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Vulnerability Assessment of Agricultural Sector in Syria (Modeling)

Related to the Project Activity

Programs Containing Measures to facilitate Adaptation to Climate Change

Project Title

Enabling activities for preparation of Syria's initial national Communication to the UNFCCC, (Project Nr.00045323).

National Project Director
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March 2009

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The project implemented in the ministry of local administration and Environment (MLAE)/General Commission of Environmental Affairs (GCEA), in collaboration with Global Environmental Facility (GEF) and United Nation Development Programm (UNDP) in Syria.

Vulnerability Assessment and Adaptation Measures of Agricultural Sector in Syria

(Modeling)

(INC-SY_V&A_ Agriculture Model -En)

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March / 2009

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This report has been approved unanimously by the technical committee, during the Technical Workshop which took place on 24/ 03/ 2009 in the Dedeman Hotel Palmyra.

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1. Abstract

Wheat, cotton, and olive are among the main crops in Syria; and therefore, were selected to study the impact of climate change on crop water use and yield reduction. *Al-Hassakeh* governorate was selected to study the impact of climate change on cotton and wheat production; while Aleppo governorate was selected to study the impact of climate change on olive production Outputs of B2 scenario– Hadley Model-CM3 for the period 2070 to 2100 were used to evaluate the climate change impact on Wheat, cotton, and olive water use and yield.

For wheat, the expected changes in temperature and precipitation lead to increased wheat actual crop requirement from 563 mm to 617 mm. If no additional irrigation water was added to compensate this increase in demand, the crop production will be reduced by 15.7 %.

For rainfed wheat actual crop requirement is increased from 428 mm to 469 mm the crop production will be reduced by 21 %.

For cotton, the actual crop requirement increased from 1169 mm to 1287 mm due to expected climate change. If no additional irrigation water was added to compensate this increase in demand, the crop production will be reduced by 7.5 %.

For irrigated olive tree, the actual crop water requirements increased from 858 mm to 945 mm. If no additional irrigation water was added to compensate this increase in demand, the production will be reduced by 17 %.

2. Introduction

Syria's economy is heavily dependent on agriculture. It contributes nearly 25 % to the Gross Domestic Product (GDP) and employs one-third of the active population (Statistical Abstract, 2004). Of total number of 18,517971 hectares of land, 5932869 million (32 %) are suitable for arable production although only an estimated 5523356 hectares of this is currently cultivated (Statistical Abstract, 2005). The primary agricultural products are cotton, olives, wheat, barley, lentils, chickpeas, and sugar beets.

Because only about 29 percent of the cropped area was irrigated (Statistical Abstract, 2005), the output of agriculture was heavily dependent on rainfall. The great variation in the amounts and timing of rainfall can immediately cause very substantial shifts in areas planted, yields, and production.

Predicted responses to global warming are increased temperatures, altered precipitation patterns and changes in the amount of precipitation, all of which will have an impact on the crop water supply-demand relationship increases in crop water use, reduction of the growing season and decreases in water availability, depending on changes in the form of precipitation and the timing of precipitation events.

To determine the ultimate effects of climate change, researchers will need to look at the future extent and effects of land degradation, the quantification of future rainfall variability, the actual response of plants to the combined effects of increased concentrations of CO_2 and elevated temperatures, the consequences of improved cultivation practices, and the altered social, economic and political circumstances.

This study was undertaken for assessing the impact of climate change on main crops grown in Syria.

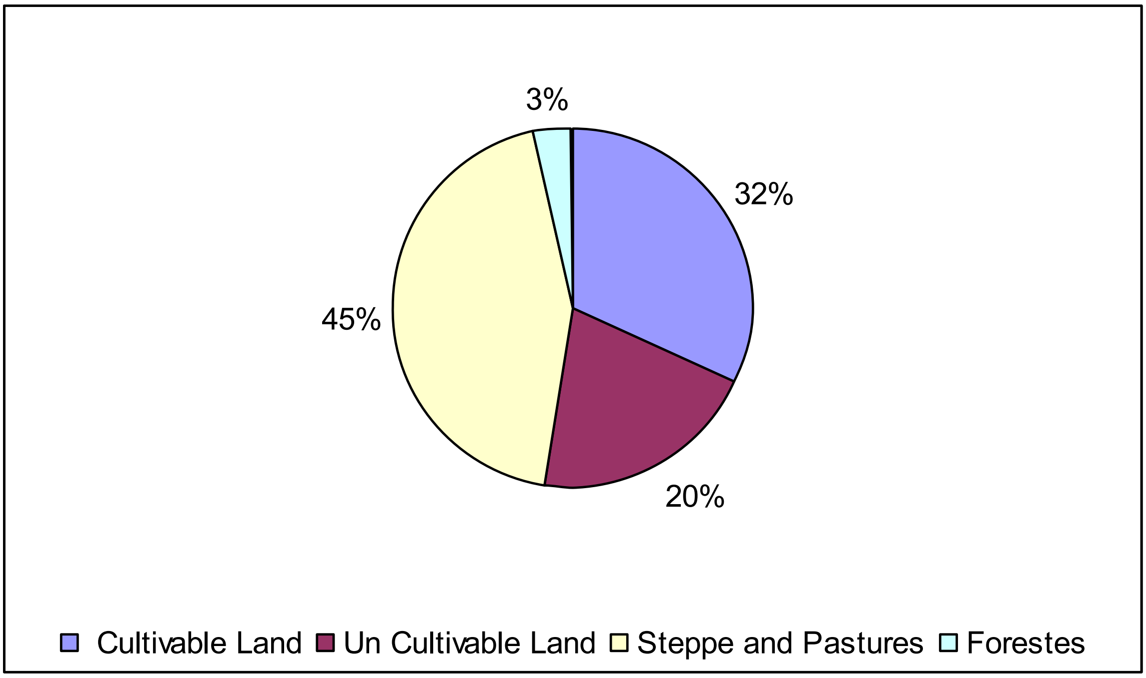

Fig. (1): Land use in Syria

Of the many crops grown in Syria, wheat is considered as the most important staple and strategic crop in Syrian agriculture (NAPC, 2002). Wheat production covers 34 % of the cropping area in Syria (Statistical Abstract, 2005). However, 55 % of this is irrigated and 45 % are rainfed. The effect of wheat production on the Syrian economy must not be underestimated. Adverse climate impacts on agriculture in Syria may therefore destabilize the country.

Raw cotton is by far the single most important agricultural export in Syria. It is accounted for 29.5 % of the agricultural export value and 13.8% of agricultural trade volume (NAPC, 2002). Almost all the cotton was grown on irrigated land, largely in north eastern part of Syria.

Olive trees constitute the most important fruit tree in Syria. According to The International Olive Oil Council (IOOC) Syria is the world fifth olive oil producer, with 175 thousand tons in 2004 and world sixth olive oil producer in 2005 (IOOC, 2006). In 2006, the area planted by olive tree reached 564938 hectare and the production was about 1,200000 ton of olive (Statistical abstract, 2006).

Given the general consensus that current rainfall is likely to be reduced by 5 % to 10 %, accompanied by a projected increase in temperature of 1 C° to 3 C°, efficient crop water use in Syria will be of the utmost importance. In this study CROPWAT was used to assess the effect of climate change on wheat, cotton, and olive tree water use and yield in Syria.

