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Irrigation Schedules and Crop Water Requirements for Some Main Crops in Saudi Arabia

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Abstract:

The Food and Agriculture Organization (FAO) CROPWAT 8.0 standard software and the CLIMWAT 2.0 tool affixed to it have been utilized in this study for Qassim Region of Saudi Arabia to find CWRs and irrigation plans for numerous extremely valuable crops of KSA. We were used CROPWAT P. M. method for find out the ETo and (USAD) S. C. method utilized to determine roughly effective rainfall. The analysis demonstrated that ETo change over from 2.84 mm/day in January to reach maximum 9.61 mm/day in July due to high temperature in summer with annual mean was 6.33 mm/day, effective rainfall changes from 0 mm to 53.4 mm. The total IWRs were 308.3 mm/dec, 335.9 mm/dec, 343.6 mm/dec, 853 mm/dec and 1479.6 mm/dec for Barley, Wheat, Maize, Rice and Citrus, respectively. Due to low demand in winter and high demand in summer, the total net irrigation and total gross irrigations are 210.6 mm and 147.4 mm, 176.6 mm and 123.6 mm, 204.5 mm and 143.2 mm, 163.9 mm and 114.7mm for Wheat, Barley, Citrus, and Maize respectively except rice crop. These results showed that Wheat, Barley, Citrus, Maize and Rice crops have 4, 4, 12, 4 and 12 irrigation schedules respectively in a year.

Keywords: Saudi Arabia; Effective Rainfall; CWRs; IWRs; USAD S. C method; CROPWAT; CLIMWAT

Nomenclature

IWRs: Irrigation Water Requirements

CWRs: Crop Water Requirements

Dev.: Development

Init.: Initial

Irr. Req.: Irrigation Requirement

Gr. Irr.: Gross Irrigation

Net Irr. : Net Irrigation

ETc: Crop Evapotranspiration

ETo: Reference Evapotranspiration

NIR: Net Irrigation Requirement

Depl.: Depletion

Percol.: Percolation

ITS: Irrigation Time Schedules

IM: Irrigation Management

(USDA) S. C.: United States Department of Agriculture soil conservation

P. M: Penman–Monteith

1. Introduction

The agricultural development of Wheat, Rice, Maize, Citrus and Barley in Saudi Arabia stand facing enormous challenges, which are average of arid areas described with water shortage, low precipitation, and above average evapotranspiration requirement. Greatest of irrigation water is acquired from groundwater storage capacity. The farming segment expended more than 85% of water ingesting, which achieved more than 23 billion m³ in 2012 see [1]. An efficient and precise assessment of CWR is necessary for preparing, constructing, operational, controlling farm systems due to rise the demand of water with time. Precise assessment of CWR can assist to sustain cost-effective utilization of water reserves for irrigation. Evapotranspiration (ET) performs a most important part in sustainability of irrigation water [2].

CROPWAT model can perform a valuable part in improving useful suggestions for enhancing yield production beneath circumstances of sparse water resource [3]. It permits the expansion of suggestions for improved irrigation practices, the planning of irrigation timetables beneath differing water allocation requirements, and the estimation of production under rainfed circumstances or shortfall irrigation. The approximately the yield decline triggered by water pressure and climatical effects. The simulation results study recommends that in both situation rainfed and watered, the major yield decline happened in the developmental stage [4].

CROPWAT and CLIMWAT software's are used by many researchers for the estimation of CWR, and irrigation pattern and preparation. These tools were built by the Food and Agriculture Organization (FAO) for assistance researchers in water irrigation investigations and irrigation

sustainability [7]. In the current analysis, the irrigation water requirements and irrigation scheduling of a few chosen crops (Rice, Maize, Citrus and Barley, Wheat) in Qassim region, Saudi Arabia were investigated using the CLIMWAT and CROPWAT models.

2. Materials and Methodology

2.1. Study Area

The Al-Qassim Province (Region) is located at the heart of the Saudi Arabia, geographically center of Arabian Peninsula. The total population of this region is 1370727 and total area of this region is 58046Km². This region is an agricultural asset of Saudi Arabia. The average Maximum and Minimum temperature of this region is 31.4 °C and 16.5°C in 2019. The average humidity, wind and sunshine of this region are 30 %, 238 Km/day and 8.1 per hour, respectively. The latitude and longitude of Qassim region are 26°30'N and 43°76'E with altitude is 650m. The average rainfall of Qassim region is 183 mm [5, 15, 16].

