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IRRIGATION SCHEDULE FOR TOMATO CROP IN BUSA IRRIGATION SCHEME IN THE UPPER WEST REGION USING CROPWAT 8.0 MODEL

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ABSTRACT

The inadequate capacity of irrigation managers to plan and to execute irrigation schedule in community-based managed small-scale irrigation schemes in the Upper West region such as the Busa irrigation scheme is one major constraint of ensuring water use efficiency and optimum crop yield. Irrigation schemes in the region are poorly managed. In general, properly managed irrigation scheme is preferred than properly designed schemes that is poorly managed. Irrigation schedule provides information on how much water to irrigate (quantity) and when to irrigate (frequency), based on the crop type, climate, the soil, the command area to be irrigated, the availability of the water supply system, the flexible irrigation timing and the irrigation application method. Irrigation schedule using the computation method is a complex process without the use of computer model. The FAO CropWat 8.0 software, a computer model was therefore used to plan irrigation schedule for tomato crop at Busa irrigation scheme. The information provide in this paper will help irrigation engineers, technicians, students, extension officers, water user's association (WUA) members and other stakeholders to be able to plan irrigation schedule to ensure water use efficiency and optimum crop yield.

I. INTRODUCTION

In irrigated agriculture, the crop water requirements are met by applying water using any prescribed irrigation application methods such as surface irrigation method (furrow, basin, border and flooding), drip (trickle), sprinkler, traditional methods (watering-cans, buckets, gouges, and calabash). In Busa irrigation scheme the traditional irrigation methods are practiced (the use of watering-cans or buckets to irrigate beds). This method is labour intensive and time consuming. The water use efficiency of this system can be very low without proper irrigation management due to its labour intensive and time consuming nature. Therefore the planning of proper irrigation schedule is important to ensure that the crops have adequate soil moisture for optimum growth, development and yield, while also ensuring that the farmers have adequate time for other farm operations and personal activities.

The Extension Officers and farmers in community-based small-scale irrigation schemes in the region have inadequate skills to plan irrigation schedule and the result is inefficient water use and hence poor yields. They are unable to determine the amount of water their crops require per irrigation and irrigation is done with the basic knowledge that crops need water for it growth and development but unable to determine the right amount to apply. Some by experience irrigate when the soil top is dried and stop irrigating when the soil top is wet or a ball of soil can be formed with the hand after irrigation.

Mostly constant irrigation is done where for example if a bucket or watering-can is used, the same number of it is applied throughout the crop growth period depending on the water availability. While experience is important in determining the amount of water to be applied, estimation by the computation method is more desirable for proper planning of crop irrigation schedule.

To be able to plan effective irrigation schedule, the following steps are required: determination of reference crop evapotranspiration ( ) using climate data; determination of the specific crop evapotranspiration ( ) also known as the crop water requirements (CWR) using the and the crop coefficient ( ); determining the total available water (TAW) of the soil and the readily available water (RAW) using the allowable depletion factor ( ) of the crop; determining the scheduling criteria that is the irrigation timing, irrigation application depth and irrigation efficiency. Also the capacity of the canals and the laterals are important in determining the volume that can be discharge during the operational time per irrigation. The discharge of the canals and laterals and the operational time determines the command area that be irrigated per irrigation.

In Busa irrigation farmers mostly depends more on shallow dug-out wells than the canals and laterals. The canals and laterals are left in a deplorable state; full of growth grasses, silt and debris, broken and linkages. Conveyance and distribution water efficiency is greatly compromised. The canals and laterals are only used by farmers to feed the wells when there run dry or when the depth goes deeper. Farmers therefore use watering-cans and buckets to irrigate the raised and sunken beds which are mostly constructed. Here the discharge and operational time does not influence the irrigation scheduling than the availability of source of water which is also not a challenged for most farmers. The challenged is for each beds how many watering-cans or buckets are required and when is the next irrigation and this is based on the plan irrigation schedule.

This paper therefore evaluates irrigation practices in the Busa irrigation scheme and plan irrigation schedule for tomato crop. The information provided in this paper will help understand and plan irrigation schedule for small-scale irrigation schemes.

