Kurdish Studies
Feb 2024
Volume: 12, No: 2, pp.5553-5563
ISSN: 2051-4883 (Print) | ISSN 2051-4891 (Online)
www.KurdishStudies.net

Received: December 2023 Accepted: January 2024
DOI: https://doi.org/10.58262/ks.v12i2.411

Evaluation of an Irrigation Project; A Case Study the Main Canal Part of Al Khachiya Irrigation Project

Othman T. Tuman[1], Riyadh Z. Azzubaidi[2]

Abstract

Iraq is one of the most affected countries, the increase in population growth and the detrimental effects of global warming, along with the neighboring countries' exploitation of transboundary rivers, have resulted in severe water resource shortages and detrimental effects on the environment, society, and economy. However, low irrigation efficiency, a decline in rainfall, and wasteful water use necessitate reevaluating irrigation systems and enhancing their effectiveness. Al Khachiya Irrigation Project is one of the most important projects located north of Wasit Governorate in Iraq, it runs along the left side of the Tigris River for about 55 km and serves about 55.8 km². Three fields A1, A2, and A3 were selected to evaluate Al Khachiya Irrigation Project. These fields are cultivated with different crops and applied irrigation methods (furrow and border). The Main Canal is a part of the Al Khachiya Irrigation Project with a length of 27.3 km, it is designed to pass an estimated discharge of 25.7 m³/s. The evaluation of the Main Canal depended on some of the selected performance indicators like the efficiencies of storage and distribution of water, water application efficiency, water conveyance efficiency, and lastly the overall efficiency of the canal. A1 field is selected to evaluate the Main canal. Measurements made in the field during the growing season to ascertain the moisture content before and after irrigation, as well as the field's capacity and permanent wilting point, were all done with a venturi flume to control field input. The results showed that the average water application efficiency for the A1 field is 44.8 %. That means that farmers use water more than the actual demand. The average value of water storage efficiency is 69.67%. Furthermore, the efficiency of water distribution is about 88.87%. Field measurements showed that the actual water conveyance efficiency of the main canal is 97.51%. The overall efficiency for the main canal is 38.82 %. Evaluation results for the Main canal of the Al Khachiya Irrigation Project revealed that the amount of water used is more than required, resulting in a large number of water losses by deep percolation and surface runoff observed in this search due to inefficient use, increase in operating times, and lack of experience and skills of farmers in water management.

Keywords: *Irrigation efficiency, application efficiency, Water losses, storage efficiency, moisture content, and distribution efficiency, population, evaluation of an irrigation, water distribution, main canal.*

1. Introduction

Water management is essential because, generally speaking, the water supply has become insufficient and the Tigris River's scarcity is a result of a deficiency in water resources that feed the river. Climate change and population expansion have also increased the water demand, which has complicated the situation. The amount of entering flow observed at the borders dropped as a result of the increased construction of dams in Turkey and Iran. (Abbas and

[1] Water Resources Engineering Department, College of Engineering /University of Baghdad, Baghdad /Iraq, Email: osman.tuman2110m@coeng.uobaghdad.edu.iq
[2] Water Resources Engineering Department, College of Engineering /University of Baghdad, Baghdad /Iraq, Email: riyadh.z.azzubaidi@coeng.uobaghdad.edu.iq

Azzubaidi, 2020) and lack of rainfall, this problem will certainly worsen later, (Almasraf and Salim). Every river and wadi had a different discharge which varied between 0 and 888.8 m^2/s (Al Thamiry and Azzubaidi, 2020). Because of all these factors, the people who make decisions about irrigation projects in Iraq reevaluate how best to manage water resources by assessing the irrigation projects' water loss figures and determining the most effective way to cultivate land and install contemporary irrigation systems. Most irrigation projects, especially large-scale projects, require an evaluation of the water application efficiency on land to ascertain the number of water losses and whether the real water supply is performing less than planned (Alcon et al., 2017). It is necessary to take fast steps to achieve a strategic aim for water management and to improve the use of water for irrigation through application the of modern irrigation systems, technologies, and agriculture processes, (Al Mosawi and Al Thamiry, 2022). As a result, it's critical to use irrigation water as efficiently as possible to reap financial rewards and ensure the availability of irrigation water over time. In this regard, efficient irrigation systems perform better than inefficient ones, (Hameed, and Al Thamiry, 2023). Maintaining agriculture production requires the best crop water management to increase sustainability (Webster, 2014).

