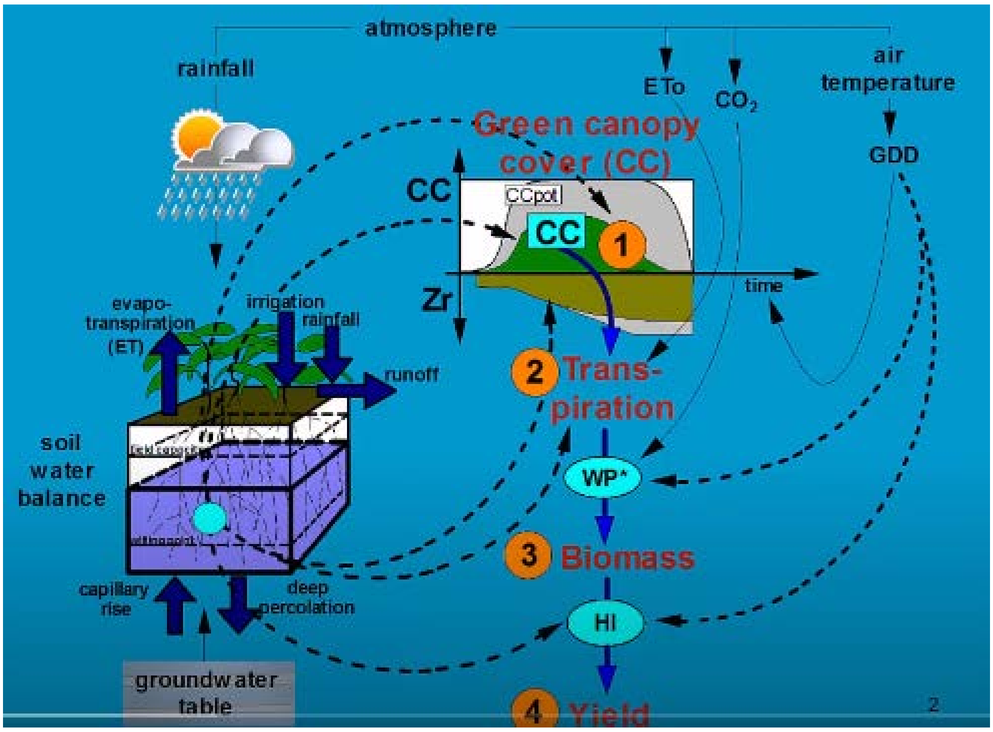
“National Adaptation Plan (NAP) to advance medium and long-term adaptation planning in Armenia” UNDP-GCF Project

Updating Irrigation Norms in Armenia based on FAO Irrigation and Drainage Paper No 56

Final Report



Prepared by:
Stefan GALCA, International Consultant on Crop Water Requirements and Irrigation Scheduling

Supporting Experts:
Vahagn Tonoyan, National Consultant on Water Sector Vulnerability and Adaptation Issues
Gevorg Afyan, National Expert of Crop Water Requirements and Irrigation Scheduling

Contract Number: No: UNDP/ARM/ RLA-003-2020

MARCH 2021

Contents

List of Tables

List of Figures

Abbreviations

BM	Benchmark
CEO	Chief Executive Officer
CIS	Commonwealth of Independent States
CWR	Crop Water Requirement
CTA	Chief Technical Advisor
DEM	Digital Elevation Models
EE	Energy Efficiency
EU	European Union
FA	Financial Analysis
FAO	Food and Agriculture Organisation
FC	Financial Cooperation
FS	Feasibility Study
GDP	Gross Domestic Product
GIS	Geographic Information System
GeoTIFF	Picture File type with georeferencing information
GHG	Greenhouse gases
GoA	Government of Armenia
GPS	Global Positioning System
IC	International Consultant
IWRM	Integrated Water Resources Management
MCA	Millennium Challenge Account
masl	meters above sea level
Meteo	Meteorological
NC	National Consultant
NCCS	National Climate Change Strategy
NFWUA	National Federation for Water Users Associations
NPC	National Project Coordinator
NTCI	National Training Center
O&M	Operations and Maintenance
TOR	Terms of Reference
QGIS	Free and Open-Source Geographic Information System Application Software
UNDP	United Nations Development Programme
WB	World Bank
WUA	Water Users' Association
WT	Water Table

1. Introduction

This Final Report "Updating Irrigation Norms in Armenia based on FAO Irrigation and Drainage Paper No 56" summarizes the main results of the study undertaken since June 2020 within the "National Adaptation Plan to advance medium and long-term adaptation planning in Armenia" UNDP-GCF project. The study aimed to support Armenia in integrated management of water resources and particularly improving irrigation water management, taking into consideration the forecasted impact of climate change, through introduction of crop water requirement model based on FAO Irrigation and Drainage Paper No 56[1] and subsequently updating existing irrigation norms in Armenia[2].

The proper and efficient management of water resources plays a key role in the socio-economic development of Armenia, which is considered as a country with high baseline water stress[3] and low water availability[4], and is also prioritized in the National Security Strategy of the Republic of Armenia (2020). Compared with other countries in the region, Armenia is highly vulnerable to climate change. Armenia shows high exposure, high sensitivity, and limited adaptive capacity to climate change. Future climate projections indicate continued increases in temperature and decreases in precipitation. The impacts of climate change will be particularly severe for Lake Sevan and Ararat valley, which is the main agricultural region of the country. With overall water resources availability expected to decline, it becomes more and more difficult to meet water demand for irrigation, which is by far the largest consumptive waster user in the country, and thus proper and more efficient management of scarce water resources, particularly for irrigation, becomes priority.

The study on updating irrigation norms in Armenia focuses on Ararat valley as the pilot area, and the selected set of corps: table grapes, tomato, cucumber and water-melon.

---

[1]) "Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements", 1998.

[2]) "Irrigation Norms and Regimes of Agricultural Crops for Irrigated Lands in the Republic of Armenia", developed by the "Institute of water problems and hydraulic engineering named after academic I.V. Yeghiazarov" CJSC, 2007.

[3]) According to the World Resource Instituted Armenia is ranked as the 34th most water stressed country among the 164 UN member countries.

[4]) According to the Organization for Economic Co-operation and Development, Armenia is subject to water stress with 45% of Water Exploitation Index.

Figure 1. Location of Ararat Valley (Source: USAID ASPIRED Program, 2017)

The Ararat valley is the largest agricultural zone in Armenia, providing up to 40% of the agricultural GDP. Various crops for export and local consumption are produced, including wheat, vegetables, grapes, and other fruits. Due to climate change, the Ararat valley region is projected to experience higher warming than the rest of the country for all seasons. Temperature increases are predicted to be highest in the summer, and precipitation decline to be the greatest in the summer, the key agricultural season. In the agriculture sector, the most climate-sensitive sector, crop yields are predicted to decline and irrigation demands to increase with climate change. In order to maintain crop yields, substantially more irrigation will be needed, and updating the irrigation norms with an intend to cover the increased irrigation water demand becomes prerogative.

Hence, the subsequent chapters of this Final Report summarize the main results of each key component of the study, including the detailed methodology for updating the irrigation norms for the selected set of crops in Ararat valley, taking into consideration data availability and the approach in FAO Irrigation and Drainage Paper No 56, comparative results of updating the irrigation norms for the selected set of crops in Ararat valley, and development of a detailed step-by-step recommendations for replicating the work for the entire territory of Armenia.

The recommendations on the process of updating the existing irrigation norms in Armenia are of particular interest due to changing irrigation demand as a result of climate change in the country, as well as taking into consideration the advantages that that crop water requirements model based on FAO Irrigation and Drainage Paper No 56 could bring for the country in terms of more efficient allocation and use of scare irrigation water resources. It is expected that decision makers in charge of water resources allocation, authorities in charge of development of irrigation policy and management of irrigation systems, Water Users Associations, as well as farmers can benefit from the findings of this study.

2. Methodology for Calculation of Crop Water Requirements and Irrigation Scheduling

Crop Water Requirements and Irrigation Scheduling are now calculated based on internationally recommended and worldwide used methodology from FAO Irrigation and Drainage Paper 56 “Crop evapotranspiration - Guidelines for computing crop water requirements”.

Three possible methodologies based on FAO Irrigation and Drainage paper 56 have been proposed:

- **Excel Template** with live formula embedded in the sheet cells,
- **CROPWAT 8** - FAO software application for calculation of Crop Water Requirements and Irrigation Scheduling, and
- **AquaCrop** - FAO software application for calculation of Crop Water Requirements and Irrigation Scheduling and yield estimation.

Each methodology has been described in detail with example of calculations in the output “**Detailed Methodology for Updating the Irrigation Norms for the selected set of crops in Ararat Valley**” completed in September 2020.

Below it is provided a short description of each methodology, differences between them and the reason of selecting the AquaCrop methodology to carry out the Crop Water Requirements and Irrigation Scheduling for updating the Irrigation norms in Ararat Valley.

2.1 Excel Template for Calculation of Crop Water Requirements and Irrigation scheduling

For a good understanding of all formula and coefficients from FAO Irrigation and Drainage Paper 56 an Excel template has been developed with live formula embedded in each cells and detailed explanations of each variable and data and where from to get data. Definitions and formula used to calculate each parameter were provided in additional sheets of the same Excel file. In addition, the template shows an example of calculation for Tomato which allows the users to calculate the water requirements and irrigation scheduling for any period of time where the climatic data and soil hydraulic characteristics are known.

The Figure 2, below shows the view of the Excel Template and the description of the 15 steps necessary to pass before obtaining the final results: Irrigation norms and the date of application of each norm (irrigation dose). The cells and columns coloured in yellow represents data that should be supplied to the Excel Template. The cell and columns coloured in green are results of Reference Evapotranspiration, Crop Water Requirements and the columns coloured in blue show the results of Irrigation norms as individual norms (doses) and the date of application (Irrigation Scheduling).

The Excel Template can be used for **design** of irrigation schemes by using climate data from years with rainfall events occurrence of 50 and 75% and for **current irrigation scheduling** using the climatic data from the current year up to the current date.

The results can also be viewed as graphical diagram as in Figure 3, below.

Step by step example of Calcualtion of Crop Water Requirements and Irrigatgion Schedulle for Tomato grown in area of Artashat Meteo Station for year 1991 which has 50% probability

Step 1. Location

Location	Artashat Meteo Station			
Altitude z=	835	m		
Latitude	39°57'36.47"N			
Longitude	44°32'35.08"E			
Latitude decir	39.96013	39.96013	degrees	
Latitude radia	0.69708227		rad	Eq.22
φ =	0.69708227		rad	Eq.22

Step 2. Number of day

J= data in table below numbered from 01 January to 31 December 1991

Step 3. Calculation of Ra – Extra-terrestrial radiation for each day with the equation Eq. 21.

$$R_a = \frac{24(60)}{\pi} G_{sc} d_r [\omega_s \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_s)]$$ Eq. 21

dr=	1+ 0.033 * cos(2 * 3.14* J / 365)	rad	Eq. 23
δ =	0.409 *sin(2 * 3.14 * J/365 - 1.39)	rad	Eq. 24
Gsc=	0.082		constant
ωs=	arccos[-tan(φ) * tan(δ)]	rad	Eq. 25

Step 4. Calculation of Solar radiation Rs

$$R_s = \left(a_s + b_s \frac{n}{N}\right) R_a$$ Eq. 35

as= 0.25
bs= 0.5

$$N = \frac{24}{\pi}\omega_s$$ Eq. 34

Step 5. Calculation of Rns – net solar or shortwave radiation

$$R_{ns} = (1-\alpha)R_s$$ Eq. 38

Rns = 0.77 * Rs
α= 0.23 albedo

Step 6. Calculation of Rso – clear sky solar or clear sky shortwave radiation

$$R_{so} = (0.75 + 2\,10^{-5} z)R_a$$ Eq. 37

Step 7. Calculation of Rnl – net longwave radiation

$$R_{nl} = \sigma\left[\frac{T_{max,K}^4 + T_{min,K}^4}{2}\right](0.34 - 0.14\sqrt{e_a})\left(1.35\frac{R_s}{R_{so}} - 0.35\right)$$ Eq. 39

$$e_a = \frac{RH_{mean}}{100}\left[\frac{e^o(T_{max}) + e^o(T_{min})}{2}\right]$$ Eq. 19

$$e^o(T) = 0.6108 * e^{(17.27 * T / (T+237.3))}$$ Eq. 11

σ = 4.903*10^{-9} MJ K^{-4} m^{-2} day^{-1}

Step 8. Calculation of Rn – net radiation

Rn=Rns-Rnl Eq. 40

Step 9. Calculation of Δ – slope vapour pressure curve (kPa/°C)

$$\Delta = \frac{4098\left[0.6108\exp\left(\frac{17.27T}{T+237.3}\right)\right]}{(T+237.3)^2}$$ Eq. 13

Step 10. Calculation of γ – psychrometric constant

$$\gamma = \frac{c_p P}{\varepsilon \lambda} = 0.665 \times 10^{-3} P$$ Eq. 8

$$P = 101.3\left(\frac{293 - 0.0065z}{293}\right)^{5.26}$$ Eq. 7

Step 11. Calculation of u2 – wind velocity at 2 m height

u2 = uh * conversion factor Data from Meteo Station

Step 12. Calculation of ETo - Reference Evapotranspiration

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$ Eq. 6

es = (eo(Tmax) + eo(Tmin))/2

Step 13. Calculation of Peff - Effective Evapotranspiration

Peff = P * (125 – 0.2 * P)/125, for the case P <= 250 / 3 = 83.3 mm.

Step 14. Calculation of ETc - Crop Evapotranspiration (Crop Water Requirements - CWR)

$$ET_c = K_c\, ET_o$$ Eq. 56

$$K_{ci} = K_{c\,prev} + \left[\frac{i - \Sigma(L_{prev})}{L_{stage}}\right](K_{c\,next} - K_{c\,prev})$$ Eq. 66

$$K_{c\,mid} = K_{c\,mid(Tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0.3}$$ Eq. 62

$$RH_{min} = \frac{e^o(T_{min})}{e^o(T_{max})}100$$ Eq. 64

$$K_{c\,end} = K_{c\,end(Tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0.3}$$ Eq. 65

Step 15. Soil Water Balance

De,i = De,i-1 + Pi – Roi + Ii -ETc – DPi + CRi Eq. 2

This Excel template can be used for any other crop or Meteo Station by changing data in yellow background cells

Step 15. Data for calculation Soil Moisture Balance

Crop=	Tomato irrigated by sprinkler irrigation, no adjustment for Kc ini need						
Sowing date=	15-Apr						
Height of crop h=	0.6	m	Data from tabsheet FAO-Table 12 - Crop coeffcient				
deph of roots=	0.8	m	value selected from table 23 in Tabsheet FAO-Table 23 - Root and Moisture				
Crop grows stage	Length (days)	L stage	Kc from Table 12 from tabsheet FAO-Table 12 - Crop Coefficient				
initial	30	Lini	0.6	Kc ini			
crop development	40	Ldev		To calculate using Eq.66			
mid seasson	45	lmid	1.15	Kcmid	Correction of Kc mid using Eq. 62		
late seson	30	llate		To calculate using Eq.66			
End season	0	0	0.7	Kc end			
Soil hydraulic parameters: Data from Table 19 from tabbsheet FAO Equations							
Texture	Silt clay loam	Selected values					
Field Capacity θFC	0.30 - 0.37	0.335	m3/m3	335	mm/m	268	mm/0.8m
Wilting Point θWP	0.17 - 0.24	0.205	m3/m3	205	mm/m	164	mm/0.8m
Stage 1 REW	8 - 11	9.5	mm/0.1 m				
Stasge 1 and 2 TEW (Ze = 0,1 m)	22 - 27	24.5	mm/0.1 m				
Soil water reserve at star	242	mm/0.8m					
Soil water reserve at Irrigation application	226.4	mm/0.8m	calculated using recommendations in table 23 in tabsheet FAO-Table 23-Root and Moisture				
Irrigation size=	41.6	mm/0.8m					
In case soil water reserve in soil exceeds θFC then the soil reserve is equal to θFC.	268	mm/0.8m					

		Step 2	Step 3				Step4			Step 5	Step 6	Step 7							Step 8	For Step 12
Month	Day number in month	Day number in year	Invers relative distance Earth - Sun, Eq. 23	Solar decimatio n, Eq. 24	Sunset hour angle, Eq. 25 or Eq. 26	Extra-terrestrial radiation for each day with the equation, Eq. 21.	Maximum number of daylight hours, Eq. 34	Number of sunshine hours from Meteo Station	Solar or shortwave radiation, Eq. 35	Net solar or shortwave radiation, Eq. 38	Clear sky radiation, Eq. 37	Mean Air Relative Humidity from Meteo Station	Max Air Temperature from Meteo Station	Min Air Temperature from Meteo Station	Saturation vapour pressure at air temperature T, Eq. 11	Saturation vapour pressure at air temperature T, Eq. 11	Eq. 19	Net outgoing longwave radiation, Eq. 39	Net radiation, Eq. 40	Eq. 12
		J	dr	δ	ωs	Ra	N	n	Rs	Rns	Rso	RHmean	Tmax	Tmin	eo(Tmax)	eo(Tmin)	ea	Rnl	Rn	es
		#	rad	rad	rad	MJ m^{-2} day^{-1}	hours/day	hours/day	MJ m-2 day-1	MJ m-2 day-1	MJ m^{-2} day^{-1}	%	°C	°C	kPa	kPa	kPa	MJ m^{-2} day^{-1}	MJ m^{-2} day^{-1}	kPa
April	15	105	0.992291	0.165494	1.711106	34.69485584	13.07851	5.7	16.2342315	12.5003582	26.6	85	19.1	5.2	2.2	0.9	1.3	2.8	9.7	1.5
April	16	106	0.99174	0.171905	1.716686	34.90444777	13.12117	0.9	9.92318549	7.64085283	26.8	86	21.2	11.5	2.5	1.4	1.7	0.8	6.8	1.9
April	17	107	0.991192	0.178264	1.722239	35.11149965	13.16361	0	8.77787491	6.75896368	26.9	86	21.1	12.7	2.5	1.5	1.7	0.5	6.3	2.0
April	18	108	0.990646	0.184571	1.727763	35.31596399	13.20583	4.3	14.5786729	11.2255781	27.1	96	15.7	8.5	1.8	1.1	1.4	2.1	9.1	1.4
April	19	109	0.990103	0.190823	1.733257	35.51779505	13.24782	10	22.2845949	17.1591381	27.2	86	21.1	4.8	2.5	0.9	1.4	4.3	12.9	1.7
April	20	110	0.989563	0.197019	1.738719	35.71694882	13.28957	8.6	20.4858851	15.7741316	27.4	86	25.1	6.2	3.2	0.9	1.8	3.5	12.3	2.1
April	21	111	0.989026	0.203156	1.744148	35.91338299	13.33107	6.8	18.137816	13.9661183	27.5	77	23.8	12.4	2.9	1.4	1.7	3.0	11.0	2.2
April	22	112	0.988492	0.209233	1.749542	36.10705699	13.3723	7.7	19.4222975	14.9551691	27.7	70	25.1	11.5	3.2	1.4	1.6	3.5	11.5	2.3

Month	Day number in month	Step 9		Step 10		Step 11	Step 12	Step 13		Step 14									Step 15			
		Average Temperature	Slope vapour pressure curve, Eq. 13	Atmospheric pressure, Eq. 7	Psychrometric constant, Eq. 8	Wind velocity at 2 m from Meteo Station	Reference Evapotranspiration, Eq. 6	Precipitation Data from Meteo Station	Effective Rainfall	Min. Relative Humidity of air, Eq. 64	Day of Cropping season	Crop Coef. Initial	Crop Coef. Development, Eq. 66	Crop coef. Mid, Eq.62	Crop coef. Late	Crop coef. End, Eq. 65	Crop Coeff	Crop Water Requirements, CWR, Eq. 56	Soil moisture reserve at beginning of day i	Irrigation applied on day i	Soil moisture reserve at the end of day i, Eq. 2	Verification of upper limit of soil moisture to be less than field capacity
		T=(Tmax+Tmin)/2	Δ	P	γ	u2	ETo	Pi	Peffi	Rhmin	i	Kcini	Kc dev	Kc mid	Kc late	Kc end	Kc	ETc =Kc * ETo	De,i-1	Ii	De,i	
		°C	kPa/°C	kPa	kPa/°C	m/s	mm/day	mm/day	mm/day	%	days							mm/day	mm/0.8 m	mm/0.8 m	mm/0.8 m	mm/0.8 m
April	15	12.2	0.093287	91.8	0.06105	0.6	2.38	0	0.0	40	1	0.6					0.60	1.43	242.0	0.0	240.6	240.6
April	16	16.4	0.118430	91.8	0.06105	1.1	1.91	0	0.0	54	2	0.6					0.60	1.14	240.6	0.0	239.4	239.4
April	17	16.9	0.122114	91.8	0.06105	1	1.79	0.8	0.8	59	3	0.6					0.60	1.07	239.4	0.0	239.2	239.2
April	18	12.1	0.093018	91.8	0.06105	0.4	2.15	7.7	7.6	62	4	0.6					0.60	1.29	239.2	0.0	245.5	245.5
April	19	13.0	0.097690	91.8	0.06105	0	3.23	0	0.0	34	5	0.6					0.60	1.94	245.5	0.0	243.5	243.5
April	20	15.7	0.113880	91.8	0.06105	0	3.27	0	0.0	30	6	0.6					0.60	1.96	243.5	0.0	241.6	241.6
April	21	18.1	0.130488	91.8	0.06105	0	3.04	0	0.0	49	7	0.6					0.60	1.83	241.6	0.0	239.7	239.7
April	22	18.3	0.131930	91.8	0.06105	0	3.20	0	0.0	43	8	0.6					0.60	1.92	239.7	0.0	237.8	237.8

Figure 2. The Excel Template for Calculation of Crop Water Requirements and Irrigation Scheduling

