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Water Requirements of Crops under Various K_c Coefficient Approaches by Using Water Evaluation and Planning (WEAP)

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ABSTRACT

In this study, the Dual-K_c approach within FAO-56 paper was applied by water evaluation and planning (WEAP) to get the K_c parameters (K_{cb} and K_e) and to calculate the water requirement for various soil textures. The results compared with the outputs of Single-K_c approach for summer and winter crops in addition to trees. The results showed when applying Dual-K_c approach, the water requirements was more compared with the Single-K_c approach, except the tomato, eggplant, and Broad bean crop, which decreased by 5%, 4%, and 17% respectively. Also, there was a different in values of coefficient when compare two approaches, it was increased in Dual-K_c approach for wheat by 62% with 20% during initial and end-stage while ranged between 26-58% for trees during all season with more different for other winter and summer crops. The water requirement of crops was different according to soil texture. The net water requirement of wheat was 429 mm and 433 mm for sandy loam and clay loam respectively, with different in irrigation intervals 11 and 12 respectively, while the silt loam was recording water requirement 417 mm with 8 irrigation intervals.

1. INTRODUCTION

The study area located between 33°26' 84 " N to 33°22'15.46" N Latitude and 43°35'36.63 "E to 42°57'59.50" E longitude Figure 1. It has a climate characterized by high temperatures in summer and relatively rainfall in winter. Crops depend on irrigation to meet their water needs under surface irrigation method. Irrigation defines as the process of adding water to soil in different methods to provide the water requirements of crops by achieving optimum moisture for soil, and thus achieve more crop productivity [1].

Many factors effects on irrigation amount and irrigation intervals such as climate conditions, soil texture and the quantity with quality of available water resources, it represented by rain, water bodies and wells. These factors are important to recognize water consumption [2, 3].

The agricultural has important for providing livelihoods directly and indirectly to the population of developing countries through achieving food security and economic returns, especially for rural areas [4].

Estimating the values of reference evapotranspiration (ET_0) is important, where crop evapotranspiration (ET_c) calculated by depended on it. reference evapotranspiration (ET_0) represents reference surface of grass with height 0.12m and fixed resistance 70 s/m [5, 6].

In the FAO-56, there are two approaches, complex approach and simple approach. The dual-K_c approach is more accurate to calculate (ET_c), where depends on the soil texture, climate conditions and characteristics of crops with requires good knowledge of crop science [7, 8].

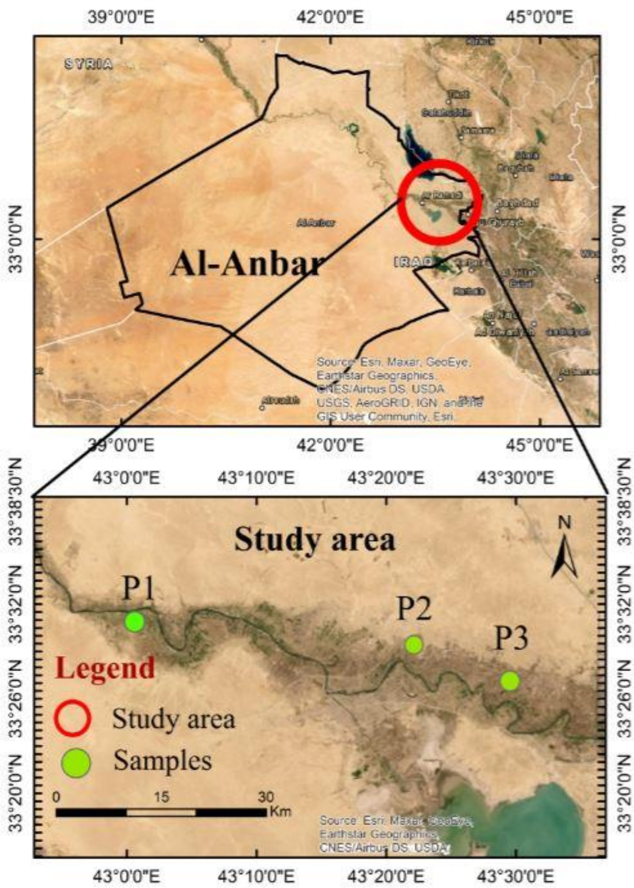


Figure 1. Location of the study area

The simple approach (Single-K_c) mixed coefficient of evaporation from soil (K_e) with the transpiration coefficient (K_{cb}) in one coefficient (K_c) [9]. But in complex approach (Dual-K_c), it separates two coefficient of soil and of transpiration (K_{cb} and K_e). Therefore, when applying the Dual-Kc approach, the daily transpiration (ET_T) calculates by separately about soil evaporation (ET_V) by depending on (K_{cb} and K_e), where the basal crop (K_{cb}) represents the ratio between the crop evapotranspiration (ET_c) to the reference evaporation (ET_0), when the soil surface layer is dry with a low value of sufficient water content within the root zone [10-12].

This study explains the difference between the two approaches of FAO-56 (Single and Dual approach). It describes the effect of soil texture on coefficients (K_e).

The Dual-Kc approach considers complicated and needs a computer to calculate, where the WEAP model considers the best choice to calculate this approach. Also, to explain the difference between irrigation intervals with water amount under different soil textures.

The impact of groundwater and capillary rise on crops was ignored within the irrigation project.

2. THEORY AND METHODS

In first step was collected data, Characteristics of crops, global researches, and climate condition as shown in Figure 2.

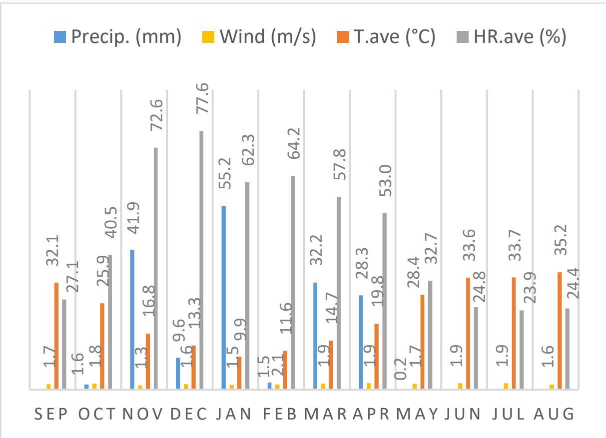


Figure 2. Daily Climate Data for the study area [12]

The second step involved taking samples of soil from the Ramadi irrigation project to describe the soil texture of each project by using Standard Test Method for Particle-Size Analysis of Soils [13] as shown in Table 1.