Al Khachiya Irrigation Project is selected for evaluation and measures the efficiencies of water irrigation application, water distribution, water storage and conveyance of water then know the overall efficiency for all the project. Irrigation efficiency and water distribution standards have recently become very important tools for the development of agriculture activities. Assessing the effectiveness of irrigation projects gave stakeholders a hands-on understanding of how the system functions and what has to be improved for it to be improved. A thorough understanding of how irrigation systems operate was provided to stakeholders through the evaluation of their performance. (Hameed, and Al Thamiry, 2023). By gathering information, measuring the discharge and water applied depth, and determining the required net depth, the study seeks to estimate the water losses inside the fields of the Al Khachiya Irrigation Project and determine the water application efficiency to the irrigation surface system (furrows and borders). Next, offer suggestions for improving the system's water irrigation efficiency.

2. Irrigation Efficiencies

Not every water extracted from a river or well reaches the crop's root zone. Water may be lost in part in the fields and during canal transportation. The plant's root zone holds onto any leftover water. To put it another way, some water that was intended for irrigation is lost while a tiny amount is used effectively. The ratio of the amount of water used for plant growth requirements to the total amount of water from the source is known as irrigation efficiency. (A. Hamdi, 2007). The irrigation efficiency includes field application efficiency, conveyance efficiency, and distribution efficiency, (D.F. Hermann, W.W. Wallender and M.G. Bos, 1990).

2.1 Distribution Efficiency. The regularity of the water distribution at the root zone region is referred to as distribution efficiency. It was once used to store and distribute water for crops. To calculate distribution efficiency mathematically is expressed as:

$E_d = (1-y/d)$ (2)

where: E_d is distribution efficiency; d is water stored depth; and y is the average deviation from the average depth of water stored depth.

2.2 Water Application Efficiency. Water use efficiency or Application Efficiency is the ratio between the depth of water in the root zone of plants and the total depth of water supplied in the field. Application Efficiency is expressed as

$$E_a = \frac{dn}{dg} x100\% \quad (3)$$

where: E_a is Application Efficiency in fields (%); d_n is the depth of water within root zone (mm); and d_g is the total water depth applied (mm).

2.3 Moisture Content and Water Stored Depth. Moisture content was calculated by the following expressed (Musa et al.,2016):

$$p_w = \frac{w_w}{w_s} x100\% \quad (4)$$

where: p_w is the weight of moisture content; w_s is the weight of solid soil; and w_w is the weight of water. To obtain the moisture content (by volume), can use the following formula:

$$P_V = P_W \, x \, A_S \quad (5)$$

where: P_V is the volumetric moisture content, and A_S is the specific gravity of soil.

To calculate the water stored depth can use the following expressed:

$$d = \frac{P_w}{100} x \, A_S \times D \quad (6)$$

where: d is the net depth of water before and after irrigation ; D is the depth of root zone.

2.4 Conveyance Efficiency. Conveyance efficiency is the ratio between the water of the canal from the reservoir or pumping station to the water of offtakes of the distribution canals. Conveyance efficiency is expressed as:

$$E_C = \frac{Q_2}{Q_1} x100\% \quad (7)$$

where: E_C is the Conveyance efficiency(%),Q_1 is the water entering (m^3/s); and Q_2 is the water delivered to the system (m^3/s) (Hansen, 1960).

2.5 Efficiency of Water Storage. The ratio of the depth of water storage in the root zone to the depth of water required by the plant is knowing water storage efficiency and it is expressed as:

$$E_S = \frac{d_n}{d_s} x100\% \quad (8)$$

where: E_s is the water storage efficiency(%); and d_s is the water depth required by plant during irrigation (mm) (FAO, 1989).

2.6 Overall Irrigation Efficiency. Overall Irrigation Efficiency (E_p) represents the average efficiency of the full operation between river diversion and the root zone of the plants, Overall efficiency can expressed as,