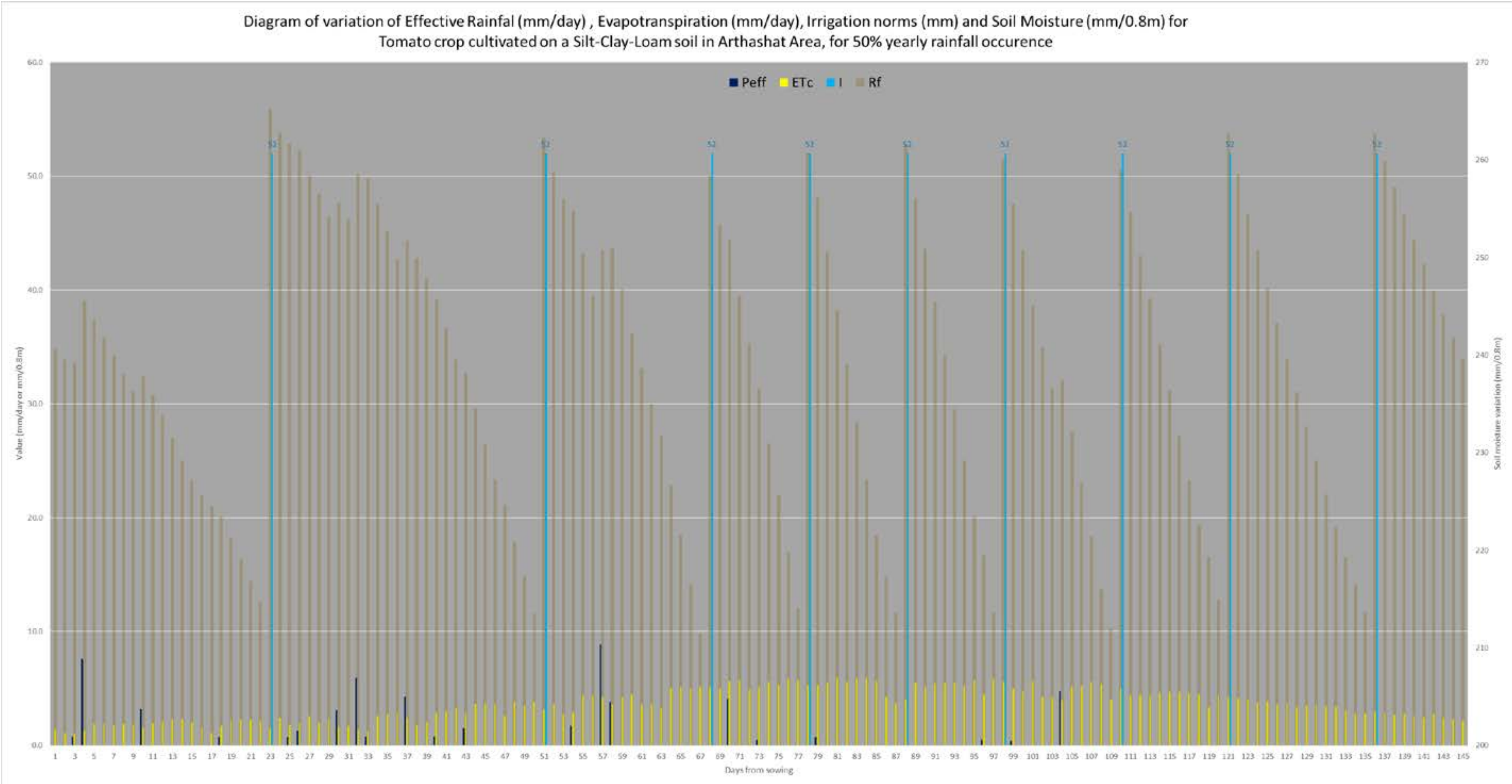


Figure 3. Diagram of daily variation of Rainfall, Crop water requirements, Irrigation Schedule and Soil moisture

2.2 FAO - CROPWAT

An alternative to the above Excel Template, much faster and easier to use, is the software application CROPWAT - 8 developed by FAO and freely downloadable at this link: http://www.fao.org/land-water/databases-and-software/cropwat/en/

CROPWAT - 8 has been developed based on FAO Irrigation and Drainage Paper 56, which is requested by TOR to calculate the irrigation norms under this contract. Consequently, this software is considered as a better methodological alternative to the Excel Template methodology to calculate the irrigation norms and schedule to apply irrigation. In addition, it is much faster and easier to use due to its graphical interface which is friendly with the user.

The results of Crop Water Requirements and Irrigation Scheduling are consolidated to be presented on decades and total, as in figures below.

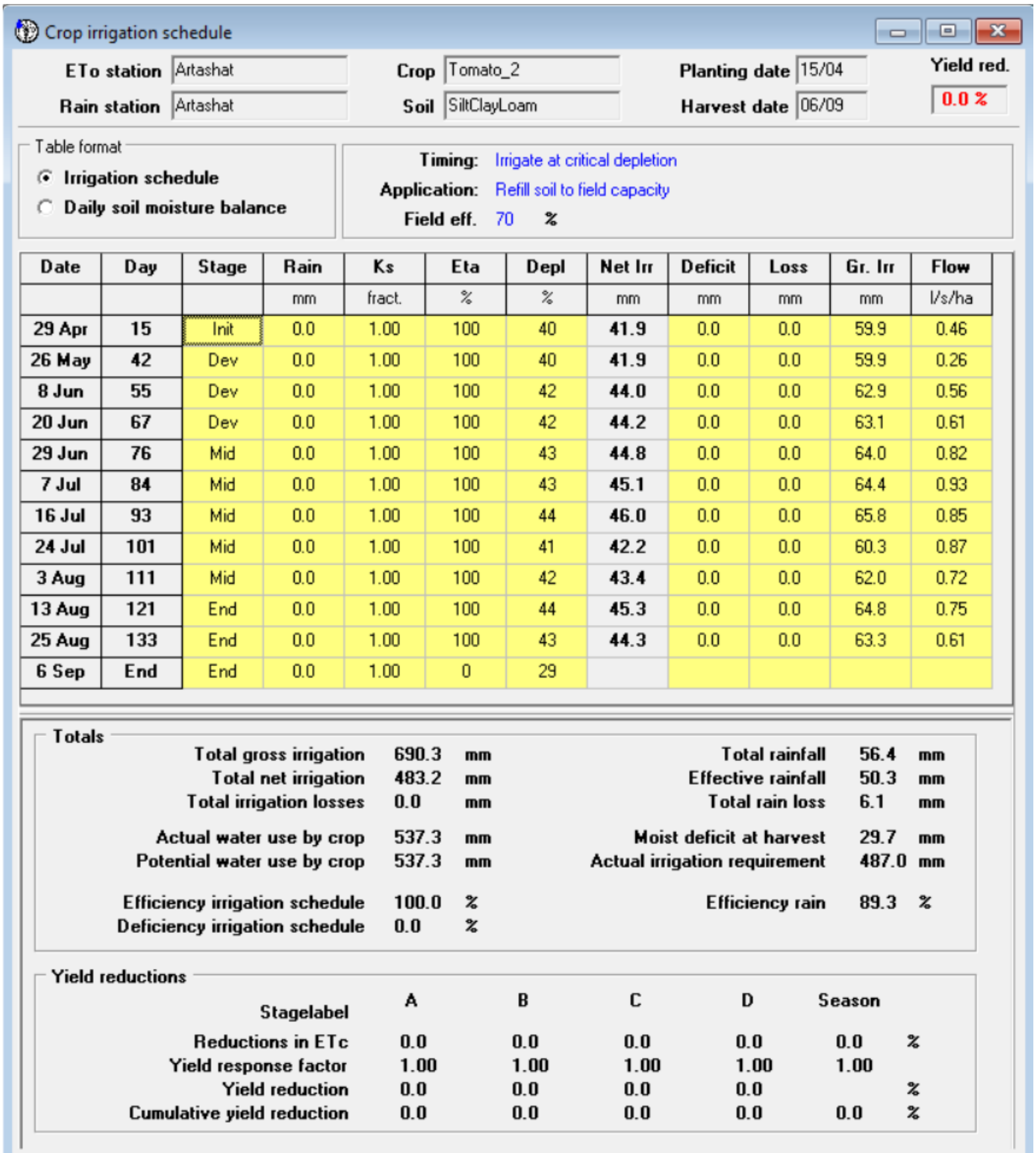
Crop Water Requirements

ETo station: Artashat | Crop: Tomato_2

Rain station: Artashat | Planting date: 15/04

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	2	Init	0.60	1.51	9.1	7.3	3.0
Apr	3	Init	0.60	2.02	20.2	3.2	17.0
May	1	Init	0.60	2.01	20.1	2.7	17.4
May	2	Deve	0.62	2.20	22.0	9.4	12.6
May	3	Deve	0.74	3.01	33.2	6.4	26.8
Jun	1	Deve	0.87	3.73	37.3	10.2	27.2
Jun	2	Deve	0.98	4.36	43.6	3.7	39.8
Jun	3	Mid	1.07	5.52	55.2	4.5	50.7
Jul	1	Mid	1.07	5.41	54.1	0.7	53.4
Jul	2	Mid	1.07	5.35	53.5	0.5	53.0
Jul	3	Mid	1.07	5.10	56.1	5.1	51.0
Aug	1	Late	1.06	4.66	46.6	0.0	46.6
Aug	2	Late	0.95	3.95	39.5	0.0	39.5
Aug	3	Late	0.79	3.12	34.3	0.0	34.3
Sep	1	Late	0.66	2.47	14.8	0.0	14.8
					539.4	**53.5**	**487.1**

Figure 4. Results of Crop Water Requirements for Tomato in Artashat area



Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
29 Apr	15	Init	0.0	1.00	100	40	41.9	0.0	0.0	59.9	0.46
26 May	42	Dev	0.0	1.00	100	40	41.9	0.0	0.0	59.9	0.26
8 Jun	55	Dev	0.0	1.00	100	42	44.0	0.0	0.0	62.9	0.56
20 Jun	67	Dev	0.0	1.00	100	42	44.2	0.0	0.0	63.1	0.61
29 Jun	76	Mid	0.0	1.00	100	43	44.8	0.0	0.0	64.0	0.82
7 Jul	84	Mid	0.0	1.00	100	43	45.1	0.0	0.0	64.4	0.93
16 Jul	93	Mid	0.0	1.00	100	44	46.0	0.0	0.0	65.8	0.85
24 Jul	101	Mid	0.0	1.00	100	41	42.2	0.0	0.0	60.3	0.87
3 Aug	111	Mid	0.0	1.00	100	42	43.4	0.0	0.0	62.0	0.72
13 Aug	121	End	0.0	1.00	100	44	45.3	0.0	0.0	64.8	0.75
25 Aug	133	End	0.0	1.00	100	43	44.3	0.0	0.0	63.3	0.61
6 Sep	End	End	0.0	1.00	0	29					

Totals

Total gross irrigation	690.3	mm	Total rainfall	56.4	mm
Total net irrigation	483.2	mm	Effective rainfall	50.3	mm
Total irrigation losses	0.0	mm	Total rain loss	6.1	mm
Actual water use by crop	537.3	mm	Moist deficit at harvest	29.7	mm
Potential water use by crop	537.3	mm	Actual irrigation requirement	487.0	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	89.3	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	1.00	1.00	1.00	1.00	1.00	
Yield reduction	0.0	0.0	0.0	0.0		%
Cumulative yield reduction	0.0	0.0	0.0	0.0	0.0	%

Figure 5. Schedule of irrigation of Tomato cultivated in Artashat Area

In addition, results of irrigation norms and irrigation duty can be exported to an excel table as in Table 1, below. Also, a graphical diagram is available as in Figure 6, below.

This method can be used for **design** of irrigation schemes by using climate data from years with rainfall events occurrence of 50 and 75% and for **current irrigation scheduling** using the climatic data from the current year up to the current date.

Table 1. Results of Net Irrigation Requirements for Tomato in Artashat area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation deficit (mm)													
1. Tomato_2	0	0	0	20	56.7	117.8	157.3	120.4	14.8	0	0	0	487
Net scheme irr. req.													
in mm/day	0	0	0	0.7	1.8	3.9	5.1	3.9	0.5	0	0	0	
in mm/month	0	0	0	20	56.7	117.8	157.3	120.4	14.8	0	0	0	487
in l/s/ha	0	0	0	0.08	0.21	0.45	0.59	0.45	0.06	0	0	0	
Irrigated area (% of total)	0	0	0	100	100	100	100	100	100	0	0	0	100
Irrigation duty (l/s/ha)	0	0	0	0.08	0.21	0.45	0.59	0.45	0.06	0	0	0	0.59

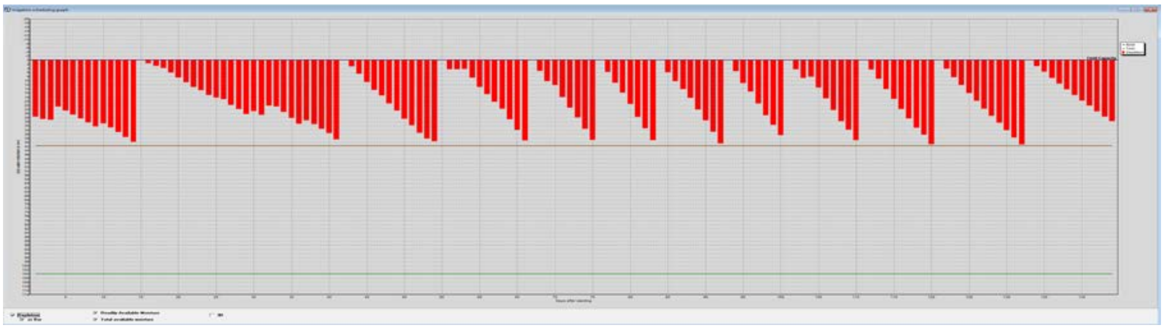


Figure 6. Diagram of irrigation scheduling and variation of the moisture in soil for Tomato in Artashat Area, proposed by CROPWAT

2.3 AquaCrop

A better alternative, more complex for calculation of crop water requirements and irrigation norms and scheduling is the FAO software application **AquaCrop**, shown in figure below. AquaCrop can be freely downloaded from FAO website at the link below: http://www.fao.org/aquacrop/software/aquacropstandardwindowsprogramme/en/

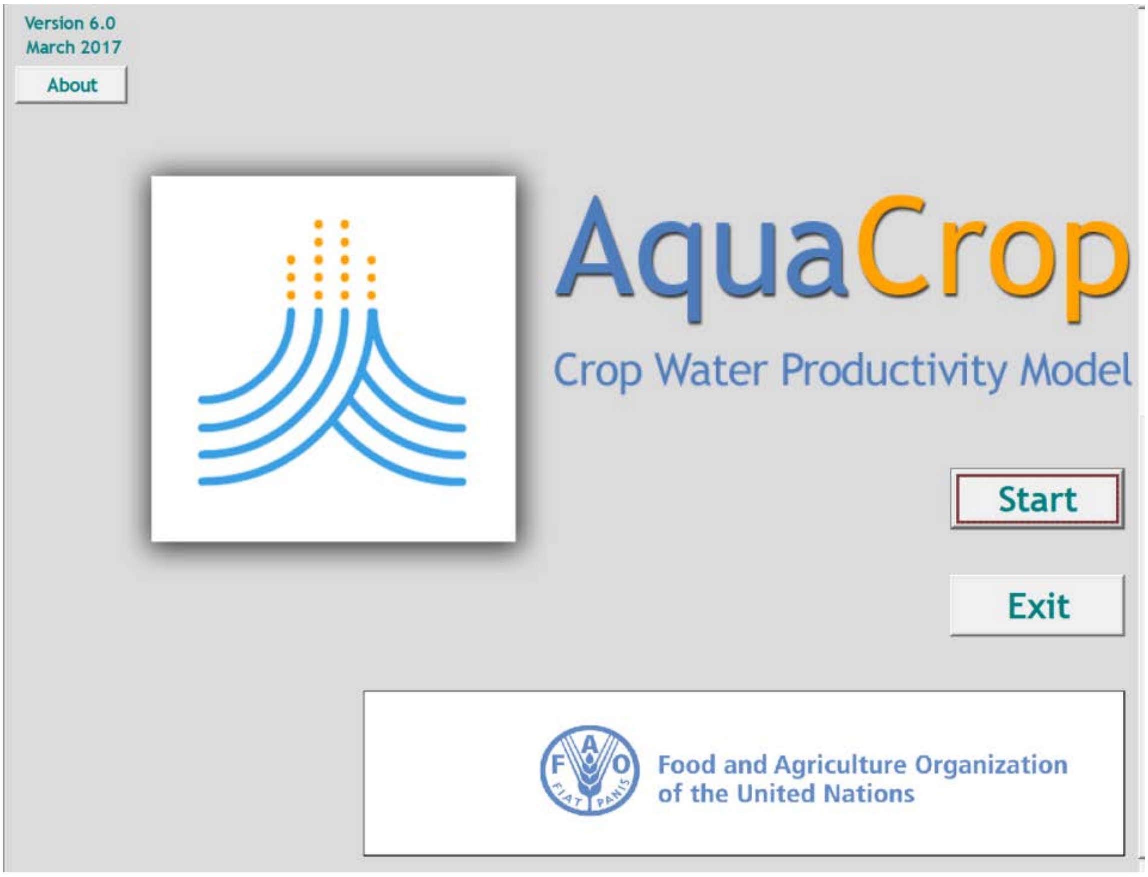


Figure 7. Start window of AquaCrop

AquaCrop and CROPWAT both have the following common functions:

i. Calculation of ETo based on Penman-Monteith equation, as described in FAO I & D Paper 56;
ii. Calculation of Crop Water Requirements based on Crop Coefficients Kc from FAO I & D Paper 56;
iii. Calculation of Irrigation requirements based on the same set of rules to calculate the size of irrigation norm and the timing.

AquaCrop software application is superior to CROPWAT by following functions which are not common with CROPWAT:

i. Takes into consideration the groundwater depth and salinization;
ii. Takes into consideration the CO_2 content of the air to allow simulation of Climate Change;
iii. Allows the user to change different parameters to simulate different scenarios of copping pattern, size of irrigation application, frequency of irrigation applications and displays the results for further analysis;
iv. Includes soil fertility and weed management into analysis and simulations
v. Includes yield analysis and water productivity to be used for comparing the simulation results.

The figure below shows the input data window.

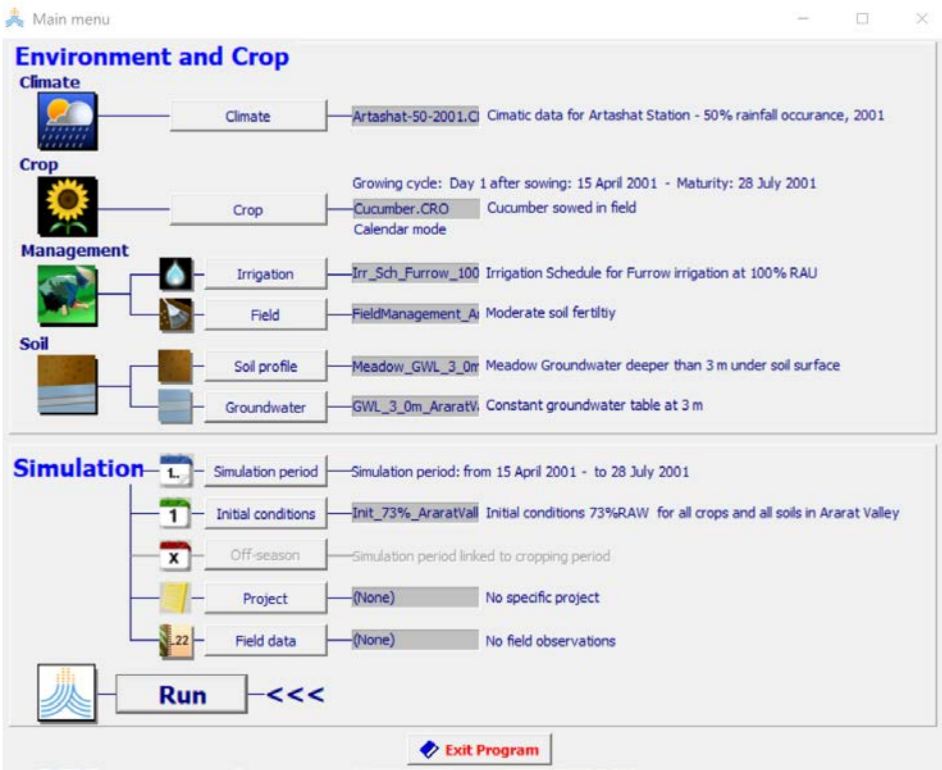


Figure 8. Main menu for input data

The results are presented graphically in figures below. In addition, the results can be exported as text files which can be imported in Excel files for further processing and graphical display.

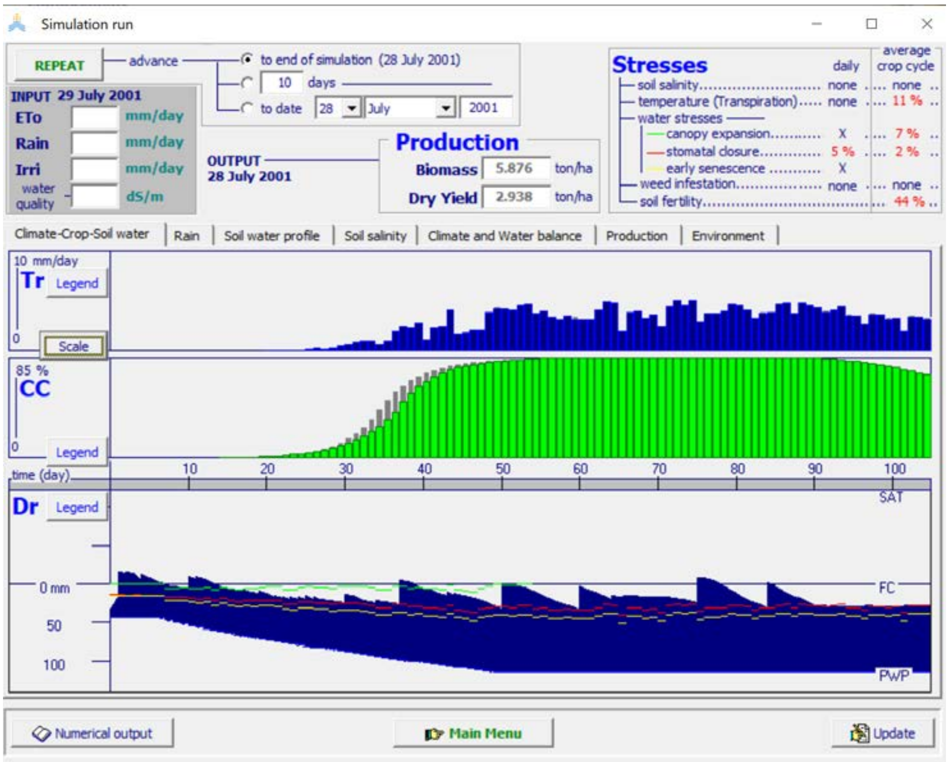


Figure 9. Result of simulation for the whole period

In the above figure the **Tr** diagram is showing the transpiration during the growing season, **CC** is showing the Crop Canopy development during the growing period and **Dr** is showing the moisture content in soil between the Wilting Point (PWP) and Field Capacity (FC).