The third step was using the WEAP-model with (FAO 56, dual-K_c, daily) approach and compared the results with the single-K_c approach, by based on FAO-56 paper [14].

In the last step was estimating the crop water requirements for both approaches, and compared the results of both approaches.

Table 1. Soil textures for Ramadi irrigation project

Project	Clay %	Silt %	Sand %	Soil texture
1	18.8	24	57.2	Sandy Loam
2	30.8	32	37.2	Clay loam
3	20.8	50	29.2	Silt loam

3. WATER CONSUMPTION

Penman-Monteith equation used to calculate reference evapotranspiration by basis on daily climate changes as the following: [15]

$$ET_0 = \frac{0.408\Delta\,(R_n - G) + \gamma\,\frac{C_n}{T + 273}\,U_2\,(e^0{}_s - e_a)}{\Delta + \gamma\,(1 + C_d U_2)} \quad (1)$$

where, ET_0 was the reference evapotranspiration [mm day^{-1}], R_n was the net radiation at the crop surface [MJ m^{-2} day^{-1}], G was the soil heat flux density [MJ m^{-2} day^{-1}], T was the mean daily air temperature at 2 m height [°C], U_2 was the wind speed at 2 m height [m s^{-1}],e_s was the saturation vapor pressure [kPa], e_a was actual vapor pressure [kPa], $e_s - e_a$ was the saturation vapor pressure deficit [kPa], D is the slope vapor pressure curve [kPa °C^{-1}], and g is psychometric constant [kPa °C^{-1}].j.

For estimate the water requirement of a crop uses the crop coefficient (K_c) to calculate the crop evapotranspiration (ET_c) from reference evapotranspiration (ET_0) as following:

$$ET_c = K_c \text{ x } ET_0 \quad (2)$$

where, ET_c the crop evapotranspiration in (mm) was, K_c is the crop coefficient, and ET_0 was the reference evapotranspiration in (mm).

FAO-56 paper contents two methods to estimate ET_c, which is (Singe-K_c) and (Dual-K_c) approach. The (single-K_c) is using (K_{cb} and K_e), which is more complex in the calculation. But more studies indicated (Dual-K_c) approach has high accuracy in estimate ET_c and suitable in arid and semi-arid regions [16].

3.1 Single-K_c approach

The evaporations of soil and transpiration of crop are combined in (Single-K_c). This method applied by the Ministry of Water Resources of Iraq for different Iraq zones in 2014. In this approach, correct the standard value of FAO-56 by using Wind speed and the minimum humidity as the following:

$$K_{c\,correct} = K_{c\,(Tab)} + [\,0.04\,(U_2 - 2) - 0.004\,(RH_{min} - 45\,)[\frac{h}{3}]^{0.3} \quad (3)$$

where, K_c (Tab) was the value of K_c (mid or end), which taken from FAO-56, u_2 was the mean value at 2 m height during the stage, RH_{min} was the mean value for daily minimum humidity during the mid or end season.

If the K_c end was less than < 0.45 it does not need to correct and can use directly.

The effective rainfall represents the amount of water, which used by crop after subtracting the loss from rainfall as (percolation to groundwater, evaporation and surface runoff) [17, 18]. The effective rainfall was calculated by the Smith method, which bases on USDA SCS method and applied with reference evaporation (ET_0) ≈ 203 mm/month. It uses widely in global researches and CROPWATER model as a default method [18].

$$ER = \begin{cases} \frac{p \text{ x } (125 - 0.2 \text{ x } p)}{125}, & \text{for } p \le 250 \text{ mm / month} \\ 125 + 0.1 \text{ x } p, & \text{for } p > 250 \text{ mm /month} \end{cases} \quad (4)$$

where, ER was the effective precipitation in (mm/month), and p was the monthly precipitation in (mm/month).

$$CWR = K_C \, X \, ET_0 - ER \quad (5)$$

where, CWR was the crop water requirement in (mm), ET_0 was the reference evapotranspiration [mm day^{-1}], and EF was the effective rainfall in (mm).

3.2 Dual-K_c approach

It separates into K_{cb} represent the transpiration of crop and K_e represent the evaporation of soil. The transpiration coefficient K_{cb} was taken from FAO-56 paper [19] and corrected by depending on the following equation:

$$Kcb = Kcb\,(Tab) + [0.04(U2 - 2) - 0.004(RHmin - 45)](\frac{h}{3})^3 \quad (6)$$

where, K_{cb} (Tab) was the K_{cb} under stander condition, which take from FAO-56 paper under standard condition, U_2 (m/s) was the wind speed during the stage, and h (m) was the crop height during the stage and calculated by the following equation:

$$h_i = \frac{K_{cbi}}{K_{cb\,mid}} h_{max} \quad (7)$$

where, hi was the crop height at day i in (m), $K_{cb\,ini}$ was the basal coefficient at day i, $K_{cb\,mid}$ was the basal coefficient at the mid stage, and h_{max} was the maximum crop height at mid stage in (m).

And to calculate K_{cb} during the development and end stage use the following formula:

$$K_{cbi} = K_{cb\,prev} + \left[\frac{i - \sum L_{prev}}{L_{stage}}\right](K_{cb\,next} - K_{cb\,prev}) \quad (8)$$

where, i was the day during the season, K_{cbi} was the crop coefficient at day i, L_{stage} was length of stage in days, and $\sum (L_{prev})$ was the total previous lengths stages in days.

The second coefficient was K_e, which refer to evaporation of soil and calculated by depending the daily water balance equation:

$$K_e = K_r(K_{c\,max} - K_{cb}) \leq f_{ew} K_{c\,max} \quad (9)$$

where, K_{cb} was basal coefficient, $K_{c\,max}$ was maximum value when happen rain or irrigation with maximum value of K_e, K_r was dimensionless Coefficient affected by daily solar radiation, and f_{ew} was exposed soil, which subjected to solar radiation.