Figure 1: Al-Qassim Region, Saudi Arabia

2.2. Reference Evapotranspiration (ET_o)

The ET_o gradually increase from nearly 2.84 mm/day in January to the highest worth of approximately 9.61 mm/day in Jul. Then it again declines steadily to 2.97 mm/day in December

as shown in table 1 and 3D figure 1. The maximum ETo rises from 5.26 to 6.98 mm/day in April. The average yearly ETo was 6.33mm/day in 2019.

Month	Min Temp. °C	Max Temp. °C	Humidity %	Wind km/day	Sun hours	Radiation MJ/m ² /day	ETo mm/day	Rainfall (mm)	Effective Rainfall (mm)
January	6.5	18.4	52	216	6.8	13.4	2.84	18.0	17.5
February	8.2	21.6	43	216	7.9	16.7	3.77	10.0	9.8
March	12.3	26.4	36	259	6.7	17.5	5.26	59.0	53.4
April	16.9	30.9	31	302	7	19.6	6.98	37.0	34.8
May	22	36.9	24	302	8.3	22.4	8.79	4	4
June	23.7	40.5	16	259	10.3	25.5	9.47	0	0
July	24.5	41.4	16	259	10.2	25.2	9.61	0	0
August	24.4	41.1	13	216	10	24.2	8.6	0	0
September	22.4	39.4	17	173	8.5	20.6	6.96	0	0
October	17.2	33.9	23	216	8.2	17.8	6.31	4	4
November	12.4	25.8	38	216	8	15.2	4.37	20.0	19.4
December	7.8	20.1	51	216	5.4	11.3	2.97	31.0	29.5
Total								183	172.3
Average	16.5	31.4	30	238	8.1	19.1	6.33		

Table 1: shows the date of Minimum Temperature (°C), Maximum Temperature (°C), Humidity (%), Wind speed (km/day), Sunshine (hour), Radiation (MJ/m²/day) and Reference Evapotranspiration (mm/day), Rainfall (mm) and Effective rainfall (mm).

Source: Statistical Yearbook, Ministry of Planning, 2019.

Figure2: shows the date of Minimum Temperature (°C), Maximum Temperature (°C), Humidity (%), Wind speed (km/day), Sunshine (hour), Radiation (MJ/m²/day) and Reference Evapotranspiration (mm/day), Rainfall (mm) and Effective rainfall (mm).

The effective rainfall as shown in table 1 and figure 2. The maximum effective rainfall was 53.4 mm in November 2019, although it was zero in June to September and between 4mm – 37 mm in the other months of year 2019. The total twelve-monthly effective rainfall was expected to be 172.3 mm. There are many methods to calculate the effective rainfall but in this study, we use USAD S. C. method.

2.3. Crop Water Requirement (CWR) of Rice, Wheat, Citrus, Maize (Grain) and Barley

The crop water essential is the quantity (or depth) of water that equals the water loss by ET. Crops have distinct water needs varying on the agriculture technique, effective rain, location, atmosphere, land type, etc., and the overall water necessary for crop development is not equally disseminated over its entire life span [6].

Evaluation of CWRs is obtained from crop evapotranspiration (ET_c) and reference evapotranspiration (ET_o) which can be analyzed by the following relation [7]:

$$ET_c = K_c \times ET_o, \quad (1)$$

where K_c called crop, coefficient introduced by [8] is the ratio of the ET_o and ET_c . This coefficient incorporates the impacts of four necessary measures that distinguish the crop from reference grass, and it covers reflectance of the soil surface, height evaporation from soil and resistance canopy. The crop coefficient K_c will vary due to ET effect at different stages of growth: initial, development, mid-season, and late see [2, 9].

The ET_o values of different months by using CROPWAT software as shown in table 1 and figure 2.

Table 2 to 6 shows the IWRs and Effective rain of Rice, Wheat, Citrus, Maize (Grain) and Barley. All results are calculated here by using CROPWAT software [10].

