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Evaluation of Actual Evapotranspiration and Crop Coefficient in Carrot by Remote Sensing Methodology Using Drainage and River Water to Overcome Reduced Water Availability

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Abstract

Searching for alternative methods for traditional irrigation is World trend at days due to a reduction in water and increased of drought due to climate changes therefore farmers need use modern methods of scheduling water and minimizing water losses while also increasing yield. To meet the future increasing demands water and food there is a need to utilize alternative methods to reduce evaporation, transpiration and deep percolation of water. Any countries use recycled water (drain and sewage) and desalination water from the sea or drains to irrigate crops plus computing actual crop evapotranspiration (ET_c) so as to calculate the amount of water to apply to a crop. The paper aims to assess the actual evaporation and evaporation coefficient of carrots, by planting carrots in a field and the crop was exposed to several sources of water (DW and RW) and comparing ET_c, K_c and production among plots of three sites (A, B and C). The study used two types of irrigation water (drain water (DW) and river water (RW)). The results were to monthly rate and accumulated actual evapotranspiration to C (irrigation by RW only) more than A (67% RW and 33% DW) and B (17% RW and 83% DW) via 7% and 58%, respectively. The yield to C more than A and B by 17% and 75%, respectively. In conclusion the use of DW can cause a reduction in crop consumptive of carrot crops also causes a reduction in yield, crop length, root length, root size, canopy of crop, number of leaves and biomass of the plant therefore, the drainage water needs to treated before irrigating crops And making use of it to irrigate the fields and fill the shortfall in the amount of water from the river. The drain water helped on filling the water shortage due to climate changes and giving production of carrot crop but less than

river water.

Keywords

Carrot, Reference Evapotranspiration, Actual Evapotranspiration (ET_a), Marginal Water, Crop Coefficient, Landsat Satellite

1. Introduction

The expansion uses drain, sea and sewage water after treatment in cultivation to reduce the losses of water due to climate changes. Using advanced water management methods are important in the agricultural due to the climatic changes that occur in some regions of the world, especially in Iraq. Therefore, it requires the use of multiple methods and techniques same as remote sensing and GIS techniques are considered the modern scientific techniques with wide applications in science and engineering in the agricultural. These techniques become the basic engineering necessities, knowing that these techniques and software have developed with the development of space technologies in the second decade of the last century, which carry different sensors. The study used modern techniques to measure the evaporation coefficient and actual evaporation of carrots. This crop is considered one of the spring and summer crops [1], it is a rooted and versatile plant that blooms in different shapes, sizes and colors [2].

There are many studies that included the cultivation of carrot crop. [3] studied the required amount of water between 2006-2007 using the WUE system, as well as knowing the extent of the effect of that quantity on the carrot yield, where treated water was used at a rate of (25% - 125% Epan) under the drip irrigation system. In this study gave increase in the applied water 125% Epan decreased the root length and the density of the carrot crop. This will help to develop water management in conditions of scarcity. [4] conducted on the carrots, irrigation scheduling used with high irrigation efficiency. The maximum carrots yield was at available water by 40% in root zone. [5] compared to corresponding results from the remote sensing approach using SEBAL through 1997-1998, resulting in a difference of less than 1%, providing a strong validation of SEBAL in arid environments. The ET calculated from the K_c approach was 14% higher than the ET calculated by the water balance approach.

[6] worked during 2006-2007 to calculate crop evapotranspiration (ET_c) of carrot crop utilizing lysimeter at Udhagamandalam. Reference crop evapotranspiration of carrot (ET_o) worked by FAO. This ET_o along with tested ET_c from lysimeter was utilized to estimate the crop coefficient (K_c) through growing stages based on the ET_c and K_c. The average K_c for 3 stages were 0.70, 1.1 and 0.77; and ET_c were 2.62, 3.53 and 3.01 mm/day with weekly water requirement of 22 mm. [7] calculated ET_c from discharge gages provides the opportunity to evaluate the accuracy and consistency of an independently applied K_c and ET_o procedure integrated over the project. Computation K_c and ET_0 were based on the FAO.

Grass ET_o was calculated by utilizing the CIMIS Penman equation and ET_c was calculated for over 30 crop types. K_c-based ET computations exceeded ET_c determined by water balance (referred to as ET_c WB) by 8% on an annual basis over a 7 year. [8] studied Carrot crop through growing season 100 day (arid climate). The K_c in development, mid and late of season was 0.7, 1.05 and 0.95, respectively. The root was 0.5 - 1 m. Allowable deplation fraction (P) was 35% and allowable electric conductivity (threshold) was 1 ds/m.

This study aims to assess the ET_a and K_c of carrots in a field and the crop was exposed to several sources of water (DW and RW) and compering ET_c, K_c and production between plots of 3 sites (A, B and C). Using modern remote sensing and models helped to monitor evapotranspiration and yield of crops also the impact of water scarcity and water salinity on them and compared the work to previous studies. In addition to these studies, modern models and techniques to monitor water consumption, which in turn help to ration water.

2. Materials and Methods

2.1. Study Area

The research fields in Al Mahanawia Village located at Sadat Al-Hindiya Town, in Babylon province. Sadat Al-Hindiya Town located at 70 Km south of Baghdad Capital. Al Hindiya barrage 18 Km from field. Location (A) sited at 32˚35'30"N and 44˚20'25"E, Location (B) sited at 32˚37'10"N and 44˚19'20"E while Location (C) sited at 32˚35'35"N and 44˚20'30"E. **Figure 1** shows the GIS map for the three sites of fields.

