

Estimation Of Water Requirement Of Lycopersicon Esculentum Mill

Manaturikumwe Emmanuel¹, Rukangantambara Hamoud², Gasana Gasabato Quénan³, Niyonkuru Rose⁴,
Nsengiyumva Jean Nepo⁵

^{1,3,4,5}University of Rwanda, College of Agriculture, Animal Science and Veterinary Medicine, School of Agriculture Engineering, Department of Irrigation and Drainage, Nyagatare Campus, Rwanda School of agricultural engineering, College of Agriculture, Animal Science and Veterinary Medicine, University of Rwanda, Rwanda)

²University of Rwanda, College of Agriculture, Animal Science and Veterinary Medicine, School of Agriculture and Food Sciences, Busogo campus



Abstract – Crop water requirements of Roma tomato that planted on different spacing for four treatment and its replications in Nyagatare district Kinyihira village have been computed with CROPWAT 8.0 using the meteorological parameters. The water requirement was computed using evapotranspiration (ET₀), effective rainfall, Net Irrigation demand, the Gross Irrigation demand and irrigation interval for crops grown in different treatment of different spacing have been computed. Based on the rainfall data, effective rainfall and soil characteristics of the experiment site, it was shown that the total net irrigation requirement of tomato in experiment site as presented in CROPWAT 8.0 is 286.2mm and the total gross irrigation requirement is 408.8mm. The total water loss during irrigation is obtained by taking the total gross irrigation requirement minus the total net irrigation requirement and found to be 122.6mm. As per CROPWAT 8.0, Tomato water requirement in whole growing stages is 620.3mm. This total water required by tomato at experimental site was supplied to crop by rainfall as effective rainfall (211.5mm) and the remaining portion (408.8mm) was supplied to crop through irrigation. A wide spectrum of scenarios has been discussed in the paper along with the guidelines for future management of water resources.

Keywords – Crop Evapotranspiration, Crop Water Requirement, Net Irrigation, Gross Irrigation.

I. INTRODUCTION

The uneven rainfall distribution pattern and low water holding capacity of soils, soil moisture stress occurs during summer season and it is considered as one of the major limiting factors for higher productivity of tomato. Many studies conducted by various research institutions like Kerala Agricultural University, Central Plantation Crops Research Institute, Centre for Water Resources Development and Management etc. have shown that irrigation can enhance the productivity of the crops in the State (Surendran et al., 2015). Hence this need to be improved to attain an improved productivity, one of the main reasons for the low irrigation efficiency in the State is the lack of location-specific scientific information on irrigation scheduling for different crops. The studies have identified the influence of one or more parameters on irrigation water requirements. To achieve effective planning on water resources, accurate information is needed for crop water requirements, irrigation withdrawal as a function of crop, soil type and weather conditions. Studies of such climatic parameters are thus helpful in defining risk levels in arable agriculture (Surendran et al., 2015). Keeping all this in background the study was carried out with the following objective to compute the agricultural water

demand (crop water requirements) of tomato cultivar at Kinihira, Nyagatare district with the long term climatic data by using CROPWAT 8.0 model (Raes *et al.*, 2009).

Penman-Monteith method is used in the present study for determining reference crop evapotranspiration (ET₀) since it is reported to provide values that are very consistent with actual crop water use data worldwide (Allen, 2005, Cai *et al.*, 2007, Farahani *et al.*, 2007). The irrigation schedule recommendations for tomato crop should be determined by considering the soil types and agro ecological conditions. The scientific crop water requirements are required for efficient irrigation scheduling, the reference evapotranspiration (ET₀), effective rainfall (Pe), gross irrigation requirement (GIR), net irrigation requirement (NIR) and to assess the potential for crop production (Bonachela *et al.*, 2006, Savva & Frenken, 2002, Katerji *et al.*, 2013) . Hence, in this paper an attempt has been made to compute the crop water requirements of tomato crops at Kinihira village Nyagatare district using CROPWAT 8.0 (FAO 2009) and comparing the same with the available water resources in that district to assess the current status and future demand, which is essential for planning.

