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DETERMINATION OF WATER REQUIREMENTS FOR ONION IN METEKEL ZONE, BENISHANGUL GUMUZ REGIONAL STATE

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ABSTRACT: *The model simulation is a simplification of the field processes. Irrigation scheduling is important for developing best management practices for irrigated areas. In metekel zone understanding how much and when to irrigate their crops is proplems of farmers. Therefore, this study was conducted to determine the crop water requirement and irrigation scheduling of onion for the study area to solve the problem. Crop data, soil physical and chemical data, collected long-term daily climatic data and irrigation water quality data, used for crop water requirement and irrigation scheduling using CropWat and AquaCrop models. Reference evapotranspiration was estimated using the FAO Penman Monteith method. The minimum ETc of onion was 401.9mm in Bullen and the maximum Crop water requirement of onion was 495.6 mm in Guba using CropWat Model. But the maximum ETc of onion was 523.7 mm in Pawe and minimum ETc was 355 mm in Wembera using AquaCrop model. The irrigation scheduling with a fixed interval time criterion of 5 days with 20 irrigation events has been determined. Among the performance indicators, NSE values of onion were 0.9,12. 0.88, 0.91, 0.86, 0.85, RMSE values of onion were 8.3, 9.2, 8.17, 8.15, 5.8, and in Pawe, Mandura, Guba, Bullen, Wembera respectively. This indicated that Aqua Crop model used to simulate irrigation scheduling and ETc of onion as CropWat in Metekel zone.*

KEYWORDS: CropWat, AquaCropCrop water requirement, Climate data.

INTRODUCTION

Crop water requirements vary in space and time [1]. The role of simulation models in understanding the processes in the soil-plant-atmosphere system has increased significantly in recent years[2]. Numerous models have been developed and used for simulation of water balance in the cropped field such as BUDGET [3] and CropWat [4].

Onions require 350-550 mm of water for optimum production but may use more than that in areas where ET is appreciably higher. National and world average yield of onion indicated as 10.5 and 13.4 tons per ha, respectively [5].

CROPWAT (currently in version 8) is a Windows computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions.

CROPWAT is an irrigation management and planning model simulating the complex relationships of on-farm parameters the climate, crop and soil. The CROPWAT facilitate the estimate of the reference evapotranspiration, crop evapotranspiration, irrigation schedule and agricultural water requirements with different cropping patterns for irrigation planning [6].

However, productivity of water use and to increasing efficiency and more accurate predictions are required for yield response under actual field conditions, AquaCrop allows more accurate modelling of actual crop growth and yield formation processes under various soil fertility, climate and water availability conditions [7].

AquaCrop is widely applicable due to the only use of the relatively small number of explicit parameters and mostly-intuitive input-variables that can be determined by simple methods. Besides, the calculation procedures are ground on the basic and often complex biophysical processes to guarantee an accurate simulation of the crop response in the plant-soil system [8 and 9].

The application of computer-based simulation models as tools for providing support for decision-making in agricultural research has increased tremendously in the last three decades [10]. Models are mathematical representations of mechanisms that govern natural phenomena that are not fully recognized, controlled, or understood. In order to study the responses of crops to soil fertility and environmental conditions, crop models are often used to complement field experiments.

Almost all farmers are poor in water resource management and lack of experience and knowledge about how much and when to irrigate efficiently for irrigation water saving-strategies in Metekel zone. This results soil erosion, in waterlogging, , accumulation of salt, and loss of irrigation water resources. Therefore, there is a need to improve the water use efficiency and one of the strategies to improve crop productivity per unit of water under full irrigation is the employment of the aid of models to fill the gaps during dry spells [11].

Statement of the Problem

Information on appropriate time for irrigation application and the precise quantity of irrigation, which is the best application method available under given conditions are the key problem faced by farmers in the study area. Under such challenging conditions, advice on quantity and time of application of irrigation is nesessary. This in turn demands determination of the crop water requirements and irrigation scheduling of onion.

Objective of the Study

The general objective of this study aims to determine crop water requirements for onion using different models to improve water productivity for sustainable agricultural production under irrigated agriculture. With the following specific objectives.

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- ✓ To compare the significance of AquaCrop and CropWat models for adoption at different situations in Metekel zone.
- ✓ To develop irrigation scheduling for onion using AquaCrop and CropWat model.

Materials and Methods

Study area Description

The study was conducted in Metekel zone. It is the largest zone of Benishangul Gumuz Regional State, North-West of Ethiopia. It covers an area of 3,387,817 hectares consisting of seven districts: Pawe, Manbuk, Bullen, Wembera, Dibate, Mandura, and Guba, Woredas. The annual rainfall of the area is 900-1580mm and the topography of the zone have varying altitudes from 600- 2800 m.a.s.l. and. About 80 % of the the study area is characterized by a sub-humid and humid tropical climate [12]. The surrounding of Metekel Zone has a wide climatic range within hot to warm moist lowlands and hot to warm -sub-humid lowlands agroecological zones. Farmers practice a mixed crop-livestock production system. Cereals (sorghum ,maizeand finger millet) and oilseeds (sesame,soybean, and groundnut) are the most important food grains mainly cultivated in the zone. [13].

The soil type of the study area is characterized by heavy clay soil with total available soil moisture level range 222-259 (mm/meter depth) and initial available soil moisture depletion level range 111-129 (mm/meter depth) varying with soil depth. The mean infiltration rate of the soil is 70 mm/day and the bulk density is varying from 1.12-1.31gm/cm3 across the depth of 1.2 meter. The annual maximum and minimum temperature of the study area is 35^{o}C and 20^{o}C respectively [14].

Acording to [15]. agricultural activities in the zone dominated by mixed crop-livestock production, which accounts 96.2% of the farmers and the rest 3.8% were involved only in livestock production.