3. Agro- ecological zones

In Syria, farming systems have to a large extent been influenced by the physical and climatic characteristics of the five major agro-ecological zones (Figure 2):

Zone 1: Receives an average rainfall of more than 350 mm and consists of two sub zones. The first receives more than 600 mm annually where yields of rainfed crops are certain for all years.

Zone 2: Receives 250- 350 mm precipitation annually and main crops are wheat, barley and summer crops. This zone makes up 13.3 % of the country area.

Zone 3: Receives 250-mm of precipitation annually which is certain for crop production in more than 50 % of monitored years i.e. 1- 2 of 3 years, the production is certain. This zone has mainly grain crops, however legumes can be grown. This zone makes up 7.11 of the total area.

Zone 4: (Marginal zone):
It receives 200- 250 mm precipitation annually. This amount of rainfall is certain for more than 50 % of monitored years. However only barely can be grown and it can be used as permanent pastures. This zone makes up 9.91 of total area**.**

Zone 5: This is the steppe lands that make up 55. 1 % of the total area of the country and receives less than 200 mm precipitation annually. These lands are not suitable for rainfed cultivation.

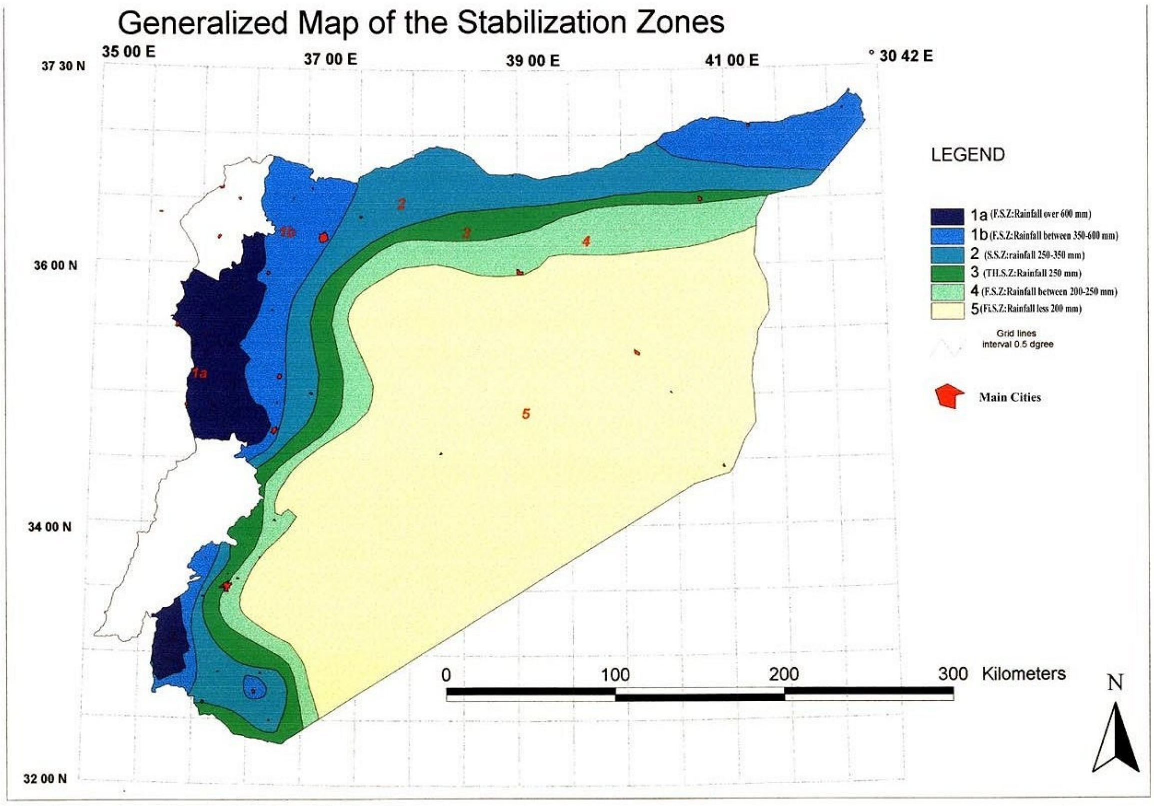

Fig. (2): Agro- ecological zones in Syria

4. Methodology

- **Sites**

Al-Hassakeh governorate (Figure 3); (295 m above sea level, 36.33° N and 40.45° E) was selected to study the impact of climate change on cotton and wheat production because it is the main agricultural area for these two crops (Figures 4 and 5). However, for studying the impact of climate change on olive trees production, Aleppo governorate (390 m above sea level, 36.11° N and 37.13° E) was selected because it is the first producer of olive in Syria and it contributes of 23 % to the National production (Figure 6).

