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# Calculating the Yield, Water Utilize Efficiency and Water Productivity for Carrot Crop under Climate Change Effects

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## Abstract

The present work analyzed the yield, water utilize efficiency and water productivity for carrot Crop under climate change effects. In this research, river water was used with irrigation ratios with drain water to irrigate the carrots (*Daucus carota* L.) crop during the winter growing season 2021-2022 in free field and utilizing furrow irrigation method with calculation the water use efficiency and water productivity to three sites. The study was conducted in the three sites in the Babil province in Town of Sadat-AlHindya reached 80 km from Baghdad city. Site 1 was used 33% drain water and 67% river water while site 2 was used 83% drain water and 17% river water but the site 3 was used 100% river water. The reduction of yield in site 1 was 17.3% and in site 2 was 75%. The reducing of WUE in site 1 was 23% and in site 2 was 77%. The decrease of WP in site 1 was 22.98% and in site 2 was 82.28%. The value of water stress coefficient (Ks) because irrigation by water salanity and soil salanty was 0.83, 0.78 and 0.92 in site 1,site 2 and site 3, respectively, water salanity and soil salanty reduction in productivity by 9%, 14% and 7% in production of site 1, site 2 and site 3, respectively in every irrigating.

## Keywords

Climate Change, Carrot, Water Use Efficiency, Water Productivity

## 1. Introduction

Because of the lack of available water resources over time, so it needs to emphasize the attention to the efficiency of the use of irrigation in order to give an increase in economic returns and the ability to use less water to give more production. The study was worked to compare of water use efficiency and carrot yield with drainage and river water under water scarcity. [1] compared WP of furrow irrigation T1 and traditional of furrow irrigation T2 with sunflower crops. The WUE in T1 was 8.19 kg/m$^3$ and WUE in T2 was 4.28 kg/m$^3$. WP of T1 more than T2 resulted in the APFI best from CFI. [2] did the investigate the growth and yield responses of carrot to vary irrigation frequency by 5 intervals of irrigation (A, B, C, D, E, treatment). The maximum fresh root mass was given with treatment C, at best water utilize efficiency. The yield of carrot was 8.89 kg/m$^2$ and WUE was 2.96 kg/day also the water requirement was 344 mm [2]. Determining the water requirements and water utilize efficiency (WUE) with impact on yield between 2006-2007 growth season in Chillán, Chile. The applying water with 5 different evaporation below trickle irrigation. The conclusion is given maximum carrot yield at 100% pan evaporation (Epan) while maximum WUE at 75% Epan. This relation between yield and supplied water will be improving the water resources management below water shortage. Yield = 6.75 KG/M$^2$, Applied water was 238 mm and WUE was 28.3 kg·m$^{-3}$ [3]. [4] tested the hypothesis that root yield minimizes with maximizes in the high potential soil moisture deficit. Field of carrots growth below a rain outside of New Zealand with drip irrigation of 6 treatments that varied in time with moderate and high intensity of water stress. The yield was 6, 18, 19, 21, 12, 16, 6 ton/ha with potential soil moisture deficit. Yields on good fields with no nematode, water, or other limiting problems may exceed 15 tons (600 50-lb bags) per acre. Minicarrots yield about 5.24 to 6.55 ton/don, obtained on increasing of yield, WUE and WP in treatments was used the sheet more than other treatments. The WUE of chili pepper in T1, T2 and T3 treatments were 5.54, 3.7, 3.48 kg/m$^3$, respectively [5]. [6] carried out in field to study yield at Horticultural Research Farm, NWFP Agricultural University, Peshawar during 2003-2004. They had on yield (13.79 t/ha) and total yield (24.65 t/ha). [7] used 3 vary irrigation intervals with six vary irrigation water salinity levels. The influence of interaction between irrigation interval and salinity was on yield. The highest yield was observed in S1. The water salinity up to 1.5 dS/m was nonsignificant on yield. Increasing in soil salinity by 1 dS/m will decrease of 3.83%, 2.93%, and 3.03% in the yield. [8] used 5 treatments depths and 4 replicates. The supplying depths via drippers with vary flow rates, and the irrigation was run via time domain reflectomtery (TDR) technology. The ETo and ETc was 286.3 and 264.1 mm in 2010, and 336.0 and 329.9 mm in 2011. The yield was between 30.4 to 68.9 t/ha. The WUE was between 1.02 and 0.96. The Carrot was effected via vary water depths treatments supplied. [9] showed the water quality should be under 1 dS/m. The crops are irrigated with water and have salt 400 - 800 ppm TDS. In hot climate, impacting of salinity depends on climate, soil type and irrigation management. [10] studied the influence of 6 irrigation salinity levels on carrot yield in Turkey. Tap water was ECi = 0.75 dS/m supplied as a control treatment. Irrigation water salinity (T0 = 0.75, T1 = 1.5, T2 = 2.5, T3 = 3.5, T4 = 5.0 and T5 = 7.0 dS/m) caused increase in salt of soil and decrease in yield and WUE. 50% of yield loss occurred even below at 2.5 dS/m salt of soil level. The aim of study is search on many methods to fill the shortage of water by various methods, including the use of modern methods and unconventional water such as drainge or sewage water.