$$E_p = E_a . E_d . E_c \quad (9)$$

3. Methodology and Procedure

3.4 The Study Area

Al Khachiya Irrigation Project is located north of Wasit Governorate the center of Iraq and the administrative border between the governorate of Wasit and Baghdad. The project area is located between 33^{o} 01' 51" and 33^{o} 06' 15" latitude and 44^{o} 44' 11" and 44^{o} 56' 15" longitude. The gross area of the project is 279 km^2 and the irrigated area is about 216.5 km^2. The maximum rainfall amount occurring in Jan. with the mean annual recorded in the project is 170 mm, where the relation between rainfall and runoff is very important to manage the available water (Farhan and Abed, 2021). The minimum and temperature range changed between 3.8-26.4 ^{o}C and 16.7-49.5 ^{o}C respectively. The lowest possible wind speed was in December at 1.89 m/s and the highest in March at 3.3 m/s. The recorded sunshine hour showed a large variation (6.5-12.5). The type of soil in the project is silt loam and sandy loam. Evaporation which exhausts 61% of the total precipitation (Al Sudani and Salim, 2022). The methods of irrigation used in the project are surface, pump (border, and furrow). The main irrigation network in the Al Khachiya project consists of a main canal and distributary canals with watercourses. The Wasit governorate water resources directorate supervises all agricultural lands and their irrigation sources, which include the Al Khachiya Project. Figure.1 Lands irrigated from the Al Khachiya Project.

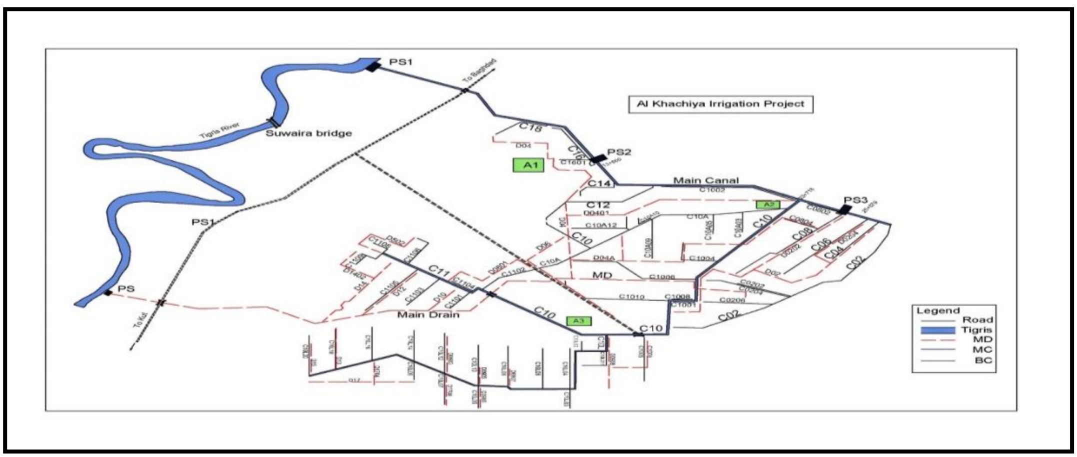

Fig.1: Illustrates the General Layout of the Al Khachiya Irrigation Project and its Branches.

3.2 Selected Field within Study Area

The evaluation of The Main Canal Part of the Al Khachiya Irrigation Project requires finding the actual irrigation efficiency in lands that are irrigated from it. Fieldwork is very important to collect the necessary data for evaluating and improving the system and investigate the hydraulic system within the zone area (Al-Saadi, and Al Thamiry, 2021). The field was selected to evaluate the irrigation performance within the project as shown in Table .1. It is irrigated by the Main canal and it was divided into three sections to ensure the accuracy of measurements, where the moisture content was conducted before and after irrigation to measure the actual required depth of water by crop and the depth of water applied, then knowing the amount of water losses.

Table 1: Details of the A1 Field Within the Study Area.

No.	Canal Name	Field	Station Km	UTM Coordinates(m)	
				Easting	Northing
1	Main Canal	A1	13+100	33º07'19"	44º48'41"

3.3 Soil Physical Properties of Field

Soil Properties are very important parameters to evaluate the performance of the irrigation project. Permanent wilting point (PWP), field capacity (FC), bulk density soil, soil texture, PH, EC, and (Mg^+, Na^+, and Ca^+ content) are required data in the evaluation. Soil samples were taken for the field at the depth (0-80) cm to cover the root zone and to know the variation of soil properties between layers. The soil analysis was made in the laboratory of the college of Agriculture, University of Baghdad. All the physical properties were tested in the laboratory, and only the bulk density was determined in the field using the core. **Table .2** shows the laboratory results for soil properties.

Table 2: The Laboratory Results of Soil Properties.

