the storage and distribution efficiencies based on the fields measurements showed that the amount of water added to the fields is greater than the needed water, as the field water storage efficiency values for fields W1 and W2 ranged between (52.1 to 60.97%), (43.95 to 86.19%), respectively. As for the efficiency of water distribution for all fields, it was above 90% and is classified as excellent (**Hansen, 1960)**. Results indicate the extent of the uniform water distribution along with the flow as a result of flooding the entire fields with water, which helps the uniform irrigation. The average distribution efficiencies for fields W1 and W2 were about (98.77%), and (98.39 %), respectively**. Figs 8** and **9**. show the efficiency of water storage and distribution in fields W1 and W2. The irrigation methods used in the selected fields in the study area (surface irrigation) help to increase irrigation uniformity due to adding large quantities of water but at the expense of other irrigation efficiencies.

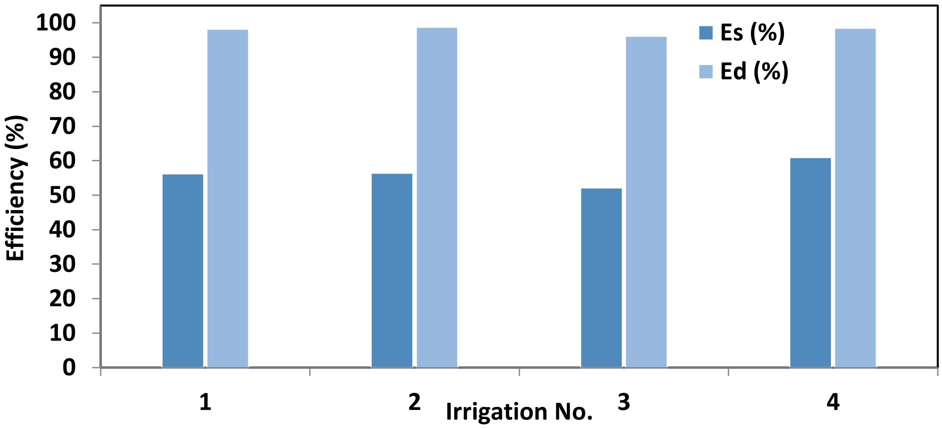

Figure 8. The efficiency of water storage and distribution for field W_1.

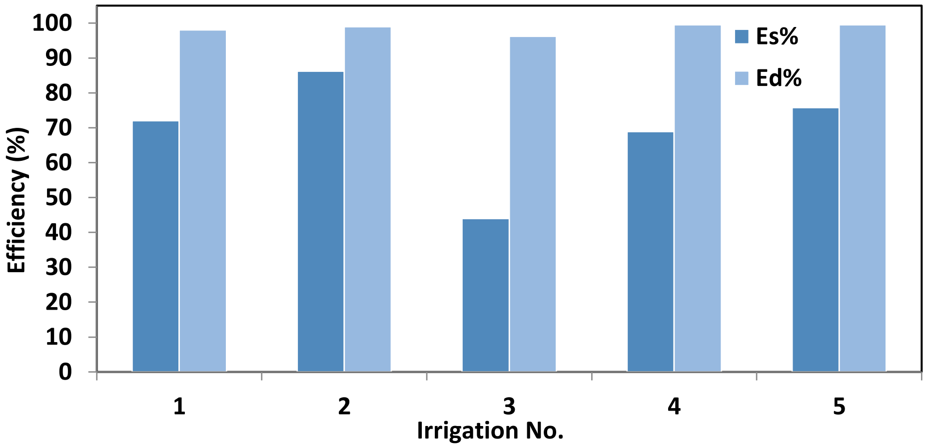

Figure 9. The efficiency of water storage and distribution for field W_2.

4.4 Water Application Efficiency

The water application efficiency in the selected farms for the Al-Ishaqi irrigation project for the western canal was calculated from the ratio of the water added to the root zone to the amount of water applied in the field. Where the field measurements showed the actual water application efficiency for field W1, which was irrigated with furrow, about 36.51%, this value is not within the range of water use efficiency which is allowed for surface irrigation (furrow and borders irrigation systems), that is, 40 - 60% as listed by (**FAO, 1989). Additionally**, the actual average application efficiency of water in field W2 irrigated with the borders, is about 26.32%. The results of the efficiency of water application that was conducted in the study area show that farmers use water more than the actual demand for the plant's need, so it was possible to increase the efficiency of field water application by simply controlling the irrigation time and making it, for example, 3 hours instead of exceeding 5 hours. This process alone is enough to raise the irrigation efficiency from 37% to 60%, but the insistence of the farmer to fill the furrow and border to their upper edges led to a decrease in the irrigation efficiency as a result of the increase in the volume of water that used by them. **Fig. 10** .shows the trend of the application efficiency curves for the selected fields and reveals the increase in application efficiency after the 1st irrigation due to the increase in the root zone and a decrease in the water infiltration rate in the soil**.**