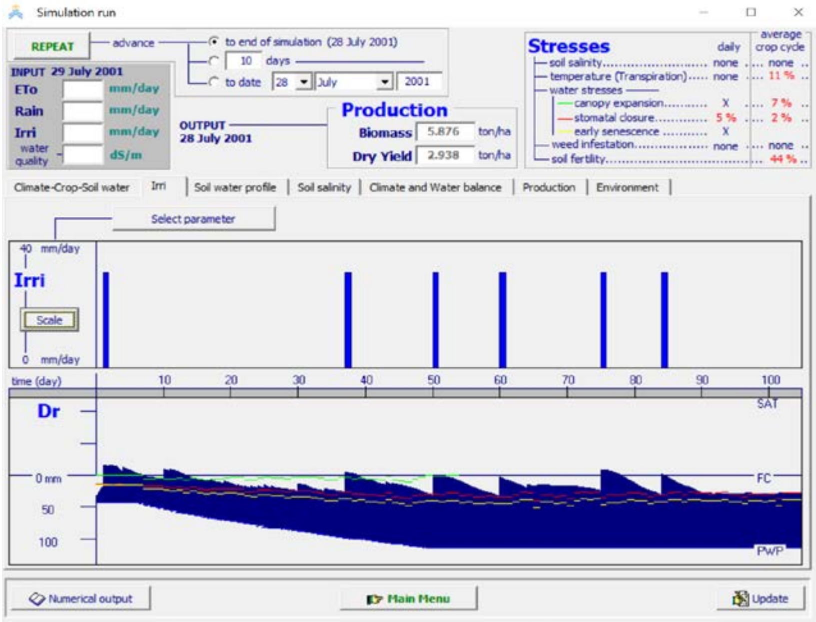


Figure 10. Irrigation Diagram

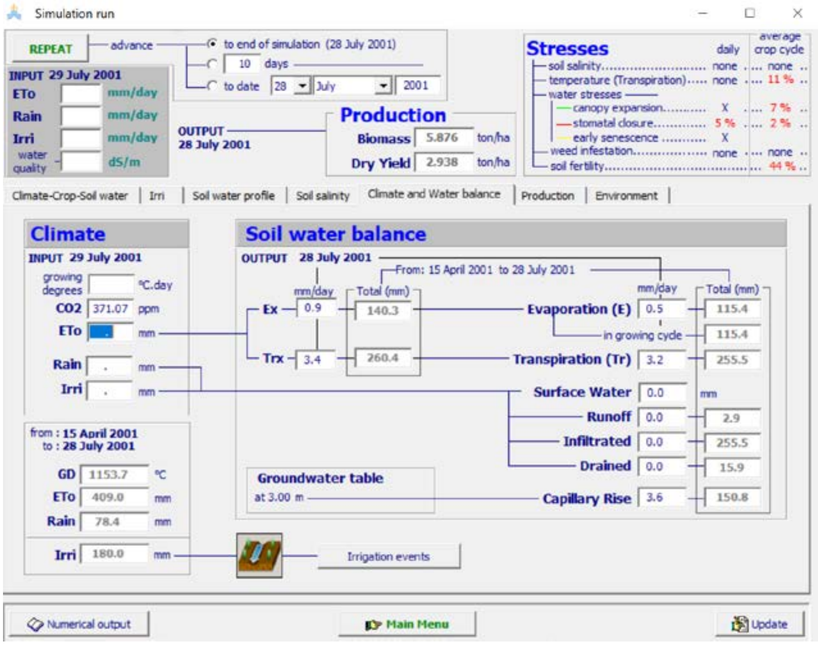


Figure 11. Climate and Soil Moisture Balance

AquaCrop has been developed specifically for the purpose to carry out simulations to optimise the size and the time of irrigation applications. An example is shown in table below.

Table 2. Simulations for the irrigation of cucumber by furrow method

Rules to apply irrigation	Irrigation			Runoff	Drainage	Ground-water	Evapotranspiration			CO_2	Yield				
RAW depleted to:	Events	Size of one dose:	Total season	Runoff	Drainage	Capilary Rise	Evaporation E	Transpiration T	Sum E+T	CO_2	Biomass	Dry Yield	Water Producti-vity	Percent of dry matter	Fresh Yield
%	#	mm/event	mm/season	mm/season	mm/season	mm/season	mm/season	mm/season	mm/season	ppm	ton/ha	ton/ha	kg/m³	%	ton/ha
Day 1 to end at 100% RAW	4	variable	105.8	2.6	7.6	213	106.3	258.9	365.2	371.07	5.956	2.978	0.82	10.00%	29.780
Day 1 to end at 100 % RAW, 30 mm/application	8	30	240	2.9	17.6	101.1	116.3	257.7	374	371.07	5.923	2.961	0.79	10.00%	29.610
Day 1 to 95 at 100% RAW, 30 mm/application	7	30	210	2.9	17.6	106.5	115.4	250.5	365.9	371.07	5.766	2.883	0.79	10.00%	28.830
After day 95 no irrigation	0	0													
Day 1 to 85 at 100% RAW, 30 mm/application	6	30	180	2.9	15.9	150.8	115.4	255.5	370.9	371.07	5.876	2.938	0.79	10.00%	29.380
After day 85 no irrigation	0	0													

Adequate and applicable simulation rules have been used to carry out Crop Water requirements and Irrigation Scheduling for the selected crops in Ararat Valley. The green line indicates the best simulation to follow in case of irrigating cucumber by furrow method.

The updated norms and irrigation scheduling for the selected simulation is displayed as in figure below:

Irrigation Events

Event	Day	Date	Net application (mm)
1	2	16 April 2001	30.0
2	38	22 May 2001	30.0
3	51	4 June 2001	30.0
4	61	14 June 2001	30.0
5	76	29 June 2001	30.0
6	85	8 July 2001	30.0

Close

Figure 12. Irrigation norms and schedule of application

AquaCrop method can be used for **design** of irrigation schemes by using climate data from years with rainfall events occurrence of 50 and 75% and for **current irrigation scheduling** using the climatic data from the current year up to the current date.

2.4 Conclusions and proposals on methodology to use for updating the Irrigation Norms

Three methods for calculation of Crop Water Requirements and Irrigation Scheduling based on FAO Paper 56 have been analysed and described: Excel Template, CROPWAT and AquaCrop.

Presently, CROPWAT and AquaCrop are recommended by FAO to be used for Crop Water Requirements and Irrigation Scheduling calculations and they are now more and more used by international consultant in projects financed by international donors, such as World Bank, Millennium Challenge Corporation and many more.

The proposed methodologies can be used for:

i) **Design** of rehabilitation or new irrigation schemes using the climate data for 50% and / or 75% rainfall occurrence;
ii) **Current scheduling of the irrigation application date and volume** by using the climate data from the current year, up to the current day;

For **design** purpose, the best methodology is **AquaCrop** which has proven to be the most advanced methodology for calculation of Crop Water Requirements and Irrigation Scheduling.

The **current scheduling** of irrigation application can be used in manual or automatic mode, as described below:

Current scheduling in manual mode can be applied by using the **Excel Template** file and using the climate data for the current year, up to the current date. This method can be used by farmers with minimal knowledge of Excel and good knowledge of irrigation of crops.

Current scheduling in automatic mode can be applied using **AquaCrop** by collecting data from one or a network of automatic weather stations. To apply this automatic methodology a software program has to be developed to automatically collect current data from the weather stations and convert them into text file with climatic data to be further used by AquaCrop for calculating the irrigation scheduling of the next few days.

The AquaCrop methodology have been used for updating the methodology and values of Irrigation Norms and Irrigation Scheduling presently existing in the documentation "Irrigation Norms and Regimes of Agricultural Crops for Irrigated Lands in the Republic of Armenia, 2007".

3. Updated Irrigation Norms for the selected set of crops in Ararat Valley

3.1 Data

For use of FAO **AquaCrop** software, following data is required, as input:

- Climatic data: Temperatures Maximum and Minimum, Air Humidity, Wind Velocity, Sunlight Duration and Precipitation;
- Crops variety and information on growing stages and demand for water, nutrients, climate and soils;
- Soil types and properties;
- Groundwater depth and mineralization;
- Initial soil moisture, at start of simulations.

The figure below shows the input data window of Aquacrop before proceeding with running of simulations.

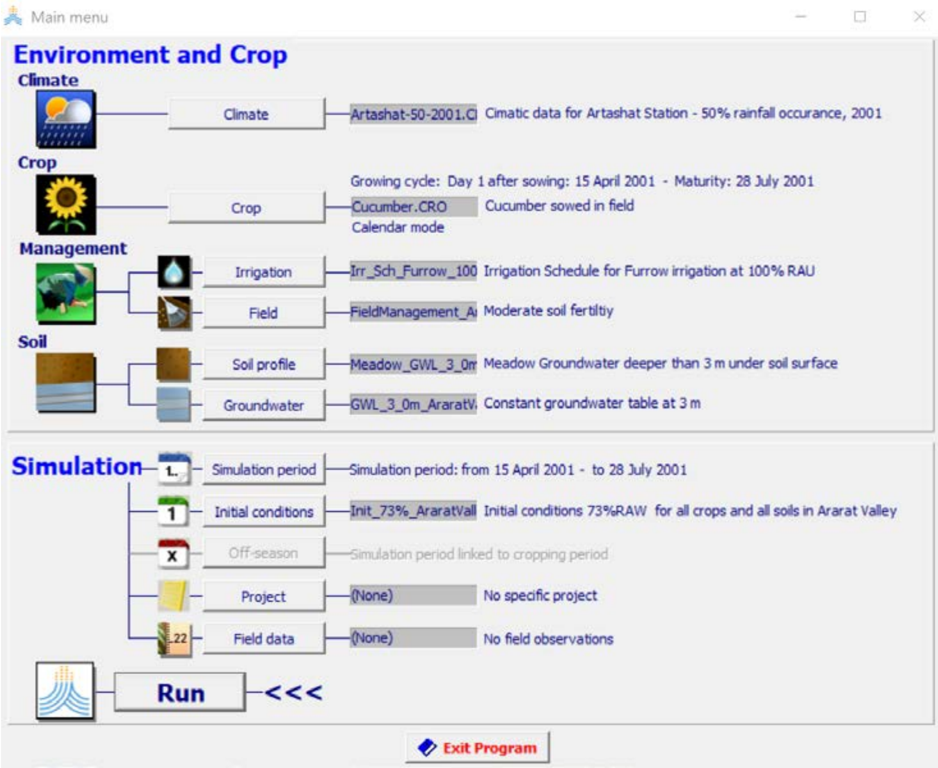


Figure 13. Aquacrop data input window

3.2 Climatic data

Climatic data have been provided as Excel files for Meteorological Stations: Armavir, Artashat and Ararat located inside the area of Ararat Valley. These Meteorological Stations are representatives for Ararat Valley. The area of influence for each Meteorological Station has been set out using the tool Voronoi Polygon from QGIS. The tool calculates the equal distances between two adjacent Meteo Stations and assigns area for each station as in Figure 14 and Figure 15, below.

Figure 14. Map of Armenia and Location of Meteorological Stations in Ararat Valley
(Source: Hydrometeorology and Monitoring Centre, 2020)

***Figure 15. Location of Meteorological Stations in Ararat Valley and assigned area for each station** (Source: Google Earth, 2020)*

The missing data from one station will be supplied with data from the neighbour station, since the distances are small, the terrain elevation is almost same and climatic variation is not significant.

The climatic data received are Daily Minimum Temperature, Daily Maximum Temperature, Precipitation, Daily Average Air Humidity, Daily Wind Velocity and Daily Sunlight duration for each day in period 1980 - 2019. This data is sufficient to start calculation of Crop Water Requirements (CWR) using the formulas provided in FAO Irrigation and Drainage Paper 56 and for use in Aquacrop, which calculates CWR using same formula.

Data on elevation and geographical coordinates of each Meteo station has also been provided, as is shown in Table 3, below.

Table 3. Geographical coordinates and altitude of each Meteorological Station in Ararat Valley

Meteorological Station	**Longitude** (degrees)	**Latitude** (degrees)	**Altitude** (m)
Armavir	44.0499995897	40.1300018965	865
Artashat	44.5430773244	39.9601310623	835
Ararat	44.7200014423	39.8200002246	822

Data from Armavir and Artashat meteorological stations are used for calculation of CWR and Irrigation scheduling in Ararat Valley.

3.2.1 Calculation of rainfall events with probability of 50% and 75%

The calculation of rainfall event probability will be calculated using the FAO methodology described in the documentation FAO-Irrigation and Drainage Paper 25 “Effective rainfall in

irrigated agriculture", in "Chapter III-Application of effective rainfall data in irrigation and drainage", found at following link:
http://www.fao.org/3/X5560E/x5560e04.htm#TopOfPage

Rainfall data from the two selected meteorological stations have been processed for calculation of rainfall occurrence probability of 50 and 75 %, using the FAO methodology.

The figure below shows the distribution of occurrence probabilities at Armavir and Artashat Meteorologic Station and the rainfall with occurrence probability of 50 and 75% (in red dot and red characters).

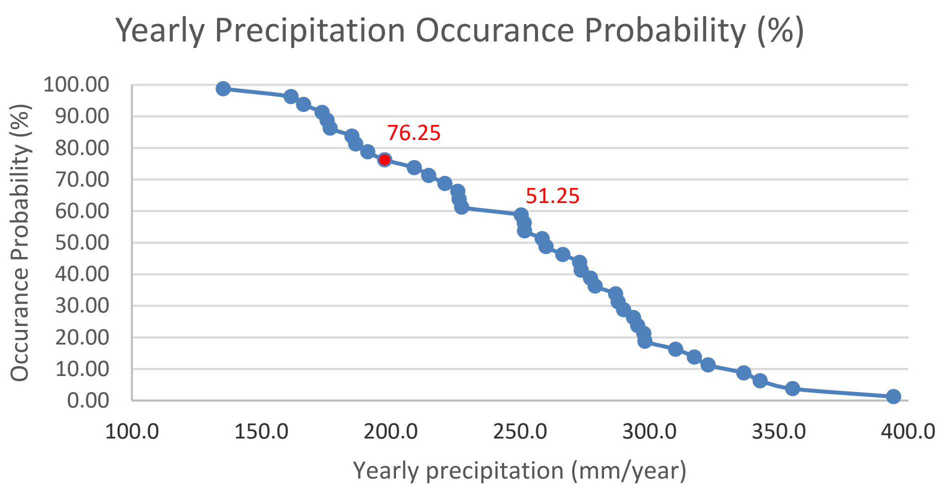


Figure 16. Rainfall occurrence probability at Armavir Meteorological Station for the period 1980-2019

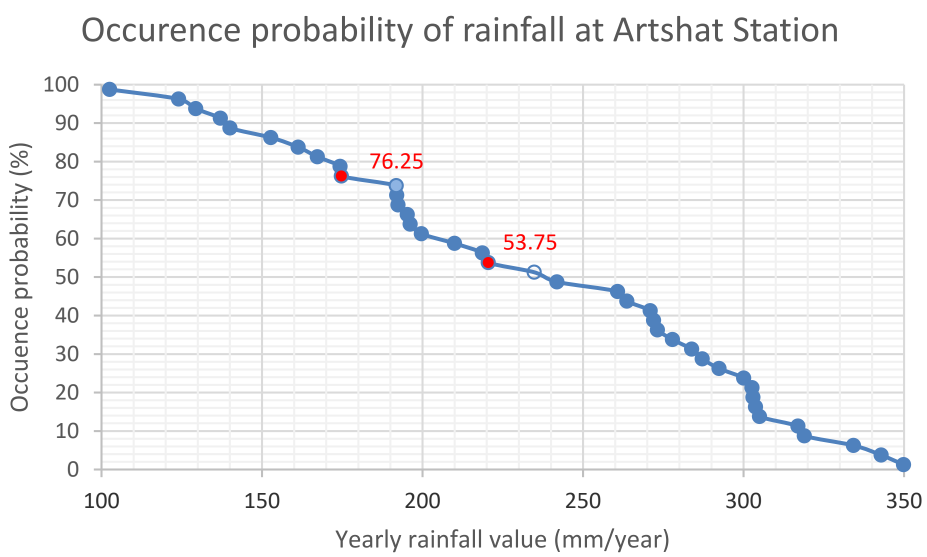


Figure 17. Rainfall occurrence probability at Artashat Meteorological Station for the period 1980-2019

All daily climatic data for each meteorologic station and each probability have been imported and loaded in the Aquacrop database. Once uploaded in AquaCrop the climatic data can be reused anytime as is shown in figure below.

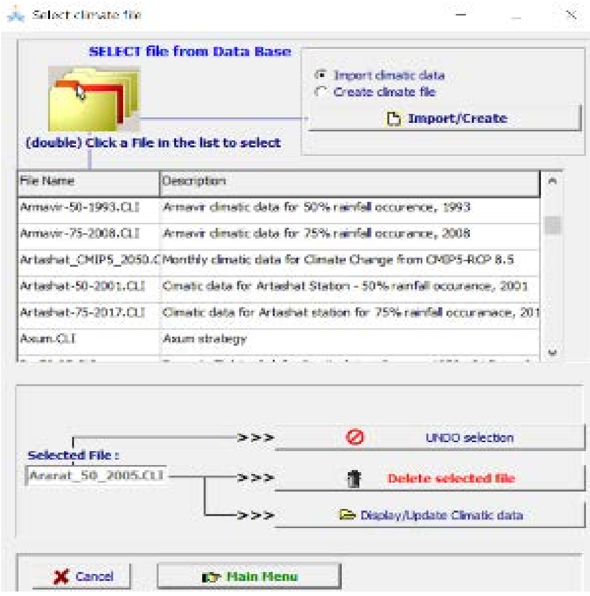


Figure 18. Aquacrop window to select the climatic file

3.2.2 Climate Change

Data for Climate Change have been downloaded from WorldClim website (link: https://www.worldclim.org/data/v1.4/cmip5_30s.html) for the year 2050 (average for 2041-2060) and for the CMIP 5 - CCSM4 scenario, for the Representative Concentration Pathway RCP 8.5, which is the worst-case scenario (basically little or no change in the carbon emissions in the future 30 years). The climatic model CCSM4 and emission scenario RCP8.5 have also been applied in Armenia's Third National Communication on Climate Change (2015).

Data are in form of raster GeoTIFF files which can be viewed and processed using QGIS or ArcGIS. Available parameters are: Average Monthly Minimum Temperature, Average Monthly Maximum Temperature and Monthly Precipitation. QGIS 3.14 software has been used to view and process data for Artashat Meteorological Station which is somehow in the middle of the Ararat Valley and can be considered representative for the whole area. Resulted data are presented in table below.

Table 4. Climate Change Data for CMIP 5 - CCSM4, RCP 8.5

Year 2050	Monthly Maximum Temperatures, Tmax	Monthly Maximum Temperatures, Tmin	Monthly Rainfall
Month	[°C]	[°C]	[mm]
Jan-50	4.1	-3.9	24
Feb-50	7.1	-2.4	9
Mar-50	14.6	2.8	49
Apr-50	21.3	7.5	20.4
May-50	27.3	12.6	19.2
Jun-50	31.8	16.3	19.1

Year 2050	Monthly Maximum Temperatures, Tmax	Monthly Maximum Temperatures, Tmin	Monthly Rainfall
Jul-50	37.2	20.8	6.4
Aug-50	36.7	20.4	0
Sep-50	32.3	15.6	0
Oct-50	22.9	8.5	13.5
Nov-50	15.1	3.1	46
Dec-50	7.3	-9	28.2

These monthly climatic data have been used with Aquacrop to calculate the CWR and Irrigation scheduling. Aquacrop has the capabilities to estimate the missing data such as wind velocity and air humidity from location data and minimum temperatures.

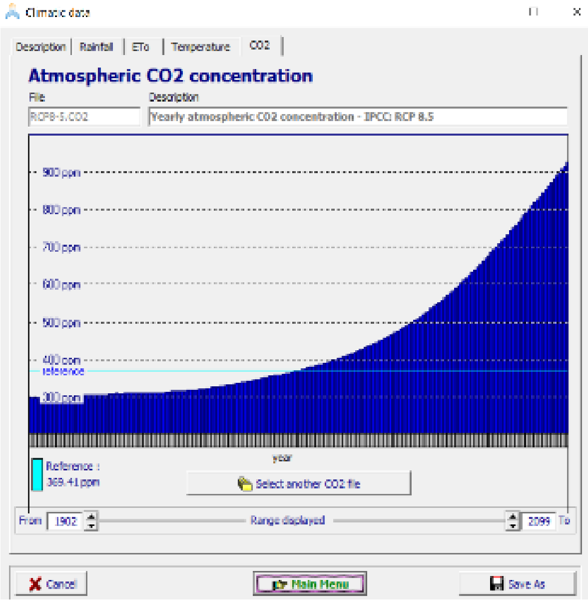


Figure 19. Aquacrop - window to select and view the CO_2 concentration and climatic change scenario (CMIP 5 - RCP 8.5)

In addition, Aquacrop has a capability to estimate the crop yield based on different climate change scenarios including RPC 8.5 and location of crops as latitude and elevation. This capability has been activated and used to calculate CWR and Irrigation scheduling. The figure below shows the window of Aquacrop which allows selection and view of carbon dioxide concentration in air and climatic change scenario.

