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Research Article

Developing of crop coefficient model with growth degree days and crop wat based water deficit sensitive growth stage for different crops 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 develop crop coefficient model from growing degree days for wheat, maize, pepper and onion crops. To estimate crop coefficients, crop evapotranspiration was measured by using soil water balance Equation after measuring of soil water content before and after irrigation and reference evapotranspiration also observed from automatic climate station that install near the experimental area through the crop growth stage.

Total seasonal crop evapotranspiration and reference evapotranspiration of the wheat, maize, pepper and onion crops were 412.6 and 537.5 mm, 473.2 and 581 mm, 392.9 and 512 mm and 321.8 and 501 mm respectively. Polynomial degree four, three, five and three are the best fit Equation to predict crop coefficients from daily basis growth degree days with R^2 are 0.93, 0.92, 0.96 and 0.94 for wheat, maize, pepper and onion crops respectively.

Keywords: Crop coefficient, Growth stage, Growth degree days, Evapotranspiration, Irrigation

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. Crop coefficients mostly evaluate directly by weighing and non-weighing lysimeter [2]. But that may not available in very remote area to measure crop Evapotranspiration (ETC) that challenges practice of irrigation water management and scheduling. To solve this problem growth degree days and indirect soil water balance methods of crop coefficient estimation are very important and the temperature will consider in crop growing period [3].

Growing degree days based crop coefficient evaluation is based on environmental climate condition and minimum base temperature of the crop due to that this method is more adaptably and accuracy. Therefore the research was conduct develop crop coefficient model based on growth degree days of the crop [4].

MATERIALS 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 37.6^0 E (Figure 1).

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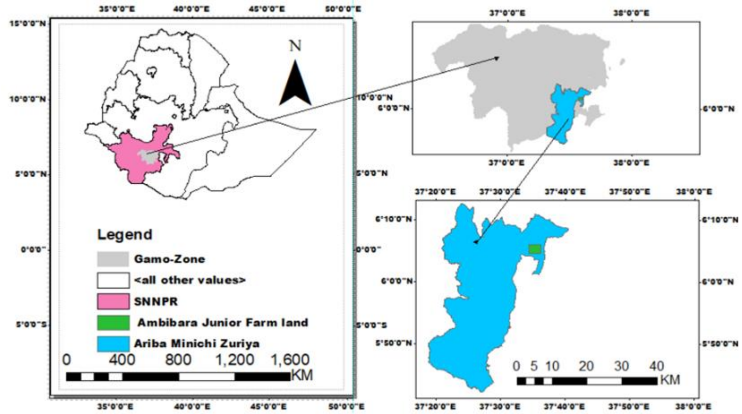

Figure 1. Location of the study area.

Climate

Based on agro ecological climate zone classification; the Climate zone of the experimental site is kola (dry climate). Average climate data of study was described based on 31 years record Climate data that was from (1990-2020) [5].

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 650 mm (Figure 2).

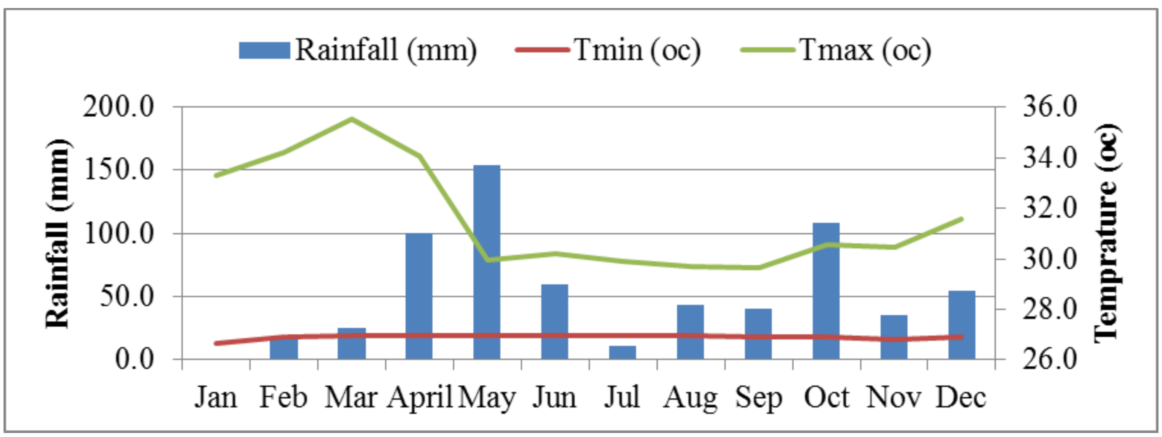

Figure 2. Average monthly minimum temperature, maximum temperature and rainfall.