The irrigation source from river that was taken from water course (W4R) which was taken from distributary canal (4R) from branch canal (BC1) witch feeding from Shat-ALHilla and drain that was taken from water branch drain (BD23) that was pour his water in main drain that pour his water Alfourat-Alsharqi drain next in fall main drain. The analysis was carried out to obtain on the physical properties of the soil to obtain soil texture and physical characteristic of the soil that represent specific gravity (G), soil texture, field capacity (F.C), and permanent wilting point (P.W.P.). The soil texture was clay loam in one layer has depth 1 m and loam soil after 1 m. The F.C was 44.6% by volume and P.W.P. was 25% by volume, G of clay loam soil was 1.32 and allowable depletion of carrot was 35% [8] as shown in **Table 1** that use in Laboratory department of National center of water resources management of Minister of Water Resources of Iraq, 2022. The high effective root zone was 0.5 meter. **Figure 2** shows the soil texture triangle.

2.2. Treatments Experimental Design and Crop Material

Three sites were utilized: the first location A was utilized 33% drain water and 67% river water (2 irrigating from drain and four irrigating from river). Second location (B) was used 83% drain water and 17% river water (five times irrigating from drain and one time irrigating from river). Third location (C) was utilized

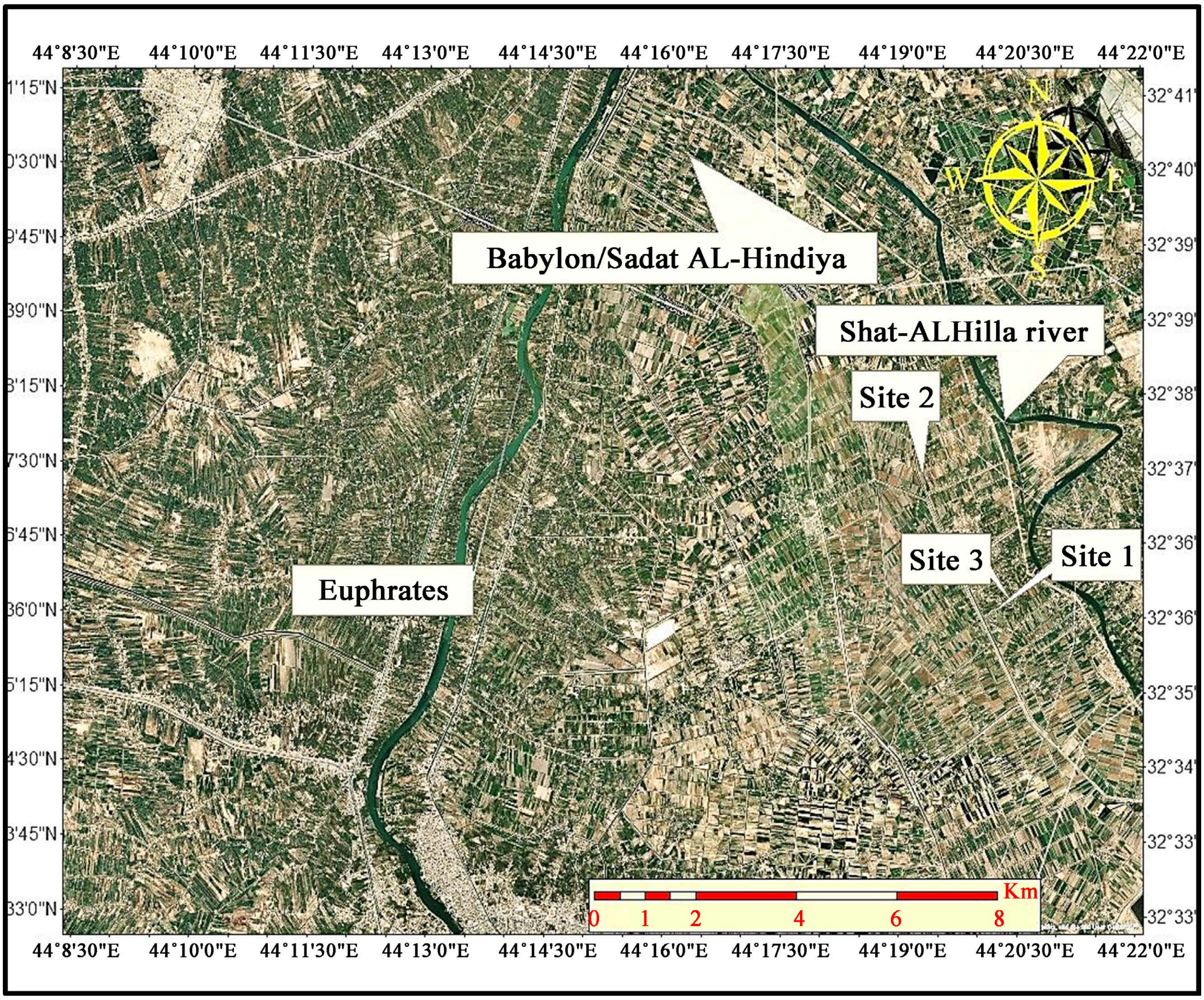

Figure 1. Google map image of fields location.

Table 1. Show the percent of sand, silt, clay, texture of soil and specific gravity.

No	Sites	sand	silt	clay	Soil texture	specific gravity
1	Location (A)	24	43	33	Clay loam	1.32
2	Location (B)	24	43	33	Clay loam	1.32
3	Location (C)	24	43	33	Clay loam	1.32

0% drain water and 100% river water (0 irrigating from drain and six times irrigating from river). Carrot (*Daucus carota* L.) was seeded in the first of October 2021. The total area of location 1, location 2 and location 3 equal 2500, 5000 and 5000 m^2, respectively. The strip irrigation system was used. The average discharge of each drain water was 20 l/s. The average discharge of each river water is 60 l/s. Table 2 shows water properties (PH, temperature, electric conductivity (ECw) and total dissolved salt (TDS). Table 3 shows the depth of applied water.