## 2. Materials with Methods of Works

### 2.1. Field Conditions and Site of Study

The research was worked in Sadat Al Hindya Town in Almhanawia village on Sada-Abo gharak road, in the Hilla twonship at Babil province. The study far away 20 Km south of sadat alhindya town and 30 km from Karbala province also 30 km from Baylon province as well as it 80 km from Baghdad city. Three sites, sit 1 (S1) located at 32˚35'33"N and longitude = 44˚20'24"E, and altitude: 31 m, sit 2 (S2) located at 32˚37'8"N and longitude = 44˚19'25"E, and altitude: 31 m, sit 3 (S3) located at 32˚35'34"N and longitude = 44˚20'27"E, and altitude: 31 m. Figure 1 shows the GIS map for the location of the study.

The source of water irrigation from three source, first source from branch canal is taken the its water from kifil project is named BC1 from W4R/BC1/4R (by water course W4R and distrebutery canal 4R) which have discharge 59 liter/s on land had water duty 1 $m^3$/s/4400 donum. The second source from HMC (hilla main canal) at cross regulater CR4 HMC which taken its water from kifil project at joint regulator by syphone had discharge 6 liter/s. Third source from branch drain named BD23 have discharge by pump 20 liter/s which connected with main

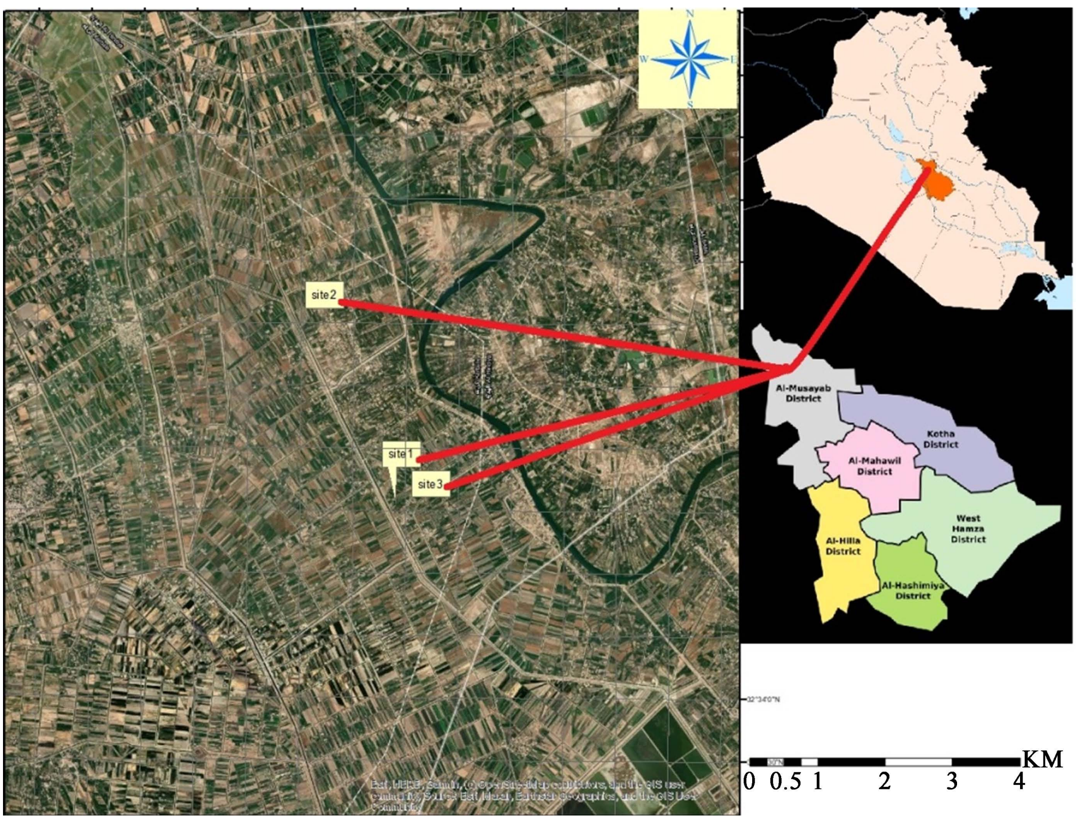


Figure 1. The Map study by GIS 10.8.