Experimental plot design

Experiments were conduct for maize, wheat, pepper and onion under full irrigation methods. Total experimental plots were fixing 3 m x 5 m size for the wheat and maize. Lengths and width of furrow for onion and paper crops were 10 m and 6 m with 1.5 m and 1 m center to center furrow spacing, respectively and all experiments were conducted with three replications [6].

Soil physical properties and sampling

Soil sample was collect at 90 cm soil depth with 30 cm depth interval to analysis soil physical properties. 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 and it was used to determine volumetric water content of soil [7].

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

Field capacity and permanent wilting point of soil were evaluated by using pressure plate apparatus from Hawassa agriculture research center (Figure 3).

Figure 3. 1 is hydrometer test and 2 is soil oven dry.

Average basic infiltration rate from the experiment was estimate by using double ring infiltrometer to estimate the Run off (RO), occurring whenever rain intensity or irrigation infiltration rate exceeds the infiltration capacity of the soil [8].

Reference evapotranspiration

Daily reference evapotranspiration was observed from an automated weather station located near the experimental area. 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 [9].

Crop Evapotranspiration (ETc)

Field water balance method

Total irrigation applied to the field time to time in order to bring the soil moisture level to field capacity was measured by using RBC flume. Soil water content before to determine soil water depletion and after irrigation to determine soil water storage were measured by calibrated Time Domain Reflector (TDR) instrument according the effective root depth of the crops. TDR was calibrated with gravimetric soil water content that was measured with oven dray method.
Based on the crop Evapotranspiration (ETc) was determined from the water balance Equation, which was based on the mass conservation law and the total water applied to field that include irrigation and rainfall.

ETc=Wa+ETc1-R-DP-S (2)

Where: Wa: applied water depth (mm); ETc1: crop evapotranspiration for one day after next irrigation (mm) a R: runoff (mm); Dp: Deep percolation (mm); S: Soil water storage.

Crop coefficient (kc)

Crop coefficients were evaluated at initial, development, mid and late stages of growth period and it was calculated based on Allen, et al.

$$Kc = \frac{\text{Crop evapotransparation (ETC)}}{\text{Reference evapotranspiration (ETo)}} \quad \ldots\ldots (3)$$

Growing degree days

Growing Degree Days (GDD) is the accumulation of the Growing Degree Days (GDD), which is a cumulative temperature that contributes to plant growth during the growing season and is expressed as follows:

$$CGDD = \sum_{i=1}^{n} \frac{Tmax + Tmin}{2} - Tbase \quad \ldots\ldots (4)$$

Base temperature (T_{base}) is the minimum the temperature at which crop can be adapted or growing and below that temperature crop can't grow on the environment and that varies with crop type. All temperature such as maximum, minimum and base temperature were considered during crop growing period [10].

Agro meteorological index

Heat Use Efficiency (HUE) and Photo Thermal Index (PTI) are the most agro meteorological index that was express according which indicates the amount of crop yield produced per unit of growing degree days.

Heat use efficiency=Y/CGDD (5)

Where: Y: Grain yield (Kg/ha); CGDD: Cumulative Growing Degree Days (oC day); PTI: Photo Thermal Index

Photo thermal index=CGDD/(Growing days) (6)

RESULTS 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 1.3 gm/cm^3, 39% and 26.5%, respectively as discussed in the Table 1.

Table 1. Soil physical properties.

Depth (cm)	%clay	%silt	% sand	Texture	BD (gm/cm^3)	FC (%)	PWP (%)
0-30	44.5	29.7	25.8	clay	1.2	38	27
30-60	44.10	20.1	35.8	clay	1.3	40	26
60-90	44.7	20.40	34.9	clay	1.4	39	27.2
average	44.5	23.4	32.1	clay	1.3	39	26.7

Soil characteristics was describe with it depth as presented in the Figure 4 and basic infiltration rate was used as saturated hydraulic conductivities. Total available water was estimated by subtracting permanent wilting point from field capacity and average value for layer 1, layer 2 and layer 3 were 110 mm/m, 144 mm/m and 123 mm/respectively. Total available soil water content was used to monitor irrigation scheduling to apply irrigation water to the field [11].