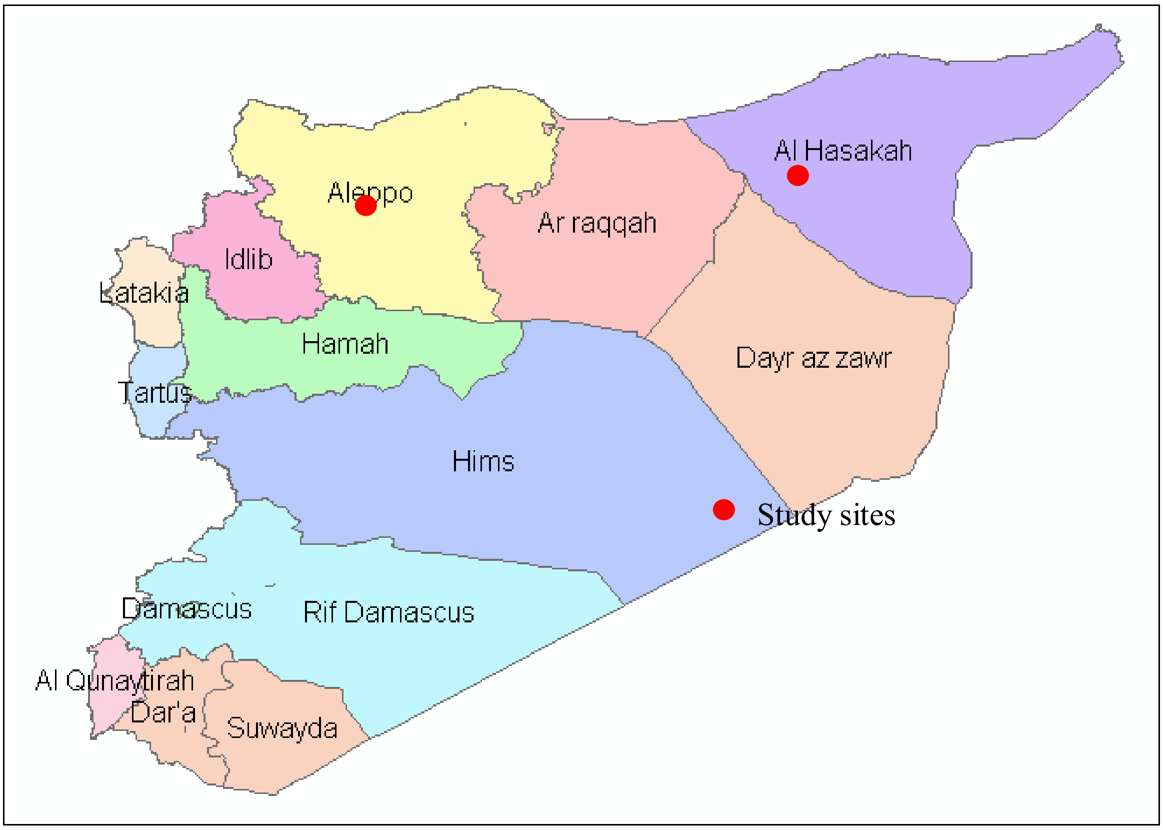

Fig. (3): study sites

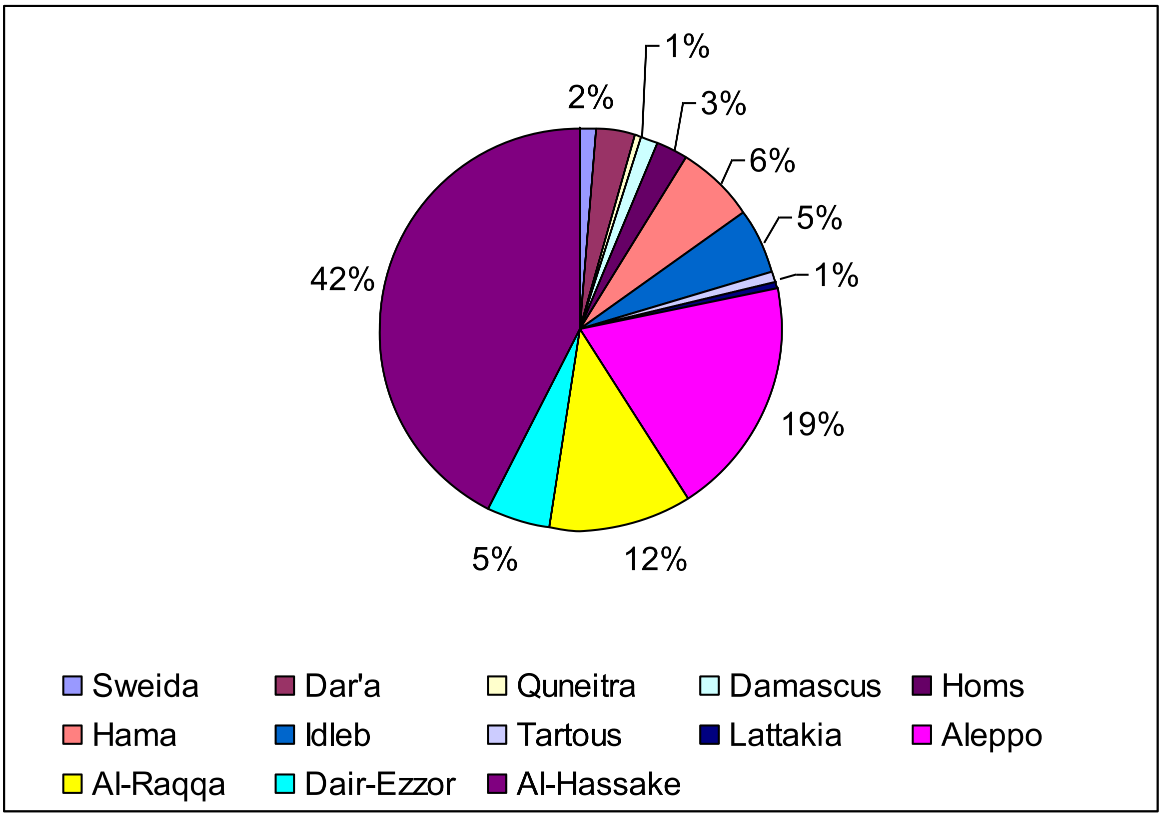

Fig. (4): percentage of area planted with wheat in the Syrian governorates

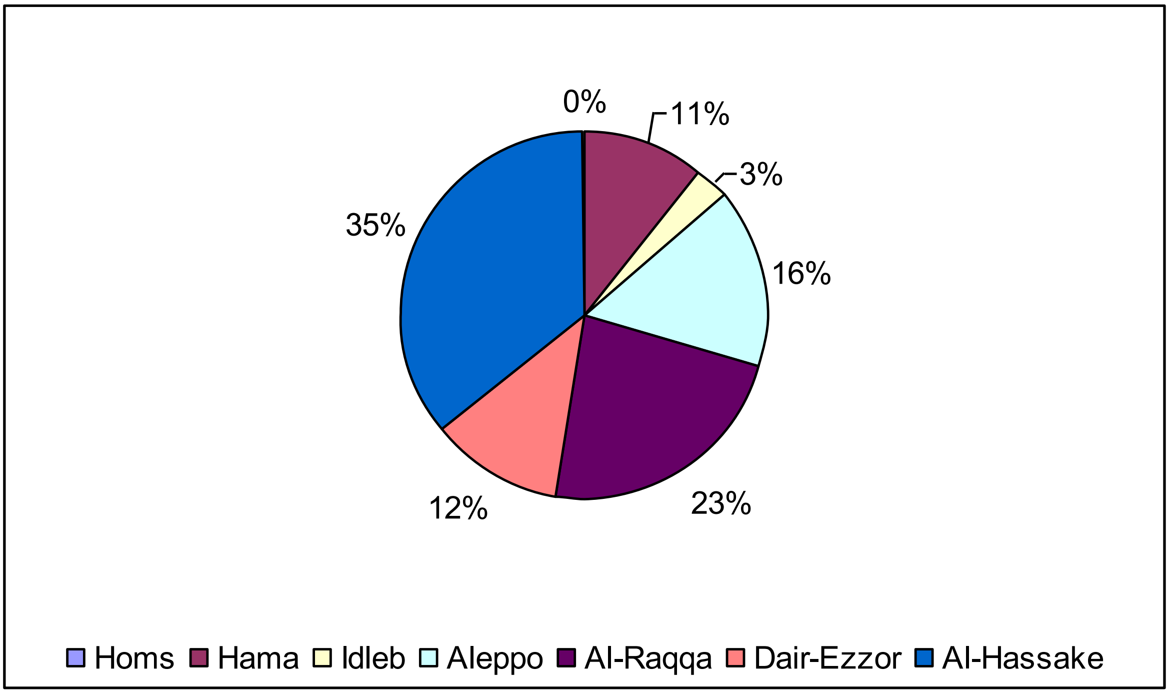

Fig. (5): percentage of area planted with cotton in the Syrian governorates

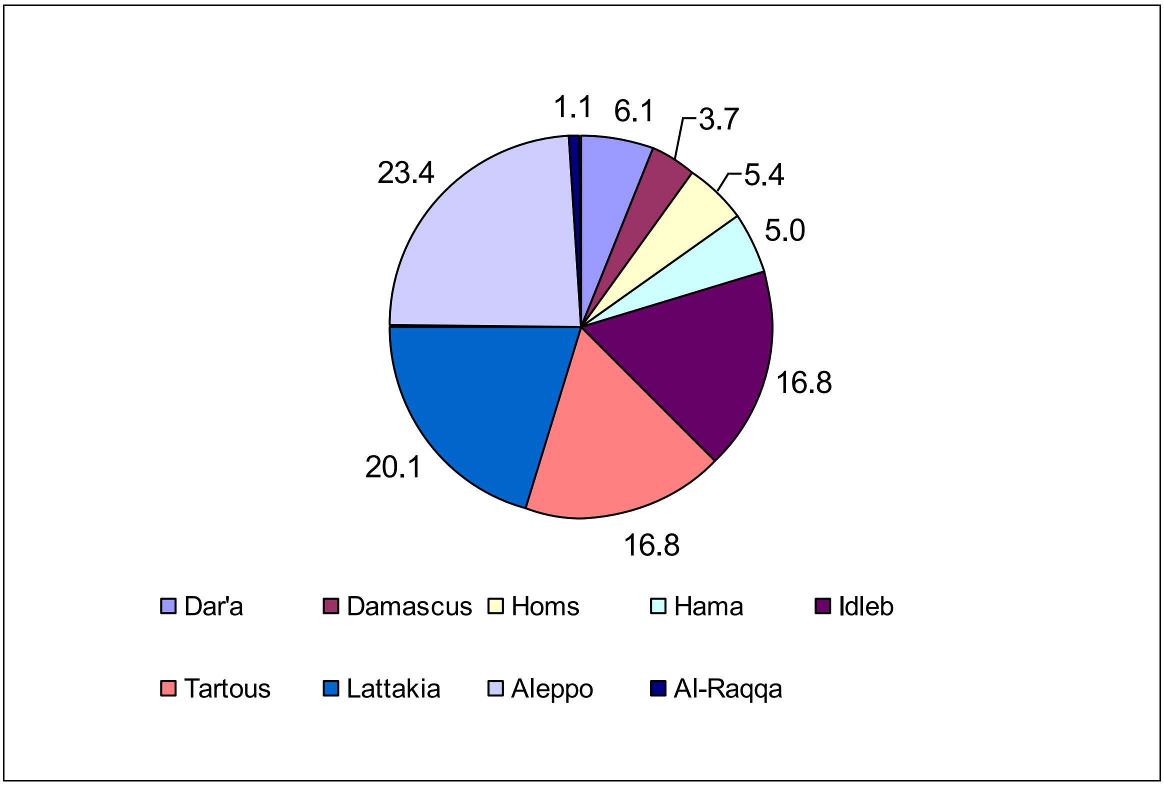

Fig. (6): percentage of olive production in the Syrian governorates

5. Using CROPWAT to assess crop water use

The CROPWAT model, developed by FAO Land and Water Management Division (Smith, 1992), is an irrigation management model to evaluate the crop water requirements and irrigation needs. The program estimate the potential "*evapotranspiration*" (*ETo*) using the Penman- *Monteith* methods (*Allen et al*. 1998) and the crop parameters. The data required for using CROPWAT are area, planting date, crop coefficients and length of growth stage. Calculations of the crop water requirements were carried out with inputs of climatic, crop and soil data. These data sets were obtained from CLIMWAT (FAO, 2003). Required climatic data are minimum and maximum air temperature, relative humidity, sunshine duration and wind speed.

For future climate scenarios, centered on the simulated time periods 2080 to 2099, the monthly means of maximum temperature, minimum temperature, and precipitation were used as input to CROPWAT. For the necessary relative humidity, sunshine duration and wind speed input, these climatic parameters were assumed to be the same as for the base climate data.

The relationship between crop yield and water supply can be determined when crop water requirements and crop water deficits on the one hand and maximum and actual crop yield on the other can be quantified. In CROPWAT, the amount of yield reduction can be estimated as following

$$\left[1-\frac{Ya}{Ym}\right]=Ky\left[1-\frac{ETa}{ETm}\right] \qquad (1)$$

Where:

Ya is actual yield
Ym is maximum/potential yield
Ky is yield response factor. Ky describes the reduction in relative yield according to the reduction in ETm caused by soil water shortage.
ETa = ETc actual = actual crop evapotranspiration.
ETm is maximum/potential evapotranspiration.

The advantage of using the CROPWAT model as a tool for assessing crop water use is that it is simple and easy to use.

6. Climate data of *Al-Hassakeh* governorate

The total average annual precipitation here is about 279 mm. The maximum temperature is about 40.4 C° (in July), the minimum is about 1.5 C° (in January), and the mean annual temperature is 18.7 C°. Evapotranspiration is relatively high during the summer. The maximum evapotranspiration is 9.3 mm per day in July and the minimum 1.1 mm per day in January. The relative humidity is rather low during summer and high during winter: on average it is 35 % in July and 82 % in January. Wind speeds range from 130 km/ day in October to 259 km/ day in June (Table 1).