The K_r coefficient different from soil texture to another by various value of total evaporate water (TEW) and readily evaporate water (REW) with the available water content (AW) and depletion [20] , where the WEAP model take the value of this properties of each soil texture From FAO-56 to applying the calculation formula as following:

$$K_r = \frac{TEW - D_{e,i-1}}{TEW - REW} \quad (10)$$

where, TEW was the total evaporate from soil surface layer in (mm), which take 0.08m in MABIA method, REW was the readily evaporate water from soil surface layer without restriction in (mm), and $D_{e,i-}$ was the sum depletion depth of soil layer at the end previous day i.

4. RESULTS AND DISCUSSION

4.1 Single- K_c approach

By using Eq. (3) and Eq. (8) the monthly value of the Single-K_c coefficient was corrected for the study area as shown in Table 4, which was taken from FAO-56 paper under standard condition.

The monthly effective rainfall was estimated by depending on the SCS method into Eq. (4) and the results were as the following in Figure 3.

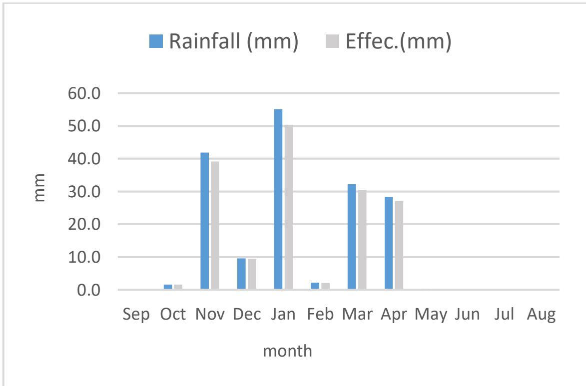


Figure 3. The monthly effective rainfall in (mm)

The effective rainfall was between 85 - 95% due to few monthly rainfalls, which caused high infiltration where the effective represent the amount of water that infiltrates and can be used by crop without losses (evaporation, surface runoff and percolation).

The Penman-Monteith equation shown the reference evapotranspiration for the study area was low during the period from September to February and increased from March to reach the peak at Mid-July as shown in Figure 4.

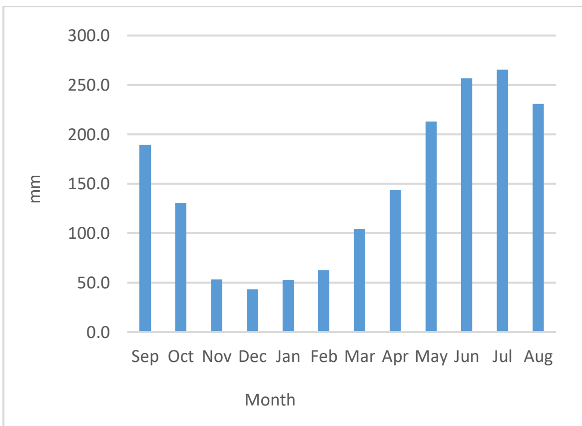


Figure 4. The average monthly reference evapotranspiration

The water requirement of crops was calculated by based on Eq. (5) with the effective rainfall from Figure 3 and the daily reference evapotranspiration from Eq. (1). The results compare with the results of the Iraqi Ministry of Water

Resources for the water requirements of crops for the central Iraq regions as shown in Table 2.

The was a different between two results as in Table 2, where the wheat and barley decreased by 27% and 26% with different ranged from 2% to 54 for others crops. The reason for this difference related to the average climate condition for the mid-Iraq zone, which took by the ministry water resources as average for 2014 year.

Table 2. Compare NIWR with the Reference in (mm)

Crops	By (reference)	By (Study)	Different %
Wheat	530	417	-27
Barley	395	314	-26
Maize	1215	993	-22
Cucumber	682	605	-13
Eggplants	558	707	+21
Kidney beans	388	363	-7
Potato Spring	645	693	+7
Sesame	1123	767	-46
Sunflower	815	841	+3
Sweet Pepper	869	941	+8
Tomato	791	901	+12
Watermelon	774	567	-37
Berseem	576	567	-2
Broad bean	246	375	+34
Cauliflower	514	333	-54
Potato autumn	485	282	-72
Citrus	1227	1154	-6
Grap	1329	1138	-17
Olives	1269	1178	-8
Palm	1759	1661	-6

The water depth in the Table 3 represents the net water requirement of crops without any loss by system irrigation. And to calculate the total water requirement with field losses, it must add the surface irrigation with efficiency 55% [21].

4.2 Dual- K_c results

The K_{cb} crop coefficient was calculated by depending on wind speed at 2 m height and minimum humidity by equation (3). Each crop had the same K_{cb} in each project despite different soil texture due to K_{cb} depending on climate condition without taking soil texture into account.

The evaporation coefficient of soil (K_e), the study showed there is a difference between projects as shown in Figure 5. Each soil texture has available water capacity (AW) different from soil to another. This different caused difference in the depth of total water evaporation from the top layer (TEW). The WEAP-model based on FAO-56 paper in estimating the (Aw) of each soil texture. Thus, the values of K_c differed between projects and the irrigation schedule varied for the same crop according to soil texture, also the amount of water required for each crop during the season as in Table 5.

The crop in the initial growth period requires fewer water quantities with more irrigation interval because of the short effective root depth during this period, which does not exceed 10 cm for most crops within the surface layer subject to significant evaporation also the K_{cb} coefficient of transpiration will few during the first period due to the limited Vegetation cover. In this period, evaporation is mainly from the exposed topsoil layer with an increase in K_e coefficient, which depends on K_r coefficient.

