FORECASTING CROP WATER REQUIREMENT BY ET-HS MODEL FOR ARID AND SEMI ARID REGION OF IRAN

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Abstract: Estimating actual crop water requirement and irrigation schedule are essential for designing of the irrigation systems, storage construction and water conveyance structures. Many models have developed for estimating crop water requirement. Although most of these methods need different climatic parameters, providing and forecasting all of these parameters always are not available. Most of the time, some of these forecasted parameters are incorrect, through of these the maximum and minimum temperature are more accurate. In addition, temperature is the most affective factor on evapotranspiration in arid and semi-arid region. In this paper, ET-HS has been presented which after calibration by regional factors, could be predicted the time of irrigation. This model only needs daily maximum and minimum temperature for this prediction.

Keywords: model, forecasting, crop water requirement, irrigation schedule, evapotranspiration, arid and semi-arid region

1. INTRODUCTION

By the increase of the world population especially in the developing countries has caused serious lacking of food. In addition, the situation which causes climate changes and repeated droughts in recent years have resulted that fresh water became scarce. The shortage of surface fresh water has caused anomalous usage of ground water resource (Arvandi and Kamyab-Moghadas, 2001). In these conditions, calculating evapotranspiration, accurate plants water requirement (CWR) and prediction of irrigation schedule has a great deal of importance for saving water resource.

A large number of scientists have developed numerous equations to compute potential evapotranspiration (ET_0) during the last 50 years (Allen et al., 1998). These equations range from the most complex energy balance equations requiring detailed climatological data (Allen et al., 1998) to simpler equations requiring limited data (Samani 2000). Some of the studies showed that the radiation and temperature methods could estimate ET_0 better than other methods, especially in arid and semi-arid regions (Najafi and Tabatabaei, 2007). Among the numerous methods, the Hargreaves-Samani is ones that having a global validity and estimating ET_0 based on temperature. Najafi et al. (1999) compared several methods for estimating ET_0 with actual evapotranspiration data for reference grass in Isfahan, IRAN. They concluded that the Hargreaves-Samani could be satisfactorily used to estimate potential evapotranspiration in Isfahan, IRAN. Najafi and Tabatabaei (2005) improved the Hargreaves-Samani for arid and semi-arid region. ET-HS is a model which used improved Hargreaves-Samani equation and was developed by Najafi (2002). Najafi and Mousavi (2002) compared CropWat and ET-HS computer models based on grass lysimeter data in 10 different arid and semi-arid regions of Iran and concluded that estimation of ET_0 using ET-HS model was more precise than CropWat.

The objective of the present paper is the description of ET-HS method which is suitable model for the evaluation of daily water consumption, actual crop evapotranspiration (ET_C) and irrigation schedule of crops during the crop growth period in arid and semi-arid region.

2. METHOD

2.1 Potential Evapotranspiration

In this model, four equations have presented for estimating the ET_0. The equations have selected based on regional wind speed (W) condition and after that the model checks the ET_0 value. If the ET_0 is more than 6mm/day, the model recalculates the ET_0 by another equation. The Figure 1 shows the process of ET_0 calculating in ET-HS model.

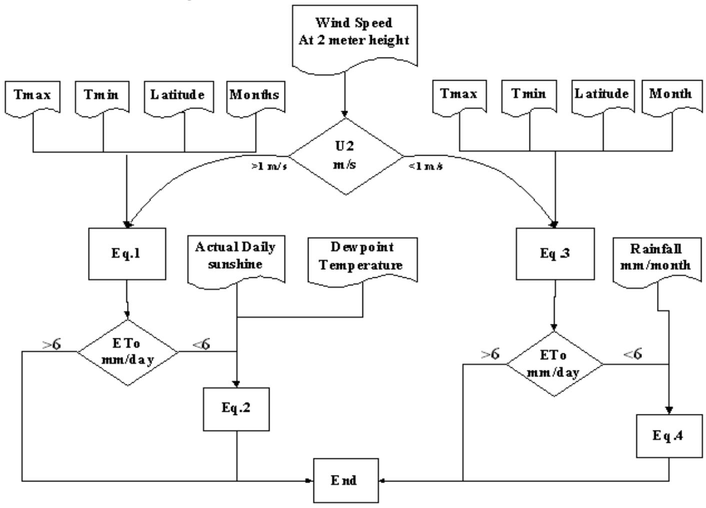

Fig.1: ET-HS model for estimating Potential Evapotranspiration

In case that W<1 m/s, Najafi (2002) improved Hargreaves-Samani for arid and semi-arid region of IRAN as eq. 1:

$$ET_0 = 0.002 \times R_A \times TD^{0.5} \times (T_a + 17.8) + 0.4 \qquad (1)$$

Where, R_A; is Extraterrestrial radiation [mm/d], $TD=T_{max}-T_{min}$, $Ta=(T_{max}+T_{min})/2$ and T_{max} and T_{min} are daily maximum and minimum Temperature [^{0}C]. If after in above equation, ET_0 has been more than 6 mm/d, the model recalculates ET_0 by eq. 2:

$$ET_0 = 0.0077 \times K_{RS} \times R_A \times [T_{max} - T_d)]^{0.5} \times (T_a + 17.8) \qquad (2)$$