II. MATERIALS AND METHODS

2.1. CONCEPT OF CROP IRRIGATION SCHEDULE

Crops need water to live, grow, develop and reproduce. The term crop water needs (CWN) or crop water requirements (CWR) which is used interchangeable to mean the same thing, is therefore used to quantify the amount of water that the crop requires for optimum growth, development and yield production. The CWR is simply express as the of depth of water (mm) required per day of a given crop as influence by its growth stages, climatic conditions and crop management practices. The unit of the CWR is therefore in mm/day. The amount of water the crop needs is supplied either through or a combination of the following: rainfall, flooding, groundwater, irrigation and other atmospheric waters such as dew, mist and frost. All, except irrigation are natural means of supplying water to crops. Irrigation is therefore simply defined as the artificial application of water to crops to supplement the natural water supply or to fully meet the CWR.

To quantify the amount of water to be applied by irrigation, the term irrigation water requirement (IWR) is often used. Irrigation water requirement (IWR) of a crop is the total amount of water that must be supplied by irrigation to a disease-free crop, growing in a large field with adequate soil water and fertility, and achieving full irrigation potential under the given growing environment [1]. The IWR is also express in mm/day as the depth of water to be supplied through irrigation to the crop in a day.

The CWR and the IWR are greatly influenced by the climate. The climate is the driving force that influences the rate at which water available to the crop is lost to the atmosphere through the combined process of transpiration and evaporation known as evapotranspiration also often term as the reference crop evapotranspiration (ETo). Hence the CWR is directly proportional to the

ETo. The proportionality constant is termed the crop coefficient (Kc) which converts the ETo to a specific crop evapotranspiration (ETc). The crop evapotranspiration (ETc) is the same as the CWR since research indicates that 99% of water taken by a crop is to meet atmospheric demand the evapotranspiration, which is climate driven. The ETc will therefore be used in place of the CWR onwards.

The Food and Agricultural Organization (FAO) defines the reference crop evapotranspiration (ETo) as the rate of evapotranspiration from a hypothetic crop with an assumed crop height of 12 cm, a fixed canopy resistance of 70 sm-1 and albedo of 0.23, closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, completely shading the ground and not short of water [2, 3]. The ETo which is express in mm/day is simply the rate at which water in depth [mm] available to the reference crop is lost as water vapour to the atmosphere in a day through the combine process of transpiration and evaporation.

From the above explanations, irrigation therefore should be a daily activity. But it may be exhausting and expensive depending on the location of the irrigator from the irrigable field to irrigate on daily bases. It is possible to irrigate based on rotational intervals or cycles and this allows the irrigator time for other operations and also saves labour and travelling cost. The planning of irrigation based on rotational intervals or cycles brings us to the concept of crop irrigation schedule which is the interest of this paper.

Irrigation schedule can best be explained than defined. Many scholars defined irrigation schedule as a schedule that shows when to irrigate (frequency) and how to irrigate (quantity). When to irrigate (frequency) is influence by crop water requirements, root zone soil water holding capacity of the type of soil, water availability from the water source and convenience of the irrigator. How much to irrigate (quantity) is influence by crop type, it growth stages and the irrigation water requirements (IWR). The IWR as explained above is influence by ETc and ETo. The concept of irrigation schedule is well understood by irrigation engineers, technicians, students and stakeholders into irrigation but its' proper planning in reality is considered complex more so in small-scale irrigation schemes which are challenged with inadequate structures and data. Irrigation can be done on daily bases without any complication, but in irrigation schedule, the irrigation application is based on irrigation operational intervals or cycles where possible and is flexible. The soil water storage capacity or soil water holding capacity plays a very important role in irrigation schedule and cannot be ignored as in the previous explanations in the IWR determination. This requires determining the maximum soil water holding capacity, which is the total available water (TAW) content for non-puddling crops and also the readily available water (RAW) since most crops starts experiencing water stress before all the TAW are depleted. The crop allowable depletion factor (p) is required to determine the RAW below which the crop will begin to experience water stress as a result of water deficit. When the RAW is depleted at this point, the ETc for non-restricted moisture cannot be achieved hence the adjusted crop evapotranspiration ($ETcadj$) is less the ETc and the result is relative yield reduction.

Since the RAW is the benchmark for which the frequency or irrigation cycle can be based without causing water stress and yield reduction which is the aim of this paper, the soil water deficit (SWD) or simply determining when to irrigate using the soil-water balance model can be based on the criterion used to determined the length of the irrigation cycle. User defined irrigation depth [mm] can be used but to ensured the crop do not suffer water stress, the defined irrigation depth should be equal or less the RAW. The user can also define the fixed or variable days for when irrigation should be done which again should avoid water stress unless deficit irrigation is practiced which is outside the scope of this paper.