3.3 Crop data

Terms of reference for this contract requires calculation of Crop Water Requirements and irrigation scheduling for Tomato, Cucumber, Watermelon and Table grapes cultivated in Ararat Valley. The usual planting/sowing dates and expected yields for irrigated crops are shown in table below.

Table 5. Planting/Sowing dates and expected yields

Crop	Date of sowing	Seedlings planting date	Yield, t/ha
Tomato	1-10.03	1-10.05	80-100
Cucumber	15-20.04	-	24 -30
Watermelon	15-20.04	-	40 -45
Table grapes	Start season: 22.03	End season: 12.10	20-30

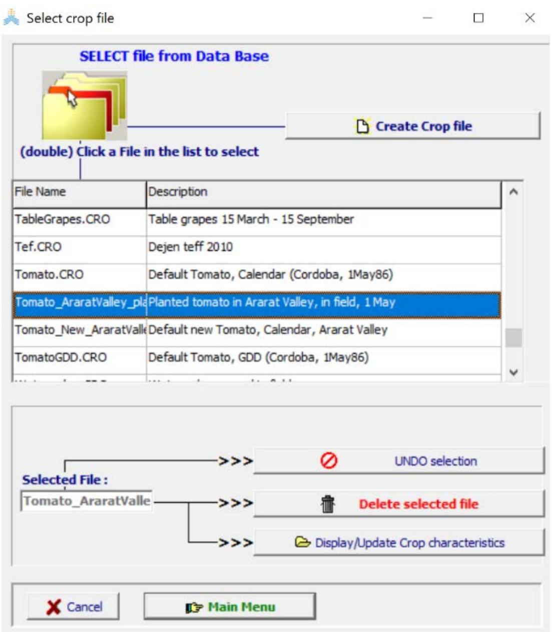


Figure 20. Selection of crop file in AquaCrop

For each crop has been prepared a file with all required data to be used with Aquacrop. Once prepared, the files can be accessed by AquaCrop anytime later for other simulations, as is shown in figure below:

3.4 Soil data

Soil data has been supplied by in form of GIS maps which can be opened with QGIS and ArcGIS software applications, as in Figure 21, below.

.

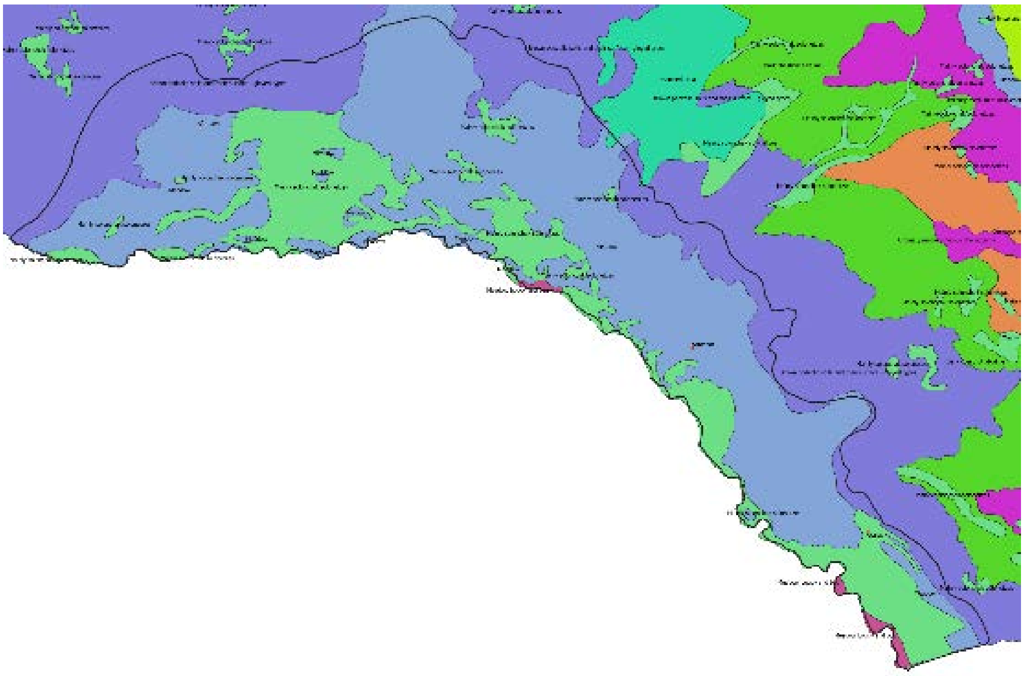


***Figure 21. Soils in Ararat Valley** (Source: Scientific Centre of Soil Science, Melioration and Agrochemistry)*

The soils in each area of influence of Meteorological Station has been derived using functions from QGIS. Soil types in area under the influence of Armavir Meteorological Station are presented in Figure 22, below.

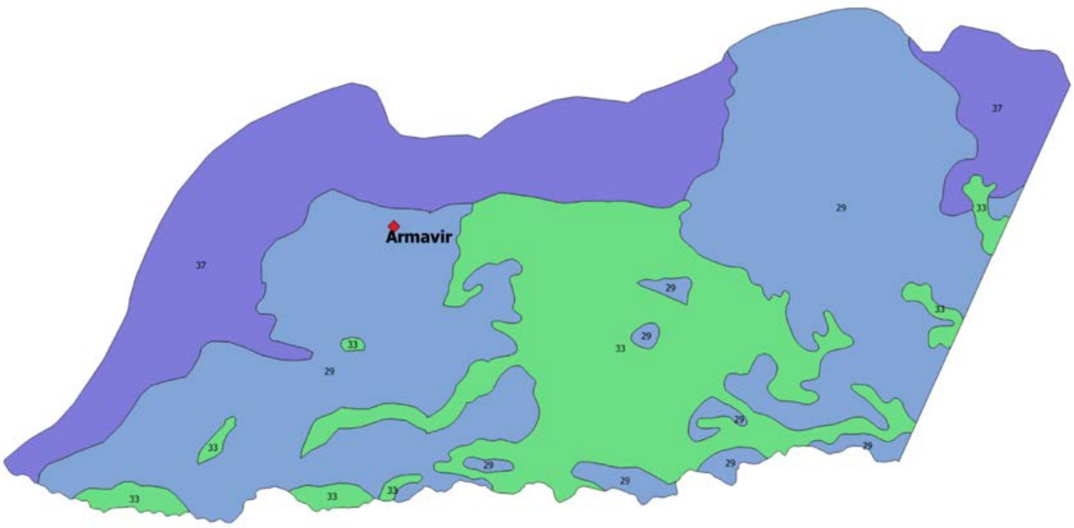


***Figure 22. Soil types in Armavir area** (Source: Scientific Centre of Soil Science, Melioration and Agrochemistry)*

The value of area covered by each soil type in Armavir area is measured with QGIS 3.14 and presented in Table 6, below.

Table 6. Soil types and covered areas in Armavir

Soil Description	Code, as in map in Figure 22	Area (ha)
Total Armavir out of which:		**60,048.91**
Meadow	29	29,531.52
Mainly solonchak solonetzes	33	14,515.31
Brown podzolic soils and their surface - gleyed types	37	16,002.08

Meadow soils are shown in blue colour with code 29, Solonetz and Solonchak soils are shown in green with code 33 and Brown soils are shown in magenta with code 37.

Soil types in Artashat plus Ararat area are presented in Figure 23, below.

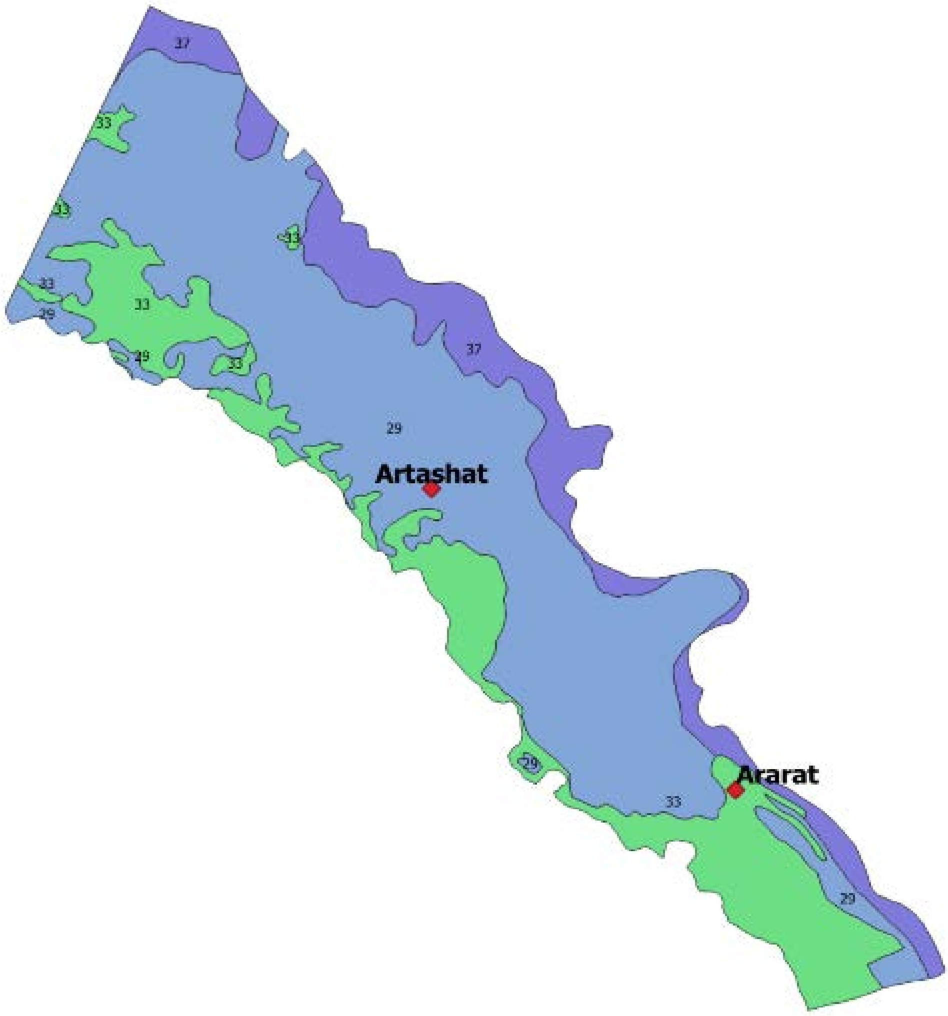


***Figure 23. Soil types in Artashat area** (Source: Scientific Centre of Soil Science, Melioration and Agrochemistry)*

The value of area covered by each soil type in Artashat area is measured with QGIS 3.8 and presented in Table 7, below.

Table 7. Soil types and covered areas in Artashat + Ararat area

Soil Description	Code, as in map in Figure 23	Area (ha)
Total Artashat + Ararat out of which:		**63,498.92**
Meadow	29	39,666.59
Mainly solonchak solonetzes	33	14,588.69
Brown podzolic soils and their surface - gleyed types	37	9,243.63

Meadow soils are shown in blue colour with code 29, Solonetz and Solonchak soils are shown in green with code 29 and Brown soils are shown in magenta with code 37.

The value of area covered by each soil type in entire Ararat Valley area is presented in Table 8, below.

Table 8. Area of each soil type in entire Ararat Valley

Soil Description	Code, as in map in Figure 21 above	Area (ha)
Total Ararat Valley out of which:		**123,547.82**
Meadow	29	69,198.11
Mainly solonchak solonetzes	33	29,104.00
Brown podzolic soils and their surface - gleyed types	37	25,245.71

The soils are grouped into 3 types:

i. Meadow;
ii. Mainly solonchak and solonetzes;
iii. Brown podzolic soils and their surface - gleyed types.

The available data for soils have been supplied from Atlas as follows:

Table 9. Soil texture for each type in Ararat Valley - average values

#	Soil type	Texture		
		Clay (%)	Loam (%)	Sand (%)
i	Meadow	50	40	10
ii	Mainly solonchak and solonetzes	73	27	0
iii	Brown podzolic soils and their surface - gleyed types	2	84	14

Average Groundwater depth 1.5 m and mineralization 1-3 g/l = 1.5 – 4.7 dS/m

In order to calculate the Crop Water Requirements and Irrigation Scheduling the soil-water characteristics are also needed.

Since these characteristics were missing, then the software tool "Soil Water Characteristics" has been used to derive the required parameters. Results are shown in Table 10, below.

Table 10. Soil water characteristics in Ararat valley

#	Soil type	Texture			WP	FC	Sat	Available water	Ksat	Bulk Density	Type
		clay	loam	Sand							
		%	%	%	% Vol	% Vol	% Vol	mm/m	mm/h	g/cm^3	
i	Meadow, irrigated.	50	40	10	29.3	43.5	58.7	140	6.63	1.09	Silty Clay
ii	Mainly solonchak and solonetzes	73	27	0	35.3	47	59.8	120	6.95	1.06	Clay
iii	Brown podzolic soils and their surface - gleyed types	2	84	14	4.2	28.5	47.6	240	31.1	1.39	Silt

WP - Soil moisture at Wilting point
FC - Soil moisture at Field Capacity
Sat - Soil moisture at saturation
Available water = FC – WP
Ksat - soil permeability for water at saturation moisture

For estimation of soil fertility, data in table below has been used:

Table 11. Soil nutrients availability in Ararat Valley arable lands (% of arable land)

Region	Nitrogen	Phosphorus			Potassium		
	mg/100 g soil						
	Low 0-8	Low 0-3	Medium 3-6	High >6	Low 0-18	Medium 18-36	High >36
Ararat	100	72	23	5	19	69	12
Artashat	100	69	24	7	14	67	19
Masis	100	74	22	4	17	68	15
Total Ararat Marz	100	72	23	5	17	68	15
Armavir	100	71	23	6	18	65	17
Echmiadzin	100	67	25	8	13	66	21
Total Armavir Marz	100	69	24	7	15	66	19
Total Ararat Valley	100	70.6	23.4	6	16.2	67	16.8

Humus content in the soils of the Ararat Valley:

a) saline-alkali soils < 0.5%
b) other soils 1.5 -2.5%

Soil reaction pH:

a) saline-alkali soils 8.4 - 10.5
b) other soils 7.2 - 8.4

(Source: “Centre of the Agricultural Services” SNCO)

Table 12. Ararat Valley soils agrochemical characteristics

Soil Profile	**Horizon, cm**	**Hygro scopic water, %**	**Total Content, %**				**Mobile nutrient, Mg/100g soil**			**pH**		**Amount of Absorbed Bases, Mg-eqv per 100g soil**	**Soil Texture**	
			Humus, %	N	P_2O_5	K_2O	N	P_2O_5	K_2O	Water	Salt		Sand ≥ 0.01	Clay ≤ 0.01
Profile 1 Brown, non-carbonate, Irrigated meadow on alluvial sediments	A1 0-30	4.6	1.80	0.15	0.22	1.83	8.5	75.4	55.5	7.8	6.4	34.2	64.7	35.28
	B1 30-57	3.5	1.08	0.06	0.28	1.80	6.3	56.2	25.7	7.7	6.6	21.3	39.92	60.00
	B2 57-81	4.5	0.71	0.03	0.16	1.82	3.3	32.3	21.3	8.2	7.9	14.1	66.31	33.67
	C 81-106	2.1	0.42	0.03	0.15	2.08	1/5	18.1	16.1	8.3	7.8	11.4	77.37	22.68
Profile 2 Dark, brown, non-carbo-nate, Irrigated meadow on alluvial sediments	A1 0-25	4.8	1.95	0.16	0.26	2.01	9.3	82.3	67.4	7.7	6.1	32.4		
	B1 25-52	4.2	1.03	0.08	0.22	1.90	8.5	61.2	30.7	7.5	6.2	17.2		
	B2 52-90	3.8	0.81	0.04	0.20	1.94	3.1	35.6	22.8	7.9	6.8	12.5		
	C 90-120	2.5	0.40	0.03	0.18	2.05	1.6	23.5	18.2	8.1	7.5	9.8		

(Source: “Scientific Center for Farming” CJSC)

All the above soil data have been examined and used for preparing the Soil files for use in Aquacrop. These files have been uploaded in AquaCrop and can be used anytime for simulations, as in figure below:

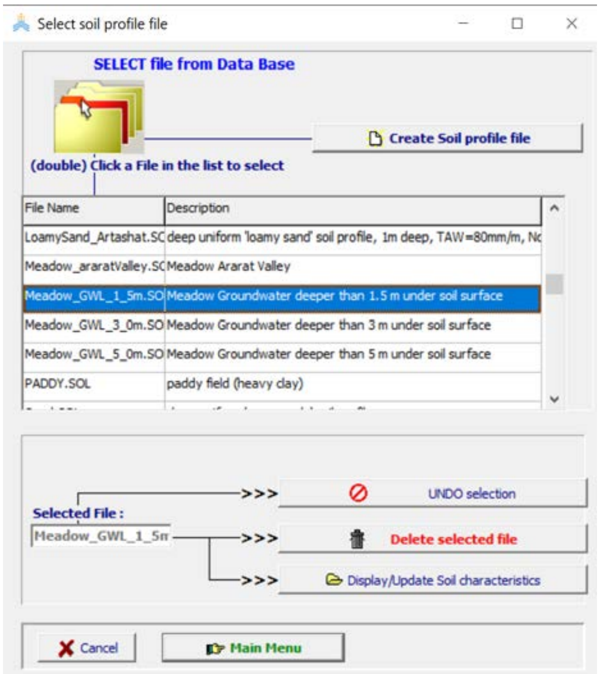


Figure 24. Aquacrop - window for selection of soil files

3.5 Elevation data

The elevation data has been provided by in the form of DEM file, which has been processed under QGIS 3.8 to visualise the relief and elevations of the Ararat Valley.

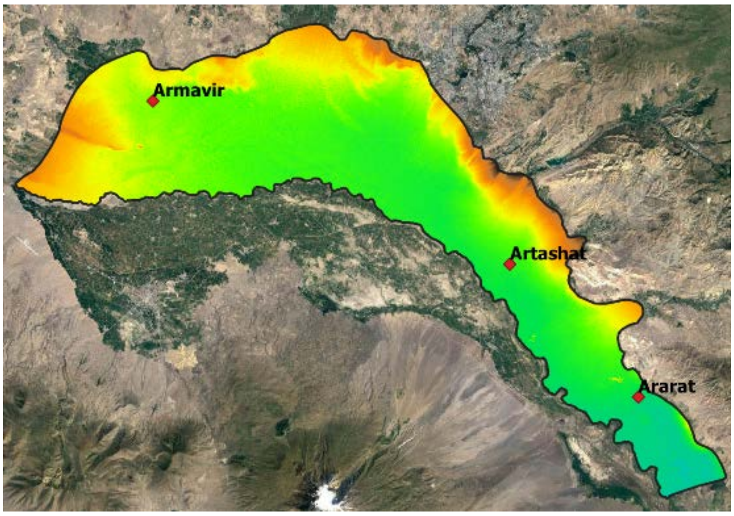


***Figure 25. Elevation image for Ararat Valley** (Source of data: SWCIS of Armenia, Processed IC using QGIS 3.8)*

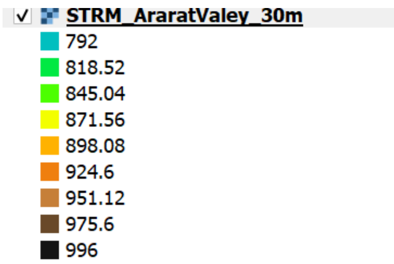


Figure 26. Legend of elevation (m) colours in Figure 25, above

The relief in Ararat Valley looks relatively flat, and the average elevation is in the range 800 - 850 m. In this case any irrigation method can be employed to distribute water to crops.

3.6 Data Gaps approach

In case of data gaps then following approach is proposed:

3.6.1 Climate data gaps

In case climatic data is missing then data from 2 - 3 closest weather station can be used. The value of gap should be calculated from as inverse proportional with distance from the current location to each of the closest weather station. Alternatively, data form FAO - CLIMWAT software application can be used, as monthly average data. Also, NASA website NASA POWER | Prediction of Worldwide Energy Resources offers free access to climatic data derived from satellite imagery. The density of points is based on a grid of 1° latitude and 1° longitude. NOAA website Search | Climate Data Online (CDO) | National Climatic Data Center (NCDC) (noaa.gov) also can supply climatic data such as Temperatures Maxim, temperature Minim and Precipitation for most of weather stations in Armenia.

AquaCrop, has the possibility to overcome some climate data gaps such as: missing air humidity can be derived from Temperature minim, The Solar radiation can be derived from Temperature Maximum and Temperature Minimum and the Wind data missing can be estimated from regional climate. However, in case of missing climate data mentioned above, the results will not be accurate but the errors will not exceed 5%.

For Ararat Valley, all required climatic data were available so no data gap approach should be applied.

3.6.2 Soil data gaps

In case missing the soil data such as Field capacity, Wilting Point, Soil moisture at saturation, Bulk density and Soil permeability at saturation moisture then a software application such as Soil Water Characteristics from the website Soil Water Characteristics | NRCS (usda.gov) can be used. However, at least the content of sand and clay should be known and based on these available data to derive all the other soil characteristic data. This was the case of Ararat Valley, where only the content of clay and sand has been known and the other above mentioned characterizes were derived using the software tool Soil Water Characteristics and results are shown in Table 10, above. These soil water characteristics are required by AquaCrop for calculation of Irrigation Requirements and Scheduling.

3.6.3 Elevation data gaps

Elevation data gaps can be overcome by using STRM 30 m data from USGS website EarthExplorer (usgs.gov). Data are in form of .tif file which can be uploaded and processed using ArcGIS or QGIS software applications. With elevation data, the elevation of relief features at intervals of 30 m in any direction as well as land slope can be derived.