II. MATERIALS AND METHODS

2.1. Study location

The area is located in the granite low valley whose altitude is 1513. 5m and experiences small quantity of rains and hot temperatures. The annual average temperature varying between 25.3 °C to 27.7 °C. The monthly distribution of the rains varies from one year to another. Annual rain falls are both very weak (827 mm/year) and very unpredictable to satisfy the needs in agriculture and livestock. The soil of this area is characterized by the tightness of the humifere layer of the soil brought about by the grassy savanna and by the vertisoils that are rich in nutrients mineral elements but lacking organic substances. Kinihira village is characterized, in general, by lowly inclined hills separated by dry valleys. The area experiences the following seasons as follow:

Table1. Seasons of the study area

Climate	Duration	Local name
Short dry season	January to mid-March	Urugaryi
Long rainy season	Mid-March to Mid-June	Itumba
Long dry season	Mid June to Mid-October	Impeshyi
Short rainy season	Mid October to December	Umuhindo

Source:<https://Nyagatare.gov.rw/index.php?id=83>

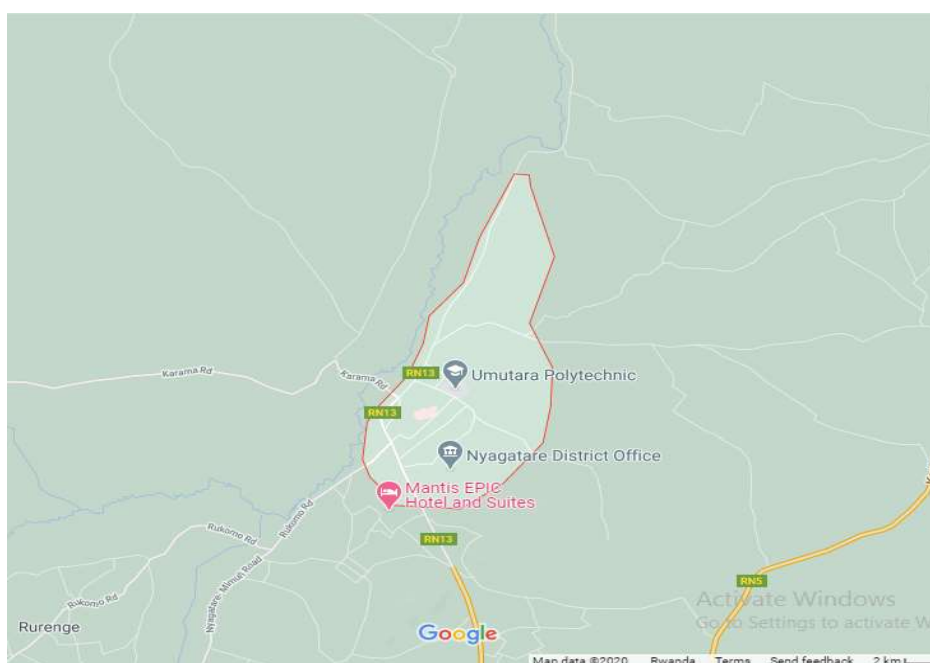


Figure 1: Map of experimental site

2.2. Crop water requirement

The data from Rwanda meteorological station (RMS) for 30 years (1989-2019) were used. The parameters used are latitude, longitude and altitude of Nyagatare station, maximum and minimum temperature ($^{\circ}\text{C}$), Relative humidity (%), wind speed (km/day) and sunshine hours. To calculate crop water requirements and irrigation requirement of Roma tomato cultivar, soil and climate data of experimental site were considered. The reference evapotranspiration (ET_0), Effective rainfall (Pe), Gross irrigation requirement (GIR), Net irrigation requirement (NIR) and Irrigation schedule of Roma tomato are calculated by FAO Penman-Monteith method, using decision support software –CROPWAT 8.0 developed by FAO.

