# HYDRO-MODULE DETERMINATION FOR VANAEI VILLAGE IN ESLAM ABAD GHARB, IRAN

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## ABSTRACT

In order to design a network of irrigation channels, it is necessary to determine cropping pattern and Hydro-Module of area. Then according to the water requirement (Hydro-Module), flow through each irrigation channels is calculated. In addition, in many villages, due to the poor knowledge about water requirement to agricultural uses, irrigation efficiency is low or crops are exposed to water stress. Thus, Hydro-Module determination gives many advantages to experts and farmers. In this study, after being informed from cropping pattern of Vanaei Village located at Eslam Abad Gharb in Iran (query from local farmers and using NETWAT software), by using CROPWAT software, Hydro-Module determined for this village. Finally, results compared with AGWAT software. The amounts of calculated Hydro-Module using CROPWAT software and AGWAT software were 0.78 and 0.73 liter per second in each hectare, respectively. Among the cultivated crops in the villages, sugar beet has the greatest net irrigation requirement. Therefore, according to the water resources limitation, it should be considered further. Because there is sugar factory in the Eslam Abad Gharb city, there is no possibility of sugar beet production reduction or changing of cropping pattern. Therefore, it is essential to use the correct administrative procedures in this village for avoid from water loss and increasing of crop yield.

**Keywords:** Hydro-Module, agricultural water requirement, CROPWAT software, cropping pattern, evapotranspiration, farming calendar, net irrigation requirement, Vanaei Village.

## INTRODUCTION

Estimating irrigation water requirements accurately is important for water project planning and management (Michael, 1990). Agricultural water requirement determination and other related subjects has been aimed at many researches; some of them will be described in the following.