Where, T_d is dew point temperature. In each location, it could be found a linear regression between minimum temperature and dew point temperature. In addition, K_{RS} is Hargreaves-Samani Coefficient which could be calculated in each an area by location long term values of ratio actual daily sunshine and measurement daylight hours. This linear regression, it must be inputted as a calibration factor before starting model.

In case that the W>1m/s, the model presented eq. 3:

$$ET_0 = 0.0025 \times R_A \times TD^{0.5} \times (T_a + 17.8) - 0.42 \qquad (3)$$

If after in above equation, ET_0 has been more than 6mm/d, the model recalculates ET_0 by eq. 4:

$$ET_0 = 0.001 \times R_A * (T_a + 17) * [(T_{max} - T_d) - 0.0123 * P]^{0.76} + 1.5 \quad (4)$$

Where, P; is precipitation [mm/day].

2.2 Actual crop evapotranspiration

ET-HS model calculates actual plant evapotranspiration with consideration irrigation water quality and soil moisture condition. In addition, the irrigation system and evaporation from soil surface are the others parameters which must be considered in ETc. For this way, the following equation has presented:

$$ETc_{0(i,j)} = (Ks_{(i,j)} * Km_{(i,j)} * Kcb_{(i,j)} + E/q * Ke_{(i,j)} * ET0_{(i,j)} \quad (5)$$

Where, Ks; is salinity stress coefficient [-], Km; soil water stress coefficient [-], Kcb; basal crop coefficient [-], E/q; evaporation losses [mm/mm](this parameter directly relates to irrigation system) , Ke; soil evapotranspiration coefficient [-] and ET_0; reference evapotranspiration (mm/day). i; number of the day after recent irrigation and j; number of the day in growing season. Each of above mention factors are estimated daily based on regional input information which presented in Figure 3.

2.3 Readily available water

Based on this model, irrigations were achieved when total crop water requirement in i day after recent irrigation were equal or less than readily available water at day i in irrigation period $\sum_0^i CWR(i,j) \geq RAWj$. RAW equation is:

$$RAW_j = \frac{1000 MAD_j(\theta_{FC} - \theta_{PWP})Z_j}{4WU_{cq}} \quad (6)$$

Where, MAD is maximum allowable depletion [percent], θ_{FC}; volumetric soil water content at field capacity [m^3 m^{-3}], θ_{PWP}; volumetric soil water content at wilting point [m^3 m^{-3}], Z; crop root zone [m], WU_{cq}; moisture extraction pattern for critical quarter of crop root zone [percent], i; number of the day after recent irrigation and j; number of the day in growing season.

2.4 Crop water requirement

Daily plant crop water requirement estimates as follows:

$$CWR_{(i,j)} = \frac{ETc_{(i,j)}}{1 - \max(LR_{EC}, LR_{SAR}, LR_{Ci})} \quad (7)$$

Where, LR_{EC}, LR_{SAR} and LR_{CL} are leaching requirement for salinity, sodium absorption ratio and chloride , respectively . In the above equation the maximum leaching requirement selects for calculating CWR.

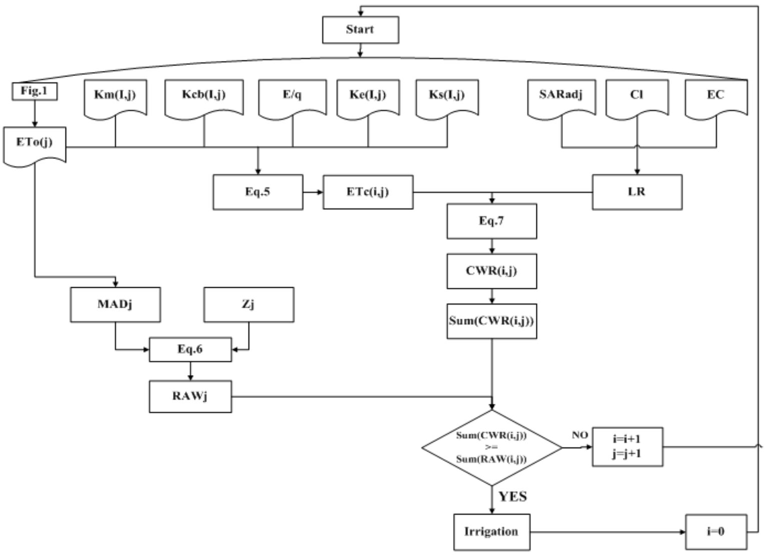

Fig.2: ET-HS model.