2.3. Crop Data

The cultivated crop in study is Roma tomato that are planted in different spacing of 30cm, 40cm, 50cm and 60 cm under drip irrigation. Crop coefficient values (Kc) are taken from available published data. Kc values for initial, mid and late growth stages of tomato were used.

III. RESULTS AND DISCUSSION

3.1. Determination of Reference Evapotranspiration (ET_0)

The reference evapotranspiration (ET_0) is an important agro meteorological parameter which has been used in a number of applications. In present study daily ET_0 was determined for Nyagatare meteorological station using 30 years weather data following P-M approach. The reference crop evapotranspiration was determined using CROPWAT8.0 with referring to Penman-Monteith approach. Thirty years climate data from 1989 to 2019 was considered. Minimum temperature, Maximum temperature, relative humidity, wind speed, sunshine hours and solar radiation average data of thirty years was used to determine the average, optimum and maximum ET_0 of the experimental site.

Table2: Determination of Reference Evapotranspiration (ET_0)

Month	Min Temp	Max Temp	Wind	Sun	Rad	ET_0
	$^{\circ}\text{C}$	$^{\circ}\text{C}$	km/day	hours	$\text{MJ/m}^2/\text{day}$	mm/day
January	15.9	26.9	349	5.6	17.7	5.29
February	16.1	27.7	351	6.2	19.1	5.87
March	15.7	26.9	395	5.7	18.5	5.97
April	16.8	26.2	324	5.4	17.4	5.18
May	16.9	25.9	340	5.8	16.9	5.07
June	15.9	26.4	426	7.5	18.6	5.45
July	15.4	27.9	372	7.8	19.3	4.99
August	16.6	28	271	6.5	18.5	4.56
September	16.6	28.7	197	6.7	19.7	4.56
October	15.9	27.2	303	5.6	18.1	5.26
November	15.7	27.1	352	5.5	17.6	5.48
December	15.9	27.4	361	5.6	17.4	5.31
Average	16.1	27.2	337	6.2	18.2	5.25

The optimum ET_0 was found in August and September and found to be 4.56mm/day. The maximum ET_0 was found in March and found to be 5.97mm/day. The average ET_0 was calculated automatically by CROPWAT 8.0 software and found to be 5.25mm/day. The growing of tomato by considering meteorological parameters within the study area show that the optimum ET_0 of tomato crops is 4.5mm/day mean a while, in general the ET_0 was lowest during the peak of the rainy season to highest during the peak of the dry season for the respective. As discussed in the research conducted by Surendran et al. (2015) AEU, the effect of higher reference evapotranspiration of the crop is to act adversely against the effect water stored in zone of the tomato.

3.2. Determination of effective rainfall

Aside from soil, air and daylight, crops need water to develop. How much water the different yields need has been clarified. This water can be provided to the harvests by precipitation (likewise called precipitation), by water system or by a blend of precipitation and water system. In the event that the precipitation is adequate to cover the water needs of the harvests, water system isn't needed. In the event that there is no precipitation, all the water that the yields require must be provided by water system.

Table3: Determination of effective rainfall

	Rain (mm)	Eff rain (mm)
January	77.9	68.2
February	92.6	78.9
March	115.4	94.1
April	157.3	117.7
May	88.8	76.2
June	18.9	18.3
July	11.9	11.7
August	31.9	30.3
September	69.9	62.1
October	106.2	88.2
November	112.8	92.4
December	78.3	68.5
Total	961.9	806.5