Mahmood and Ahmad (2005) determine water requirements and response of wheat to irrigation at different soil moisture depletion levels. Results indicated that grain yield, harvest index and water use efficiency were greater when irrigation was applied at 50% SMD and was reduced at 70% SMD. Valipour (2012) determined critical areas of Iran for agriculture water management according to the annual rainfall. Arabfard and Firouzabadi (2012) survived monthly changes of irrigation Hydro-Module for agricultural crops of Hamedan. They resulted that as to the changed pattern of cultivation and increasing under-pressure irrigation system in most of the agricultural plains in Iran, it is better to review the irrigation efficiency and Hydro-Module in each plain and to schedule the irrigation and determine the permitted hours of pumping the wells on this basis. Aghdasi (2010) studied crop water requirement assessment and annual planning. She showed that annual crop water planning using Markov chain, which considering probability of occurrence of deferent climate states proved to produce results very close to reality. Theoretical Landscape water requirements for hibiscus (Rosa sinensis) irrigated in Maiduguri metropolis which experiences rainfall only from July to September annually were determined (Arku *et al*., 2012). They showed that since the water need is for only dry conditions, there is no need for irrigation from the month of July to September when rainfall was established except if it is observed in a particular day that the plant is water stressed. Him-Gonzalez (2012) claimed that under sub-humid and arid climates, given the continuous water deficit, the irrigation water requirements could be as much as 95 percent of the total plant water needs. Accurate short-term estimates of crop water requirements in protected cultivation are a prerequisite for a good and efficient management of irrigation and greenhouse microclimate (Baille, 2012). Valipour *et al*. (2012) studied soil heat flux based on energy balance equation used to estimate evapotranspiration successfully. Valipour (2013) examined increasing irrigation efficiency using different types of inflow regimes include continuous flow, cutback, fixed surge, and variable surge in border irrigation. Obtained results from performed simulation using SIRMOD software showed that cutback and surge irrigation methods were able to increasing irrigation efficiency to the amount of 11.66% and 28.37%, respectively. Bluemling *et al*. (2007) make water productivity using a concept of agricultural water productivity exemplified at wheat - maize cropping pattern in the North China plain. Results showed that even if farmers improved agricultural water productivity for the output yield and achieved optimal precipitation allocation efficiency, production would always be negative, i.e., at the expense of other users in the watershed. Wriedt *et al*. (2009) estimated irrigation water requirements in Europe. A comparison with national and regional data on water abstractions for irrigation illustrated the information deficit related to currently available reported data, as not only modeled limitations but also different national approaches, country-specific uncertainties (illegal or unrecorded abstractions), and restrictions of actual water used came into play. Faramarzi *et al*. (2010) modeled wheat yield and crop water productivity in Iran. The results showed that 88% of the additional wheat production would need to be produced in the water scarce provinces. Therefore, a strategic planning in the national agricultural production and food trade to ensure sustainable water use was needed. Abdelhadi *et al*. (2000) estimated crop water requirements in arid region using Penman - Monteith equation with derived crop coefficients on Acala cotton in Sudan Gezira irrigated scheme. The trends of weather examined for the period 1966 - 1993 showed an increasing $ET_o$ during the rainy season due to the recent drought conditions that prevailed in the region. Valipour (2012) compared ability of full hydrodynamic, zero inertia, and kinematic wave models in surface irrigation simulation. Kazbekov et al. (2009) evaluated planning and delivery performance of Water User Associations (WUAs) in Osh Province, Kyrgyzstan. The study identified uncertainties in the estimation of WUA water demands based on previous methods and suggested more attention and care required in calculating water requirements. Almiñana *et al.* (2010) presented the models and the algorithms, which were being used in a decision support system (DSS) to determine water irrigation scheduling. Valipour (2012) determined number of required observation data for rainfall forecasting to agricultural water management. Kuo *et al*. (2006) estimated rrigation water requirements with derived crop coefficients for upland and paddy crops in ChiaNan Irrigation Association, Taiwan. For the irrigated scheme with single and double rice cropping patterns in the ChiaNan Irrigation Association, the CROPWAT model simulated results indicate that the annual crop water demands were 507 and 1019 mm, respectively, and the monthly water requirements peaked in October at 126 mm and in January at 192 mm, respectively. George *et al*. (2000) developed and tested an irrigation-scheduling model (ISM). The model was tested against field data and the CROPWAT model. The model-predicted soil moisture contents were compared with the field-measured data for both single and multiple field cases. The two models, ISM and CROPWAT, gave similar values of soil moisture but showed some variation after the second irrigation. For both the single- and multiple-field cases, simulated bean yield was slightly higher than measured yield. In addition, except for the Turc method, all $ET_o$ estimation methods resulted in higher yield as compared to measured yield. The ISM was a flexible and user-friendly irrigation-scheduling tool, which could be used for efficient use of irrigation water. Dechmi *et al*. (2003) analyzed an irrigation district in northeastern Spain. The effect of irrigation scheduling on crop yield and net benefit was analyzed using the CROPWAW simulation model. Simulations of the 1997 irrigation practices performed on a limited number of plots detected a 12% decrease in crop yield due to deficit irrigation and/or large irrigation intervals. Valipour and Montazar (2012a,b,c) evaluated SWDC and WinSRFR models to optimize of infiltration parameters in furrow irrigation. By comparing results it was indicated that the goal of optimization in WinSRFR model is to achieve full irrigation status, while the results obtained from SWDC model showed that amount of the optimal discharge which total efficiency is obtained for it, will not occur necessarily in full irrigation. The results showed that using VB and GA programming water delivery and farm size could be optimized. Bronstert et al. (2000) presented an integrated modeling of water availability and water use in the semi-arid Northeast of Brazil. Feng et al. (2007) studied water requirements and irrigation scheduling of spring maize using GIS and CROPWAT model in Beijing-Tianjin-Hebei region. Cornejo *et al*. (2006) presented irrigation potential of the TRASVASE system (Santa Elena Peninsula, Guayas, Ecuador). The advantage of this method was that it required minimal climatic and geographic information coupled with well-established FAO models to produce tangible results. Kaledhonkar *et al*. (2006) survived regional salinity modeling for conjunctive water use planning in Kheri command. The CROPWAT model was used to determine the evapotranspiration requirements of different wheat and cotton crops, while the RETC model estimated soil water retention parameters.