Table 2: CWR for Rice at different stages

Month	Decade	Stages	Kc	ETc (mm/day)	ETc (mm/dec)	Effective Rainfall (mm/dec)	Irr. Req. (mm/dec)
November	2	Nure	1.20	0.52	3.1	6.7	0
November	3	Nurs/LPr	1.12	2.68	26.8	7.8	110.1
December	1	Nurs/LPr	1.06	3.59	35.9	3.1	122.8
December	2	Initial	1.09	3.12	31.2	0.2	89.1
December	3	Initial	1.10	3.15	34.7	0.6	34
January	1	Dev	1.11	3.14	31.4	1	30.3
January	2	Dev	1.15	3.17	31.7	0.9	30.7
January	3	Dev	1.20	3.70	40.7	2.5	38.1
February	1	Mid	1.23	4.25	42.5	5.2	37.2
February	2	Mid	1.23	4.63	46.3	7.1	39.1
February	3	Mid	1.23	5.24	41.9	5	37
March	1	Mid	1.23	5.85	58.5	1	57.5
March	2	Late	1.22	6.42	64.2	0	64.2
March	3	Late	1.17	6.85	75.4	0.8	74.6
April	1	Late	1.13	7.22	72.2	4	68.2
April	2	Late	1.10	7.66	23	1.7	20.1
Total					659.3	47.9	853.0

Table 3: CWR for Wheat at different stages

Month	Decade	Stages	Kc	ETc (mm/day)	ETc (mm/dec)	Effective Rainfall (mm/dec)	Irr. Req. (mm/dec)
December	2	Init	0.3	0.86	5.2	6.5	0
December	3	Init	0.3	0.86	9.5	9.2	0.3
January	1	Init	0.3	0.85	8.5	7.1	1.4
January	2	Dev	0.38	1.05	10.5	5.7	4.8
January	3	Dev	0.68	2.1	23.2	4.9	18.3
February	1	Dev	0.99	3.43	34.3	2.5	31.8
February	2	Mid	1.18	4.44	44.4	0.9	43.6
February	3	Mid	1.18	5.04	40.4	6.5	33.8
March	1	Mid	1.18	5.63	56.3	14.9	41.4
March	2	Mid	1.18	6.22	62.2	20.7	41.5
March	3	Late	1.11	6.46	71.1	17.7	53.4
April	1	Late	0.81	5.22	52.2	14	38.2
April	2	Late	0.52	3.64	36.4	12.2	24.2
April	3	Late	0.33	2.5	7.5	2.6	3.2
Total					461.5	125.2	335.9

Table 4: CWR for Citrus at different stages

Month	Decade	Stages	Kc	ETc (mm/day)	ETc (mm/dec)	Effective Rainfall (mm/dec)	Irr. Req. (mm/dec)
December	2	Init	0.74	2.12	12.7	6.5	3.1
December	3	Init	0.7	2	22.1	9.2	12.9
January	1	Init	0.7	1.97	19.7	7.1	12.7
January	2	Init	0.7	1.92	19.2	5.7	13.5
January	3	Init	0.7	2.16	23.8	4.9	18.9
February	1	Init	0.7	2.42	24.2	2.5	21.7
February	2	Dev	0.7	2.64	26.4	0.9	25.5
February	3	Dev	0.7	2.99	24	6.5	17.4
March	1	Dev	0.7	3.35	33.5	14.9	18.6
March	2	Dev	0.7	3.71	37.1	20.7	16.4
March	3	Dev	0.71	4.12	45.3	17.7	27.6
April	1	Dev	0.71	4.53	45.3	14	31.3
April	2	Dev	0.71	4.95	49.5	12.2	37.3
April	3	Dev	0.71	5.39	53.9	8.5	45.3
May	1	Dev	0.71	5.87	58.7	3.9	54.8
May	2	Mid	0.71	6.33	63.3	0.1	63.3
May	3	Mid	0.71	6.47	71.2	0	71.1
June	1	Mid	0.71	6.59	65.9	0.1	65.7
June	2	Mid	0.71	6.75	67.5	0	67.5
June	3	Mid	0.71	6.78	67.8	0	67.8
July	1	Mid	0.71	6.86	68.6	0	68.6
July	2	Mid	0.71	6.91	69.1	0	69.1
July	3	Mid	0.71	6.65	73.2	0	73.2
August	1	Mid	0.71	6.37	63.7	0	63.7
August	2	Mid	0.71	6.13	61.3	0	61.3
August	3	Mid	0.71	5.74	63.2	0	63.2
September	1	Mid	0.71	5.3	53	0	53
September	2	Late	0.74	5.05	50.5	0	50.5
September	3	Late	0.74	4.92	49.2	0.1	49
October	1	Late	0.74	4.86	48.6	0.5	48
October	2	Late	0.74	4.72	47.2	0.8	46.4

