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Evaluations of Crops Coefficient Cross Ponding to Growth Stage in Semiarid Climate Zone, Arba Minch, Ethiopia

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Abstract

Crop coefficients are very important to manage irrigation water throughout the irrigation period and that will depend on crop growth stage. In most irrigation practice, the recommended crop coefficients in food and agricultural organization irrigation and drainage paper manual used to fix crop water requirement. Therefore, this research was to compare measure and recommend crop coefficients. Soil physical properties such as texture, bulk density, field capacity and permanent wilting point were estimate in the laboratory after collecting of soil sample at 90cm soil depth and infiltration rate also evaluate by using double ring infiltro meter.To estimate crop coefficients, crop evapotranspiration was measured by using weighting lysimeter through the crop growth stage and reference evapotranspiration also estimated with Cropwat model. The average bias of crop coefficients of the wheat, maize, pepper and onion were .4.0%, -12.9%, -7.1% and -32.0%, respectively. The average land and water productivities of wheat, maize, pepper and onion were 2.2ton/ha & 0.7kg/m3, 2.8ton/ha & 1.1kg/m3, 11ton/ha & 2.2kg/m3 and 9.6ton/ha & 1.8kg/m3, respectively. The recommended value of crop coefficients for the onion crop is not logical to fix crop water requirement. Therefore measured value will be used for future irrigation practice. The small farm holders will practice pepper crops because it is high productivity.

Key words:

Crop Coefficient • Growth stage • Productivities

Introduction

Estimation of crop cops coefficient is very important to fix amounts of irrigation water depth for specific crop. Crop coefficient are depend on crops types and climate (such as temperature, humidity, wind speeded, etc) [1]. Most evaluation of crop coefficient was depend on FAO irrigation and drainage paper manual especial FAO 56 and 24. This method is very important especially for remote are that led challenge to estimate based on field experiment. Weighing lysimeters are used to measure crop Evapotranspiration (ETC) during the growing season and ratio of crop evapotranspiration to reference evapotranspiration (ETo) determines a crop coefficient (Kc) value, which is related to a specific crop growth development stage [2]. To evaluate crop coefficient with above methods, environmental validation and calibration is very important. Therefore the research was conduct to compare measured with crop coefficients that were suggested by food and agricultural organization irrigation and drainage prepare (Fao56).

Material and Methods

Study area description

The experimental research was conducted at Arba Minch university demonstration farmland (demo farm), Arba Minch Zuria Woreda, Gamo Zone, SNNPR National Regional State, Ethiopia. Geographically the study area is located at an altitude of 1200 m.a.s.l with latitude of 6.060 N, the longitude of 37.60 E.

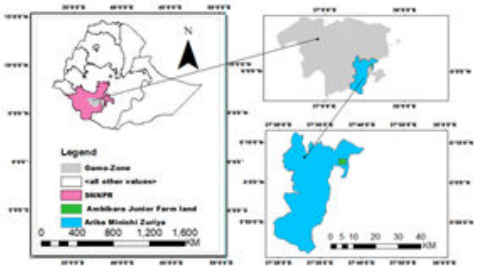

Figure 1: Location of the study area.

Climate

Based on agro-ecological climate zone classification; the Climate zone of the experimental site is kola (dry climate). Average climate

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data of study was described based on 31 years' record climate data that was from (1990-2020). The average minimum and maximum temperature of the study area varies between 13.2-19.6℃ and 29.6-35.5℃, respectively. The total received average annual rainfall was 650mm.

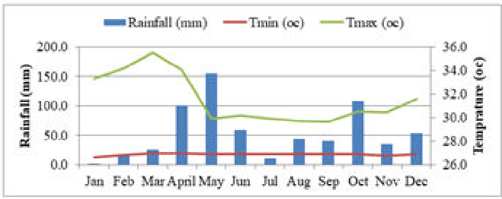

Figure 2: Average monthly minimum temperature, maximum temperature and rainfall.

Experimental plot design

Experiments were conduct for maize, wheat, pepper and onion under full irrigation methods. Total experimental plots were fix 3mx5m size for the wheat and maize. Lengths and width of furrow for onion and paper crops were 10 m and 6 m with 1.5m and 1m center to center furrow spacing, respectively and all experiments were conducted with three replications.

Soil physical properties and sampling

Soil sample was collect at 90cm soil depth with 30cm depth interval to analysis soil physical properties [3]. Soil texture and bulk density were evaluate by using hydrometer test after disperse by sodium Meta phosphate detergent at Arba Minch university soil mechanics laboratory. Collected soil sample was dry in oven dry for 24 hours at 105℃ and mass dry soil and water were calculated. After that bulk density of soil was expressed by (Blake, 1965) and it was used to determine volumetric water content of soil.

$$\text{Bulk density } (\rho b) = \frac{Mass\ of\ dry\ soil\ (gm)}{Total\ volume\ of\ soil\ sample} \ldots\ldots (1)$$

Field capacity and permanent wilting point of soil were evaluated by using pressure plate apparatus from Hawassa agriculture research center
ture, humidity, wind speeded…

Figure 3: Figure 1 is hydrometer test and Figure2 is soil oven dry.