Apart from the water holding capacity of the soil, irrigation schedule can be influence by the availability of water especially if a stream flow or groundwater is used. Since in Busa irrigation shallow dug-out are used wells which recharge is from the dam, only the irrigable area to be cropped is influence. Here the volume of water per watering-can or bucket per bed is more important in determining the irrigation schedule since the field discharge is not often practiced in Busa irrigation scheme.

2.2. CLIMATE DATA

The climate data for computing the reference crop evapotranspiration was taken from Wa Meteorological Station located at the Wa township on latitude 10.04°N, longitude 2.30°W and at altitude 322.7m above sea level. It consists of long-term monthly averages of air temperature (maximum and minimum), relative humidity, wind speed, sunshine hours. The long-term daily rainfall data from 1961-2011 was also provided for the computation of the irrigation water requirement (IWR) and for the soil-water-balance module. The FAO soil file was used and medium soil type was selected for the computation of the irrigation water schedule. The FAO crop file was also used for the three selected crops.

2.3. FAO CROPWAT 8.0

The CropWat 8.0 for windows version was employed in this paper for the planning of irrigation schedule for Busa irrigation. The CropWat 8.0 is use for the design and management of irrigation [4]. In the design and management of an irrigation scheme, the following are required: the reference crop evapotranspiration (ETo) which the software uses the climate data to compute, the crop water requirements (CWR/ETc) which is determined using the crop factor (Kc) and the computed ETo. The rainfall data is required for the computation of the irrigation water requirement (IWR) and for the soil-water-balance model. Once the IWR is determined, the soil data which provides the water holding capacity of the type of soil is required together with the scheduling criteria for the computation of the irrigation water schedule. The computation steps are outlined in this section below.

The FAO Penman-Monteith (FAO-PM) method is employed by the CropWat 8.0 software for calculating the ETo. To compute the ETo using the FAO Penman-Monteith, the following averaged monthly climate data were required: the air temperature (maximum and minimum), mean relative humidity, wind speed, sunshine hours. The station altitude, latitude and longitude were also required. The FAO-PM equation for the hypothetical reference crop evapotranspiration is presented in (1) [3].

$$ETo_{FAO-PM} = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (1)$$

where ETo_{FAO-PM} ET_o estimated by the FAO-PM [mm/day]; R_n net radiation at the crop surface [MJ m^2/day]; G soil heat flux density [MJ m^2/day]; T mean monthly air temperature [^{o}C]; u_2 mean monthly wind speed at 2 m height [m/s]; e_s saturation vapour pressure [kPa]; e_a actual vapour pressure [kPa]; $e_s - e_a$ vapour pressure deficit [kPa]; Δ slope of the saturation vapour pressure temperature curve [kPa/^{o}C]; and γ psychrometric constant [kPa/oC].

2.4. COMPUTATION OF THE CROP WATER REQUIREMENTS

The ETc is directly proportional to the ETo which is computed using the FAO-PM and the dimensionless proportionality constant which is the crop coefficient (Kc). The Kc depends on the crop type, the growth stages of the crop (height, number and breadth of leaves, number of branches, root development) and the climate (ETo). The expression of ETc is as in (2):

$$ETc\,[mm/day] = KcETo \qquad (2)$$

The Kc values are therefore usually presented in growth stages and converted into monthly bases. The Kc values on average growth stages are presented in the FAO crop file (Table 2). The Kc of the crop development stage is computed by linear interpolation as the crop develops till it reaches the mid-season stage.

2.5. EFFECTIVE RAINFALL

The effective rainfall ($Eff\ rain$) is the amount of rainfall water available in the root zone for plant used after surface runoff, subsurface runoff, deep percolation and evapotranspiration demands are satisfied. The fixed percent method was used. A fixed percentage of 80% was adopted as research indicates that for most irrigation basins in Ghana, the effective rainfall is 80% of the total rainfall.

2.6. IRRIGATION WATER REQUIREMENT (IWR)

The IWR which is the amount of water applied by irrigation exclusive of the natural mean (effective rainfall ($Eff\ rain$), groundwater (Gw), flood and other atmospheric waters) to meet the ETc . The IWR is express in (3) below. The expression in (3) is a soil-water-balance equation in an irrigation field and where the contribution of any of the factors is negligible the equation is reduced.

$$IWR = \frac{ETc - Eff\ rain - Gw - Flood - \Delta S - Dw}{1 - LR} \qquad (3)$$

Where Dw is dew, LR is leaching factor and ΔS is change in soil moisture.