Canal Name	Fields	Depth of soil sample (cm)	Soil texture	The moisture content at F.C by vol. (%)	Moisture content at wilting point by vol. (%)	EC (ds/m)	PH	Ca^+ (ml/l)	Mg^+ (ml/l)	Na^+ (ml/l)
MC	A1	0-40 40-80	Silt loam	31.8	16.2	2.8	7.32	12.52	8.05	1.07

3.5 Measurement of Inflow

A Venturi Flume was put in at the entrance of the canal assigned to the field to measure and calculate the discharge, where it is a critical-flow open flume with a confined flow that creates a critical depth because of the dip in the hydraulic grade line **(Sathe et al., 2016).** Venturi Flume consists:

A- Upstream section 40 cm wide uniformly converges.
B- Short throat section 20 cm wide.
C- The downstream section uniformly diverges to 40 cm wide.
D- The floor section is level in all directions.
E- It has a total length of 1.5 m and a height of 40 cm; it is made from stainless steel.

$$Q_C = CB_2y_2\sqrt{\frac{2gH}{1-\left(\frac{B_2y_2}{B_1y_1}\right)^2}} \quad (1)$$

Where

Q_C = discharge (m^3/sec). C Coefficient of discharge.
B_1= Upstream width (m). And B_2 =Throat width (m).

y_1= Upstream depth (m). And y_2= Throat depth (m).
H= Difference depth (y_1- y_2).

Fig. 2 and Fig. 3 illustrate the details of the venturi flume that is used to measure the discharge.

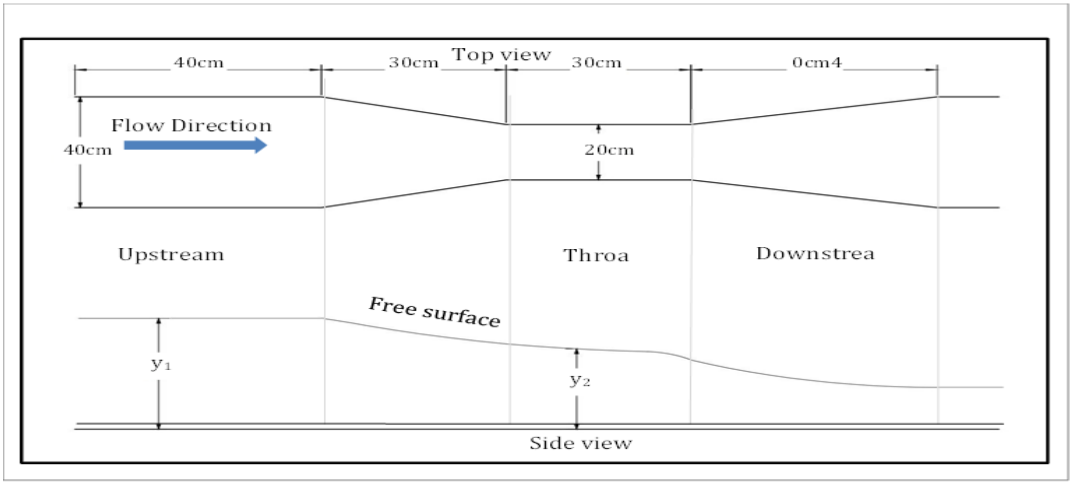

Fig. 2: Shows the Details of a Top and Side View of the Venturi Flume.

Fig. 3: Snapshots During the Discharge Measurement by Venturi Flume.

3.6 Root Zone Depth

The root depth will be calculated for the alfalfa crop By using an approximate method to estimate the root depth (vertical) by carefully excavating the soil near and around the root of the crop without causing root scratches. The root depth is measured by using a measuring tape for each irrigation. Table 3 illustrates the depth of roots according to (FAO 1989) and soil water depletion fraction (AD).

Table 3: Measuring Root Zoon Depth of Crop for A1 field.

Date	Canal name	Crop type	Average root depth (cm)
Dec- 29, 2022	Main Canal	Alfalfa	18
Jan- 28, 2023			25
Mar-1,2023			34
Apr-4, 2023			40

3.7 Water Applied Depth

The volume of applied water is determined by dividing its volume by the size of the field. This allows one to determine the depth of the applied water. The volume of applied water is computed from the product of the discharge during irrigation. **Table 4** shows the applied water depth for the A1 field. **Fig.4** illustrates the depth of applied water, stored water, and lost water. Where the average applied depth of water in the field is 65.61 mm and the depth of water stored is 28.94 mm, while 36.67 mm is deep percolation, which means about 56% of water lost in the field.

Table.4: The Measurement of Water Applied Depth for the A1 Field.

