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Estimation of the Daily Crop Irrigation Requirements under Abu Dhabi Conditions I-Vegetables

Ali Alshrouf[1]*, Ihsan Abu-Alrub[1] and Hassan Al Marzouqi[2]

[1]Agriculture Research Section, R&D Division, Abu Dhabi Agriculture and Food Safety Authority (ADAFSA), Abu Dhabi, United Arab Emirates.
[2]Food Research Section, R&D Division, Abu Dhabi Agriculture and Food Safety Authority (ADAFSA), Abu Dhabi, United Arab Emirates

Abstract

Knowledge of crop water requirements and irrigation scheduling is crucial to improve the irrigation application and irrigation scheduling, since the measurement method for the actual crop water requirements are quite time consuming, the estimation method could be a good alternatives to increase the irrigation efficiency. In this study, the crop water requirements for the open field grown vegetables under Abu Dhabi Emirate conditions is estimated using FAO-modified penman Monteith equation for the main three agro-regions. The results showed the highest crop water requirements are in the AlAin area with average 5-13 mm/day, followed by Al Dhafra and Abu Dhabi. Also the study examines the impact of two scenarios for the climate change on the water resources demand. His study is a useful tool for planning and management of the irrigation water.

Keywords: Crop water Requirements; Irrigation Efficiency; Irrigation scheduling; Climate change; Cropping pattern

Introduction

The UAE lies in the southeastern part of the Arabian Peninsula between latitudes 22° 40' and 26° 00' N, and longitudes 51° 00' and 56° 00' E. It is located within the arid region, with very high summer temperature and less than 100 mm annual average rainfall. Abu Dhabi Emirate is the largest Emirate in the UAE, accounting for approximately 87% of its total area. Abu Dhabi has two mains Agroecological zones; (a) the coastal areas have a hot and humid climate in the summer season and mild winter. (b)The interior southern desert region has hot summers with temperatures rising to about 50°C and cool [1].

The United Arab Emirates (UAE) is among the most water-scarce countries in the world. This water challenge involves different factors including the severe scarcity of groundwater reserves, groundwater salinization, high cost of desalinated water for domestic and agriculture use, limited re-use of treated water [2]. Additionally, UAE has one of the highest per capita water usages of globally. The average per capita water consumption rate in the UAE is 500 Liters per person per day which is more than double the world national average of 180 liters per person per day [3].Furthermore, rapid population growth, socio-economic development, and the increase in the living standards had led to dramatic increase on water demands for different uses [4].

On the other hand, agriculture in the UAE totally depends on irrigation and consumes around two-thirds of water consumption in the country. The irrigational water uses for the three main crop types: date palm and fruit trees, field crops, and vegetable crops. Domestic and industrial demands are covered by desalinated water, whereas agriculture demands are met mainly by groundwater [5].

So securing a safe and sustainable water supply in Abu Dhabi consider a challenge to fulfill the Agriculture, domestic and industrial needs. Accordingly a range of essential strategic initiatives are already being adapted in Abu Dhabi continuous pursuit in order to increase the irrigation efficiency and narrow the gap between the agricultural water supply and the need without affecting the agricultural food production.

Efficient water resources use requires a good development, and operating system with considering the vegetation pattern of the region. Accurate estimation or determining the actual crop water requirement and amount of irrigation water for the plants in the crop pattern enable to develop suitable irrigation programs and can also prevent irrigation-induced yield reductions. The main purpose of irrigation is to ensure stability in actual crop water requirement and to deliver sufficient moisture in the root zone of the crops. Since water is an important input for crop production, it should be well-planned and distributed effectively. The expected benefit from irrigation can be increased and irrigation efficiencies can be improved with the appropriate modifications of conventional irrigation systems [6].

Under these circumstances, it is important to adopt water saving strategy in agriculture, which intends to raise the water utilization rates and water use efficiency resulting in higher economic yield on irrigated farm land with a minimum input of water. It is comprehensive exercise using every drop of water for lint production including the use of natural precipitation as well as efficient management of irrigation network through a suitable irrigation method. A better understanding of the complicated relations between climate, water and crop growth needs to be a priority area in the UAE. Here comes the importance of developing the scientific crop water requirements for enhancing efficient irrigation scheduling, water balance, canal design capacities, regional drainage, water resources planning, reservoir operation studies, and to assess the potential for crop production

FAO Penman-Monteith method [7]is used for determining reference crop evapotranspiration (ET0) and provide values that are very consistent with actual crop water use data worldwide [8-10]. The irrigation schedule recommendations for various crops should be location-specific, considering the soil types and agro-ecological

***Corresponding author:** Ali Alshrouf, Agriculture Research Section, R&D Division, Abu Dhabi Agriculture and Food Safety Authority (ADAFSA), Abu Dhabi, United Arab Emirates, E-mail: ali.alshrouf@adafsa.gov.ae

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conditions. The right estimation of the crop evapotranspiration (Etc) is essential in the management and improvement of water resources. The scarcity of freshwater resources or the mismanagement of water in agriculture has made the effective and valuable use of water even more vital.