3.7 Field management data

The crop response as development and yield depends on the way the soil surface is maintained and on the soil fertility. Aquacrop allows the user to input data, set parameters and view the data as in Figure 27, below.

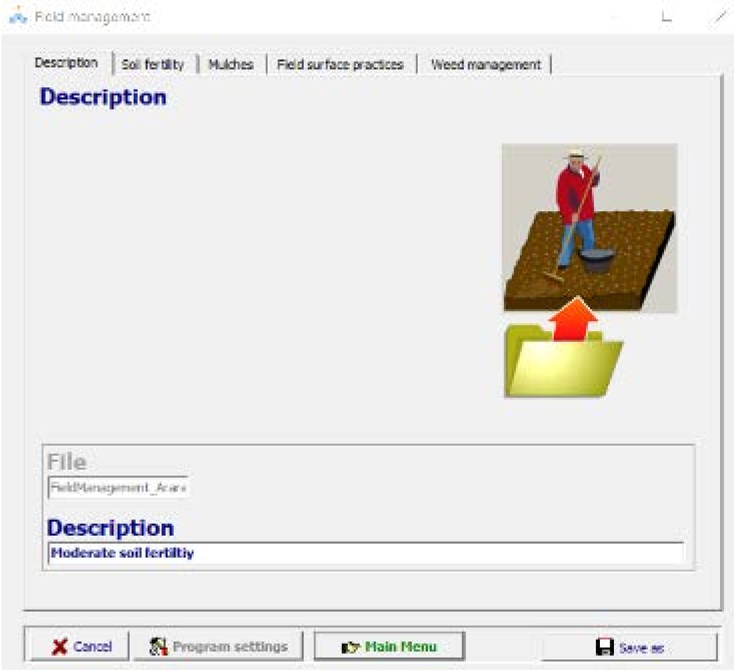


Figure 27. Aquacrop - window to set Field management description

The soil fertility has been considered as moderate and not limiting the biomass production.

3.8 Initial conditions

To start the moisture balance in the soil, Aquacrop needs data on the initial moisture of soil at the start of the growing season of crops.

For the case of Ararat Valley, for all soils and locations, it is assumed that the initial moisture of the soil is of 73% of TAW (Total Available Water = Field Capacity – Permanent Wilting Point).

3.9 Simulations of Irrigation norm sizes and irrigation schedules using FAO Aquacrop software

3.9.1 Generation of irrigation schedules

For each irrigation method, applicable to local conditions of Ararat Valley and to crop type, has been set a file in Aquacrop with all required setting, as is shown in figures below.

3.9.2 Generation of irrigation schedules for Furrow irrigation

The predominant irrigation method in Ararat Valley is furrow irrigation and it applies to all selected crops: tomato, cucumber, watermelon and table grapes. An example of generation of irrigation schedule for cucumber grown on Meadow soils with groundwater level depth of less than 3 m, irrigated by furrow method is sown in figure below.

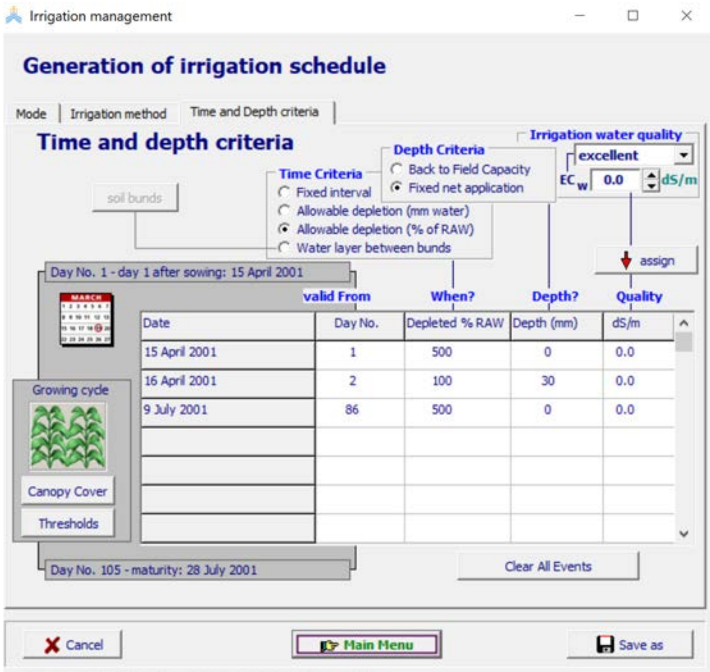


Figure 28. Aquacrop - window to set the size (depth) of norm and time of application

3.9.3 Generation of irrigation schedules for Drip and Sprinkler irrigation

Drip irrigation is applicable to all four selected crops but not yet wide spread in Ararat Valley. However, it might become more and more common in the future years and for that, the irrigation norms and schedules have been developed for all four selected crops. Below is presented a figure showing the setting the Aquacrop for drip irrigation.

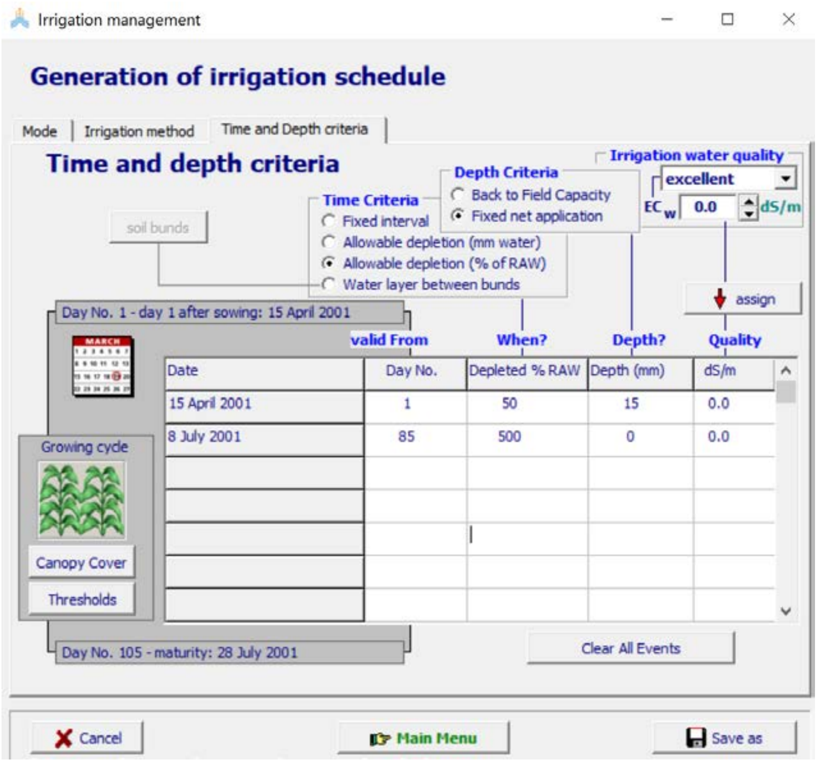


Figure 29. Aquacrop - window to set the size (depth) of norm and time of application

In the case of drip and sprinkler irrigation the individual irrigation norms (doses) can be smaller compared to furrow irrigation because of easier way to apply the irrigation and because of much lower cost of application. The results of reducing irrigation norms is increasing in frequency of irrigation and increase in yields.

3.9.4 Simulations rules

Aquacrop allows the user to set several rules of simulating the size of norm and time of application for helping generate an optimum option of size of norm and time of application (frequency of application) which leads to the least stress to the crop and to the highest yields.

For each crop and irrigation method (furrow, drip and sprinkler), has been set specific simulation rules to allow selecting the option which offers highest yield with lowest consumption of irrigation water.

3.10 Selection of the best option between simulations

The simulations are applied in view of verification if water consumption can be reduced without reducing significantly the yield of crops, especially in future years when the effects of climate change will reduce the availability of water.

Out of 4 - 5 simulations the best option is selected if the results indicate that the water productivity is highest and the fresh yield does not decrease more than 3 - 5% compared to the optimum simulation which is simulation 1;

More details on data collection and processing as well as defining climate files, crop files, soil files, field management files, irrigation generation files and simulation rules and detailed results of calculations / simulations are presented in the report “**Updated Irrigation Norms for the selected set of crops in Ararat Valley** - **final**”.

3.11 Results of simulations and Updated Irrigation Norms

The summary of results for the best option of size of irrigation norms and the irrigation scheduling for each crop, soil and climate are presented in Annex 2 at the end of this report.

Details of each simulations and reasons for selecting the best option are provided in the report “**Updated Irrigation Norms for the selected set of crops in Ararat Valley**”.

For comparison, in tables below are presented the existing Irrigation Norms and Updated Irrigation Norms. The comparison shows that the Updated Irrigation Norms are much lower than the existing Irrigation Norms allowing water volume savings in the range of 3000 - 4000 m^3/ha for vegetables and 2000 m^3/ha for Table Grapes. The reason of such a big difference is the more detailed data considered by AquaCrop such as: soil-water characteristics, depth or root for each crop, and more reliable crop coefficients for calculation of Crop Water requirements. In addition, the AquaCrop simulations allows the user to reduce the number of last watering to be reduced while the crop yield remains close to the maximum value, in the range of 3 - 5% lower.

Table 13. Comparison between present irrigation norms and updated norms using AquaCrop - 2021 for soils with groundwater depth higher than 5 m

No	PRESENT NORMS IN MANUAL - Furrow Irrigation - Groundwater depth > 5m							UPDATED NORMS - Furrow Irrigation - Groundwater depth >5m												
	Crop	50%			75%			Crop	50%			75%			CLIMATE CHANGE CMIP5-RCP-8.5		
		Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm	Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm		Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm	Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm	Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm
#	-	#	m^3/ha	m^3/ha	#	m^3/ha	m^3/ha	-	#	m^3/ha	m^3/ha	#	m^3/ha	m^3/ha	#	m^3/ha	m^3/ha
1	Vegetable	11	650	7150	13	650	8450	Tomato	9	550	4950	10	550	5500	9	550	4950
								Cucumber	10	300	3000	12	300	3600	12	300	3600
								Watermelon	10	300	3000	12	300	3600	13	300	3900
2	Table Grapes	7	950	6650	8	900	7200	Table Grapes	9	500	4500	10	500	5000	10	500	5000

Table 14. Comparison between present irrigation norms and updated norms using AquaCrop - 2021 for soils with groundwater depth less than 3 m

No	PRESENT NORMS IN MANUAL - Furrow Irrigation - Groundwater depth <3m							UPDATED NORMS - Furrow Irrigation - Groundwater depth <3m									
	Crop	50%			75%			Crop	50%			75%			CLIMATE CHANGE ICM4-RCP-8.5		
		Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm	Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm		Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm	Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm	Watering Numbers	Single Irrigation Norm	Seasonal Irrigation Norm
#	-	#	m^3/ha	m^3/ha	#	m^3/ha	m^3/ha	-	#	m^3/ha	m^3/ha	#	m^3/ha	m^3/ha	#	m^3/ha	m^3/ha
1	Vegetable	0	0	0	13	550	7150	Tomato	5	550	2750	7	550	3850	8	550	4400
								Cucumber	6	300	1800	12	300	3600	13	300	3900
								Watermelon	7	300	2100	8	300	2400	13	300	3900
2	Table Grapes	0	0	0	6	950	5700	Table Grapes	6	500	3000	6	500	3000	8	500	4000

3.12 Conclusions and proposals on updated irrigation norms

Crop Water Requirements and Irrigation Scheduling in Ararat Valley has been calculated using FAO software **AquaCrop** that is based on methodology described in FAO Irrigation and Drainage Paper 56.

Calculation of Crop Water Requirements and Irrigation Scheduling in Ararat Valley has been carried out for the pilot crops: Tomato, Cucumber, Watermelon and Table Grapes.

For each crop adequate irrigation method has been considered:

- For tomato: furrow, drip and sprinkler methods;
- For cucumber, watermelon and table grapes: furrow and drip methods.

As climate, the **50%** rainfall probability, **75%** rainfall probability and **climate change** 50% rainfall probability for year 2050 have been considered for each crop. Climatic stations relevant and with almost complete set of data considered for these calculations were Artashat and Armavir. For Climate Change the climatic station Artashat has been considered since it is in the middle of the Ararat Valley.

Ararat Valley is located on 3 soil types and different depth of underground water level which have been classified in intervals of less than 1.5 m, 1.5 - 3 m and deeper than 5.3 m.

The results of simulations presented as size of one application (dose) for the best options are presented in Chapter 7 - **Annex 2** and these represent the **Updated Irrigation Norms** for selected crops in Ararat Valley. These resulted irrigation norms are recommended to replace the existing, obsolete, norms in the Manual "Irrigation Norms and Regimes of Agricultural Crops for Irrigated Lands in the Republic of Armenia, 2007".

The Updated Irrigation Norms are now much better justified since the size of norms and irrigation scheduling are based on a detailed analysis of 4 - 5 simulations and on the expected water productivity and yield.

The results of Updated Irrigation Norms for years with rainfall probability of 50% and 75% show that for most of cases it is possible to **reduce the water consumption** by 1 - 3 norms (doses) representing **10 - 30%** of total yearly irrigation requirements without affecting the yield by more than 3 - 5%.

Compared to present Irrigation Norms from the Manual the Updated Irrigation Norms using AquaCrop are much less, as can be seen from Table 13 and Table 14, above. The reason of the difference is that AquaCrop takes into consideration more detailed soils and crop characteristics and also uses the most reliable crop coefficients for calculation of evapotranspiration. In this case, the Updated Irrigation Norms are expected to better suit to crops needs and to allow water saving in the range of 3000 - 4000 m^3/ha for vegetables and 2000 m^3/ha for Table Grapes. These water volume savings have to be validated by the field tests which should be carried out next period.

For the case of Climate Change, at the level of the year 2050, the water requirements are significantly higher than for years with 50% and are equal or little higher than the requirements for present year with 75% probability. However, on soils with underground water level less deep than 1.5 m now it is not necessary to irrigate because the capillary rise can supply the root zone with sufficient water to keep the crops at high level of production but in case of Climate Change at the level of year 2050 for the same crops on the same soil and underground water level the crop water requirements exceed substantially the capillary rise and crops need at least 3 or more irrigation applications each year. The good effect related to Climate Change is the increasing of the crop yields by 30 - 40% due to increased content of CO_2 in air.

The resulted reduction of water volumes consumption, if applied, will substantially reduce the irrigation costs and creates important water resources for irrigating adjacent areas and to increase the volume of the yields (with yield increase from newly irrigated areas).

As recommendation, initiating systematic researches at least in Ararat Valley area to validate the crop coefficients and expected fresh yield values for each crop and each soil type would be very helpful to calibrate the functionalities of AquaCrop to produce more accurate results.

4. Step-by-Step Recommendations for replicating the work for the entire territory of Armenia

The results obtained in Chapter 3 , above, cannot be extrapolated to the entire territory of Armenia because the climate and soil data have a great variability. However, the Methodology of calculation of Crop Water Requirements and of the Irrigation Requirements and Scheduling, presented in Chapter 0, above, can be used throughout the world and also throughout Armenia territory.

In order to replicate the work done for Ararat Valley to the entire territory of Armenia, the methodology for calculation of irrigation norms and scheduling has to be applied in few steps, as followings:

Step 1 - organising working teams and setting up testing fields

Step 2 - collecting data and field surveys

Step 3 - preliminary calculation of crop water requirements and irrigation scheduling using AquaCrop and deciding the field-testing scenarios to get data for calibration of AquaCrop

Step 4 - final calculation of crop water requirements and irrigation scheduling and updating the irrigation norms based on field verified results

4.1 Step 1 - Organising working Teams and setting-up testing fields

Since the AquaCrop software has been found the most advanced way to calculate Crop Water Requirements and Irrigation Scheduling, it is proposed to be used to replicate the updating irrigation norms and irrigation scheduling over the entire territory of Armenia. To do this, it is necessary to create a team of experts to learn how to use AquaCrop software application for calculation of Crop Water Requirements and Irrigation Scheduling.

The working team should include one Team leader and 3 members at central level, under Ministry of Agriculture or the Water Committee. This team at central level shall be supported by several local/field teams.

The Central Team shall collect data from relevant data suppliers and from local/field teams and will use them as input in AquaCrop for calculating the Crop Water Requirements and Irrigation Scheduling.

At least 5 local / field teams should be organised out or which one team located in Ararat Valley, one team located in Sevan - Hrazdan zone, one in Akhuryan zone, one team in Northern zone and one team in Southern zone, which are the most relevant zones for irrigated agriculture in Armenia. Location of each irrigation zone is shown in Figure 30 , below.

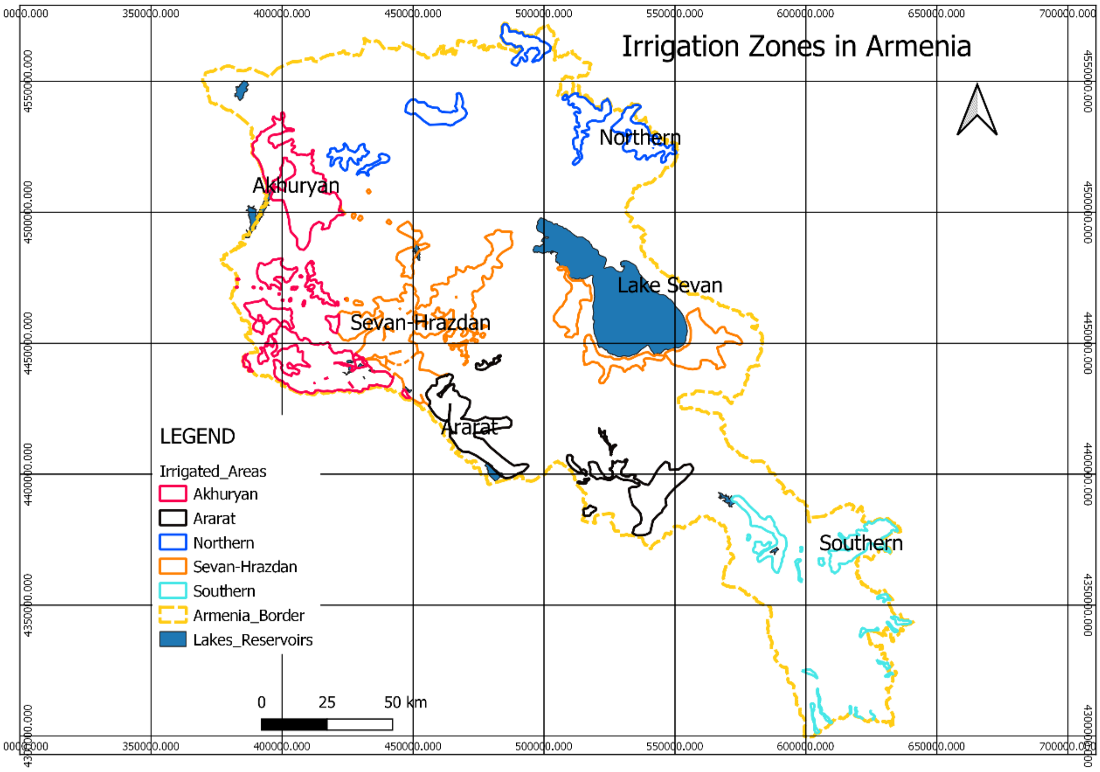


Figure 30. Irrigation zones in Armenia ***(Source: Water Committee, WUAs)***

The local / field teams will be involved in setting up and maintaining experimental plots located on different soil conditions and depth of underground water. Each local team should be composed of a Team leader - agriculture engineer, one technician with background in agriculture and irrigation and two assistants. The main tasks of the field team are to organise field testing plots, to apply the irrigation schedule, and maintaining the field testing plots. In addition, the Field Teams will permanently monitor the soil moisture content and the climatic data. The field team will record for each crop all relevant field data, irrigation applications, soil moisture, crop growing stages and yields.

The Central Team will be trained on how to use and calibrate AquaCrop software based on historical climatic data and based on data obtained in field testing plots.

4.2 Step 2 - Collect data and field surveys

4.2.1 Step 2-1 - Collect and process Historical Climatic data

The Central Team will identify the relevant meteorological stations located within the range of 20 km from each field-testing plot and will process the data as required to be used in AquaCrop.

Data on elevation and geographical coordinates of each Meteorological Station needs also to be collected as such data is necessary to be used as input data in AquaCrop for calculation of Reference Evapotranspiration.

4.2.2 Step 2-2 - Collect and process Climate Change climatic data

Data for Climate Change can be downloaded from WorldClim website (link: https://www.worldclim.org/data/v1.4/cmip5_30s.html) for the year 2050 (average for 2041 - 2060) and for the CMIP 5 - CCSM4 scenario, for the Representative Concentration Pathway RCP 8.5, which is the worst-case scenario (basically little or no change in the carbon emissions in the future 30 years).

4.2.3 Step 2-3 - Collect Soil Data

Soil data has to be collected for each field-testing plot set up in Step 1 above and data will be loaded in AquaCrop.

Data gaps shall be addressed by carrying out systematic soil surveys of all irrigation zones in Armenia (Figure 30). The soil surveys will be of much help for farmers and experts working in the field of increasing the soil productivity by irrigation, fertilizing and field management.

The area of each irrigation zone in Armenia, shown in the above map, is presented in table below.

Table 15. Armenia - irrigation zones

ID	Irrigation zones name	Area (ha)
1	Sevan-Hrazdan	214,246.03
2	Northern	68,620.69
3	Akhuryan	165,865.19
4	Ararat	87,054.77
5	Southern	42,770.48
	Total	**578,557.16**

The intensity of the soil survey should be of at least 1 to 250 ha for each soil type with area larger than 1000 ha and at least 1 to 100 ha for smallest areas. At this rate, the total maximum estimated number of soil pits will be of 2,365. The number of pits in each Irrigation Zone is proposed in table below.

Table 16. Proposed number of pits in each irrigation zone

ID	Irrigation zones name	Proposed number of test pits
1	Sevan-Hrazdan	862
2	Northern	280
3	Akhuryan	667
4	Ararat	370
5	Southern	186
	Total	**2365**

This number of soil pits requires a considerable amount of resources such as, soil experts, kits for soil sampling, transportation, and a large laboratory capacity to carry out the soil analysis. The sampling methodology should be in line with methodology described in USDA documentation Field Book for Describing and Sampling Soils - September 2012, link: [Field Guides | FAO SOILS PORTAL | Food and Agriculture Organization of the United Nations]

The estimated time-frame to carry out soil surveys for all irrigation zones is one year.

