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Forecasting the water requirements of agricultural crops under the agro climatic conditions of the Republic of Armenia and climate change

G.Yeghiazaryan, A.Yeghiazaryan, V.Kobelyan and N.Avetyan

Armenian National Agrarian University, Chair of Hidrotechnical Constructions and Amelioration.

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ABSTRACT

The study aimed at estimating the crop water requirements under climatic and geographical conditions of Armenia with the help of FAO-56 methods to improve irrigation. To calculate the evapotranspiration at 5, 25, 50, 75 and 95 % probability using 10 years' meteorological data of 24 meteorological stations the Republic territory was conditionally divided into six irrigation zones. The comprehensive analysis show that by the end of this century the air temperature increases by 2^0 C degrees and precipitation decreases by 10 %, thus the crop water requirements increases resulting in irrigation water consumption change. The Republic irrigated land area will increase by 25-50 % over the existing one. The resulting evapotranspiration patterns before and after the climatic changes were mapped with the use of GIS technology.

Introduction

Armenia is a mountainous country, which area is 29.74 thousand km^2. Its geographical coordinates are 38°50'-41°18' north latitude and 42°27'-46°37' east longitude. Geographical position and large elevation variation cause a variety of climatic and soil conditions. The agricultural production output under irrigation condition amounts to nearly 85%. By statistic data in 2011 the area of irrigated lands in the Republic of Armenia decreased by 88.8 thousand hectares and irrigation efficiency – about 50%. After the privatization of land in the country 340,000 small farms were formed. Under these conditions the agricultural production was carried out on 1.2 million small plots where each farm has 1.4 hectare area. Each year there are 7 km^3 runoff and 2.2-2.5 km^3 irrigation water used. However, numerous studies showed that for the future under climate change and water requirement increase we need to improve water resources use efficiency for irrigation by the research and scientific studies [1,8]. The purpose of this study was to estimate crop water requirement changes under climate changes condition in Armenia.In this research the following problems were considered: to determine the rainfall amount on the basis of long-term climate data (2000-2010) at 5, 25, 50, 75, 95% probabilities of assured rainfall, to specify the maximum irrigation water consumption and set the calculated value of reference evapotranspiration ET$_0$, as well as irrigation rate, taking into account the efficient water use and work out the measures on its conservation.

Research methodology

To conduct the study the precipitation, maximum and minimum air temperature, maximum and minimum humidity, solar radiation, wind speed, geographical coordinates and altitude of different agro climatic zones of the Republic were investigated. The criteria chosen were the variation in precipitation and air temperature. However, these parameters are very variable depending on the coordinates and time. According to this we defined different values of rainfall probability (P %) by the following formula.

$$P\% = \frac{m-0.3}{n+0.4}100 \qquad (1)$$

where m - the number of the year in a series, n - the number of members in a series

The estimated coefficient for the determination of the design year ($K_{p\%}$) is defined by the formula:

$$K_{p\%} = F_{p\%} \cdot C_V + 1 \qquad (2)$$

where $F_{p\%}$ - the number of Foster, C_v-coefficient of variation.

The atmospheric precipitation amount estimated by the rainfall probability ($P_{p\%}$) is determined by the formula:

$$P_{p\%} = K_{p\%} \cdot \overline{P} \qquad (3)$$

where

$$\overline{P} = \frac{\Sigma_{i=1}^{n} P_i}{n} \qquad (4)$$

n - number of observed years.

For each region of the Republic of Armenia maximum evapotranspiration values (ET$_0$) calculated by the formula.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \qquad (5)$$

where ET$_o$ - reference evapotranspiration [mm day^{-1}], R_n - 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 2 m height [°C], u_2 -wind speed at 2 m height [m s^{-1}], e_s- saturation vapour pressure [kPa], e_a - actual vapour pressure [kPa], e_s - e_a - saturation vapour pressure deficit [kPa], Δ- slope vapour pressure curve [kPa °C^{-1}],γ -psychrometric constant [kPa °C^{-1}].

Crop evapotranspiration, ET$_c$ is calculated by multiplying the reference crop evapotranspiration, ET$_o$, by a crop coefficient (K_c):

Tele: +37491726111

E-mail addresses: nairavetyan@yahoo.com

$$ET_c = K_c \cdot ET_0 \quad (6)$$

Maximum requirement of irrigation water ($m_{p\%}$) is determined by the formula:

$$m_{p\%} = ET_0 - P_{p\%} \quad (7)$$

where $P_{p\%}$ - monthly precipitation during the growing season for the given probability p%.

Irrigation norm (M_b) can be determined by:

$$M_b = \frac{ET_c}{\sigma} \quad (8)$$

where σ - efficiency of water use in irrigation fields [2-7].