Date	Canal name	Flow rate (lps)	Time of irrigation (Hour)	The volume of applied water(m^3)	Net Area (dounm)	Depth of water applied (mm)
Dec- 29, 2022	M.C	27	8	777.6	4	77.76
Jan- 28, 2023	M.C M.C	27	7	680.4	4	68.04
Mar-1,2023	M.C	27	6	583.2	4	58.32
Apr-4, 2023	M.C	27	6	583.2	4	58.32

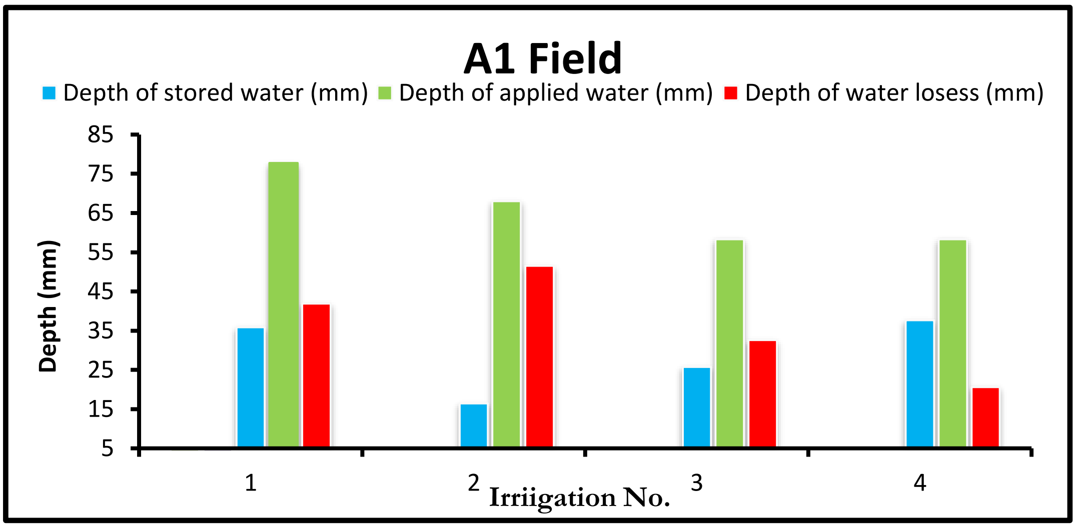

Figure.4: The Depth of Applied Water, Depth of Stored Water, and Water Losses in Each Watering for the A1 Field.

4. Results and Analysis

4.1 Distribution and Water Storage Efficiencies. Because it depends on the type of irrigation technique utilized, such as surface irrigation, the water distribution and storage efficiencies in the research region are generally high. Storage of water changes the timing amount and chemical composition of a river flow, leading to dramatic changes to groundwater–storing floodplains and wetlands (Nama A., H., 2015). Efficiencies are determined according to the field measurements, where the amount of water added to the field is more than the needed water. The value of water storage efficiency ranged between 53.45 to 86.68% and the average value of storage efficiency was 69.67%. The efficiency of water distribution for the irrigation project is above 90%, and according to (Hansen, 1960) it is considered excellent. That means a good homogeneous distribution of moisture in the root zone, which shows the growth of the plant with a high degree of uniformity. Also, the good water storage efficiency indicates that the water stored in the soil is used by the plant because it is within the limits of

FC and PWP, which affects by increases the plant productivity. The average distribution efficiency is 88.87%. Fig. 5 clears the water storage and distribution efficiencies in the A1 field.

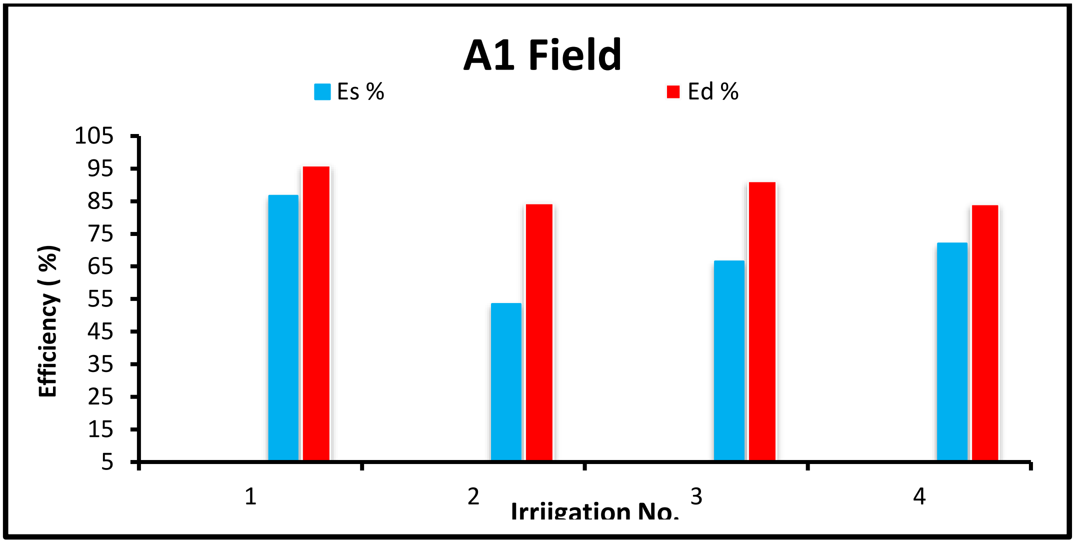

Figure 5: The Efficiency of Distribution and Water Storage for the A1 Field.