4.2.4 Step 2-4 - Collect / Monitor Depth of Groundwater Level Data

Groundwater level depth is important to be known as it can supply the root zone of crops with moisture by capillarity. Usually, the capillary rise is significant up to the depth of water less than 5 m. For deeper groundwater level depth there is no need to monitor or to use it in AquaCrop. Existing data on groundwater level depth data are very useful and can be used with AquaCrop.

In case of data gaps then a network of wells for measuring / monitoring the groundwater, depth should be installed in all irrigation zones where the groundwater level is lower than 5.5m from soil surface. A proposal of location of the wells network is presented in the report **"Step-by-step recommendations for replicating the work for entire territory of Armenia".**

The level of groundwater level should be measured by the field teams at intervals of 10 days for at least one year. On the occasion of level measurement, sample of water shall be collected for Electroconductivity measurement.

4.2.5 Step 2-5 - Collect / Monitor Field management Data

The Field Team shall record the field management of each crop regarding: the soil fertility, mulches, field surface practices and weed management. The field teams can carry out a survey to collect data on the conditions of field management for each crop. The necessary equipment for this task is the usual equipment for interviews and visual investigations such as: transportation, soil fertility test kits, notebooks, camera, tape, and similar.

For more detailed assessment, a relationship crop canopy development - biomass production should be initiated in field test plots. In addition, in such detailed assessments it is important to derive the relationship Water Productivity - Crop Water Requirements and relationship Biomass - Soil fertility stress. More details on this relationship are available in reference manual of AquaCrop.

4.2.6 Step 2-6 - Collect / Calculate Initial Conditions Data

The soil moisture shall be determined for all soil layers which will be later monitored. In case the crop is planted, then the Field Teams will supply to Central Team data on grown crops regarding the canopy cover and depth of root at the moment of planting.

4.2.7 Data gap approach

The best way to address the data gap is by measuring the missing data in field. This approach is valid for all data mentioned above except for missing historical data which can be downloaded from FAO - CLIMWAT software application, as monthly average data. Also, NASA website [NASA POWER | Prediction of Worldwide Energy Resources] offers free access to climatic data derived from satellite imagery. The density of points is based on a grid of 1° latitude and 1° longitude. NOAA website [Search | Climate Data Online (CDO) | National Climatic Data Center (NCDC) (noaa.gov)] also can supply climatic data such as Temperatures Maxim, temperature Minim and Precipitation for most of weather stations in Armenia.

For the case of missing soil water characteristics, these can be measured by field and laboratory tests or can be derived from soil texture data using the software tool Soil Water Characteristics from the website [Soil Water Characteristics | NRCS (usda.gov)].

The other missing data such as field management or initial soil moisture, this data can be estimated with a good precision.

4.3 Step 3 - Preliminary calculation of Crop Water Requirements and Designing Irrigation schedules

The Central Team will design the Irrigation schedule for each crop and will make it available to Field Teams to put into practice.

In designing the irrigation schedule, the Central Team will decide the best way to apply irrigation in Armenia using different irrigation equipment as followings:

- For surface irrigation it is easier to apply fixed irrigation norms when soil moisture in soil depletes by 100% RAW; However, the size of fixed norm should bring the soil moisture at least to Field Capacity (FC). The Central Team will decide for each crop and soil type the size of fixed norm and the soil moisture at which the Field team will apply irrigation;
- For drip irrigation even if it is not difficult to apply variable norms it is better to use fixed norms applied at 50% RAW. Same as for the case of surface irrigation the size of fixed norm should bring the soil moisture to at least Field Capacity;
- For sprinkler irrigation the rule for surface irrigation or the rule for drip irrigation should be used, as described above.

The Central Team will use the AquaCrop and available or estimated data for all crops and soil types to preliminary calculate the Crop Water Requirements and to simulate the following irrigation schedules:

i) Optimum schedule: Field tests for each crop and soil types irrigated, fertilized and maintained in optimum - no stress;

ii) Water stress schedule for last 10 - 30 days: Field tests for same crop and soil from i), above, irrigated at best simulation resulted from AquaCrop at which the last 1 - 3 doses are not applied and the yield is not decreased below 5% compared to the optimum (all required irrigation doses applied).

The resulted irrigation schedules in terms of size of fixed norms and frequency of applications will be recommended to the Field Teams to apply in the testing field plots.

The Field teams will organise the field test plots so that to obtain the results for options i) and ii) described above.

Since the results for one year cannot cover all variability of the climate data, it is recommended to repeat the above field tests for at least three years. Better results will be obtained after longer periods such as 10 - 20 years.

4.4 Step 4 - Final calculation of Crop Water Requirements and Irrigation schedules and updating the irrigation norms based on field verified results

The final calculation of Crop Water Requirements and Irrigation Schedules will be carried out after calibration of crop responses to soil fertility and soil moisture stresses.

In order to calibrate AquaCrop there are needed the two sets of data from field:

i) Field tests for each crop and soil types irrigated, fertilized and maintained in optimum - no stress;

ii) Field tests for same crop and soil from i), above, irrigated at best simulation resulted from AquaCrop at which the last 1 - 3 doses are not applied and the yield is not decreased below 5% compared to the optimum (all required irrigation doses applied).

The calibration of AquaCrop shall be carried out using the dry biomass and dry and fresh yield response of each crop to the above two different irrigation options.

The expected results are:

a) Accurate Crop Coefficients for Armenia climate and soil conditions;

b) Accurate and reliable Crop Yield Potential for the case of supplying irrigation, fertilizers and field management in optimum, as described under bullet line i), above;

c) Reliable Crop Yield Response to saving irrigation water option as described under bullet line ii), above;

d) The expected saving of irrigation water volume is of at least one irrigation dose of 500 m^3/ha which will allow either to expand irrigation areas by at least 10% compared to existing irrigation areas and obtaining more produce. Since, in case of saving the last irrigation dose the expected yield will not decrease by more than 3%, then the saved irrigation dose will be used to irrigate an area of 10% which will allow an increase in total yield by 10% which is higher than the reduction of 3%. However, this principle remains to be demonstrated by the proposed field tests.

4.5 Tools to carry out calculations of Crop Water Requirements and Irrigation Scheduling for entire territory of Armenia

4.5.1 Excel Template

The Excel Template can be used to calculate Crop Water Requirements and Irrigation Norms and Scheduling for design of irrigation schemes purpose using climatic data for rainfall occurrence of 50% and 75%.

Also, the Excel Template can be used for calculation Crop Water Requirements and Irrigation Norms and Scheduling for current year using the climatic data from current year, up to the current date.

4.5.2 AquaCrop FAO application software

AquaCrop software application can be freely downloaded from FAO website at the link below: http://www.fao.org/aquacrop/software/aquacropstandardwindowsprogramme/en/

A detailed description on how to use this software has been presented in "Detailed Methodology for Updating the Irrigation Norms for the selected set of crops in Ararat Valley" that can be downloaded from UNDP Climate Change Projects website at the following link: https://bit.ly/3qEpGni

AquaCrop can be used both for design purpose using the historical climate data for rainfall occurrence events of 50% and 75%a and for calculation of current Irrigation Norms and Scheduling using the climatic data for the current year. In addition, AquaCrop can be automated by using an additional software application to automatically collect data from a network of automatic weather stations and compiling the climate data into text file usable by AquaCrop. This methodology can be easily expanded to cover the entire territory of Armenia.

4.5.3 Soil water Characteristics application software

The tool "Soil water Characteristics" can be freely downloaded from the link below:

https://www.ars.usda.gov/research/software/download/?softwareid=492&modecode=80-42-05-10

The soil water characteristics can be estimated using the software application Soil water characteristics in case these parameters are not available but the values of texture classes of the soil are known. To use the software at least the content of clay and sand of the soil type should be known.

4.5.4 QGIS application software

The software QGIS is a free GIS software that can be downloaded from this link: Download QGIS

The software is required to obtain the values of the climatic parameters for Climate Change which are offered free of charge on WorldClim website as GeoTIFF files. These file types can be opened and extract data using QGIS or ArcGIS software applications. It is mentioned that ArcGIS is not free.

4.5.5 FAO - Basic Statistical tools

In order to avoid errors and obtain relevant results, in all field measurements and data / results processing, the basic statistical tools shall be used, as defined and explained in Chapter 6 - Basic Statistical Tools, in FAO Guidelines for Quality Management in Soil and Plant Laboratories. (FAO Soils Bulletin - 74), link: 6 BASIC STATISTICAL TOOLS (fao.org).

4.6 Conclusions and recommendations for step-by-step recommendations for replicating the work to the entire territory of Armenia

A detailed Step-by-Step methodology to replicate the calculation of Crop Water Requirements and Irrigation Scheduling to the entire territory of Armenia has been prepared as report: **"Step-by-Step Recommendations for Replicating the work for the entire territory of Armenia"**. The methodology can be undertaken by a Central Team of experts supported by 5 Field Teams of experts. These teams are proposed to carry out field testing to test in field two main irrigation schedules:

i) Field tests for each crop and soil types irrigated, fertilized and maintained in optimum - no stress;

ii) Field tests for same crop and soil from i), above, irrigated at best simulation resulted from AquaCrop at which the last 1 - 3 doses are not applied and the yield is not decreased below 3% compared to the optimum (all required irrigation doses applied).

The above field tests are expected to provide following results:

a) Accurate Crop Coefficients for Armenia climate and soil conditions;

b) Accurate and reliable Crop Yield Potential for the case of supplying irrigation, fertilizers and field management in optimum, as described under bullet line i), above;

c) Reliable Crop Yield Response to saving irrigation water option as described under bullet line ii), above;

d) The expected saving of irrigation water volume is of at least one irrigation dose of 500 m^3/ha which will allow either to expand irrigation areas by at least 10% compared to existing irrigation areas and obtaining more produce. Since, in case of saving the last irrigation dose the expected yield will not decrease by more than 5%, then the saved irrigation dose will be used to irrigate an area of 10% which will allow an increase in total yield by 10% which is higher than the reduction of 5%. However, this principle remains to be demonstrated by the proposed field tests.

The estimated duration of each step is provided in the table below:

Table 17. Estimated duration of each step

Step	**Estimated Duration** (months)
Step 1 - organising working teams and setting up testing fields	3
Step 2 - collecting data and field surveys	10
Step 3 - preliminary calculation of crop water requirements and irrigation scheduling using AquaCrop and deciding the field-testing scenarios to get data for calibration of AquaCrop	1
Step 4 - final calculation of crop water requirements and irrigation scheduling and updating the irrigation norms based on field verified results	3
Total (steps 2, 3 and 4 are overlapping each other)	12

Since the results for one year cannot cover all variability of the climate data, it is recommended to repeat the above field tests for at least three years.

One more step "Step 5 - estimating the current irrigation scheduling" can be added to expand the capabilities of the methodology to calculate the Crop Water Requirements and Irrigation scheduling for current years which can be carried out by AquaCrop in automatic mode. The results of irrigation scheduling can be made available to the farmers / irrigation Water Users' Associations in real-time by using the mobile application QField (QField - Efficient field work built for QGIS). The duration of this step can be permanent with the aim to supply to the farmers/users real-time data to irrigate each crop at each location in Armenia.

5. Conclusions on the whole assignment and recommendations

The objective of the present assignment was to support Armenia in the process of introducing **Crop Water Requirements model based on FAO Irrigation and Drainage Paper No 56** ("Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements") and subsequently **Updating Irrigation Norms in Armenia** "Irrigation Norms and Regimes of Agricultural Crops for Irrigated Lands in the Republic of Armenia", developed by the "Institute of water problems and hydraulic engineering named after academic I.V. Yeghiazarov" CJSC in 2007. Moreover, because of the **Climate Change, an update of the data of the irrigation regime** was required.

In order to achieve the above objective, following tasks have been carried out:

- Conduct desk study on the existing irrigation norms in Armenia;
- Propose detailed methodology for updating the irrigation norms for the selected set of crops in Ararat valley;
- Update the irrigation norms for the selected set of crops in Ararat valley;
- Develop detailed step-by-step recommendations, for replicating the work for the entire territory of Armenia;

In preparation of deliverable 1, available documentations have been reviewed and found that the Manual "Irrigation Norms and Regimes of Agricultural Crops for Irrigated Lands in the Republic of Armenia" presents the irrigation norms for vegetables and table grapes (Annex 1). The norms for vegetables are not differentiated for each type of vegetables such as: tomatoes, cucumber, watermelon, onions, carrots, cabbage, etc. This generalization often leads to over-watering which results in higher irrigation costs and water wasting. The Manual of Irrigation Norms (before updating) **did not consider the crop yield** and water productivity. In addition, the Manual of Irrigation Norms presents the irrigation norms only for furrow irrigation and it **cannot be used** directly for irrigation scheduling with more advanced irrigation systems, such as **drip irrigation** systems. Moreover, because of the climate change, an update of the data of the irrigation regime is required.

In conclusion, the **Manual "Irrigation Norms and Regimes of Agricultural Crops for Irrigated Lands in the Republic of Armenia" needs a new approach and detailed description of formula and coefficients and the practical way of using them explained.**

Three methodologies based on FAO Paper 56 for calculation of Crop Water Requirements and Irrigation Scheduling namely **Excel Template**, **CROPWAT** and **AquaCrop** have been proposed and described in detail. It is important to mention that presently, CROPWAT and AquaCrop are recommended by FAO and they are now more and more used by international consultants in projects financed by international donors, such as World Bank, Millennium Challenge Corporation and many more.

The proposed methodologies can be used for:

i) **Design** of rehabilitation or new irrigation schemes using the climate data for 50% and / or 75% rainfall occurrence;
ii) **Current scheduling of the irrigation application date and volume** by using the climate data from the current year, up to the current day;

For **design** purpose, the best methodology is **AquaCrop** which has proven to be the most advanced methodology for calculation of Crop Water Requirements and Irrigation Scheduling.

The **current scheduling** of irrigation application can be used in manual or automatic mode, as described below:

Current scheduling in manual mode can be applied by using the **Excel Template** file and using the climate data for the current year, up to the current date. This method can be used by farmers with minimal knowledge of Excel and good knowledge of irrigation of crops.

Current scheduling in automatic mode can be applied using **AquaCrop** by collecting data from one or a network of automatic weather stations. To apply this automatic methodology a software program has to be developed to automatically collect current data from the weather stations and convert them into text file with climatic data to be further used by AquaCrop for calculating the irrigation scheduling of the next few days.

AquaCrop has proven to be the most advanced methodology which has been proposed and used for calculation of Crop Water Requirements and Irrigation Scheduling.

Crop Water Requirements and Irrigation Scheduling in Ararat Valley have been calculated using FAO software **AquaCrop** for the pilot crops: **Tomato, Cucumber, Watermelon and Table Grapes,** cultivated in pilot area **Ararat Valley**.

For each crop adequate irrigation method has been considered:

- For tomato: furrow, drip and sprinkler methods;
- For cucumber, watermelon and table grapes: furrow and drip methods.

As climate, the 50% rainfall probability, 75% rainfall probability and climate change 50% rainfall probability for year 2050 have been considered for each crop.

Ararat Valley is located on 3 soil types and different depth of underground water level which have been classified in intervals of less than 1.5 m, 1.5 - 3 m and deeper than 5.3 m.

Aquacrop software and adequate simulations 1 - 5 as described above under paragraph 3.9, have been applied for each crop, each soil type, each underground water level class and climate 50%, 75% and climate change for year 2050.

The results of simulations presented as size of one application (dose), yearly irrigation requirements and dates when to apply each dose are presented in Annex 2 - Table 29…. Table 73, below, and these represent the **updated irrigation norms for selected crops in Ararat Valley**.

The updated irrigation norms are now much better justified since the size of norms and irrigation scheduling are based on a detailed analysis of 4 - 5 simulations and the expected water productivity and yield is also considered.

The updated norms calculated using AquaCrop is presented separately for each crop: tomato, cucumber, watermelon and table grapes.

The results for years with rainfall probability of 50% and 75% show that for most of cases it is possible to reduce the water consumption by 1 - 3 norms (doses) representing 10 - 30% of total yearly irrigation requirements without affecting the yield by more than 3 - 5%.

For the case of Climate Change, at the level of year 2050, the water requirements are significantly higher than for years with 50% and equal or little higher than the requirements for present year with 75% probability. However, on soils with underground water level less deep than 1.5 m now it is not necessary to irrigate because the capillary rise can supply the root zone with sufficient water to keep the crops at high level of production but in case of Climate Change at the level of year 2050 for the same crops on the same soil and underground water level the crop water requirements exceed substantially the capillary rise and crops need at least 3 or more irrigation applications each year. The good effect related to Climate Change is the increasing of the crop yields by 30 - 40% due to increased content of CO_2 in air.

The reduction of water norms can be applied or not now, but in the future, at the level of year 2050 might become a necessity due to reduction of water sources availability or capacity. Even today, the proposed reduction of water consumption, if applied, will substantially **reduce the irrigation costs** and **creates new available water sources** for irrigating adjacent areas and **increase the volume of the yields**.

As recommendation, initiating systematic researches at least in Ararat Valley area **to validate the crop coefficients** and expected fresh yield values for each crop and each soil type would be very helpful to **calibrate** the functionalities of AquaCrop to produce more accurate results.

Since the results obtained for tomato, cucumber, watermelon and table grapes cultivated in Ararat Valley cannot be extrapolated to other crops cultivated in same area or to same crops grown in other geographical areas in Armenia. In this case, in order to replicate the calculations of Irrigation norms to the entire territory of Armenia the methodology described below is necessary to be put in practice.

A **Step-by-Step methodology to replicate the calculation** of Crop Water Requirements and Irrigation Scheduling to the entire territory of Armenia has been developed and proposed. The methodology should be undertaken by a **Central Team** of experts with background in Irrigation, GIS, and Agriculture **supported by 5 Field Teams** of experts with background in irrigation and irrigated agriculture. These teams are proposed to carry out field testing to:

Test in field two main irrigation schedules:

i) Field tests for each crop and soil types irrigated, fertilized and maintained in optimum - no stress;

ii) Field tests for same crop and soil from i), above, irrigated at best simulation resulted from AquaCrop at which the last 1 - 3 doses are not applied and the yield is not decreased below 3% compared to the optimum (all required irrigation doses applied).

The above field tests will provide following results:

a) Accurate **Crop Coefficients** for Armenia climate and soil conditions;

b) Accurate and reliable **Crop Yield Potential** for the case of supplying irrigation, fertilizers and field management in optimum, as described under bullet line i), above;

c) Reliable **Crop Yield Response** to saving irrigation water option as described under bullet line ii), above;

d) **Calibration of AquaCrop** software to accurately provide results for different climate, locations, soils and crops grown in Armenia;

e) The expected **saving of irrigation water volume** is of at least one irrigation dose of 500 m^3/ha which will allow either to expand irrigation areas by at least 10% compared to existing irrigation areas and obtaining more produce.

The estimated duration of each step is provided in the table below:

Table 18. Estimated duration of each step

Step	**Estimated Duration** (months)
Step 1 - organising working teams and setting up testing fields	3
Step 2 - collecting data and field surveys	10
Step 3 - preliminary calculation of crop water requirements and irrigation scheduling using AquaCrop and deciding the field-testing scenarios to get data for calibration of AquaCrop	1
Step 4 - final calculation of crop water requirements and irrigation scheduling and updating the irrigation norms based on field verified results	3
Total (steps 2, 3 and 4 are overlapping each other)	12

Since the results for one year cannot cover all variability of the climate data, it is recommended to repeat the above field tests for at least three years.

One more step "Step 5 - estimating the current irrigation scheduling" can be added to expand the capabilities of the methodology to calculate the Crop Water Requirements and Irrigation scheduling for current years which can be carried out by AquaCrop in automatic mode. The results of irrigation scheduling can be made available to the farmers / irrigation Water Users' Associations in real-time by using the mobile application QField (QField - Efficient field work built for QGIS). The duration of this step can be permanent with the aim to supply to the farmers/users real-time data on size of current irrigation norms and when to irrigate each crop at each location in Armenia.

6. Annex 1 - Irrigation Norms from the present Manual "Irrigation Norms and Regimes of Agricultural Crops for Irrigated Lands in the Republic of Armenia" - 2007.

Table 19. Irrigation Regime identification number in Ararat region

No	Settlements	Numbers of the Irrigation Regimes
1	2	3
Ararat region		
1	Ararat city	1, 2
2	Vedi city	2, 3
3	Mrgavan	2,3
4	Avshar	1, 2, 3
5	Aralez	2, 3
6	Ararat	1, 2
7	Armash*	
8	Goravan*	
9	Dashtakar*	
10	Yeghegnavan	1, 2, 4
11	Yeraskh*	
12	Zangakatun	9, 10
13	Lanjanist	13

Table 20. Irrigation Regime identification number in Artashat region

Artashat region		
32	Artashat city	1, 2, 4
33	Abovyan*	
34	Azatavan	1, 2, 4
35	Aygezard	2, 3
36	Aygepat	2, 3
37	Aygestan	1, 2, 3
38	Araksavan	1, 2, 4

* Settlement is included in the chapter 5.2 of the manual.