October	3	Late	0.74	4.22	46.5	2.7	43.8
November	1	Late	0.74	3.7	37	4.9	32.1
November	2	Late	0.74	3.22	32.2	6.7	25.6
November	3	Late	0.74	2.88	28.8	7.7	21.1
December	1	Late	0.74	2.49	24.9	9.4	15.5
December	2	Late	0.74	2.12	8.5	4.3	3.1
Total					1656.4	172.5	1479.6

Table 5: CWR for Maize (Grain) at different stages

Month	Decade	Stages	Kc	ETc (mm/day)	ETc (mm/dec)	Effective Rainfall (mm/dec)	Irr. Req. (mm/dec)
December	2	Init	0.3	0.86	5.2	6.5	0
December	3	Init	0.3	0.86	9.5	9.2	0.3
January	1	Dev	0.37	1.06	10.6	7.1	3.5
January	2	Dev	0.63	1.74	17.4	5.7	11.7
January	3	Dev	0.92	2.83	31.1	4.9	26.2
February	1	Mid	1.18	4.09	40.9	2.5	38.3
February	2	Mid	1.24	4.66	46.6	0.9	45.7
February	3	Mid	1.24	5.28	42.2	6.5	35.7
March	1	Mid	1.24	5.89	58.9	14.9	44
March	2	Late	1.23	6.5	65	20.7	44.2
March	3	Late	1.03	6.01	66.1	17.7	48.5
April	1	Late	0.72	4.61	46.1	14	32.1
April	2	Late	0.45	3.17	25.3	9.7	13.2
Total					464.9	120.2	343.6

Table 6: CWR for Barley at different stages

Month	Decade	Stages	Kc	ETc (mm/day)	ETc (mm/dec)	Effective Rainfall (mm/dec)	Irr. Req. (mm/dec)
December	2	Init	0.3	0.86	5.2	6.5	0
December	3	Dev	0.31	0.89	9.8	9.2	0.6
January	1	Dev	0.56	1.59	15.9	7.1	8.8
January	2	Dev	0.91	2.5	25	5.7	19.4
January	3	Mid	1.17	3.6	39.6	4.9	34.7
February	1	Mid	1.18	4.07	40.7	2.5	38.1
February	2	Mid	1.18	4.43	44.3	0.9	43.4
February	3	Mid	1.18	5.01	40.1	6.5	33.6
March	1	Mid	1.18	5.6	56	14.9	41.1
March	2	Late	1.11	5.85	58.5	20.7	37.8
March	3	Late	0.81	4.7	51.7	17.7	34
April	1	Late	0.48	3.08	30.8	14	16.8
April	2	Late	0.28	1.96	5.9	3.6	0

Total	423.4	114.2	308.3
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From table 2 to table 5 we have the total irrigative water requirements (IWRs), total effective rainfall and crop evapotranspiration (ETc) of five crops (Rice, Wheat, Citrus, Maize, and Barley) in this area study (Qassim region, KSA) are according to this order respectively:

Barley(308.3) < Wheat(335.9) < Maize(343.6) < Rice(853) < Citrus(1479.6)

Rice(47.9) < Barley(114.2) < Maize(120.2) < Wheat(**125.2**) < Citrus(172.5)

Barley(423.4) < Wheat(461.5) < Maize(464.9) < Rice(**659.3**) < Citrus(1656.4)

From table 2 to table 5 show that 172.5 % of effective rainfall has been recorded by Citrus, 152.2 % has been recorded by Wheat, 120.2% , 114.2 % , and 47.9 % have been recoded by Maize, Barley and Rice respectively. Here we used the USDA S. C. method to find out the total effective rainfall of each crop with the help of CROPWAT software [10]

3. Results and Discussion

The data entered CROPWET and CLIMWAT software included the country (Saudi Arabia), Climatic station (Al-Qassim region), name of crop, sowing and harvesting time, soil information (Black Clay Soil). Once all data entered in system, we calculate ETo by using Penman-Monteith method [11, 12] and effective rainfall by using USDA S. C. method. Details results as shown in table 7 to table 11 etc. Scientific name of crop, Sowing and Harvesting time, Kc value, Rooting depth (m), Critical depletion, Yield response friction at different stages (initial, Development, Mid-season and Late-season), total number of days for completion and Croup height (m).