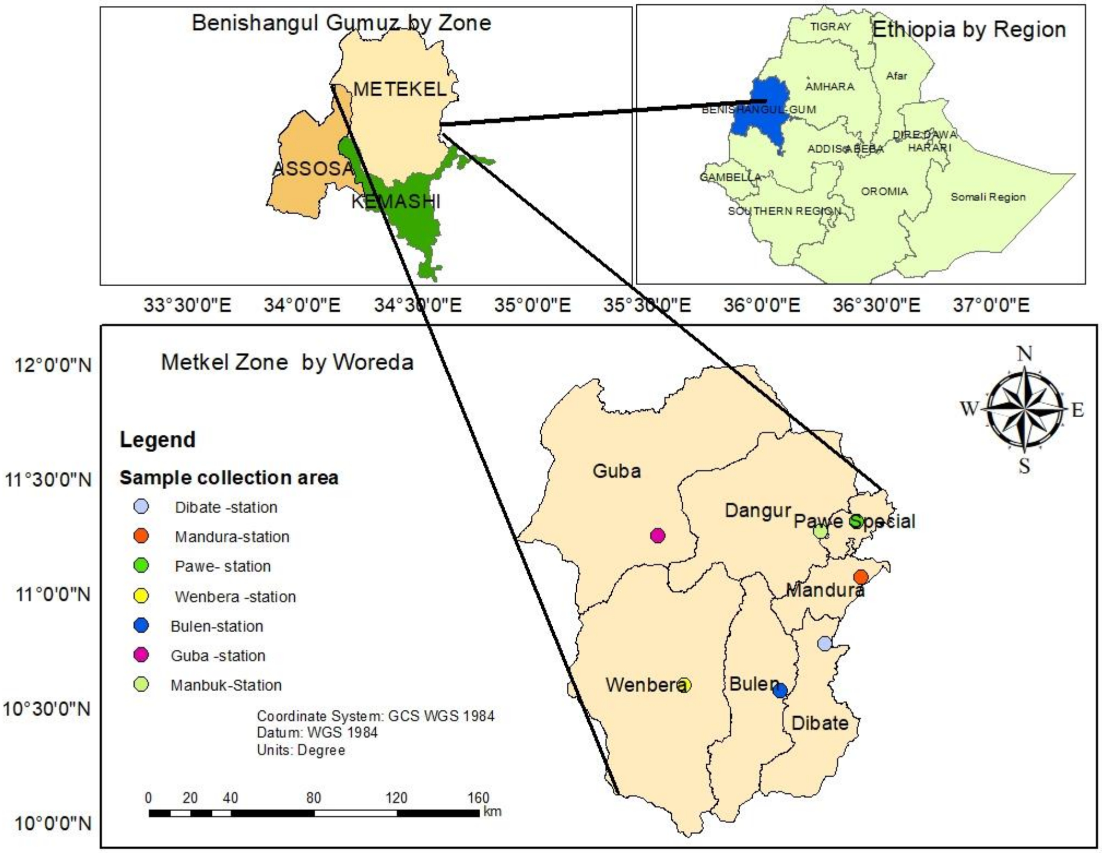

Figure 1: Location map of the study area

Data Collection and Analysis

To run models various input data were collected from observations and measurements that were necessary to effect the specific area or location.

Climatic data

Long-term monthly values of the weather variables such as minimum temperature and maximum , wind speed, relative humidity, sunshine hour, and rainfall collected from the National Metrological Agency (NMA). The stations found in the study area are Mandura, Bullen, Pawe, Wembera, and Guba. normal ratio method for the normal annual climate exceeding 10% of the normal climate data of the station and simple arithmetic average procedure for the normal annual climate data at other stations that are within about 10 % of the normal annual climate data were used for completing missing data a [16].Double mass-curve method used to checked the consistency of the climate data set of the stations with about neighborhood stations from Metekel zone and Awi zone.

FAO CropWat model for window 8.0 and ETo calculator embedded in AquaCrop were used to determine ETo using the long term- climatic data of the area from the national meteorological station.

A fixed percentage method was used to account rainfall that effectively used by the crop after rainfall losses due to deep percolation and surface runoff. AquaCrop requires the mean annual atmospheric CO_2 concentration ([CO_2]) for the adjustment of crop transpiration and biomass water productivity. The 'MaunaLoa.CO_2' file contains observed mean annual [CO_2] for the period 1902 till today. Reference CO_2 concentration (369.41 ppm) From Maunaloa.CO_2 database file.

Soil Sampling, preparation, and Analysis

Undisturbed soil samples were taken from the field using core sampler of known volume and were collected from kebeles of each district at five soil depths (0-15 cm, 15-30 cm, 30-60 cm, 60 -90 cm, and 90-120 cm) for computing bulk density of soil at different depths. Soil samples and have been oven-dried at 105^0C to obtain a constant weight. The bulk density was calculated from the weight of the soil per unit volume of known core sampler which is expressed as in equation (1) and all analysis was conducted at Pawe Agricultural Research Center Laboratory.

$$\text{Pb} = \frac{\text{Ms}}{\text{Vt}} \quad (1)$$

Where, ρ_b is bulk density (g/c.m^3), Ms is mass of the dry soil (g), Vt is volume of core sampler (c.m^3).

Composite disturbed soil samples had been collected from different kebeles of the districts as at five soil depths (0-15 cm, 15-30 cm, 30-60 cm, 60 -90 cm, and 90-120 cm), texture analysis along with, analysis of soil texture, organic carbon, electrical conductivity (EC) and soil reaction (pH) soil had been done.

Particle size distribution was determined in the laboratory by the modified Bouyoucos hydrometer method [17].Soil pH analysis was measured using a digital pH-meter and EC of soil analysis was measured using EC meter. Field capacity (FC), permanent wilting point (PWP), total available water (TAW), hydraulic conductivity and soil water content at saturation (SAT), depend on soil textural class and were determined by soil-plant air-water (SPAW).

Maximum rain infiltration rate (mm/day), initial soil moisture depletion (%), and initially available soil moisture (mmm) total available soil moisture (mm/m), maximum rooting depth (m), used as an input.

Irrigation water sampling preparation analysis

Assessment of irrigation water quality is relevance to calculate the leaching raqurements of crops depending on there water quality tolerance threshold valus of crops. Chemical characteristics of irrigation water (salt concentration of water and hydrogen ion concentration (PH) content) have been teste after water samples have been taken from water sources of irrigation in major irrigated areas. Collection and handling of irrigation water samples have been done following the procedure outlined by the US Salinity Laboratory Staff [18].

Acid-washed and rinsed polyethylene bottles (2-liters) were used to collect irrigation water samples. The samples have been transported to the laboratory and analyzed for their chemical composition immediately.

The irrigation water chemical properties have been determined at the Pawe Agricultural Research Center Soil and Water Laboratory. EC and pH of the water samples have measured in the laboratory within 24 hours using conductivity meter and a digital pH meter, respectively [19].