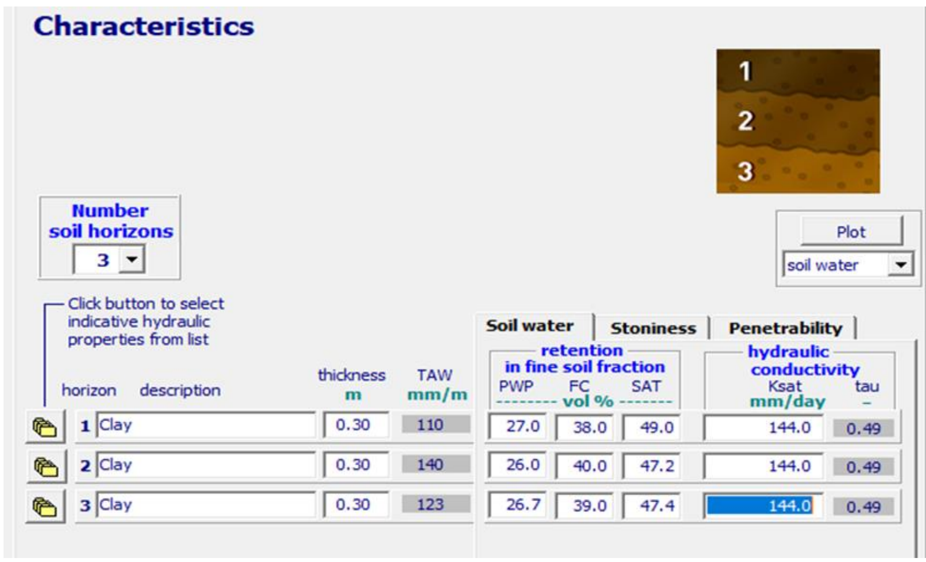

Figure 4. Soil profile.

From double ring infiltrometer test basic infiltration rate of soil (I) at experimental site was 0.1 mm/min and the coefficient and exponent of developed kostiakov Equation were 4.583 and 0.953, respectively [12]. 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 5).

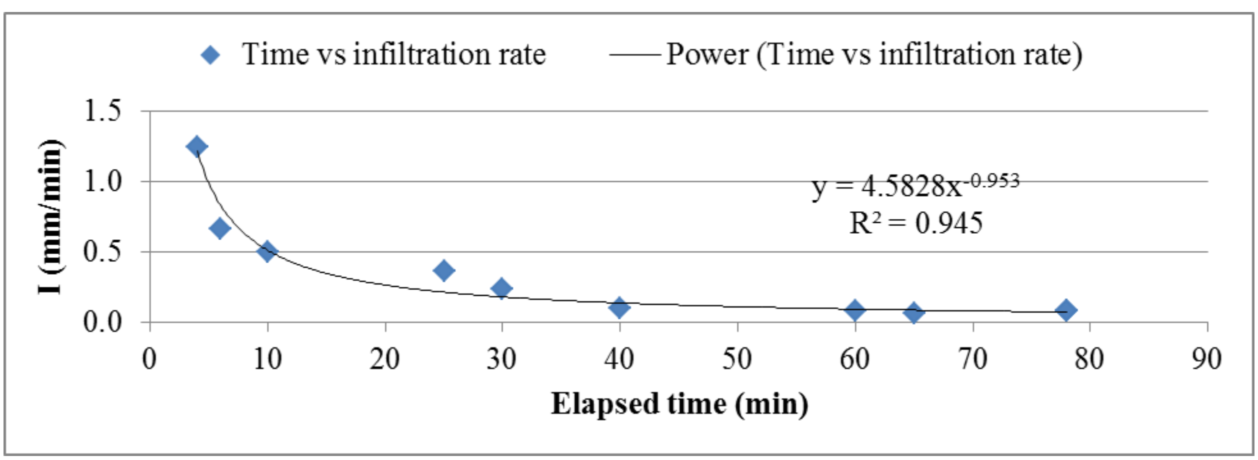

Figure 5. Soil infiltration characteristics curve.

