Food and Agriculture Organization
of the United Nations

AquaCrop

Plug-in program

Reference Manual

AquaCrop plug-in program

Version 4.0

updated November 2013

November 2013

Developed by

Dirk RAES, Pasquale STEDUTO, Theodore C. HSIAO, and Elias FERERES

FAO, Land and Water Division
Rome, Italy

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The calculation procedures in the AquaCrop plug-in program are identical to the AquaCrop standard window program (Version 4.0) but the plug-in program has no user interface. By running the program (ACsaV40.EXE) a list of projects, pre-defined in the standard window version of AquaCrop, are carried out and results are stored in output files. The plug-in program can be used in applications where iterative runs are required (e.g. GIS environment).

The November 2013 update consists in more options for creating output
See 3. Output
3.1 Seasonal output
3.2 Daily output

1. Input

In the absence of a user interface only pre-defined simulation runs can be carried out in the AquaCrop plug-in program. Therefore the input need to consist of project files, which contains all the required information for a simulation run (Tab.1). These project files can only be created[1] with the standard window AquaCrop program (i.e. the AquaCrop model with the user interface).

To run the projects in the plug-in program, the created project files need to be copied from the DATA subdirectory (of the AquaCrop window program where they were created) to the LIST subdirectory of the standalone version (Fig. 1). Since these project files contain all information to run the simulations (Tab. 2), other data files, such as the files containing the characteristics of the selected environment (climate, crop, soil profile, groundwater table, field and irrigation management) and the files with the corresponding initial and off-season conditions, need not to be copied to the LIST directory.

Table 1. Project file (files with extension 'PRO' or 'PRM')

A project file is a file which contains all the required information for a simulation run. Distinction is made between projects containing the required information for a single simulation run (with 'PRO' as the filename extension) and projects consisting of a set of successive runs (for simulations in successive years), the so called multiple run projects (with 'PRM' as the filename extension). A project file contains (Tab. 2):

- the period(s) of the growing cycle (from day 1 after sowing/transplanting to crop maturity);
- the simulation period(s): the first and last day of the simulation period which need not to coincide with the growing cycle;
- the file names (with their directory) containing the characteristics of the selected environment (climate, crop, irrigation management, field management, soil profile and groundwater table file);
- the file names (with their directory) containing the initial and off-season conditions; and
- the specific program settings for the run(s).

[1] Chapter 2 of the reference manual of AquaCrop describes how projects are created (section 2.18.2) and updated (section 2.18.3).

Table 2. Structure and example of a project file

Title (Line 1) and Version number (Line 2)
winter wheat on sandy loam soil in Tunis for 22 successive years 4.0 : AquaCrop Version (June 2012)
The simulation period (Line 3 and 4) and the period of the growing cycle (Line 5 and 6) for the (first) simulation run – See Table 3 for calculation of day numbers
28702 : First day of simulation period - 1 August 1979 28977 : Last day of simulation period - 2 May 1980 28791 : First day of cropping period - 29 October 1979 28977 : Last day of cropping period - 2 May 1980
Setting of the program parameters (Line 7 to 27)
4 : Evaporation decline factor for stage II 1.10 : Ke(x) Soil evaporation coefficient (fully wet and non-shaded) 5 : Threshold for CC below HI can no longer increase (% cover) 70 : Starting depth of root zone expansion curve (% of Zmin) 5.00 : Maximum allowable root zone expansion (fixed at 5 cm/day) -6 : Shape factor for effect water stress on root zone expansion 20 : Required soil water content in soil for germination (% TAW) 1.0 : Adjustment factor for soil water depletion (p) by ETo 3 : Number days after which deficient aeration is fully effective 1.00 : Exponent of senescence adjusting photosynthetic activity 12 : Decrease of p(sen) once senescence is triggered (% of p(sen)) 1 : Thresholds for stomatal closure are affected by soil salinity 30 : Depth [cm] of profile affected by soil evaporation 0.30 : Considered depth (m) for CN adjustment 1 : CN is adjusted to Antecedent Moisture Class 20 : salt diffusion factor [%] 100 : salt solubility [g/liter] 16 : shape factor for effect of soil water content on CR 12.0 : Default minimum temperature (°C) 28.0 : Default maximum temperature (°C) 3 : Default method for the calculation of growing degree days
The file names with their directory (path) containing the characteristics of the selected climatic conditions (Line 28 to 42) for the (first) simulation run
-- 1. Climate (CLI) file Tunis.CLI C:\FAO\AquaCrop\DATA\ 1.1 Temperature (TMP) file Tunis.TMP C:\FAO\AquaCrop\DATA\ 1.2 Reference ET (ETo) file Tunis.ETo C:\FAO\AquaCrop\DATA\ 1.3 Rain (PLU) file Tunis.PLU C:\FAO\AquaCrop\DATA\ 1.4 Atmospheric CO2 (CO2) file MaunaLoa.CO2 C:\FAO\AquaCrop\SIMUL\