4.2 Water Application Efficiency. The actual average of water application efficiency for each watering in the field, which is irrigated with furrow, is about 44.8 %, this value of efficiency is considered within the range of water application efficiency 40% - 60% as listed by (FAO, 1995). From the result above, it can be seen that the farmers use more water for irrigation than the actual plant demands. It is possible to increase the application efficiency by controlling the irrigation time. Fig.6 shows the direction of the curves of the application efficiency for the A1 field during different times of irrigation.

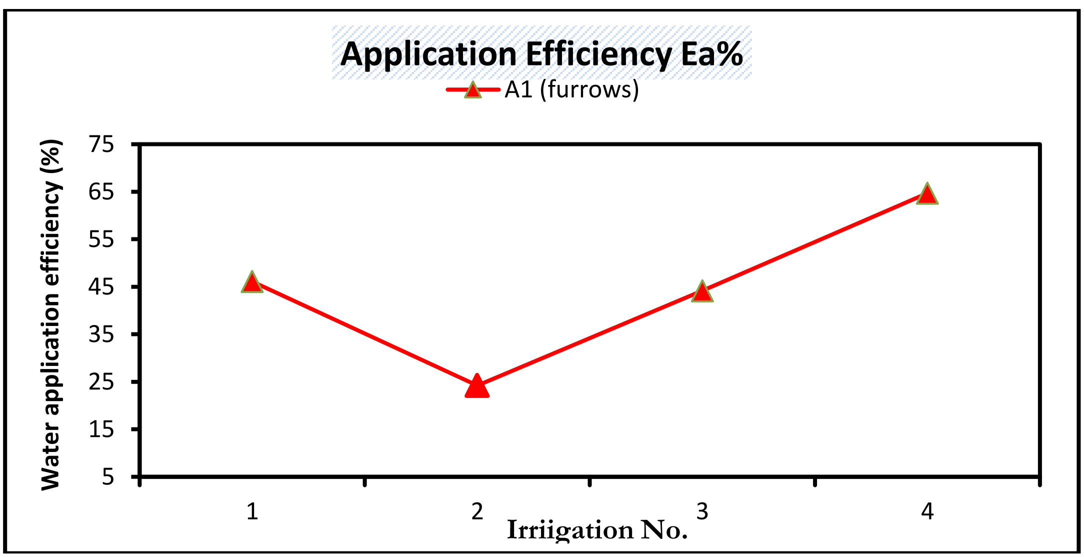

Fig.6: Shows the Direction of the Curves of the Application Efficiency for the A1 Field During Different Times of Irrigation.

4.3 Moisture Content and Water Stored Depth. Moisture content is a very important input to estimate irrigation efficiency, its content is measured and recorded on-site. This moisture content is measured within the root zone during the growing season before and after water application from Dec- 29, 2022 to Apr-8, 2023 for different root depths. The Alfalfa crop was planted on November 15, 2022, as seeds, and the harvested time was on May 15, 2023. Fig.7 illustrates the change in moisture content before and after irrigation for the field study BMC and AMC and also shows the FC and PWP levels and the allowed depletion of AD. The AD is determined based on (FAO, 1989).FC and PWP are indicators of water accessible to the crop. If the moisture content is less than PWP, the crop cannot reach the water, and the soil becomes dry.