Crop Name	Spring Wheat	Scientific Name	Triticum Aestivum		
Planting Date (KSA)	15 th December 2020				
Harvest Date	23 rd April 2021				
Stages	Initial	Develop	Mid	Late	Total
Length (days)	30	30	40	30	130
Kc Values	0.30	→	1.15	0.30	
Rooting depth (m)	0.30	→	1.20	1.20	
Critical depletion	0.55	→	0.55	0.80	
Yield response friction	0.40	0.60	0.80	0.40	
Crop height (m)			1		

Table 7: shows the Wheat crop data at various stages.

Crop Name	Citrus ca bars	Scientific Name	Rutaceae		
Planting Date (KSA)	15/12/2020				
Harvest Date	14/12/2021				
Stages	Initial	Develop	Mid	Late	Total
Length (days)	60	90	120	95	365
Kc Values	0.70	→	.65	0.70	
Rooting depth (m)	1.40	→	1.40	1.40	
Critical depletion	0.50	→	0.50	0.50	
Yield response friction	1	1	1	1	1
Crop height (m)			4		

Table 8: shows the Citrus crop data at various stages.

Crop Name	Barley	Scientific Name	Hordeum vulgare		
Planting Date (KSA)	15/10/2020				
Harvest Date	11/02/2021				
Stages	Initial	Develop	Mid	Late	Total
Length (days)	15	25	50	30	120
Kc Values	0.30	→	1.15	0.25	
Rooting depth (m)	0.30	→	1.10	1.10	
Critical depletion	0.55	→	0.55	0.90	
Yield response friction	0.20	0.60	0.50	0.40	1.00
Crop height (m)			1		

Table 9: shows the Barley crop data at various stages.

Crop Name	Maize Grain	Scientific Name	Zea mays		
Planting Date (KSA)	15/03/2020				
Harvest Date	17/07/2020				
Stages	Initial	Develop	Mid	Late	Total
Length (days)	20	35	40	30	125
Kc Values	0.30	→	1.20	0.35	
Rooting depth (m)	0.30	→	1.00	1.00	
Critical depletion	0.55	→	0.55	0.80	
Yield response friction	0.40	0.40	0.30	0.50	1.25
Crop height (m)			2		

Table 10: shows the Maize Grain crop data at various stages.

Crop Name	Rice	Scientific Name	Oryza sativa					
Planting Date (KSA)	15 th December 2020							
Harvest Date	13 th April 2021		Growth Stage					
Stages	Nursery	Land prep		Initial	Develop	Mid	Late	Total
		Total	Puddling					
Length (days)	30	20	5	20	30	40	30	150
Kc Dry Values	0.70	0.30		0.50	→	1.05	0.70	
Kc Wet Value	1.20	1.05		1.10	→	1.20	1.05	
Rooting depth (m)				0.10	→	0.60	0.60	
Puddling depth (m)			0.40					
Nursery Area (%)	10							
Critical depletion	0.20			0.20	→	0.20	0.20	
Yield response friction				1	1.09	1.09	1.09	1.09
Crop height (m)						1		

Table 11: shows the Rice crop data at various stages. Only rice crop we added Nursery and land preparation time and Kc wet value.

3.1.Corp Pattern/Schedule and Net Irrigation Requirement (NIR)

Understanding of crop IWRs and ITS enhances IM in the ground. Irrigation water management is about optimize the rate of irrigation, amount and timing and rate of irrigation in an cost-effective and organized manner. Mathematically NIR is define as:

$$\text{Net Irrigation Requirements} = ETc - \text{Effective Rainfall}$$

This sort of assessment facilitates the agriculturalists to prefer the type of crops for growing on the based of availability of water [13]

The table 12 to table 16 shows the total net irrigation mean, the total gross irrigation means and total number of irrigations of each crop. The table 12 to table 16 shows that 210.6 mm and 147.4

mm, 176.6 mm and 123.6 mm, 204.5 mm and 143.2 mm, 163.9 mm and 114.7mm and net irrigation mean, and gross irrigation mean for Wheat, Barley, Citrus, and Maize respectively except rice crop. This analysis show that Wheat, Barley, Citrus, Maize and Rice crops have four, four, twelve, four and twelve irrigation schedules respectively in a year.