Reference evapotranspiration and crop evapotranspiration

Reference evapotranspiration of crop cross ponding with its growth stage was evaluated by using automatic climate station logger and crop evapotranspiration was measured from field soil water balance equation through the base period of crop.

(Figure 6).

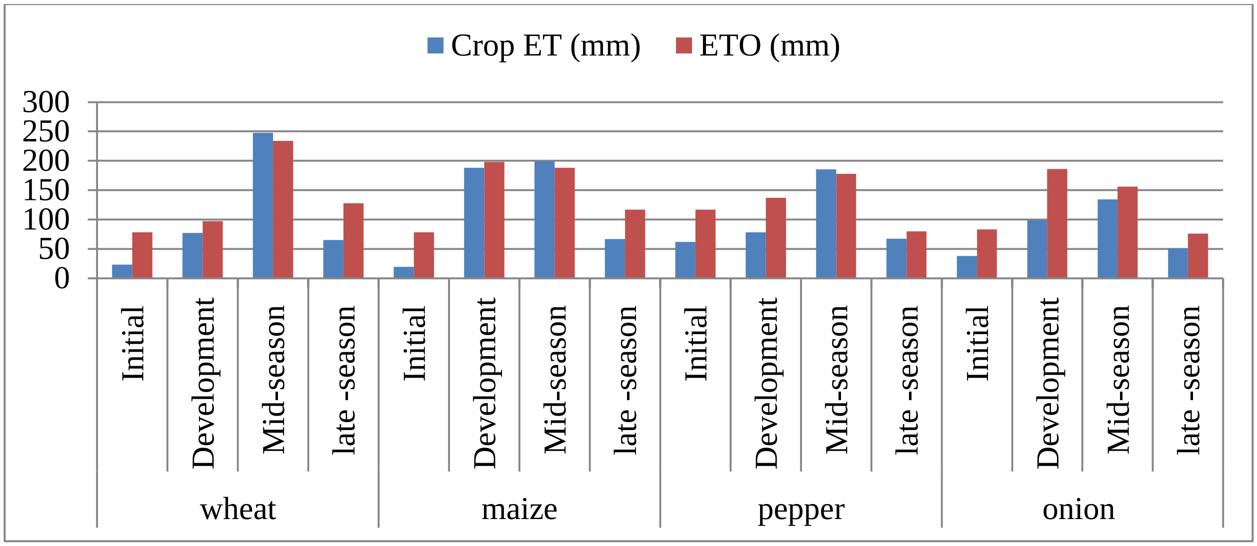

Figure 6. Seasonal crop and reference evapotranspiration.

Polynomial degree four, three, five and three are the best fit equation to predict crop coefficients from daily basis growth degree days for wheat, maize, pepper and onion crops respectively. Growing degree days based crop coefficient can help in better estimation of crop evapotranspiration that will helps to improved irrigation management practice under the upcoming climate change (Figure 7).