drain that conection with Alfurat alsharki drain. The land at S1 and S3 located betewwn collecter drains CD3L and CD2L and S2 located aligned of BD23. Taking three samples from Soil from the study to test in the laboratory of the Nation Center for water resources management, Baghdad. The analysis was carried out to obtain on the soil physical properties to obtain soil texture and soil physical properties of the that specific gravity 1.32, field capacity, and permanent wilting point. The soil texture of the study of three sites are clay loam soil for depth ranges 0 - 1.75 m as shown in Figure 2 and loamy sand soil for depth more than 1.75 m. The field capacity at depth 0 - 1.5 m was 44.57% by volume and permanent wilting point was 24.99% by volume. The apparent specific gravity of soil was and allowable depletion of squash was 35% and maximum root depth 0.5 - 1 m [11] but the root yield depth between 15 - 25 cm, readily available water (44.57 - 24.99) * 0.35 * root zone (=0.5) = 3426.5 mm, the drain water properties (BD23) were EC 4.74 ds/m, TDS = 3318 PPM, $SO_4$ = 1286 PPM, water river properties EC 1.33 ds/m, TDS = 851 ppm, $SO_4$ = 432 PPM.

## 2.2. Treatments, Experimental Design and Crop Material

Tree treatments were used, the first treatment of S1 was utilized water applied three types first irrigation ant seeding from water courcse (water river) and two irrigation by syphone (water river) next water course then two drain water irrigation as 33% drian water have electric conductivity ECi = 4, 4.78 ds/m at first and second drain irrigation, respectively, and 67% river water have ECi = 1.34 ds/m. S2 site was used water applied 17% river water and 83% drain water (one river water anf five drain water). S3 site was utilized water supplied 100% river