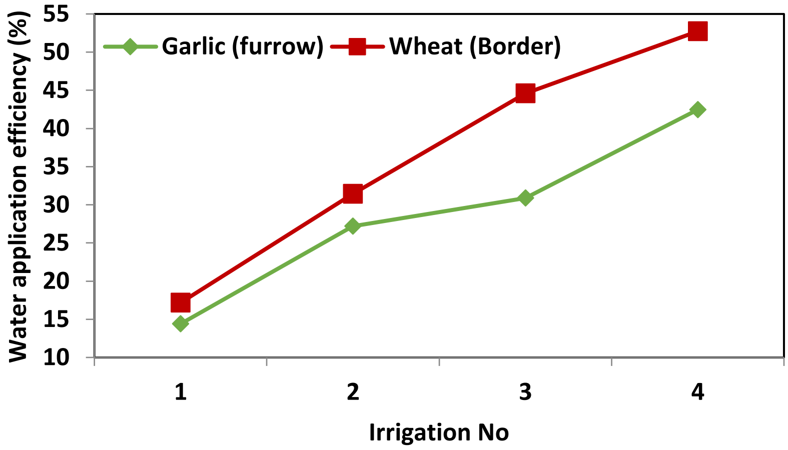

Figure 10. The direction of the curves for the application efficiency to the fields W1 and W2 (1st of Nov. 2021 to 20th of Apr. 2022).

4.5 Conveyance Efficiency

Determining water losses in irrigation canals is important to verify the losses resulting from seepage. The conveyance efficiency for the main and western canals was checked during the winter season of 2022. In the western canal, two sections were chosen to measure the discharge across the canal. As for the western canal, the first discharge measurement at station 4+170 was equal to 29.42 m^3/sec, and the other discharge was 23.23 m^3/sec at Station 11+00. The total outlet expenditures between stations 4+170 and 11+900 are 4.15 m^3/sec, so the losses are about 2.04 m^3/sec. The conveyance efficiency of the western canal is 93.0 %. It is a relatively high conveyance efficiency for earth canals. The reason for low losses despite being the unlined canal is that the canal has taken a stable situation, and the nature of the soil and sedimentation at the bottom and sides of the canal led to decreased seepage. The conveyance efficiency of secondary canals is 98%, and the conveyance efficiency of the water course is 97.5%, Directorate Al-Ishaqi Irrigation, 2022. The total conveyance efficiency adopted in preparing the designs of the Al-Ishaqi irrigation project is 75%. This means that the project's western and secondary channel can accommodate a discharge greater than the design discharge. **Table 3** shows the details of the conveyance efficiencies calculation.

Table 3. The details of the conveyance efficiency calculation for canal western

Fields selected	Monitoring station	Date	Station km	Discharge m^3/s	Conveyance efficiency Ec (%)
W1	P_1	Mar.14-2022	04+170	29.4	93.1
W2	P_2		11+600	23.2	

4.6 Overall Project Efficiency

The performance of the Al-Ishaqi Irrigation Project for the western canal was evaluated on the water supply based on average distribution, application, and conveyance efficiency results. **Table 4.** shows the average irrigation efficiencies for the project in its western canal. The overall irrigation efficiency of the western canal is 28.3%. So, it means high amounts of water are lost in the project due to poor water management in the study area. It was noted that water was applied in the fields without considering the amount of water used and the time specified for its use. The results showed that the overall irrigation efficiency of the western canal is weak since it is below the acceptable limit.

Table 4. Irrigation efficiencies in the Al-Isahqi project

Field	conveyance efficiency [%]	Application efficiency [%]	Distribution efficiency [%]	The overall efficiency [%]
W1	93.0	36.4	98.8	28.7
W2		26.3	98.4	

5. CONCLUSIONS

The results of the irrigation efficiency assessment conducted in the Al-Ishaqi Irrigation Project show that farmers are using water more than the actual water demand. This leads to water loss in the farms detected in this study due to unwise use. The percentage of losses in fields W_1 and W_2 is 58 and 72.98%, respectively. If the current situation persists, the Groundwater will likely rise, and the sustainability of the irrigation system will be threatened. According to the field visits to the project, there is no systematic way to distribute water rations during the planting season in the Al-Ishaqi irrigation project. There is a water shortage in the areas of the irrigation canal end. On the other hand, there is a surplus of water in the farms located upstream of the secondary and sub-canal. Moreover, there are excesses due to taking water directly from the canals by installing special pipes on the heads of the canals.

NOMENCLATURE

FC	Field capacity (% by volume)
PWP	Permanent Wilting Point (% by volume)
BMC	Moisture Content before Irrigation (%)
AMC	Moisture Content after Irrigation (%)

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