Table (1): average Climate data of *Al-Hassakeh* governorate

Month	Maximum Temperature (C°)	Minimum Temperature (C°)	Humidity (%)	Wind (km/ d)	Sun Shine hours (hr)	Solar radiation (MJ/ m²/ d)	ETo (mm/ d)
January	11.4	1.5	82	181	4.2	8.1	1.1
February	13.8	2.3	78	190	5.3	11.1	1.7
March	18	4.9	75	207	6.5	15.2	2.7
April	23.8	9.3	68	199	7.5	19.2	4.0
May	30.7	14.1	52	216	9.6	23.8	6.2
June	36.6	19	35	259	12	27.7	8.8
July	40.4	22.2	35	251	12.4	28	9.3
August	40.1	21.5	35	216	11.5	25.3	8.2
September	35.3	16.3	40	181	10.3	21	6.0
October	28.6	10.8	53	130	7.7	14.6	3.4
November	20.2	5.7	69	138	6.6	10.7	1.9
December	13.4	2.6	80	173	4.6	7.8	1.2
Average	**26**	**10.8**	**58.5**	**195.1**	**8.2**	**17.7**	**4.5**

6. Climate data of Aleppo governorate

The total average annual precipitation at Aleppo is about 329 mm. The maximum temperature is about 36.5 C° (in August), the minimum is about 2.2 C° (in January), and the mean annual temperature is 17.5 C°. Evapotranspiration is relatively high during the summer. The maximum evapotranspiration is 9.6 mm per day in July and the minimum 1.1 mm per day in January. The relative humidity is rather low during summer and high during winter: on average it is 49 % in July and 85 % in January. Wind speeds range from 156 km/ day in November to 415 km/ day in July (Table 2).

Table (2): average Climate data of Aleppo governorate

Month	Maximum Temperature (C°)	Mini mum Temperature (C°)	Humidity (%)	Wind (km/d)	Sun Shine hours (hr)	Solar radiation (MJ/ m²/ d)	ETo (mm/ d)
January	10.4	2.2	85	233	4	7.9	1.07
February	12.7	2.7	79	233	4.8	10.6	1.66
March	16.7	5.1	73	251	6.6	15.4	2.71
April	22.3	8.7	67	276	8.4	20.5	4.3
May	28.6	13.1	59	276	10.3	24.8	6.17
June	33.8	17.9	47	354	12.3	28.2	8.69
July	36.1	20.5	49	415	12.7	28.4	9.59
August	36.5	20.5	52	372	12	26	8.69
September	32.7	16.8	55	268	10.4	21.2	6.13
October	27.2	12.1	60	173	8.2	15.2	3.53
November	19.4	6.8	71	156	6.7	10.8	1.88
December	12.3	4	83	199	4	7.3	1.06
Average	**24.1**	**10.9**	**65**	**267.2**	**8.4**	**18**	**4.62**

7. Assessing crop water use of Irrigated wheat at *Al-Hassakeh* governorate

- **Crop evapotranspiration:**

Crop evapotranspiration or crop water use can be assessed by multiplying the reference evapotranspiration (ETo) by the crop coefficient (Kc) (Equation 2).
The reference evapotranspiration is calculated by using climatic data, with the Penman-*Monteith* equation:

$$ETc = Kc \times ETo \qquad (2)$$

Where:

ETc = Crop evapotranspiration
ETo = Reference evapotranspiration
Kc = Crop coefficient.

