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Adjustment of Irrigation Regime for the Agricultural Crops through CROPWAT Software Application

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ABSTRACT

The efficient management of the irrigation water is of utmost importance in conditions of the irrigated agriculture; hence, new methods are currently being developed and new devices are applied to achieve the maximum savings in water consumption.

The computation method introduced in the current article is the best option for the identification of efficient water consumption standards, which will entail to appropriate management and savings in irrigation water.

The abovementioned method has been applied in the other regions of Armenia as well, where the best indicators for irrigation water consumption have been also recorded.

Introduction

Identifying the opportunities of irrigated agriculture and enhancing their efficiency is crucial for poverty elimination, food safety increase and agricultural productivity in Armenia. Irrigated agriculture accounts for more than 80 % of gross crop production. In this process the irrigtion water is the only natural factor which regulates the effect of the other factors creating optimal conditions for the plants growth and development, which in its turn promotes the increase of soil fertility and yield capacity.

One of the main issues in the efficient utilization of the land and water resources in Armenia is the improvement of irrigation system and watering facilities as a result of which it becomes possible to get a high and sustainable yield from agricultural crops by preserving and improving the soil fertility. To solve the mentioned issue it is necessary to study and disclose the effect of irrigation on the soil fertility and crops yield capacity depending on the crops irrigation methods, water consumption and irrigation regime.

After the land-related reforms the available irrigation regimes not only failed to preserve the obtained economic indices, but even more, they exacerbated their decline (Terteryan, et. al, 2007).

Particularly in recent years the irrigated land area has been considerably reduced, the yield capacity of the agricultural crops has strongly decreased and the irrigated lands have been subjected to secondary salinization. According to the reserachers' evaluation one of the main reason of the abovementioned negative processes is the violation of irrigation regimes and their incomplience with the contemporary land use requirements (Yeghiazaryan, et. al, 2011).

Irrigation is watering process of the agricultural crops and the irrigation regime is the discrepancy between the provision of the humidity required by the the agricultural crops and the water regimes for the given territory. To determine the irrigation regime it is necessary to identify the water consumption standard for the agricultural crops beforehand and afterwards the real irrigation regime as the discrepancy between the water consumption of the agricultural crops and the natural water regimes of the specific area. The supplied water amount which provides the plants regular and uninterrupted growth and development is considered to be the water consumption norm. Besides, the plants water consumption is factually only transpiration, anyhow the physical evaporation from the soil is practically supplementary for the latter. The natural soil humidity very often doesn't satisfy the water consumption requirement, thus, a necessity appears to add it in an artificial way, which is implemented through irrigation. Irrigation is considered to be the key method for land reclamation and is carried out for the soils' desalination, fertilization and other purposes (FAO 2008).

Materials and methods

The irrigation regime depends on the hydrometeorological conditions, crop species, its vegetation duration and on soil properties (Wright, 1982).

Depending on the soil and climatic conditions the issue of effective irrigation planning can be handled through the application of innovative irrigation technologies, reconstruction, expansion and improvement of irrigation systems, while the highest water-saving rate can be achieved in case of identification of the appropriate irrigation regime for the agricultural crops.

The mentioned track of the problem solution aims to increase the reclaimed land areas, as well as to create and preserve the needed and sufficient air, food, thermal, water and salt regimes. The change of lands water regimes is of particular significance by means of which the impact of other regimes on the soil fertility, crops yield capacity and on the environment is regulated. The elements providing the soil fertility in natural conditions are very often mutually exclusive, for example, in the soils with extra humidity the aeration terms, availability of various types of nutrients deteriorates, the heat access into the soils' lower layers decreases, some anaerobe procedures activate resulting in the accumulation of some organic substances in the soil, hence it becomes overmoistened and swampy (Verigo, Razumova, 1973).

In such land areas the access of humidity exceeds its outlet and the ground waters usually have relatively higher location aspects. When the evaporation of the humidity from the soil exceeds its access favorable conditions appear for the development of anaerobic activities, as well as for the decomposition of organic substances, the soils heat capacity decreases, the concentration of the soil solution increases as a result of which the soils become salinized, while due to their unsustainable structure the lands can undergo soil and water erosion (FAO 2008).

The academician A. Kostyakov has mentioned that the main issue of the amelioration consists in the management of the biological and hydrogeological cycle in water and chemical elements of the environment so that the hydrogeological cycle would strive to the minimum, while the biological one to the maximum.

To achieve the mentioned goal it is necessary to solve the irrigation problems not only from the perspective of crops' requirements satisfaction, but also to consider the complex impact of different factors existing in the "ground water-soil-plant-air" system.

The need for irrigation, its conditions and application are related to the plants water consumption rate, the amount of which depends on the temperature, relative air humidity, light, wind velocity, soil fertility, its hydro-physical, physical-mechanical and biological properties, crop species and agro-technical measures.

The highest water amount which the plants use for the transpiration is subjected to continuous changes depending on the environmental conditions. Related to the crop species their water consumption rate can change under the influence of both soil-and-climatic change and that of agro-technical conditions (Kostyakov, 1951).