In Busa irrigation scheme, irrigation is mainly done in the dry spell period (dry season) when there is either no rainfall or low rainfall, hence no floods and also leaching is done naturally during the rainy season by the rains. The contribution of atmospheric waters (dew-DW) is also negligible and the groundwater (Gw) contribution and ΔS diminishes with time. The IWR is therefore reduced to the simply expression in (4) which used in CropWat model.

$$IWR\,(mm/day) = ETc - Eff\ rain \qquad (4)$$

The IWR [mm/day] is therefore the depth of water in mm that must be applied exclusively by irrigation on daily bases when need be to meet the ETc [mm/day]. Note that in the dry season most of the days are without rainfall and hence the IWR is equal to ETc in those days. And in high down pours drainage is rather required.

2.7. CROP IRRIGATION SCHEDULE

Apart from the ETo, the ETc and IWR which are required for irrigation schedule, the soil type and its moisture characteristics are required. The general soil type at the project site is loamy clay which under the FAO soil classification is under medium soil type. The soil and its moisture characteristics are presented in the Table 1.

TABLE .1.SOIL DATA

(File: C:\ProgramData\CROPWAT\data\soils\FAO\MEDIUM (Loamy Clay).SOI)

Soil name: Medium (loamy Clay)

General soil data:

Total available soil moisture (FC - WP)	290.0	mm/meter
Maximum rain infiltration rate	40	mm/day
Maximum rooting depth	900	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	290.0	mm/meter

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To determine the actual total available moisture for the crops selected, the effective rooting depths of the crops are required. These must be equal to the maximum rooting depth of the soil or less. The root zone soil moisture content is represented in the equation below.

$$TAW\ (mm) = 1000(\theta fc - \theta pwp)d \qquad (5)$$

Where θfc [mm/m] is the moisture content at field capacity, θpwp [mm/m] is the moisture content at permanent wilting point and d [m] is the effective crop rooting depth.

In planning irrigation water schedule to avoid water stress, the readily available water (RAW) is prefer since most crops starts experiencing water stress before all the TAW is depleted. The crop allowable or critical depletion factor (p) is required to determine the RAW below which the crop will begin to experience water stress as a result of water deficit. When the entire RAW is depleted beyond this point, the ETo for non-restricted moisture cannot be achieved hence the actual reference crop evapotranspiration (ETa)

is less the ETo and the result is relative yield reduction. The crop yield response factor is also presented in the crop file. The RAW is also expressed (6) below.

$$RAW\ [mm] = pTAW \tag{6}$$

The soil moisture balance module at the root zone of an irrigated field is an audit of the water inflow and outflow into the root zone. The daily determination of the soil moisture balance at the root zone is the prerequisite for irrigation schedule, which determines when to irrigate and at what irrigation depth. Expression therefore of the water content in depth as root zone depletion simplifies the determining of daily water balance as in equation (7).

$$Dr,i = Dr,i-1 + ETc_{\ adj},i - Rain - I,i + (RO,i + DP,i) \tag{7}$$

Where Dr is root zone depletion on days i and $i-1$; ETc_{adj} is the crop evapotranspiration under non-standard conditions on day i; Rain = Total rainfall over day i; I = net irrigation on day i; RO = water loss to runoff from the soil on day i; DP = water loss by deep percolation on day i.

It is assumed that RO occurs each time the rain exceeds the maximum infiltration rate. DP is estimated to occur each time the available soil moisture content in the root zone exceeds field capacity (FC). The total rainfall is used since RO and DP are losses that are included in computing the effective rainfall. The crop evapotranspiration (ETc_{adj}) under non-standard conditions is given by the expression below.

$$ETc_{adj} = Ks \times ETc \tag{8}$$

Where Ks is the crop water stress coefficient, for soil water limiting conditions, Ks<1. Where there is no soil stress, Ks =1.

The Ks value describes the effect of soil water deficit on crop evapotranspiration, which is assumed to decrease linearly in proportion to the reduction of water available in the root zone.

$$Ks = (TAW - Dr)/TAW - RAW \tag{9}$$

Since the RAW is the benchmark for which the frequency or irrigation cycle can be based without causing water stress and relative yield reduction which is the aim of this paper, the root zone depletion should not exceed the RAW. The relationship between the relative yield decline to the relative reduction in crop evapotranspiration is given in (10) [5].

$$\left(1 - Y_a / Y_m\right) = Ky\left(1 - ETc_{adj} / ETc\right) \tag{10}$$

Where $(1-Y_a/Y_m)$ is the relative yield decline and $(1-ETc_{adj}/ETc)$ is the relative reduction in crop evapotranspiration and Ky the yield response factor.