Table 2. Structure and example of project file … *continued*

The file name with its directory (path) containing the characteristics of the selected crop (Line 43 to 45) for the (first) simulation run

`-- 2. Crop (CRO) file`
`WWheatTun.CRO`
`C:\FAO\AquaCrop\DATA\`

The file name with its directory (path) containing the characteristics of the selected irrigation management (Line 46 to 48) for the (first) simulation run

`-- 3. Irrigation (IRR) file`
`(None)`
`(None)`

The file name with its directory (path) containing the characteristics of the selected field management (Line 49 to 51) for the (first) simulation run

`-- 4. Management (MAN) file`
`SF80B.MAN`
`C:\FAO\AquaCrop\DATA\`

The file name with its directory (path) containing the characteristics of the selected soil profile (Line 52 to 54) for the (first) simulation run

`-- 5. Soil profile (SOL) file`
`SANDYLOAM.SOL`
`C:\FAO\AquaCrop\DATA\`

The file name with its directory (path) containing the characteristics of the selected groundwater table (Line 55 to 57) for the (first) simulation run

`-- 6. Groundwater (GWT) file`
`(None)`
`(None)`

The file names with its directory (path) containing the initial conditions (Line 58 to 60) for the (first) simulation run

`-- 7. Initial conditions (SW0) file`
`SLiniTun.SW0`
`C:\FAO\AquaCrop\DATA\`

The file name with its directory (path) containing the off-season conditions (Line 61 to 63) for the (first) simulation run

`-- 8. Off-season conditions (OFF) file`
`(None)`
`(None)`

In case of multiple projects: *- the simulation period,* *- the crop growth cycle,* *- file names containing the characteristics of the selected environment,* *- file names containing the initial and off-season conditions* *for each of the successive run(s) are given in the next lines (Line 64 to …)*
…. …. …. ….

AquaCrop uses day numbers to specify the start and end of the simulation period and the period of the growing cycle. The day number refers to the days elapsed since 0th January 1901 at 0 am (Tab. 3).

Table 3.
Number of days elapsed since 0th January 1901, 0 am

Validity
The method is valid from 1901 to 2099 only (time range in AquaCrop)

Rules
1. Subtract 1901 from the year
2. Multiply by 365.25
3. According to the month add:
   - January : 0
   - February : 31
   - March : 59.25
   - April : 90.25
   - May : 120.25
   - June : 151.25
   - July : 181.25
   - August : 212.25
   - September : 243.25
   - October : 273.25
   - November : 304.25
   - December : 334.25
4. Add the number of the day within the month
5. Take the integer

Example
For 24 August 1982

1. Subtract 1901 from the year	1982 – 1901 = 81
2. Multiply by 365.25	81 x 365.25 = 29585.25
3. Add 212.25 for August	29585.25 + 212.25 = 29797.5
4. Add the number of the day	29797.5 + 24 = 29821.5
5. Take the integer	29821

Reference
Gommes, R.A. 1983. Pocket computers in agro meteorology. FAO Plant production and protection paper Nr. 45, Rome, Italy.