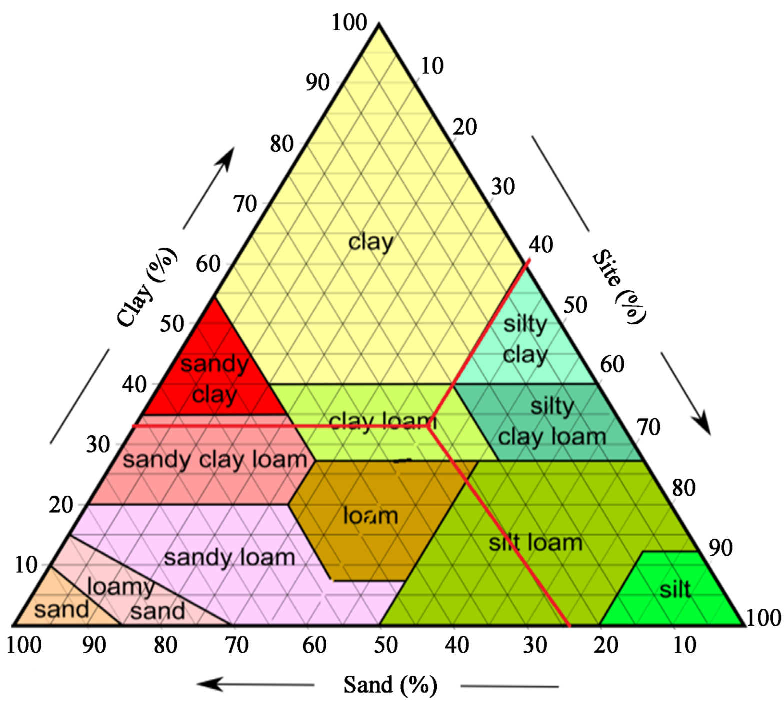


Figure 2. Soil texture of site.

water (six irrigating by river water). The treatment area of S1, S2 and S3 was 2500, 5000, 5000 $m^2$. The treatments in field treated by pesticides, fertilizers. carrots (*Daucus carota* L.) was seeded in the field work at three sites. The date of planting was began at October 2021 and finish date in harvest was started of Aperl 2022 as 185 day. Calculation average flow rate of water course, syphone and pump from drain were 59, 6, 20 l/s. The electrical conductivity ofsoil (ECe) before river irrigatin was 1.5 ds/m and after river irrigation was 1.56 ds/m by ECi of river = 1.34 ds/m. The ECe before drain irrigatin was 1.56 ds/m and after drain irrigation was 2 ds/m by ECi of river = 4 ds/m first drain irrigating and 4.78 ds/m second drain irrigating.

## 2.3. Crop Yield, Water Use Efficiency (WUE) and Water Productivity (WP)

### 2.3.1. Crop Yield

The summation of crop production from harvest till finish the harvest crop's production was use as a total production of root crop production. The crop yield was wreten as $kg/m^2$ was [12]

$$\text{Yield} = \frac{\text{total weight of crop}(\text{kg})}{\text{total area of crop}(\text{m}^2)} \tag{1}$$

### 2.3.2. Water Use Efficiency

The water use efficiency symbolizes WUE defines as result dividing the crop yield dividing on applied water. The following equation was used for computed the WUE $kg/m^3$ via the [11]:

$$\text{WUE} = \frac{\text{yield}\left(\frac{\text{Kg}}{\text{m}^2}\right)}{\text{total depth of applied water}(\text{m})} \tag{2}$$

### 2.3.3. Water Productivity

Water productivity symbolized WP was defined the crop production dividing on the of water depletion or suppling. But have modren define is price of yield as Iraqi dinar (ID) dividing on volume water applied, water productivity was used by [1] and [5]

$$\text{WP} = \frac{\text{yield price}}{\text{volume water applied}(\text{m}^3)} \tag{3}$$

where:

Yield price in ID.

In this carrot yield, water use efficiency and water productivity values of carrot crop for the three treatment were estimated and contrasted all together.

# 3. Results and Discussion

## 3.1. Frequency of Irrigation and Applied Water Depth

The schedule of irrigation was condected for three sites S1, S2 and S3 through the growing season when the soil allowable water depletion by FAO56 was 35% from the available water. The supplied water depths in month and number of watering at month for Carrot crop through the growing season 2021-2022 for S1, S2 and S3 in Table 1 date of irrigation, time of irrigation, discharge (Q), volume of water (V), applied depth (d) of site 2 (S1), Table 2 date of irrigation, time of irrigation, discharge (Q), volume of water (V), applied depth (d) of site 2 (S2) and Table 3 date of irrigation, time of irrigation, discharge (Q), volume of water

Table 1. Date of irrigation, time of irrigation, discharge (Q), volume of water (V), applied depth (d) of site 1 (S1).