Water resources should be run at an optimum level in terms of irrigation parameters. The calculation of crop water requirement is very important in local balancing of water resource and correct planning and operation of water resources, determination of water demands that may occur in the future and maintaining water supply–demand balance. crop water requirement values vary depending on climate, planting area, planting time, soil type [11] and can be estimated by using direct or indirect measurement methods and meteorological data. The direct measuring method of Etc is often complicated and expensive. Therefore, the potential evapotranspiration can be calculated using the Penman-Monteith equation in the windows-based CROPWAT 8.0 software developed by Food and Agriculture Organization (FAO) of the World. Factor crop coefficient is used to calculate actual from potential evapotranspiration. In addition, estimations of irrigation water requirements and yield reduces in response to critical reductions in irrigation water allow improvement of irrigation programs [12] The irrigation water requirement for different crop patterns can be calculated with this model (using soil, plant and climate data), and reliable estimates can be carried out.

The FAO-CROPWAT model has been effectively used in many parts of the world for various crop patterns under irrigated conditions [13].The CROPWAT 8.0 software has been widely used in different geographical regions and climatic conditions to calculate crop evapotranspiration and irrigation water requirements vegetables [14].

Sustainable agricultural development is based on a balanced framework for developing and implementing suitable farming systems and good agricultural practices. Increasing production efficiency through modern techniques and combining high value crops and animal wealth are essential. Since the agricultural sector is one of the UAE largest water consumers, and this is a reflection of the management of agricultural lands and soil treatment. And as CropWat considered as ideal software due to reliable results reported in studies conducted in semi-arid climatic conditions, without causing a decrease in yield. This review article is aiming to provide irrigation requirements as well as the irrigation scheduling, by determining the actual crop water requirements the most common open field crop grown in Abu Dhabi Emirate, to offer the Abu Dhabi agriculture sector as estimated tool to guide towards environmentally sustainable consumption of water

Materials and Method

This study is carried out in Abu Dhabi Emirate, UAE, the three main agro climatic regions were considered in this study: Al Ain, Al Dhafra and Ab Dhabi. For calculating a daily potential evapotranspiration (ET0), a long term (around 30 years) climatic parameters were analyzed for estimating the monthly averages and calculating the ET0 using FAO Penman Monteith equation. Some of the collected data were provided from the weather stations. Other parameters are related to commonly measured data and can be derived with the help of direct or empirical equations. As soon as the ET0 has been determined, a crop coefficient approach was applied to adjust ETo value for the type of crop being irrigated. The crop coefficient takes into account the crop type and crop growth development stage to adjust the ETo for corresponding crop. Crop coefficients values were obtained from the documented tabulated records for many different types of crops developed by FAO. Use of a single crop coefficient combines soil evaporation and crop transpiration into one value, Kc.

A survey for the most common grown vegetables with their possible growing season in Abu Dhabi has been done and used to calculate the seasonal needed irrigation requirements. Some of those vegetables' crops are growing in one season and others are growing in two seasons per year.

Results and Discussion

Climatic Indicator

Abu Dhabi has a hot arid climate. The temperature varies from 13°C to 43°C and is rarely below 10°C or above 46°C, August is the hottest month. The warm season started from May 15 till September 26 with an average daily high temperature above 40°C. While the cold season lasts from December 4 to March 4 with an average daily high temperature below 26°C and January if the coldest month. Relative humidity usually ranges from 20% (dry) to 90% (very humid) over the year, rarely dropping below 9% (very dry) and reaching as high as 100% (very humid).

The precipitation varies throughout the year with variation in the amount, intensity and frequency. The highest Precipitation amount occur in December with almost no rainfall likely occur during the summer months. Wind speeds vary from 2.5 m/s to 7.8 m/s (light air to moderate breeze), rarely exceeding 10 m/s (fresh breeze). The day length varies over the year, with shortest day is December 21st with 10:37 hours of daylight; the longest day is June 20 with 13:39 hours of daylight. Sunshine and blue skies can be expected almost every day in Abu Dhabi. The city experiences a really hot and humid climate in the months from April to September when the maximum temperatures average above 40 °C (104 °F). During this period, unpredictable sandstorms occur in the city and sometimes visibility gets down to a few meters.

A long-term average for the climatic parameters is shown in tables 1,2 and 3 for Abu Dhabi, Alain and Al Dhafra regions.

Potential Evapotranspiration in Abu Dhabi Agroclimatic Zones

The crop water requirement is the total quantity of water required from sowing time up to the harvest. Different crops have different water requirements at different regions in Abu Dhabi Emirate, depending upon the climate parameter, type of soil, and method of cultivation.

