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(RESEARCH ARTICLE)

Crop water requirement and irrigation scheduling of dry season irrigated crops in Pawe district, lowland hot humid area of Ethiopia

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Abstract

Knowledge of irrigation water requirements and irrigation time schedules improves irrigation water management and crop productivity in the field. The CROPWAT model calculates the ETo, CWR, and IRs to develop the irrigation schedules under different administration conditions and water supply plans. The objective of this study was to determine the crop water requirement of tomato, onion and soybean crops and their irrigation scheduling under local climate condition of Pawe district. Local climate, crop type and soil data were used as input data to determine crop water requirement (CWR) and irrigation scheduling. The finding of this study was crop water requirements of tomato, onion and soyabean were 547.7, 362.8 and 337 mm respectively per season on black clay soil of Pawe district. The obtained irrigation scheduling were twelve irrigation schedules for tomatoes, elven for onion and five for soybean. The study will help to improve the management of water resources and loss of crop productivity. This study can be used as a reference for decision-making for future irrigation scheme planning and irrigation water development of Pawe district.

Keywords: CROPWT; Crop water requirement; Irrigation scheduling; Pawe district

1. Introduction

Knowledge of irrigation water requirements and irrigation schedules improves irrigation water management in the field [1]. Crop water requirement refers to the amount of water that needed to meet the water losses through evapotranspiration, while Irrigation scheduling is a water management strategy to prevent over-application of water and minimizing yield loss due to water shortage or drought stress area [2-5]. The efficiency of water use in agriculture is low with poor management and improper designs of water application systems [6, 7].The irrigation schedule which determines the timing and amount of irrigation water is governed by many complex factors, but microclimate plays the most vital role [8-10]. High water loss results in lesser yield and reduced irrigated areas that are linked to ineffective water use [1]. But the improved irrigation practices lead to more uniform water distribution, minimize water application, irrigation costs, nutrient leaching, and result in the economic viability of irrigated agriculture [3, 11]. However, in Ethiopia traditionally anyone understood that irrigating more water for the crops means getting more yield [5]. Furthermore, poor irrigation scheduling practices have been considered as the major challenge for the sustainability of irrigation schemes because of the lack of simple and practical scheduling techniques, cost, inaccessibility of soil water monitoring tools, lack of local climate data and soil–water parameters [12, 13]. Therefore, it is important to develop irrigation scheduling techniques under prevailing vital conditions to utilize scarce and expensive water efficiently and effectively for crop production. To tackle those problem Several studies were carried out in the past on the development and evaluation of irrigation scheduling techniques under a wide range of irrigation systems and management, soil crop

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and climate conditions. Software modeling with programs such as AQUACROP and CROPWAT 8.0 is a significant practice used by scientists for crop evapotranspiration, CWR, and irrigation scheduling. The Food and Agriculture Organization (FAO) created these software programs as tools to assist irrigation engineers and agronomists in performing the standard calculations for water irrigation studies, as well as in the management and design of irrigation schemes [1, 14]. For this study CROPWAT model was used to investigate the irrigation water requirements and irrigation scheduling of tomato, onion and soyabean in Pawe district lowland hot humid area of Ethiopia. Because of this model a lot of previous tests showed locally applicable and satisfactory performance in number of worldwide locations under varying climate circumstances including Ethiopia [1, 5, 12, 13, 15].

The long-term rainfall data that was obtained from Pawe research center metrological station showed from November to April was no effective rainfall which is known as dry season. During this dry season crops like, tomato, onion and soybean are mostly cultivated crops in Pawe district. However, those crop yields that was obtained during the dry season was most probably below expectation. The reason of minimization of crop yield was farmers still practice traditional irrigation system and disease is a common factor in Pawe district lowland hot humid area. For such condition, well managed and scheduled irrigation practice with respective crop stage is very necessary. The irrigator needs knowledge of the efficient use of water resources with crop management practices and irrigation scheduling techniques. So, the objective of this study was to determine tomato, onion and soybean crops water requirement and irrigation scheduling based on local climate condition.