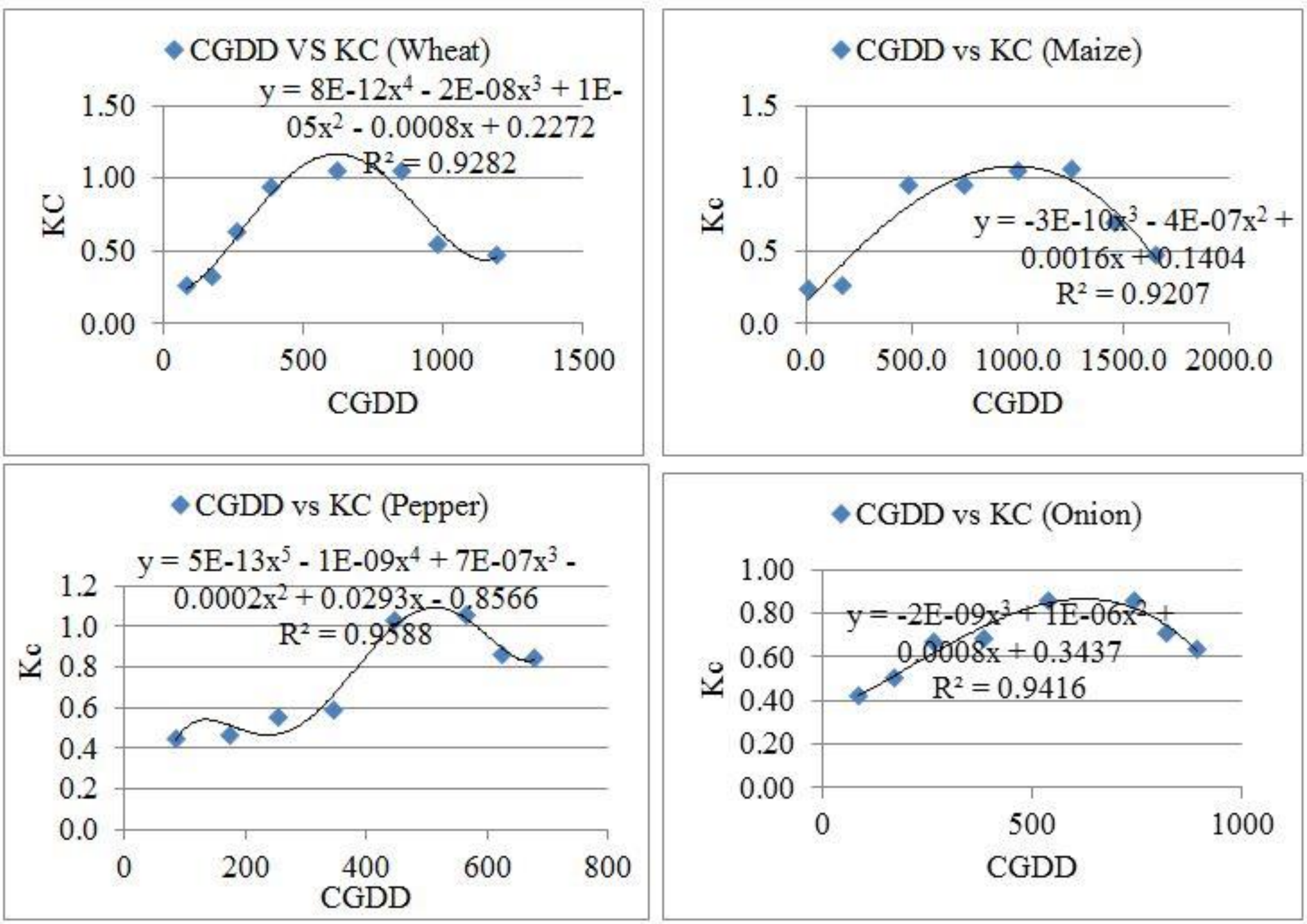

Figure 7. Crop cofficient model.

Heat use efficiency and photo thermal index

Wheat crop was have very low heat use efficiencies and photo thermal index also very high compare with other crops and that result show that the wheat crop may not adapted for semiarid climate zone. Heat use efficiency of pepper crop was high compare with other crops and crop yield also high. This result show that temperature was optimum throughout the growing period; it utilized heat more efficiently and increased biological activity that shows higher yield of the crop (Table 2).

Table 2. Utilized heat more efficiently and increased biological activity that shows higher yield of the crop.

Crop	Crop duration (days)	CGDD (ºC/day)	Yield (kg/ha)	HUE (kg/ha/ºC)	PTI (ºC/day)
Wheat	145	1195.75	232.023	0.1940	8.246552
Maize	125	1650.20	2055.90	1.2458	13.2016
Pepper	130	676.75	3034.90	4.4845	5.205769
Onion	110	895.50	2382.40	2.6604	8.140909

Based on Figure 5; yields have positive and negative linear relationship with heat use efficiencies and photo thermal index respectively. The relationship between yield and photo thermal efficiencies very poor but yield with heat use efficiencies have high positive relationship with R^2=0.81 (Figure 8).