According to the previous researches, agricultural water requirement is determined in many studies, but obtained results were not compared with another model. In this paper, using CROPWAT software Hydro-Module determined for Vanaei Village located at Eslam Abad Ghab in Iran and obtained results compared with AGWAT software and discussed about critical crop due to the maximum of net irrigation requirement.

## MATERIALS AND METHODS

For determining the Hydro-Module of an area, the following steps should be done: choice of crops for cropping pattern, determination of farming calendar for different crops of cropping pattern, determination of crop evapotranspiration ($ET_c$) in different months according to the farming calendar, calculation of net irrigation requirement (NIR) in different months according to the farming calendar, assess of peak month, and eventually determination of irrigation Hydro-Module.

### The choice of crops for cropping pattern

Generally, choice of crops for cropping pattern has been done according to the country's agricultural production overall policies and objectives, the requirements of the different products, the agricultural resources about adapting to climate products, quality and quantity of water resources and soil suitability, crop rotation, cropping intensity and economic efficiency. Table-1 shows the cropping pattern in Vanaei Village.

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**Table-1.** The cropping pattern in Vanaei Village.

| Crop | Chickpea | Sugar beet | Wheat | Corn |
|---|---|---|---|---|
| **Percent of the cultivated** | 27 | 18 | 51 | 4 |

**The determination of farming calendar for different crops of cropping pattern**

For determination of farming calendar, after data gathering from local farmers and using NETWAT software, Figure-1 was prepared.

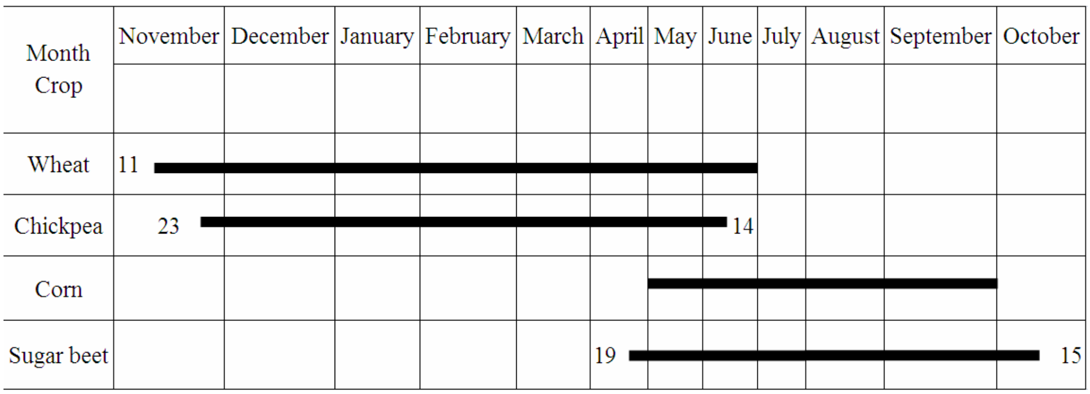


**Figure-1.** Farming calendar for vanaei village.

**The determination of crop evapotranspiration ($ET_c$) in different months according to the farming calendar**

The determination of crop evapotranspiration, used from FAO 24 methods (Doorenbos and Pruitt, 1977):

$$ET_c = K_c \times ET_o \tag{1}$$

Where $ET_c$ is crop evapotranspiration (mm), $K_c$ is crop coefficient, and $ET_o$ is potential evapotranspiration (mm). Amounts of $ET_c$ for each crop and month determined using CROPWAT software.