2. Methodology

2.1 Study Area description

This study was conducted on Pawe district it is located in the lowland hot humid area of Northwest Ethiopia it lays between 36° 15 1 and 36° 301 East and 11° 231 north longitude and latitude respectively (Figure 1). The altitude ranges from 1000-1220 m.a.s.l. it is characterized by long rain season (from May to October). According to long term rainfall and climate data the mean annual rainfall is 1586 mm and amount are reliable from year to year and its average minimum and maximum temperature is 16.5 c0 and 32.66 0c respectively. However, variation ranges from 8 0cin the coolest period especially in July and August and around 40 0c in the hottest period, March and April.

Pawe district also part of Beles basin that included two main rivers namely Main and Gilgel Beles. The head water of Beles River starts from the area close to the western periphery of Lake Tana. Along its way it collects many major and minor tributaries. Gezhig, Burzhi and Chankur, Bula (keteb) and Giligile Beles are the major tributaries. All of the tributary also located on Pawe district each of them have annually flow water that farmers used irrigation for dry season crops like tomato, onion, pepper, maize, soybean and perennial crops.

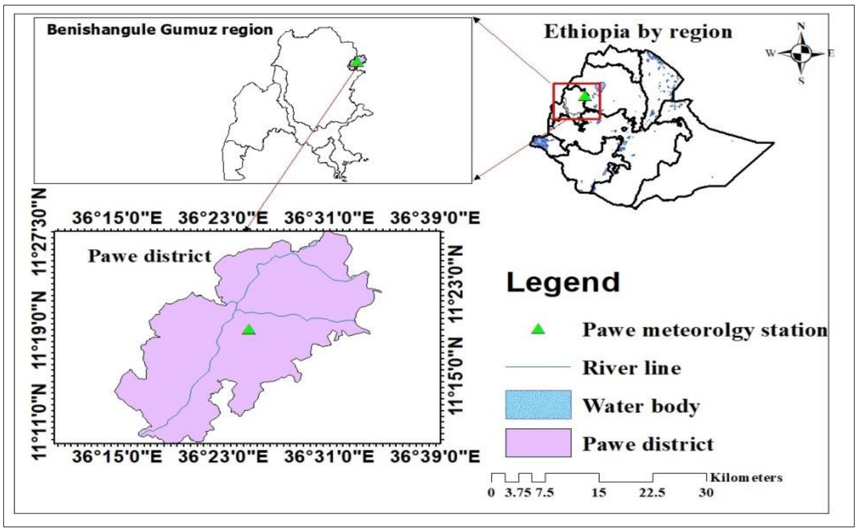

Figure 1 The study area that was Pawe district located in lowland hot humid area of Northwest Ethiopia

According to Dieci and Viezzoli [16] as cited by [17] Pawe district are broadly categorized as Vertisol soil (black clay soils), and account for 40–45% of the area; Nitisols (red or reddish-brown laterite soils) which account for 25–30%;

and intermediate soils of a blackish-brown color, which account for 25–30%. This study considers only on Vertisol (black clay soil).c

2.2 Flow chart of study

As mentioned, the following (Figure 2) was the procedures of this study that was used for CROPWAT8 step by step.