The irrigation regimes, indicated in Table 20, above, are detailed in tables below for relevant crops:

Table 21. Regime 1 Gray, clay and heavy clay loamy soils with strong and moderate profiles 800-1000 meters above sea level (extract) (Ararat and Armavir marzes)

No	Agricultural Crop	50%					75%				
		Watering Numbers	Single Irrigation Norm, m^3/ha	Seasonal Irrigation Norm, m^3/ha	Irrigation Period		Watering Numbers	Single Irrigation Norm, m^3/ha	Seasonal Irrigation Norm, m^3/ha	Irrigation Period	
										Beginning	End
1	2	3	4	5	6	7	8	9	10	11	12
							1	650		10.04	30.04
		1	650		10.04	30.04	2	650		12.04	01.05
		2	650		12.04	02.05	3	650		07.05	23.05
		3	650		13.05	26.05	4	650		24.05	06.06
		4	650		27.05	13.06	5	650		07.06	20.06
		5	650		14.06	26.06	6	650		21.06	03.07
6	Vegetable	6	650	7150	27.06	10.07	7	650	8450	04.07	16.07
		7	650		11.07	22.07	8	650		17.07	28.07
		8	650		23.07	08.08	9	650		29.07	11.08
		9	650		09.08	24.08	10	650		12.08	25.08
		10	650		25.08	15.09	11	650		26.08	09.09
		11	650		16.09	04.10	12	650		10.09	24.09
							13	650		25.09	07.10
							1	900		15.04	10.05
		1	950		15.04	10.05	2	900		20.05	15.06
		2	950		18.05	14.06	3	900		16.06	30.06
9	Grape	3	950	6650	15.06	05.07	4	900	7200	01.07	15.07
		4	950		06.07	23.07	5	900		16.07	30.07
		5	950		24.07	11.08	6	900		31.07	13.08
		6	950		12.08	29.08	7	900		14.08	31.08
		7	950		10.10	30.10	8	900		10.10	30.10

Table 22. Regime 2 Gray, heavy clay loamy and clay loamy soils with moderate and weak profiles

No	Agricultural Crop	50%					75%				
		Watering Numbers	Single Irrigation Norm, m³/ha	Seasonal Irrigation Norm, m³/ha	Irrigation Period		Watering Numbers	Single Irrigation Norm, m³/ha	Seasonal Irrigation Norm, m³/ha	Irrigation Period	
					Beginning	End				Beginning	End
1	2	3	4	5	6	7	8	9	10	11	12
6	Vegetable			7800			1	600	9000	20.04	05.05
		1	600		25.04	10.05	2	600		23.04	07.05
		2	600		27.04	12.05	3	600		26.04	10.05
		3	600		13.05	29.05	4	600		11.05	25.05
		4	600		30.05	15.06	5	600		26.05	08.06
		5	600		16.06	29.06	6	600		09.06	21.06
		6	600		29.06	10.07	7	600		22.06	01.07
		7	600		11.07	21.07	8	600		02.07	10.07
		8	600		22.07	02.08	9	600		11.07	19.07
		9	600		03.08	14.08	10	600		20.07	29.07
		10	600		15.08	26.08	11	600		30.07	09.08
		11	600		27.08	10.09	12	600		10.08	21.08
		12	600		11.09	23.09	13	600		22.08	02.09
		13	600		24.09	04.10	14	600		03.09	18.09
9	Grape			6800			1	850	7650	15.04	10.05
		1	850		15.04	10.05	2	850		16.05	10.06
		2	850		16.05	11.06	3	850		11.06	26.06
		3	850		12.06	30.06	4	850		27.06	11.07
		4	850		01.07	16.07	5	850		12.07	26.07
		5	850		17.07	03.08	6	850		27.07	08.08
		6	850		04.08	19.08	7	850		09.08	22.08
		7	850		20.08	05.09	8	850		23.08	05.09
		8	850		10.10	30.10	9	850		10.10	25.10

Table 23. Regime 3 Light Gray, loamy and light loamy soils with weak profiles

No	Agricultural Crop	50%					75%				
		Watering Numbers	Single Irrigation Norm, m^3/ha	Seasonal Irrigation Norm, m^3/ha	Irrigation Period		Watering Numbers	Single Irrigation Norm, m^3/ha	Seasonal Irrigation Norm, m^3/ha	Irrigation Period	
					Beginning	End				Beginning	End
1	2	3	4	5	6	7	8	9	10	11	12
6	Vegetable	1	500	8500	15.04	05.05	1	550	9000	13.04	05.05
		2	500		17.04	07.05	2	550		18.04	06.05
		3	500		08.05	18.05	3	550		08.05	21.05
		4	500		19.05	02.06	4	550		22.05	03.06
		5	500		03.06	15.06	5	550		04.06	13.06
		6	500		16.06	27.06	6	550		14.06	22.06
		7	500		28.06	08.07	7	550		23.06	30.06
		8	500		09.07	18.07	8	550		01.07	07.07
		9	500		19.07	28.07	9	550		08.07	16.07
		10	500		29.07	05.08	10	550		17.07	24.07
		11	500		06.08	14.08	11	550		25.07	02.08
		12	500		15.08	25.08	12	550		03.08	11.08
		13	500		26.08	04.09	13	550		12.08	20.08
		14	500		05.09	15.09	14	550		21.08	31.08
		15	500		16.09	28.09	15	550		01.09	13.09
		16	500		24.09	11.10	16	550		14.09	28.09
		17	500		12.10	24.10	17	550		29.09	18.10
8	Grape			7000			1	700	7700	15.04	10.05
		1	700		15.04	10.05	2	700		11.05	04.06
		2	700		12.05	04.06	3	700		05.06	18.06
		3	700		05.06	20.06	4	700		19.06	01.07
		4	700		21.06	04.07	5	700		02.07	14.07
		5	700		05.07	18.07	6	700		15.07	26.07
		6	700		19.07	01.08	7	700		27.07	08.08
		7	700		02.08	15.08	8	700		09.08	21.08
		8	700		16.08	30.08	9	700		22.08	03.09
		9	700		31.08	15.09	10	700		04.09	17.09
		10	700		10.10	30.10	11	700		10.10	30.10

Table 24. Regime 4 Wet meadow / meadow (hydromorphic) Gray, irrigable heavy clay and loamy with strong profiles

No	Agricultural Crop	Water table depth at spring, m	50%					75%				
			Watering Numbers	Single Irrigation Norm, m^3/ha	Seasonal Irrigation Norm, m^3/ha	Irrigation Period		Watering Numbers	Single Irrigation Norm, m^3/ha	Seasonal Irrigation Norm, m^3/ha	Irrigation Period	
						Beginning	End				Beginning	End
1	2		3	4	5	6	7	8	9	10	11	12
9	Vegetable	1.5						1	550	5900	15.04	10.05
								2	400		27.04	12.05
								3	550		25.05	14.06
								4	550		15.06	30.06
								5	550		01.07	14.07
								6	550		15.07	29.07
								7	550		30.07	14.08
								8	550		15.08	29.08
								9	550		30.08	15.09
								10	550		16.09	04.10
								11	550		05.10	23.10
		2.0						1	550	7000	25.04	11.05
								2	400		27.04	13.05
								3	550		25.05	10.06
								4	550		11.06	24.06
								5	550		25.06	06.07
								6	550		07.07	17.07
								7	550		18.07	29.07
								8	550		30.07	11.08
								9	550		12.08	23.08
								10	550		24.08	05.09
								11	550		06.09	20.09
								12	550		21.09	05.10
								13	550		06.10	23.10
12	Grapes	2.0						1	950	4750	20.04	12.05
								2	950		23.06	16.07
								3	950		17.07	05.08
								4	950		06.08	26.08
								5	950		10.10	25.10
		2.5						1	950	5700	20.04	10.05
								2	950		22.06	10.07
								3	950		11.07	26.07
								4	950		27.07	11.08
								5	950		12.08	31.08
								6	950		10.10	25.10

Table 25. Regime 6 Gray and brown, loamy soils with strong and moderate profiles, 1000-1300 meters above sea level (extract) (Ararat and Aagatsotn and Kotayk marzes)

No	Agricultural Crop	50%					75%				
		Watering Numbers	Single Irrigation Norm, m^3/ha	Seasonal Irrigation Norm, m^3/ha	Irrigation Period		Watering Numbers	Single Irrigation Norm, m^3/ha	Seasonal Irrigation Norm, m^3/ha	Irrigation Period	
					Beginning	End				Beginning	End
1	2	3	4	5	6	7	8	9	10	11	12
6	Vegetable			6050			1	550	6600	24.04	08.05
		1	550		25.04	10.05	2	550		26.04	10.05
		2	550		27.04	12.05	3	550		26.05	06.06
		3	550		29.05	10.06	4	550		07.06	18.06
		4	550		11.06	25.06	5	550		19.06	30.06
		5	550		26.06	07.07	6	550		01.07	11.07
		6	550		08.07	18.07	7	550		12.07	23.07
		7	550		19.07	29.07	8	550		24.07	05.08
		8	550		30.07	11.08	9	550		06.08	17.08
		9	550		12.08	25.08	10	550		18.08	31.08
		10	550		26.08	10.09	11	550		01.09	14.09
		11	550		11.09	26.09	12	550		15.09	26.09
10	Grape	1	800	5600	25.04	20.05	1	850	5950	25.04	20.05
		2	800		21.05	15.06	2	850		21.05	15.06
		3	800		16.06	06.07	3	850		16.06	06.07
		4	800		07.07	27.07	4	850		07.07	27.07
		5	800		28.07	18.08	5	850		28.07	18.08
		6	800		19.08	09.09	6	850		19.08	09.09
		7	800		15.10	30.10	7	850		15.10	30.10

Table 26. Regime 7 Light gray and brown, light loamy and sandy loamy soils with moderate and weak profiles

No	Agricultural Crop	50%					75%				
		Watering Numbers	Single Irrigation Norm, m³/ha	Seasonal Irrigation Norm, m³/ha	Irrigation Period		Watering Numbers	Single Irrigation Norm, m³/ha	Seasonal Irrigation Norm, m³/ha	Irrigation Period	
					Beginning	End				Beginning	End
1	2	3	4	5	6	7	8	9	10	11	12
6	Vegetable			6550			1	550	7150	23.04	15.05
		1	550		23.04	15.05	2	550		25.04	17.05
		2	550		25.04	17.05	3	550		27.05	11.06
		3	550		01.06	16.06	4	550		12.06	24.06
		4	550		17.06	30.06	5	550		25.06	06.07
		5	550		01.07	12.07	6	550		07.07	17.07
		6	550		13.07	23.07	7	550		18.07	27.07
		7	550		24.07	01.08	8	550		28.07	05.08
		8	550		02.08	12.08	9	550		06.08	16.08
		9	550		13.08	25.08	10	550		17.08	28.08
		10	550		26.08	07.09	11	550		29.08	11.09
		11	550		08.09	19.09	12	550		12.09	24.09
		12	550		20.09	05.10	13	550		25.09	07.10
10	Grape	1	700	5600	25.04	20.05	1	650	5850	23.04	15.05
		2	700		18.06	05.07	2	650		15.06	23.06
		3	700		06.07	18.07	3	650		24.06	12.07
		4	700		19.07	31.07	4	650		13.07	23.07
		5	700		01.08	12.08	5	650		24.07	02.08
		6	700		13.08	26.08	6	650		03.08	14.08
		7	700		27.08	10.09	7	650		15.08	29.08
		8	700		11.10	25.10	8	650		30.08	11.09
							9	650		15.10	25.10

Table 27. Regime 9 Mountainous brown, loamy soils with strong and moderate profiles, 1300-1500 meters above sea level (extract) (Ararat and Aagatsotn and Kotayk marzes)

No	Agricultural Crop	50%					75%				
		Watering Numbers	Single Irrigation Norm, m³/ha	Seasonal Irrigation Norm, m³/ha	Irrigation Period		Watering Numbers	Single Irrigation Norm, m³/ha	Seasonal Irrigation Norm, m³/ha	Irrigation Period	
					Beginning	End				Beginning	End
1	2	3	4	5	6	7	8	9	10	11	12
							1	550		01.05	20.05
		1	550		01.05	20.05	2	550		05.06	23.06
		2	550		10.06	28.06	3	550		24.06	05.07
		3	550		29.06	11.07	4	550		06.07	16.07
6	Vegetable	4	550	4400	12.07	24.07	5	550	4950	17.07	28.07
		5	550		25.07	05.08	6	550		29.07	08.08
		6	550		06.08	18.08	7	550		09.08	19.08
		7	550		19.08	02.09	8	550		20.08	04.09
		8	550		03.09	17.09	9	550		05.09	18.09
		1	700		17.05	12.06	1	750		17.05	12.06
		2	700		13.06	30.06	2	750		13.06	30.06
10	Grapes	3	700	4200	01.07	15.07	3	750	4500	01.07	15.07
		4	700		16.07	31.07	4	750		16.07	31.07
		5	700		01.08	20.08	5	750		01.08	20.08
		6	700		05.10	15.10	6	750		05.10	15.10

Table 28. Regime 10 Mountainous brown, light loamy soils with weak and moderate profiles, 1300-1500 meters above sea level (extract) (Ararat and Aragatsotn and Kotayk marzes)

No	Agricultural Crop	50%					75%				
		Watering Numbers	Single Irrigation Norm, m³/ha	Seasonal Irrigation Norm, m³/ha	Irrigation Period		Watering Numbers	Single Irrigation Norm, m³/ha	Seasonal Irrigation Norm, m³/ha	Irrigation Period	
					Beginning	End				Beginning	End
1	2	3	4	5	6	7	8	9	10	11	12
6	Vegetable			4500			1	500	5000	01.05	29.05
		1	500		01.05	29.05	2	500		08.06	22.06
		2	500		08.06	24.06	3	500		23.06	01.07
		3	500		25.06	05.07	4	500		02.07	11.07
		4	500		06.07	16.07	5	500		12.07	21.07
		5	500		17.07	27.07	6	500		22.07	31.07
		6	500		28.07	08.08	7	500		01.08	11.08
		7	500		09.08	19.08	8	500		12.08	22.08
		8	500		20.08	02.09	9	500		23.08	01.09
		9	500		03.09	14.09	10	500		02.09	12.09
10	Grape			4550			1	650	5200	15.05	10.06
		1	650		15.05	10.06	2	650		11.06	23.06
		2	650		11.06	25.06	3	650		24.06	03.07
		3	650		26.06	10.07	4	650		04.07	15.07
		4	650		11.07	22.07	5	650		16.07	29.07
		5	650		23.07	07.08	6	650		30.07	09.08
		6	650		08.08	28.08	7	650		10.08	27.08
		7	650		05.10	20.10	8	650		05.10	20.10

7. Annex 2 - Updated Irrigation Norms calculated using AquaCrop - 2021

Table 29. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Furrow in Armavir area, rainfall occurrence probability 50%

Crop	**Soil Type**	**Ground-water Level Depth**	**Rules to apply irrigation**	**Irrigation**			**Net irrigation duty**	**Minimum interval between applications**
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 100% RAW, 55 mm/application	5	55	275	0.579	11
			After day 110 no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 100% RAW, 55 mm/application	9	55	495	0.707	9
			After day 130 no irrigation	0	0			
Tomato	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 100% RAW, 40 mm/application	7	40	280	0.386	12
			After day 110 no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 130 at 100% RAW, 90 mm/application	5	90	450	0.579	18
			After day 130 no irrigation	0	0			

Table 30. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Drip method in Armavir area, rainfall occurrence probability 50%

Crop	**Soil Type**	**Ground-water Level Depth**	**Rules to apply irrigation**	**Irrigation**			**Net irrigation duty**	**Minimum interval between applications**
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 50% RAW, 25 mm/application	12	25	300	1.447	2
			Day 110 to end - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 50% RAW, 25 mm/application	19	25	475	0.965	3
			Day 130 to end - no irrigation	0	0			
Tomato	Solonchak	1.5	At 25% RAW	1	0	8.5	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 50% RAW, 20 mm/application	16	20	320	0.772	3
			Day 110 to end - no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 120 at 50% RAW, 45 mm/application	10	45	450	0.744	7
			After day 120 no irrigation	0	0			

Table 31. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Sprinkler method in Armavir area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 50% RAW, 25 mm/application	5	60	300	0.694	10
			Day 110 to end - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 50% RAW, 25 mm/application	8	60	480	0.772	9
			Day 130 to end - no irrigation	0	0			
Tomato	Solonchak	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 50% RAW, 20 mm/application	8	45	360	0.521	10
			Day 110 to end - no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 120 at 50% RAW, 45 mm/application	12	45	540	0.744	7
			After day 120 no irrigation	0	0			

Table 32. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Furrow in Armavir area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Cucumber	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Cucumber	Meadow	3	Day 1 to 85 at 100% RAW, 30 mm/application	6	30	180	0.694	5
			After day 85 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 100% RAW, 30 mm/application	10	30	300	0.694	5
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Cucumber	Solonchak	3	Day 1 to 95 at 100% RAW, 25 mm/application	11	25	275	0.579	5
			After day 95 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 100% RAW, 50 mm/application	6	50	300	0.643	9
			After day 95 no irrigation	0	0			

Table 33. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Drip method in Armavir area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Cucumber	Meadow	1.5	At 50% RAW	1	15.6	15.6	0.451	4
Cucumber	Meadow	3	Day 1 to 85 at 50% RAW, 15 mm/application	14	15	210	0.579	3
			After day 85 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 50% RAW, 15 mm/application	19	15	285	0.868	2
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	At 50% RAW	1	0	13	0.502	3
Cucumber	Solonchak	3	Day 1 to 95 at 50% RAW, 15 mm/application	20	15	300	0.868	2
			After day 95 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 50% RAW, 25 mm/application	12	25	300	0.723	4
			After day 95 no irrigation	0	0			

Table 34. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Furrow in Armavir area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Watermelon	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Watermelon	Meadow	3	Day 1 to 100 at 100% RAW, 30 mm/application	7	30	210	0.694	5
			After day 100 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 100% RAW, 30 mm/application	10	30	300	0.694	5
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Watermelon	Solonchak	3	Day 1 to 100at 100% RAW, 20 mm/application	9	20	180	0.579	4
			After day 100 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 90 at 100% RAW, 45 mm/application	6	45	270	0.868	6
			After day 90 no irrigation	0	0			

Table 35 Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Drip method in Armavir area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Watermelon	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Watermelon	Meadow	3	Day 1 to 90 at 50% RAW, 15 mm/application	15	15	225	0.868	2
			After day 90 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 50% RAW, 15 mm/application	20	15	300	0.868	2
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Watermelon	Solonchak	3	Day 1 to 90 at 50% RAW, 15 mm/application	18	15	270	0.868	2
			After day 90 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 90 at 50% RAW, 25 mm/application	11	25	275	0.579	5
			After day 90 no irrigation	0	0			

Table 36. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Furrow in Armavir area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	6	50	300	0.362	16
Table Grapes	Meadow	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	9	50	450	0.413	14
Table Grapes	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 40 mm/application Day 26 to 202 at 100 % RAW - fixed norm 40 mm/application Day 203 - one norm 40 mm/application After day 204 - no irrigation	6	40	240	0.356	13
Table Grapes	Brown	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 90 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	2 x 50 and 4 x 90	50 and 90	460	0.417	25

Table 37. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Drip method in Armavir area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 100 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	13	25	325	0.579	5
Table Grapes	Meadow	5	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 100 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	19	25	475	0.579	5
Table Grapes	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 20 mm/application Day 26 to 202 at 100 % RAW - fixed norm 20 mm/application Day 203 - one norm 20 mm/application After day 204 - no irrigation	12	20	240	0.386	6
Table Grapes	Brown	5	Day 1 to 24 - no irrigation Day 25 - one norm 45 mm/application Day 26 to 202 at 100 % RAW - fixed norm 45 mm/application Day 203 - one norm 45 mm/application After day 204 - no irrigation	11	45	495	0.434	12

Table 38. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Furrow in Artashat area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 100% RAW, 55 mm/application	3	55	165	0.227	28
			After day 110 no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 100% RAW, 55 mm/application	8	55	440	0.637	10
			After day 130 no irrigation	0	0			
Tomato	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 100% RAW, 40 mm/application	4	50	200	0.526	11
			After day 110 no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 130 at 100% RAW, 90 mm/application	5	90	450	0.613	17
			After day 130 no irrigation	0	0			

Table 39. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Drip method in Artashat area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 50% RAW, 25 mm/application	8	25	450	0.362	8
			Day 110 to end - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 50% RAW, 25 mm/application	18	25	450	0.723	4
			Day 130 to end - no irrigation	0	0			
Tomato	Solonchak	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 50% RAW, 20 mm/application	13	20	260	0.772	3
			Day 110 to end - no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 110 at 50% RAW, 45 mm/application	8	45	360	0.651	8
			After day 110 no irrigation	0	0			

Table 40. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Sprinkler method in Artashat area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Tomato	Meadow	1.5	Day 1 to end at 100 % RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 100% RWA, 60 mm/application	4	60	240	0.534	13
			After day 110 - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 100% RAW, 60 mm/application	8	60	480	0.579	12
			After day 130 - no irrigation	0	0			
Tomato	Solonchak	1.5	At 100% RWA	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 100% RWA, 45 mm/application	4	45	180	0.521	10
			After day 110 no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 110 at 50% RAW, 45 mm/application	9	45	405	0.651	8
			After day 110 no irrigation	0	0			

Table 41. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Furrow in Artashat area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Cucumber	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Cucumber	Meadow	3	Day 1 to 85 at 100% RAW, 30 mm/application	6	30	180	0.347	10
			After day 85 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 100% RAW, 30 mm/application	9	30	270	0.694	5
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Cucumber	Solonchak	3	Day 1 to 85 at 100% RAW, 25 mm/application	8	25	200	0.482	6
			After day 85 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 100% RAW, 50 mm/application	5	50	250	0.482	12
			After day 95 no irrigation	0	0			

Table 42. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Drip method in Artashat area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Cucumber	Meadow	1.5	At 50% RAW	1	11.7	11.7	0.339	4
Cucumber	Meadow	3	Day 1 to 85 at 50% RAW, 15 mm/application	11	15	165	0.434	4
			After day 85 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 50% RAW, 15 mm/application	19	15	285	0.347	5
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Cucumber	Solonchak	3	Day 1 to 85 at 50% RAW, 15 mm/application	13	15	240	0.579	3
			After day 85 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 50% RAW, 25 mm/application	12	25	300	0.723	4
			After day 95 no irrigation	0	0			

Table 43. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Furrow in Artashat area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Watermelon	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Watermelon	Meadow	3	Day 1 to 100 at 100% RAW, 30 mm/application	7	30	210	0.434	8
			After day 100 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 100% RAW, 30 mm/application	9	30	270	0.386	9
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Watermelon	Solonchak	3	Day 1 to 90 at 100% RAW, 25 mm/application	8	25	200	0.482	6
			After day 90 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 90 at 100% RAW, 55 mm/application	5	55	275	0.490	13
			After day 90 no irrigation	0	0			

