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The Ways of Increasing Efficiency of Crop Irrigation Management with the Help of Automatic Weather Stations and ET Gages

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Abstract

The key condition of the efficient use of the Republic of Armenia (RA) water resources and sustainable management is to specify crop water requirement for carrying out due irrigation by using innovative technologies and techniques. With this aim by FAO method we calculated the design water requirement of spring wheat for vegetation period based on the recent 5-year data provided by the RA 3 fixed hydro meteorological stations and readings recorded by 3 automatic weather stations.The Kc coefficient was determined under permanent and dual-factor conditions. The crop design water requirement was determined for 3 regions, the obtained values were assessed according to the vegetation days under permanent and dual-factor conditions. The obtained results can help apply innovative approaches while specifying the irrigation and water consumption regimes under the RA conditions that allows increasing the efficiency of crop irrigation and water resource conservation. Considering the urgency of increasing the intra farm water use efficiency, the correlation was constructed between the readings of potential evapotranspiration measured by the ET gage and the data obtained from the automatic weather stations.

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Keywords: Automatic weather station; dual crop coefficient; evapotranspiration; ET gage; irrigation

1. Introduction

About 68 % of the Republic of Armenia (RA) water resources are used for irrigation, and the rest 32 % - for domestic and industrial water supply, fishing industry. The investigations in the irrigation sphere show that the coefficient of irrigation water use efficiency ranges within 0.47-0.62, as a result in 2013 the irrigated land surface area, in comparison with 1989, reduced by 29.7%, making up 207.9 thousand hectare.

In the Republic the irrigation management is carried out by 44 water user associations (WUAs). Sometimes, the problem solutions by conventional methods bring forth some disagreements between the WUAs and water consumers. It was revealed that approximately in all WUAs and farms of the RA the determination of irrigation rates, frequency and dates is carried out by off-base methods, without control, based on random and visual observations, neglecting the agro technical rules. Currently, in the Republic the technological management of irrigation process is based on the crop irrigation regimes developed for various water availability levels (25,50,75,95%), that, in general, provide positive outcomes for big projects or long-term predictions.

Thus, the operation of irrigation system under such regimes on the small farms, which represent the current condition in the Republic of Armenia, leads to a number of the social economic and environmental problems (salinization of 35 thousand hectare lands, 67000 hectare of irrigated lands left idle, 20000 hectare lands were subjected to over wetting, waterlogging, etc). The overall evaluation of the situation revealed that, though, a considerable governmental support is annually allocated for the WUAs and water consumers, either the WUAs or water consumers are dissatisfied, even the RA government that funds them.

One of the main reasons of such situation is that there is no appropriate regulation of water use in vegetation period adequate to the newly established land use and multi-ownership. Nowadays the crop water requirement, based on the current normative documents on crop irrigation, is calculated considering only the data of the air temperature and relative humidity, the results of which, in case of averaging, do not meet the requirements of efficient management of the separate rural intra- and inter farm water use. To solve the abovementioned problem it’s for the first time in the RA the investigations have been carried out by FAO method under the Republic natural conditions. The prevalence of this method over the previous one used in Armenia is that the crop water requirement is specified taking into account the net radiation at the crop surface, soil heat flux, air temperature, wind speed and direction, saturation vapor pressure, actual vapor pressure, maximum and minimum, maximum and minimum air relative humidity, soil temperature, rainfalls, geographic coordinates.

2. Materials and methods

To carry out the research work we use the FAO Penman-Monteith equation the data required for which were provided by the RA fixed hydro meteorological stations and automatic weather stations placed in the Republic 3 regions involving 2009-2013 period, as well as the readings of the ET gages due to which we immediately calculated the crop daily water requirement during the whole vegetation period.

To calculate the crop water requirement the following equations were used [1, 2, 3, 4]:

$$ET_c = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}U(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

$$ET_c = K_c \cdot ET_0 \quad (2)$$

where ETo - 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- air temperature at 2 m height [°C], U_2 wind speed at 2 m height [m s^{-1}], e_s -saturation vapor pressure [kPa], e_a - actual vapor pressure [kPa], e_s-e_a - saturation vapor pressure deficit [kPa], Δ slope vapor pressure curve [kPa $°C^{-1}$], γ - psychometric constant [kPa °C-1], ETc - crop evapotranspiration [mm d^{-1}], Kc- crop coefficient [dimensionless] [1].