Crop characteristics data

Characteristics of onion (growing stages, maximum rooting depth ,crop coefficient, critical depletion infraction, yield response factor, crop height used as an input for CropWat and Calibrated and validated onion characteristics from the database have been used as input for the Aqua Crop. These are dates of emergence, , time to reach maximum (canopy cover, rooting depth), plant height, days of maturity dry biomass, harvest index, and total dry yield.

Crop Water Requirement

Crop and Irrigation Water Requirements using CropWat Model

crop water requirement computed using CropWat 8.0 and using monthly ETo values together ,rainfall, crop characterand and the required soil characteristics as inputs.
Kc for every growth stage was adapted from Allen et al. (1998) and then, ETc was calculated.

$$ETc = kc \ast ETo \quad (2)$$

Where, ETc is crop evapotranspiration (mm), Kc is crop factor, ETo is reference evapotranspiration (mm).
The irrigation requirement was calculated using the following equation.

$$NIR = ETc - Pe \quad (3)$$

Where, NIR is net irrigation water requirement (mm), ETc is crop water requirement (crop evapotranspiration) (mm), Pe is effective rainfall (mm).
The amount of water applied during an irrigation event (gross irrigation) was calculate using the following equation

$$GIR = NIR / Ea \quad (4)$$

Where, GIR is gross irrigation requirement, NIR is net irrigation water requirement and Ea is water application efficiency =60%.

Crop and Irrigation Water Requirements using Aqua Crop Model

Net irrigation requirement and crop water requirement for furrow irrigation have been calculated Considering groundwater table, as no shallow groundwater table and no , all stress indicators, water shortage stress, waterlogging stress, soil salinity stress air temperature stress, have been considered as zero and considering no specific field management. The simulation period has been adjusted and soil water profile at % of RAW considered as an initial condition. Crop transpiration has been calculated by the concept of the following formula

$$Tr = ETo * Ks * K_{cT}r \quad (5)$$

Where, ETo = the reference evapotranspiration, KcTr= the crop transpiration coefficient, Ks = a water stress coefficient which is 1 when water stress does not induce stomatal closure.
The crop transpiration coefficient K_{cTr} is proportional to the green canopy cover (CC):

$$K_{cTr} = K_{cTr,\, x} * K_c\, CC^{**} \quad (6)$$

Where, $Kc_{Tr,\, x}$ = the crop coefficient for maximum crop transpiration (determined by the characteristics that distinguish the crop with a complete canopy cover from the reference grass), and CC* the canopy cover adjusted for micro-advective effects.

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The total amount of irrigation water required to keep the water content in the soil profile above the specified threshold is the net irrigation water requirement for the period. The depletion (% RAW) below which the soil water content in the root zone may not drop (0 % RAW corresponds to Field Capacity). The net requirement does not consider extra water that has to be applied to the field to account for conveyance losses or the uneven distribution of irrigation water on the field.

Irrigation scheduling

Irrigation Scheduling using CropWat model

Irrigation scheduling was conducted using fixing the interval time criterea and specify back to field capacity depth criteria with CropWat 8.0 windows .

Irrigation schedules using AquaCrop model

Generation of irrigation schedules using AquaCrop have been computed by specify back to field capacity depth criterion and fixed interval time criteria.

The electrical conductivity (EC) of the irrigation water was used as an input to irrigation scheduling and irrigation events (when to irrigated and how much to irrigate have been specified by selecting the furrow irrigation method Irrigation water quality was considering for maximum dry yield production and water productivity and minimum labor cost (irrigation event).

Performance Evaluation of Models

Model performance was evaluated using the following statistical parameters: Root mean square error (RMSE), root mean square error normalized (RMSEN), Nash-Sutcliffe efficiency index (NSE)prediction error, (Pe).

Root mean square error (RMSE):

Root mean square error (RMSE) was calculated as illustrated in (Equation 7) [20].

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\mathrm{Si} - \mathrm{Oi})^2} \qquad (7)$$

Where, Si is predicted value, Oi is observed value, and N is the number of observations.

It ranges from 0 to 1 the value 0 indicating good and the value 1 indicating poor model performance. Ideally, the value of RMSE should be zero.

Root mean square error normalized (RMSEN):

The Normalized RMSE expressed in percent, was calculated as illustrated in (Equation 8) [21].

$$\mathrm{RMSEN} = \frac{1}{\mathrm{Oi}}\sqrt{\sum \frac{(\mathrm{Si}-\mathrm{Oi})^2 * 100}{N}} \qquad (8)$$

Where, Si is predicted value, Oi is observed value, and N is the number of observations.

A model can be considered as poor if NRMSE is larger than 30%, fair if NRMSE is between 20 and 30% ,good if NRMSE is between 10 and 20%, excellent if NRMSE is smaller than 10%, [22].

Nash-Sutcliffe efficiency index :

The Nash-Sutcliffe coefficient of efficiency coefficient (NSE) calculated as (Equation 9).

$$\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{N}(\mathrm{si}-\mathrm{oi})^2}{\sum_{i=1}^{N}(\mathrm{oi}-\mathrm{mo})^2} \qquad (9)$$

Where, Si is predicted value, oi is the observed value, N is the number of observations and Mo is the average of the observed values.
Nash-Sutcliffe is very commonly used, which means that there are a large number of reported values available in the [23].
Prediction error (Pe):

$$\frac{(Si-Oi)}{Oi} * 100 \quad (10)$$

Where, Si the is predicted value, Oi is observed value.
Results And Discussion

Climate Characteristics of the Study Areas

Climatic data of the study area were analyzed and reference evapotranspiration was estimated based on the FAO Penman-Monteith method [24] and the results shown in the following tables.
Table 1: Long term evapotranspiration of the the study area(mm/day)

