Application of Cropwat Model for Estimation of Irrigation Scheduling of Tomato in Changing Climate of Eastern Europe: the Case Study of Godollo, Hungary

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Abstract

Low agricultural water productivity in irrigated agriculture and very low food security is challenging due to high population explosion and water exploitation in agriculture in both developed and developing countries in the world. CROPWAT model is decision support system developed by FAO and it is used as practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements, irrigation scheduling, and also allows helps in planning and decision making in the areas were water resource availability is varying and scarce. Therefore, understanding crop water requirements (CWR) is essential for better irrigation practices, scheduling and efficient use of irrigated water since climatic variability and water scarcity is in every corner in the globe. So, the main purpose of this research was to estimate crop water requirement and irrigation scheduling of Tomato in Gödöllő under Hungarian environmental condition. The major input data has been used in CropWat-8 model was climatic data, crop data and soil data. From the result it has been observed that, the total amount of water requirement for Tomato determined to be 393.6 mm and 527 mm for 2010 and 2011 respectively were as total amount of irrigation requirement for 2010 was determined as 164.1 mm while for 2011, 363 mm irrigation water was estimated for irrigated Tomato production. The CropWat model for Tomato irrigation schedules for all growing periods in 2010 was zero, 19.2 mm, 116.1 mm and 28.9 mm in its initial, development, mid and let stages of growing period respectively and also the irrigation scheduling for Tomato in 2011 were 16.7 mm, 89 mm and 129 mm in initial and development stages respectively followed by128.3 mm in their mid and end stages. Besides in the study area, 2010 was the wettest year but 2011 was determined as the driest year this may cause adverse condition on crop yields quantity and quality especially in case of tomato in mentioned years.

Keywords - *Crop Wat, Growing period, Climatic data and Irrigation scheduling*.

I. INTRODUCTION

Water for agriculture is becoming increasingly scarce in the light of growing water demands from different sectors [10]. Water supply matters in the world that will soon have to grow food for billions more people as the world's population is estimated to increase from 6 billion to 10 billion by mid-century, which will cause the high demand of world's population for food especially in developing countries [16]. Therefore,if the water consumption continues similar in the future, it's predicted that by 2025 water scarcity will increase more than 60 percent in the world [4]. Thereby, it will be a big challenge to provide food for growing population and high water consumption by agriculture in most region of the world. Hence, for effectively and efficiently using the available water sources to meet the possibly variation of cropping pattern, irrigation management plays an important role. Moreover, improvement of irrigation directly increases crop yield; World Bank indicated that agricultural water management is a part of resource management that provides important input to farmer's income through high level of agricultural production [21]. The water consumes contains approximately 80% of globe's agricultural lands water consumption [14]. Irrigation provides about 40% of world's food from 17% of the cropped area [19]. According to recent reports, over 60% of the world's irrigation is in Asia. The main source of income and food security is the irrigated agricultural land among rural population [2]. [17]Pointed out that the concept of agricultural productivity has been the volume of the yield per unit of land but the new concept has to be based on the scarcity of water. The productivity per unit of water requires being the basic point for measuring of agricultural productivity in developing countries [17].

Irrigation played main role for long time in nourishingincreasingof population and will undoubtedly play still greater role in the future.Irrigation not only boosts the yields quantity of particular crops, but itpersists the effective crop growing period in the region where the length of the growing seasons are determined bythe lack of precipitation, thus permitting multiple cropping on the region which just a single crop could be grown. The risk of expensive inputs which wasted as a result of moisture stress can be decreases by application of irrigation [5]. In the areas where the amount and distribution of rainfall is not sufficient to sustain crop growth and development, an alternative approach is to make use of the surface and underground water for irrigation. Satisfying crop water requirements, although it maximizes production from the land unit, does not necessarily maximize the return per unit volume of water [13]. Therefore, in an effort to improving water productivity, there is an increasing interest in judicious application of irrigation water, an irrigation practice which controls different aspects of water supply to improve growth and yield, and to develop the economic efficiency of crop production and food safety. Therefore; the objective of this study is to estimate the reference evapotranspiration (ET_0), crop water requirement and irrigation scheduling for Tomatoas a high value crop in the study area.

II. METHODOLOGY

A. Study Area

The study was carried in horticultural technology department farm at Szent Istvan University (47°35’ ′N, 19°21’ E), Gödöllő city, Hungary of Eastern Europe. The site was rather flat, at an elevation of 204 m above sea level. Various physical properties of the soil at the experimental site are presented in soil data and soil attributes file of Cropwat8 model below. The experimental field is composed of brown forest soil, with a mechanical composition of loamy sand and sandy clay, and the subsoil water is below 5 m and the infiltration rate is high due to soil particle porosity. The meteorological data were collected from Aszód meteorology station which laydown 14.9 kilometers away from Gödöllő with the 162.4 m, 47^0, 39’ N and 19^0, 28’ E ; altitude, latitude and longitude respectively. All information was provided by the Hungarian Meteorological Service.

B. Selection of Model

CropWat model is a computer program used as a decision support tool that was developed by the Land and Water Development Division of UN Food and Agriculture Organization FAO [7].It is an empirical process-based crop model that is used to calculate crop water and irrigation requirements and permits to developirrigation schedules under different management conditions and the calculation of water supply schemes for various crop patterns [7] from soil, climate and crop input data. Besides; the program can also be used to estimate crop performance under both rainfed and irrigated conditions based on calculations of the daily soil water balance. It can used at the field scale and large scale; to evaluate farmer irrigation practice and to establish water supply schedules for different cropping patterns within an irrigation scheme for different cultivars as well respectively [8]. The advantages of CROPWAT are its simplicityand easiness to use and the program is linked to less intense data requirements. The model is a powerful simulation tool which analyzes complex relationships of onfarm parameters (crop, climate, and soil) for assisting in irrigation management and planning. This model is extensively used in the field of water management throughout the world because it is mainly used for estimation of the crop evapotranspiration, irrigation scheduling and agricultural water requirements with different cropping patterns for irrigation planning and decision support in water management.