2. Running simulation(s)

When the AquaCrop plug-in program is launched, the software runs one by one the projects listed in its LIST directory. Since the AquaCrop plug-in program obtains its input from files in the DATA subdirectory of the AquaCrop standard window program, both programs need to be installed on the same computer (Fig. 1).

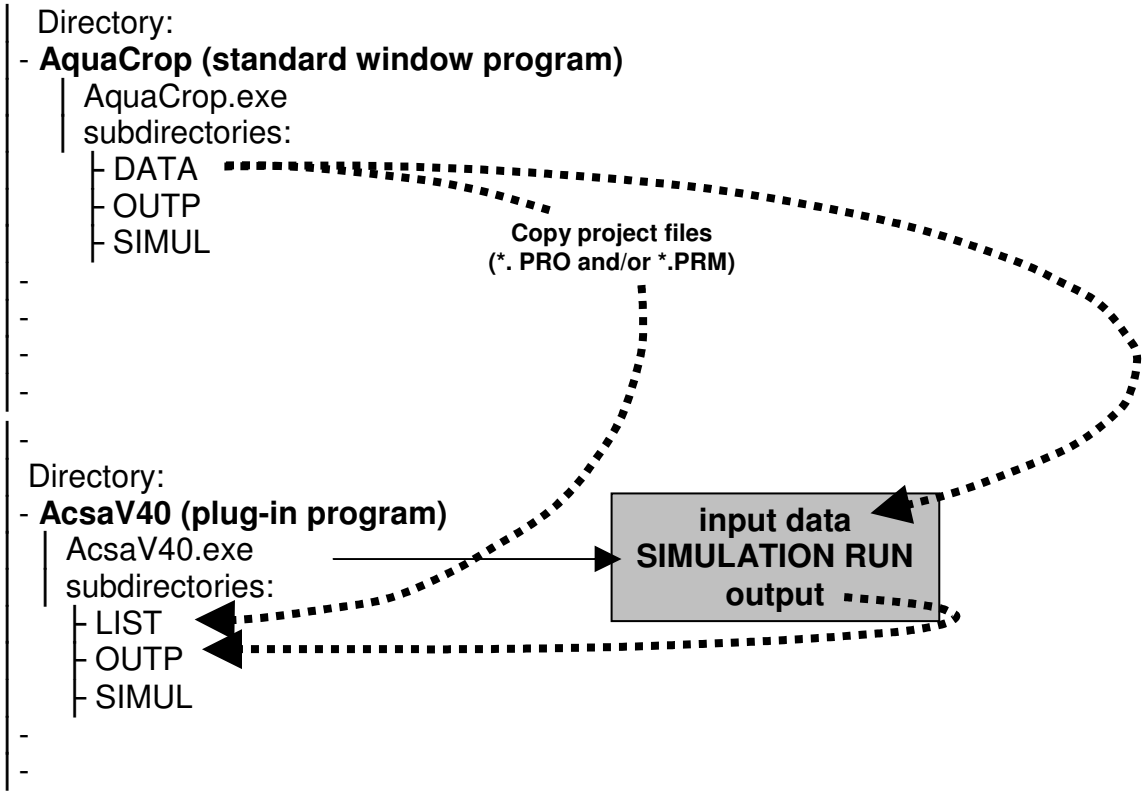

Figure 1.
Input and output data for running the AquaCrop plug-in program

- For each project (or for each run of a multiple project), the software obtains from the project file (Tab. 2):
  - the starting and end date of the simulation period and growing cycle;
  - the program settings; and
  - the path of the filenames containing the characteristics of the selected environment (climate, crop, irrigation management, field management, soil profile and groundwater table file) and the initial and off-season conditions;
- Before starting a simulation run, the program checks if:
  - the structure of the project file is correct (example presented in Tab. 2);
  - all files describing the environment are available at the specified path.