	Pawe		Mandura		Guba		Bullen		Wembera	
Month	CW	AQ	CW	AQ	CW	AQ	CW	AQ	CW	AQ
January	5.09	5.2	5.10	4.00	5.02	5.10	4.23	4.30	4.24	3.20
February	5.56	5.7	5.56	5.10	5.70	5.90	4.50	4.60	4.51	4.00
March	6.6	6.8	6.60	6.30	6.92	7.10	5.47	5.60	5.51	5.20
Aprile	6.18	6.2	6.17	6.10	6.80	6.90	5.19	5.20	5.23	5.20
May	4.85	4.7	4.85	4.80	5.21	5.10	4.26	4.20	4.31	4.30
June	4.12	4	4.12	4.10	4.45	4.30	3.72	3.60	3.75	3.80
July	3.49	3.4	3.49	3.50	3.76	3.70	3.16	3.10	3.13	3.20
August	3.17	3.2	3.18	3.20	3.57	3.60	2.93	2.90	3.05	3.10
September	3.64	3.7	3.65	3.50	3.86	3.90	3.39	3.40	3.47	3.30
October	3.67	3.7	3.68	3.30	3.83	3.80	3.39	3.40	3.48	3.10
November	3.76	3.7	3.77	2.90	4.06	4.10	3.40	3.40	3.46	2.60
December	3.91	3.9	3.92	2.70	4.25	4.30	3.47	3.50	3.51	2.40
Avarage	4.5	4.52	4.51	4.13	4.79	4.82	3.93	3.93	3.97	3.62

**CW= CropWat, AQ= AqaCrop

As shown in Table 1, The minimum reference evapotranspiration was found to be 2.4 mm/day in Bullen district and the maximum reference evapotranspiration in was found to be 6.92 mm/day in Guba.simulated using CropWat. The maximum reference evapotranspiration in the study areas simulating using AquaCrops was found to be 7.1 mm/day in Guba and minimum reference evapotranspiration was found to be 2.4 mm/day in Wembera district.

Table 2: Long term rain fall data and effective rainfall (mm) of the study area

Mouth	pawe		Mandura		Guba		Bullen		Wembera	
	p	pe	p	pe	p	pe	p	pe	p	pe
January	0.7	0.7	1.6	1.6	0	0	3.5	3.5	42.8	39.9
February	0.6	0.6	2	2	7.1	7	2.6	2.6	49.3	45.4
March	7.8	7.7	7.2	7.1	6.1	6	4.5	4.5	45.1	41.8
April	27.8	26.6	38	35.7	42	39.2	72.4	64	53.6	49
May	93.2	79.3	126.7	101	230.8	145.6	153.1	115.6	75.8	66.6
June	289.8	154	270.1	152	212.9	140.4	261.8	151.2	78.6	68.7
July	361.4	161.1	494.1	174.4	326.5	157.7	284.4	153.4	82	71.2
August	396.3	164.6	362.8	161.3	299.8	155	373.4	162.3	85	73.4
September	261.1	151.1	267.6	151.8	250.2	150	278.8	152.9	75	66
October	132.6	104.5	60.5	54.6	156.7	117.4	124.6	99.8	79	69
November	14.4	14.1	19	18.4	13.2	12.9	16.9	16.4	72	63.7
December	0.7	0.7	1.2	1.2	0.7	0.7	4.5	4.5	53	48.5
Total	1586.4	865	1650.8	861.1	1546	931.9	1580.5	930.7	791.2	703.4
Average	132.2	72	137.6	71.5	128.8	77.6	131.7	77.5	65.9	68.6

*P= Rain fall, Pe= Effective rainfall.

As shown in Table 2, Part of the rainfall that infiltrated into the soil called effective rainfall became available for crop groth in mm. Effective rainfall values used to simulate net irrigation requirements when irrigation scheduling developed using CropWat model and the rain fall values used to simulate the water balance in soil profile when irrigation scheduling developed using Aqua Crop.

The rain fall values in wembera district was relatively higher than the other districts during growing season of the sumulation period that results higher effective rain fall.

Soil Profile Characteristics of the Study Areas

The total available soil moisture content of soil on a volumetric percentage basis easily converted to mm of water per meter of soil depth by multiplying by 1000 mm/meter and then dividing by 100 to remove the percentage is a preferable unit for irrigation management.

Depths(cm)	Sand (%)	Silt (%)	Clay (%)	TAW (mm/m)	PWP	FC	SAT	Ksat (mm/day	Textural class
					Volume in %				
0-15	22	10	68	179.5	27.66	45.61	48	300	Sity loam
15-30	14	18	68	116.9	25.11	36.8	48.9	270.5	Sity loam
30-60	18	14	68	126.7	26.37	39.04	48.5	288.1	Sity loam
60-90	24	12	64	129.6	26.94	39.9	47.7	307.7	Sity loam
90-120	22	12	66	167.9	27.39	44.18	48	300	Sity loam
ATASM (mm/m)	144.12								
MIR (mm/day)	70								
MRD (c.m)	120								

Table 3 : Soil sample analysis in Pawe district
 * ATASM= Average total available soil moisture, MIR=Maximum infiltration rate, MRD =Maximum rooting depth.

As shown in Table 3, the soil moisture contents on a volume basis in Pawe district were in the range of 25.11% and 27.66%, and 36.8% and 44.18%, respectively at permanent welting point and field and the average total available soil moisture content was 144.12 mm/m.

Depths(cm)	Sand (%)	Silt (%)	Clay (%)	TAW (mm/m)	PWP	FC	SAT	Ksat (mm/day)	Textural class
					Volume in %				
0-15	38	24	38	127	23.5	36.2	46.4	61	Clay loam
15-30	36	26	38	129	23.5	36.4	46.7	67.1	Clay loam
30-60	40	26	34	128	21.3	34.1	45.9	91.1	Clay loam
60-90	35	15	50	119	30	41.9	47.7	12.2	clay
90-120	37	15	45	119	29	40.9	47.2	12.2	Clay
ATASM (mm/m)		124.4							
MIR (mm/hr)		76							
MRD (c.m)		120							

Table 4: Soil sample analysis in Mandura district
* ATASM=Average total available soil moisture, MIR=Maximum infiltration rate, MRD =Maximum rooting depth.

From Table 4, the soil moisture contents on a volume basis in Mandura district were in the range of 21.3% and 30%, and 41.9%, and 34.1%, respectively at PWP and FC and the average total available soil moisture was 124.4 mm/m.
Table 5: Soil sample analysis in Guba district

Depths(cm)	Sand (%)	Silt (%)	Clay (%)	TAW (mm/m)	PWP	FC	SAT	Ksat (mm/day)	Textural class
					Volume in %				
0-15	68	12	20	87	13.8	22.5	43.1	493.8	Sandy loam
15-30	65	19	16	95	11.5	21	44	280.4	Sandy loam
30-60	66	14	20	91	13.8	22.9	43.3	487.7	Sandy loam
60-90	65	12	23	85	15.5	24	43	347.5	Sandy lay loam
90-120	68	10	22	88	14.9	23.7	42.9	402.3	Sandy loam
TASM (mm/m)			89.2						
MIR (mm/hr)			90						
MRD (c.m)			120						

* ATASM= Average total available soil moisture, MIR=Maximum infiltration rate, MRD =Maximum rooting depth.