Previously, the Reference evapotranspiration was worked out and it was found to be 5.25mm/day for Roma tomato cultivar. The total of rain fall (Total Water requirement) and effective rain fall (Crop Water Requirement) was found to be 961.9 mm and 806.5 mm for the period of twelve months. It was also found that the maximum total rainfall and effective rainfall of 157.3 mm and 117.7 mm was found in the month of April while and the minimum values were recorded in July and June with the corresponding values of 11.9 mm and 11.7 mm (in July); 18.9 mm and 18.3 mm (in June) respectively. It shows that July is the dries month, which needs more irrigation and the high rainfall to optimize the Roma tomato yield. In addition, the distinction view of the average monthly rainfall totals over the 30 year period reveals that rainfall is generally highest in the month of March, April, October and November (Refer **Table 3**). Most of the seasonal rainfall change occurs between June and September. This situation has the potential of causing water scarcity on the fields and it requires more irrigation intensities to compensate the plant water deficit. The rainfall distribution in the month of June is very erratic and could pose dangers of dry spells. To meet the crop water demand, the farmers should rely on weather forecast. These research finding are coherent with the study conducted by Ndamani and Watanabe (2015), (Ravindran, 2001) who found similar results that when physically based seasonal forecasts are not available, crop management strategies and planning should be based on statistical assessment of historical rainfall records.

3.3. Determination of Crop water requirement of Roma tomato in experimental site

The total water requirements for different crops in various agro-ecological should be different. Based on FAO Irrigation and Drainage Paper 56(FAO 1998). The FAO CROPWAT program (FAO, 2009) incorporates procedures for reference crop evapotranspiration and crop water requirements and allow the simulation of crop water use under various climate, crop and soil conditions. So, here the following data show the crop water requirement of Roma tomato cultivar in experimental site within whole growing period of 4 months and 4 days from 19 February 2020 to 23 June 2020 was calculated using CROPWAT 8.0 and found to be 620.3 mm.

Table 4: Crop water requirement of Roma tomato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Feb	2	Init	0.45	2.64	5.3	5.2	5.3
Feb	3	Init	0.45	2.66	21.3	27.9	0

Mar	1	Init	0.45	2.67	26.7	29.4	0
Mar	2	Deve	0.56	3.36	33.6	31	2.6
Mar	3	Deve	0.78	4.44	48.8	33.8	15.1
Apr	1	Deve	0.99	5.41	54.1	38.6	15.4
Apr	2	Mid	1.15	5.99	59.9	42.3	17.6
Apr	3	Mid	1.17	6.01	60.1	36.7	23.4
May	1	Mid	1.17	5.96	59.6	30.5	29.1
May	2	Mid	1.17	5.91	59.1	26.1	33
May	3	Late	1.16	6.05	66.5	19.5	47
Jun	1	Late	1.09	5.77	57.7	10.9	46.8
Jun	2	Late	0.98	5.32	53.2	3.7	49.5
Jun	3	Late	0.91	4.79	14.4	1.1	12.5
					620.3	336.8	297.3

The amount of water was required in February, April, May and June as per planting and harvesting date .February has two decades with the crop water requirement of 26.6mm,March has three decades with the crop water requirement of 109.1mm, April was having three decades with the crop water requirement of 174.1mm, the month of May was having three decades with the crop water requirement of 185.2mm and the latest month which is June was having two decades and 3 days and was having the crop water requirement of 125.3mm. As shown by the obtained output data above, it indicated that the huge amount of water required was obtained mid -season stage starting from the second decade of April to the second decade of May and the latest stage which was starting from last decade of May up to 23 day of June with 238.7mm and 191.8 mm of water required in mid -season and latest stage of tomato growth stage respectively. While the least amount of water required by tomato in experimental site is obtained in initial stage from the first day of February to the first decade of March and in crop development stage from the second decade of march to the first decade of April with 53.3 mm and 136.5mm of water required by tomato in its initial stage and development stage respectively. This is similar to the FAO (2009) report, in that crops grown in the dry season needs more water than those grown during the rainy season hence it is essential to plan a scientific water requirement, so that the high productivity can be achieved with optimum quantity of water.