  If not so, the project is skipped and no output will be generated.
- While running the successive projects the results are saved in files in the OUTP directory. When all projects listed in the LIST directory are run, the program stops automatically.

3. Output

When running a project, intermediate and final seasonal simulation results of a project are stored in an output file in the OUTP directory of the plug-in program (Fig. 1). Additionally, daily results (available in the standard window version of AquaCrop) can be requested as output (option available in the November 2013 update of the Plug-In program).

3.1 Seasonal Output

The seasonal output file contains length and dates of the simulation period, and the totals for climatic, soil water and soil salinity parameters, for average stresses during the growing period, for biomass production, crop yield and crop water productivity (Tab. 6). Seasonal output files are stored in the OUTP directory of the programme.

- **File name:** The name of each seasonal output file corresponds with the filename of the corresponding project file but extended with 'PROseason' (for single projects) or 'PRMseason' (for multiple projects), and the extension OUT (Tab. 4). There are as many seasonal output files as project files listed in the LIST directory.

Table 4. – Examples of Projects and seasonal output files

Project files (LIST directory)	Seasonal output files (OUTP directory)
Axum.PRO	AxumPROseason.OUT
Axum19Years.PRM	Axum19YearsPRMseason.OUT

- **Option for intermediate results:** The standard output consists of totals and averages of climate, crop, soil water and salt parameters over the total simulation period. Additionally daily, 10-daily or monthly intermediate simulation results can be requested. Therefore the user has to adjust the number specified at the start of the first (and only) line of the 'AggregationResults.SIM' file (file available in the SIM subdirectory). Depending on the number either none, daily, 10-daily or monthly intermediate simulation results will be provided next to the final simulation results (Tab. 5). The following code applies:

0 : for no intermediate results
1 : for daily results
2 : for 10-daily intermediate results
3 : for monthly intermediate results

In the absence of the 'AggregationResults.SIM' file, no intermediate results will be provided.

Table 5. – Example of the AggregationResults.SIM' file (file available in the SIM subdirectory) generating 10-daily intermediate seasonal simulation results

2 : Time aggregation for intermediate results (0 = none ; 1 = daily; 2 = 10-daily; 3 = monthly)

- **Recorded simulation results:** In each seasonal output file there are for each simulation run as many lines as intermediate results plus one extra line for the totals

of the simulation run. The results are presented in 36 columns (Tab. 6) and contain information of the length and dates of the simulation period, and the totals for climatic, soil water and soil salinity parameters, for average stresses during the growing period, for biomass production, crop yield and crop water productivity.

Table 6. –Information available in the 36 columns of the seasonal output file

Nr	Symbol	Length of period	Unit
1	Period	- Tot(Number simulation run) : for total simulation run - Day : for intermediate daily results - 10Day : for intermediate 10-daily results - Month : for intermediate monthly results	-
First day of considered period			
2	Day1	Day at start of period	-
3	Month1	Month at start of period	-
4	Year1	Year at start of period	-
Climatic parameters for considered period			
5	Rain	Rainfall	mm
6	ETo	Reference evapotranspiration	mm
7	GDD	Growing degree days	°C day
8	CO2	Atmospheric CO_2 concentration	ppm
Soil water parameters for considered period			
9	Irri	- Amount of water applied by irrigation - Net irrigation requirement (if requested)	mm
10	Infilt	Amount of water infiltrated in the soil profile	mm
11	Runoff	Amount of water lost by surface runoff	mm
12	Drain	Amount of water drained out of the soil profile	mm
13	Upflow	Amount of water moved upward by capillary rise	mm
14	E	Amount of water evaporated from the soil surface	mm
15	E/Ex	Relative mean soil evaporation (100 E/Ex)	%
16	Tr	Amount of water transpired by the crop	mm
17	Tr/Trx	Relative mean crop transpiration (100 Tr/Trx)	%
Soil salinity parameters for considered period			
18	SaltIn	Salt infiltrated in the soil profile	ton/ha
19	SaltOut	Salt drained out of the soil profile	ton/ha
20	SaltUp	Salt moved upward by capillary rise from groundwater table	ton/ha
21	SaltProf	Salt stored in the soil profile	ton/ha
Average stresses during growing cycle (from germination onwards)			
22	Cycle	Length of crop cycle: from germination onwards)	days
23	SaltStr	Average soil salinity stress	%
24	FertStr	Average soil fertility stress	%
25	TempStr	Average temperature stress (affecting biomass)	%