Average basic infiltration rate from the experiment was estimate by using double ring infiltrometer and it used as input for CROPWAT model to estimate the Run Off (RO), occurring whenever rain intensity or irrigation infiltration rate exceeds the infiltration capacity of the soil.

CROPWAT model

CROPWAT software is a computer program that used to calculate crop water needs and irrigation demand based on soil, climate and crop data and it used to develop irrigation schedules for different management conditions and to calculate water supply of schemes for varying crop patterns.

Reference evapotranspiration

Daily and monthly reference evapotranspiration was calculated through Cropwat 8.0 model by using Penman-Monteith equation [4]. Daily reference evapotranspiration was used to calculate crop coefficient and total reference evapotranspiration was evaluated by adding each daily value according to the durations of crop growth stage [5].

$$ETo = \frac{0.408\Delta(Rn+G)+r*\frac{900}{T+273}u2(es-ea)}{\Delta+r(1+0.34u2)} \ldots\ldots (2)$$

Where; ET_0=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 at 2m height (oc), u2=Wind speed at 2m height (ms-1), es=Saturation vapour pressure (kPa)ea= actual vapour pressure (kpa), (es-ea)=Saturated vapors pressure deficit (kpa), Δ=slope vapour pressure curve (kPa oc-1) and r=psychrometric constant, (kPa oc-1)

Crop evapotranspiration (ETc)

Crop evapotranspiration (ETc) also measured by using lysimeter that was installed near the experiment area with two drainage outlet first installed at top to collect surface runoff and the second at bottom to collect deep percolation. After that, Based on (Garcı et al., 2018), the crop evapotranspiration (ETc) was determined from the water balance, which is based on the mass conservation law.

$$ETc = Wa - R - DP + S \ldots\ldots (3)$$

Where; Wa= applied water depth (mm), R=runoff (mm), Dp=deep percolation (mm) and S= soil water storage.

Crop coefficient (kc)

Crop coefficient of the crops were evaluate at initial, development, mid and late stages of growth period and it was calculate based on (Allen et al., 1998).

$$Kc = \frac{Crop\ evapotransparation\ (ETC)}{Reference\ evapotranspiration\ (ETo)} \ldots\ldots (4)$$

Above measured rop coefficients were compare with constant that suggest by irrigation and drainage paper manual or FAO 56 at initial, mid and late stage of crop.

Water and land productivity

Land productivity and water are important element in longer-term and strategic water resources planning, the actual and practically feasible values are hardly understood (ZWART, 2010). Water and land productivity of irrigation scheme were evaluated to assess efficient of water and land and it was expressed by [6].

$$\text{Land Productivity} = \frac{Y}{L} \quad \ldots(5)$$

$$\text{Water productivity} = \frac{Y}{Ws} \quad \ldots(6)$$

Where Y, Wi and L are yield (kg), total water supply irrigation water plus effective rainfall (m3) and irrigated land (ha), respectively.

Result and Discussion

Soil physical properties

Dominate soil texture also clay loam soil that was found from hydrometer test analysis and average bulk density, Field Capacity (FC) and Permanent Wilting Point (PWP) of the soil were 1.3gm/cm3, 39% and 26.5%, respectively as discussed in the Table 1.

depth (cm)	%clay	%silt	% sand	texture	BD (gm/cm3)	FC (%)	PWP (%)
0-30	44.5	29.7	25.8	clay	1.2	38	27
30-60	44.15	20.1	35.8	clay	1.3	40	26
60-90	44.7	20.45	34.9	clay	1.4	39	27.2
average	44.5	23.4	32.1	clay	1.3	39	26.7

Table 1: Soil physical properties.

From double ring infiltrometer test basic infiltration rate of soil (I) at experimental site was 0.1mm/min and the coefficient and exponent of developed kostiakov Equation were 4.583 and -0.953, respectively. Basic infiltration rate was important to monitor irrigation water application at the time irrigation and developed equation will be used to estimate depth of water that infiltrate into the soil profile with specific infiltration time.

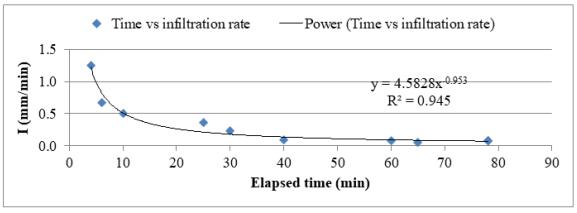

Figure 2: soil infiltration characteristics curve.