C. Model Input Data

Daily climatic data has been used to calculate ETo for each year using Penman-Monteith method [1] from a computer based Cropwat-8 mode rainfall attribute window has data specifics which the software needs for it to run smoothly. The software has other methods also for calculating effective rainfall if other users want to use for calculations. Crop data main crop characteristics such as length of the growth cycle, crop factors, rooting depth, etc., should be collected (Annex teble-1) and also soil data attribute has total available soil moisture (FC-WP), maximum rain infiltration rate, maximum rooting depth, and the initial available soil moisture (Annex teble-1 & 2).

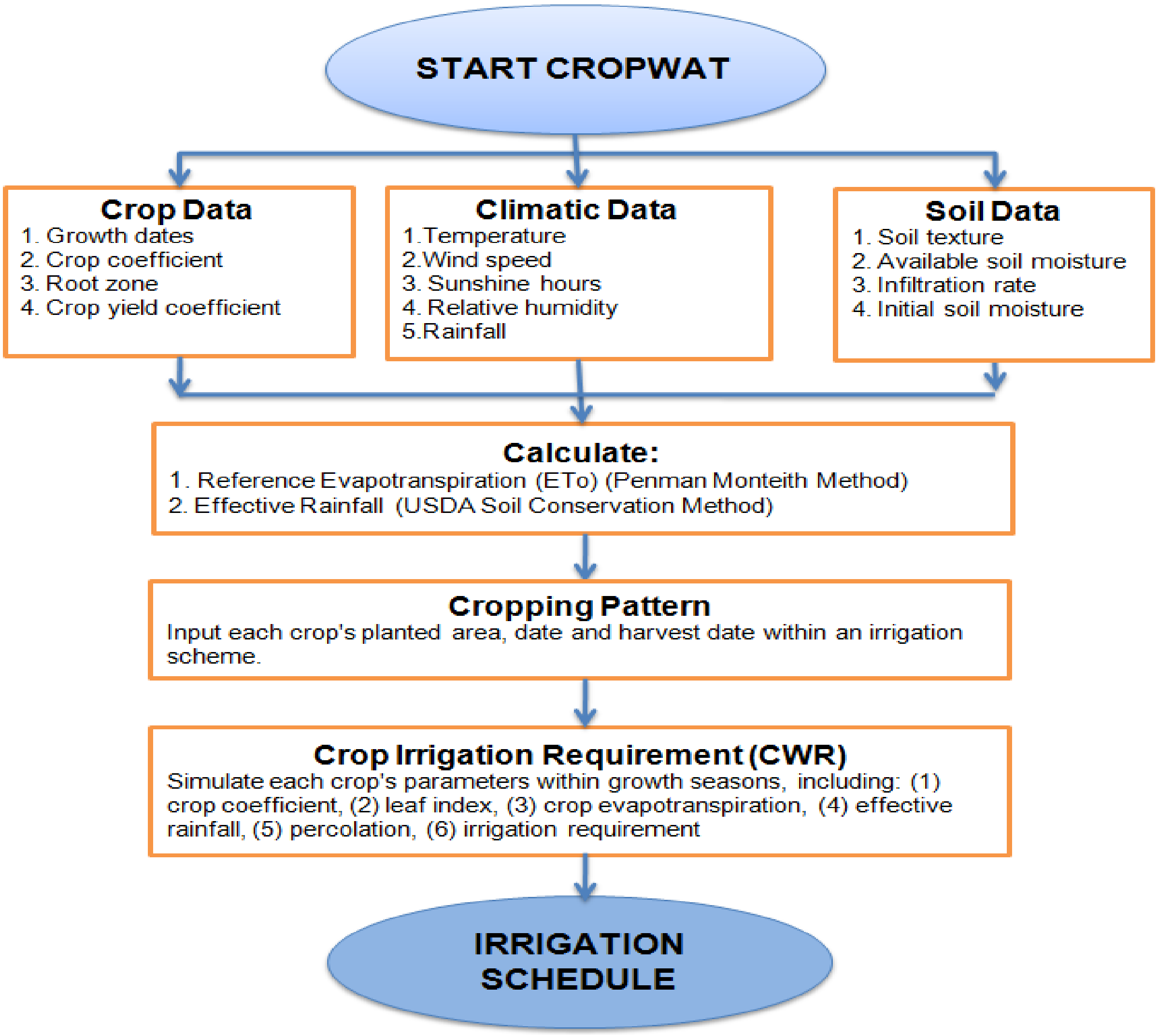


Figure 1.**Conceptual Platform of CropWat Model.**

1) *Calculation of Reference Evapotranspiration (ETo)*

The reference evapotranspiration ETo was calculated by FAO Penman-Monteith method, using decision support softwareCROPWAT 8.0 developed by FAO, based on FAO Irrigation and Drainage Paper 56 named FAO56. FAO56 adopted the Penman-Montieth method as global standard to estimate ETo from meteorological data. The Penman Monteith equation integrated in the CROPWAT program is expressed by the following equation (Equation1).