The crop coefficient varies with growing stages from plantation to harvesting. The *Kc* values used in this study (Figure 7) were taken from (*Allen et al*. 1998) and were validated using data from an actual field experiments**.**

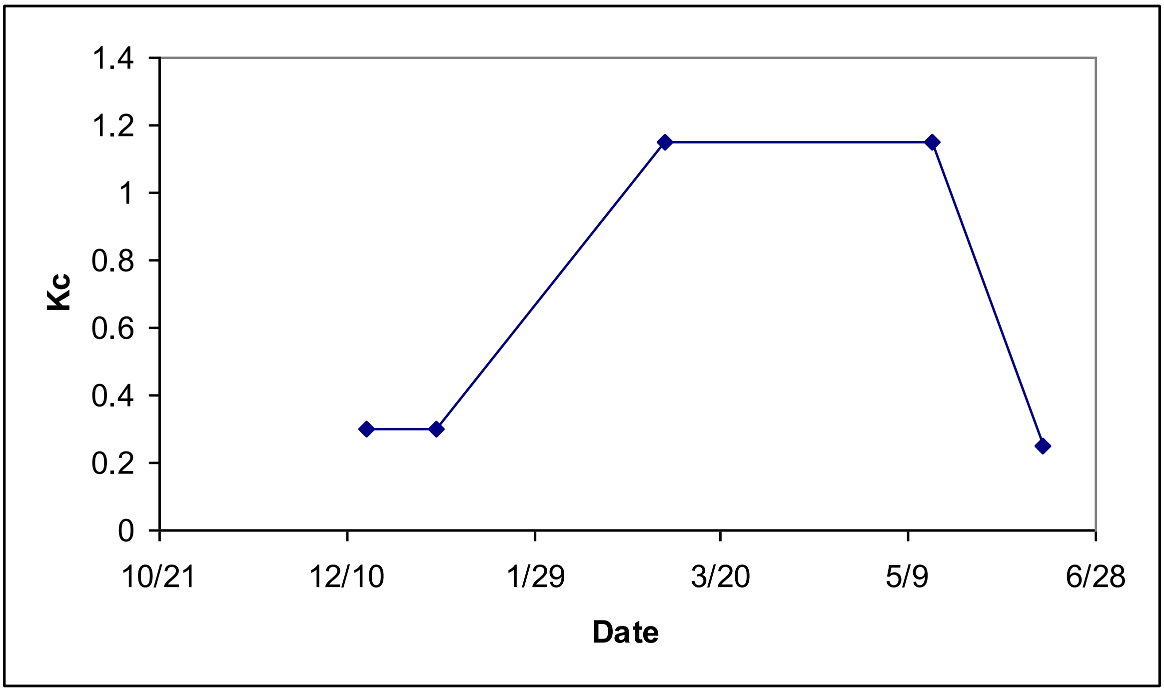

Fig. (7): crop coefficient curve of irrigated wheat

Under current climate conditions, the reference evapotranspiration (ETo) at *Al-Hassakeh* governorate is 613 mm**.** The average crop coefficient (Kc) for the wheat crop is 0.84 and the crop water requirements (ETm) are 563 mm**.**

Table (3): water use for irrigated wheat *Al-Hassakeh* governorate under current climate condition

date	ET_0 mm/pieriod	Kc	ETc mm	Total rain mm	Effective rain mm
15/12	8.44	0.3	2.53	15.1	13.95
25/12	7.54	0.3	2.26	17.37	15.84
4/1	6.81	0.38	2.57	17.35	15.8
14/1	6.6	0.52	3.43	16.81	15.34

date	ET_0 mm/pieriod	Kc	ETc mm	Total rain mm	Effective rain mm
24/1	7.61	0.66	5.05	16.07	14.73
3/2	9.88	0.8	7.97	15.3	14.09
13/2	13.36	0.94	12.67	14.63	13.54
23/2	17.95	1.09	19.56	14.12	13.14
5/3	23.49	1.15	27.01	13.79	12.88
15/3	29.79	1.15	34.26	13.58	12.72
25/3	36.64	1.15	42.14	13.39	12.56
4/4	43.81	1.15	50.38	13.03	12.24
14/4	51.04	1.15	58.7	12.33	11.59
24/4	58.12	1.15	66.84	11.08	10.44
4/5	64.8	1.15	74.53	9.12	8.63
14/5	70.89	0.99	69.69	6.38	6.08
24/5	76.19	0.69	52.07	2.91	2.82
3/6	80.54	0.38	30.91	0.12	0.12
Total	**613.51**		**562.57**	**222.48**	**206.51**

The *ETc* calculated through Equation (2) is the evapotranspiration from crops grown under optimal management and environmental conditions, with good water availability and no limitations of any other input. In reality plants experience stress from water shortages which affects their phonological and growth processes. To account for this in calculating the actual crop water use, a stress factor has to be incorporated. The stress factor as described in Irrigation and Drainage Paper No. 33 (*Doorenbos* and *Kassam*, 1979) is defined as:

$$ks = 1 - \frac{1}{ky}\left[1 - \frac{Ya}{Ym}\right] \quad (3)$$

Where:

Ya is actual yield
Ym is maximum/potential yield
Ky is yield response factor. Ky describes the reduction in relative yield according to the reduction in ETm caused by soil water shortage
ETa is ETc_{actual} ***= actual crop evapotranspiration***
ETm is maximum/potential evapotranspiration. ETm = ETc
Ks is Water stress coefficient.

The actual crop water use is calculated as following:

$$ETc_{actual} = Ks \times ETc \quad (4)$$

Ks is a dimensionless transpiration reduction factor and affects only crop transpiration. The near to 1, the less stress plants experience and thus the nearer the evaporation of the plants will be close to Etc.

The results in table 4 indicate that wheat were stressed, and the differences between actual and potential ET are 161 mm.

Table (4): Actual crop water use for wheat under current climate condition

ETo (mm)	ETc (mm)	Ky[1]	Ya[2] t/ ha	Ym[3] t/ ha	Ks	Etc actual (mm)	Yield reduction (%)
613	563	1.00	3.5	5.0	0.7	402	30

[1] *Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979)*
[2] *Yield average of 15 years in Al-Hasakah governorate*
[3] *From Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979) and local data.*

8. Assessing the impact of climate change on irrigated wheat

Table 5 shows the predicted changes in temperature and precipitation for B2 scenario– Hadley Model-CM3 for the period 2070 to 2100 at *Al-Hassakeh* and *Aleppo* governorates as obtained in this study.

Using B2 climate change scenario, the climatic data were modified and entered into the CROPWAT and by following the methodology used to calculate crop water use for potential optimum production under the current climate scenarios; crop water use of wheat was calculated using CROPWAT under climate change conditions **(**table 6).

Table (5): Seasonal temperature and precipitation changes from B2 scenario – Hadley Model-CM3 for the period 2070 to 2100 for *Al-Hassakeh* and *Aleppo* governorates

Season	DJF	MAM	JJA	SON
Al-Hassakeh governorate				
Temperature response (C)	2.8	3	5.4	3.6
Precipitation response (mm)	-18	-24	-8	-12
Aleppo governorate				
Temperature response (C)	2.6	3	4.8	3.4
Precipitation response (mm)	-16	-18	-4	-18

Table (6): water use for irrigated wheat at *Al-Hassakeh* governorate under climate change conditions.