2.3. Calculation of Actual Evapotranspiration for Carrot Crop

Applied Water depth

Applied depth of irrigation water was calculated by using the following equation:

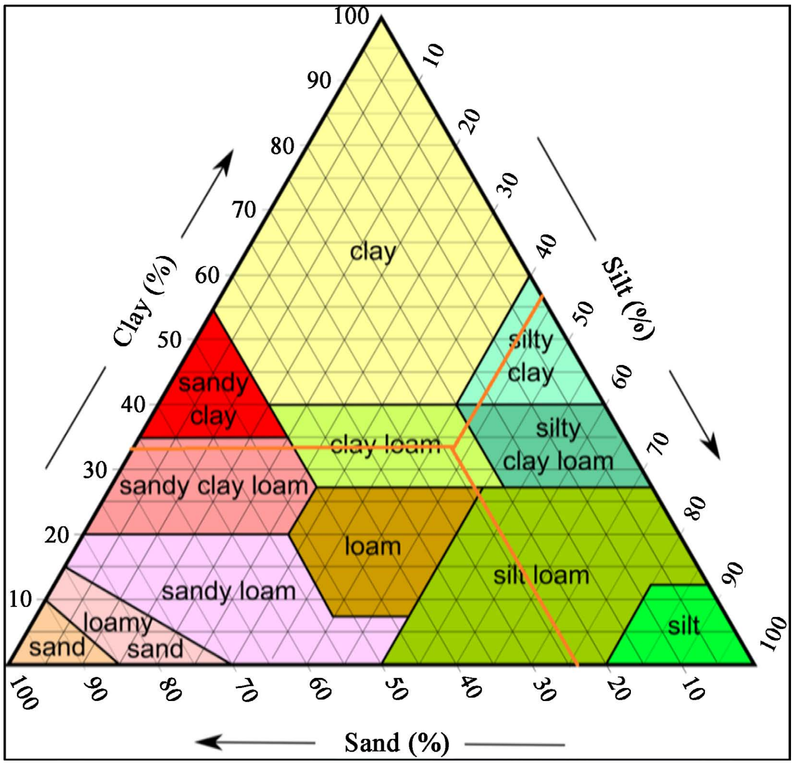

Figure 2. Soil texture triangle.

Table 2. Water properties (PH, temperature, electric conductivity (ECw), total dissolved salt (TDS) and changing of electric conductivity of soil ECe.

First drain irrigation	ph	7.41
	temp	18.5
	ECw (ds/m)	4
	TDS (ppm)	2560
Second drain irrigation	ph	7.4
	temp	19.6
	ECw (ds/m)	4.78
	TDS (ppm)	3059
Water of RIVER	PH	6.9
	temp	15.5
	EC w(ds/m)	1.382
	TDS (ppm)	885

ECE before IRR.RIVER	ECe (ds/m) after IRR.RIVER	ECe (ds/m) after IRR.DRAIN1	ECe (ds/m) after IRR.DRAIN2
1.5	1.56	1.64	2

Table 3. Depth of applied water of A, B and C.

	A	B	C
Depth of applied water (mm)	407.4	411.4	406
Volume of applied water (m^3/dounm) through growing season	1018.5	1028.5	1015
Production (ton/dounm) through growing season	5367	1625	6510

$$Q * T = dg * A \tag{1}$$

where

Q = supplied discharge from the river or drain system (m^3/s),

T = time of irrigation (second),

A = area (m^2), and

dg = supplied depth of water (m).

2.4. Estimation of Reference Evapotranspiration (ET_o) from the Meteorological Parameters

Modified Penman-Monteith model was depended to estimate the reference evapotranspiration (ET_o) in open field [8]

$$ET_o = \frac{0.408 * \Delta\left(R_n - G\right) + \gamma \frac{900}{T + 237} U_2\left(e_s - e_a\right)}{\Delta + \gamma\left(1 + 0.34U_2\right)} \tag{2}$$

where:

ET_o: reference evapotranspiration (mm/day),

R_n: net radiation at the crop surface (MJ/m^2/day),

G: soil heat flux density (MJ/m^2/day),

T_{mean}: mean daily air temperature at 2 m height (˚C),

U_2: wind speed at two m height (m/s),

e_s: saturation vapor pressure kPa,

e_a: actual vapor pressure kPa,

$e_s - e_a$: saturation vapor pressure deficit (kPa),

Δ: slope vapor pressure curve (kPa/˚C),

and γ: psychrometric constant (kPa/˚C).

$$\Delta = \frac{40984098\left[0.6108 \exp\left(\frac{17.27T_{mean}}{T_{mean} + 237.3}\right)\right]}{\left(T_{mean} + 237.3\right)^2} \tag{3}$$

$$\gamma = 0.665 * 10^{-3} * P_a \tag{4}$$

where:

P_a = atmospheric pressure [kPa].

2.5. Crop Coefficient Values

The advantage of using the crop coefficient (K_c) for estimating the irrigation requirement and scheduling the irrigation process through the growing stages.

The K_c is basically according to [8]:

$$K_c = \frac{ET_c}{ET_o} \quad (5)$$

K_c values for carrot crop were predicted for all carrot crop's stages through monts (initial, development, mid and end of seasons) during the growing seasons 2021-2022 with depending remote sensing methodology by NDVI to calculate K_c. Remote sensing approaches for estimating evapotranspiration are gaining prominence for their large area coverage using a consistent dataset and the capability to map the spatial variability of ET at subfield scales. There are a lot of ways in remote sensing to find on ET of existing irrigated fields. In this paper used the Operational Simplified Surface Energy Balance (SSEBop) approach [9]. The SSEBop approach predefines unique sets of "hot/dry" and "cold/wet" limiting values for each pixel, which uses a set of reference hot and cold pixel-pairs applicable for a limited, uniform hydro-climatic region. To estimate ET routinely, we need the data to use in SSEBop method which include the surface temperature (T_s, K), air temperature (T_a, K), and a potential ET, represented by a preferred reference crop type and adjusted by a scaling factor. In this case used the grass reference ET (ET_o, mm) [10], The overall approach of the SSEBop model [11] as shown in **Figure 3**.