Climate change is projected to have significant impacts on agricultural production. Therefore, understanding the regional impacts of climate change on irrigation demand for crop production is important for managers and agricultural producers to understand for effective water resources management.

The amount of water needed for irrigation depends on many different factors. A reasonably accurate estimate of the amount of irrigation water needed can be made using potential evapotranspiration data. on other hand, to study the possible impact of the climate change on the irrigation requirements in Abu Dhabi CROPWAT model (FAO, 2009) have been used. Figure 1 showed the average monthly of potential evapotranspiration between the years 2003-2016. The results showed that Al Ain region needs the highest irrigation requirements as compared with Abu Dhabi and Al Dhafra regions except in January when Abu Dhabi region required a slightly more water compared to Al Ain. The potential evapotranspiration (ET0) is the summation of

Table 1: Summarizes the geographical and climatic parameters for Abu Dhabi Metrological Station average monthly measurement between 1980 to 2016.

Climatic Station: Abu Dhabi I.A. Latitude : 24 25 59 N					Al-attitude: 27 m Longitude : 54 39 04 E	
Month	**Temperature (°C)**		**Humidity (%)**		**Wind (km/hr)**	**Solar Radiation (wh/m^2)**
	Max	**Min**	**Mean Max**	**Mean Min**	**Mean Wind**	
January	34.3	5.6	86	44	12.5	4114.5
February	38.1	5.4	85	40	14.5	4994.3
March	43	8.4	83	33	14.8	5789.1
April	44.7	11.2	77	25	14.6	6733.2
May	46.9	16.6	74	21	14.4	7527.1
June	48.5	19.8	79	25	14.7	7593.8
July	49.1	22.2	77	26	14.5	7073.1
August	49.2	23.8	76	26	14.6	6757.8
September	47.7	19.9	83	26	13.3	6398.9
October	43.1	14.6	84	30	12.2	5566.9
November	37.9	12	83	38	12	4621.2
December	33.8	7.3	86	45	12.1	3969.6

Table 2: Summarizes the geographical and climatic parameters for Alain Metrological Station average monthly measurement between 1980 to 2016.

Climatic Station: Abu Dhabi I.A. Latitude : 24 25 59 N					Al-attitude: 27 m Longitude : 54 39 04 E	
Month	**Temperature (°C)**		**Humidity (%)**		**Wind (km/hr)**	**Solar Radiation (wh/m^2)**
	Max	**Min**	**Mean Max**	**Mean Min**	**Mean Wind**	
January	31.8	5.6	86	38	12.4	4408.5
February	36.6	5.9	81	30	14.6	5290.6
March	42.9	9.9	75	24	15.3	6024.7
April	44.4	13.2	61	18	15.1	7010.6
May	49.3	18	53	13	14.8	7744
June	49	20.9	60	13	14.6	7747.6
July	49.2	22.8	62	18	14.8	7261.9
August	48.8	21.9	57	18	15.4	7131.4
September	47.8	21.8	67	17	14.4	6763.8
October	43.1	16.2	72	19	13.1	5941.5
November	37.5	13	79	29	12.2	4864.1
December	35	7.4	85	36	12.1	4287.9

Table 3: Summarizes the geographical and climatic parameters for Al Dafra Metrological Station average monthly measurement between 1980 to 2016.

Climatic Station: Abu Dhabi I.A. Latitude : 24 25 59 N					Al-attitude: 27 m Longitude : 54 39 04 E	
Month	**Temperature (°C)**		**Humidity (%)**		**Wind (km/hr)**	**Solar Radiation (wh/m^2)**
	Max	**Min**	**Mean Max**	**Mean Min**	**Mean Wind**	
January	33.1	5.6	94	42	11	4413
February	38.3	5.5	92	36	12	5338
March	41.7	7.8	86	30	13	6149
April	44.5	13.7	79	22	13	6574
May	48.1	17.1	73	17	13	7130
June	49.4	20.4	80	16	14	7285
July	48.7	24.6	78	20	13	6842
August	49.4	24.7	83	21	13	6637
September	47.6	21.6	92	21	12	6385
October	43.2	18.4	94	24	10	5708
November	37.7	12.5	92	36	11	4705
December	31.8	6.9	96	45	11	4221

the monthly ETo for each region, this reflects the relative irrigation amount variation in the three of Abu Dhabi regions.

Table 4 shows the percentage of the monthly potential evapotranspiration for Abu Dhabi and Al Dhafra regions. The results showed the potential evapotranspiration for both regions over the whole year is less than that for Al Ain (< 100%) except for Abu Dhabi in January which showed almost the same evapotranspiration as Al Ain.