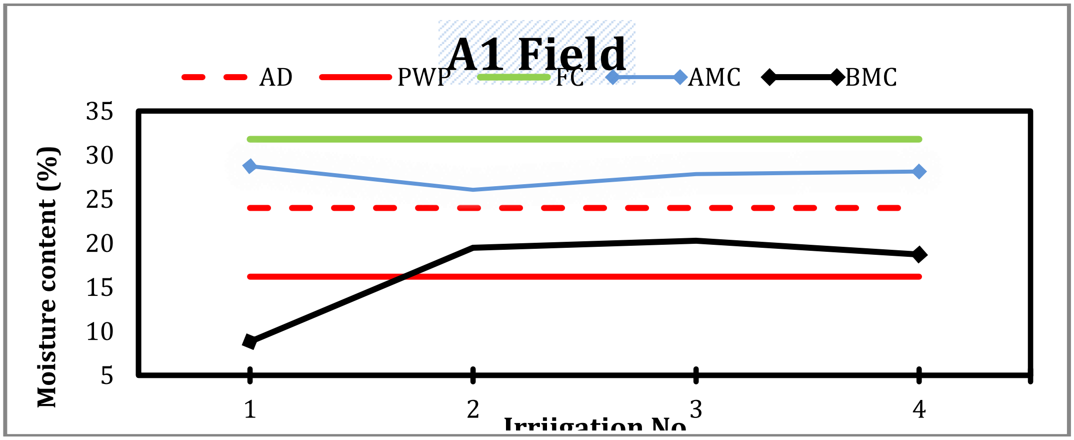

Fig.7: The Moisture Content for the Effective Root Zone in the A1 Field Before and after Irrigation During the Period Dec- 29, 2022 to Apr-4, 2023.

4.4 Conveyance Efficiency. Actual conveyance efficiency is measured in the Main Canal to determine the amount of loss water due to seepage and evaporation from the surface of water, so it is very important to determine the losses to know the actual amount of water delivered to the field; it is checked in winter 2023 for the Main canal and the discharge is measured at station 5+350 km and 23+718 km and it is 23.4 m^3/s and 22.95 m^3/s respectively, as shown in Table 5. Thus, the water losses in this distance are 450 l/s (equivalent to 24.50 l/s/km length), which is equivalent to about 0.58 m^3/s along the main canal. So the conveyance efficiency is 97.51%, and such conveyance efficiency for the lined canal is very good (Halcrow, 1992).

Table 5: Shows the Calculations of the Conveyance Efficiencies for the Main Canal.

No.	Canal name	Monitoring station	Station (km)	Discharge m^3/s)(	Seepage losses (l/sec/km)	Conveyance efficiency (%)
1	Main	M_1	05+350	23.4	24.50	97.51
2	Canal	M_2	23+718	22.95		

4.5 Overall Irrigation Efficiency. To evaluate the overall efficiency of the Main canal of the Al Khachiya Irrigation Project, the average results of water application, water distribution, and conveyance efficiencies are calculated. Table 6 shows the average irrigation efficiencies for the project in its Main canal.

Table 6: Overall Irrigation Efficiency of Main Canal in Al Khachiya Irrigation Project.

Canal name	Field	Ea (%)	Ea (%) Avg.	Ed (%)	Ed (%) Avg.	E_C (%)	E_o (%)
Main Canal	A1	44.80	44.80	88.87	88.87	97.51	38.82

From Table 6, the overall efficiency of the Main canal is 38.82%. So, the overall efficiency of the main canal is poor because it is below the acceptable limit. This means that more water is lost in the project due to defects in water management practices. Also, the amount of water delivered to the field is more than needed. To improve the water management in the project should know the actual crop water requirement of each plant, these requirements consist of the quantity of water consumed by the plant due to the process of transpiration, water evaporates from the surface of the earth, water consumed by the plant, washing requirements, and water lost in the field due to the irrigation process and compares it with the amount of applied water to avoid excess water.

5. Discussion

The results of irrigation efficiency in the Main Canal of the Al Khachiya Irrigation Project showed large amounts of irrigation water are lost by deep percolation and surface runoff due to the use amounts of water for irrigation than plants needed caused by weak water management of the farmers, where the percentage of water losses in A1 field is 56%, so it is very important to re-evaluate the irrigation project efficiency instead of relying on design standard to estimate water requirements.

Below the main points are concluded:

1. The water application efficiency for the field is an average of 44.8 % (furrow irrigation). Low values of application efficiency are due to applying water more than the plant requirements, in addition to inappropriate timings for irrigation. Application efficiency can be improved by proper water management within the field and reduced operation times.
2. Requires rescheduling irrigation times according to the actual need for each field and using the water standard application in the project.
3. Surface irrigation is the method used in the study area, in which the field is completely flooded with water, it leads to an increase in storage and distribution efficiencies, on the other hand, this irrigation method gives a high homogeneity of moisture distribution in the root zone but in the return a loss of large quantities of water due to surface runoff and deep percolation. The water storage efficiency is **69.67%**. Also, the water distribution efficiency is **88.87%**.