**The calculation of net irrigation requirement (NIR) in different months according to the farming calendar**

Amount of *NIR* calculated from the equation (2):

$$NIR = ET_c - P_e - Wb - G_e \tag{2}$$

Where *NIR* is net irrigation requirement (mm), $W_b$ is initial moisture of soil (mm), $G_e$ is groundwater recharge (mm), and $P_e$ is effective rainfall (mm) which calculated using USDA method:

$$P_e = [1.252496 \times P^{0.82416} - 2.93522] \times 10^{(0.000955 \times ETc)} \tag{3}$$

Where $P$ is average monthly rainfall (mm). Amounts of *NIR* for each crop and month determined using CROPWAT software.

**The assess of peak month**

Irrigation system in the worst situations (peak month) must be able to meet crop water requirement. For changing evapotraspiration of peak month to maximum of daily evapotranspiration used from SCS formula:

$$U_p = 0.034 \times (U_m)^{1.09} \times (fn) - 0.09 \tag{4}$$

Where $U_p$ is maximum of daily evapotranspiration in peak month (mm/day), $U_m$ is evapotraspiration of peak month (mm), and $f_n$ is depth of net irrigation (mm) which calculated using FAO 24 method (Doorenbos and Pruitt, 1977):

$$f_n = S_a \times RAW \times D \tag{5}$$

Where $S_a$ is depth of available water in one meter of soil depth (mm/m), *RAW* is amount of readily available water, and *D* is developed depth of crop root (m).

**The determination of irrigation hydro-module**

After calculating all mentioned parameters, amount of irrigation Hydro-Module determined for Vanaei Village. For this purpose, information from Tables 2 and 3 were used.

**Table-2.** Used area information in this study.

| Watershed | Climate | Longitude | Altitude | Elevation related to sea level (m) | Soil texture | Weather station |
|---|---|---|---|---|---|---|
| Karkheh Olya | Temperate | 46°26' | 34°8' | 1346 | Loam | Eslam Abad Gharb synoptic station |

**Table-3.** Used crop information in this study.

| Crop | $S_a$ (mm/m) | RAW (%) | D (m) |
|---|---|---|---|
| Chickpea | 160 | 50 | 0.8 |
| Sugar beet | 160 | 50 | 1.0 |
| Wheat | 160 | 50 | 1.0 |
| Corn | 160 | 50 | 1.0 |

Figure-2 shows location of Vanaei Village in Eslam Abad Gharb and Iran.

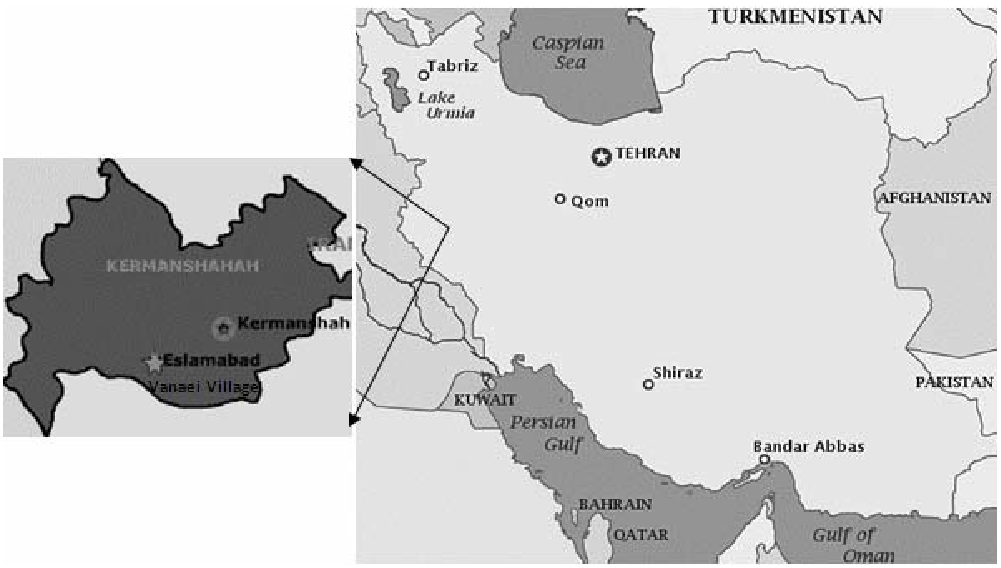


**Figure-2.** Location of Vanaei Village in Eslam Abad Gharb and Iran.

## RESULTS AND DISCUSSIONS

Tables 4 to 7 shows obtained results for $ET_c$ according to the equation (1) and using CROPWAT software.