The CropWat module is therefore an appropriate module for irrigation scheduling. Its' allows for the selection of the scheduling criteria (timing and application depth) to determine when to irrigate and how much to irrigate.

In Busa irrigation scheme, since each farmers used shallow dug-out wells, irrigation is done at their own convenience, but in the mid of the dry season when the water table is low the canals and laterals are operated every three days and those that are within the canals and laterals reach direct water into their wells and use it till the next irrigation. Therefore three days irrigation timing was used which is flexible in that in the event of rains which are rare during the mid of the dry season. The application depth is therefore to field the soil moisture back to field capacity. It is assumed that the soil is at field capacity in the beginning of the farming or irrigated to field capacity at the beginning. This was the basic for which the irrigation schedule was generated after providing all the necessary data described earlier.

TABLE .2.DRY CROP DATA

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(File: C:\ProgramData\CROPWAT\data\crops\FAO\TOMATO.CRO)
 Crop Name:  Tomato              Planting date: 01/11    Harvest: 25/03

Stage              initial    develop     mid       late      total

Length (days)           30        40        45        30       145
Kc Values             0.60       -->      1.15      0.80
Rooting depth (m)     0.25       -->      1.00      1.00
Critical depletion    0.30       -->      0.40      0.50
Yield response f.     0.50      0.60      1.10      0.80      1.05
Crop height (m)                           0.60
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III. RESULTS AND DISCUSSIONS

3.1. THE MONTHLY ETO BY FAO PENMAN-MONTEITH

The results of the ETo computed using FAO Penman-Monteith method is presented in Table 3 below. The incoming solar incident radiation is computed using the recorded sunshine hours and the relationship as presented in FAO irrigation and drainage paper 56 [3]. The ETo is presented for only the duration of the cropping period. The computed ETo is then used to compute the ETc.

Table .3. MONTHLY ETO PENMAN-MONTEITH DATA

(File:C:\ProgramData\CROPWAT\data\climate\WaETo.PEM)

Country: Ghana Station: Wa Meteo

Altitude: 323 m. Latitude: 10.04 °N Longitude: 2.30 °W

M	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
Nov	21.8	35.3	53	91	9.2	21	4.77
Dec	20.1	35.1	34	91	9.1	20.1	4.61
Jan	20.2	34.9	26	117	8.8	20.2	5.07
Feb	23.1	36.9	34	103	8.6	21.3	5.27
Mar	25.4	38	45	110	7.7	21.1	5.61

3.2. THE CROP WATER REQUIREMENTS

The ETc is calculated using the computed ETo and the crop factor (Kc). The ETo as in Table 3 is presented in mm/day which is the daily monthly averages. More accurate daily values will be achieved using daily time step or decades (10 days). Though the ETo is in mm/day which is daily monthly averages, in calculating the ETc , the months are divided by CropWat 8.0 into decades. The Kc is therefore determined in decades instead of the single time-averaged which are mostly presented in growth stages (initial, crop development, mid-season and late season) which are then converted into monthly bases when computing ETc for irrigation planning on monthly bases. The Kc presented in decades makes the presentation of the ETc more accurate than the monthly. Since the Kc is dimensionless the computation of the ETc divided into decade (10 days) is in mm/day since the ETo is mm/day. The computation of monthly ETo to decades is by simple interpolation algorithm. Multiplying the daily values by ten gives the ETc in mm/decade (Table 5). Daily and decade are considered more accurate than monthly averages.

To determine the IWR (Irr. Req.) (Table 5), the effective rainfall is computed using the fixed percentage that is the effective rainfall is 80% of the total rainfall (Table 4). Although, the rainfall was presented as daily rainfall the cumulative monthly is presented in Table 4. In Table 5 by simple interpolation and extrapolation algorithm the monthly rainfall is computed into decade rainfall and the effective rainfall computed per decade this makes the values in Table 4 difference from Table 5. Since, the ETc and the effective rainfall is converted to mm/decade, the IWR (Irr. Req.) is also determined in mm/decade (4).