3.4. Net irrigation requirement (NIR), Gross irrigation requirement (GIR) and Irrigation schedule for tomato

Net Irrigation Requirement (NIR) of crops mainly depends on reference crop evapotranspiration (ET_o) and hence, accurate estimate of ET_o is a key component in hydrological studies. ET_o depends on several climatological factors, such as temperature, humidity, wind speed, radiation, type and stage of growth of the crop and so on (Khandelwal & Dhiman, 2017). Gross irrigation requirement (GIR) is the total amount of water applied through irrigation is termed as 'gross irrigation requirement'. In other words, it is the net irrigation requirement plus losses in water application and other losses. The gross irrigation requirement can be determined for a field, for a farm, for an outlet command area or for an irrigation project, depending on the need, by considering the appropriate losses at various stages of growth of the crop. Irrigation scheduling is the decision of when and how much water to apply to a field, Its purpose is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level, Irrigation scheduling saves water and energy, All irrigation scheduling procedures consist of monitoring indicators that determine the need for irrigation

Table 5: Net irrigation requirement (NIR), Gross irrigation requirement (GIR) and Irrigation schedule for tomato

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	Mm	mm	Mm	mm	l/s/ha
20-Apr	61	Mid	0	1	100	52	56.3	0	0	80.4	0.15
11-May	82	Mid	0	1	100	52	56.3	0	0	80.4	0.44
26-May	97	Mid	0	1	100	54	57.8	0	0	82.6	0.64
06-Jun	108	End	0	1	100	54	58.8	0	0	84	0.88

17-Jun	119	End	1.7	1	100	53	57	0	0	81.4	0.86
23-Jun	End	End	0	1	0	22					

Based on the rainfall data, effective rainfall and soil characteristics of the experiment site, it was shown that the net irrigation requirement by Roma tomato in June was found to be 115.8mm, 114.1mm in May and 56.3mm in April. while the Gross irrigation requirement of tomato was found to be 80.4mm, 163mm and 165.4mm in April, May and June respectively. The water losses during irrigation was calculated and found to be 24.1mm, 48.9mm and 49.6mm in April, and June respectively. The total net irrigation requirement of tomato in experiment site as presented in CROPWAT 8.0 is 286.2mm and the total gross irrigation requirement is 408.8mm. The total water loss during irrigation is obtained by taking the total gross irrigation requirement minus the total net irrigation requirement and found to be 408.8mm-286.2mm=122.6mm. As per CROPWAT 8.0, Tomato water requirement in whole growing stages is 620.3mm. This total water required by tomato at experimental site was supplied to crop by rainfall as effective rainfall (211.5mm) and the remaining portion (408.8mm) was supplied to crop through irrigation. These shows that crop water requirement of tomato for experimental site should be the same and hence it shows the significance of requirement of scientific planning for irrigation in Nyagatare district, Barija cell.

IV. CONCLUSION AND RECOMMENDATION

The crop water requirement of Roma tomato cultivar for experimental site were determined by difference factors including meteorological data of 30 years from (1989 up to 2019) were used for getting the optimum data that lead to obtain the parameters related with all input, gathering Crop evapotranspiration (ET_o) by considering meteorological parameters within the study area 4.5mm/day as the optimum (ET_o) of tomato crops, The total effective rainfall for experimental site were 806.5mm calculated using CROPWAT 8.0 and by following USDA S.C approach as per USDA S.C 806.5mm is the downpour water permeates beneath the root zone of the plants to be utilized by Roma tomato crop in experimental site the detailed effective rainfall per months are shown above in Tab2. The water requirement indicated that the huge amount of water required was obtained mid-season stage starting from the second decade of April to the second decade of May and the latest stage which was starting from last decade of May up to 23 day of June with 238.7mm and 191.8 mm of water required in mid-season and latest stage of tomato growth stage respectively. While the least amount of water required by Roma tomato in experimental site is obtained in initial stage from the first day of February to the first decade of March and in crop development stage from the second decade of March to the first decade of April with 53.3 mm and 136.5mm of water required by Roma tomato in its initial stage and development stage respectively. The details output data are above in Tab3, Net irrigation requirement (NIR), Gross irrigation requirement (GIR) and Irrigation schedule for Roma tomato are other parameters that were discussed in Tab4 using calculations from rainfall data, effective rainfall and soil characteristics of the experiment site. where effective rainfall (211.5mm) supplied by rain fall and the remaining portion of (408.8mm) was supplied to crop through irrigation hence total water required of Roma tomato for experimental site were 620.3 mm. Nevertheless, our analysis showed a clear relationship between rainfall variability and crop production in our study area and also because production practices have not changed much over the period of study. To resolve rainfall challenge and sustain crop production in the area, piloting irrigation for selected crops via a new cultivars, as some farmers are already doing, is highly recommended.