With regards to K_c were used also the Remote sensing approaches, the K_c was extracted from Normalized Difference Vegetation Index (NDVI) utilizing the Red and Near Infra-Red (NIR) bands, Where was the equal on that used.

$$K_c = 1.25 * \text{NDVI} + 0.20 \quad [12] \quad (6)$$

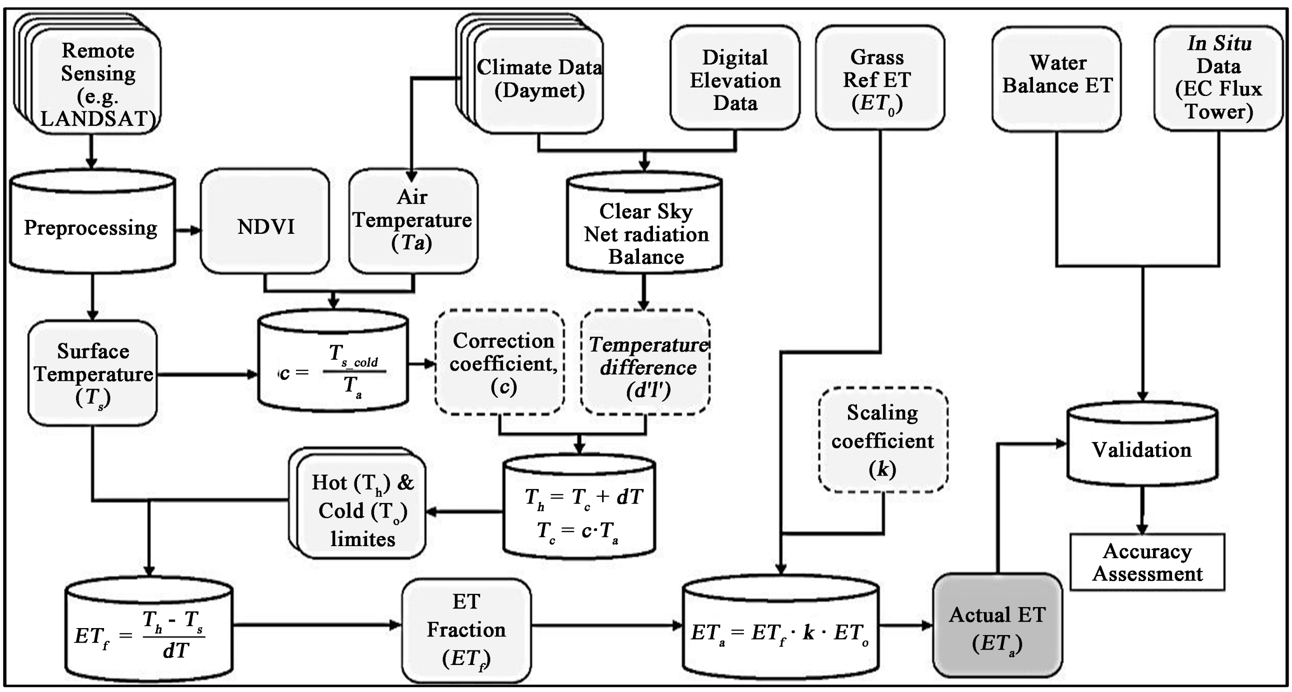

Figure 3. Overview of the SSEBop model methodology.

3. Input Datasets

In this study downloaded eight Landsat-8 and Landsat-9 images [13] downloaded from Earth Explorer Data Portal that had cloud cover 0% over the agricultural fields of study, and it's covered the agricultural season of carrot crop as shown in Table 4 below.

Thermal band 10 was used to compute land surface temperature (T_s), and the Normalized Difference Vegetation Index (NDVI) was computed from red and near-infrared bands. The reference daily evapotranspiration (ET_o) product used Daily Global GDAS ET_o, 6-hr weather forecast data from NOAA: Radiation, temp, wind, RH and pressure to solve the standardized P-M Equation (3) downloaded Raster images of (ET_o) product from USGS FEWS NET Data Portal For the agricultural season of carrot crop (1st Oct 2021-5th Apr 2022). The implementation of the SSEBop model is based on Python code, and used the IDLE Version 2.7.10 to execute the code. Monthly AET estimates were created from available ET_f values for each satellite overpass date. Aggregated ET_a values are derived from the daily ET_o and its nearest respective overpass ET_f value, also a Python code are used to estimates the monthly AET as shown in Figure 4 and Figure 5.

The applied water from different supplying (drainage and river) with period of irrigation by Months with calculation a depth of supplied water and number of irrigation interval (frequency of irrigation) of carrot crop in A, B and C treatments through the growing season 2021-2022 as shown in Table 5.

4. Results and Discussions

Monthly carrot crops evapotranspiration values were measured by using remote sensing methodology from the date of seeding to the end of the season (harvesting). Moreover, for the date of irrigation process, depth and volume of water applied were calculated by applying Equation (2). Table 6 average predicted Carrots's K_c values for the growing stages carried out via various models and approaches as shown p. 363. Table 7 growing season of carrot crop as shown p. 364. Table 8 month, ET_c of A, B, C and ET_o. The ET_a and production of A and B were less than C because

Table 4. Covered the agricultural season of carrot crop.