Table .4.MONTHLY RAIN DATA

(File: C:\ProgramData\CROPWAT\data\rain\Wa-1961-2011.CRM)

Station: Wa

Eff. rain method: Effective rain is 80 % of actual rain

	Rain mm	Eff rain mm
November	5.8	4.6
December	2	1.6
January	5	4
February	5.2	4.2
March	19.6	15.7
Total	37.6	30.1

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Table .5. CROP WATER REQUIREMENTS

ETo station: Wa Meteo Crop: Tomato

Rain station: Wa Planting date: 01/11

Month	Dec	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Init	0.6	2.81	28.1	4.6	23.5
Nov	2	Init	0.6	2.86	28.6	0	28.6
Nov	3	Init	0.6	2.83	28.3	0.2	28.2
Dec	1	Dev	0.67	3.14	31.4	0.7	30.7
Dec	2	Dev	0.81	3.72	37.2	0.3	36.9
Dec	3	Dev	0.95	4.51	49.6	0.7	49
Jan	1	Mid	1.09	5.34	53.4	1.1	52.3

Jan	2	Mid	1.13	5.76	57.6	1.4	56.2
Jan	3	Mid	1.13	5.83	64.2	1.4	62.8
Feb	1	Mid	1.13	5.91	59.1	1	58
Feb	2	Mid	1.13	5.98	59.8	0.9	59
Feb	3	Lat	1.11	5.99	47.9	2.3	45.6
Mar	1	Lat	1.01	5.55	55.5	2.7	52.8
Mar	2	Lat	0.89	4.99	49.9	3.3	46.5
Mar	3	Lat	0.8	4.5	22.5	4.4	17.6

Table .6.SCHEME SUPPLY

ETo station: Wa Meteo Cropping pattern: Tomato

Rain station: Wa

	Nov	Dec	Jan	Feb	Mar
Precipitation deficit					
1. Tomato	79.2	116.2	170.3	161.6	114.3
Net scheme irr.req.					
in mm/day	2.6	3.7	5.5	5.8	3.7
in mm/month	79.2	116.2	170.3	161.6	114.3
in l/s/h	0.31	0.43	0.64	0.67	0.43
Irrigated area (% of total area)	100	100	100	100	100
Irr.req. for actual area (l/s/h)	0.31	0.43	0.64	0.67	0.43

3.3. THE IRRIGATION SCHEDULE AND SCHEME SUPPLY

The scheme supply (Table 6) is a summary of the generated crop irrigation schedule table (Appendix A). It becomes complicated especially for small-scale irrigation schemes to follow the irrigation schedule table generated and to supply the water required per each irrigation. Monthly planning as presented in the scheme supply makes it easier. The precipitation deficit in mm/month is the summary of the soil moisture deficit in the soil which has to be supplied by irrigation on monthly bases. That is the total root zone soil moisture required by the crop which could not be supplied by precipitation (rainfall). Simply put precipitation deficit is equal to the net irrigation requirement. Dividing that value by the number of days in that month gives the net scheme irrigation water requirement in mm/day. This is the amount water in depth (mm) to be supplied by irrigation per day. Remember that the irrigation operational cycle is 3 days but the scheme supply table gives the daily net irrigation requirement. Therefore to agree with the 3 days operational cycle or rotational interval, the value has to be multiplied by three (3) to give the net irrigation requirement per each irrigation which is every 3 days. The table below represents the scheme supply per irrigation (3 days).

Table .7.NET IRRIGATION REQUIREMENTS

Month	Irrigation requirement (mm) per day	Irrigation requirement (mm) per irrigation (3 days)
Nov	2.6	7.8
Dec	3.7	11.1
Jan	5.5	16.5
Feb	5.8	17.4
Mar	3.7	11.1

The net scheme irrigation requirement in l/s/h is the continuous flow rate per hectare. That is the continuous field discharge for 24hrs per day per ha. This is the non-stop flow of the scheme. In surface and the traditional irrigation system, schemes operations are not continuous for 24hrs per day. In general irrigation should be done in the morning or evening, hot day irrigation should be avoided for these systems. The computation of the flow in l/s/h therefore is the daily discharge and not the 3 days cycles net irrigation requirement and is express below (11). The actual volume required for a particular scheme command area is therefore computed by multiplying with the actual area and the operational time the scheme operates which could be variable or fixed.

$$IN_{net}(l/s/ha) = \frac{10000 IWR \times 1A}{24 \times 3600 \times 1A} \qquad (11)$$

Where IN_{net} is the net scheme irrigation requirement, IWR is the net irrigation water requirement in mm/day and A is 1 ha command area.