Table 12: Shows the irrigation schedules for Wheat

Date	Day	Stage	Rain (mm)	Ks (fract.)	Eta (%)	Depl. (%)	Net Irr. (mm)	Deficit (mm)	Loss (mm)	Gr. Irr. (mm)	Flow (L/s/ha)
22-Jan	8-Feb	Dev	0	1	100	56	98.8	0	0	141.2	0.42
24-Feb	12-Mar	Mid	0	1	100	57	136.8	0	0	195.5	0.69
31-Mar	16-Apr	End	0	1	100	61	147.4	0	0	210.6	0.7
23-Apr	End	End	2	1	100	25

Figure 3: shows the irrigation schedules for Wheat

Table 13: Shows the irrigation schedules for Barley

Date	Day	Stage	Rain (mm)	Ks (fract.)	Eta (%)	Depl. (%)	Net Irr. (mm)	Deficit (mm)	Loss (mm)	Gr. Irr. (mm)	Flow (L/s/ha)
10-Jan	27	Dev	0	1	100	56	93.5	0	0	133.6	0.57
11-Feb	59	Mid	0	1	100	55	121.1	0	0	173	0.63
12-Mar	88	Mid	0	1	100	56	123.6	0	0	176.6	0.7
13-Apr	End	End	6.4	1	100	37

Figure 4: shows the irrigation schedules for Barley

Table 14: Shows the irrigation schedules for Citrus

Date	Day	Stage	Rain (mm)	Ks (fract.)	Eta (%)	Depl. (%)	Net Irr. (mm)	Deficit (mm)	Loss (mm)	Gr. Irr. (mm)	Flow (L/s/ha)
15-Dec	1	Init	0	1	100	51	142.1	0	0	203	23.5
6-Mar	82	Dev	0	1	100	51	141.9	0	0	202.7	0.29
25-Apr	132	Dev	0	1	100	51	142.6	0	0	203.8	0.47
20-May	157	Mid	0	1	100	50	140.4	0	0	200.6	0.93
11-Jun	179	Mid	0	1	100	51	143.6	0	0	205.2	1.08
2-Jul	200	Mid	0	1	100	51	142.2	0	0	203.2	1.12
23-Jul	221	Mid	0	1	100	51	144	0	0	205.6	1.13
14-Aug	243	Mid	0	1	100	51	141.5	0	0	202.1	1.06
8-Sep	268	Mid	0	1	100	51	142.4	0	0	203.4	0.94
7-Oct	297	End	0.3	1	100	51	143.7	0	0	205.2	0.82
12-Nov	333	End	0	1	100	51	143.2	0	0	204.5	0.66
14-Dec	End	End	0	1	0	21

Figure 5: shows the irrigation schedules for Citrus

Table 15: Shows the irrigation schedules for Maize

Date	Day	Stage	Rain (mm)	Ks (fract.)	Eta (%)	Depl. (%)	Net Irr. (mm)	Deficit (mm)	Loss (mm)	Gr. Irr. (mm)	Flow (L/s/ha)
12-Jan	29-Jan	Dev	0	1	100	55	73.6	0	0	105.2	0.42
12-Feb	29-Feb	Mid	0	1	100	57	114.4	0	0	163.4	0.61
10-Mar	26-Mar	Mid	0	1	100	57	114.7	0	0	163.9	0.73
18-Apr	End	End	0	1	100	64

Figure 6: show the irrigation schedules for Maize (Grain)