From Table 5, the average total available soil moisture was 89.2 mm/m. The soil moisture contents in Guba were in the range of 11.5% and 15.5%, and 21 and 24%, respectively at PWP and FC on a volume basis.

Table 6: Soil sample analysis in Bullen district

Depths(cm)	Sand (%)	Silt (%)	Clay (%)	TAW (mm/m)	PWP	FC	SAT	Ksat (mm/day)	Textural class
					Volume in %				
0-15	20	40	40	144	24.3	38.7	49.9	85.3	Silty clay
15-30	25	37	38	142	22.8	37	48.5	85.3	Clay loam
30-60	26	37	37	141	17	31.1	46.5	91.4	Clay loam
60-90	26	36	38	139	17	30.9	46.2	85.3	Clay loam
90-120	24	36	40	142	15.5	29.7	45.9	79.2	Clay
TASM (mm/m)		141.6							
MIR (mm/hr)		74							
MRD (c.m)		120							

* ATASM= Average total available soil moisture, MIR=Maximum infiltration rate, MRD =Maximum rooting depth.

As shown in Table 6, the average total available soil moisture was 141.6 mm/m. The soil moisture contents in the Bullen district were in the range of 15.5% and 24.3%, and 29.7% and 38.7%, respectively at PWP and FC on a volume basis.

Table 7: Soil sample analysis in Wembera district

Depths(cm)	Sand (%)	Silt (%)	Clay (%)	TAW (mm/m)	PWP	FC	SAT	Ksat (mm/day)	Textural class
					Volume in %				
0-15	23	29	48	135	28.7	41.3	50.1	35.576	clay
15-30	20	34	46	132	27.5	40.7	50.5	54.864	clay
30-60	28	25	47	126	28.2	40.8	49	30.48	clay
60-90	23	35	42	136	25.5	39.1	49.5	67.056	clay
90-120	23	36	43	135	26	39.5	49.6	60.96	clay
TASM) mm/m)	132.8								
MIR (mm/hr)	45								
MRD (c.m)	120								

* ATASM= Average total available soil moisture, MIR=Maximum infiltration rate, MRD =Maximum rooting depth

As shown in Table 7, the soil moisture contents on a volume basis in Wembera were in the range of 25.5% and 28.7%, and 39.1% and 41.3% respectively at PWP and FC and the average total available soil moisture was 132.8 mm/m. The values of saturated hydraulic conductivity, soil moisture contents at permanent welting point , field capacity and saturation and total available soil moisture depend soil textural class. Generally all soil textural class could be found in each districtes. The soil analysis results shoun in the above tables (from table 3-7) represents only areas where irrigation practice observed by smallholder farmers ,small irrigation shems, around perennial rivers that are serving as irrigaton water source. The soil textural class sampled and analysis around the study areas ranges from light (sandy loam) in Guba to clay soil texture in Mandura, Bullen and Wembera.

Irrigation water quality of the study areas

Assessment of electrical conductivity or Salinity values of irrigation water have been conducted to calculate leaching requitement and identify effect of salinity stress if the salinity values grater than threshold salinity values of selected crops.

Table 8: Irrigation water quality results of the study area

Name of rivers (irrigation water source)	Hydrogen ion concentration (PH)	electrical conductivity (CE_w)
Midimida	7.64 moles per liter	0.273ds/m
Changure	7.43 moles per liter	0.41ds/m
Abat Beles	7.69 moles per liter	0.36ds/m
Gilgel Beles	7.47 moles per liter	0.466ds/m
Baguna	7.83 moles per liter	0.521ds/m
Libite	7.7 moles per liter	0.511ds/m
Average	7.63 moles per liter	0.4235 ds/m

* $\mu s/cm$`=Micro Siemens per centimeter.

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As shown in Table 8, the electrical conductivity of irrigation water ranged from 0.273 ds/m to 0.521 sd/m and the average electrical conductivity were 0.4235 Sd/m and hydrogen ion concentration of irrigation water ranged from 7.43 moles per liter to 7.83 moles per liter and average hydrogen ion concentration was 7.63 moles per liter. The nature of sampled rivers was perennial, representative, and cross many districts in the zone

Characteristics of onion Used as Input

Information on, the local transplanting date onion, which was around December first had been collected from farmers experience around the study area and used for the computation of crop water requirement and to made irrigation scheduling using both CropWat and AquaCrop model.

Table 9: Characteristics of onion used as input for CropWat

Crop characteristics	Growing stages				Total
	Initial	Development	Mid	Late	
Kc	0.5	0.7-0.8	1.15	0.99	
Stages	20	25	35	20	100
Rooting depth	0.25		0.6		
Critical depletion (fraction)	0.3	0.45		0.5	
Yield response factor	0.8	0.4	1.2	1	1
Crop height		0.4 (optional)			

As shown in Table 9, Since there was no determined rooting depth, critical depletion,crop coefficient, and yield response factor, for this area, the FAO recommended values for the onion growth stages are used to simulate crop water requirement and to made irrigation scheduling.

Table 1: Characteristics onion used as input for AquaCrop

Initial canopy	Initial canopy cover (%)	5
	Canopy size seedling (c.m^2/plant)	15
	Plant density (plants/ha)	333,333
Development	Maximum canopy cover (%)	65
	From day 1 after sowing to emergence (day)	4
	Maximum canopy(day)	44
	Senescence (day)	74
	Maturity (day)	100
Flowering and yield formation (root/tuber formation)	Length building up of harvest index (day)	51
	Duration of flowering (day)	-
	From day 1 after sowing to flowering(day), yield formation	38
Root deepening	Maximum effective root depth (m)	0.6
	From day 1 after sowing to maximum root depth (day)	28
	Average root zone expansion (cm/day)	1.5

Most of the onion characteristics have been taken with minimum calibration [25].) as shown in table 10.