Since the potential evapotranspiration is closely affected by the temperature and other climatic parameters, the monthly percentage ratio of the total annual evapotranspiration for each region is increased in the summer months and decreased in the winter months. Table 5 shows the monthly percentage ratio of the annual potential evapotranspiration

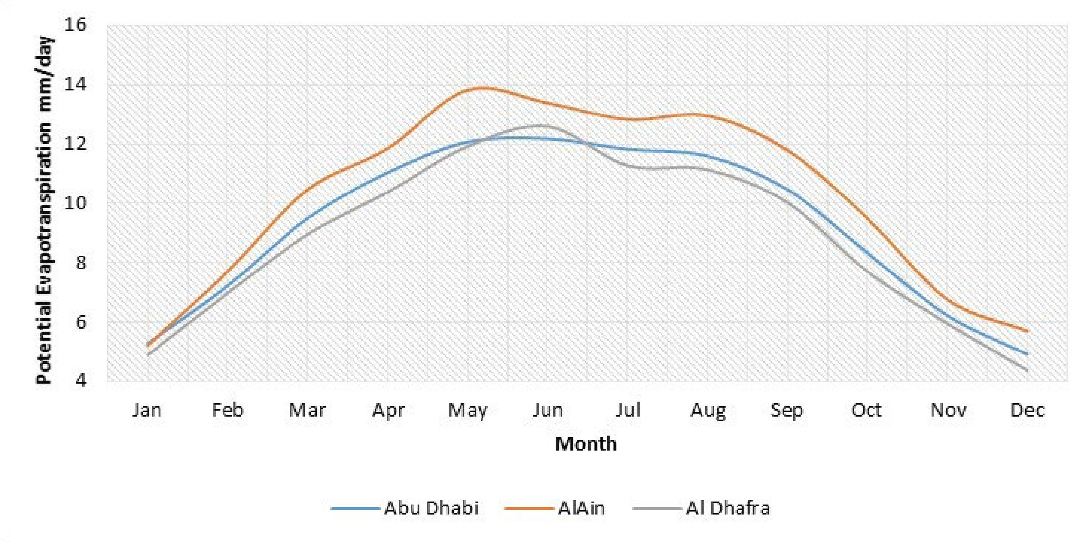

Figure 1: The average monthly evapotranspiration for the three main regions in Abu Dhabi for the period 2003-2016.

Table 4: The percentage of the average monthly evapotranspiration for Abu Dhabi and Al Dhafra as compared with Al Ain region.

	% of average evapotranspiration	
Month	Abu Dhabi	Al Dhafra
Jan	101.3	93.8
Feb	93.7	90.6
Mar	90.8	85.6
Apr	93.2	87.6
May	87.3	86.2
Jun	91.0	94.1
Jul	92.1	87.9
Aug	89.5	86.0
Sep	88.8	85.1
Oct	87.8	81.2
Nov	92.0	88.1
Dec	86.3	76.8

Table 5: The monthly percentage of the annual potential evapotranspiration for the three Abu Dhabi main regions.

Month	Abu Dhabi	Al Ain	Al Dhafra
Jan	4.86	4.35	4.69
Feb	6.00	5.81	6.04
Mar	8.74	8.73	8.59
Apr	9.83	9.57	9.63
May	11.10	11.54	11.43
Jun	10.85	10.81	11.69
Jul	10.88	10.71	10.82
Aug	10.67	10.81	10.68
Sep	9.32	9.52	9.31
Oct	7.67	7.92	7.39
Nov	5.54	5.46	5.53
Dec	4.52	4.76	4.20
Total	100	100	100

for the three regions in Abu Dhabi Emirate. The monthly percentage ratios showed the potential evapotranspiration in the three regions is about one tenth of the total annual evapotranspiration for the months May, June, July, August and September. The ratio of evapotranspiration to the rainfall range from 11 to more than 3741 times (Table 6). With an average ratio of 41 times for the months between November to April and to about 1100 for the period between May to October.

Table 6: The monthly ratio of the evapotranspiration to rainfall the three agricultural location in Abu Dhabi Emirate.

Month	Evaporation/ Rainfall	Al Ain	Al Dhafra
	Abu Dhabi	Al Ain	Al Dhafra
January	17	14	24
February	11	47	65
March	18	17	58
April	53	57	41
May	3,741	1,429	1,232
June	731	574	756
July	611	71	3497
August	3,595	251	288
September	628	272	1,003
October	1,292	491	478
November	93	119	44
December	18	22	20

Due to climate change, there is probable increase in temperature and decrease in the relative humidity therefore it is essential for long-term water resources development and planning to estimate the agricultural water demand in the changing environment.To estimate this probable increase in the irrigation requirements two scenarios been analyzed to indicate the possible impact of the climate change.