Date	ET0 (mm/ period)	Kc	Etc (mm)	Total rain (mm)	Effective rain (mm)
15/12	9	0.3	3	13	12
25/12	8	0.3	3	16	14
4/1	8	0.38	3	17	15
14/1	7	0.52	4	17	16
24/1	8	0.66	5	16	15
3/2	11	0.8	9	15	14
13/2	15	0.94	14	12	12
23/2	20	1.09	21	10	10
5/3	26	1.15	29	9	8
15/3	33	1.15	37	8	8
25/3	40	1.15	46	10	9
4/4	48	1.15	55	12	11
14/4	56	1.15	64	13	12
24/4	64	1.15	73	10	9
4/5	71	1.15	82	1	1
14/5	78	0.99	77	0	0

Date	ET0 (mm/ period)	Kc	Etc (mm)	Total rain (mm)	Effective rain (mm)
24/5	84	0.69	57	0	0
3/6	89	0.38	34	0	0
Total	674		617	180	168

The findings presented in Table 7 generally reveal that changes in temperature and precipitation lead to increased wheat crop requirement from 563 mm to 617 mm. If no additional irrigation water was added to compensate this increase in demand, the crop production will be reduced by 15.7 % (from 3.5 ton/ ha into 2.95 ton/ ha).

Table (7): Actual crop water use for irrigated wheat under climate change conditions

ETo (mm)	ETc (mm)	Ky	Ya t/ ha	Ym t/ ha
670	614	1.00	2.95	5.0

9. Assessing crop water use of rainfed wheat at *Al-Hassakeh* governorate

Crop productivity under rainfed condition largely reflects rainfall condition. (Fig. 8) shows that rainfed wheat productivity in *Al-Hasakah* governorate ranged between 280 kg/ ha and 2377 kg / ha for range of rainfall between 95 mm and 530 mm. In some years as the 1983/1984 and 1999/2000 production seasons there was a total crop failure. Therefore, any drastic change in climate will adversely effect rainfed wheat production.

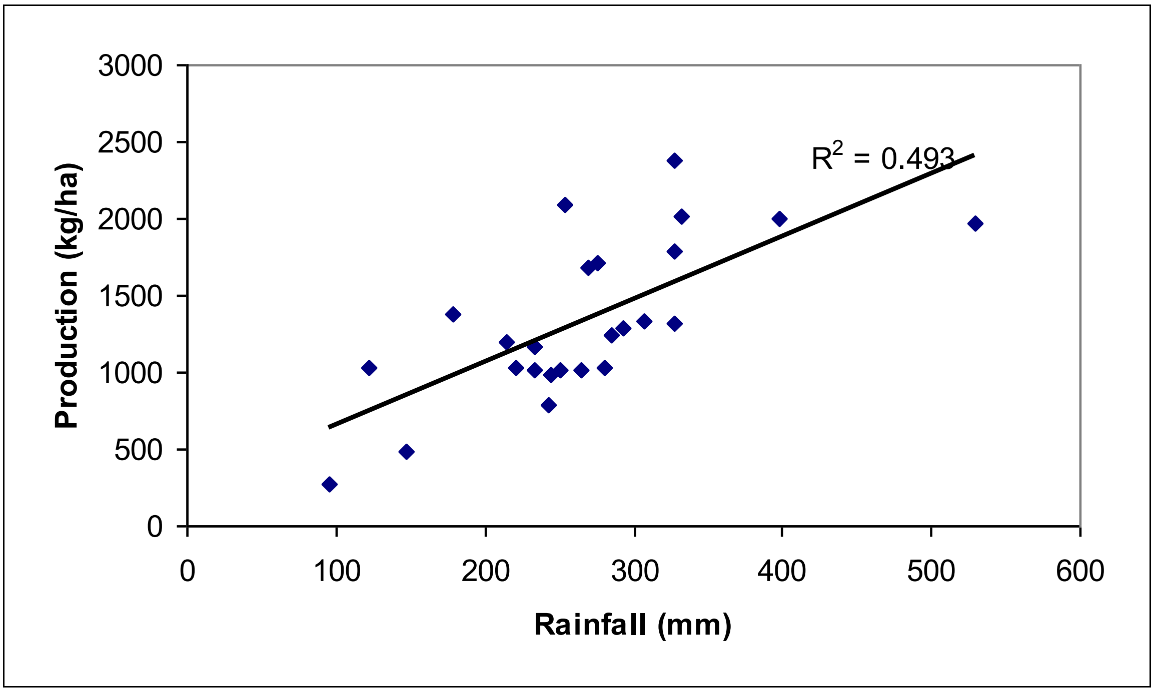

Fig. (8): Relation between rainfall and rainfed wheat production at *Al-Hassakeh* governorate.

Following the methodology explained earlier it was found that the reference evapotranspiration (ETo) under current climate conditions is 494 mm The average crop coefficient (Kc) for the rainfed wheat for the various growth stages is 0.82. The crop water requirements for rainfed wheat (ETc) are 428 (Tables 8 and 9).

Table (8): Water use for rainfed wheat in Al Hasakah under current climate conditions.

date	ET0 (mm/ period)	Kc	ETc (mm)	Total rain (mm)	Effective rain (mm)
12/15	8.4	0.30	2.5	14.2	13.2
12/25	7.5	0.30	2.3	16.8	15.3
1/4	6.8	0.31	2.1	19.8	17.8
1/14	6.6	0.48	3.2	20.5	18.4
1/24	7.6	0.69	5.3	17.8	16.2
2/3	9.9	0.91	9.0	14.1	13.2
2/13	13.4	1.11	14.8	13.6	12.7
2/23	18.0	1.15	20.6	13.0	12.2
3/5	23.5	1.15	27.0	12.2	11.5
3/15	29.8	1.15	34.3	12.1	11.4
3/25	36.6	1.15	42.1	13.3	12.4
4/4	43.8	1.15	50.4	14.7	13.7
4/14	51.0	1.15	58.7	14.8	13.7
4/24	58.1	1.03	59.8	11.5	10.8
5/5	64.8	0.77	49.5	7.5	7.2
5/14	70.9	0.50	35.4	6.0	5.8
5/24	37.5	0.30	11.3	2.3	2.2
Total	494.3		428.4	223.9	207.5

Table (9): Actual crop water use for rainfed wheat under current climate condition

ETo (mm)	ETc (mm)	Ky[1]	Ya[2] t/ ha	Ym[3] t/ ha	Ks	Etc actual (mm)	Yield reduction (%)
494.3	428.4	1.05	1.40	2.95	0.475	203	52.5

[1] *Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979)*
[2] *Yield average of 15 years in Al-Hasakah governorate*
[3] *From local data.*

Under the climate change scenario The crop water requirements for rainfed wheat (*ETc*) is increased from 428 mm to 469 mm. The crop production will be reduced by 21 % (from 1.4 ton/ha into 1.1 ton/ha) (table 10 and 11).