Table 3. Total water requirement of crop (with field losses)

Crops	Net (mm/ season)	(Total mm / season)
Wheat	417	758
Barley	314	571
Maize	993	1805
Cucumber	605	1100
Eggplants	707	1285
Kidney beans	363	660
Potato Spring	693	1260
Sesame	767	1395
Sunflower	841	1529
Sweet Pepper	941	1711
Tomato	901	1638
Watermelon	567	1031
Berseem	567	1031
Broad bean	375	682
Cauliflower	333	605
Potato autumn	282	513
Citrus	1154	2098
Grap	1138	2069
Olives	1178	2142
Palm	1661	3020

Table 4. Monthly crop coefficient by using (Single-K_c) approach

Crops	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug
Wheat	0	0	0.71	0.88	1.1	1.18	1.18	1.03	0.45	0	0	0
Barley	0	0	0.32	0.72	1.14	1.17	1.12	0.63	0.29	0	0	0
Maize	0	0	0	0	0	0	0.7	0.83	1.23	1.3	1	0
Cucumber	0	0	0	0	0	0	0.6	0.77	1.06	1.03	0	0
Eggplants	0	0	0	0	0	0.6	0.69	1.06	1.12	1.04	0	0
Kidney beans	0	0	0	0	0	0	0.52	0.94	1.09	0	0	0
Potato Spring	0	0	0	0	0	0.5	0.61	1.12	1.19	0.95	0	0
Sesame	0	0	0	0	0	0	0	0.39	0.91	1.2	0.89	0
Sunflower	0	0	0	0	0	0	0.35	0.62	1.24	1.26	0.7	0
Sweet Pepper	0	0	0	0	0	0	0.6	0.83	1.14	1.14	1.06	0
Tomato	0	0	0	0	0	0	0.6	0.74	1.19	1.18	0.88	0
Watermelon	0	0	0	0	0	0	0.4	1.07	0.98	0.86	0	0
Berseem	0	0	0.4	0.5	0.88	1.17	1.18	1.18	1.17	0	0	0
Broad bean	0	0.5	0.5	0.5	0.58	1.03	1.19	1.19	0	0	0	0
Cauliflower	0.7	0.72	0.87	1.02	1.05	1.02	0	0	0	0	0	0
Potato autumn	0.66	1.2	0.78	0	0	0	0	0	0	0	0	0
Citrus	0.7	0.7	0.7	0.71	0.72	0.72	0.72	0.72	0.72	0.75	0.79	0.83
Grap	0.3	0.3	0.3	0.3	0.3	0.52	0.87	0.95	0.95	0.95	0.93	0.64
Olives	0.65	0.66	0.68	0.71	0.74	0.76	0.76	0.76	0.77	0.79	0.81	0.83
Palm	0.9	0.9	0.9	0.9	0.93	1.1	1.09	1.09	1.09	1.09	1.09	1.11

The K_e coefficient values decreased during the flowering period due to the density of the vegetation cover and the spacing of irrigation interval of crops due to the increase in effective root depth, so the crop needs a longer period to be supplied by water as in Figure 5.

In the initial stage, the number of irrigation intervals in Figure 5 (a), (b), and (c) was 4, 4, and 3 respectively with few rainfalls, which caused increased in K_e coefficient during this period and increased in K_c coefficient for wheat. As for the number of irrigation intervals of barley was 4, 4 and 3 for (a), (b) and (c) respectively. The K_c in Table 6 represents sum of soil evaporation coefficient (K_e with transpiration coefficient ($K_{cb)}$ as in Table 6.

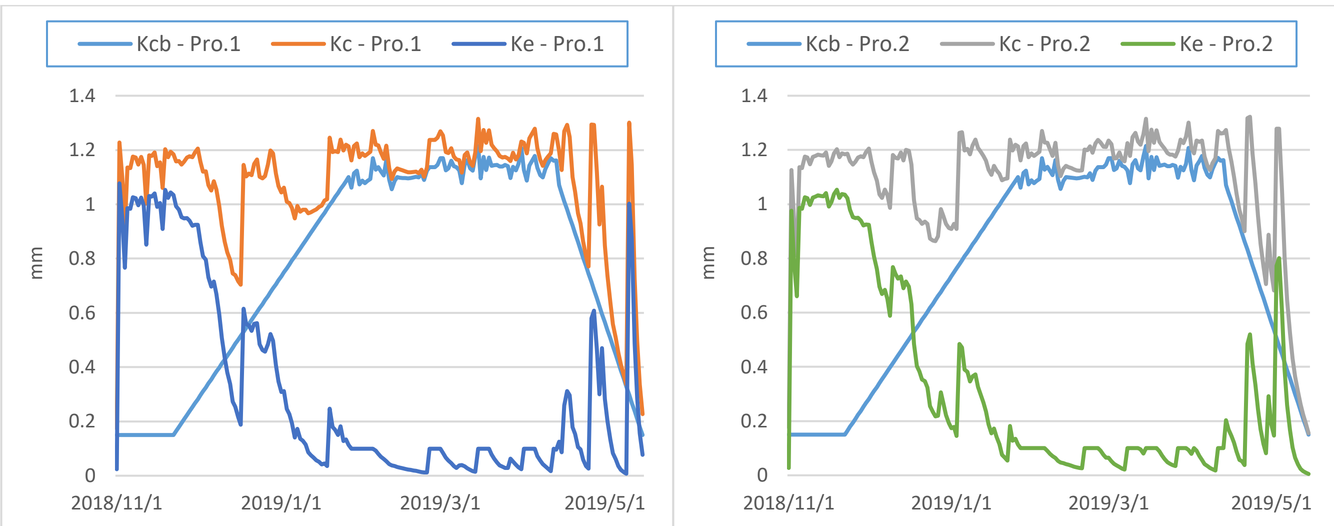
The irrigation interval was related to different in water content of soil (AW) with different the (TAW) and (RAW) of soil, where the irrigation was given to crop when depletion all RAW, which depend on TAW with depletion factor of crop. In the last stage, the wheat record irrigation number 3, 2, and 2 for (a), (b), and (c) respectively, with the same number of irrigations for barley by 3, 2, and 2 for (a), (b), and (c) respectively. The mid stage in general has a less value of K_e due to evaporation occur from vegetation cover. K_{cb} was constant of each project without any change due to clime was the same for each project.