Scenario 1: increase of the average annual temperature by 1 °C and reduction of the relative humidity by 1%

Scenario 2: increase of the average annual temperature by 2 °C and reduction of the relative humidity by 2%. For both scenarios with the temperature rises and relative humidity declines, it is expected that the amount of ground water will extracted more rapidly to fulfill the irrigation requirements which might not be sufficient (in term of quantity and quality) in the future to retain the common agricultural pattern. The results of the above suggested scenarios are obtained using CROPWAT irrigation model (Table 7).The results show the monthly percentage increase in the water demand for the three locations in Abu Dhabi Emirate as compared with the current status. The average annual increases in the irrigation water demand in the three locations are about 3% and 6% for the scenarios 1 and 2, respectively. The annual increase of 3% in the irrigation water demand indicates that the water

Table 7: monthly annual percentage increase in the irrigation water demand for the three locations of Abu Dhabi Emirate per the two expected climatic scenarios.

Month	Scenario 1			Scenario 2		
	Abu Dhabi	Al Ain	Al Dhafra	Abu Dhabi	Al Ain	Al Dhafra
Jan	3.64	3.67	3.62	7.37	7.43	7.33
Feb	3.50	3.49	3.37	7.09	7.06	6.82
Mar	3.20	3.11	3.13	6.46	6.29	6.33
Apr	2.97	2.82	2.81	5.99	5.70	5.68
May	2.69	2.49	2.57	5.44	5.03	5.19
Jun	2.62	2.42	2.55	5.29	4.88	5.14
Jul	2.55	2.41	2.40	5.15	4.87	4.85
Aug	2.54	2.46	2.46	5.13	4.98	4.96
Sep	2.70	2.54	2.61	5.45	5.13	5.27
Oct	2.97	2.84	2.75	6.01	5.75	5.56
Nov	3.25	3.17	3.23	6.57	6.41	6.54
Dec	3.63	3.56	3.70	7.35	7.21	7.50
Year Average	3.02	2.92	2.93	6.11	5.89	5.93
#years the irrigation water requirement will double	33	34	34	16	17	17
Scenario Average		34			17	

demand will be doubles after 34 years (Scenario 1). While the 2nd scenarios only 17 years will lead to double the annual irrigation water requirements.

Agriculture and Natural Resources Indicator

Water used for irrigation purpose in Abu Dhabi are classified to three subsectors; Agricultural farm, amenity and forest. The discussion focus on the agricultural farm as the category for producing food. The major crops which are planted in Abu Dhabi could come under four classes; Fruits (included Date palm), Field crops and vegetables either in the open field or protected greenhouses. Statistics for the area of the cultivated agricultural land in Abu Dhabi Emirates showed less than 5% reduction between 2005 till 2007 and followed by 6.5% increment in 2015 as compared with 2007, with no change after 2015 reaching to 2019. Groundwater accounts for 94 % water consumption in the agriculture sector in the Emirate. However, the current usage of groundwater reservoirs is about 15 times more than the natural recharge rates, according to the Environment Agency-Abu Dhabi [15-20].

Fruit trees occupy the largest proportion of 36.3% of the total plant holdings area. Palm trees are the main type of fruit trees in terms of cultivated area and total production. The date palm production in 2015 was 93,075 tons which is less by 0.6% compared with 2014. Field crops occupy 6.4% of the total plant holdings area, a significant decrease of 18.6% compared with 2014. The total production of field crops in 2015 was 148,195 tons. Vegetable crops grown in open fields and under greenhouses constituted 2.6% of the total plant holdings area. Cucumber accounted for 22.2% of the total area of vegetable crops, followed by tomatoes at 19.1%. Cabbage, onion, accounted for 10.0%, 6.8% respectively, meanwhile rest of the crops formed 41.9% of the total area of vegetable crops in 2015. Forest trees and windbreaks occupied 2.2% of the total plant holdings area. The current fallow area represented 37.5% and buildings area represented 1.7%. Data shows that the potentially productive area accounted for 13.2% of the total plant holdings in 2015.

Crop Calendar for Abu Dhabi

UAE is a hot country,that creates unfavourable conditions for growing vegetables in open fields all year around. The Crop calendar provides timely information on suitable planting and harvesting periods of specific crops. In conjugation with irrigation management knowledge and optimum agricultural practices can help to overcome the climate challenges. A large range of vegetables is growing in Abu Dhabi such as tomato, cucumber, eggplant; onion, squash and even pumpkin are suitable. The production of those vegetables in open field is low due to lack of knowledge about optimal agricultural practices such as irrigation. The water scarcity and salinity are a pressing challenge on this production system. Most area of open field growing in Abu Dhabi is drought types that grown alongside, those vegetables ate love the warm nights and moderate daylight. According to local observation, table 8 shows the most common winter and spring open field cultivated vegetables growing in Abu Dhabi, as Vegetables planting dates affect yield and water consumption, the information in the table chosen the best date/duration to start sowing vegetables to avoid most probably heat shock and to maximize yield and minimize water use which increases the water use efficiency.