Table 16: Shoe the irrigation schedules for Rice

Date	Day	Stage	Rain (mm)	Ks (fract.)	Eta (%)	Puddl.	Percol.	Depl. SM (mm)	Net Gift (mm)	Loss (mm)	Depl. SAT (mm)
25-Nov	-19	PrePu	0	0.9	90	Prep	0	41	91.3	0	40
10-Dec	-4	Puddl	0	1	100	Prep	0	4	90	0	40
14-Dec	0	Puddl	0	1	100	OK	4.9	0	54.3	0	4.3
23-Dec	9	Init	4.8	1	100	OK	3.1	0	95.5	0	-4.5
10-Jan	27	Dev	0	1	100	OK	3.1	0	100.4	0	0.4
26-Jan	43	Dev	0	1	100	OK	3.1	0	95.3	0	-4.7
9-Feb	57	Mid	0	1	100	OK	3.1	0	95.3	0	-4.7
22-Feb	70	Mid	0	1	100	OK	3.1	0	100.8	0	0.8
8-Mar	84	Mid	0	1	100	OK	3.1	0	98.3	0	-1.7
21-Mar	97	End	0	1	100	OK	3.1	0	100.1	0	0.1
2-Apr	109	End	0	1	100	OK	3.1	0	100.8	0	0.8
13-Apr	End	End	2	1	100	OK	38	0

Figure7: show the irrigation schedules for Rice

In figure 3 to figure 7, the total water available to the crop is denoted by (TAM) and RAM is the part of the water available to the crop that plant can get from the root zone and red line in graph shows the depletion. [14]

The production of these four crops in the province represents an insignificant percentage of the total KSA production and, consequently, there is an important requirement to modernize agricultural and irrigation practices for the intention of boosting production. Irrigation structure transformation supports innovative practices such as spraying and trickle irrigation with prominence on essential yields, water accessibility and topsoil value. An essential component is to increase understanding amongst agriculturalists about the necessity to protect water and use of innovative practices.

Table 17 illustrates the cultivated and harvested areas of the crops (Rice, Wheat, Barley, Maize and Citrus) and total amounts of production and sold production contained by this research in the Qassim region of Saudi Arabia.

	Cultivated Area (m²)	Harvest Area (m²)	Total Production (Ton)	Total Sold Production (Ton)
Total Qassim region	453099.0	427050.1	236505.1	219285.3
All KSA	2683311.7	2597886.4	1440065.0	1237558.7

Table 17 shows the total area and total production see [17].

4. Conclusion

The aim of this research was to establish the IWRs and approximate crop coefficient K_c for Wheat, Barley, Citrus, Maize and Rice crops in Qassim region. The average evapotranspiration approximate by Penman-Monteith's model was 6.33 mm/day. Above results show that Citrus had more amounts of evapotranspiration and more frequent irrigation schedules as compare other four crops following this order:

Barley(308.3) < Wheat(335.9) < Maize(343.6) < Rice(853) < Citrus(1479.6),

and order of effective rainfall of all crops are

Rice(47.9) < Barley(114.2) < Maize(120.2) < Wheat(**125.2**) < Citrus(172.5).

In these results, the value of E_T change from 2.84 mm/day to 9.61 mm/day and effective rainfall change from 0 mm to 53.4 mm. The total IWRs were 308.3 mm/dec, 335.9 mm/dec, 343.6 mm/dec, 853 mm/dec and 1479.6 mm/dec for Barley, Wheat, Maize, Rice and Citrus, respectively. Due to low demand in winter and high demand in summer, the total net irrigation and total gross irrigations are 210.6 mm and 147.4 mm, 176.6 mm and 123.6 mm, 204.5 mm and 143.2 mm, 163.9 mm and 114.7mm for Wheat, Barley, Citrus, and Maize respectively except rice crop. The results show that Wheat, Barley, Citrus, Maize and Rice crops have 4, 4, 12, 4 and 12 irrigation schedules, respectively.

Statement of Data Availability: The data that support the findings of this study are openly available in General Authority for Statistics, KSA at [<https://www.stats.gov.sa>], reference number [34].

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Figures

Figure 1

Al-Qassim Region, Saudi Arabia Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

shows the date of Minimum Temperature ($^{\circ}\text{C}$), Maximum Temperature ($^{\circ}\text{C}$), Humidity (%), Wind speed (km/day), Sunshine (hour), Radiation ($\text{MJ}/\text{m}^2/\text{day}$) and Reference Evapotranspiration (mm/day), Rainfall (mm) and Effective rainfall (mm).

Figure 3

shows the irrigation schedules for Wheat

Figure 4

shows the irrigation schedules for Barley

Figure 5

shows the irrigation schedules for Citrus

Figure 6

show the irrigation schedules for Maize (Grain)

Figure 7

show the irrigation schedules for Rice