To specify the water consumption standards the method of Penman-Monteith (Monteith, 1981) has been adopted. By means of the mentioned method it is possible to compute the evaporation rate (total evaporation) from the plants and soils.

The computations have been conducted through the CROPWAT software developed by the Food and Agriculture Organization of the United Nations (FAO). When implementing calculations the minimum and maximum air temperature peculiar to the given location, relative air humidity, wind velocity, sunshine duration, precipitation rates, altitude above the sea level, geographical data and a number of other information (FAO, 1988) has been taken into account.

Results and discussions

The average data of "Yerevan agro" meteorological center provided for 2012-2017 by the hydromet center of the RA Ministry of Emergency Situations have been served as a base to calculate and adjust the water consumption standards through the total evaporation in the Baghramyan province at the RA Armavir Marz (region).

Through the CROPWAT software the irrigation regimes of the grape and orchards cultivated in the given province have been computed; the data on average monthly total evaporation and efficient precipitation amounts have been retrieved.

The soil type has been selected according to its mechanical composition as well. Mid clay and sandy (loam) soil types are characteristic to the mentioned province on the background of which the further computations have been conducted.

Table 1. Meteorological indices in the Baghramyan province

Country -	Armenia				Station -	Yerevan-agro	
Altitude -	1080m	Latitude -	40.11^{0}N		Longitude -	43.5^{0}E	
Month	Min.Temp	Max. Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m^{3}/day	mm/day
January	-16.2	11	79	95	3.4	6.5	0.89
February	-11.4	14.8	71	121	5.5	10.4	1.48
March	-6.8	19.8	59	181	6.4	14.3	2.8
April	-1	28	53	181	7.9	19.1	4.45
May	6.8	30.8	55	181	8	21.1	5.12
June	11.1	37	45	242	10.8	25.7	7.51
July	14.2	38.5	43	302	11.5	26.2	8.55
August	15	38.1	39	302	10.8	23.6	8.24
September	8.1	34.4	46	207	9.7	19.2	5.7
October	1.9	28.6	63	138	6.7	12.4	3.14
November	-5.2	18.3	73	104	5.5	8.6	1.55
December	-13.8	10.7	81	86	2.8	5.5	0.86
Average	**0.2**	**25.8**	**59**	**179**	**7.4**	**16.1**	**4.19**

Table 2. The average monthly efficient precipitation rate in Baghramyan province

Station -	Yerevan-agro		Eff. Rain method -FAO/AGLW formula	
		Rain, mm	Eff. Rain, mm	
	January	29	7.4	
	February	25	5	
	March	34.2	10.5	
	April	29.8	7.9	
	May	48.9	19.3	
	June	33.1	9.9	
	July	20.4	2.2	
	August	10.6	0	
	September	10.3	0	
	October	34.3	10.6	
	November	26.3	5.8	
	December	28.5	7.1	
	Total	330.4	85.7	

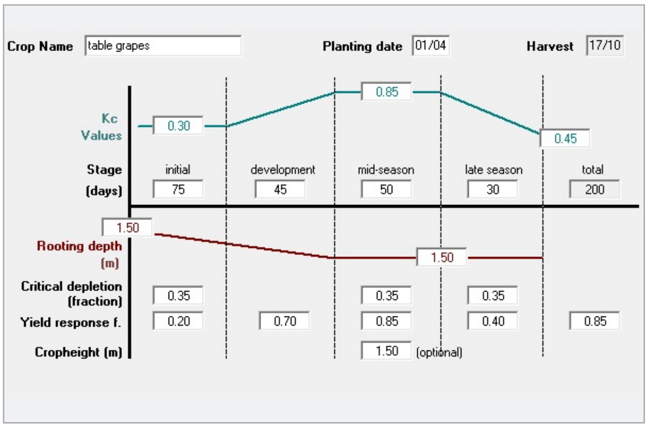

Figure. The plants coefficients considering the sprouting, bushing, blossoming and maturation phases.

Table 3. Soil type according to its mechanical composition

General soil data	Soil name -	Medium(loam)
Total available soil moisture (FC-WP)	290.0	mm/meter
Maximum rain infiltration rate	40	mm/day
Maximum rooting depth	900	centimeters
Initial soil moisture depletion (as % TAM)	0	%
Initial available soil moisture	290.0	mm/meter

Water requirements (the example refers to the grape vineyards) for each crop have been computed due to the plants coefficients considering the sprouting, bushing, blossoming and maturation phases.

According to the computations during the vegetation period 7627 m^{3}/ha water is required for the vineyards instead of previously planned 9600m^{3}/ha water.