Table 5. NIWR of crops for different project in (mm/ season)

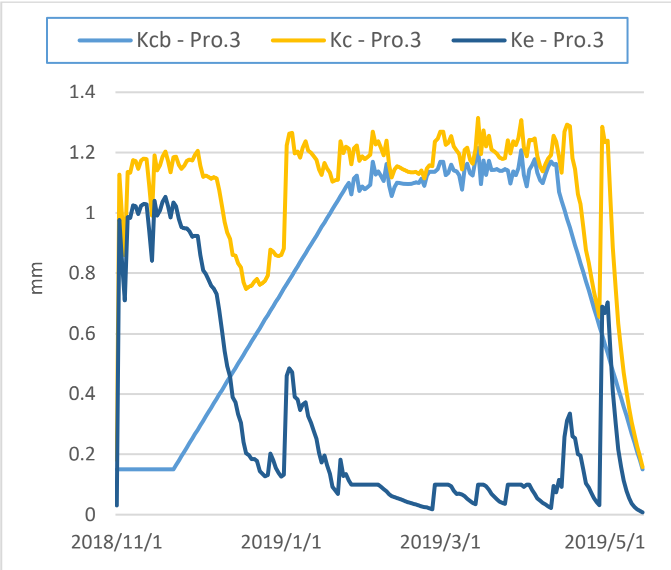
Crop	Pro.1	Pro.2	Pro.3
Wheat	475	424	413
Barley	343	351	370
Maize	977	996	1006
Cucumber	773	792	779
Eggplants	666	698	682
Kidney beans	428	452	417
Potato Spring	808	804	789
Sesame	869	906	947
Sunflower	912	945	898
Sweet Pepper	965	968	970
Tomato	840	879	850
Watermelon	860	895	838
Berseem	576	596	555
Broad bean	304	326	307
Cauliflower	562	550	538
Potato autumn	397	408	393
Citrus	1820	1886	1817
Grap	1314	1389	1350
Olives	1381	1558	1396
Palm	2028	2042	2046

Table 6. Average monthly coefficient (Dual-K_c) by researcher

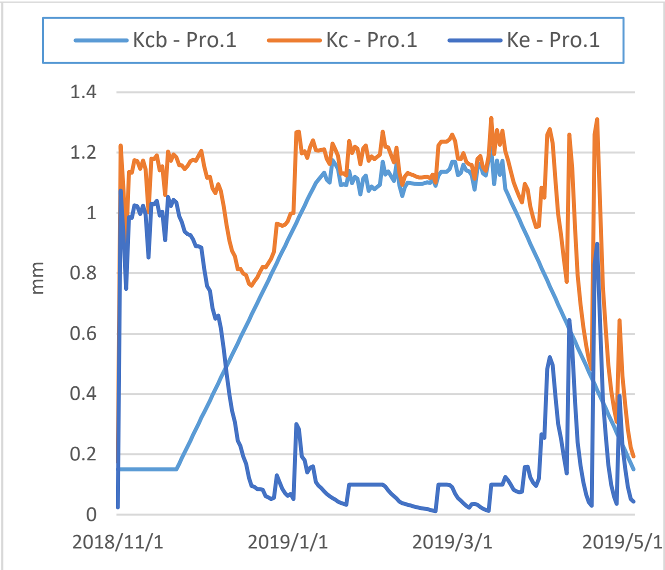
Crops	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug
Wheat	0	0	1.12	1.05	1.10	1.17	1.21	1.13	0.61	0.00	0	0
Barley	0	0	1.11	0.96	1.18	1.17	1.19	0.86	0.44	0.00	0	0
Maize	0	0	0	0	0	0	0.66	1.17	1.23	1.29	0.87	0
Cucumber	0	0	0	0	0	0	1.14	1.15	1.18	1.17	0	0
Eggplants	0	0	0	0	0	0.91	1.16	1.16	1.22	1.19	0	0
Kidney beans	0	0	0	0	0	0	1.10	1.19	1.15	0.00	0	0
Potato Spring	0	0	0	0	0	0.98	1.21	1.23	1.26	1.25	0	0
Sesame	0	0	0	0	0	0	0	1.12	1.06	1.23	0.92	0
Sunflower	0	0	0	0	0	0	1.16	1.20	1.25	1.27	0.94	0
Sweet Pepper	0	0	0	0	0	0	0.31	1.23	1.25	1.27	1.23	0
Tomato	0	0	0	0	0	0	1.17	1.20	1.23	1.24	1.11	0
Watermelon	0	0	0	0	0	0	1.17	1.12	1.17	1.13	1.06	0
Berseem	0	0	1.14	1.15	1.14	1.17	1.20	1.22	1.22	0.00	0	0
Broad bean	0	0.71	1.15	1.17	1.21	1.06	1.19	1.06	0	0.00	0	0
Cauliflower	1.17	1.21	1.10	1.08	1.16	1.10	0	0	0	0.00	0	0
Potato autumn	1.18	1.24	1.09	0	0	0	0	0	0	0.00	0	0
Citrus	0.89	0.92	1.10	1.04	1.01	1.06	1.10	1.10	1.10	1.22	1.23	1.22
Grap	0.15	0.21	0.63	0.39	0.52	0.80	0.98	1.16	1.14	1.15	1.11	0.77
Olives	0.65	0.62	0.98	0.93	1.01	0.97	1.02	1.00	1.00	0.99	0.98	0.94
Palm	0.97	1.01	1.09	1.09	1.17	1.20	1.26	1.29	1.30	1.32	1.34	1.32