2.5 Regional input Data for calibration model

Before starting the application model in each area, It must be inputted some parameters for calibration the model. The parameters are classified into four groups. The first group is included basal crop coefficient (Kcb), maximum effective rooting depth, planting date and lengths of crop development stages (L). If these values for selected crop are not available on an area, these could be found in FAO No. 56 (Allen et al., 1998). Based on these initial information, the generalized crop coefficient curve and effective rooting depth curve through the four growth stages (Allen et al., 1998) are drown and arrived into calculating process.

The second group of input values is irrigation water quality indexes as description on Fig. 3. These parameters are arrived to actual crop evapotranspiration (eq. 5) and crop water requirement (eq. 7) estimating process. The thrid group is soil physical parameters which is essential for computing RAW (eq. 6). The fouth group is climatic and geographic data which intoduced as "*Regional Condition*" in Fig. 3. Climatic parameters can be collected from values of synoptic stations database through several years ago.

2.6 Daily Input Data

After inputting the different regional information into the model, for calibration, the model is ready to start. For forecasting irrigation schedule and amount of irrigation water, the model only needs two parameters. These two parameters are daily maximum and minimum temperature (Fig. 3). Temperature parameter is the most accurate climatic factor which is forecasted by meteorology organizations; therefore the model could be very successful to predict irrigation event and CWR through future days. This is very important for saving water, especially in arid and semi-arid region, where the fresh water is scarce.

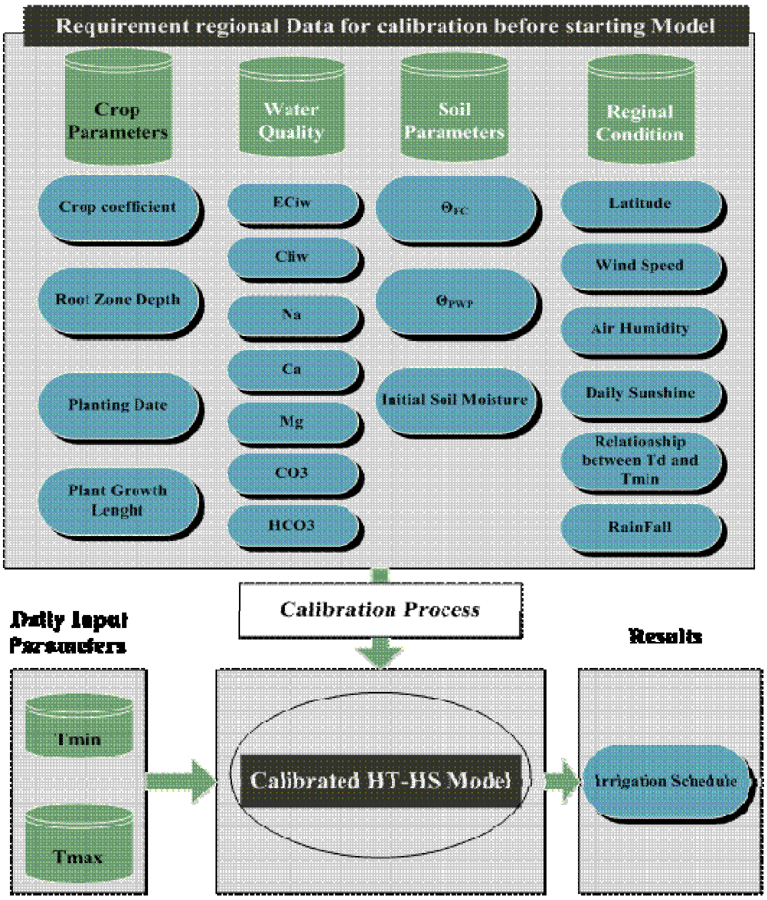

Fig.3: ET-HS process for estimating irrigation schedule.

3. CONCLUSION

Many methods were presented for irrigation water management through several recent years. But most of these have not suitable response to predict amount of irrigation water in arid and semi-arid region. These methods require wide different weather parameters while accurate measurement all of these factors is very difficult. In addition, some of studies indicated that the temperature provide satisfactory estimate of ET_0 for Middle East arid and semi-arid region. Furthermore, among of climatological factors, temperature has a highest accurate in forecasting sites.

ET-HS is estimating amount of irrigation water and irrigation period with minimum climatological variable. Weather parameters, crop characteristics, management and environmental aspects are factors affecting on crop evapotranspiration and irrigation water requirement. In ET-HS model, these parameters as constant factors are arrived to the model and after calibration model, with using daily maximum and minimum temperature as variable factors, it's predicted irrigation event and water requirement for selected crop.

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