| Date of irrigation | Time of irrigation (Hr) | Q ($m^3$/S) | V($M^3$) | A ($M^2$) | d app | rain | TYPE OF IRRIGATION |
|---|---|---|---|---|---|---|---|
| 1/10/2021 | 0.7 | 0.059 | 148.68 | 2500 | 59.472 | | W.C RIVERS |
| 2/11/2021 | 8 | 0.006 | 172.8 | 2500 | 69.12 | 4.2 | SYPHONE RIVERS |
| 17/12/2021 | 8 | 0.006 | 172.8 | 2500 | 69.12 | | SYPHONE RIVERS |
| 1/1/2022 | | | | | | 5.7 | |
| 20/2/2022 | 2 | 0.02 | 144 | 2500 | 57.6 | | WATER DRAIN |
| 15/3/2022 | 2 | 0.02 | 144 | 2500 | 57.6 | 5.5 | WATER DRAIN |
| | | | | sum | 312.91 | 15.4 | dap + rain = 328.3 |

Table 2. Date of irrigation, time of irrigation, discharge (Q), volume of water (V), applied depth (d) of site 2 (S2).

| date of irrigation | time of irrigation (Hr) | Q ($m^3$/S) | V($M^3$) | A ($M^2$) | d app | rain | TYPE OF IRRIGATION |
|---|---|---|---|---|---|---|---|
| 1/10/2021 | 1.575 | 0.059 | 334.53 | 5000 | 66.906 | | W.C RIVERS |
| 2/11/2021 | 4.5 | 0.02 | 324 | 5000 | 64.8 | 4.2 | SYPHONE RIVERS |
| 17/12/2021 | 4.5 | 0.02 | 324 | 5000 | 64.8 | | SYPHONE RIVERS |
| 1/1/2022 | 4.5 | 0.02 | 324 | 5000 | 64.8 | 5.7 | |
| 20/2/2022 | 4.5 | 0.02 | 324 | 5000 | 64.8 | | WATER DRAIN |
| 15/3/2022 | 4.5 | 0.02 | 324 | 5000 | 64.8 | 5.5 | WATER DRAIN |
| | | | | sum | 390.91 | 15.4 | Dap + drain = 406.31 |

Table 3. Date of irrigation, time of irrigation, discharge (Q), volume of water (V), applied depth (d) of site 3 (S3).

| date of irrigation | time of irrigation (Hr) | Q ($m^3$/S) | V($M^3$) | A ($M^2$) | d app | rain | TYPE OF IRRIGATION |
|---|---|---|---|---|---|---|---|
| 1/10/2021 | 1.4 | 0.059 | 297.36 | 5000 | 59.472 | | W.C RIVERS |
| 2/11/2021 | 1.4 | 0.059 | 297.36 | 5000 | 59.472 | 4.2 | SYPHONE RIVERS |
| 17/12/2021 | 1.4 | 0.059 | 297.36 | 5000 | 59.472 | | SYPHONE RIVERS |
| 1/1/2022 | 1.4 | 0.059 | 297.36 | 5000 | 59.472 | 5.7 | |
| 20/2/2022 | 1.4 | 0.059 | 297.36 | 5000 | 59.472 | | WATER DRAIN |
| 15/3/2022 | 1.4 | 0.059 | 297.36 | 5000 | 59.472 | 5.5 | WATER DRAIN |
| | | | | sum | 356.832 | 15.4 | Dap + drai = 372.23 |

(V), applied depth (d) of site 2 (S3). The number of irrigation operation which required for carrot crop in all sites is same number. Additionaly the depth of water applied in S1 and S2 is equal but S3 were lesser than that in S1 by 7%. Treatment S3 was saving water in the soil root depth higher than S1 & S2 because of the using high dischare with less time duet to reduce deepercolation.

### 3.2. Yield and Water Use Efficiency of Carrot Crop

The crop yield of was calculated by Equation (1) for sites S1, S2 and S3: 2.15 kg/m$^2$, 0.65 kg/m$^2$ and 2.6 kg/m$^2$, respectively. The carrot yield for S3 was higher than that in S1 and S2 by 17.31% and 75% respectively. This raising in crop yield in S1 was because of the water applied from river only while S2 was used twice irrigation from drain and S3 five times irrigation from drain. Table 4, Table 5 and Table 6 crop yield of carrot at production month for S1, S2 and S3, respectively for