Crop Water Requirements- Open Field Vegetables

Consideration of crop water requirement (CWR) is essential for better irrigation use efficiencies, and irrigation scheduling. This study estimates the reference evapotranspiration (ET0) using FAO modified Penman Monteith equation, based on the average climatic parameters in the three Abu Dhabi Emirate main regions, Crop water and net irrigation requirements is estimated using FAO crop coefficients (Table 9, 10, 11).

Conclusions

This study carried out to estimate the crop water requirements of major crops in different Abu Dhabi Emirate agro-ecological zones using CROPWAT 8.0 model of FAO and showing the current scenario and the future impact on crop water requirements under two different scenarios of climate change. The major grown vegetable crops. Study results showed that ET0 varied from 5 mm during the winter session to 13 mm/day for summer months. There is a higher water demand for crops during the dry seasons (summer and autumn) and a lower demand during the wet seasons (winter and spring).

Study results enhance our understanding of the water requirements of some major crops in Abu Dhabi Emirate, which will consequently

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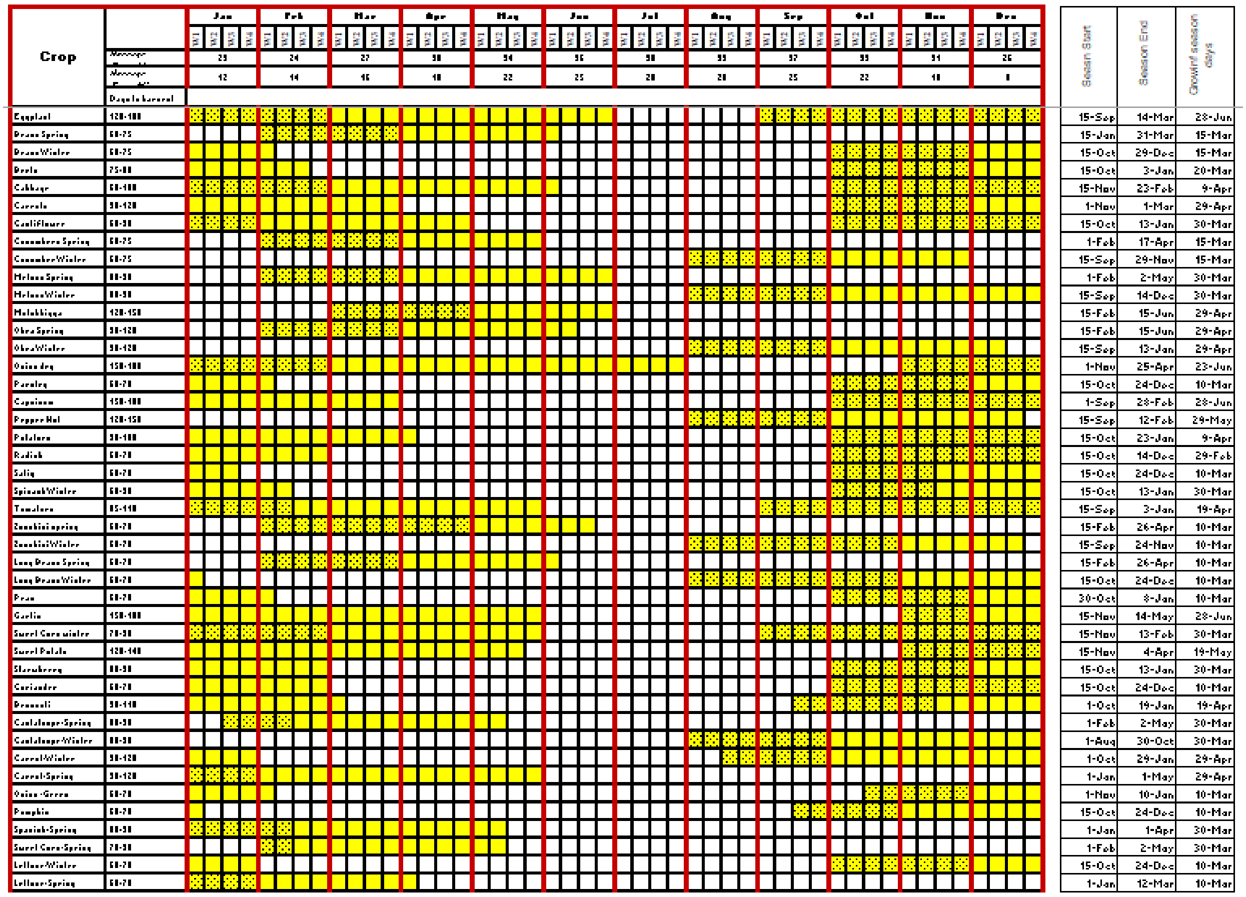
Table 8: Cropping pattern and calendar for the open field vegetables growing in Abu Dhabi.