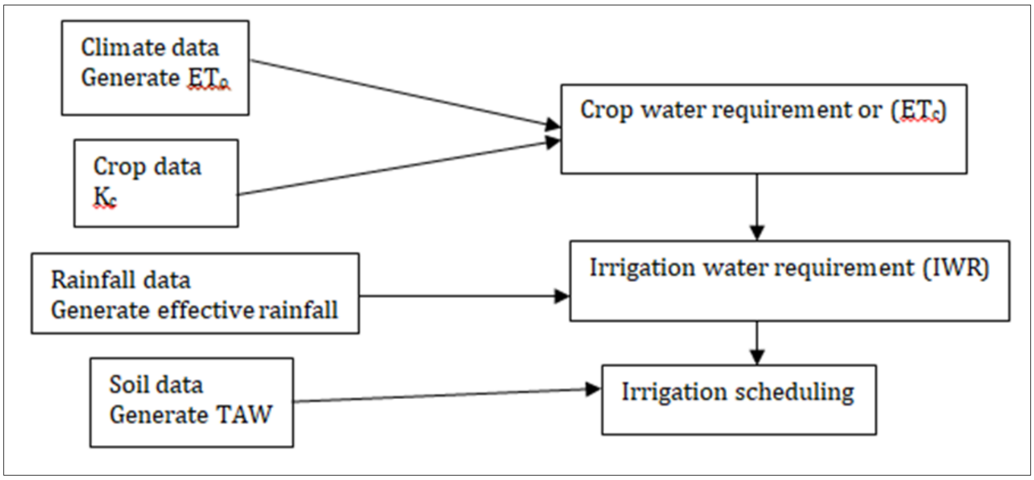

Figure 2 procedural step of the study

2.3 CROPWAT 8.0 Model Description

CROPWAT for Windows version 8.0 is a decision support system developed by the Water Resources Development and Management Service of based on a number of equations, developed by the FAO to calculate reference evapotranspiration (ET0), crop water requirement (CWR), irrigation scheduling, and irrigation water requirement (IR), using rainfall, soil, crop, and climate data [1, 18-20]. The model is important at worldwide including Ethiopia [5, 21].

2.4 Data Requirement

Four types of data are required for using the CROPWAT software, namely, rainfall data, climatic data, soil data, and crop data [20] which used to determine crop water requirement and irrigation scheduling of the selected crops .

Climatic data for thirty-four years (1987–2021) were gathered from the Ethiopian National Meteorological Agency (ENMA) at Pawe meteorology station (Table 3). These parameters are monthly maximum and minimum temperature (°C), wind speed (km/h), mean relative humidity (%), sunshine hours (hr), rainfall data (mm), and effective rainfall (mm).

The crop data for tomatoes was obtained from the FAO Manual 56 details and were added to the CROPWAT program, including rooting depth, crop coefficient, critical depletion, yield response factor, and length of plant growth stages [22]. Planting dates was decided accordingly effective rainfall of Pawe area.

The soil parameters obtained from Pawe agricultural research center (PARC) soil quality research laboratory by taking the soil sample from the experimental site were percentage of hydrogen (PH), field capacity (FC), permanent welting point (PPT) and total available moisture content. The rest specification initial moisture depletion, maximum rain infiltration rate, and maximum rooting depth were taken from FAO irrigation and drainage paper 56. The United States Department of Agriculture (USDA) soil conservation (S.C.) method was used in this study [23]. According to FAO standards, the soil class in the experimental area is a heavy clay soil type [24].

2.5 Estimations of Reference Evapotranspiration (ETo)

Transpiration (water lost from the plant surface) and evaporation (water lost from the soil surface) occur at the same time and, that is known as evapotranspiration (ET). The CROPWAT 8 model was used to estimate the reference evapotranspiration (ETo) using the Penman-Monteith method [25]. The Windows CROPWAT model uses the FAO Penman–Monteith equation for the calculation of the ETo where most of the parameters are measured from the weather data.

The Penman–Monteith equation form is as follows:

$$\text{ETo} = \frac{0.408\Delta(Rn-G)+\gamma\frac{---}{T+273}U2(es-ea)}{\Delta+\gamma(1+0.34U2} \quad (1)$$

Where:

ETo = reference evapotranspiration [mm day-1], Rn = net radiation at the crop surface [MJ m-2 day-1], G = soil heat flux density [MJ m-2 day-1], T = mean daily air temperature [°C], U2 = wind speed at 2 m height [m s-1], es = saturation vapour pressure [kPa], ea = actual vapour pressure [kPa], es-ea = saturation vapour pressure deficit [kPa], Δ = slope vapour pressure curve [kPa °C-1], γ = psychrometric constant [kPa °C-1]

2.6 Rainfall Data and estimation of effective rainfall

Similarly, climate data 32 years for monthly rainfall data was collected from the Ethiopian National Meteorological Agency (ENMA) at Pawe meteorology station. Effective rainfall (Pe) was determined using the dependable rain food and agricultural organization (FAO) method [26] and [15] as shown in (Equation 2). If there is rain fall through the total growing season, the effective rainfall was used to determine irrigation water requirement for tomato, onion and soyabean.

$$\begin{pmatrix} \text{Pe} = 0.8\text{P} - 25 & \text{P} > 75\ \text{mm/month} \\ \text{Pe} = 0.6\text{P} - 10 & \text{P} < 75\ \text{mm/month} \end{pmatrix} \quad (2)$$

Where Pe and P are effective rainfall and precipitation in mm/month, respectively

2.7 Crop Water Requirement (CWR)

Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ETo) and the effect of crop characteristics (Kc) are important. As estimated reference evapotranspiration of the study area, crop data like crop coefficient, growing season and development stage, effective root depth, critical depletion factor of each crop tomato, onion and soybean were used as input data to calculate crop water requirement using CROPWAT model.