No	satellite	Date Acquired	path	row
1	Landsat-8	4th Oct 2021	168	37
2	Landsat-8	20th Oct 2021	168	37
3	Landsat-9	24th Nov 2021	168	37
4	Landsat-9	22nd Dec 2021	169	37
5	Landsat-8	24th Jan 2022	168	38
6	Landsat-9	24th Feb 2022	169	37
7	Landsat-8	13th Mar 2022	168	37
8	Landsat-8	5th Apr 2022	169	37

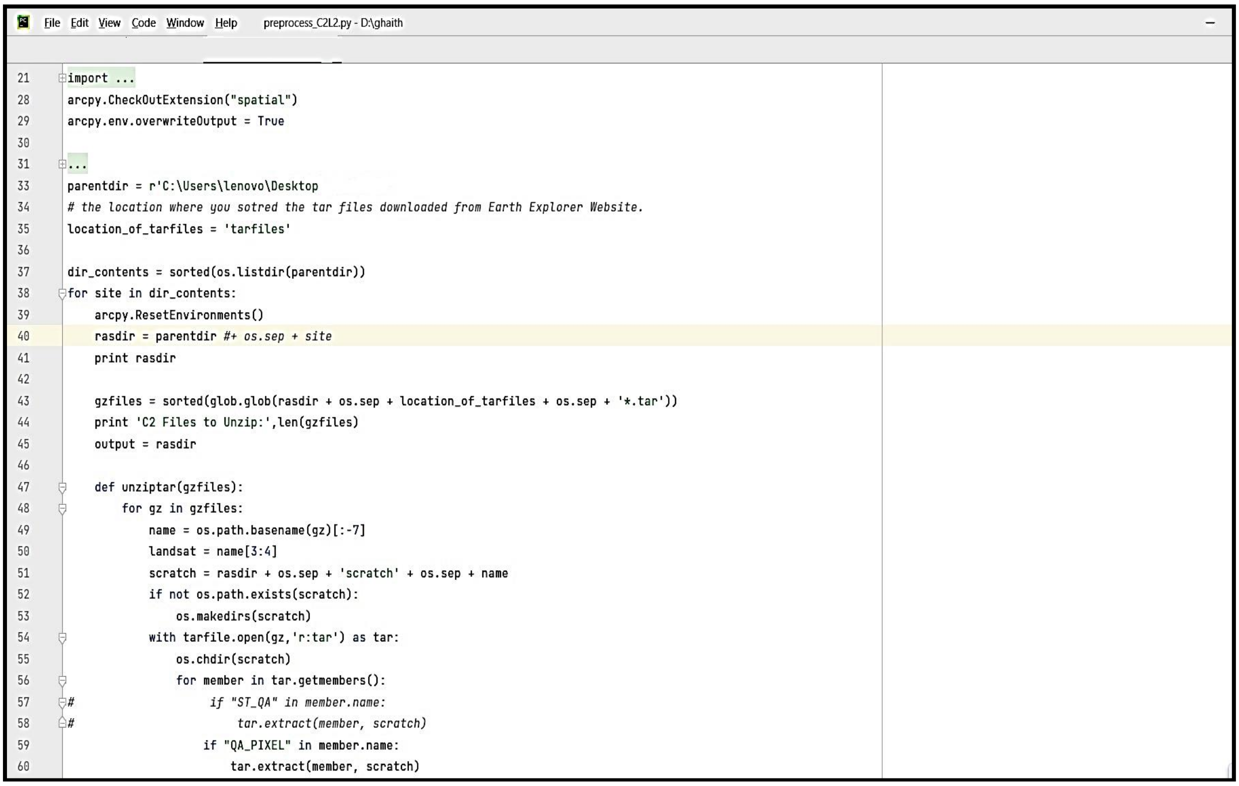

Figure 4. Python code execution.