26	ExpStr	Average leaf expansion stress	%
27	StoStr	Average stomatal stress	%
Biomass production in considered period			
28	Biomass	Above-ground biomass produced	ton/ha
29	Brelative	Relative biomass (Reference: well watered and well fertilized soil)	%
Crop yield (only specified at end of simulation run)			
30	HI	Harvest Index	%
31	Yield	Yield (HI x Biomass)	ton/ha
32	WPet	ET Water Productivity for yield part (kg yield produced per m^3 water evapotranspired)	kg/m^3
Last day of considered period			
33	DayN	Day at end of period	-
34	MonthN	Month at end of period	-
35	YearN	Year at end of period	-
Project			
36	File	Project file name	-

3.2 Daily Output

In the standard window version of AquaCrop, daily simulation results are stored in a set of 7 output files (see 2.23 'Output files' in Chapter 2 of the reference manual). The output files contain information on the:

- Crop development and production (file --Crop.OUT);
- Soil water content at various depths of the soil profile (file --CompWC.OUT);
- Soil salinity at various depths of the soil profile (file --CompEC.OUT);
- Soil water content in the soil profile and root zone (file --Prof.OUT);
- Soil salinity in the soil profile and root zone (file --Salt.OUT);
- Various parameters of the soil water balance (file --Wabal.OUT);
- Net irrigation water requirement (file --Inet.OUT).

These daily output files can also be requested as output of the Plug-In program (option available in the November 2013 update of the Plug-In program). As the seasonal output files, the daily output files are stored in the OUTP directory of the programme.

- **File name:** The name of the daily output files corresponds with the filename of the corresponding project file but extended with 'PROday' (for single projects) or 'PRMday' (for multiple projects), and the extension OUT (Tab. 7). There are as many daily output files as project files listed in the LIST directory.

Table 7. – Examples of Projects and daily output files

Project files (LIST directory)	Output files (OUTP directory)
Axum.PRO	AxumPROday.OUT
Axum19Years.PRM	Axum19YearsPRMday.OUT

- **Content:** The user specifies the daily data that needs to be recorded with the help of codes (one code per line) in the 'DailyResults.SIM' file (file available in the SIM subdirectory). The number of codes (specified in successive lines), and the value of the code (specified at the start of each of the successive lines) determine the content of the output (Tab. 8).

1 : Various parameters of the soil water balance. When net irrigation is calculated column 8 (Irri) contains the daily net irrigation requirement; 2 : Crop development and production; 3 : Soil water content in the soil profile and root zone; 4: Soil salinity in the soil profile and root zone; 5 : Soil water content at various depths of the soil profile; 6 : Soil salinity at various depths of the soil profile.

In the absence of the 'DailyResults.SIM' file, no daily results will be provided.

Table 8. – Example of a 'DailyResults.SIM' file (file available in the SIM subdirectory) requesting a record of daily results of the (i) Crop development and production and of the (ii) Soil water content at various depths of the soil profile

2 : Crop development and production 5 : Soil water content at various depths of the soil profile

- **Structure:** In each daily output file there are for each simulation run as many lines as days in the simulation period. The individual runs of a multiple projects (PRM) are separated by an empty line and the Run number. The number of columns depend on the daily data that needs to be recorded and can be up to 86 column if all daily results are requested (Tab. 9).