Table (10): water use for rainfed wheat in Hasakah under climate change conditions

date	ET0 (mm/ period)	Kc	ETc (mm)	Total rain (mm)	Effective rain (mm)
12/15	9.42	0.3	2.83	13.3	12.41
12/25	8.47	0.3	2.54	15.7	14.46
1/4	7.71	0.31	2.41	16.75	15.35

date	ET0 (mm/ period)	Kc	ETc (mm)	Total rain (mm)	Effective rain (mm)
1/14	7.53	0.48	3.63	17.19	15.74
1/24	8.66	0.69	6.04	16.49	15.14
2/3	11.15	0.91	10.15	14.76	13.65
2/13	14.93	1.11	16.56	12.44	11.64
2/23	19.91	1.15	22.89	10.16	9.67
3/5	25.9	1.15	29.78	8.64	8.37
3/15	32.71	1.15	37.61	8.45	8.23
3/25	40.09	1.15	46.11	9.74	9.36
4/4	47.81	1.15	54.98	11.89	11.23
4/14	55.6	1.15	63.94	13.12	12.24
4/24	63.21	1.03	65	10.03	9.37
5/5	70.4	0.77	53.79	0.89	0.87
5/14	76.93	0.5	38.44	0	0
5/24	40.66	0.3	12.3	0	0
Total	**541.09**		**469**	**179.55**	**167.73**

Table (11): Actual crop water use for rainfed wheat under climate change condition

ETo (mm)	ETc (mm)	Ky	Ya t/ ha	Ym t/ha
541.1	469	1.05	1.1	2.95

10. Assessing crop water use for Cotton at *Al-Hassakeh* governorate

Following the methodology explained earlier it was found that the reference evapotranspiration (ETo) under current climate conditions is 1307 mm. The average crop coefficient (Kc) for the cotton for the various growth stages is 0.86 (Figure 9). The crop water requirements for cotton (ETc) is 1169 (table 12).

Table (12): Actual crop water use for cotton under current climate condition

ETo (mm)	ETc (mm)	Ky[1]	Ya[2] t/ ha	Ym[3] t/ ha	Ks	Etc_{actual} (mm)	Yield reduction (%)
1307	1169	0.8	4.0	5.0	0.84	982	20

[1] *Irrigation and Drainage Paper No. 33 (FAO 1979)*
[2] *Yield average of 15 years in Al-Hasakah governorate*
[3] *from Irrigation and Drainage Paper No. 33 (FAO 1979) and local data*

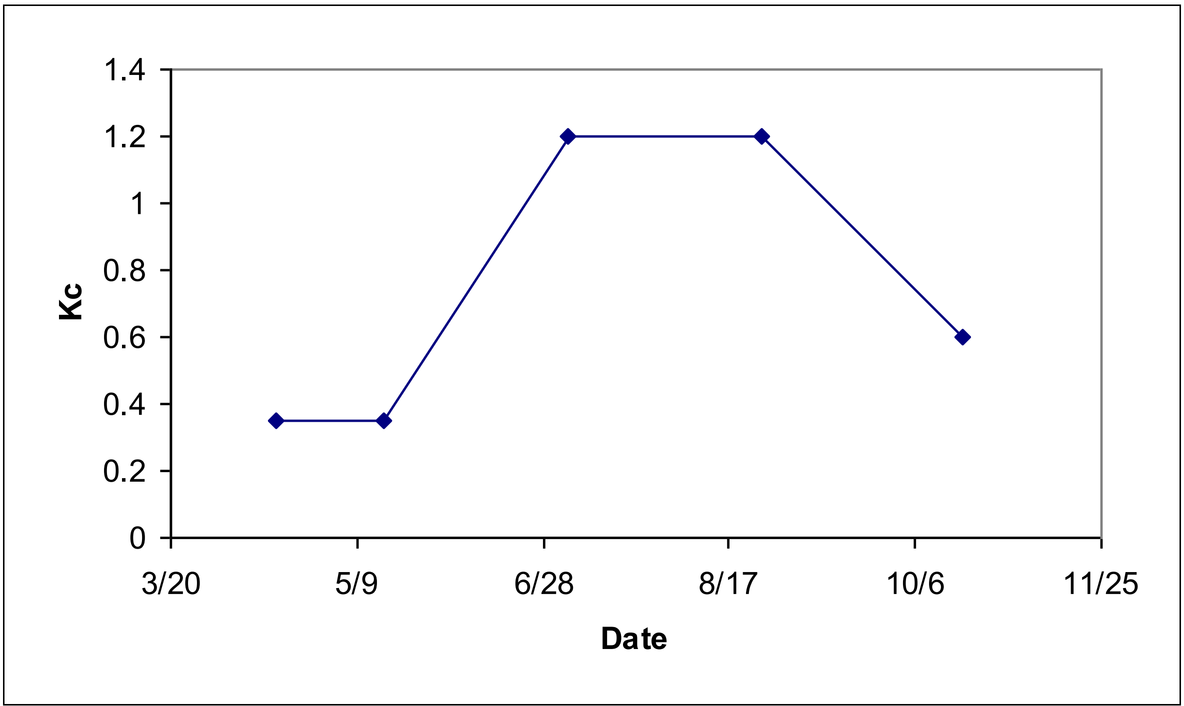

Figure (9): crop coefficient curve of Cotton

Under the climate change scenario the crop water requirements for cotton (ETc) is increased from 1169 mm to 1287 mm. If no additional irrigation water was added to compensate this increase in demand, the crop production will be reduced by 7.5 % (from 4.0 ton/ ha into 3.7 ton/ ha) (Table 13).

Table (13): Actual crop water use for cotton under climate change condition

ETo (mm)	ET crop (mm)	Ky	Ya t/ ha	Ym t/ ha
1415	1287	0.85	3.7	5.0

11. Assessing crop water use for olive tree at Aleppo governorate

Following the methodology explained earlier it was found that the reference evapotranspiration (ETo) under current climate conditions is 1446 mm. The average crop coefficient (Kc) for the olive tree for the various growth stages is 0.49 (Figure 10). The crop water requirements for olive tree (ETc) is 858 mm (Tables 14 and 15).