Crop and Irrigation Water Requirements

Crop and irrigation water requirements with CropWat model

Equation (2) used to calculate crop water requirements using CropWat model.

Table 2: Simulated ETc and IR of onion in the study areas using CropWat

Parametres	Pawe	Mandura	Guba	Bullen	Wembera
ETC (mm)	484.5	484.6	495.6	401.9	403.6
ER (mm)	3.7	6.1	8.9	10.9	148
IR (mm)	480.8	478.6	486.6	391	255.9

* ETC=Crop water requirement, ER =Effective rainfall, IR= Irrigation requirement.

As shown in Table 11, The minimum irrigation requirement of onion was found to be 255.9 mm in Wembera district. The maximum seasonal irrigation requirement of onion was found to be 486.6 mm in Guba district. Relatively height amount of the required water was satisfied by seasonal effective rain (Pe) with 148 mm in Wembera district.

The seasonal net irrigation application for Onion was found to be 2890 m^3 in Debre Zeit, 2920 m^3, in Akaki, 3870 m^3 in Modjo 3840 m^3 and in Alem-Tena [26] using 60% field efficiency.

Crop and irrigation water requirements using the AquaCrop model

The irrigation requirement using AquaCrop simulation is the total simulated irrigation depth considering the water balance on effective root depth of the soil profile. The actual evapotranspiration (ET) throughout the growing season were then determined based on equation (5) using Aqua Crop model.

Table 3: Simulated ETc and IR of onion in the study areas using AquaCrop

Parametres	Pawe	Mandura	Guba	Bullen	Wembera
TIR (mm)	537.5	402.7	463.5	408.5	264.0
ET_C (mm)	493.8	406.3	463.4	412.1	356.4
ETo (mm)	508.1	411	525.1	424.8	336.1
Rain (mm)	3.8	5.8	1.9	10.6	159.2

TIR =Total irrigation requirement , ETc=crop water requirement, ETo=reference evapotranspiration,

This total simulated irrigation requirements shown in table 12, used to generating irrigation scheduling according to the specified time, a fixed interval and bring the soil water content in the root zone at field capacity depth criteria.

The minimum total irrigation requirement and crop water requirement of onion were found to be 281.6 and 355 mm respectively in Wembera district and the maximum total irrigation requirement and crop water requirement were 582.8 and 523.7 mm respectively in Guba district.

Irrigation Scheduling

Irrigation scheduling of onion using CropWat model

CropWat model has different options To carry out irrigation scheduling. However, based on the research evidence and field data available in the study area refill soil to field capacity depth criteria and irrigate at fixed interval per stage time criteria a were used. Since main irrigation application methods for the area is surface irrigation , irrigation efficiency of 60% was considered.

Table 13: Irrigation scheduling of onion in Pawe using irrigate at a fixed interval

Irrigation events	Date	Day	Stage	NIR (mm)	GIR (mm)
1	5 December	5	Initial	9.1	15.2
2	10 December	10	Initial	9.1	15.2
3	15 December	15	Initial	9.5	15.9
4	20 December	20	Initial	9.5	15.9
5	25 December	25	Development	13.9	23.2
6	30 December	30	Developmen	13.9	23.2
7	4 January	35	Developmen	20.3	33.9
8	9 January	40	Developmen	21.9	36.6
9	14 January	45	Developmen	27.7	46.2
10	19 January	50	Mid	29.1	48.6
11	24 January	55	Mid	30.2	50.3
12	29 January	60	Mid	30.5	50.8
13	3 February	65	Mid	31.1	51.8
14	8 February	70	Mid	31.4	52.4
15	13 February	75	Mid	32	53.3
16	18 February	80	Mid	32.3	53.9
17	23 February	85	End	32.3	53.9
18	28 February	90	End	32.5	54.2
19	5 March	95	End	32.2	53.6
Total				448.5	748.1

* GIR= Gross irrigation requirement, NIR=net irrigation requirement.

As shown in Table 13, irrigation scheduling of onion in Pawe using refill soil to field capacity depth criteria and 5 days fixed interval per stage time criteria and had 19 irrigation event and had the net irrigation requirements and total gross were 448.5 mm 748.1 mm respectively with no yield reduction.

The minimum net and gross irrigation requirement were found to 9.1 mm and 15.2 mm in the first irrigation event respectively and the maximum net and gross irrigation requirement reach up to 32.5 mm and 54.2 mm at 18th irrigation events (the end stage) respectively.

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Table 14: Irrigation scheduling of onion in Mandura using irrigate at a fixed interval

Irrigation events	Date	Day	Stage	NIR (mm)	GIR (mm)
1	5 December	5	Initial	8.9	14.8
2	10 December	10	Initial	8.9	14.8
3	15 December	15	Initial	9.5	15.9
4	20 December	20	Initial	9.5	15.9
5	25 December	25	Development	13.9	23.2
6	30 December	30	Developmen	13.9	23.2
7	4 January	35	Developmen	20.2	33.7
8	9 January	40	Developmen	21.8	36.4
9	14 January	45	Developmen	27.6	45.9
10	19 January	50	Mid	29	48.3
11	24 January	55	Mid	30	50
12	29 January	60	Mid	30.3	50.5
13	3 February	65	Mid	30.9	51.5
14	8 February	70	Mid	31.2	52.1
15	13 February	75	Mid	31.7	52.9
16	18 February	80	Mid	32.1	53.5
17	23 February	85	End	32.1	53.5
18	28 February	90	End	32.3	53.8
19	5 March	95	End	32.3	53.9
Total				446.1	743.8

* GIR=gross irrigation requirement, NIR=Net irrigation requirement.

As shown in Table 14, irrigation scheduling of onion in Mandura using refill soil to field capacity depth criteria and 5 days fixed interval per stage time criteria and had 19 irrigation event and had the total gross irrigation requirements of 743.8 mm and total net irrigation requirements of 446.1 mm with yield reduction was 0.0%.

The minimum net and gross irrigation requirement were found to 8.9 mm and 14.8 mm in the first irrigation event respectively and the maximum net and gross irrigation requirement reach up to 32.3 mm and 53.9 mm at 19^{th} irrigation events (the end of end stage) respectively.