Table 44. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Drip method in Artashat area, rainfall occurrence probability 50%

Crop	**Soil Type**	**Ground-water Level Depth**	**Rules to apply irrigation**	**Irrigation**			**Net irrigation duty**	**Minimum interval between applications**
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Watermelon	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Watermelon	Meadow	3	Day 1 to 100 at 50% RAW, 15 mm/application	13	15	195	0.579	3
			After day 100 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 50% RAW, 15 mm/application	20	15	300	0.868	2
			After day 95 no irrigation	0	0			
Watermelon	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Watermelon	Solonchak	3	Day 1 to 100 at 50% RAW, 15 mm/application	17	15	255	0.579	3
			After day 100 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 100 at 50% RAW, 25 mm/application	11	25	275	0.723	4
			After day 100 no irrigation	0	0			

Table 45. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Furrow in Artashat area, rainfall occurrence probability 50%

Crop	**Soil Type**	**Ground-water Level Depth**	**Rules to apply irrigation**	**Irrigation**			**Net irrigation duty**	**Minimum interval between applications**
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	2	50	100	0.579	10
Table Grapes	Meadow	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	9	50	450	0.413	14
Table Grapes	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 40 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 40 mm/application After day 204 - no irrigation	2	40	80	0.463	10
Table Grapes	Brown	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	6	2 x 50 and 4 x 90	460	0.386	27

Table 46. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Drip method in Artashat area, rainfall occurrence probability 50%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 100 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	9	25	225	0.413	7
Table Grapes	Meadow	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 25 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	18	25	450	0.482	6
Table Grapes	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 20 mm/application Day 26 to 202 at 100 % RAW - fixed norm 20 mm/application Day 203 - one norm 20 mm/application After day 204 - no irrigation	10	20	200	0.331	7
Table Grapes	Brown	5	Day 1 to 24 - no irrigation Day 25 - one norm 45 mm/application Day 26 to 202 at 100 % RAW - fixed norm 45 mm/application Day 203 - one norm 45 mm/application After day 204 - no irrigation	10	45	450	0.401	13

Table 47. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Furrow in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 100% RAW, 55 mm/application	7	55	385	0.909	7
			After day 110 no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 100% RAW, 55 mm/application	10	55	550	1.061	6
			After day 130 no irrigation	0	0			
Tomato	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 100% RAW, 40 mm/application	7	40	280	0.772	6
			After day 110 no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 130 at 100% RAW, 90 mm/application	6	90	540	0.801	13
			After day 130 no irrigation	0	0			

Table 48. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Drip method in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 50% RAW, 25 mm/application	14	25	350	0.965	3
			Day 110 to end - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 50% RAW, 25 mm/application	21	25	525	0.965	3
			After day 130 - no irrigation	0	0			
Tomato	Solonchak	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 50% RAW, 20 mm/application	18	20	360	0.772	3
			Day 110 to end - no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 110 at 50% RAW, 45 mm/application	10	45	450	0.868	6
			After day 110 no irrigation	0	0			

Table 49. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Sprinkler method in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Tomato	Meadow	1.5	Day 1 to end at 100 % RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 100% RWA, 60 mm/application	5	60	405	0.694	10
			After day 110 - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 110 at 100% RWA, 60 mm/application	5	60	540	0.868	8
			After day 110 - no irrigation	0	0			
Tomato	Solonchak	1.5	At 100% RWA	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 100% RWA, 45 mm/application	9	45	405	0.651	8
			After day 110 no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 110 at 50% RAW, 45 mm/application	9	45	495	1.302	4
			After day 110 no irrigation	0	0			

Table 50. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Furrow in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Cucumber	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Cucumber	Meadow	3	Day 1 to 95 at 100% RAW, 30 mm/application	12	30	360	0.868	4
			After day 95 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 100% RAW, 30 mm/application	12	30	360	1.157	3
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Cucumber	Solonchak	3	Day 1 to 95 at 100% RAW, 20 mm/application	15	20	300	1.157	2
			After day 95 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 85 at 100% RAW, 45 mm/application	7	45	315	0.868	6
			After day 95 no irrigation	0	0			

Table 51. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Drip method in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Cucumber	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Cucumber	Meadow	3	Day 1 to 95 at 50% RAW, 30 mm/application	22	15	330	0.868	2
			After day 95 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 50% RAW, 15 mm/application	23	15	345	0.868	2
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	At 50% RAW	0	0	0	0.000	4
Cucumber	Solonchak	3	Day 1 to 95 at 50% RAW, 15 mm/application	23	15	345	0.868	2
			After day 95 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 50% RAW, 25 mm/application	14	25	350	0.965	3
			After day 95 no irrigation	0	0			

Table 52. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Furrow in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Watermelon	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Watermelon	Meadow	3	Day 1 to 90 at 100% RAW, 25 mm/application	8	25	200	0.723	4
			After day 90 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 100% RAW, 30 mm/application	13	30	390	0.694	5
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Watermelon	Solonchak	3	Day 1 to 100 at 100% RAW, 20 mm/application	15	20	300	1.157	2
			After day 100 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 90 at 100% RAW, 45 mm/application	8	45	360	0.868	6
			After day 90 no irrigation	0	0			

Table 53. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Drip method in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Watermelon	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Watermelon	Meadow	3	Day 1 to 100 at 50% RAW, 15 mm/application	23	15	345	0.868	2
			After day 100 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 50% RAW, 15 mm/application	23	15	345	0.868	2
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Watermelon	Solonchak	3	Day 1 to 100 at 50% RAW, 15 mm/application	24	15	360	0.868	2
			After day 100 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 100 at 50% RAW, 25 mm/application	15	25	350	0.965	3
			After day 100 no irrigation	0	0			

Table 54. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Furrow in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irriga-tion duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	6	50	300	0.413	14
Table Grapes	Meadow	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	10	50	500	0.643	9
Table Grapes	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 40 mm/application Day 26 to 202 at 100 % RAW - fixed norm 40 mm/application Day 203 - one norm 40 mm/application After day 204 - no irrigation	6	40	240	0.579	8
Table Grapes	Brown	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 90 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	2 x 50 and 5 x 90	50 and 90	550	0.801	13

Table 55. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Drip method in Armavir area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irriga-tion duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 50 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	14	25	350	0.723	4
Table Grapes	Meadow	5	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 50 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	20	25	500	0.579	5
Table Grapes	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 20 mm/application Day 26 to 202 at 50 % RAW - fixed norm 20 mm/application Day 203 - one norm 20 mm/application After day 204 - no irrigation	16	20	320	0.463	5
Table Grapes	Brown	5	Day 1 to 24 - no irrigation Day 25 - one norm 45 mm/application Day 26 to 202 at 50 % RAW - fixed norm 45 mm/application Day 203 - one norm 45 mm/application After day 204 - no irrigation	12	45	540	0.579	9

Table 56. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Furrow in Artashat area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 100% RAW, 55 mm/application	6	55	330	0.707	9
			After day 110 no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 100% RAW, 55 mm/application	10	55	550	0.707	9
			After day 130 no irrigation	0	0			
Tomato	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 100% RAW, 40 mm/application	8	40	320	0.514	9
			After day 110 no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 130 at 100% RAW, 90 mm/application	6	90	540	0.694	15
			After day 130 no irrigation	0	0			

Table 57. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Drip method in Artashat area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Tomato	Meadow	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 50% RAW, 25 mm/application	13	25	325	0.579	5
			Day 110 to end - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 50% RAW, 25 mm/application	22	25	550	0.723	4
			After day 130 - no irrigation	0	0			
Tomato	Solonchak	1.5	At 25% RAW	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 50% RAW, 20 mm/application	16	20	320	0.772	3
			Day 110 to end - no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 130 at 50% RAW, 45 mm/application	12	45	540	0.744	7
			Day 130 to end - no irrigation	0	0			

Table 58. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Sprinkler method in Artashat area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Tomato	Meadow	1.5	Day 1 to end at 100 % RAW	0	0	0	0.000	0
Tomato	Meadow	3	Day 1 to 110 at 100% RWA, 60 mm/application	8	60	480	0.694	10
			After day 110 - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 100% RAW, 60 mm/application	9	60	540	0.868	8
			After day 130 - no irrigation	0	0			
Tomato	Solonchak	1.5	At 100% RWA	0	0	0	0.000	0
Tomato	Solonchak	3	Day 1 to 110 at 100% RWA, 45 mm/application	10	45	450	0.651	8
			After day 110 no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 110 at 50% RAW, 45 mm/application	12	45	540	0.868	6
			After day 110 no irrigation	0	0			

Table 59. Furrow Irrigation: Net Irrigation Norms and Net Irrigation Duty, Cucumber, Artashat area, 75% -2017

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Cucumber	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Cucumber	Meadow	3	Day 1 to 85 at 100% RAW, 30 mm/application	10	30	300	0.694	5
			After day 85 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 100% RAW, 30 mm/application	12	30	360	0.868	4
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Cucumber	Solonchak	3	Day 1 to 85 at 100% RAW, 20 mm/application	10	20	200	0.579	4
			After day 85 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 100% RAW, 50 mm/application	7	50	350	0.723	8
			After day 95 no irrigation	0	0			

Table 60. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Drip method in Artashat area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Cucumber	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Cucumber	Meadow	3	Day 1 to 95 at 50% RAW, 30 mm/application	22	15	330	0.868	2
			After day 95 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 50% RAW, 15 mm/application	24	15	360	0.868	2
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Cucumber	Solonchak	3	Day 1 to 95 at 50% RAW, 15 mm/application	23	15	345	0.868	2
			After day 95 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 50% RAW, 25 mm/application	14	25	325	1.447	2
			After day 95 no irrigation	0	0			

Table 61. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Furrow in Artashat area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Watermelon	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Watermelon	Meadow	3	Day 1 to 100 at 100% RAW, 30 mm/application	11	30	330	0.694	5
			After day 100 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 100% RAW, 30 mm/application	12	30	360	0.868	4
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Watermelon	Solonchak	3	Day 1 to 90 at 100% RAW, 20 mm/application	10	20	200	0.579	4
			After day 90 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 100 at 100% RAW, 50 mm/application	7	50	350	0.723	8
			After day 100 no irrigation	0	0			

Table 62. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Drip method in Artashat area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Watermelon	Meadow	1.5	At 50% RAW	0	0	0	0.126	10
Watermelon	Meadow	3	Day 1 to 100 at 50% RAW, 15 mm/application	23	15	345	0.868	2
			After day 100 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 50% RAW, 15 mm/application	25	15	375	0.868	2
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Watermelon	Solonchak	3	Day 1 to 100 at 50% RAW, 15 mm/application	24	15	360	0.868	2
			After day 100 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 100 at 50% RAW, 25 mm/application	15	25	375	0.723	4
			After day 100 no irrigation	0	0			

Table 63. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Furrow in Artashat area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irriga-tion duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	At 100% RAW	0	0	0	0.000	0
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	6	50	300	0.526	11
Table Grapes	Meadow	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	10	50	500	0.413	14
Table Grapes	Solonchak	1.5	At 100% RAW	0	0	0	0.000	0
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 40 mm/application Day 26 to 202 at 100 % RAW - fixed norm 40 mm/application Day 203 - one norm 40 mm/application After day 204 - no irrigation	7	40	280	0.421	11
Table Grapes	Brown	5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 90 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	7	2 x 50 and 5 x 90	550	0.434	24

Table 64. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Drip method in Artashat area, rainfall occurrence probability 75%

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irriga-tion duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/ event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	At 50% RAW	0	0	0	0.000	0
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 50 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	11	25	275	0.482	6
Table Grapes	Meadow	5	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 50 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	21	25	525	0.482	6
Table Grapes	Solonchak	1.5	At 50% RAW	0	0	0	0.000	0
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 20 mm/application Day 26 to 202 at 50 % RAW - fixed norm 20 mm/application Day 203 - one norm 20 mm/application After day 204 - no irrigation	17	20	340	0.772	3
Table Grapes	Brown	5	Day 1 to 24 - no irrigation Day 25 - one norm 45 mm/application Day 26 to 202 at 50 % RAW - fixed norm 45 mm/application Day 203 - one norm 45 mm/application After day 204 - no irrigation	13	45	585	0.521	10

Net Irrigation Norms for Climate Change impact, at probability of 50% - 2050, for crops cultivated in Ararat Valley

Table 65. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Furrow in Ararat Valley, in year 2050

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Tomato	Meadow	1.5	Day 1 to 110 at 100% RAW, 55 mm/application	6	55	330	0.637	10
			After day 110 no irrigation	0	0			
Tomato	Meadow	3	Day 1 to 110 at 100% RAW, 55 mm/application	8	55	440	0.637	10
			After day 110 no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 100% RAW, 55 mm/application	9	55	495	0.637	10
			After day 130 no irrigation	0	0			
Tomato	Solonchak	1.5	Day 1 to 110 at 100% RAW, 45 mm/application	7	45	315	0.651	8
			After day 110 no irrigation	0	0			
Tomato	Solonchak	3	Day 1 to 110 at 100% RAW, 45 mm/application	10	45	450	0.651	8
			After day 110 no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 110 at 100% RAW, 95 mm/application	5	95	475	0.647	17
			After day 110 no irrigation	0	0			

Table 66. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Drip method in Ararat Valley, in year 2050

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Tomato	Meadow	1.5	Day 1 to 110 at 50% RAW, 30 mm/application	12	30	360	0.694	5
			After day 110 - no irrigation	0	0			
Tomato	Meadow	3	Day 1 to 110 at 50% RAW, 30 mm/application	13	30	390	0.694	5
			After day 110 - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 50% RAW, 30 mm/application	16	30	480	0.694	5
			After day 130 - no irrigation	0	0			
Tomato	Solonchak	1.5	Day 1 to 110 at 50% RAW, 25 mm/application	15	25	375	0.723	4
			After day 110 - no irrigation	0	0			
Tomato	Solonchak	3	Day 1 to 110 at 50% RAW, 25 mm/application	16	25	400	0.723	4
			After day 110 - no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 110 at 50% RAW, 45 mm/application	9	45	405	0.651	8
			After day 110 no irrigation	0	0			

Table 67. Net Irrigation Norms and Net Irrigation Duty for Tomato irrigated by Sprinkler method in Ararat Valley, in year 2050

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Tomato	Meadow	1.5	Day 1 to 110 at 100% RAW, 60 mm/application	6	60	360	0.694	10
			After day 110 no irrigation	0	0			
Tomato	Meadow	3	Day 1 to 130 at 100% RWA, 60 mm/application	9	60	540	0.694	10
			After day 130 - no irrigation	0	0			
Tomato	Meadow	>5.5	Day 1 to 130 at 100% RAW, 60 mm/application	9	60	540	0.694	10
			After day 130 - no irrigation	0	0			
Tomato	Solonchak	1.5	Day 1 to 110 at 100% RWA, 45 mm/application	9	45	405	0.744	7
			After day 110 no irrigation	0	0			
Tomato	Solonchak	3	Day 1 to 130 at 100% RWA, 45 mm/application	12	45	540	0.744	7
			After day 130 - no irrigation	0	0			
Tomato	Brown	>5.5	Day 1 to 110 at 50% RAW, 45 mm/application	11	45	495	0.651	8
			After day 110 no irrigation	0	0			

Table 68. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Furrow in Ararat Valley, in year 2050

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irrigation duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Cucumber	Meadow	1.5	Day 1 to 95 at 100% RAW, 30 mm/application	10	30	300	0.579	6
			After day 95 no irrigation	0	0			
Cucumber	Meadow	3	Day 1 to 95 at 100% RAW, 30 mm/application	13	30	390	0.579	6
			After day 95 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 100% RAW, 30 mm/application	12	30	360	0.579	6
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	1.5	Day 1 to 100 at 100% RAW, 25 mm/application	14	25	350	0.579	5
			After day 100 no irrigation	0	0			
Cucumber	Solonchak	3	Day 1 to 95 at 100% RAW, 30 mm/application	14	30	420	0.579	6
			After day 95 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 100% RAW, 55 mm/application	6	55	330	0.637	10
			After day 95 no irrigation	0	0			

Table 69. Net Irrigation Norms and Net Irrigation Duty for Cucumber irrigated by Drip method in Ararat Valley, in year 2050

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irriga-tion duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Cucumber	Meadow	3	Day 1 to 95 at 50% RAW, 30 mm/application	18	15	270	0.579	3
			After day 95 no irrigation	0	0			
Cucumber	Meadow	3	Day 1 to 95 at 50% RAW, 30 mm/application	20	15	300	0.579	3
			After day 95 no irrigation	0	0			
Cucumber	Meadow	>5.5	Day 1 to 95 at 50% RAW, 15 mm/application	20	15	300	0.579	3
			After day 95 no irrigation	0	0			
Cucumber	Solonchak	3	Day 1 to 100 at 50% RAW, 12 mm/application	24	12	288	0.868	2
			After day 100 no irrigation	0	0			
Cucumber	Solonchak	3	Day 1 to 100 at 50% RAW, 12 mm/application	27	12	324	0.579	3
			After day 100 no irrigation	0	0			
Cucumber	Brown	>5.5	Day 1 to 95 at 50% RAW, 25 mm/application	13	25	325	0.723	4
			After day 95 no irrigation	0	0			

Table 70. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Furrow in Ararat Valley, in year 2050

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irriga-tion duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Watermelon	Meadow	3	Day 1 to 100 at 100% RAW, 30 mm/application	10	30	390	0.579	6
			After day 100 no irrigation	0	0			
Watermelon	Meadow	3	Day 1 to 100 at 100% RAW, 30 mm/application	13	30	390	0.579	6
			After day 100 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 100% RAW, 30 mm/application	13	30	390	0.579	6
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	3	Day 1 to 100 at 100% RAW, 25 mm/application	14	25	350	0.579	5
			After day 100 no irrigation	0	0			
Watermelon	Solonchak	3	Day 1 to 100 at 100% RAW, 25 mm/application	16	25	400	0.579	5
			After day 100 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 90 at 100% RAW, 50 mm/application	6	50	300	0.579	10
			After day 90 no irrigation	0	0			

Table 71. Net Irrigation Norms and Net Irrigation Duty for Watermelon irrigated by Drip method in Ararat Valley, in year 2050

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irriga-tion duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Watermelon	Meadow	1.5	Day 1 to 100 at 50% RAW, 15 mm/application	18	15	270	0.579	3
			After day 95 no irrigation	0	0			
Watermelon	Meadow	3	Day 1 to 100 at 50% RAW, 15 mm/application	21	15	315	0.579	3
			After day 100 no irrigation	0	0			
Watermelon	Meadow	>5.5	Day 1 to 100 at 50% RAW, 15 mm/application	21	15	315	0.579	3
			After day 95 no irrigation	0	0			
Watermelon	Solonchak	1.5	Day 1 to 100 at 50% RAW, 15 mm/application	19	15	285	0.579	3
			After day 95 no irrigation	0	0			
Watermelon	Solonchak	3	Day 1 to 100 at 50% RAW, 15 mm/application	22	15	330	0.579	3
			After day 100 no irrigation	0	0			
Watermelon	Brown	>5.5	Day 1 to 90 at 50% RAW, 25 mm/application	12	25	300	0.579	5
			After day 90 no irrigation	0	0			

Table 72. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Furrow in Ararat Valley, in year 2050

Crop	Soil Type	Ground-water Level Depth	Rules to apply irrigation	Irrigation			Net irriga-tion duty	Minimum interval between applications
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	7	50	350	0.445	13
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/applicatior Day 203 - one norm 50 mm/application After day 204 - no irrigation	8	50	400	0.482	12
Table Grapes	Meadow	5.5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	10	50	500	0.413	14
Table Grapes	Solonchak	1.5	Day 1 to 24 - no irrigation Day 25 - one norm 40 mm/application Day 26 to 202 at 100 % RAW - fixed norm 40 mm/application Day 203 - one norm 40 mm/application After day 204 - no irrigation	10	40	400	0.463	10
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 50 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	10	40	400	0.463	10
Table Grapes	Brown	5.5	Day 1 to 24 - no irrigation Day 25 - one norm 50 mm/application Day 26 to 202 at 100 % RAW - fixed norm 90 mm/application Day 203 - one norm 50 mm/application After day 204 - no irrigation	2 x 50 and 5 x 90	50 and 90	550	0.434	24

Table 73. Net Irrigation Norms and Net Irrigation Duty for Table Grapes irrigated by Drip method in Ararat Valley, in year 2050

Crop	**Soil Type**	**Ground-water Level Depth**	**Rules to apply irrigation**	**Irrigation**			**Net irriga-tion duty**	**Minimum interval between applications**
			RAW depleted to:	Events	Norm size	Total season		
		m	%	#	mm/event	mm	l/s/ha	day
Table Grapes	Meadow	1.5	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 100 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	13	25	325	0.482	6
Table Grapes	Meadow	3	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 100 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	16	25	400	0.482	6
Table Grapes	Meadow	5.5	Day 1 to 24 - no irrigation Day 25 - one norm 25 mm/application Day 26 to 202 at 100 % RAW - fixed norm 25 mm/application Day 203 - one norm 25 mm/application After day 204 - no irrigation	20	25	500	0.413	7
Table Grapes	Solonchak	1.5	Day 1 to 24 - no irrigation Day 25 - one norm 20 mm/application Day 26 to 202 at 100 % RAW - fixed norm 20 mm/application Day 203 - one norm 20 mm/application After day 204 - no irrigation	13	20	260	0.331	7
Table Grapes	Solonchak	3	Day 1 to 24 - no irrigation Day 25 - one norm 20 mm/application Day 26 to 202 at 100 % RAW - fixed norm 20 mm/application Day 203 - one norm 20 mm/application After day 204 - no irrigation	18	20	360	0.463	5
Table Grapes	Brown	5.5	Day 1 to 24 - no irrigation Day 25 - one norm 45 mm/application Day 26 to 202 at 100 % RAW - fixed norm 45 mm/application Day 203 - one norm 45 mm/application After day 204 - no irrigation	12	45	540	0.434	12