Crop	Days to harvest	Season Start	Season End	Growing season days
Eggplant	120-180	15-Sep	14-Mar	28-Jun
Beans Spring	60-75	15-Jan	31-Mar	15-Mar
Beans Winter	60-75	15-Oct	29-Dec	15-Mar
Beets	75-80	15-Oct	3-Jan	20-Mar
Cabbage	60-100	15-Nov	23-Feb	9-Apr
Carrots	90-120	1-Nov	1-Mar	29-Apr
Cauliflower	60-90	15-Oct	13-Jan	30-Mar
Cucumbers Spring	60-75	1-Feb	17-Apr	15-Mar
Cucumber Winter	60-75	15-Sep	29-Nov	15-Mar
Melons Spring	80-90	1-Feb	2-May	30-Mar
Melons Winter	80-90	15-Sep	14-Dec	30-Mar
Molokhiya	120-150	15-Feb	15-Jun	29-Apr
Okra Spring	90-120	15-Feb	15-Jun	29-Apr
Okra Winter	90-120	15-Sep	13-Jan	29-Apr
Onion dry	150-180	1-Nov	25-Apr	23-Jun
Parsley	60-70	15-Oct	24-Dec	10-Mar
Capsicum	150-180	1-Sep	28-Feb	28-Jun
Pepper Hot	120-150	15-Sep	12-Feb	29-May
Potatoes	90-100	15-Oct	23-Jan	9-Apr
Radish	60-70	15-Oct	14-Dec	29-Feb
Saliq	60-70	15-Oct	24-Dec	10-Mar
Spinach Winter	60-90	15-Oct	13-Jan	30-Mar
Tomatoes	85-110	15-Sep	3-Jan	19-Apr
Zucchini spring	60-70	15-Feb	26-Apr	10-Mar
Zucchini Winter	60-70	15-Sep	24-Nov	10-Mar
Long Beans Spring	60-70	15-Feb	26-Apr	10-Mar
Long Beans Winter	60-70	15-Oct	24-Dec	10-Mar
Peas	60-70	30-Oct	8-Jan	10-Mar
Garlic	150-180	15-Nov	14-May	28-Jun
Sweet Corn winter	70-90	15-Nov	13-Feb	30-Mar
Sweet Potato	120-140	15-Nov	4-Apr	19-May
Strawberry	80-90	15-Oct	13-Jan	30-Mar
Coriander	60-70	15-Oct	24-Dec	10-Mar
Broccoli	90-110	1-Oct	19-Jan	19-Apr
Cantaloupe-Spring	80-90	1-Feb	2-May	30-Mar
Cantaloupe-Winter	80-90	1-Aug	30-Oct	30-Mar
Carrot-Winter	90-120	1-Oct	29-Jan	29-Apr
Carrot-Spring	90-120	1-Jan	1-May	29-Apr
Onion-Green	60-70	1-Nov	10-Jan	10-Mar
Pumpkin	60-70	15-Oct	24-Dec	10-Mar
Spinach-Spring	80-90	1-Jan	1-Apr	30-Mar
Sweet Corn-Spring	70-90	1-Feb	2-May	30-Mar
Lettuce-Winter	60-70	15-Oct	24-Dec	10-Mar
Lettuce-Spring	60-70	1-Jan	12-Mar	10-Mar

Table 9: Estimation of daily Irrigation crop water requirements for open field vegetables grown in Al Dhafra- Abu Dhabi based on the period of the local growing season.

Plant	Daily irrigation volume liter/plant												Seasonal Summation
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Broccoli	1.49								0.51	0.49	1.27	1.41	146.78
Tomato	1.20	2.59	3.33	3.10	2.81						0.31	0.29	359.17
spring cucumber	0.27	1.41	2.88	3.06	2.81								259.47
Winter cucumber	1.58	1.73								0.39	0.67	1.31	142.29
Broad Bean			0.45	1.82	4.39	4.53							302.70
Cabbage	1.58	2.11							0.51	0.41	0.89	1.24	192.08
Cantaloupe - winter	0.25	0.47	1.67	2.62	2.34								182.87
Cantaloupe - summer								0.61	1.24	1.72	1.33	0.74	150.35
Capsicum	1.66	2.36	3.03	3.10	3.21					0.39	0.50	1.21	405.42
Carrot-winter	1.54	2.01								0.39	0.94	1.41	150.27
Carrot-spring	0.25	1.03	2.84	3.04									197.04
Cauliflower	1.51	2.01							0.51	0.48	1.17	1.39	151.97
Eggplant	1.66	1.93								0.39	0.50	1.21	153.19
Melon	0.25	1.00	2.78	3.49	3.63	2.97							368.88
Onion	1.58	2.24	2.82	2.27	2.61					0.39	0.85	1.38	376.08
Potato	0.27	1.80	3.33	2.85	2.61								276.26
Pumpkin			0.60	2.73	3.46	2.97							234.39
Radish			1.27	2.88									76.19
Spanish-winter	1.49	1.87									0.31	0.64	113.98
Spanish-spring				0.52	1.74	3.80	3.02						248.80
Squash-winter								1.69	2.12	2.34	1.58		193.20
Squash-spring		1.10	2.36	3.01	3.01								215.00