Equation 1.FAO Penman-Monteith equation.

$$ET_0 = \frac{0.408 \, \Delta \, (Rn - G) + \gamma \frac{900}{T+273} U2(es - ea)}{\Delta + \gamma(1 + 0.34u2)}$$

Where: ET_0 is reference evapotranspiration (mm day^{-1}), T, G and Rn are daily mean temperature ^oC at 2 m height, soil heat flux density (MJ m^{-2} day^{-1}) and net radiation value at crop surface (MJ m^{-2} day^{-1}) respectively. Also, u2, e_se_a, (es–ea), D and c represent wind speed at 2 m height (m s^{-1}), saturated vapour pressure at the given temperature (kPa), actual vapour pressure (kPa), saturation vapour pressure deficit (kPa), slope of the saturation vapour pressure curve (Pa/^{o}C) and psychometric constant (kPa/^{o}C), respectively [1]. According to Yin et al. (2008) being a significant part of the hydrological cycle, the ET_0 will have its important impacts on ecosystem models, water uses by agriculture, humidity/aridity conditions and runoff due to precipitation estimation. There are several equations for calculating of ET_0. The ET_0 was calculated using FAO Penman-Monteith method which is one of the most precise equations and Cropwat8 model is based on this equation:

2) *Calculation of Total Available Soil Moisture (TAW)*

To calculated the total available soil moisture for Cropwat8 model, it's need to use the total available soil water (TAW) formula that will be computedfrom the soil permanent wilting point (PWP) and at field capacity (FC))using the following expression indicated under Annex-II teble-2 &3.

Equation 2.Total available water continent in the soil profile.

$$TAW = \frac{(\mathbf{FC - PWP})}{\mathbf{100}} * BD * Dz$$

Where:TAW is total available soil water (mm/m), FC and PWP in % on weight basis, BD is the bulk density of the soil in gm cm^{-3}, and Dz is the maximum effective root zone depth in mm.

Optimal irrigation regime will be applied at 100 % ASMD and hence 100% ETc, RAW to bring the soil root zone depth back to FC. The ASMD, RAW is the amount of water that crops can extract from the root zone without experiencing any water stress. The RAW could be computed from the expression indicated under Annex-II teble-2 &3.

Equation 3.Readily available water continent in the soil.

$$RAW = p * TASW$$

Where, RAW is the readily available water in mm; p the critical soil moisture depletion in % and TAW is the total available water in mm/ m.

III. RESULTS AND DISCUSSION

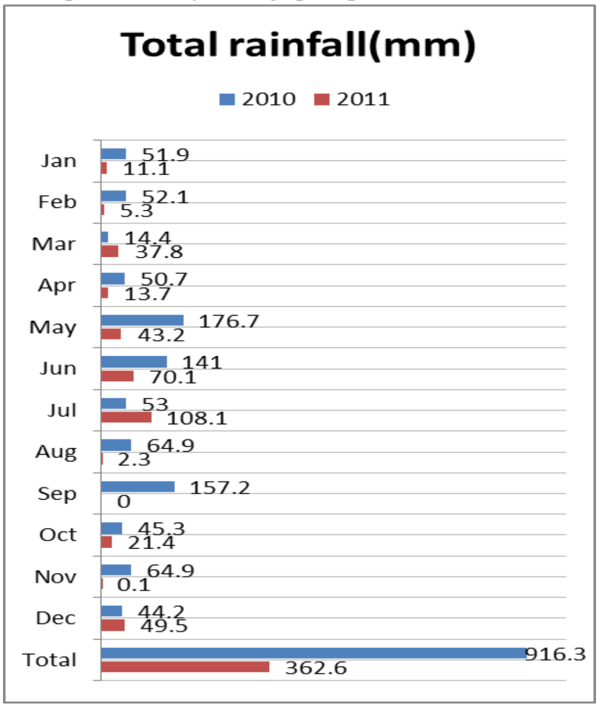
A. *Daily Reference Evapotranspiration*

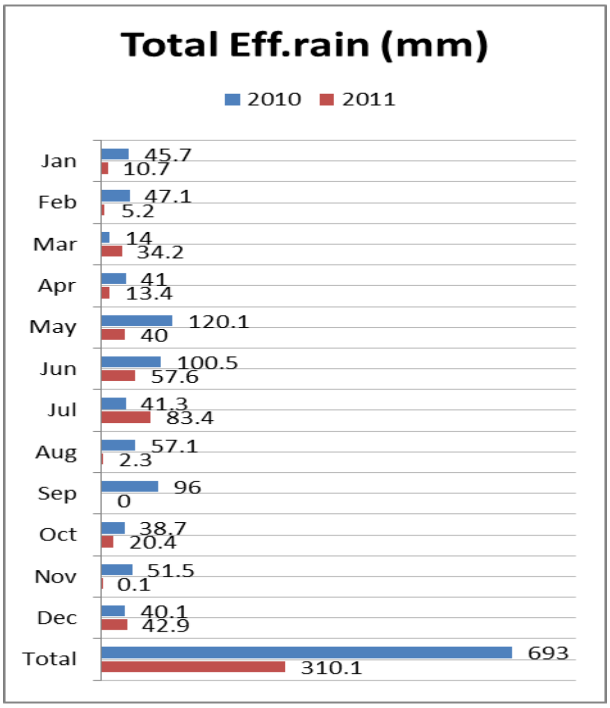
Reference evapotranspiration (ETo) is estimated at 1 967 mm. Table 1 and Figure 2 show ETo by month. The months December to May have a relatively high values, more than 160 mm per month and the months June to November showed lowest ETo, those periods coincide with the dryand rainy season respectively. However; the low values of ETo in rainy season may be due to the high frequencies of rainfall combined with high relative humidity and relative low temperatures.As the trend of ETo affecting by climatic factors such as temperatures, solar radiation, and rainfall as well as wind, relative humidity of the air consequently ETo is a climatic parameter. The results are in accordance with [6], which showed that ETo was lowest during the peak of the rainy season to highest during the peak of the dry season. The maximum average reference evapotranspiration in 2010 was recorded 4.13mm/day onJuly (Table-9 Annex-I) and the highest average reference evapotranspiration in 2011 was estimated 4.68mm/day Aug(Table-10 Annex-I).