ACKNOWLEDGMENT

The author would like to thank the Government of Rwanda through the Ministry of Education and Higher Education Council (HEC) for the scholarship granted to the researcher. My special acknowledgement go to Dr Hamoudou Rukangantambara who led this research. Last but not the least, my thanks also go to the field and Lab technicians who helped us to daily record data and their laboratory analysis as well as the stakeholders who contributed financially to complete this study on due time.

CONFLICTS OF INTEREST

The author of this article declare that there is no conflicts of interest regarding the publication of this paper.

REFERENCE

- [1] Allen, R., 2005: Evapotranspiration: the FAO-56 dual crop coefficient method and accuracy of prediction for project-wide evapotranspiration. *Monografías INIA. Agrícola (España)*.

- [2] Bonachela, S., A. M. González and M. D. Fernández, 2006: Irrigation scheduling of plastic greenhouse vegetable crops based on historical weather data. *Irrigation Science*, **25**, 53.
- [3] Cai, J., Y. Liu, T. Lei and L. S. Pereira, 2007: Estimating reference evapotranspiration with the FAO Penman–Monteith equation using daily weather forecast messages. *Agricultural and Forest Meteorology*, **145**, 22-35.
- [4] Farahani, H. J., T. A. Howell, W. J. Shuttleworth and W. C. Bausch, 2007: Evapotranspiration: progress in measurement and modeling in agriculture. *Transactions of the ASABE*, **50**, 1627-1638.
- [5] Katerji, N., P. Campi and M. Mastrorilli, 2013: Productivity, evapotranspiration, and water use efficiency of corn and tomato crops simulated by AquaCrop under contrasting water stress conditions in the Mediterranean region. *Agricultural Water Management*, **130**, 14-26.
- [6] Khandelwal, S. S. and S. D. Dhiman, 2017: Estimation of Net Irrigation Requirements of Crops in the Deterministic and Stochastic Regimes for Limbasi Canal Command Area. *Kalpa Publications in Civil Engineering*, **1**, 265-272.
- [7] Ndamani, F. and T. Watanabe, 2015: Influences of rainfall on crop production and suggestions for adaptation. *International journal of agricultural sciences*, **5**, 367-374.
- [8] Raes, D., P. Steduto, T. C. Hsiao and E. Fereres, 2009: AquaCrop—the FAO crop model to simulate yield response to water: II. Main algorithms and software description. *Agronomy Journal*, **101**, 438-447.
- [9] Ravindran, C., 2001: Use of Rainfall Analysis in the Planning and Management of Rainfed Cotton.
- [10] Savva, A. P. and K. Frenken, 2002: *Crop water requirements and irrigation scheduling*. FAO Sub-Regional Office for East and Southern Africa Harare.
- [11] Surendran, U., C. Sushanth, G. Mammen and E. Joseph, 2015: Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad district of humid tropical Kerala, India. *Aquatic Procedia*, **4**, 1211-1219.