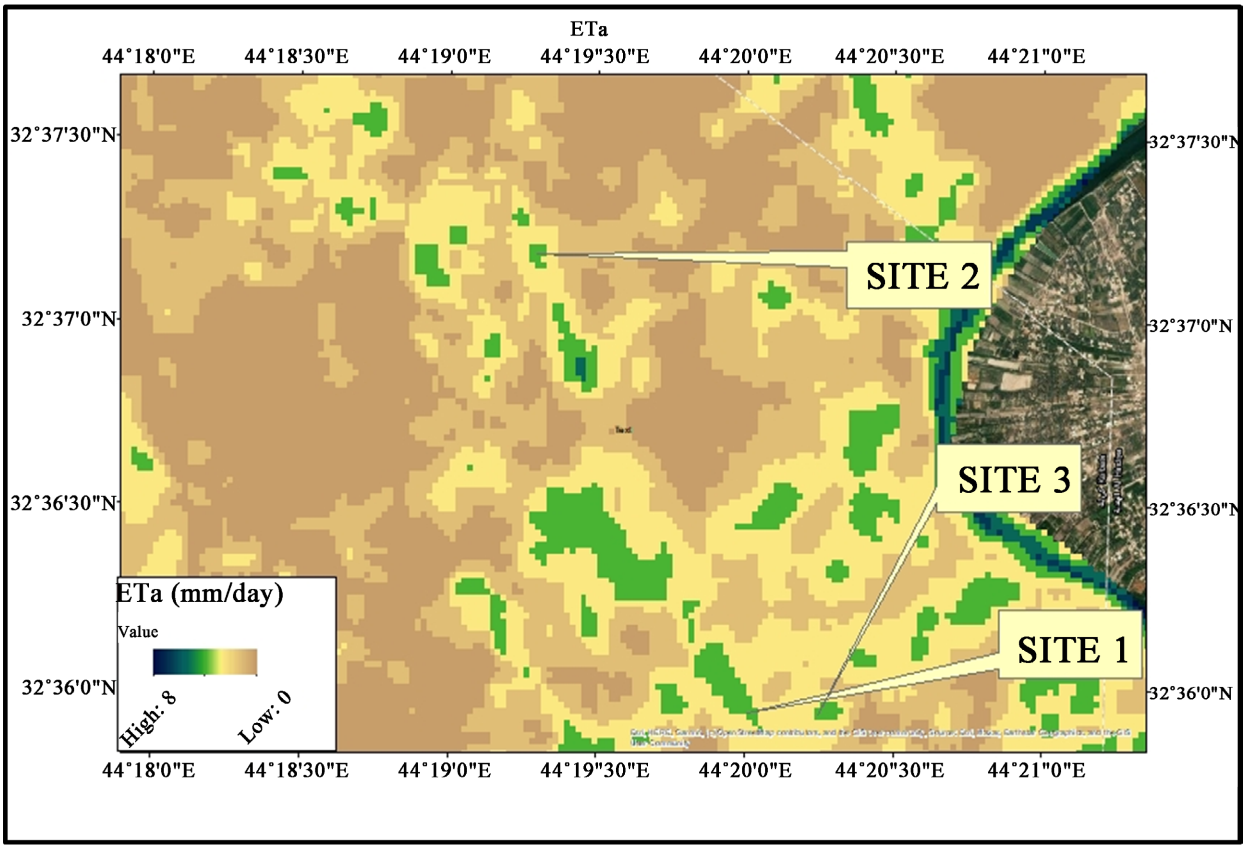

Figure 5. Map showing the locations of the three fields and daily evapotranspiration values for October month of 2021.

of using drain water by specific proportions. From results were shown actual evapotranspiration to C (irrigation by river water only) more than A (67% river water and 33% drain water) and B (17% river water and 83% drain water) via 7% and 58%, respectively. The production to C more than A and B by 17% and 75%, respectively. Figure 6 monthly variation of the carrot's ET_c values for sites A, B and C. as shown p. 361. Figure 7 daily variation of the carrot's ET_o values as

Table 5. Month, depth of supplied water and frequency of irrigation of carrot in A, B and C for the growing season 2021-2022.

Month	Depth of applied water (mm) in plot A	irrigation Number A	Depth of applied water (mm) in plot B	irrigation Number B	Depth of applied water (mm) in plot C with rain	irrigation Number C
Oct.	67	1	67	1	65.6	1
Nov.	65 + 4.2 rain	1	65 + 4.2 rain	1	65 + 4.2 rain	1
Dec.	65	1	67	1	65	1
Jan.	65 + 5.7 rain	1	65 + 5.7 rain	1	65 + 5.7 rain	1
Feb.	65	1	67	1	65	1
Mar.	65 + 5.5 rain	1	65 + 5.5 rain	1	65 + 5.5 rain	1
Total	**407.4**	**6**	**411.4**	**6**	**406**	**6**

Total volume of irrigation of A, B and C were 1018.5, 1028.5, 1015 m^3.

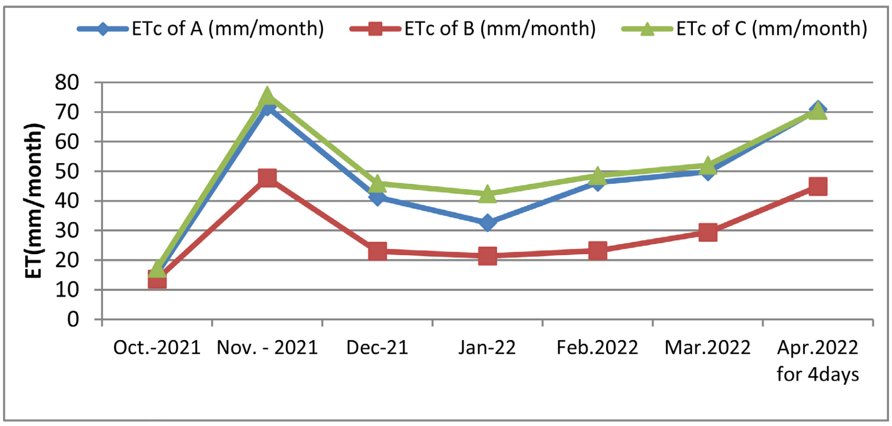

Figure 6. Monthly variation of the carrot's ET_c values for sites A, B and C.

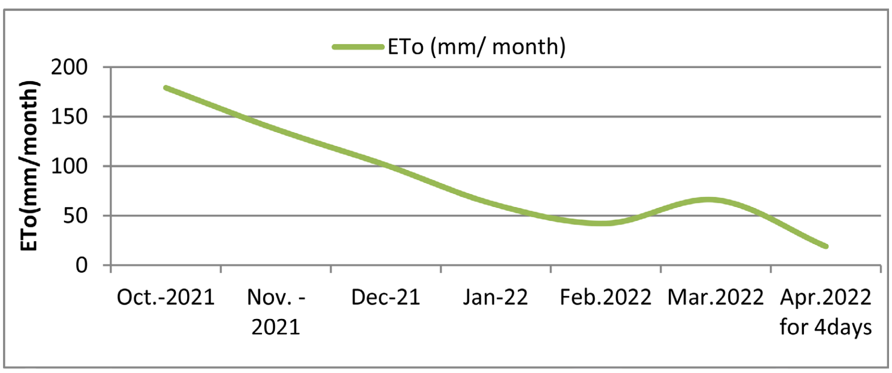

Figure 7. Daily variation of the carrot's ET_o values.

shown p. 361. Figure 8 accumulated values of carrot crop through the growing season in both sites A, B and C as shown p. 362. Figure 9 average predicted crop coefficient values of carrot crop in initial, development, mid and late of season in site 1 (A) as shown p. 362. Figure 10 shows average predicted crop coefficient values of carrot crop in initial, development, mid and late of season stage in site 2 (B) as shown p. 362. Figure 11 average predicted crop coefficient values of carrot crop in initial, development, mid and late of season stage in site 3 (C) as shown p. 363. Figure 12 shows the value of concentration of parameters and