B. *Daily Rainfall and Effective Rain*

The input data for precipitation was daily basis but the output of totalprecipitationand effective rainfall of model outputs was summarized in graph1 as follow. The results show that 2010 was wet year relative to 2011 because the amount of rainfall and effective rainfall recorded was decreased by 40 % and 45 % respectively. 2010 was the wettest and 2011 the driest year since 1901.

Graph 1.Monthly average precipitation for 2010 and 2011.





C. *Daily Crop Water Requirement*

Crop coefficient (Kc)values of tomato were as follows in 2010: initial stage (0.6) for 26 days, the development stage (0.6-0.98) for 34 days, mid-season stage (1.09) for 40 days, and the late season stage (1.04-0.77) for 25 days (table 1). The K_c values of tomato were for 2011: initial stage (0.6) for 26 days, development stage (0.6-1.03) for 34 days, mid-season stage (1.14-1.15) for 40 days, and the late season stage (1.1-0.85) for 25 days (Table 2).

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.6	1.68	10.1	18	0
May	2	Init	0.6	1.34	13.4	50.3	0
May	3	Dev	0.6	2.18	24	39.8	0
Jun	1	Dev	0.69	2.63	26.3	35.9	0
Jun	2	Dev	0.84	3.23	32.3	48.7	0
Jun	3	Dev	0.98	3.5	35	15.9	19.2
Jul	1	Mid	1.09	4.89	48.9	3.2	45.7
Jul	2	Mid	1.09	5.04	50.4	0.6	49.8
Jul	3	Mid	1.09	3.67	40.3	37.6	2.8
Aug	1	Mid	1.09	3.77	37.7	19.9	17.8
Aug	2	Late	1.04	3.71	37.1	26.9	10.2
Aug	3	Late	0.89	2.64	29	10.3	18.7
Sep	1	Late	0.77	1.51	9.1	31.4	0
			Total:		**393.6**	**338.5**	**164.1**

Table 1.**Decadal crop water requirements for Tomato in 2010 calculated by Cropwat8.**

Month	decade	stage	Kc	Etc	Etc	Eff rain	Irr.Req
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.6	2.42	14.5	5.6	9.8
May	2	Init	0.6	2.49	24.9	18	6.9
May	3	Dev	0.6	2.9	31.9	12.6	19.3
Jun	1	Dev	0.7	2.85	28.5	34.5	0
Jun	2	Dev	0.87	4.16	41.6	0	41.6
Jun	3	Dev	1.03	5.12	51.2	23.1	28.1
Jul	1	Mid	1.14	5.94	59.4	7	52.4
Jul	2	Mid	1.15	6.89	68.9	37.2	31.7
Jul	3	Mid	1.15	2.78	30.6	39.2	0
Aug	1	Mid	1.15	4.71	47.1	2.3	44.9
Aug	2	Late	1.1	5.17	51.7	0	51.7
Aug	3	Late	0.96	4.97	54.6	0	54.6
Sep	1	Late	0.85	3.66	22	0	22
				Total:	**527**	**179.5**	**363**

Table 2.**Decadal crop water requirements for Tomato in 2011 calculated by Cropwat8.**

The total tomato crop water requirement,effective rainfall and irrigation requirement were 393.6mm/dec, 338.5mm/dec, 164.1mm/dec in 2010 and 527mm/dec, 179.5mm/dec, 363mm/decrespectively in 2011.

D. *Daily Irrigation Scheduling*

The software scheduled seven times irrigation for tomato in different days of growing season in 2010. The total amount of gross irrigation was 67.4 mm which from this amount, 47.2 mm was applied for crop as total net irrigation in development stage while in the mid-season from the 177.4 mm of total gross irrigation, 124.2 mm total net irrigation used by crop. Eventually, from the 65.6 mm total amount of gross irrigation, 45.9 mm was applied tocrop as total net irrigation in the end stage of growing period (Table 3).

Date	Day	Stage	Rain	Depl	Net Irr	Gr. Irr	Flow
			Mm	%	mm	mm	l/s/ha
9-Jun	36	Dev	0	38	19.1	27.2	0.09

30-Jun	57	Dev	3	40	28.1	40.2	0.22
7-Jul	64	Mid	0	40	29.7	42.4	0.7
13-Jul	70	Mid	0	43	31.5	45	0.87
19-Jul	76	Mid	0	40	29.5	42.1	0.81
12-Aug	100	Mid	0	46	33.5	47.9	0.23
25-Aug	113	End	0	47	34.8	49.7	0.44
6-Sep	End	End	0.1	11			

Table 3.Daily irrigation schedule of Tomato (2010).