Table 15 : Irrigation scheduling of onion in Guba using irrigate at fixed interval

Irrigation events	Date	Day	Stage	NIR (mm)	GIR (mm)
1	5 December	5	Initial	10	16.7
2	10 December	10	Initial	10.1	16.8
3	15 December	15	Initial	10.6	17.7
4	20 December	20	Initial	10.6	17.7
5	25 December	25	Development	14.8	24.7
6	30 December	30	Developmen	14.8	24.7
7	4 January	35	Developmen	20.8	34.6
8	9 January	40	Developmen	22.3	37.1
9	14 January	45	Developmen	27.4	45.7
10	19 January	50	Mid	28.7	47.8
11	24 January	55	Mid	30	50
12	29 January	60	Mid	30.3	50.5
13	3 February	65	Mid	30.3	50.5
14	8 February	70	Mid	30.7	51.2
15	13 February	75	Mid	31	51.7
16	18 February	80	Mid	31.4	52.4
17	23 February	85	End	32.1	53.5
18	28 February	90	End	32.5	54.2
19	5 March	95	End	33.5	55.8
Total				451.9	753.3

* GIR=gross irrigation requirement ,NIR=Net irrigation requirement.

As shown in Table 15, The total gross irrigation requirements of 753.3 mm and net irrigation requirements of 451.9 mm with a yield reduction of 0.2%. Irrigation scheduling of onion using refill soil to field capacity depth criteria and fixed interval (5 days) per stage time criteria had 19 irrigation events in Guba district.

The minimum net and gross irrigation requirement were found to 10 mm and 16.7 mm in the first irrigation event respectively and the maximum net and gross irrigation requirement reach up to 33.5 mm and 55.8 mm at 19th irrigation events (the end of end stage) respectively.

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Table 16: Irrigation scheduling of onion in Bullen using irrigate at a fixed interval

Irrigation events	Date	Day	Stage	NIR (mm)	GIR (mm)
1	5 December	5	Initial	7.3	12.2
2	10 December	10	Initial	7.3	12.2
3	15 December	15	Initial	8.2	13.6
4	20 December	20	Initial	8.2	13.6
5	25 December	25	Development	11.7	19.5
6	30 December	30	Developmen	11.7	19.5
7	4 January	35	Developmen	16.7	27.8
8	9 January	40	Developmen	17.9	29.9
9	14 January	45	Developmen	22.5	37.5
10	19 January	50	Mid	23.6	39.3
11	24 January	55	Mid	24.3	40.6
12	29 January	60	Mid	24.5	40.8
13	3 February	65	Mid	24.9	41.5
14	8 February	70	Mid	25.1	41.8
15	13 February	75	Mid	25.4	42.4
16	18 February	80	Mid	25.6	42.7
17	23 February	85	End	25.9	43.2
18	28 February	90	End	26.2	43.6
19	5 March	95	End	26.9	44.8
Total				363.9	606.5

* GIR=gross irrigation requirement, NIR=Net irrigation requirement.

As shown in Table 16 The total net and gross irrigation requirements of onion were 363.9mm and 606.5 mm respectively with no yield reduction.

Irrigation scheduling of onion using refill soil to field capacity depth criteriaand fixed interval (5 days) per stage time criteria had 19 irrigation events.

The minimum net and gross irrigation requirement were found to 7.3 mm and 12.2 mm in the first irrigation event respectively and the maximum net and gross irrigation requirement reach up to 26.9 mm and 44.8 mm at 19th irrigation events (the end of end stage) respectively.

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Table 17: Irrigation scheduling of onion in Wembera using irrigate at a fixed interval

Irrigation events	Date	Day	Stage	NIR (mm)	GIR (mm)
1	5 December	5	Initial	5.2	8.7
2	10 December	10	Initial	7	11.7
3	15 December	15	Initial	5.3	8.8
4	20 December	20	Initial	7	11.7
5	25 December	25	Development	7.4	12.4
6	30 December	30	Developmen	9.9	16.5
7	4 January	35	Developmen	10	16.6
8	9 January	40	Developmen	11.2	18.7
9	14 January	45	Developmen	16.4	27.3
10	19 January	50	Mid	17.5	29.1
11	24 January	55	Mid	17.7	29.4
12	29 January	60	Mid	17.8	29.7
13	3 February	65	Mid	17.4	29
14	8 February	70	Mid	17.6	29.3
15	13 February	75	Mid	17.4	29
16	18 February	80	Mid	17.6	29.4
17	23 February	85	End	18.4	30.6
18	28 February	90	End	18.6	31.1
19	5 March	95	End	19.5	32.6
Total				258.9	431.6

* GIR=gross irrigation requirement, NIR=Net irrigation requirement.

As shown in Table 17, Irrigation scheduling of onion in Wembera using refill soil to field capacity depth criteria and fixed interval (5 days) per stage time criteria and had 19 irrigation event and had the total gross irrigation requirement of 431.6 mm and net irrigation requirement of 258.9 mm with no reduction.

The minimum net and gross irrigation requirement were found to 5.2 mm and 8.7 mm in the first irrigation event respectively and the maximum net and gross irrigation requirement reach up to 19.5 mm and 32.6 mm at 19th irrigation events (the end of end stage) respectively.

Generating irrigation scheduling using the AquaCrop model

AquaCrop Generating irrigation scheduling according to the specified depth and time criterion. AquaCrop model has different options like CropWat to carry out irrigation scheduling. However, based on the research evidence and field data available in the study area refill soil to field capacity depth criteria and irrigate at fixed interval per stage time criteria a were used.

.Table 18: Generated irrigation scheduling of onion in the study area at a fixed interval