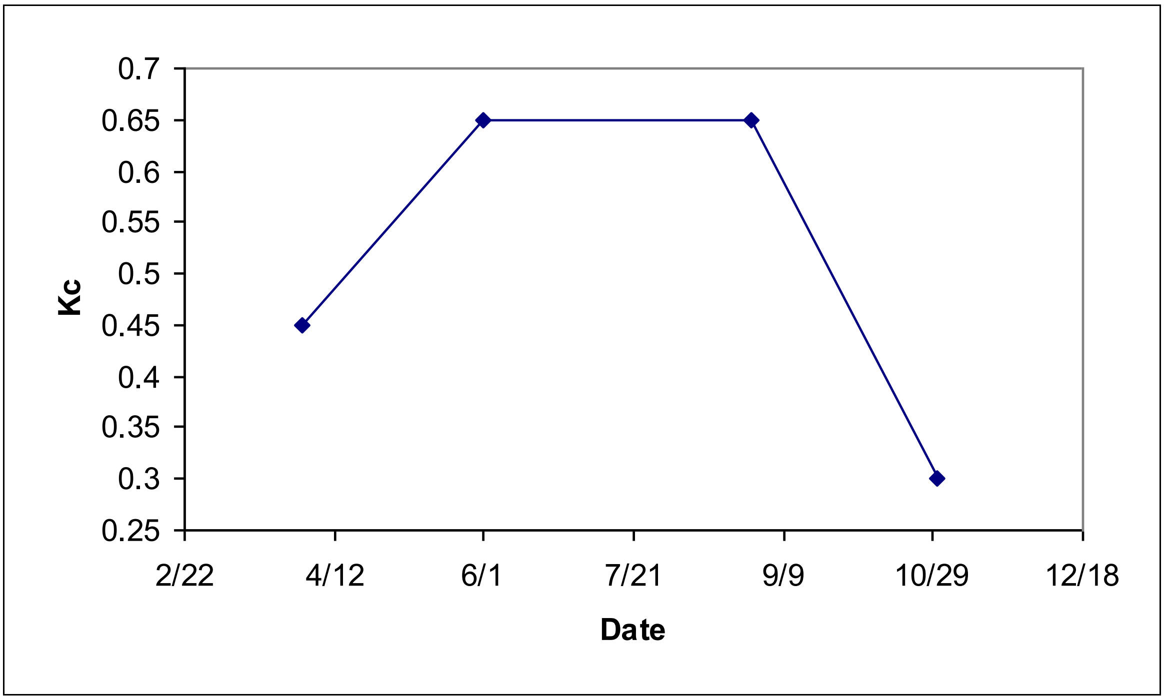

Fig. (10): crop coefficient curve of olive tree

Table (14): water use for olive tree under current climate conditions

date	ET0 mm/ period	Kc	ETc (mm)	Total rain (mm)	Effective rain (mm)
1-Apr	42	0.47	20	12.4	11.6
11-Apr	49	0.5	25	11.1	10.5
21-Apr	57	0.53	30	9.6	9.2
1-May	64	0.56	36	7.9	7.6
11-May	70	0.6	42	5.9	5.7
21-May	76	0.63	48	3.5	3.5
31-May	81	0.65	53	0.8	0.8
10-Jun	85	0.65	55	0.0	0.0
20-Jun	87	0.65	57	0.0	0.0
30-Jun	89	0.65	58	0.0	0.0
10-Jul	89	0.65	58	0.0	0.0
20-Jul	88	0.65	57	0.0	0.0
30-Jul	85	0.65	55	0.0	0.0
9-Aug	81	0.65	53	0.0	0.0
19-Aug	77	0.65	50	0.0	0.0
29-Aug	71	0.62	44	0.0	0.0
8-Sep	65	0.57	37	0.0	0.0
18-Sep	58	0.51	29	0.5	0.4
28-Sep	51	0.45	23	6.2	5.6
8-Oct	43	0.39	17	6.8	6.5
18-Oct	36	0.33	12	5.3	5.3
28-Oct	3	0.3	1	0.5	0.5
Total	**1447**		**858**	**70.5**	**67.2**

Table (15): Actual crop water use for olive under current climate condition

	ETo (mm)	ETc (mm)	Ky[1]	Ya[2] Kg/ tree	Etc actual (mm)
Irrigated	1446	858	1.1	17.5	463

[1] from calibration of local data
[2] Yield average of 15 years in Aleppo governorate

Under the climate change scenario the crop water requirements for olive tree (ETc) is increased from 858 mm to 945 mm (table 16). If no additional irrigation water was added to compensate this increase in demand, the production for irrigated olive will be reduced by 17 %.(Table 17).

Table (16): water use for olive tree under climate change conditions

Date	ET0 mm/ period	Kc	ETc (mm)	Total rain (mm)	Effective rain (mm)
1-Apr	46	0.47	21	11	10
11-Apr	54	0.5	27	9	9
21-Apr	62	0.53	33	7	7
1-May	70	0.56	40	2	2
11-May	77	0.6	46	0	0
21-May	83	0.63	53	0	0
31-May	89	0.65	58	0	0
10-Jun	93	0.65	60	0	0
20-Jun	96	0.65	62	0	0
30-Jun	98	0.65	63	0	0
10-Jul	98	0.65	64	0	0
20-Jul	96	0.65	63	0	0
30-Jul	94	0.65	61	0	0
9-Aug	90	0.65	58	0	0
19-Aug	85	0.65	55	0	0
29-Aug	79	0.62	49	0	0
8-Sep	72	0.57	41	0	0
18-Sep	64	0.51	33	0	0
28-Sep	56	0.45	25	0	0
8-Oct	48	0.39	19	0	0
18-Oct	40	0.33	13	1	1
28-Oct	4	0.3	1	0	0
Total	**1593**		**945**	**31**	**30**

Table (17): Actual crop water use and yield for olive tree under climate change conditions

	ETo (mm)	ETc (mm)	Ya* Kg/ tree	Etc actual (mm)
Irrigated	1588	945	14.5	437

Yield calculated using CROPWAT.

12. Adoption

Adaptation to climate change where the projected scenarios are less water and higher Temperatures means firstly more efficient use of water and secondly a change in farming Practices Future strategies for adapting to climate change may involve the following measures:

- ✓ Adopting heat-tolerant cultivars. The general commission of Agricultural Research (GCSAR), (ACSAD), and (ICARDA) are working for long time on developing more drought resistant wheat cultivars. Some of these cultivars can be adopted for both irrigated and rainfed regions.
- ✓ Changing crop practices (optimum sowing date, cultivars, water amount and plant density).
- ✓ Since climate change will result in higher water use, irrigation would be necessary to maintain current production for wheat and cotton,
- ✓ Rainfall efficiency is the amount of rainfall that is effectively stored the root zone. It is dependent on relative losses through runoff or percolation below the root zone and will be influenced by rainfall intensity, soil and slope characteristics. ***Rainfall efficiency could be increased throw applying Conservation farming practices including minimum tillage, strip cropping, building contour terraces and contour plowing***.
- ✓ The construction of water harvesting structures of need to be considered. So rainfall water can be stored to be used during prolonged droughts.
- ✓ Improving irrigation management. It has be noticed in this study that even under current climate condition the reduction in the yields are 30 % and 20 % for irrigated wheat and cotton, respectively. This is mainly for poor irrigation practices. The application of irrigation at critical growth periods of the crop are important to maintain high yield.
- ✓ The Ministry of Agriculture and Agrarian Reform should have to bring out Information Guide about wheat and cotton, with cultivar recommendations for various ***Agro- ecological zones*** based on the results of various cultivar trials conducted by (GCSAR).
- ✓ Climate projections which covers topics of projected rainfall and temperature should widely published in the general media and agricultural press.

13. Conclusions

In this study the potential impact of climate change on crop seasonal evapotranspiration (ET) and productivity was evaluated using the CROPWAT model. Wheat, cotton and olive were selected for the study since they are the major crops in Syria and represent different growing seasons and water needs. The evaluation was performed in *Al-Hassakeh* governorate for cotton and wheat production and in Aleppo governorate for olive tree production because they are the main agricultural area for these crops.

Future climate data were derived from B2 scenario– Hadley Model-CM3 for the period 2070 to 2100.

According to the study, climate warming resulted in increasing water use by about 9.6 %, 9.6 %, 10 %, and 10.1 % for irrigated wheat, rainfed wheat, cotton, and olive tree, respectively, compared with crop water use under current conditions. At the same time, increasing temperature and reducing precipitation under climate change simulations caused yield reduction, by about 15.7 %, 21 %, 7.5 %, and 17 % for irrigated wheat, rainfed wheat, cotton, and irrigated olive tree, respectively.

Adaptation measures such as considering heat-tolerant cultivars, changing crop practices, and improving irrigation management would be necessary to maintain current production for wheat and cotton.

Like most studies on climate change, effects on agriculture using crop models, this study suffers from several limitations. For instance, the crop model used assumes that nutrients are not limiting. Also, the study did not take in consideration the effect of climate change on the duration of the growing seasons and predicting the yield loses due to this change. This limitation in study is mainly due to decadal time studies, and limited field experiment. However, the results of this study would meet our objective to assess the Vulnerability of major agricultural crops in Syria to climate change scenario.

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