References

Abbas, M. S., and Azzubaidi, R. Z., 2020. Current and Modified Flood Discharge Capacity of a Reach of Tigris River between Kut and Amarah Barrages. Journal of Engineering. https://doi.org/10.31026/j.eng.2020.02.10.

A. Hamdi: Water Use Efficiency in Irrigated Agriculture, CIHEAM (2007), Mediterranean Agronomic Institute of Bari, Italy.

Alcon, F., Garcia-Bastida, P.A., Soto-Garcia, M., Martinez-Alvarez, V. Martin-Gorriz, B., and Baille, A., 2017, Explaining the performance of irrigation communities in a water-scare region. Irrigation Science, 35, pp.193-203. doi: 10.1007/s00271-016-0531-7.

Al-Saadi, T. S., and Al Thamiry, H. A., 2021, Evaluation and Development of Shatt Al-Diwaniya and the diversion canal of Shatt Al-Diwaniya. Journal of Physics: Conference Series. https://doi:10.1088/1742-6596/1973/1/012180.

Al Thamiry, H. A., and Azzubaidi, R. Z., 2020. SURVEY AND DISCHARGE

MEASUREMENTS OF THE IRAQI BORDER CROSSING RIVERS. Journal of Engineering Science and Technology. https://researhgate.net/publication/347836543.

Al Sudani, Z. A. and Salim, G. S., 2022. Evaporation Rate Prediction Using Advance Machine Learning Models: A Comparative Study. Hindawi, Advance in Meteorology. https://doi.org/10.1155/2022/1433835.

Al Masraf, S. A. and Salim, A. H., 2018. Improvement of the Water Use Efficiency and Yield of Eggplant by Using Subsurface Water Retention Technology. Journal of Engineering. https://doi:10.31026/j.eng.2018.03.12.

Al Mosawi, M., and Al Thamiry, H. A.,2022, Evaluation of Elaj Irrigation Project in Babil Governorate. Journal of Engineering. https://doi:10.31026/j.eng.2022.08.02.

Farhan, A. A. and Abed, B. Sh., 2021. Estimation of Surface Runoff to Bahr AL-Najaf. Journal of Engineering. https://doi.org/10.31026/j.eng.2021.09.05.

Sathe, N. J., 2016. Investigation of Miniature Venturi Flume, Journal of Water Resource Engineering and Management, 3(2), pp.26-21P. doi:10.3759/ jowrem.v 3i2.1834.

Halcrow, W., and Partners., 1992, Infrastructure Operation and Maintenance Manual: Kapunga Project. National Agricultural and Food Cooperation, Tanzania.

Hameed, A. S., and Al Thamiry, H. A., 2023, Evaluation the Western Canal of Al –Ishaqi Irrigation Project. Journal of Engineering. https://doi:10.31026/j.eng.2023.05.02.

Hameed, A. S., and Al Thamiry, H. A., 2022, Evaluation of Al –Ishaqi Irrigation Project: A Case Study Eastern Canal of the Project. IIETA, Mathematical Modeling of Engineering Problems. http://doi:10.18280/mmep.090413.Aug2022.

Hansen, VE., 1960, New concepts in irrigation efficiency. Trans Am Soc Agric Eng/ASAE 3:55–64.

Hermann, D. F.; Wallender, W. W.; Bos, M. G. Irrigation Efficiency and Uniformity. In Management of Farm Irrigation Systems Hoffman, G. J., Howell, T. A., Solomon, K. H., Eds.; Am. Soc. Agric. Engrs.: St. Joseph, MI, 1990; 125-149.

FAO (Food and Agriculture Organization)., 1989, Guidelines for Designing and Evaluating Surface Irrigation Systems: Irrigation and Drainage Paper. No. 45. FAO, Rome.

FAO (Food and Agriculture Organization)., 1995, Irrigation in Africa in Figures. FAO Water Reports No. 7. FAO, Rome.

Musa, J.J., Mustapha, I.H., Yerima, I.Y., Kuti, I.A., and Abogunrin, M.E., 2016, Evaluation of irrigation application efficiency: a case study of Chinchaga irrigation scheme. Arid Zone Journal of Engineering, Technology, and Environment; Vol. 12: 58-64.

Nama, A. H., 2015. Deterioration of water quality and quality in iraq due to storage. 2nd International Conference on Buildings, Construction and Environmental Engineering (BCEE2), 2015. https://researhgate.net/publication/330534961.

Webster, T. P., 2014. Extension Engineer; Irrigation system types and typical application, ACAE Pub No32, AGDEX. No.