$$(ETc = \text{Kc} \times \text{ETo}) \qquad (3)$$

where Kc is the crop coefficient. It is the ratio of the crop ETc to the ETo, and it represents an integration of the effects of four essential qualities that differentiate the crop from reference grass, and it covers albedo (reflectance) of the crop–soil surface, crop height, canopy resistance, and evaporation from the soil. As shown (Table 1) Due to the ET differences during the growth stages, the Kc value of the crop will vary over the developing period which can be divided into four distinct stages: initial, crop development, mid-season, and late season [22].

Table 1 Category of crop growth stage classifications with each criterion

Growing Stages	Descriptions
Initial stage	Germination and early growth, little of the soil (less than 10%) is covered with a crop.
Crop development	Up to when the crop achieves full ground cover
Mid-season	From full cover is achieved to maturity, when leaves start to discolour or fall off. Flowering and fruit set occur during this phase.
Late	From mid-season until harvest.

Source Smith [1] as cited by [2] CROPWAT: A computer program for irrigation planning and management

2.8 Net irrigation requirement (NIR) and gross irrigation water requirement (GIR)

The irrigation requirement (IR) is the main parameter for the planning, design, and operation of irrigation and water resources systems. According to Savva and Frenken [24] irrigation water requirement is the optimal allocation of water resources for policy and decision-makers during the operation and management of irrigation systems. Missed management of irrigation requirements may lead to inappropriate capacities storage reservoirs, low water uses efficiency, reduction of the irrigated area, and increased development costs. The CROPWAT Model can compute the water balance of the root zone as far as root zone depletion by the following equation [1].

$$\mathrm{IRn} = \mathrm{ETc} - \mathrm{Pe} \qquad (4)$$

Where, IRn = Net irrigation requirement (mm), ETc = Crop evapotranspiration (mm), Pe = Effective dependable rainfall (mm),

The gross irrigation water requirement account losses of water acquired during conveyance and application to the field. The gross irrigation requirement was expressed in terms of efficiencies. According to Allen, Pereira [15] and Brouwer, Prins [27], surface irrigation application efficiencies general vary from 40-60%. For this experiment, 60% application efficiency was used to estimate the gross irrigation water requirement.

$$\mathrm{GIR} = \frac{\mathrm{NIR}}{\mathrm{Ea}} \qquad (5)$$

Where: GIR is gross irrigation water requirement (mm),
Ea is field application efficiency (fraction),
NIR is net irrigation requirement (mm).

2.9 Irrigation Scheduling

Irrigation scheduling determines the correct measure of water to irrigate and the correct time for watering. The CROPWAT model calculates the ETo, CWR, and IRs to develop the irrigation schedules under different administration conditions and water supply plans [28]. For this study when and how much irrigate for (tomatoes, onion and soyabean) were done. The options of CROPWAT irrigation scheduling criteria without yield reductions, critical depletion, refill to filed capacity of the soil and 60% of irrigation efficiency were used.

3. Result and discussion

3.1 Soil physical characteristics

According to Dieci and Viezzoli [16] as cited by [17] Pawe district are broadly categorized as Vertisol soil (black clay soils), and it accounts more than 40% of the area. So, we were sampled from this Vertisol and analyzed using laboratory procedure on Pawe Agricultural Research Center (PARC) soil quality research laboratory. Hydrometer method with laboratory procedures were used to determine particle size of the sample [29]. The result showed that the soil texture was heavy clay soil from surface to the maximum root depth of the crop (120cm) (Table 2).

Table 2 Soil physical parameter for percentage of (sand, silt clay field capacity (FC), permanent wilting point (PWP) and soil available water (AWS)

Depths(cm)	Sand (%)	Silt (%)	Clay (%)	Soil class	FC (%)	PWP (%)	AWS (%)
15	22	10	68	Clay	45.61	27.66	17.95
30	14	18	68	Clay	36.8	25.11	11.69
60	18	14	68	Clay	39.04	26.37	12.67
90	24	12	64	Clay	39.9	26.94	12.96
120	22	12	66	Clay	44.18	27.39	16.79

4. Evapotranspiration (ETc) of Pawe

The data which were entered to CROPWAT the obtained monthly minimum and maximum reference evapotranspiration (ETo) of Pawe were 104.65 for July and 154.75 mm month-1 for April respectively. Thus, minimum and maximum reference evapotranspiration come from due to the variation of temperature, humidity, wind speed and sunshine hours

(Table 3). The long-term annual reference evapotranspiration also showed 1451.02 mm year− 1 (Table 3). Similarly studies also showed the factors that can cause the variation of reference evapotranspiration are temperature, humidity, wind speed and sunshine hours [1, 5, 24].