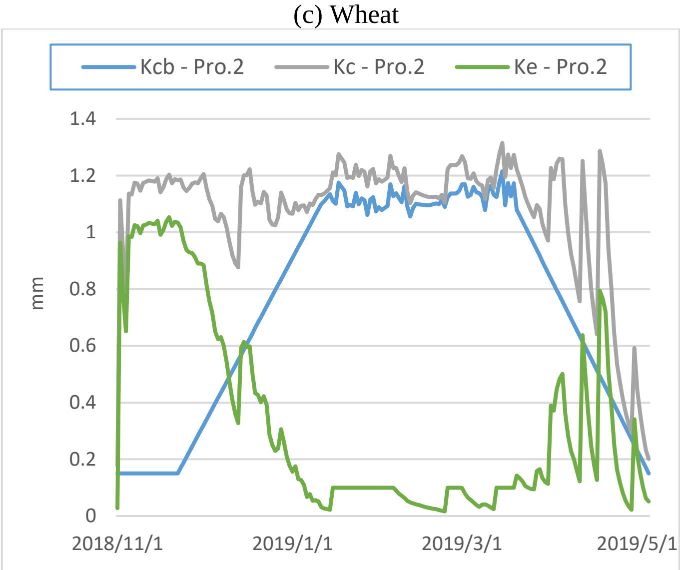
(a) Wheat (b) Wheat



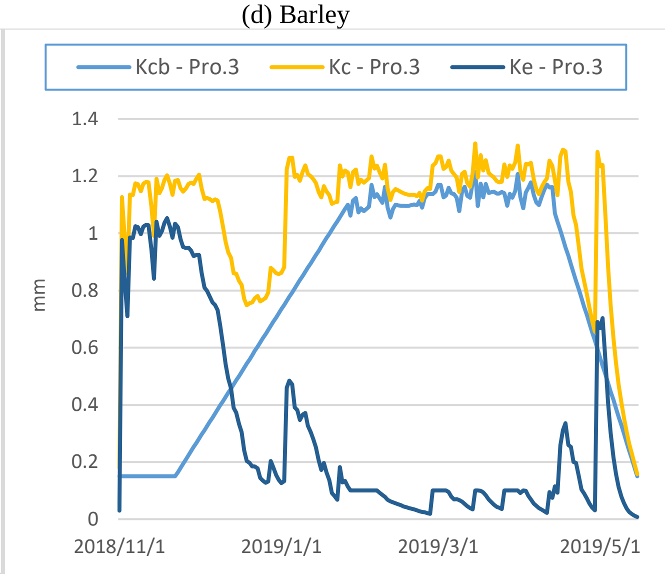
(c) Wheat



(d) Barley



(e) Barley



(f) Barley

Figure 5. The Dual-K_c with parameters for each irrigation project
(Where (a),(b),and (c) represents the Dual-K_c parameters for wheat crop within project 1,2,3 respectively while (d) ,(e) ,and (f) represents the Dual-K_c parameters for barley crop within project 1,2,3 respectively).

4.3 Comparison Dual-K_c with Single-K_c approach

The Single-K_c method depends on the climatic condition only, which represented by the minimum humidity and wind speed to correct the standard coefficient value of FAO-56 paper for the flowering and the harvest stage. The initial stage, did not adjusted and take as approximated value for planning and management purposes.

In the dual K_c approach, depends on daily climate condition, soil texture, and characteristics of crops in calculate transpiration coefficient represented by K_{cb} coefficient, and the evaporation coefficient K_e for top layer soil with the daily water balance of the surface layer of the soil and the moisture Period between the irrigation.

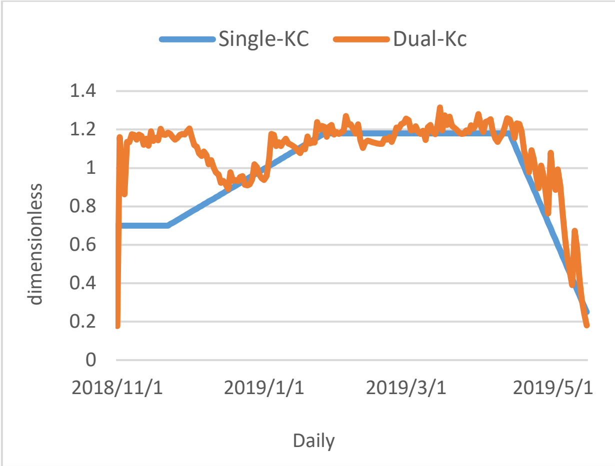
The research showed there was a difference in the water required for each crop during the season with different approaches as in Table 7, depending on the difference values of the coefficient for each approach as in Figure 6.

The water requirements of crops were low compared with the Dual K_c approach, except the tomato, eggplant, and Broad bean crop, which recorded an increase of 5%, 4%, and 17% respectively by using Single approach. The other crops increase by 2% to 65% under Dual approach.

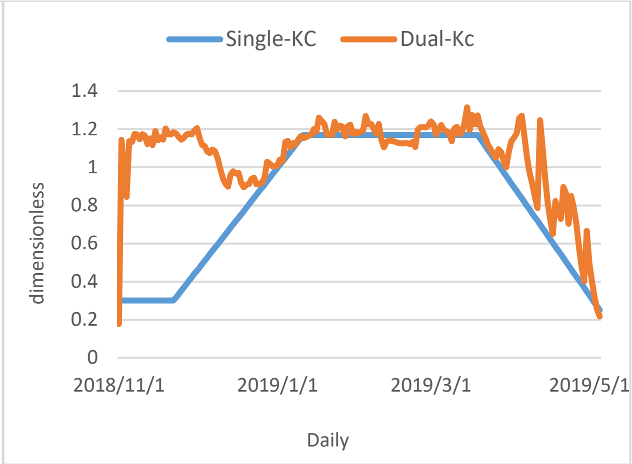
The results showed convergence coefficients during flowering stage for winter and summer crops with large different during initial and end-stage related with differences between two approaches as in Figure 6.

The wheat crop coefficient was increased with Dual-K_c approach by 62%, 17%, and 20% during initial, development, and end-stage respectively, while the barley was increased by 278%, 64%, 30% for initial, developing and end-stage respectively.

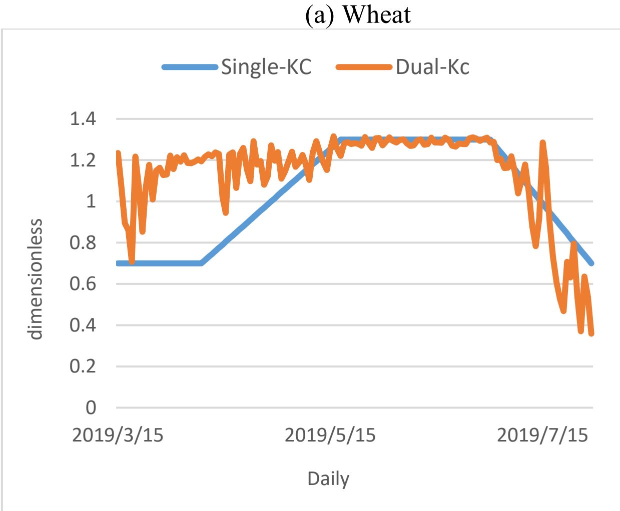
For maize and tomato crop, the different appeared by more during initial and developing stage by 58% and 22% for maize, with 94% and 37% for tomato due to short effective root depth during these stage with high temperature. The crop needs more irrigation intervals during initial stage due to limited of vegetation cover with exposed the subject surface top layer of soil to solar radiation, which caused increased in K_e coefficient.