**Table 4.** Shown crop yield of carrot at production month for S1.

| DATE | PROD | A | YIELD |
|---|---|---|---|
| 25/1/2022 | 400 | 2500 | 0.16 |
| 3/2/2022 | 800 | 2500 | 0.32 |
| 20/2/2022 | 1500 | 2500 | 0.60 |
| 5/3/2022 | 1666.667 | 2500 | 0.67 |
| 4/4/2022 | 1000 | 2500 | 0.40 |
| Total | 5367 | | 2.15 |

**Table 5.** Shown crop yield of carrot at production month for S2.

| DATE | PROD | A | YIELD |
|---|---|---|---|
| 25/1/2022 | 450 | 5000 | 0.09 |
| 3/2/2022 | 600 | 5000 | 0.12 |
| 20/2/2022 | 700 | 5000 | 0.14 |
| 5/3/2022 | 700 | 5000 | 0.14 |
| 4/4/2022 | 800 | 5000 | 0.16 |
| Total | 3250 | | 0.65 |

**Table 6.** Shown crop yield of carrot at production month for S3.

| DATE | PROD | A | YIELD |
|---|---|---|---|
| 25/1/2022 | 2476 | 5000 | 0.50 |
| 3/2/2022 | 2783 | 5000 | 0.56 |
| 20/2/2022 | 2697 | 5000 | 0.54 |
| 5/3/2022 | 2565 | 5000 | 0.51 |
| 4/4/2022 | 2498 | 5000 | 0.50 |
| Total | 13019 | | 2.60 |

the growth season 2021-2022. By using Equation (2), the calculating values of WUE for S1, S2 and S3 were: 5.83 kg/m$^3$, 1.6 kg/m$^3$ and 6.99 kg/m$^3$ respectively. WUE in S3 was higher than that in S1, S2 by 16.6% and 77.11%. The crop yield and WUE of the S3 were higher than S1 and S2 because of USING water river only due to use drain water contain on four times of salt from river water (the river water had 858 mg/L and drain water had 3000 mg/L). Figure 3 the crop yield of carrot and Figure 4 the WUE values for Ta and Tb.

### 3.3. Water Productivity

Water productivity is symbolized WP also in some studies named Water irrigation profitability [1] is crop production dividing on volume water supplied as kg/m$^3$ [13] [14] [15] [16] [17], when the production was computing via kg/ha and volume water applied was calculated as m$^3$/ha. The WP can be computed by ID/m$^3$ that quantiying by Equation (3). The setup costs and in changing costs were estimated for the three sites S1, S2 and S3 that consist the costs of seeds can, fertilizers with pesticides and oil of pump. Table 7 shows the production of carrot, average total cost (ID), Average total sell price (ID), return (ID), net return (ID), applied volume of water (m$^3$) and WP (ID/m3) of three sites S1 and S2 during the growth season 2021-2022. WP of S3 was higher S1 and S2 by 23

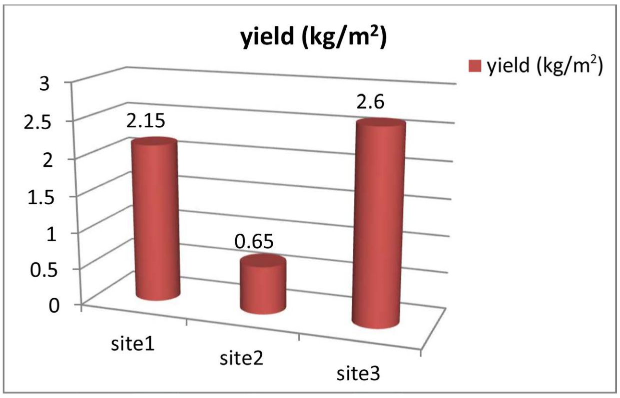


Figure 3. Yield and FWUE for carrot filed season 2022.