Table 3 Pawe Mean Monthly climatic data and reference evapotranspiration produced using 34 years (1987-2021)

Month	Min Temp	Max Temp	Humidity	Wind	Sun	ETo
	(°C)	(°C)	(%)	(km/day)	(Hours)	(mm/month)
January	11.8	34.2	38	40	9.7	110.32
February	14.5	36.2	40	54	9.3	116.24
March	17.9	37.6	45	65	8.7	147.25
April	19.4	37.4	48	76	8.8	154.75
May	19.4	34.9	58	79	8	150.4
June	18.1	30.1	67	79	6.5	122.16
July	17.8	27.8	72	59	4.6	104.64
August	17.6	27.7	71	51	4.8	105.09
September	17.3	29.1	67	47	6.1	110.04
October	16.8	30.5	63	30	7.3	113.76
November	14.1	32.4	47	28	9.3	107.66
December	12.2	33.7	40	41	9.8	108.71
Average	16.4	32.6	55	54	7.7	1451.02

4.1 Monthly rainfall and effective rainfall of Pawe

From long term mean monthly rainfall data Pawe district showed they have rainfall for each month (Table 4).However, thus rainfall to be effectively used for crop production is only May to October the rest (November to April) there is no effective rainfall so that the irrigation is required. In this area May to October is wet season or rainfall season that applies rainfall system agriculture and also November to April is dry season known as irrigation time. Out there that August is peak rainfall month while in February there is low rain fall month that is 396.3 mm and 0.6 mm respectively (Table 4). Similarly effective rainfall for crop production showed August was highly effective as compared to others.

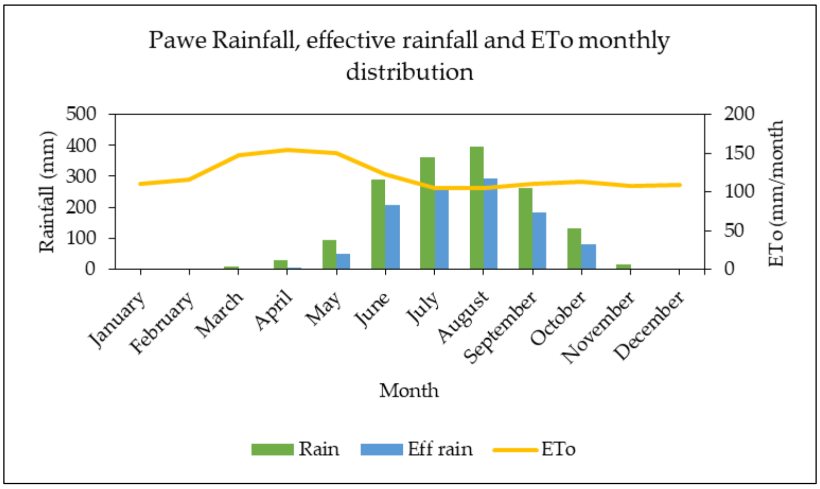

Figure 3 Mean monthly distributions of rainfall, effective rainfall and evapotranspiration of Pawe Depending on the above determined effective rainfall and reference evapotranspiration, irrigation water requirement and irrigation scheduling was decided for this dry season. The lowest effective rainfall was observed starting from November to April (Figure 3). The average monthly rainfall of the last 34 years (1987–2021) was used as input parameter to estimate

effective rainfall by using FAO dependable rainfall formula then to determine the irrigation water requirement and irrigation scheduling of tomato, Onion and Soybean crops. According to long term climate data (Figure 2) indicated that April end started effective rainfall that is a time to preparing land, May to June is sowing time, July to September is vegetative time, October to November first is harvesting time and the rest November end to April first is dry season that is irrigation time. This research also predicts for irrigated crop land preparation, vegetative time, and harvesting time were November end to December first, December end to March first, and March end to April first respectively. Depending on thus season circulation agricultural practice is to be conducted effectively for productivity