Table 9. – Structure of the daily output file

Nr	Symbol	Description	Unit
1	Day		-
2	Month		-
3	Year		-
4	DAP	Days after planting/sowing	-
5	Stage	Crop growth stage: 0: before or after cropping; 1: between sowing and germination or transplant recovering; 2: vegetative development; 3: flowering; 4: yield formation and ripening -9: no crop as a result of early canopy senescence	-

IF Code 1: Various parameters of the soil water balance			
6	WC(x.xx)	Water content in total soil profile with (x.xx): the soil depth in meter	mm

7	Rain	Rainfall	mm
8	Irri	Water applied by irrigation Or net irrigation requirement if the determination of Net Irrigation requirement is requested in the IRR file	mm
9	Surf	Stored water on soil surface between bunds	mm
10	Infilt	Infiltrated water in soil profile	mm
11	RO	Surface runoff	mm
12	Drain	Water drained out of the soil profile	mm
13	CR	Water moved upward by capillary rise	mm
14	Zgwt	Depth of the groundwater table	m
15	Ex	Maximum soil evaporation	mm
16	E	Actual soil evaporation	mm
17	E/Ex	Relative evaporation (100 E/EX)	%
18	Trx	Maximum crop transpiration	mm
19	Tr	Actual crop transpiration	mm
20	Tr/Trx	Relative transpiration (100 Tr/Trx)	%
21	ETx	Maximum evapotranspiration	mm
22	ET	Actual evapotranspiration	mm
23	ET/ETx	Relative evapotranspriation (100 ET/ETx)	%

If Code 2: Crop development and production			
24	GD	Growing degrees	°C-day
25	Z	Effective rooting depth	m
26	StExp	Percent water stress reducing leaf expansion	%
27	StSto	Percent water stress inducing stomatal closure	%
28	StSen	Percent water stress triggering early canopy senescence	%
29	StSalt	Percent salinity stress	%
30	CC	Green canopy cover	%
31	Kc(Tr)	Crop coefficient for transpiration	-
32	Trx	Maximum crop transpiration	mm
33	Tr	Actual crop transpiration	mm
34	Tr/Trx	Relative transpiration (100 Tr/Trx)	%
35	WP	Crop water productivity adjusted for CO2, soil fertility and products synthesized	g/m^2
36	StBio	Percent temperature stress affecting biomass production	%
37	Biomass	Cumulative biomass produced	ton/ha
38	HI	Harvest Index adjusted for failure of pollination, inadequate photosynthesis and water stress	%
39	Yield	Yield (HI x Biomass)	ton/ha
40	Brelative	: Relative biomass (Reference: no water, no soil fertility, no soil salinity stress)	%

41	WPet	ET Water productivity for yield part (kg yield produced per m3 water evapotranspired)	kg/m^3

IF Code 3: Soil water content in the soil profile and root zone			
42	WC(x.xx)	Water content total soil profile with (x.xx): the soil depth in meter	mm
43	Wr(x.xx)	Water content in maximum effective root zone with (x.xx): the maximum effective root zone	mm
44	Z	Effective rooting depth	m
45	Wr	Water content in effective root zone	mm
46	Wr(SAT)	Water content in effective root zone if saturated	mm
47	Wr(FC)	Water content in effective root zone at field capacity	mm
48	Wr(exp)	Water content in effective root zone at upper threshold for leaf expansion	mm
49	Wr(sto)	Water content in effective root zone at upper threshold for stomatal closure	mm
50	Wr(sen)	Water content in effective root zone at upper threshold for early canopy senescence	mm
51	Wr(PWP)	Water content in effective root zone at permanent wilting point	mm

IF Code 4: Soil salinity in the soil profile and root zone			
52	SaltIn	Salt infiltrated in the soil profile	ton/ha
53	SaltOut	Salt drained out of the soil profile	ton/ha
54	SaltUp	Salt moved upward by capillary rise from groundwater table	ton/ha
55	Salt(x.xx)	Salt content in the total soil profile with (x.xx): the soil depth in meter	ton/ha
56	SaltZ	Salt content in the effective root zone	ton/ha
57	Z	Effective rooting depth	m
58	ECe	Electrical conductivity of the saturated soil-paste extract from the root zone	dS/m
59	ECsw	Electrical conductivity of the soil water in the root zone	dS/m
60	StSalt	Salinity stress	%
61	Zgwt	Depth of the groundwater table	m
62	ECgw	Electrical conductivity of the groundwater	dS/m