Irrigation event	DAP	IR (mm)					EC_W (ds/m)
		Pawe	Mandura	Guba	Bullen	Wembera	
1	5 December	17.5	12.8	13.7	15.1	7.4	0.4
2	10 December	16.5	10.8	12.9	12.7	6.3	0.4
3	15 December	17.3	11.6	14.2	14.3	8.3	0.4
4	20 December	19.0	12.3	16.0	15.6	8	0.4
5	25 December	21.3	13.5	18.4	16.8	8.8	0.4
6	30 December	22.1	13.6	19.8	17.5	9	0.4
7	4 January	26.5	17.1	22.2	21.1	12.1	0.4
8	9 January	28.5	18.8	23.3	21.7	12.6	0.4
9	14 January	28.7	19.7	24	21.6	12.9	0.4
10	19 January	28.9	20.6	24.6	21.6	13.4	0.4
11	24 January	29.1	21.5	25.1	21.7	14.1	0.4
12	29 January	29.4	22.4	25.6	21.8	14.7	0.4
13	3 February	29.1	23.1	26	21.7	14.6	0.4
14	8 February	30.8	23.9	26.5	21.7	15	0.4
15	13 February	30.6	24.8	27.1	22.1	15.6	0.4
16	18 February	30.9	25.4	27.4	22.3	16.2	0.4
17	23 February	31.2	26.2	27.8	22.8	16.1	0.4
18	28 February	31.5	26.8	28.2	23.3	16.5	0.4
19	5 March	34	28.8	30.3	26.3	21.5	0.4
20	10 March	34.4	29.2	30.4	26.6	20.6	0.4
TIR (mm)		537.5	402.7	463.5	408.5	264.0	
DY (T/ha)		9.387	9.387	9.348	9.387	9.387	
Wp (k.g/m^3)		1.90	2.31	2.02	2.28	2.63	

*IR= Irrigation requirement, DY=Dry yield, TIR=Total irrigation requirement, WP= Water productivity, EC_{W}=Electrical conductivity of irrigation water , DAP=Days after planting.
As shown in Table 18, refill soil to field capacity depth criteria and a fixed interval of 5 days time criterion used to generate irrigation scheduling of onion and which had 20 irrigation events. The simulation indicated that with TIR of 402.7, 408.5, 537.5, and 264.0 mm, the bulb yield of 9.387 T/ha of onion can be produced in Mandura, Bullen, Pawe, and Wembera respectively and the bulb yield of 9.348 T/ha of onion can be produced in Guba district with TIR of 463.5 mm.

Irrigation water requrements of onion were found to be 286 mm and 360 mm for the sandy and sandy loam soils, respectively during the ‘driest’ year, seasonal (March to mid-September) ,rainfall (138 mm) and ETo (682 mm) [26]

The threshold soil Salinity and water salinity value in dS/m of onion is 1.2 and 0.8 respectively as shown in table 1. Water salinity of the study area as shown in table 8 is lower than the threshold values, so water salinity value in irrigation scheduling of onion should be considered as zero as showed in table 18.

Performance Evaluation of Models

Performance evaluation was calculated considering and simulated cropwater requirement values of AquaCrop as simulated values (Si), and simulated cropwater requirement values of CropWat as observed values (Oi) and the districts as a number of observations (N).

Table 19: Performance evaluation considering the districts as a number of observations

Parameter	Onion
Root mean square error	43.78
Root mean square error normalized (%)	9.6%
Nash-Sutcliffe coefficient of efficiency coefficient	0.98
Prediction Error	0.00

RMSE provides information on the short-term performance of a model by allowing the term by term comparison of the actual difference between the simulated and the measured value. In this study case, RMSE provides information comparison of the actual difference between the simulated values of AquaCrop and simulated values of CropWat . According to [28] the simulation is considered and poor when it is greater than 30%, reasonable when it comes between 20% and 30%, good if it comes between 10% and 20% and excellent if RMSEN is less than 10%. When NSE < 0.5 simulation is an unsatisfactory fit , When NSE = 0.5 to 0.64 simulation is a satisfactory fit , When NSE = 0.64 to 0.74 simulation is a good fit , When NSE > 0.75 simulation is a very good fit, When NSE = 1.0, simulation is the perfect fit, [29]

When Pe, approaches zero, they represent positive indicators of model performance and used to evaluate the model prediction error. Pe used to define the robustness of the model as well as to predict the values.As shown in Table 19, Considering the districts as a number of observations, RMSE values for onion when simulating crop water requirement were fund to be 43.8 and the simulation was poor. Considering the districts as a number of observations, RMSEN values for onion the values was 9.6%and it lied less than 10% and the simulation was excellent. Considering the districts as a number of observations, simulating crop water requirements using AquaCrop in all district for onion were founed to be a very good fit (NSE > 0.75) (NSE= 0.98 for onion) with simulating crop water requirement using CropWat. Generally from the overall model performance indicators indicated that AquaCrop model can simulate crop water requirements and irrigation application deths almost with similar result as CropWat model.

Summary, Conclusions and Recommendations

SUMMARY AND CONCLUSIONS

The objective of the study was to compare the significance of models for adoption at different situations in the study area and to simulate water requirement and irrigation scheduling for onion

Based on crop, soil, and meteorological data Co_2, groundwater, field management, and fertility status Crop water requirement and irrigation scheduling of onion in selected districts of Metekel zone were estimated using using AquaCrop and CropWat.

(Normalized Root mean square errors (NRMSE), Prediction error (Pe), model by Nash-Sutcliffe efficiency (NSE)) were used to show relationship between simulated results of CropWat usingand the simulated results of AquaCrop.

The seasonal crop requirement of onion were found to be 484.5 mm,in Pawe, 484.6 mm,in Mandura, 495.6 mm,in Guba, 401.9 mm,in Bullen and 403.6 mm in Wembera using CropWat and 493.8 mm in Pawe, 406.3 mm in Mandura, 463.4 mm in Guba, 412.1mm in Bullen and , 356.4 mm in Wembera districts using AquaCrop.

This study also shown that there was a strong close relation between simulated cropwater requirement values of CropWat and the simulated cropwater requirement values of AquaCrop. Hence Model performance indicators showed that the models well simulated in all districtes.
It has been observed shown that the appropriate irrigation interval at initial developments mid and late growth stages should be identified for ease of work to the users.

Recommendations

The developed irrigation schedule both using AquaCrop and CropWat should be validated and calibrated in all soil textural classes in each district of the study areas.
It is recommended that end-users and farmers should adopt fixed irrigation intervals to save time, energy water, and labor during irrigation water application of onion in the study area.
Aqua Crop model should be adopted to compare attainable and actual yields in a field, farm, or a region and to simulate water productivity simultaneously, simulating crop water requirement and irrigation application depth and to improve water productivity.
Therefore, AquaCrop model should recommended due to its merit that easy for an application ,a user friendly, accuracy and robustness and address the conditions where water is a key limiting factor for crop production.
It is also recommended that farmers and end-users should adopt AquaCrop as a planning tool or to assist in management decisions for both rainfedand irrigated agriculture and thus advisable to use the this model in to the development action at scale through developing appropriate pakcages and extension quidelines.

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Conflict of interest

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