Table 4 Monthly rainfall and effective rainfall of Pawe

	Rain	**Eff rain**
	(mm)	(mm)
January	0.7	0
February	0.6	0
March	7.8	0
April	27.8	6.7
May	93.2	50.6
June	289.8	207.8
July	361.4	265.1
August	396.3	293
September	261.1	184.9
October	132.6	82.1
November	14.4	0
December	0.7	0
Total	1586.4	1090.2

Note: Eff rain and mm were effective rain fall and millimetre respectively

4.2 Crop water requirements of tomato onion and soyabean in the study area of Pawe

As stated above prediction of irrigation season, sowing or planting date was November fifteen for tomatoes, onion and soyabean which used to estimate crop water requirement. The input of crop, rainfall and reference evapotranspiration (ETo) were used as input data of CROPWAT to simulates crop water requirement (ETc), and irrigation water requirement with respective crop growth stages of tomatoes, onion and soyabean (Table 5).

Table 5 Data that used to estimate crop water requirements of different crops

Crop		**Tomatoes**	**Onion**	**Soyabean**
planting time and harvesting time		Nov. to April	Nov. to March	Nov. to March first
Root depth (m)		1	0.4	0.6
Depletion fraction (P)		0.4	0.3	0.5
Growth stage	Initial	20	30	20
	Development	30	30	20
	Mid	45	40	45
	Late	25	20	25

NB: the growth stage of tomatoes and onion is including nursery time.

Crop evapotranspiration and irrigation water requirement (CWR) for tomato (Table 6) varied from 12.9 mm dec-1 in November to 52.6 mm dec -1 in March. In the case of effective rain fall, the value of crop water requirement and irrigation requirement through all growing stage except late stage were similar The similarity in the values of ETcrop and Irrigation requirement is because the effective rain during the growing period was null except late stage. The obtained result displayed that Kc and CWR were higher during the mid and late season growth stages and lower during the initial and developmental stages. This indicates that tomato crop grown on the black clay soils in Pawe district may need more water during the last two growth stages than the first two stages. This result supports pervious study decided as tomato is sensitive to water stress fruit initiation stages [30].

Table 6 Tomatoes cultivated season growth stage, crop coefficient (KC), crop evapotranspiration (ETc), effective rainfall and irrigation requirements

Month	Decade	Stage	Kc	ETc	Etc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.6	2.15	12.9	0	12.9
Nov	3	Init	0.6	2.14	21.4	0	21.4
Dec	1	Init	0.6	2.12	21.2	0	21.2
Dec	2	Deve	0.63	2.21	22.1	0	22.1
Dec	3	Deve	0.77	2.7	29.7	0	29.7
Jan	1	Deve	0.91	3.24	32.4	0	32.4
Jan	2	Deve	1.05	3.75	37.5	0	37.5
Jan	3	Mid	1.15	4.34	47.7	0	47.7
Feb	1	Mid	1.16	4.58	45.8	0	45.8
Feb	2	Mid	1.16	4.81	48.1	0	48.1
Feb	3	Mid	1.16	5.04	40.3	0	40.3
Mar	1	Late	1.16	5.26	52.6	0	52.6
Mar	2	Late	1.08	5.13	51.3	0	51.3
Mar	3	Late	0.96	4.67	51.4	0.1	51.2
Apr	1	Late	0.84	4.23	33.8	0.3	33.5
Total					548.2	0.4	547.7

Table 7 Onion cultivated season growth stage, crop coefficient (KC), crop evapotranspiration (ETc), effective rainfall and irrigation requirements

Month	Decade	Stage	Kc	ETc	Etc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.5	1.79	10.8	0	10.8
Nov	3	Init	0.5	1.78	17.8	0	17.8
Dec	1	Init	0.5	1.77	17.7	0	17.7
Dec	2	Deve	0.51	1.8	18	0	18
Dec	3	Deve	0.58	2.06	22.6	0	22.6
Jan	1	Deve	0.66	2.33	23.3	0	23.3
Jan	2	Mid	0.71	2.52	25.2	0	25.2
Jan	3	Mid	0.71	2.66	29.3	0	29.3
Feb	1	Mid	0.71	2.8	28	0	28
Feb	2	Mid	0.71	2.95	29.5	0	29.5