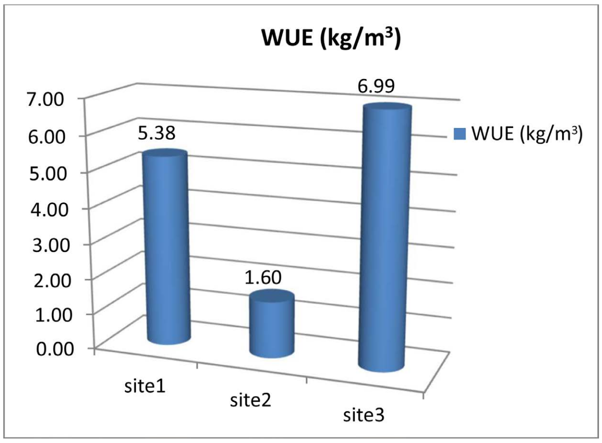


Figure 4. Yield and FWUE for carrot filed season 2022.

and 82.3%, respectively. Raising value in crop was because of using the water of river in S3 compared with the S2 and S1 that are used drain water in proportions. Figure 5 shows the comparison in WP among sites S1, S2 and S3 of carrot in the growing season 2021-2022. Figure 6 shows the applied water of S1, S2, S3. Figure 7 shows the KS and Ky of S1, S2, S3. Figure 8 shows the Ece before irrigation, after first irrigation, After second irrigation and after last irrigation. Figure 9 shows the ECi of river, first irrigation of drain and second irrigation of drain. Figure 10 shows the rainfall during of months of growing season 2021-2022.

Table 7. Production, average total cost, return, net return and applied volume of water and water productivity of all sites 1, 2 and 3.

| | site 1 | site 2 | Site 3 |
|---|---|---|---|
| Production (kg) | 5367 | 3250 | 13,019 |
| Average total cost (ID) | 230,000 | 405,000 | 405,000 |
| Average total sell price (ID) | 420 | 420 | 420 |
| Return (ID) | 2,325,000 | 1,383,750 | 5,464,125 |
| Net return (ID) | 2,095,000 | 978,750 | 5,059,125 |
| Applied volume of water ($m^3$) | 1000 | 1015 | 930 |
| Water productivity ($ID/m^3$) | 2095 | 482.1 | 2720 |

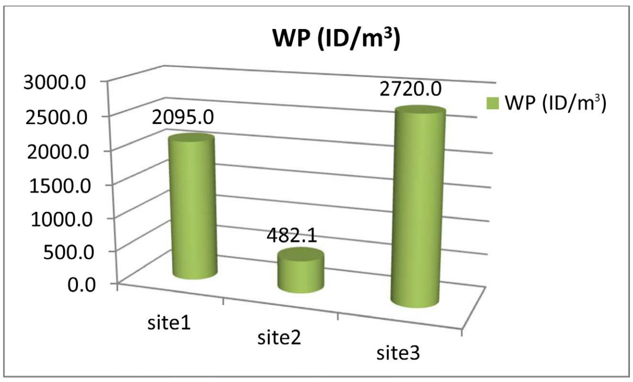


Figure 5. The WP of S1, S2, S3.

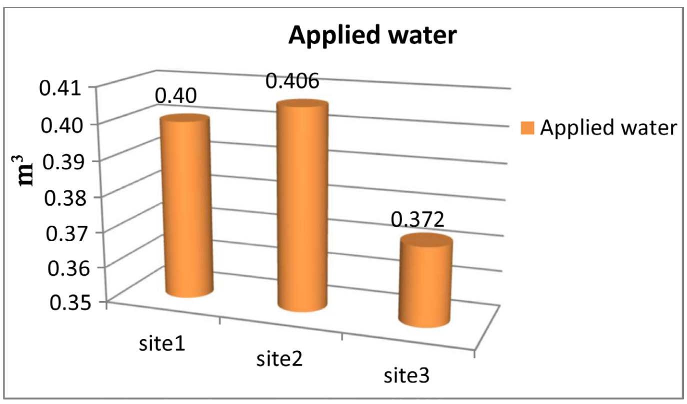


Figure 6. The applied water of S1, S2, S3.