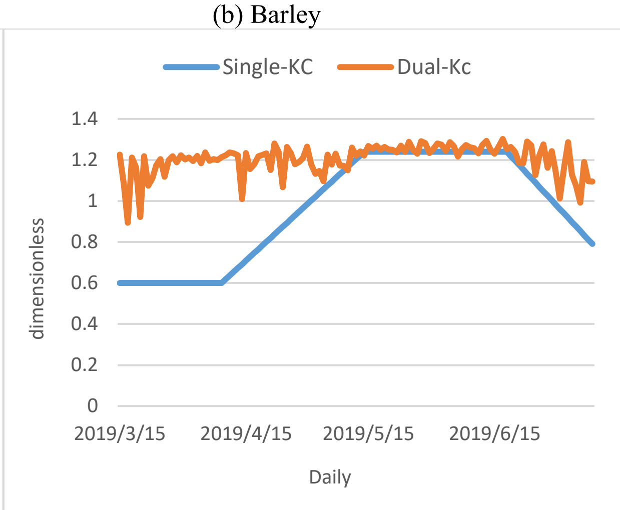
(a) Wheat



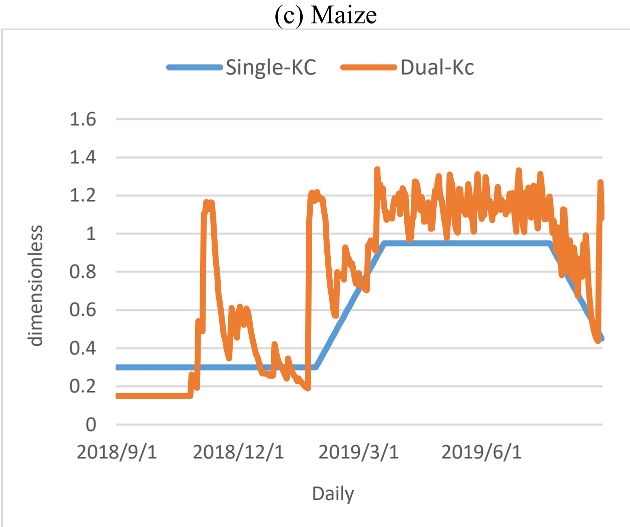
(b) Barley



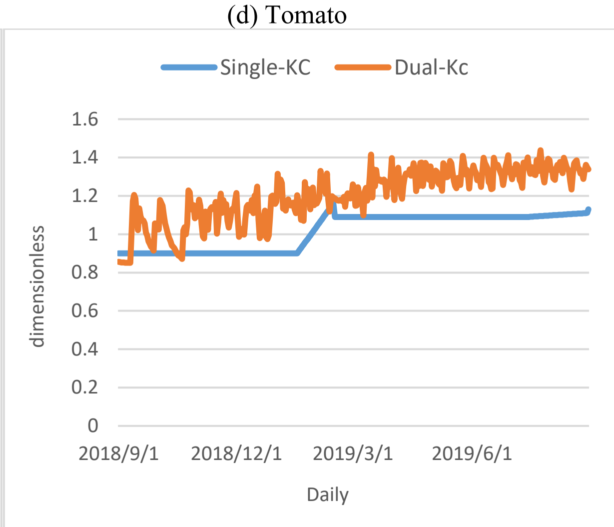
(c) Maize



(d) Tomato



(e) Grap



(f) Palm

Figure 6. Compare average Dual-K_c with Single-K_c

(Where (a),(b),(c),(d),(e), and (f) represents compare average dual-K_c coefficient with Single-K_c coefficient for wheat, barley, maize, tomato, Grap, and the palm respectively.)

For the trees, the results show increased ranged between 26-58% for grap during the season with increase 16-22% for palm trees due to the height of crop where the wind speed caused an increase in the transpiration of the plant, in addition to increase evaporation from the surface layer of soil during high-temperature months, which need more irrigation intervals.

4.4 Irrigation interval with water requirement

The irrigation intervals depended on daily depletion, where the water provided to crops at depletion all RAW, and different between soil textures according to the difference in water content (AW) of the soil and the (TAW) that depended on (AW) with effective root zone as in Figure 7. The crop during the initial stage has short effective root about 10 cm, where the top layer soil subjected to the solar radiation, which caused dry this layer and the crop will need water in a short time. So, there were several irrigations interval during initial stage more than other stages during one month.

In the flowering and harvesting stage, the root depth reaches the maximum vale with limited effective of (K_e) coefficient due to density of vegetarian cover, also the water will be provided to large depth according to the increase of (RAW) with an increase (TAW) with large effect depth as in Figure 8. The strategic crop wheat takes for example. The effective root during initial stage was 10 cm, then increases by depending on Eq. (8) as linearly to reach maximum effective depth 60cm at the mid-stage to continue as constant until harvesting as in Figure 7.

The water amount in Table 5, represents the net water requirement of the crop without any losses of field or convey, and when applying field losses of surface irrigation 45% for each soil, the water requirement for example for the wheat crop will be 780 mm, 787 mm, and 758 mm for project 1,2, and 3 respectively. Also, the irrigation intervals were different between projects as in Figures 9-11.