Feb	3	Late	1.04	4.54	36.3	0	36.3
Mar	1	Late	1.15	5.25	52.5	0	52.5
Mar	2	Late	1.15	5.48	21.9	0	21.9
Total					332.9		332.9

Similarly for onion, lowest water requirement is 10.8 mm/dec obtained in initial stage of November and the maximum water requirement 52.5 mm/dec was obtained in late stage of March (Table 7). However, for soyabean minimum and maximum water requirement were observed initial and mid stage that were 8.6 and 47.9 mm/dec respectively (Table 8). The finding was linked with the studies reported that for onion and soyabean sensitive for water stress is the stage of bulb initiation time [31] and seed beginning time [32, 33] respectively.

The author argued that, the crop water requirement (CWR) is low at the beginning (initial stage), medium in the middle (developing stage), extremely high in the middle (mid-season stage), and very high in the end (end of season stage). The variation might be depending on crop coefficient and variations of monthly reference evapotranspiration's are common factors . The finding of this study will be used as guidance for the irrigators to use the following crop water requirement for, Tomato, Onion and Soybean crops, 547.7, 362.8 and 337 mm respectively per season on black clay soil of Pawe district.

Table 8 Soyabean cultivated season growth stage, crop coefficient (KC), crop evapotranspiration (ETc), effective rainfall and irrigation requirements

Soyabean	**Decade**	**Stage**	**Kc**	**ETc**	**Etc**	**Eff rain**	**Irr. Req.**
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	2	Init	0.4	1.44	8.6	0	8.6
Nov	3	Init	0.4	1.42	14.2	0	14.2
Dec	1	Deve	0.48	1.7	17	0	17
Dec	2	Deve	0.84	2.93	29.3	0	29.3
Dec	3	Mid	1.14	4.01	44.1	0	44.1
Jan	1	Mid	1.16	4.1	41	0	41
Jan	2	Mid	1.16	4.12	41.2	0	41.2
Jan	3	Mid	1.16	4.35	47.9	0	47.9
Feb	1	Late	1.07	4.21	42.1	0	42.1
Feb	2	Late	0.81	3.35	33.5	0	33.5
Feb	3	Late	0.59	2.56	17.9	0	17.9
Total					337	0	337

4.3 Irrigation scheduling of tomato onion and soyabean in the study area of Pawe

Irrigation scheduling was worked out using CROPWAT 8.0 windows by selecting without yield reduction and water loss; and the 100% readily available soil moisture depletion. As shown (Table 9,10, and 11) net irrigation (mm), gross irrigation (mm) and flow discharge (l/s/ha)were obtainable for tomatoes, onion and soyabean. The reviled result showed that irrigation scheduling interval (days) increased as net and gross irrigation amount increased from initial to late stage. This increment might be due to the enhancement of crop root depth and their higher amount of water requirement. The obtained irrigation scheduling were twelve irrigation schedules for tomatoes, elven for onion and five for soyabean. Studies reported that, when the growth stage increased the irrigation scheduling amount of water also increased, [34-36]. On the other hand, the first watering flow discharge for each crop was maximum then decreasing development and mid stage and also at the end of growth stage partially increasing in late stage.

Thus, displayed the initial stage that is a time of sowing or transplanting the soil was disturbed or less compaction in the case of that it has high infiltration rate then it guides flow of water also maximum. The flow discharge for each scheduling of crops directed that balancing between maximum infiltration rate and flow of amount of water. However, when the flow discharge of water is less than infiltration rate, it consumes time for watering and the flow discharge also more than infiltration rate it crates runoff. Similar studies reported that watering flow rate for agricultural filed is equivalent to infiltration rate [37-39]. The author argued that around Pawe district on black clay soil cultivations of tomatoes, onion and soyabean can be used irrigation scheduling with respective depth and flow rate of each watering time.