Reference evapotranspiration

From Cropwat model, reference evapotranspiration of the experimental site was varies from 3.31-4.93mm/day with 3.95mm/day average value. The minimum and maximum reference evapotranspiration were observed on July and March. This result show that minimum and maximum crop water requirement need at month July and March, respectively.

month	Min Temp °C	Max Temp °C	Humidity °C	wind km/day	Sun hours	Rad MJ/m2/day	Eto mm/day
January	13.2	33.3	29	33	10.3	23.3	3.93
February	17.7	34.2	40	43	8.4	21.6	4.25
March	19.6	35.5	43	42	9.5	24.2	4.93
April	18.9	34.1	47	49	8.5	22.5	4.81
May	19	30	60	30	7.9	20.6	4.12
June	19	30	60	40	7.3	19.5	3.9
July	18.9	30.2	52	38	4.4	15.4	3.31
August	19	29.2	55	38	4.9	16.6	3.52
September	18.1	29.7	54	26	6.3	19	3.74
October	18.3	29.6	56	23	5.4	17.2	3.46
November	15.8	30.5	57	22	8.5	20.9	3.77
December	13	31.8	49	28	9.2	21.3	3.62
Average	17.6	31.6	48	34	7.5	20.2	3.95

Table 3: Monthly reference evapotranspiration.

Crop evapotranspiration and reference evapotranspiration

Reference evapotranspiration of crop cross ponding with its growth stage was evaluated by using Cropwat model that was summarized in the following Figure. The maximum reference evapotranspiration was observed at mid stage each crop that indicates that stages have maximum duration through crop period [7]. Crop evapotranspiration from lysimeter through the base period of crop was summarized in the following Table.

Crop type	Crop growth stages	Duration (days)	Crop ET (mm)	ETO (mm)
Wheat	Initial	20 (1-20 days after sowing)	23	78
	Development	25 (21-45 days days after sowing)	77	97.5
	Mid-season	60 (46-105 days days after sowing)	247.6	234
	late -season	30(106-165 days days after sowing)	65	128
Maize	Initial	20 (1-20 days after sowing)	19.3	78
	Development	35 (21-55 days days after sowing)	188	198
	Mid-season	40 (56-95 days days after sowing)	198.9	188
	late -season	30(96-125 days days after sowing)	67	117
Pepper	Initial	30 (1-30 days after sowing)	61.8	117

	Development	35 (31-65 days days after sowing)	78.2	137
	Mid-season	45 (66-110 days days after sowing)	185.4	178
	late -season	20(111-130 days days after sowing)	67.5	80
Onion	Initial	20 (1-20 days after sowing)	38	83
	Development	45 (21-65 days days after sowing)	98.8	186
	Mid-season	20 (66-85 days days after sowing)	67	78
	late -season	20(86-105 days days after sowing)	51	76

Table 4: Seasonal crop and reference evapotranspiration.

Crop coefficient

The average bias of crop coefficients of the wheat, maize, pepper and onion were .4.0%, -12.9%, -7.1% and -32.0%, respectively. This result show that measured and FAO value of crop coefficients have very poor relationship for onion crop this may be due climate and soil condition of experimental area [8].

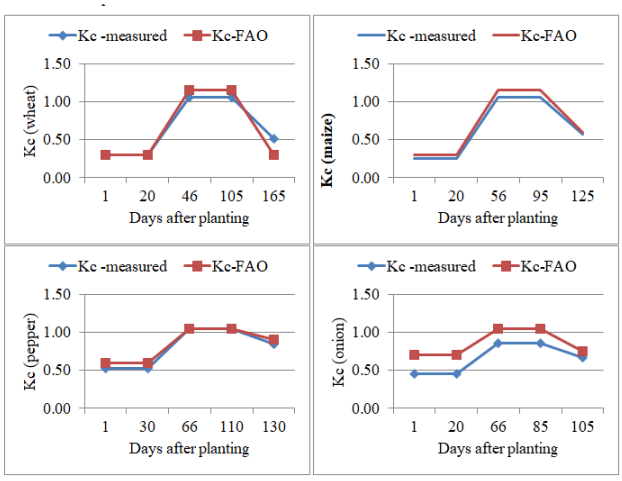

Figure 4: Stage based crop coefficients.

Land and water productivity

The average land and water productivities of wheat, maize, pepper and onion were 2.2ton/ha and 0.7kg/m3, 2.8ton/ha & 1.1kg/m3, 11ton/ha & 2.2kg/m3 and 9.6ton/ha & 1.8kg/m3, respectively. Based on this result, the most productivity crop in the area was pepper but productivity of wheat was too less compare with other crops [9].

Conclusions and Recommendation

The relationships between measured and recommended value of crop coefficient of the wheat, maize, and pepper approximately related but for onion crops were very poor. Therefore, to manage irrigation water for all above crops except onion, recommended value is reasonable to use in irrigation practice.

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