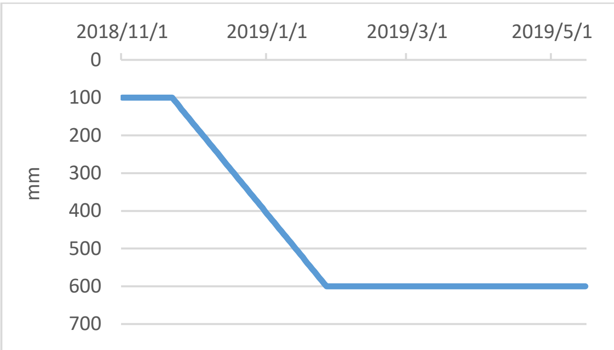


Figure 7. Daily effective root depth of wheat in (mm)

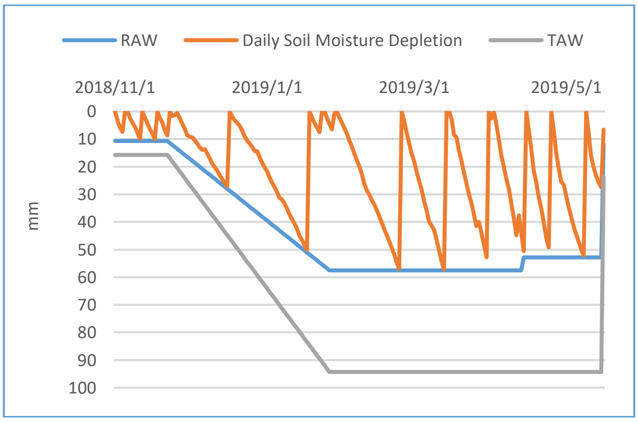


Figure 8. Daily depletion of wheat within project 1

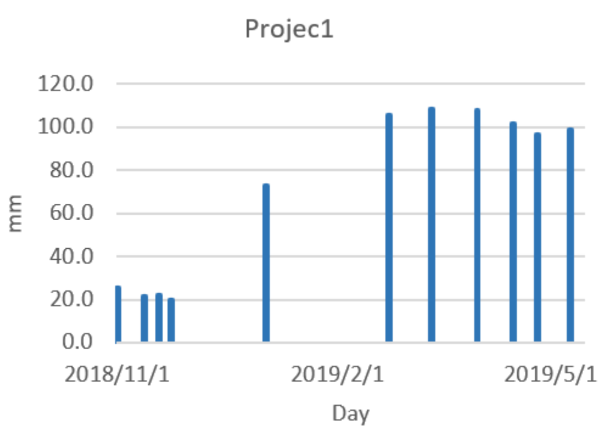


Figure 9. The irrigation intervals of wheat in Project 1

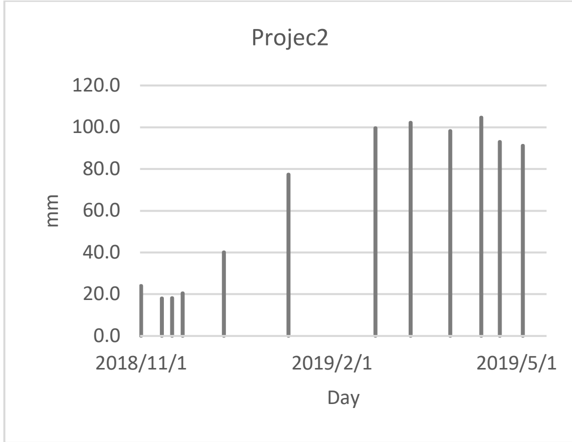


Figure 10. The irrigation intervals of wheat in Project 2

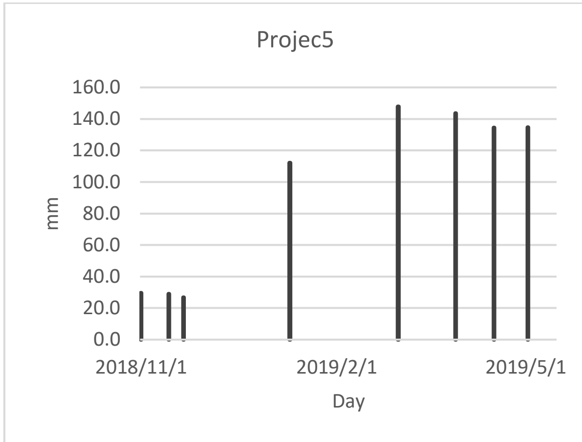


Figure 11. The irrigation intervals of wheat in Project 3

Table 7. Compare NIWR for single and dual approach

Crops	Single-K_c mm / season	Dual-K_c mm / season	Different %
Wheat	417	437	+5
Barley	314	355	+13
Maize	993	993	0
Cucumber	605	781	+29
Eggplants	707	682	-4
Kidney beans	363	432	+19
Potato Spring	693	800	+15
Sesame	767	907	+18
Sunflower	841	918	+9
Sweet Pepper	941	968	+3
Tomato	901	856	-5
Watermelon	567	864	+52
Berseem	567	576	+2
Broad bean	375	312	-17
Cauliflower	333	550	+65
Potato autumn	282	399	+41
Citrus	1154	1841	+60
Grap	1138	1351	+19
Olives	1178	1445	+23
Palm	1661	2039	+23

5. CONCLUSION

1- When applying Single-K_c approach, the water requirements of crops was low compared with the Dual K_c approach, except the tomato, eggplant, and Broad bean crop, which increase by 5%, 4%, and 17% respectively by using Single approach. The other crops increase from 2% to 65% under Dual approach.

2- When applied Dual-K_c approach there was a difference in the water required for each crop during the season, depending on the soil texture of each project, which was different in water-holding and the rate of evaporation from the surface layer of the soil.

3- There was a convergence in the coefficient of the crops for both approaches in the flowering stage for summer and winter crops with an increase during the initial and end-stage for potato and maize. It was depending on the high temperatures that cause increased evaporation from the top layer surface soil of the tomato and Maize crop, and requires more irrigation intervals. As for trees, there was an increase during all stages of growth for the dual-K_c, ranging from 26-58%.

4- There was different in daily K_e coefficient between projects according to different soil textures, which cause different in irrigation amount with irrigation intervals.

5- According to differences in water requirement of crops under various soil texture, when developing a cultivated area, the crop should be grown in the area that is consuming the least water. For example, the wheat consumes 429 mm and 417 mm (without losses) for project1 and project 3, therefor it should Planting in more per cent in the project 3. Also, the barley, it consumes less amount within project 1 with net water requirement depth 347 mm.

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