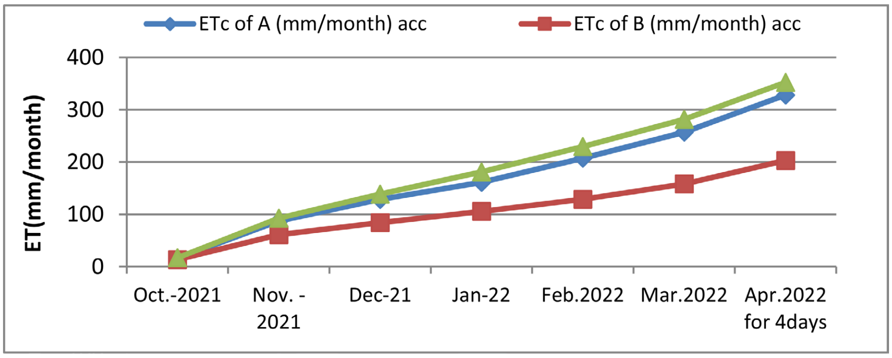

Figure 8. Accumulated ET_c values of carrot through the growing season in both sites A, B and C.

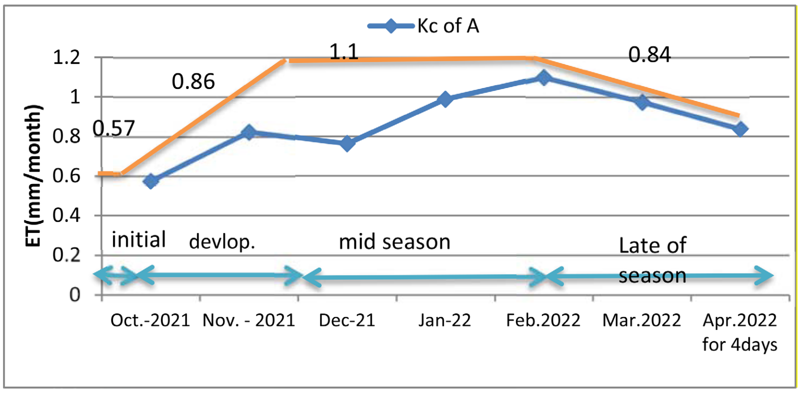

Figure 9. Average predicted crop coefficient values of carrot crop in initial, development, mid and late of season stage in location 1 (A).

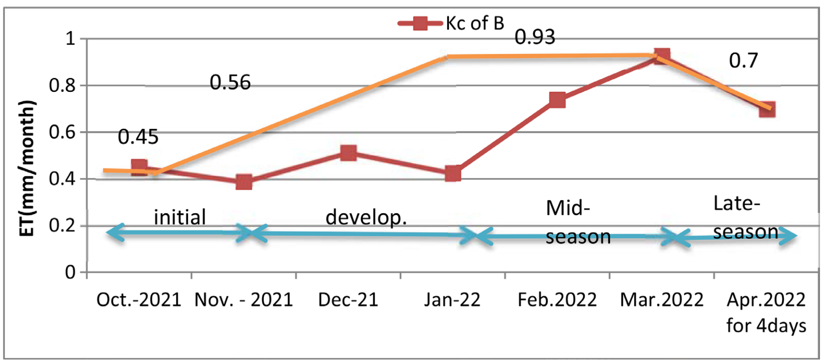

Figure 10. Average predicted crop coefficient values of carrot crop in initial, development, mid and late of season stage in location 2 (B).

Candian water quality index and Table 9 shown irrigation sources, F1, F2, NSE, F3, CWQI and Description.

Of the three figures, it was clear that the drain water affected the crop coefficient in all stages of growth, and the greatest effect was the B treatment that used the most percentage of the drain water by 10%, 35%, 15% and 17% in initial, development, mid of season and late season, respectively. Average predicted Carrots's K_c values for the growing stages 2021-2022 carried out by various using of treatment with different of percent using of drainage water and comparing the treatments A, B and C with FAO56 and FAO site in 29/4/2022 as shown Table 6.

Table 7 shown growing season of carrot crop (initial 20 day, development 40 day, mid of season 60 day and late of season 30) and total day was 150 day. In this study, did not notice any difference in the growth period during the three sites and treatments.

Affecting the drain water on ET_c is obvious effect as shown Table 8 the ET_c is reduction due to using drain water However, in certain proportions, it depends on the amount of drain water through growing season. Affecting was 38% of B treatment and 7% of C treatment depending on mixing ratio.

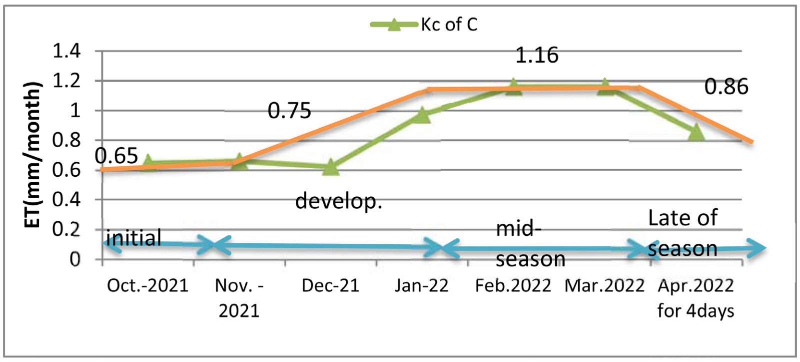

Figure 11. Average predicted crop coefficient values of carrot crop in initial, development, mid and late of season stage in location 3 (C).