Since watering-cans and buckets are used in Busa irrigation scheme as the mode of water application the expression in (11) is not relevant here and is not considered further. The determination of the volume of the container (watering-can or bucket) to be used to meet the IWR for 3 days interval for a given determined command is very important here for efficient water used. The volume is given in the expression (12) below. Since command area of sunken and raised are basically small, the unit of the area is meters square.

$$V(l) = Net\ Irr \times A \qquad (12)$$

Where, $Net\ Irr$ is net irrigation in mm and A is command area in m^2.

Table .8.VOLUME IN LITRES FOR GIVEN NET IRRIGATION AN AREA

Month	**Net Irr. (mm) (every 3 days)**	**Bed area (m^2)**			
		1	2	3	4
Nov	7.8	8	16	23	31
Dec	11.1	11	22	33	44
Jan	16.5	17	33	50	66
Feb	17.4	17	35	52	70
Mar	11.1	11	22	33	44

The Table 8 represents volume in litres that should be supplied to meet the net irrigation depth in mm for a given command area. The water application method to supply the required volume is through the use of watering-cans and buckets and the sizes varies in the market. The volume of watering-cans ranges between 10 litres to 15 litres and buckets ranging between 12 litres to 30 litres. Selecting a big size may be too tiring to handle.

In Table 8 to irrigate a 2 m^2 command area of the tomato crop using a 15 litres watering-can for example, in the whole of November the tomato is at the initial growth stage (Appendix A) and the net irrigation of 7.8 mm is required every 3 days and the volume required is 16 litres for each irrigation, therefore one watering-can (15 litres) can be used to irrigate it without causing any severe water stress. In the whole of December the tomato is in the crop development stage and the net irrigation is 11.1 mm and the volume required is 22 litres, therefore one and half watering-can of the 15 litres should be used. Part of January is in the crop development and part in the mid-season stage and the net irrigation is 16.5 mm and volume required for per each irrigation is 33 litres and therefore two watering-cans of the 15 litres and 3 litres is required. In February the tomato is still in the mid-season and just a few days in late February is in the maturity stage and the net irrigation is 17.4 mm and the volume is 35 litres and hence two watering-cans of the 15 litres and 5 litres is required during each irrigation. In the month March the tomato is in the maturity stage and hence net irrigation is reduced to 11.1 mm the same as in the month of December and should be treated the same as in the month December. The watering-cans are graduated in rings and each ring is a litre. Therefore, it's easy to apply approximately the exact litres required once Table 8 is generated. Using therefore the expression in (12) and constructing a standard bed, the approximate volume can be applied using watering-cans or buckets either daily or on rotational bases to ensure good water used efficiency and optimum yield.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1. CONCLUSIONS

The FAO CropWat 8.0 model is an appropriate tool for design, planning and management of an irrigation scheme. But experience is required in manipulating the generated irrigation schedule and the scheme supply considering other factors such as the operational time, the command area, water availability and irrigation application method.

Generating irrigation schedule for new and existing irrigation schemes will ensure that water use efficiency is improve for small-scale irrigation systems such as Busa.

The three days irrigation interval planned for tomato in Busa irrigation scheme is considered appropriate since the result of the irrigation schedule showed a 0% yield reduction. It therefore means that the soil is able to conserve enough soil moisture within three days interval evaluated throughout the growing period without water stress effects if the required amount is applied at the right time.

The result indicate that depth of water or volume of water to be applied to a given command area differ from month to month or growth stages throughout the entire growing period. Therefore using the same number of watering-cans or buckets for the same command area throughout the growing period is likely to cause over-irrigation in the initial and late-season and under-irrigation in the crop development stage to the mid-season which is usually the case.

The construction of a standard sunken and raised beds and the selections of the size or volume of the watering-cans and buckets to meet the requirement in the irrigation schedule table will ensure potential yield of tomato in Busa.

4.2. RECOMMENDATIONS

Experts should be consulted in the planning and evaluation of Irrigation systems to assist in generating irrigation schedule and also to train Extension Officers and WUA member on simple but best practice methods of managing small-scale irrigation in the region to improve crop yield.

V. REFERENCES

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[2] M. Smith, R. Allen, J.L Monteith, L.A. Pereira, A. Perrier, and A. Segeren, "Report on the Experts Consultation for the Revision of FAO Methodologies for Crop Water Requirements", 1992.