**Table-4.** Obtained $ET_c$ for wheat.

| Growing season | $ET_o$ (mm/day) | $K_c$ | $ET_c$ (mm/month) |
|---|---|---|---|
| November | 1.6 | 0.50 | 12.00 |
| December | 1.0 | 0.55 | 16.50 |
| January | Dormancy | | |
| February | Dormancy | | |
| March | 1.5 | 0.95 | 41.33 |
| April | 2.4 | 1.05 | 78.12 |
| May | 3.4 | 1.05 | 110.67 |
| June | 4.5 | 0.60 | 83.70 |
| **Sum** | | | 342.32 |

**Table-5.** Obtained $ET_c$ for chickpea.

| **Growing season** | $\mathbf{ET_o}$ (mm/day) | $\mathbf{K_c}$ | $\mathbf{ET_c}$ (mm/month) |
|---|---|---|---|
| November | 1.6 | 0.50 | 8.00 |
| December | 1.0 | 0.50 | 15.00 |
| January | Dormancy | | |
| February | Dormancy | | |
| March | 1.5 | 0.95 | 41.33 |
| April | 2.4 | 1.05 | 78.12 |
| May | 3.4 | 1.00 | 105.40 |
| June | 4.5 | 0.55 | 62.00 |
| **Sum** | | | 309.85 |

**Table-6.** Obtained $ET_c$ for sugar beet.

| **Growing season** | $\mathbf{ET_o}$ (mm/day) | $\mathbf{K_c}$ | $\mathbf{ET_c}$ (mm/month) |
|---|---|---|---|
| April | 2.4 | 0.60 | 21.60 |
| May | 3.4 | 0.70 | 73.78 |
| June | 4.5 | 0.90 | 125.55 |
| July | 5.3 | 1.10 | 180.73 |
| August | 5.1 | 1.10 | 173.91 |
| September | 4.1 | 0.90 | 114.39 |
| October | 2.8 | 0.65 | 18.20 |
| **Sum** | | | 708.16 |

**Table-7.** Obtained $ET_c$ for corn.

| **Growing season** | $\mathbf{ET_o}$ (mm/day) | $\mathbf{K_c}$ | $\mathbf{ET_c}$ (mm/month) |
|---|---|---|---|
| May | 3.4 | 0.45 | 47.43 |
| June | 4.5 | 0.70 | 97.65 |
| July | 5.3 | 1.05 | 172.67 |
| August | 5.1 | 1.10 | 173.91 |
| September | 4.1 | 0.80 | 101.68 |
| **Sum** | | | 593.34 |

According to Tables 4 to 7, amount of $ET_c$ for sugar beet was the maximum between cultivated crops. Figures 3 and 4 shows a comparison between amount of $ET_c$ for each month which was estimated using CROPWAT and AGWAT softwares.