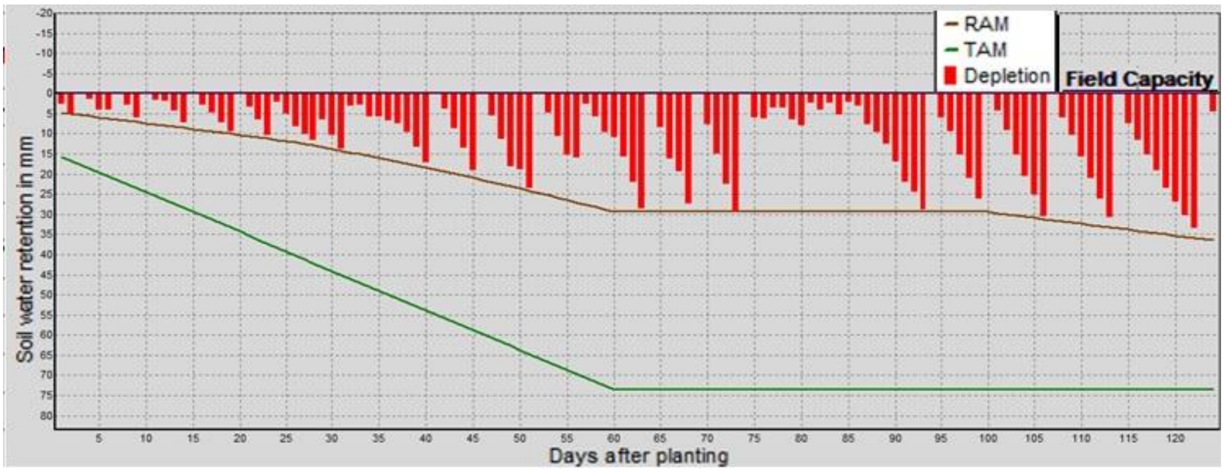
Graph 2.Irrigation scheduling for tomato, 2010.

Additionally, the actual water use by crop was 392.2 mm that this amount had applied 177.6mm by effective rainfall and 206.2 as total net irrigation. The actual irrigation requirement and the total gross irrigation for tomato in this year were 214.6 mm and 294.5mm respectively.

The model scheduled 16 times irrigation within tomato growing period in 2011. With 62.5 mm total amount of gross irrigation, 43.8 mm total net irrigation was used by crop in its initial season. In the development-season, the crop used about 73.4 mm as total net irrigation from the 105 mm total amount of gross irrigation and in the mid-season, the estimation indicated 244.1 mm total gross irrigation which from this total amount only 170.8 mm could be apply as total net irrigation. Finally the growing period was end by application of 111.5 mm total amount of net irrigation from the total amount of 159.1mm gross irrigation (Table 18). The total gross irrigation and actual irrigation requirement were 570.7 mm and 404 mm individually. Moreover, the actual water use by crop predicted 523 mm that this amount had applied 119.6 mm by effective rainfall and 399.5 mm as total net irrigation.

Date	Day	Stage	Rain	Depl	Net Irr	Gr. Irr	Flow
			mm	%	mm	mm	l/s/ha
7-May	3	Init	0.8	41	7.2	10.2	0.39
11-May	7	Init	0	32	6.8	9.7	0.28
14-May	10	Init	0.8	32	7.7	11	0.43
19-May	15	Init	0	33	9.6	13.8	0.32
24-May	20	Init	0	36	12.5	17.8	0.41
14-Jun	41	Dev	0	38	20.7	29.6	0.16
19-Jun	46	Dev	0	38	22.9	32.8	0.76
25-Jun	52	Dev	0	45	29.8	42.6	0.82
7-Jul	64	Mid	0	48	35.2	50.3	0.49
12-Jul	69	Mid	0	47	34.3	49	1.13
17-Jul	74	Mid	0	50	37	52.8	1.22
6-Aug	94	Mid	0	46	34.1	48.8	0.28
12-Aug	100	Mid	0	41	30.2	43.2	0.83
19-Aug	107	End	0	50	36.8	52.5	0.87
26-Aug	114	End	0	51	37.2	53.1	0.88
4-Sep	123	End	0	51	37.5	53.5	0.69
6-Sep	End	End	0	6			

Table 4.Daily irrigation schedule of Tomato (2011).