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Appendix A: Crop Irrigation Schedule

CROP IRRIGATION SCHEDULE

ETo station: Wa Meteo Crop: Tomato Planting date: 01/11

Rain station: Wa Soil: Medium (loamy Clay) Harvest date: 25/03

Yield red.: 0.0 %

Crop scheduling options

Timing: Irrigate at fixed intervals per stage

(Intervals in days: Init 3, Dev 3, Mid 3, Late 3)

Application: Refill to 100 % of field capacity

Field eff. 90 %

Table format: Irrigation schedule

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
3-Nov	3	Init	2.9	1	100	7	5.6	0	0	6.2	0.24
6-Nov	6	Init	0	1	100	9	8.4	0	0	9.4	0.36
9-Nov	9	Init	0	1	100	8	8.4	0	0	9.4	0.36
12-Nov	12	Init	0	1	100	8	8.5	0	0	9.5	0.37
15-Nov	15	Init	0	1	100	7	8.6	0	0	9.5	0.37
18-Nov	18	Init	0	1	100	7	8.6	0	0	9.5	0.37

21-Nov	21	Init	0	1	100	6	8.6	0	0	9.5	0.37
24-Nov	24	Init	0	1	100	6	8.4	0	0	9.3	0.36
27-Nov	27	Init	0.1	1	100	5	8.4	0	0	9.3	0.36
30-Nov	30	Init	0	1	100	5	8.5	0	0	9.4	0.36
3-Dec	33	Dev	0.4	1	100	5	9	0	0	10	0.38
6-Dec	36	Dev	0	1	100	5	9.4	0	0	10.5	0.4
9-Dec	39	Dev	0	1	100	5	9.4	0	0	10.5	0.4
12-Dec	42	Dev	0	1	100	5	10.6	0	0	11.8	0.45
15-Dec	45	Dev	0	1	100	5	11.2	0	0	12.4	0.48
18-Dec	48	Dev	0	1	100	5	11	0	0	12.2	0.47
21-Dec	51	Dev	0	1	100	5	12	0	0	13.3	0.51
24-Dec	54	Dev	0	1	100	5	13.1	0	0	14.6	0.56
27-Dec	57	Dev	0.4	1	100	5	13.1	0	0	14.6	0.56
30-Dec	60	Dev	0	1	100	5	13.5	0	0	15	0.58
2-Jan	63	Dev	0	1	100	6	15.2	0	0	16.9	0.65
5-Jan	66	Dev	0	1	100	6	16	0	0	17.8	0.69
8-Jan	69	Dev	0	1	100	5	15.3	0	0	17	0.66
11-Jan	72	Mid	0	1	100	6	16.4	0	0	18.3	0.7
14-Jan	75	Mid	0	1	100	6	16.4	0	0	18.2	0.7
17-Jan	78	Mid	0.9	1	100	6	16.4	0	0	18.2	0.7
20-Jan	81	Mid	0	1	100	6	17.3	0	0	19.2	0.74
23-Jan	84	Mid	0.9	1	100	6	16.6	0	0	18.5	0.71
26-Jan	87	Mid	0	1	100	6	17.5	0	0	19.4	0.75

29-Jan	90	Mid	0	1	100	6	17.5	0	0	19.4	0.75
1-Feb	93	Mid	0	1	100	6	17.6	0	0	19.5	0.75
4-Feb	96	Mid	0	1	100	6	17.1	0	0	19	0.73
7-Feb	99	Mid	0.6	1	100	6	17.1	0	0	19	0.73
10-Feb	102	Mid	0	1	100	6	17.7	0	0	19.7	0.76
13-Feb	105	Mid	0.5	1	100	6	17.4	0	0	19.3	0.75
16-Feb	108	Mid	0	1	100	6	18	0	0	19.9	0.77
19-Feb	111	Mid	0	1	100	6	18	0	0	19.9	0.77
22-Feb	114	Mid	0	1	100	6	18	0	0	20	0.77
25-Feb	117	End	0	1	100	6	18	0	0	20	0.77
28-Feb	120	End	0	1	100	6	16.5	0	0	18.4	0.71
3-Mar	123	End	1.7	1	100	5	15	0	0	16.6	0.64
6-Mar	126	End	0	1	100	6	16.6	0	0	18.5	0.71
9-Mar	129	End	0	1	100	6	16.6	0	0	18.5	0.71
12-Mar	132	End	0	1	100	5	15.5	0	0	17.2	0.67
15-Mar	135	End	0	1	100	5	15	0	0	16.6	0.64
18-Mar	138	End	0	1	100	4	12.9	0	0	14.3	0.55
21-Mar	141	End	0	1	100	5	14.5	0	0	16.1	0.62
24-Mar	144	End	0	1	100	3	9	0	0	10	0.39
25-Mar	End	End	0	1	0	0					