Table 10: Estimation of daily Irrigation crop water requirements for open field vegetables grown in Al Ain- Abu Dhabi based on the period of the local growing season.

Plant	Daily irrigation volume liter/plant												Seasonal Summation
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Broccoli	1.58								0.59	0.60	1.44	1.83	172.24
Tomato	1.27	2.86	3.88	3.53	3.25						0.35	0.38	408.07
spring cucumber	0.28	1.55	3.35	3.48	3.25								296.06
Winter cucumber	1.68	1.91								0.48	0.75	1.70	164.28
Broad Bean			0.53	2.07	5.08	4.79							338.64
Cabbage	1.68	2.33							0.59	0.51	1.01	1.61	220.21
Cantaloupe - winter	0.27	0.52	1.94	2.98	2.71								209.24
Cantaloupe - summer								0.71	1.45	2.12	1.50	0.97	178.63
Capsicum	1.77	2.60	3.53	3.53	3.71					0.48	0.57	1.57	464.71
Carrot-winter	1.63	2.21								0.48	1.07	1.82	173.92
Carrot-spring	0.27	1.13	3.30	3.46									225.13
Cauliflower	1.60	2.21							0.59	0.59	1.33	1.80	177.50
Eggplant	1.77	2.13								0.48	0.57	1.57	175.39
Melon	0.27	1.10	3.23	3.98	4.19	3.14							419.96
Onion	1.68	2.47	3.28	2.58	3.02					0.48	0.96	1.78	432.08
Potato	0.29	1.98	3.88	3.24	3.02								315.08
Pumpkin			0.70	3.11	4.00	3.14							266.91
Radish			1.47	3.27									87.25
Spanish-winter	1.58	2.06									0.35	0.84	127.86
Spanish-spring				0.60	2.01	4.02	3.43						274.62
Squash-winter								1.96	2.48	2.87	1.79		228.91
Squash-spring		1.21	2.74	3.42	3.48								245.79

Table 11: Estimation of daily Irrigation crop water requirements for open field vegetables grown in Abu Dhabi based on the period of the local growing season.

Plant	Daily irrigation volume liter/plant												Seasonal Summation
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Broccoli	1.61								0.53	0.53	1.33	1.59	159.34
Tomato	1.30	2.70	3.55	3.32	2.86						0.32	0.33	380.50
spring cucumber	0.29	1.46	3.06	3.27	2.86								274.54
Winter cucumber	1.71	1.80								0.43	0.70	1.48	154.10
Broad Bean			0.48	1.95	4.47	4.40							306.45
Cabbage	1.71	2.20							0.53	0.45	0.94	1.39	206.09
Cantaloupe - winter	0.27	0.49	1.78	2.80	2.38								193.27
Cantaloupe - summer								0.64	1.30	1.87	1.39	0.84	160.49
Capsicum	1.80	2.46	3.23	3.32	3.27					0.43	0.53	1.36	431.79
Carrot-winter	1.66	2.09								0.43	0.99	1.58	162.66
Carrot-spring	0.27	1.07	3.02	3.25									209.62
Cauliflower	1.63	2.09							0.53	0.52	1.23	1.56	164.85
Eggplant	1.80	2.01								0.43	0.53	1.36	165.21
Melon	0.27	1.04	2.96	3.74	3.69	2.89							384.77
Onion	1.71	2.33	3.00	2.43	2.66					0.43	0.89	1.55	400.96
Potato	0.30	1.87	3.55	3.05	2.66								292.23
Pumpkin			0.64	2.92	3.52	2.89							242.48
Radish			1.35	3.08									81.43
Spanish-winter	1.61	1.94									0.32	0.73	122.30
Spanish-spring				0.56	1.77	3.69	3.19						251.03
Squash-winter								1.77	2.22	2.54	1.66		205.42
Squash-spring		1.14	2.51	3.22	3.07								227.70

help improve the management of water resources and the yield through strategies based on these outcomes, and providing a help for water resource planners for future planning, so helping to save water in matching the CWRs, and can be used as a guide for farmers to select the amount and frequency of irrigation for the crops being studied. Study also showed the impact of two climate change scenarios on crop water demand.

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