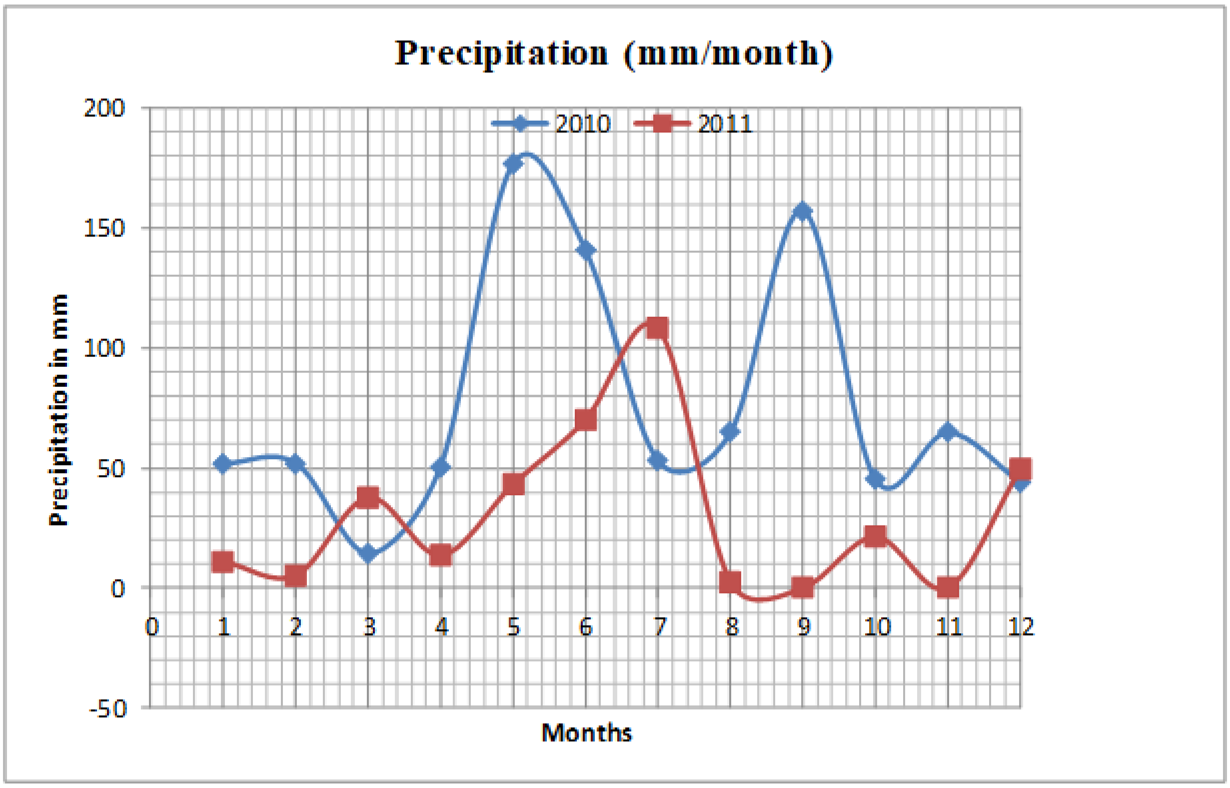


Graph 3.Irrigation scheduling for tomato, 201.

The crop yield response factors of tomato are considerable to be 0.50 initial stages,0.60 development stages,1.10 mid-season stages,0.80 late season stage, and 1.05 at the end of the season (harvest). The yield response change variesin both year and the entire seasons of 2010 and 2011 with mid-season stage recording the highest value.

E. Effect of climate change on Tomato's Water Requirements

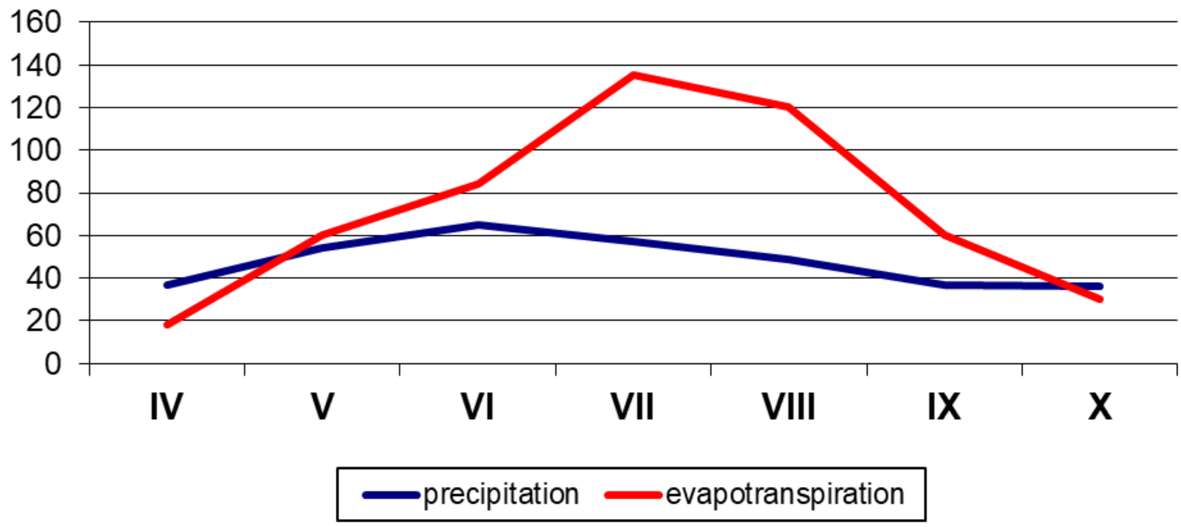
Weather has significant role for the success of agricultural production. Most of crops are dependent to weather to provide energy and water for their life continuation and also an adverse weather can cause yield losses, especially during critical growing stages. Solar irradiation and temperature above 32^{o}C causes degradation of lycopene which is the source of tomato red coloration. In the other hand, a widespread of fungi diseases recorded as a result of very moist weather condition in 2010. July is very important time in the vegetation period.



Graph 4.Precipitation of study area in 2010 and 2011 (mm).

Maximum plant water requirements are in July, which highlights the role of the July precipitation. The general precipitation features of a given year can modify the overwhelming role of the July precipitation. Therefore, Tomato could be strongly affected especially during maturing stage on dry July of wettest 2010 year and wet July of driest 2011, as it can be seen on the irrigation scheduling. However, the length of crops growing period was the same for both years.

The amount of water use by tomato was determined 43.8 mm on May (initial stage) of 2011 followed by 73.4 mm and 170 mm net irrigation on June and July (development and mid-stages) respectively. In this case tomato was harvested after application of 111.5 mm net irrigation in its end stage of growing period on August –September of 2011.



Graph 5.Precipitation vrs Evaporation of study area [22].

The highest precipitation reach to 65mm on July and the lowest precipitation about 36 mm on October, in the same time the highest evapotranspiration are on July and August about 135 mm and 120 mm respectively.Therefore, there is big gap between precipitation and evapotranspiration on July - August and then evapotranspiration drop down gradually on September (Graph 5). During high evapotranspiration period, the plant needs high amount of water application which is important to be clear more for the better irrigation scheduling and further implementation, and/or better soil moisture management to avoid the yield reduction due to crop water stress.