Table 6. Average predicted Carrots's K_c values for the growing stages carried out via various models and approaches.

Models and approaches	Growing stage-K_c				Total period time (day)
	Initial	Develop.	Mid-season	Late-season	
Present work in A	0.57	0.86	1.1	0.84	150
Present work in B	0.45	0.56	0.93	0.7	150
Present work in C	0.65	0.75	1.16	0.86	150
FAO56 (1998)	---	0.7	1.05	0.95	100
FAO site in 29/4/2022	0.45	0.75	1.05	0.9	100-150

The reduction of K_c in B and A from C because of using the drain water in A and B sites.

Table 7. Growing season of carrot crop.

	Initial	Development	Mid of season	Late of season
Period (day)	20	40	60	30

Table 8. Month, ET_c of A, B, C and ET_o.

Date	ET_c of A (mm/month	ET_c of B (mm/month)	ET_c of C (mm/month)	ET_o (mm/day)	ET_o (mm/month)	K_c of A	K_c of B	K_c of C
Oct.-2021	15.6	13.6	17.2	5.78	179.18	0.575	0.45	0.65
Nov.-2021	71.69	47.72	75.64	4.58	137.4	0.825	0.388	0.663
Dec.-2021	41.27	23	45.9	3.26	101.06	0.763	0.513	0.625
Jan.-2022	32.6	21.36	42.39	1.97	61.07	0.988	0.425	0.975
Feb.-2022	46.25	23.2	48.55	1.51	42.28	1.1	0.738	1.163
Mar.-2022	49.82	29.38	52.05	2.13	66.03	0.975	0.925	1.163
Apr.-2022 for 4 days	70.9	44.86	70.58	4.76	19.04	0.838	0.7	0.863
Sum (mm)	328.13	203.12	352.31		575.72			

Table 9. Irrigation sources, F1, F2, NSE, F3, CWQI and Description.

Loc.	F1	F2	NSE	F3	CWQI	Description
Up stream of Sadat Al-Hindiya	10	10	0.088	8.09	90.6	Excellent
BD23	35	35	0.87492	46.66	60.7	Marginal

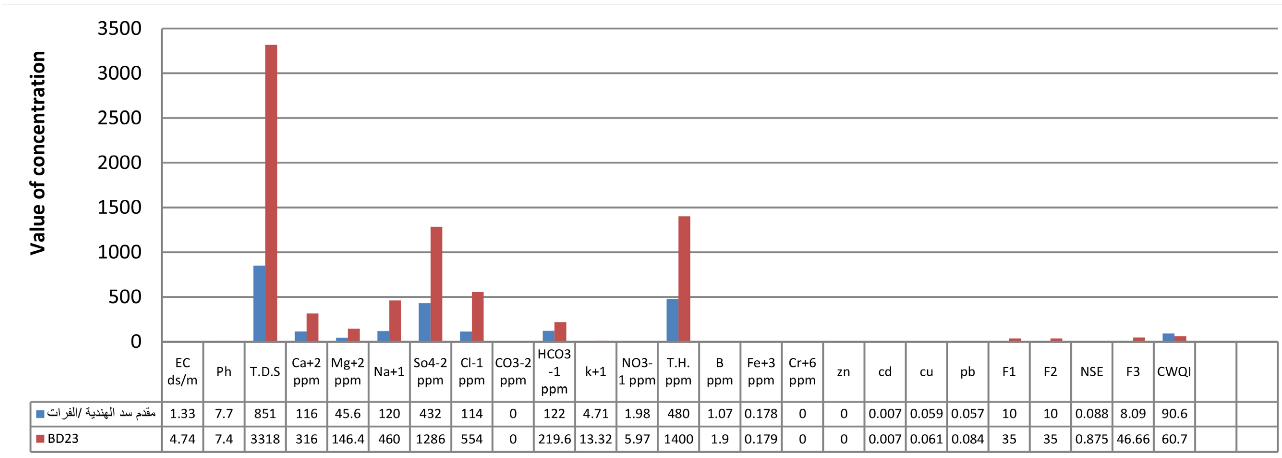

Figure 12. Value of concentration of parameters and Candian water quality index.

by sampling and testing the water samples which used to irrigate in A,B and C sites and evaluating them by the Canadian water quality index, the river water was found to be 90.6 is excellent and suitable for agriculture. The water for drainage is 60.7 Marginal which more salinity from fresh water and use to cultivate some types of crops also effect on growing, yield and evapotranspiration of crop but in this study the drain water (marginal) help on fill lack of water applied because of water scarcity due to climate change. As shown in **Table 9** and **Figure 12**.

5. Conclusions

The following conclusions were resulted from the field work of this research:

- The total ET_c of carrot through the growing season of A, B and C were 328.13, 203.12 and 352.31 mm, respectively. The total growing days were 150 days.
- Identical ET_c values were found in carrot crop of A and B less than C. The irrigation of drain water was affected crop's ET_c.
- Identical production values were found in carrot crop of A and B less than C. The irrigation of drain water was affected crop production.
- The predicted K_c values for carrot crop during the months of growing season, initial, development, mid and end of season in sites A, B and C were by remote sensing methodology.
- The drain water effect on crop evaporation, crop coefficient, canopy of crop, length of crop, number of leaves of crop and production of carrot crop.

Recommendation

For further studies, the following recommendations were suggested:

- Utilizing well, sewage and drain water after treatment to irrigation of all crops.
- Utilizing well, sewage and drain water after treatment to irrigation strategic crops (wheat, barley, maize and rice) for all texture soil.
- To study the influence drain water on production, canopy, number of leaves and biomass of crops.
- To study the influence drain water with percent of river water a well water or water eyes on production.

Conflicts of Interest

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

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