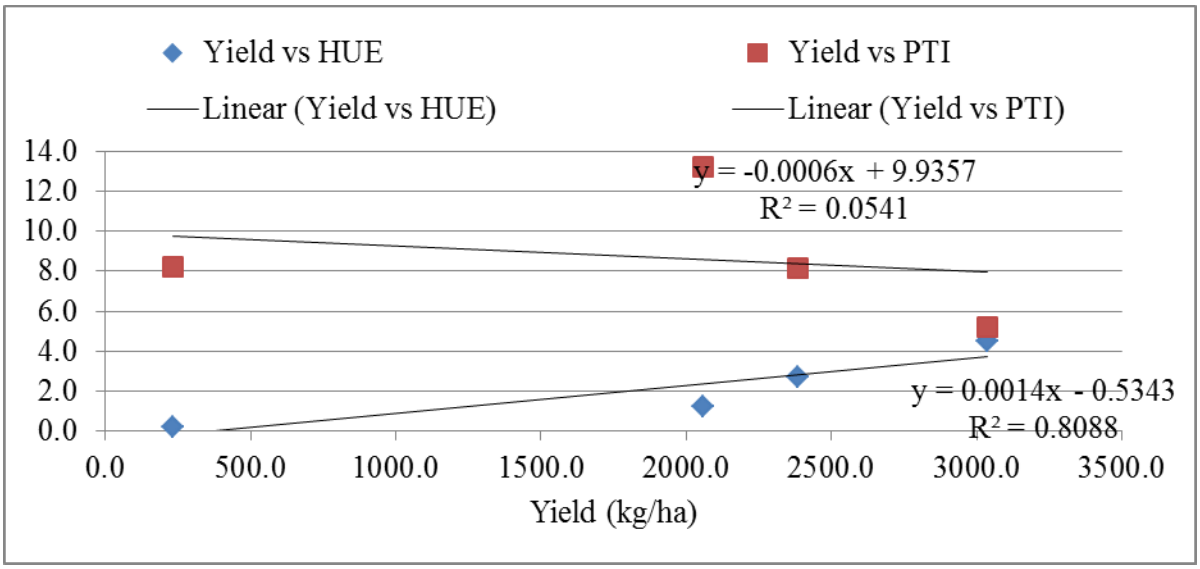

Figure 8. Relationships of the crop with heat use efficiencies and photo thermal index.

CONCLUSION

Polynomial functions were the most important crop coefficient model in semi-arid climate zone that were varies with crop type. To manage irrigation water management growing degree days based crop coefficient evaluation is very important to develop irrigation scheduling in semiarid climate.

Acknowledgments

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REFERENCES

1. Abdulla D, Diku A, Hyseni B (2015). Use of CROPWAT 8.0 Program for the Assessment of Water Demand of some Agricultural Crops in Albania. Int J Sci. 4:1-7.
2. Abedinpour M (2015). Evaluation of Growth Stage Specific Crop Coefficients of Maize Using Weighing Lysimeter. Soil and Water Res. 2(10): 99–104.
3. Allen RG, Pereira LS, Raes D, Smith M (1998). Crop evapotranspiration Guidelines for computing crop water requirements. 1st edition. Rome: FAO, Italy.
4. Amrawat T, Solanki NS, Sharma SK, Jajoria DK, Dotaniya ML (2013). Phenology growth and yield of wheat in relation to agrometeorological indices under different sowing dates. African J Agric Res. 8:6366-6374.
5. Blake G (1965). Bulk density in Methods of Soil. Agron.
6. Ranaa G, Katerji N (2000). Crop evapotranspiration measurements and estimation in the Mediterranean region. Europ J Agronomy. 13:125–153.
7. Garcı´a-Tejero IF, Lo´pez-Borrallo D, Miranda L, Medina JJ, Arriaga J, Muriel-Ferna (2018). Estimating strawberry crop coefficients under plastic tunnels in Southern Spain by using drainage lysimeters. Sci Hort. 231:233–240.

8. De Medeiros GA, Daniel LA, Fengler FH (2016). Growth, Development, and Water Consumption of Irrigated Bean Crop Related to Growing Degree Days on Different Soil Tillage Systems in Southeast Brazil. Int J Agron. 2016: 1-8.
9. Montazar A, Rejmanek H, Tindula G, Little C (2017). Crop Coefficient Curve for Paddy Rice from Residual Energy Balance Calculations. J Irrig Drain Eng. 143:0001117.
10. Moriasi DN, Amold J, Van Liew MW, Bingner RL, Harmel RD, Veith TL (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Trans ASABE. 50:885–900.
11. Sammis TW, Mapel CL, Lugg DG, Lansford RR, McGuckin JT (1985). Evapotranspiration crop coefficients predicted using growing degree days. Trans ASAE. 28:773–780.
12. Trout TJ, DeJonge KC. (2018). Crop Water Use and Crop Coefficients of Maize in the Great Plains. J Irrig Drain Eng. 144:0001309.