The values of Kc coefficient were determined for 2 conditions. For the first case the single crop is considered, for the second - dual crop. For the second case the Kc coefficient was deduced from the following equation [2].

$$K_c = K_{cb} + K_e \quad (3)$$

Where Kcb - basal crop coefficient, Ke - soil evaporation coefficient:

Kcb coefficient was determined by the following equation:

$$K_{cb} = K_{cb(Tab)} + [0.04(U_2 - 2) - 0.004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0.3} \quad (4)$$

Where K_{cb} – basal crop coefficient, the values of K_{cb}(tab) are introduced in the table form [1], so, we chose from the table subject to the crop species, U_2 - wind speed, RH_{min} – minimum air relative humidity, h – the crop height.

Ke was determined according to the mathematical condition:

$$K_e = K_r(K_{cmax} - K_{cb}) \leq f_{ew} \cdot K_{cmax} \quad (5)$$

where K_e - soil evaporation coefficient, K_{cb} - basal crop coefficient, $K_{c\,max}$ - maximum value of K_c -following rain or irrigation, K_r - dimensionless evaporation reduction coefficient dependent on the cumulative depth of water depleted (evaporated) from the topsoil, f_{ew} - fraction of the soil that is both exposed and wetted, i.e., the fraction of soil surface from which most evaporation occurs.

3. Results

The research was carried out in 2009-2013 based on the data provided by the RA Ashtarak, Voskehat and Dzoraghbyur hydro meteorological fixed stations and automatic weather stations. The spring wheat crop was used as a case study. According to the accepted method the crop coefficients were calculated considering single and dual crop cases. The results are introduced in figures 1,2,3,4,5,6 and 7.

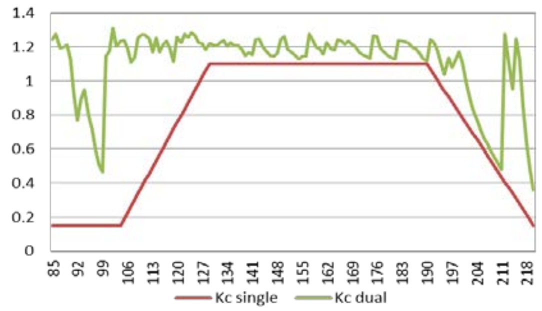

Figure 1. Daily single and dual crop coefficients for spring wheat in Voskehat weather station.

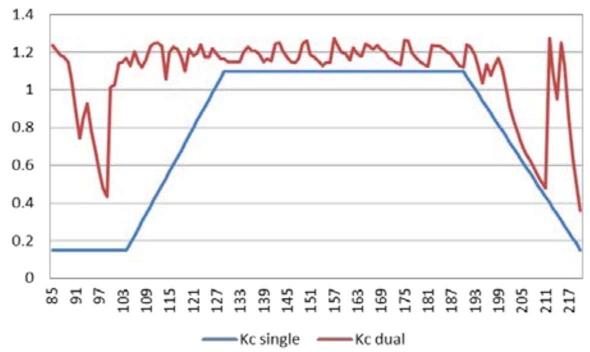

Figure 2. Daily single and dual crop coefficients for spring wheat in Ashtarak weather station.

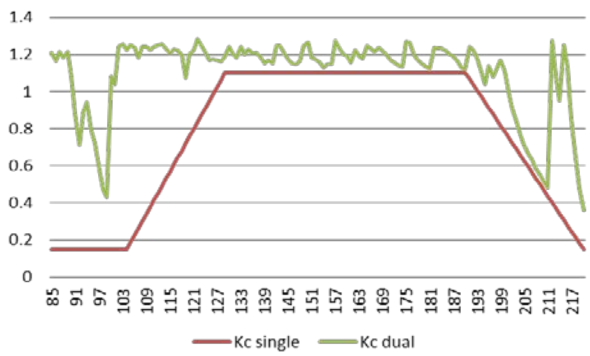

Figure 3. Daily single and dual crop coefficients for spring wheat in Kotayk weather station.

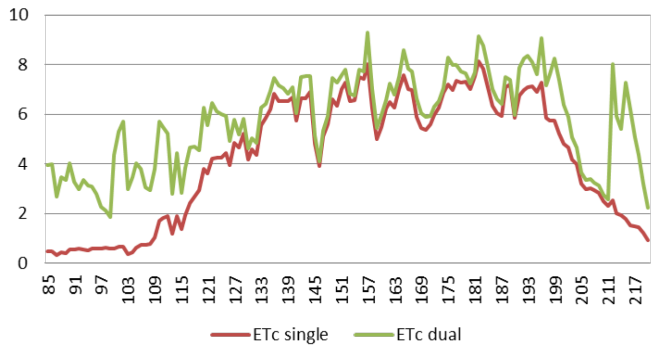

Figure 4. Daily crop water requirement for spring wheat in Voskehat region.