Table 4. Irrigation requirement for table grapes per ten days and plant coefficients

Eto station -	Yerevan-agro				Crop -	table grapes	
Rain station -	Yerevan-agro				Planting date - 01/04		
Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Apr	1	Init	0.3	1.19	11.9	2.5	9.4
Apr	2	Init	0.3	1.36	13.6	2	11.7
Apr	3	Init	0.3	1.42	14.2	3.5	10.7
May	1	Init	0.3	1.43	14.3	5.8	8.5
May	2	Init	0.3	1.48	14.8	7.4	7.4
May	3	Init	0.3	1.74	19.1	6	13.1
Jun	1	Init	0.3	2.03	20.3	4.3	16
Jun	2	Deve	0.33	2.51	25.1	3.2	21.9
Jun	3	Deve	0.47	3.7	37	2.4	34.6
Jul	1	Deve	0.61	5.07	50.7	1.5	49.2
Jul	2	Deve	0.76	6.56	65.6	0.5	65.1
Jul	3	Mid	0.91	7.73	85	0.4	84.7
Aug	1	Mid	0.96	8.1	81	0.1	80.9
Aug	2	Mid	0.96	8.07	80.7	0	80.7
Aug	3	Mid	0.96	7.2	79.2	0	79.2
Sep	1	Mid	0.96	6.26	62.6	0	62.6
Sep	2	Late	0.95	5.4	54	0	54
Sep	3	Late	0.84	4.05	40.5	0.1	40.4
Oct	1	Late	0.7	2.73	27.3	2.8	24.5
Oct	2	Late	0.58	1.75	12.2	3	8
					809.5	45.5	762.7

Table 5. Computation of watering days and standards through the software program

Eto station -	Yerevan-agro			**Crop -**	table grapes			**Planting date -** 01/04		**Yield red.**	
Rain station -	Yerevan-agro			**Soil -**	medium(loam)			**Harvest date -** 17/10		0.0%	
Table format				**Timing**	Irrigate at critical depletion						
*** Irrigation schedule**				**Application**	Refill soil to field capacity						
Daily soil moisture balance				**Field eff.**	70%						
Date	**Day**	**Stage**	**Rain**	**Ks**	**Eta**	**Depl**	**Net. Irr.**	**Deficit**	**Loss**	**Gr. Irr/**	**Flow**
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
19 Jul	**110**	Dev	0	1	100	36	**156.1**	0	0	223.0	0.23
9 Aug	**131**	Mid	0	1	100	36	**154.6**	0	0	220.8	1.22
30 Aug	**152**	Mid	0	1	100	36	**154.4**	0	0	220.6	1.22
30 Sep	**183**	End	0	1	100	35	**154.0**	0	0	219.9	0.82
17 Oct	**End**	End	0	1	0	3					

Total

Total gross irrigation	**884.4**	**mm**	**Total rainfall**	**176.2**	**mm**
Total net irrigation	**619.1**	**mm**	**Effective rainfall**	**173.6**	**mm**
Total irrigation losses	**0.0**	**mm**	**Total rain loss**	**2.6**	**mm**
Actual water use by crop	**807.8**	**mm**	**Moist deficit at harvest**	**15.1**	**mm**
Potential water use by crop	**807.8**	**mm**	**Actual irrigation requirement**	**634.2**	**mm**
Efficiency irrigation schedule	**100.0**	**%**	**Efficient rain**	**98.5**	**%**
Deficiency irrigation schedule	**0.0**	**%**			

The software program enables to identify the watering standards needed for the total evaporation and for the provision of the plants growth and development, as well as yield capacity enhancement. The analysis shows that the difference between the values of the total evaporation and water requirement is the rate of atmospheric precipitation, which has made 455 m^3/ha according to the data of hydromet station.

Based on the entered baseline data the software has developed the schedule of the crops irrigation, which is determined upon the term that the regular watering should be implemented during the period of the plants optimal pre-watering humidity, i.e in the state of humidity, the lower indices of which would cause stress to the crops due to which yield capacity decrease is recorded. It means that the scheduled watering should be implemented in time until the minimum humidity so as to save the yield. The computations are summed up in figure 4, where the scheduled irrigation days, their appropriate watering standards and surface flows are clearly demonstrated. The same calculations have been conducted for the orchards of the mentioned province and according to the computations conducted by the Penman-Monteith method the annual water requirement for the vineyards of the Baghramyan province at Armavir region makes 7627 m^3/ha, that of the orchards - 7380 m^3/ha which is less than the previously stated standards by about 18 %-20 %.

Conclusion

Thus, based on the abovementioned data provided by the meteorological station and upon the results of the computations it is possible to accurately identify the annual water requirement for the specific crop, which will entail to 18 %-20 % of water saving and its efficient utilization. Besides, through the contribution of an innovative irrigation technique, such as the drip irrigation system, the crops yield capacity will increase by 20 %-50 %.

The aforementioned computations are conducted by the example of crop rotation scheme as well, where the crops, their planting times, occupied areas are mentioned. When comparing the water amount required for the irrigation per 1 ha area with that of determined through the graph regulated by means of hydro module of the previous regimes, a considerable difference is observed, which testifies that in case of applying irrigation water amount planned and computed through the recommended method the irrigation water is consumed more efficiently with high water-saving outcomes.

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