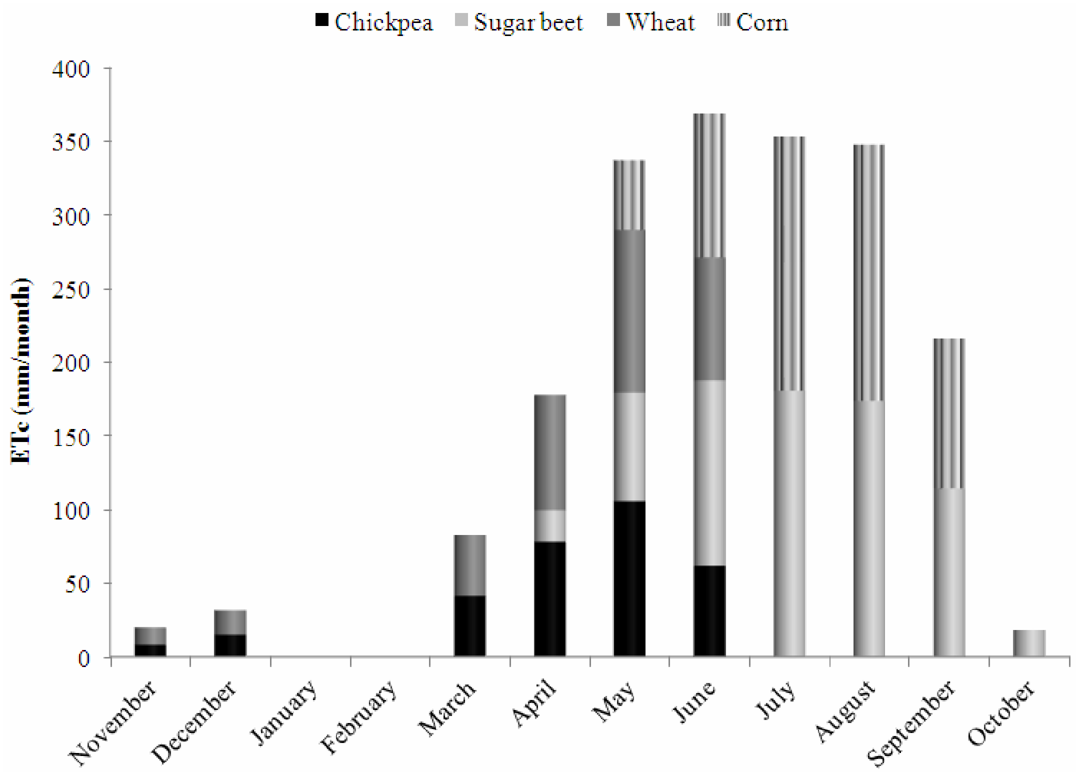


**Figure-3.** Amounts of $ET_c$ for each month estimated using CROPWAT software.

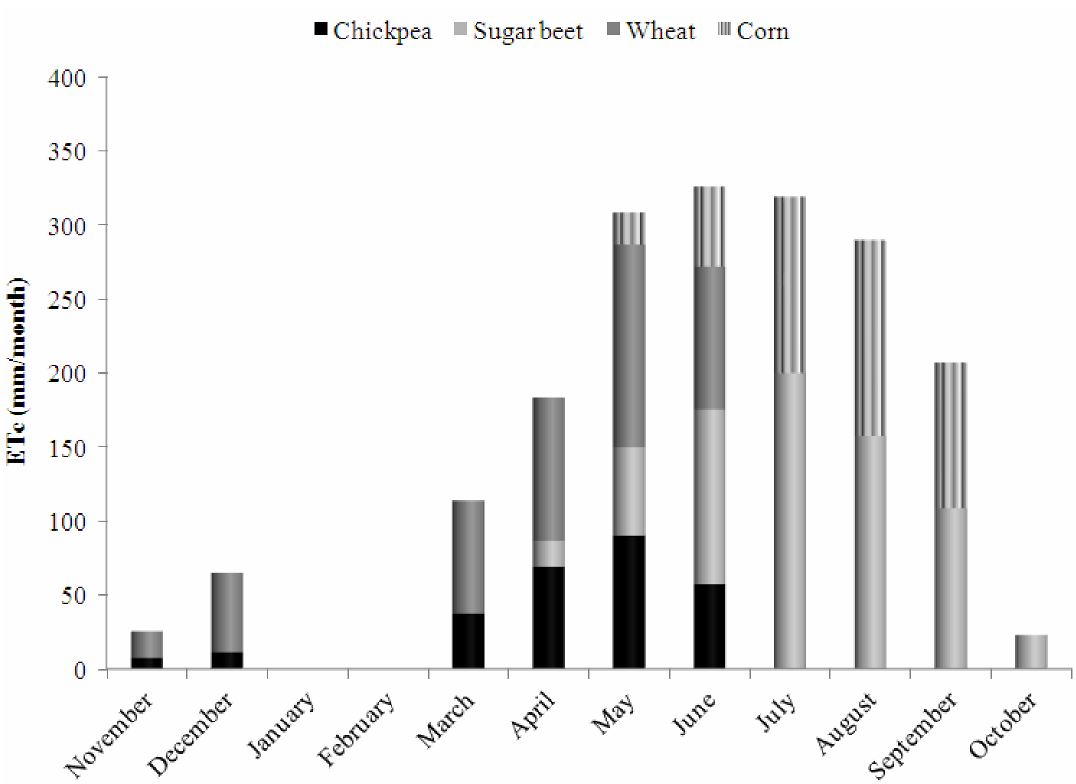


**Figure-4.** Amounts of $ET_c$ for each month estimated using AGWAT software.

Comparison between Figures 3 and 4 showed that estimate of AGWAT was lower than CROPWAT for $ET_c$.

Tables 8 and 9 shows amount of $P_e$ and *NIR* estimated, respectively, using CROPWAT software. According to the Table-9 amount of *NIR* in May was maximum. Therefore, all of the calculation to estimate Hydro-Module must be done for his month. The significant point was that amount of $ET_c$ in June was higher than May (Figure-3) and amount of $P_e$ and $W_b$ in June were lower than May (Tables 8 and 9) but *NIR* in May was in higher than June (Table-9). Why? Because amount of *NIR* in May was higher than June for wheat and chickpea into the corn and sugar beet (Table-9). Since percents of the cultivated, for wheat and chickpea were higher than corn and sugar beet (Table-1), so the final amount of *NIR* in May was higher than June.

Table-10 shows irrigation Hydro-Module for Vanaei Village. In Table-10 amount of determined Hydro-Module for Vanaei Village, using CROPWAT software was equal to 0.78 liter per second in one hectare. This amount for AGWAT software was 0.73 l/s/ha which is due to the lower estimate of $ET_c$ (Figures 3 and 4) was expected. A safety factor between 1.1 and 1.5 can be useful for final Hydro-Module determination. However, amount of Hydro-Module for wheat was higher than other crops (Table-10) but as is clear from Table-9, amount of *NIR* for sugar beet was higher than other crops (This was expected due to the higher $ET_c$ (Tables 4 to 7)), thus according to the water resources limitation, it should be considered further. Since there is sugar factory in the Eslam Abad Gharb City, there is no possibility of sugar beet production reduction or changing of cropping pattern. Therefore, it is essential to use the correct administrative procedures in this village for avoid from water loss and increasing of crop yield. Since sugar beet is grown in surrounding villages as well as the integration of land can be a useful means to increase water use efficiency (WUE).

## CONCLUSIONS

In this study, using CROPWAT software, Hydro-Module determined for Vanaei Village located at Eslam Abad Gharb in Iran. The results compared with AGWAT software. The amounts of calculated Hydro-Module using CROPWAT software and AGWAT software were 0.78 and 0.73 liter per second in each hectare, respectively.

Among the cultivated crops in the villages, sugar beet has the greatest net irrigation requirement. Therefore, according to the water resources limitation, it should be considered further.