Research results and analysis

To calculate potential evapotranspiration the Republic territory was conditionally divided into six irrigated zones and it is expected that in future due to the climatic changes the average temperature in these zones will rise by 2 degrees and precipitation will decrease by 10 percent. To calculate the potential evapotranspiration by the proposed method under different water availability levels the initial data were given.

Table 1. Potential evapotranspiration subject to Kc

Climatic zones	Probability, %				
	5%	25%	50%	75%	95%
Ararat foothills	1127	1234	1130	1240	1125
Sevan basin	417	459	422	463	432
Shirak area	866	951	923	1010	894
North eastern zone	412	447	456	495	519
Lori Pambak area	908	989	782	853	841
Vayots Dzor and Synuik areas	969	1047	943	1018	1033

The results are presented in the following figures (Fig. 1-6).

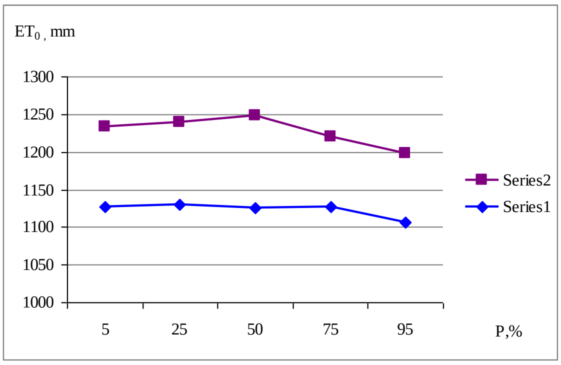

Figure 1. Ararat foothill area, 1 – before, 2 – after

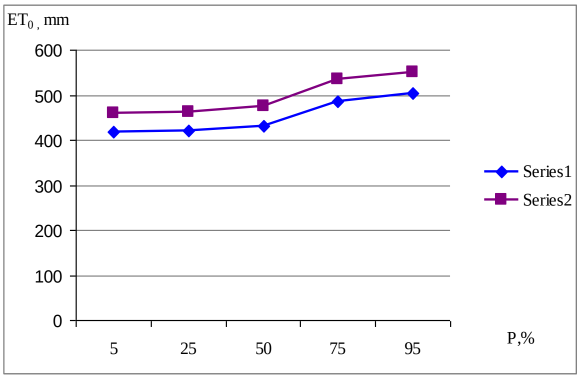

Figure 2. Sevan basin, 1 – before, 2 – after

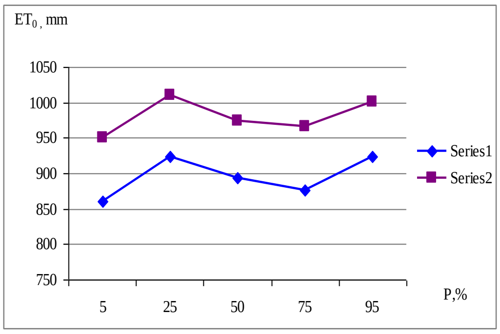

Figure 3. Shirak area, 1 – before, 2 – after

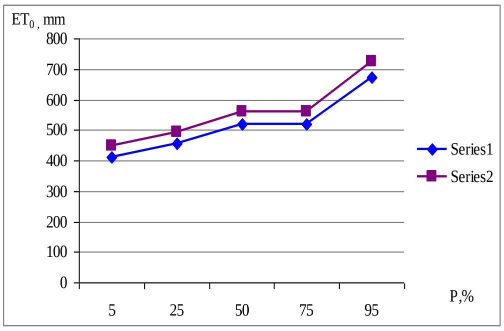

Figure 4. North-eastern zone,1 – before, 2 – after

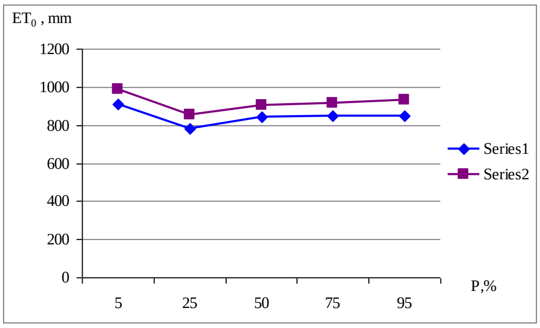

Figure 5. Lori Pambak area, 1 – before, 2 – after

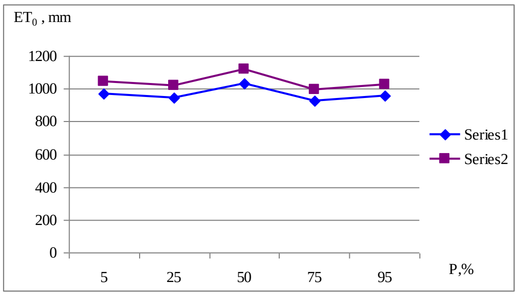

Figure 6. Vayots Dzor and Syunik areas. 1 – before, 2 – after

The analysis of the research results revealed the correlation between potential evapotranspiration and maximum air temperature.