IV. CONCLUSION

From the study, it has been observed that that there were 40 percent decreases of rain in 2011 with a wet July compare to 2010 with a dry July. Therefore, 2010 and 2011 nominated as the wettest and driest years respectively, since 1901.The total amount of water requirement for Tomato's growing seasons were 393.6 mm and 527 mm in 2010 and 2011 respectively. Additionally, the total amount of irrigation requirement for Tomato was determined 164.1mm and 363 mm individually in 2010& 2011 respectively. Although, the timing of irrigation was different in both years but the output of model showed specific irrigation intervals in particular days of crop's all growing stages. The highest net irrigation were 124.2 mm on July(mid-stage) Tomato and the lowest irrigation determined zero in initial and developments stages of growing period due to high precipitation for the 34.8 mm net irrigation for tomato on August(mid stage) in 2010. Similarly in 2011, the highest net irrigation were determined to be 170 mm on July (mid stage) for Tomato and the lowest net irrigation requirement for Tomato were 43.8 mm on May(initial stage) in 2011.

The model setting for scheduling attributes was considering to timing, application and field efficiency which the irrigation timing option was controlled by (irrigate at 100% critical depletion), irrigation application option selected as (refill soil moisture content to 100% field capacity) and irrigation efficiency was supposed to 70 percent. Therefore, the crops yield reduction was zero in both years (2010, 2011) and surface irrigation considered to be used in this study due to its high feasibility and common usages among farmers in different countries of the world.

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Annex-I

Table-1: Daily ET0 for 2010 calculated by Cropwat8 in mm/day

No	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.2	0.15	0.82	2.01	5.46	1.72	4.83	4.77	1.62	0.87	0.4	0.19
2	0.11	0.19	0.73	1.35	3.83	1.93	4.68	4.56	2.67	0.83	0.44	0.21
3	0.19	0.22	0.91	2.06	3.37	1.8	5.02	3.91	1.83	0.91	0.46	0.2
4	0	0.2	0.57	1.19	3.52	1.92	4.65	3.34	1.28	0.8	0.48	0.12
5	0.16	0.27	0.84	1.17	3.33	4.62	3.82	3.04	2.56	0.8	0.46	0.07
6	0.19	0.34	0.78	1.33	2.33	4.69	4.31	2	1.87	1.11	0.37	0.07
7	0.19	0.33	0.57	1.82	3.79	4.99	2.99	3.08	1.86	1.15	0.43	0.04
8	0.19	0.25	0.79	2.36	2.27	5.19	4.83	2.43	1.22	1.1	0.42	0.23
9	0.22	0.26	0.64	2.38	2.23	5.29	4.84	3.62	1.44	1.04	0.42	0.23
10	0.25	0.34	0.74	1.61	2.86	4.91	4.97	3.75	1.22	0.98	0.4	0.02
11	0	0.38	0.62	1.41	3.46	4.95	5.1	4.04	1.24	1.06	0.26	0.17
12	0.12	0.4	0.66	1.12	1.71	5.42	4.41	4.19	1.5	1.03	0.3	0.16
13	0.21	0.39	0.76	1.2	2.46	5.19	5.27	3.91	1.32	0.94	0.25	0.03
14	0.22	0.42	0.84	1.66	2.88	3.9	5.5	4.01	1.77	0.94	0.27	0.01
15	0.14	0.41	1.17	1.46	1.9	4.16	4.39	2.94	1.68	0.81	0.18	0.14
16	0.05	0.37	0.88	2.39	1.4	2.78	4.45	2.91	1.25	0.75	0.34	0
17	0.21	0.41	0.99	2.64	1.94	3.6	4.99	3.21	1.08	0.63	0.23	0.12

18	0.22	0.45	1.31	2.45	2.33	2.64	3.92	3.29	1.49	0.63	0.37	0.13
19	0.23	0.46	1.49	1.67	2.28	3.82	3.76	3.73	1.08	0.7	0.34	0.11
20	0.23	0.48	1.53	2.93	1.98	2.46	4.4	3.35	1.68	0.63	0.13	0
21	0.22	0.61	1.21	2.67	3.47	2.14	3.8	3.38	1.91	0.61	0.32	0.16
22	0.22	0.45	1.09	2.66	4.51	1.92	5.13	3.86	1.84	0.58	0.32	0.18
23	0.12	0.56	1.17	1.34	3.7	4.24	4.84	3.83	1.88	0.53	0.24	0.01
24	0.12	0.56	1.81	3.06	4.51	4.42	3.94	3.48	2	0.54	0.13	0.19
25	0.1	0.76	1.8	3.02	3.44	2.91	1.85	3.26	1.22	0.58	0	0.21
26	0.2	0.58	2.04	3.29	3.23	1.96	1.82	3.44	1.03	0.51	0.12	0.17
27	0.09	0.72	1.58	2.28	3.92	2.49	2.22	3.56	1.11	0.44	0.13	0.12
28	0.19	0.65	1.88	2.94	3.91	4.86	2.8	1.53	1.09	0.41	0.21	0.06
29	0.21		1.88	3.39	3.92	5.18	3.88	3.04	1.43	0.43	0.16	0
30	0.26		1.48	3.63	3.15	5.16	2.88	1.47	1.43	0.39	0.17	0.11
31	0.28		1.58		2.12		3.8	1.28		0.39		0.13
Av	**0.17**	**0.42**	**1.13**	**2.15**	**3.07**	**3.71**	**4.13**	**3.3**	**1.55**	**0.75**	**0.29**	**0.12**