Table 9 Tomatoes irrigation scheduling, net irrigation requirement, gross irrigation requirement and flow speed of irrigated water

Date	**Day**	**Stage**	**Rain**	**Ks**	**ETa**	**Depl**	**Net Irr**	**Deficit**	**Loss**	**Gr. Irr**	**Flow**
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Nov	1	Init	0	0.71	71	54	22.4	0	0	37.3	4.32
20-Nov	6	Init	0	1	100	30	15.1	0	0	25.2	0.58
27-Nov	13	Init	0	1	100	34	21	0	0	34.9	0.58
5-Dec	21	Init	0	1	100	31	23.6	0	0	39.3	0.57
15-Dec	31	Dev	0	1	100	32	29.9	0	0	49.9	0.58
27-Dec	43	Dev	0	1	100	35	40.3	0	0	67.2	0.65
9-Jan	56	Dev	0	1	100	38	51	0	0	85	0.76
23-Jan	70	Dev	0.1	1	100	40	64.7	0	0	107.8	0.89
7-Feb	85	Mid	0	1	100	42	66.5	0	0	110.9	0.86
21-Feb	99	Mid	0	1	100	42	66.8	0	0	111.4	0.92
6-Mar	112	Mid	0	1	100	41	65.5	0	0	109.2	0.97
20-Mar	126	End	0	1	100	44	70.3	0	0	117.2	0.97

Table 10 Onion irrigation scheduling, net irrigation requirement, gross irrigation requirement and flow speed of irrigated water

Date	**Day**	**Stage**	**Rain**	**Ks**	**ETa**	**Depl**	**Net Irr**	**Deficit**	**Loss**	**Gr. Irr**	**Flow**
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Nov	1	Init	0	1	100	34	14.1	0	0	20.1	2.33
22-Nov	8	Init	0	1	100	31	14.5	0	0	20.8	0.34
1-Dec	17	Init	0	1	100	33	18.5	0	0	26.5	0.34
11-Dec	27	Init	0	1	100	30	19.8	0	0	28.3	0.33
24-Dec	40	Dev	0	1	100	36	28.1	0	0	40.2	0.36
10-Jan	57	Dev	0	1	100	45	42.2	0	0	60.3	0.41
27-Jan	74	Mid	0.1	1	100	46	43.9	0	0	62.8	0.43
12-Feb	90	Mid	0	1	100	46	44.5	0	0	63.6	0.46
25-Feb	103	End	0	1	100	48	45.9	0	0	65.6	0.58
7-Mar	113	End	0.7	1	100	51	48.6	0	0	69.5	0.8
14-Mar	End	End	0	1	0	32					

Table 11 Soyabean irrigation scheduling, net irrigation requirement, gross irrigation requirement and flow speed of irrigated water

Date	Day	Stage	Rain	Ks	ETa	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Nov	1	Init	0	1	100	53	26.9	0	0	44.8	5.18
3-Dec	19	Init	0.4	1	100	51	51.9	0	0	86.5	0.56
27-Dec	43	Mid	0	1	100	61	97.6	0	0	162.6	0.78
20-Jan	67	Mid	0	1	100	61	97.9	0	0	163.1	0.79
27-Feb	End	End	0	1	0	86					

5. Conclusion

This study showed that the predictions of rainfall and irrigation agricultural season by using CROPWAT model. In addition to that for irrigation season estimations of crop water requirement, irrigation water requirement and irrigation scheduling of tomatoes, onion and soyabean around Pawe districts on black clay soil.

The result indicated that April end started effective rainfall that is a time to preparing land, May to June is sowing time, July to September is vegetative time, October to November first is harvesting time and the rest November end to April first is dry season that is irrigation time. For that dry season or irrigation season this study showed that crops water requirement (CWR) was low at the beginning (initial stage), medium in the developing stage, extremely high in the middle (mid-season stage), and very high in the end (end of season stage). The finding of this study was used as indicators for irrigators they will be used crop water requirements of tomato, onion and soyabean were 547.7, 362.8 and 337 mm respectively per season on black clay soil of Pawe district. The irrigation scheduling also showed that increased interval (days) with net and gross irrigation amount from initial to late stage. The obtained irrigation scheduling were twelve irrigation schedules for tomatoes, elven for onion and five for soyabean.

We conclude that CROPWAT is generates water depth to determine the crop water requirement of field crops. The study will help to improve the management of water resources and loss of crop productivity. CROPWAT tool can help to assess crop water requirement and irrigation scheduling of field crops in areas where water resource is limited. This study may be a reference for decision-making for future planning.

Compliance with ethical standards

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Disclosure of conflict of interest

All Authors declare that there is no conflict of interest.

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