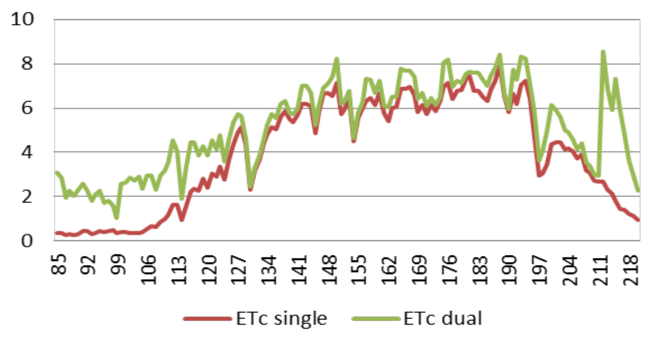

Figure 5. Daily crop water requirement for spring wheat in Ashtarak region.

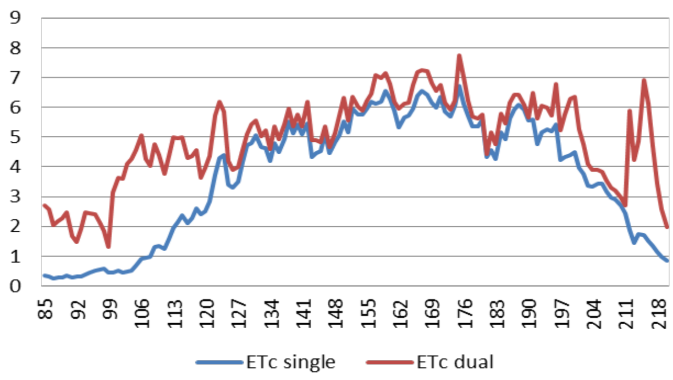

Figure 6. Daily crop water requirement for spring wheat in Kotayk region.

Considering the actual problems of irrigation process sustainable management and irrigation water rational use the crop evapotranspiration was measured also by the ET gages. The ET gage is equipped with ceramic head covered with flax green canvas cover and attached to it vessel filled with distilled water. For single filling 2 litres water is require. The ET was mounted in the unshaded part of the spring wheat field. The evaporated water amount was measured by the side vessel providing 0.1 mm accuracy readings [5, 6]. We took into consideration that while using the readings taken by the ET gage, the amount of rainfalls of the same period is to be deducted which value is measured by the designed for this special device attached to the opposite side of the ET. We tried to find out the correlation between the results of measurements, ET readings and potential design water requirements calculated by the FAO method for the spring wheat growing period.

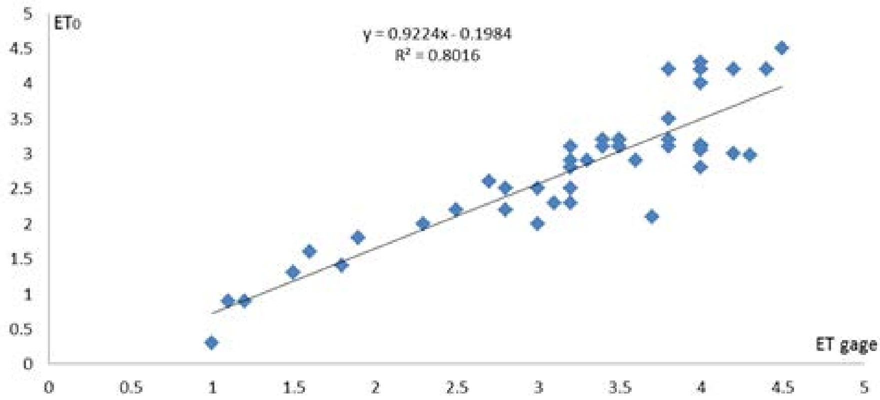

Figure 7. Correlation between calculated ET0 and measured ET gage value.

4. Conclusion

The research results on spring wheat design water requirement for growing period, which was calculated by FAO-56 method based on the recent 5-year data of the RA Ashtarak, Voskehat and Dzoraghbyur automatic weather stations, show that the crop water requirement variates subject to the Kc coefficient value. This variation turns to be more apparent in the early and late vegetation period when the Kc is specified for dual-factor condition.For calculation FAO-56 based crop water requirement, the farmers need to access a list of meteorological data. Except of this the usage of ET gages is more preferable for farmers, because of its easy construction and use. To develop efficient water use management for the farms we drew a correlation between the data on the crop water requirement obtained from the ET gages and weather stations, which will also increase the accuracy of the measurements ET gages comparing with automated weather stations. The obtained regularities can be successfully used while planning irrigation process and arranging hydrometric works.

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