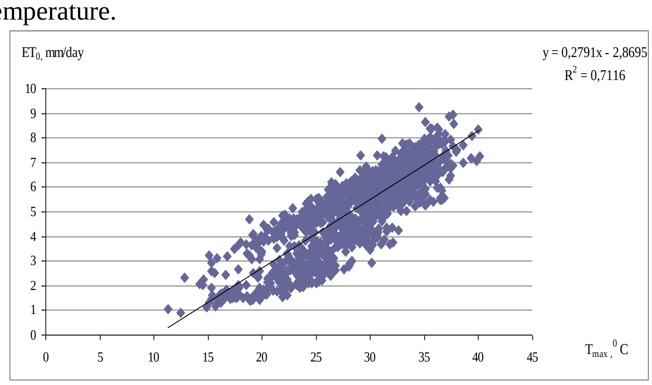

Figure 7. Evapotranspiration subject to T_{max} H=850-1100 m

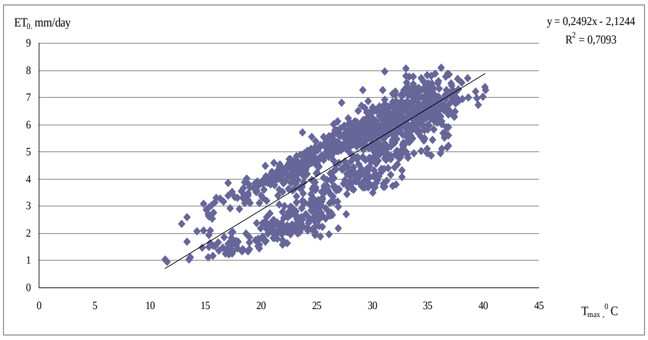

Figure 8. Evapotranspiration subject to T_{max} H=1100-1500 m

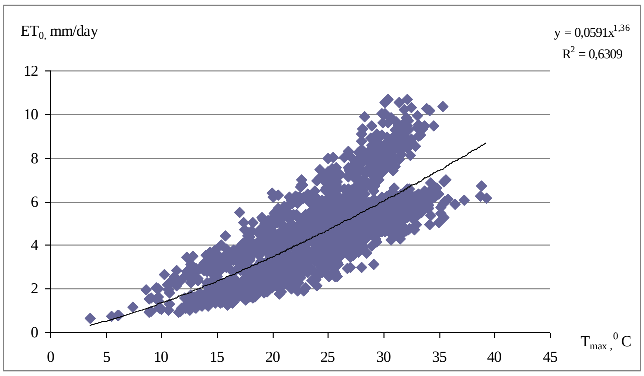

Figure 9. Evapotranspiration subject to T_{max} H≥1500m

Due to the research results, based on the GIS data, we mapped the potential evapotranspiration before and after climate change.

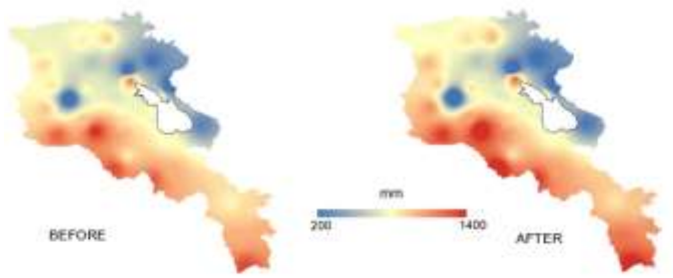

Figure 10. Dynamics of evapotranspiration before and after climate change in case of T±2^0 C and 0.9P scenario

Conclusion

The irrigation water supply and crops water requirements were estimated considering T±2^0 C and 0.9P scenario. If climate changes according to the mentioned scenario, the evapotranspiration, crop water requirement at 5, 25, 50, 75, 95 % probability levels will change by the following regularities: in the Ararat valley at 850-1500 m altitudes the crop maximum water requirements will increase by 730-2450 m^3/ha, in Shirak area, situated at 1400-1900 m altitudes – by 1270-1820 m^3/ha, in Sevan basin – by 508-1080 m^3/ha, in the north-eastern zone – by 620-1300 m^3/ha, in Lori Pambak region – by 885-1570 m^3/ha and in Vayots Dzor and Syunik region – by 210-930 m^3/ha.

The adaptive measures

The adaptive measures includes development of complex program for irrigation water efficient use which considers the gradual pass from the current open irrigation system to the closed network, using modern technologies, drip, subterranean systems. For successful management of irrigation it is necessary to develop irrigation regime based on the maximum evapotranspiration computation by FAO-56 method. To organize the process of irrigation efficiently all agricultural activities should be strictly followed.

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