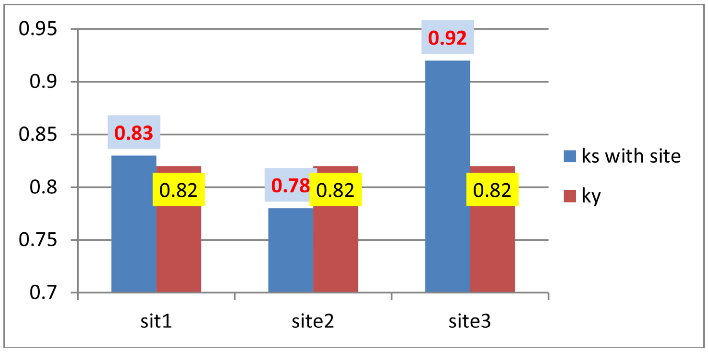


Figure 7. The KS and Ky of S1, S2, S3.

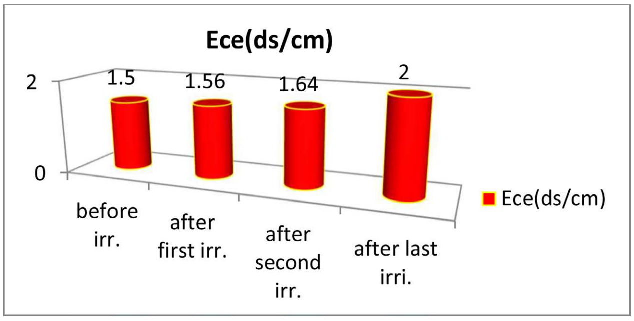


Figure 8. The Ece before irrigation, after first irrigation, after second irrigation and after last irrigation.

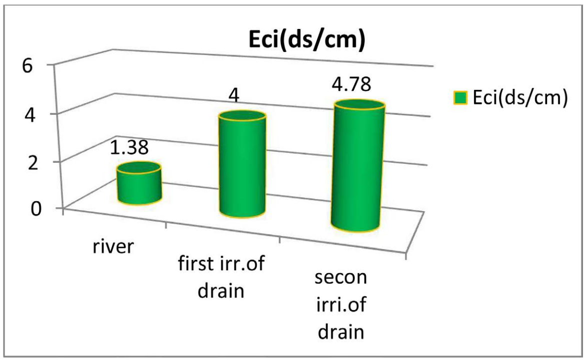


Figure 9. The ECi of river, first irrigation of drain and second irrigation of drain.

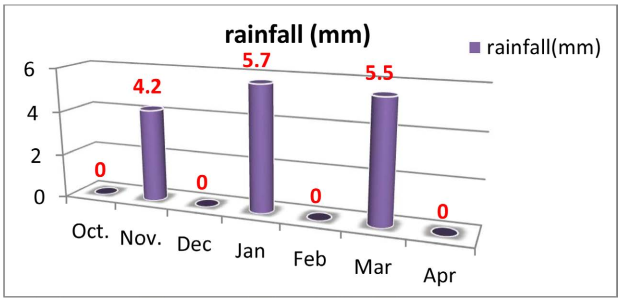


Figure 10. The rainfall during of months of growing season 2021-2022.

## 4. Conclusions

- Using the water river helped in increasing production and crop yield and water use efficiency(WUE) also water productivity(WP) values compared with using water of drain.

- The amount of applied water of all sites is nearly equal depending on farmer irrigation and discharge of source also time of irrigation.
- The crop yield of carrots in S3 was higher than S1 and S2 by 17.31% and 75%, respectively.
- WUE of carrot crop in S3 was more than in S1 and S2 by 16.6% and 77.11%, respectively.
- WP of carrot crop in S3 was more than S2 and S3 by 23% and 82.3%, respectively.
- The drain water increase salt in soil by increasing soil electric conductivity from 1.5 ds/m to 2 ds/m.
- The river water was increasing water use efficiency and water productivity.

## 5. Recommendations

- For further studies, the following recommendations were suggested.
- Using drain water at coarse texture soils and multi soil texture in free field area with multi crops after the treatment of water drain to reduce the salinity of drain water and calculation the changing in yield.
- Using drain water with mixing river water varies crops and calculation the changing in yield.
- Using the drain water with well water and drain water also mixing with multi crops and multi soil texture with calculation the changing in yield.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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