Table-2: Daily ET_0 for 2011calculated by Cropwat8 in mm/day

No	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.18	0.31	0.68	2.06	1.56	4.08	3.23	3.03	3.97	3.03	0.6	0.2
2	0.13	0.44	0.74	2.47	3.61	4.27	3.94	3.75	3.91	2.37	0.63	0.19
3	0.17	0.46	0.56	2.66	3.69	5.62	2.97	4.52	3.65	2.26	0.99	0.18
4	0.2	0.57	0.85	4.13	3.22	4.96	4.23	2.14	4.82	2.83	1.03	0.29
5	0.24	1.19	0.9	2.82	4.25	4.47	5.58	3.77	5.43	3.02	0.92	0.67
6	0.22	1.04	1.16	3.38	3.94	3.92	5.62	4.66	4.2	4.11	1.74	0.28
7	0.12	1.93	1.19	5.44	5.09	4.08	5.81	5.27	4.46	1.5	1.06	1.1
8	0.2	1.01	1	6.86	2.43	3.08	7.25	3.79	2.74	1.5	0.39	0.73
9	0.17	1.1	1.18	6.07	4.25	3.12	6.93	5	3.44	1.42	0.66	0.19
10	0.2	0.79	0.87	5.4	4.23	3.23	6.35	5.19	2.7	1.61	0.85	0.44
11	0.18	0.69	1.72	3.73	4.78	2.54	7.08	4.39	4.96	1.8	0.3	0.34
12	0.31	1.32	2.16	4.1	4.58	4.65	6.06	3.49	3.84	2.04	0.39	0.31
13	0.33	0.74	2.25	3.68	5.34	4.66	6.63	3.68	4.45	1.45	0.57	0.12
14	0.58	1.27	2.09	1.99	4.29	4.21	7.47	4.43	4.02	1.26	0.26	0.19
15	0.51	1.5	1.78	2.4	2.62	4.47	6.56	5.49	2.63	1.11	0.31	0.21
16	0.53	0.53	1.48	2.63	1.89	5.67	5.76	5	2.63	1	0.17	0.74
17	0.06	0.52	1.08	3	4.31	5.38	6.79	4.25	3.91	1.54	0.21	0.52
18	0.15	0.54	1.05	3.35	4.6	6.08	5.3	4.87	4.81	2.36	0.32	0.39
19	0.26	0.57	0.85	3.9	4.15	4.21	5.42	5.97	3.57	1.72	0.32	0.28
20	0.23	0.58	1.14	3.85	4.86	5.87	3.05	5.68	1.45	0.69	0.27	0.43
21	0.29	0.63	1.59	3.62	4.11	6.04	1.95	4.4	3.13	0.79	0.3	0.29
22	0.69	0.71	1.88	3.69	4.14	7.02	2.82	5.12	2.36	0.73	0.3	0.19
23	0.19	0.58	2.21	3.59	3.78	6.86	2.04	5.54	2.47	0.74	0.49	0.19
24	0.44	0.55	4.22	2.76	5.05	4.65	2.02	5.12	2.36	0.77	0.25	0.17
25	0.3	0.44	3.61	1.82	5.34	6.1	1.92	4.58	2.09	0.89	0.22	0
26	0.29	0.74	3.97	2.88	5.35	4.56	2.06	6.76	1.82	1.36	0.22	0.17
27	0.31	0.77	1.72	2.57	6.59	5.54	3.12	7.89	2.63	1.28	0.28	0.17
28	0.16	0.47	1.9	2.39	3.4	4.28	1.86	4.35	2.64	0.69	0.22	0.14
29	0.24		1.78	3.02	5.03	3.17	2.62	4	2.14	0.62	0.26	0.31
30	0.33		2.7	3.41	5.14	2.26	4.17	4.42	2.9	0.5	0.26	0.26
31	0.24		3.14		5.17		2.09	4.65		0.49		0.05
Average	**0.27**	**0.79**	**1.72**	**3.46**	**4.22**	**4.64**	**4.47**	**4.68**	**3.34**	**1.53**	**0.49**	**0.31**

Annex-II

Table -1: Crop coefficient (Kc values), critical depletion and yield response factors for Tomato.

Kc and Yield Factors	**Scientific name**	**Growing stages (day)**				**Additional factor**
		Initial season	Mid-season	Late-season	Development	NA
Kc values	UNO Rosso F1	0.6	1.15	0.8	NA	
Critical depl. frac.	UNO Rosso F1	0.3	0.4	0.5		
Yield response F.	UNO Rosso F1	0.5	1.1	0.8	0.6	1.05

Source:*Departments of Horticulture and Crop production, Szent Istvan University and FAO (1998).*

Table-2: Soil properties

Soil layers (cm)	**Sand** (%)	**Silt** (%)	**Clay** (%)	**Field capacity (v %)**	**Wilting point (v %)**	**Bulk density (g cm–3)**
0–32	82.3	8.4	9.3	16.8	7.3	1.57
32–75	78.1	8.6	13.2	17.5	7.7	1.64
75–138	77.7	6.8	15.5	18.4	8.2	1.73
138–150	86.1	5	8.9	12.9	5.8	1.54

Source:*Department of Horticulture, Szent Istvan University.*

Table-3: Soil and specific characters related to water

Soil Characteristics	**Calculated Values**
Total available soil moisture (FC-WP):	**98 mm/meter**
Maximum rain infiltration rate	90 mm/day
Maximum rooting depth	200 centimeters
Initial soil moisture depletion (as% TAM)	0%
Initial available soil moisture	98 mm/meter

Source:*Department of Soil sciences and Department of Horticulture, Szent Istvan University.*