**Table-8.** Amounts of $P_e$ estimated using CROPWAT software.

| Crop | Parameter | November | December | January | February | March | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wheat | P (mm) | 10.0 | 15.6 | Dormancy | | 14.6 | 16.7 | 17.5 | 14.1 | Arid | | | |
| | $P_e$ (mm) | 5.6 | 9.5 | Dormancy | | 9.2 | 11.7 | 13.2 | 9.8 | Arid | | | |
| Chickpea | P (mm) | 7.0 | 15.6 | Dormancy | | 14.6 | 16.7 | 17.5 | 12 | Arid | | | |
| | $P_e$ (mm) | 3.2 | 9.4 | Dormancy | | 9.2 | 11.7 | 13.0 | 7.8 | Arid | | | |
| Corn | P (mm) | Arid | | | | | | 17.5 | 14.1 | 6.1 | 0.4 | 0.9 | Arid |
| | $P_e$ (mm) | Arid | | | | | | 11.5 | 10.1 | 3.8 | 0.0 | 0.0 | Arid |
| Sugar beet | P (mm) | Arid | | | | | 7.0 | 17.5 | 14.1 | 6.1 | 0.4 | 0.9 | 5.0 |
| | $P_e$ (mm) | Arid | | | | | 3.5 | 12.1 | 10.8 | 3.9 | 0.0 | 0.0 | 1.9 |

**Table-9.** Amounts of *NIR* estimated using CROPWAT software.

| Crop | Parameter | November | December | January | February | March | April | May | June | July | August | September | October | Sum of NIR (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wheat | $W_b$ (mm) | 0.0 | 0.0 | Dormancy | | 32.0 | 28.0 | 0.0 | 0.0 | Arid | | | | |
| | NIR (mm) | 6.4 | 7.0 | Dormancy | | 0.0 | 38.4 | 97.5 | 73.9 | Arid | | | | 223.2 |
| Chickpea | $W_b$ (mm) | 0.0 | 0.0 | Dormancy | | 32.0 | 28.0 | 0.0 | 0.0 | Arid | | | | |
| | NIR (mm) | 4.6 | 5.6 | Dormancy | | 0.0 | 38.4 | 93.4 | 54.2 | Arid | | | | 196.2 |
| Corn | $W_b$ (mm) | Arid | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | Arid | |
| | NIR (mm) | Arid | | | | | | 35.9 | 87.6 | 168.9 | 173.9 | 101.7 | Arid | 568.0 |
| Sugar beet | $W_b$ (mm) | Arid | | | | | 18.0 | 42.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | NIR (mm) | Arid | | | | | 0.0 | 19.7 | 114.8 | 176.8 | 173.9 | 114.4 | 16.3 | 596.2 |
| Sum of NIR ($m^3$/ha) | | 45.0 | 50.8 | 0.0 | 0.0 | 0.0 | 299.5 | 796.7 | 764.8 | 358.8 | 382.6 | 246.6 | 29.3 | |

**Table-10.** Irrigation Hydro-Module for Vanaei Village.

| **Crop** | **fn** (mm) | **Up** (mm/day) | **Irrigation time** (hr) | **Irrigation efficiency** (%) | **Hydro-Module** (l/s/ha) |
|---|---|---|---|---|---|
| Chickpea | 80 | 3.2 | 24 | 50 | 0.20 |
| Sugar beet | 64 | 4.1 | 24 | 50 | 0.17 |
| Wheat | 80 | 3.4 | 24 | 50 | 0.40 |
| Corn | 80 | 1.1 | 24 | 50 | 0.01 |
| **Sum** | | | | | 0.78 |

Since sugar beet is grown in surrounding villages as well as the integration of land can be a useful means to increase water use efficiency (WUE).

**Abbreviations**

$ET_c$ = Crop evapotranspiration (mm)
$K_c$ = Crop coefficient
$ET_o$ = Potential evapotranspiration (mm)
*NIR* = Net irrigation requirement (mm)
$W_b$ = Initial moisture of soil (mm)
$G_e$ = Groundwater recharge (mm)
$P_e$ = Effective rainfall (mm)
*P* = Average of monthly rainfall (mm).
$U_p$ = Maximum of daily evapotranspiration in peak month (mm/day)
$U_m$ = Evapotraspiration of peak month (mm)
$f_n$ = Depth of net irrigation (mm)
$S_a$ = Depth of available water in one meter of soil depth (mm/m)
*RAW* = Amount of readily available water
*D* = Developed depth of crop root (m).
WUE = Water use efficiency (%)

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