IF Code 5: Soil water content at various depths of the soil profile			
63	WC1	soil water content compartment 1 *	vol%
64	WC2	soil water content compartment 2	vol%
65	WC3	soil water content compartment 3	vol%

66	WC4	soil water content compartment 4	vol%
67	WC5	soil water content compartment 5	vol%
68	WC6	soil water content compartment 6	vol%
69	WC7	soil water content compartment 7	vol%
70	WC8	soil water content compartment 8	vol%
71	WC9	soil water content compartment 9	vol%
72	WC10	soil water content compartment 10	vol%
73	WC11	soil water content compartment 11	vol%
74	WC12	soil water content compartment 12	vol%
* The corresponding soil depth (at the centre of the compartment) is specified in meter below the symbol			

IF Code 6: Soil salinity at various depths of the soil profile			
75	EC1	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 1 *	dS/m
76	EC2	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 2	dS/m
77	EC3	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 3	dS/m
78	EC4	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 4	dS/m
79	EC5	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 5	dS/m
80	EC6	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 6	dS/m
81	EC7	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 7	dS/m
82	EC8	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 8	dS/m
83	EC9	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 9	dS/m
84	EC10	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 10	dS/m
85	EC11	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 11	dS/m
86	EC12	Electrical conductivity of the saturated soil-paste extract (ECe) - compartment 12	dS/m
* The corresponding soil depth (at the centre of the compartment) is specified in meter below the symbol			

4. Installation

- **Standard procedure**

Zipped files containing the executable program for installing (i) the Standard Window and (ii) the Plug-in program of AquaCrop can be downloaded from the FAO website.

http://www.fao.org/nr/water/aquacrop.html

1. Copy the zipped file to the PC;
2. Unzip; and
3. Run SETUP.EXE.

When running the installation file, a series of windows will pop up. By selecting 'Next >' in each of the windows, the AquaCrop program will be installed by default in a subfolder of the PC (which will be created if not available):

- for the AquaCrop standard window program: C:\FAO\AquaCrop
- for the AquaCrop plug-in program: C:\FAO\ACsaV40

- **64-bit PC**

Notwithstanding that the AquaCrop program is not compatible with 64-bit PCs, an elegant solution consists in installing a 'Virtual PC' (2007). This is a free program from MicroSoft. Once installed, an operating system (such as XP) and AquaCrop have to be installed on the Virtual PC. AquaCrop can run in that environment. It is a simple solution, often done for software that is not compatible with a 64-bit system.

Another possibility is to install AquaCrop on a regular 32-bit PC and to copy the whole folder with its subfolders to the 64-bit PC. Experience shows that this work as well.

- **Once installed**

When AquaCrop is properly installed, you will find in the AquaCrop directory:

For the AquaCrop standard window program:

- the AquaCrop executable file (AquaCrop.EXE);
- some files with extension PAR (these are the last selected settings for program parameters);
- the default crop and soil file (DEFAULT.CRO and DEFAULT.SOL);
- the list of soil characteristics for default soil types (SOILS.DIR);
- a DATA subdirectory, with the calibrated and validated crop files by FAO and some examples files with environmental data (climate, soil, ..);
- an OUTP subdirectory, where simulation results will be stored by default;
- an OBS subdirectory, where files with field data can be stored;
- a SIMUL subdirectory, with the Mauna Loa CO2 file.

For the AquaCrop plug-in program:

- the AquaCrop executable file (ACsaV40.EXE);
- a LIST subdirectory, where the copied project files should be stored;
- an OUTP subdirectory, where simulation results will be stored;
- a SIMUL subdirectory, with eventually the 'AggregationResults.SIM' and the 'DailyResults.SIM' file.