Food and Agriculture Organization
of the United Nations

AquaCrop

Section 2.21 Input files (Chapter 2 – Users guide)

Section 2.21 of Reference Manual AquaCrop Version 4.0
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2.21 Input files

Input files contain the characteristics of the crop, of the environment (climate, management, soil) in which the crop is cultivated, and of the conditions outside the growing period and at the start of the simulation run. By default the input files are stored in the DATA subdirectory of the AquaCrop folder. Distinction is made between:

- Climate files (*.CLI) which contains the names of a set of files containing
  - air temperature data (*.TMP),
  - reference evapotranspiration data (*.ETo),
  - rainfall data (*.PLU), and
  - atmospheric CO_2 data (*.CO2);
- Crop files (*.CRO) containing crop characteristics;
- Irrigation files (*.IRR) containing, apart from the irrigation method, (i) information for the calculation of the net irrigation requirement, (ii) the timing, applied irrigation amounts and the irrigation water quality of an irrigation schedule, or (iii) information for generating irrigation schedules;
- Field management files (*.Man) containing characteristics of the field on which the crop is cultivated;
- Soil profile files (*.SOL) containing characteristics of the soil profile;
- Groundwater files (*.GWT) containing characteristics of the groundwater table;

- Files with the specific conditions in the soil profile at the start of the simulation period (*.SW0);
- Files with off-season field management conditions (*.OFF).

Project files contain all the required information for a simulation run. Distinction is made between:
- Single run project files (*.PRO) containing information on the growing and simulation period, the settings of program parameters, and the names of the set of input files describing the environment, and the initial and off-season conditions;
- Multiple runs project files (*.PRM) containing information on the settings of program parameters and on the growing and simulation period, names of the set of input files describing the environment, and the initial and off-season conditions for each of the runs.

Also field observations can be stored in text files and compared with simulation results at the end of a simulation run. By default the field observations files are stored in the OBS subdirectory of the AquaCrop folder.
- Files with field observations (*.OBS).

2.21 Input files .....

2.21.1 Climate file (*.CLI)

A climate file (Tab. 2.21.1a, Fig. 2.21.1) contains the names of the air temperature file (*.TMP), ETo file (*.ETo), rainfall file (*.PLU), and CO_2 file (*.CO2). An example is given in Tab. 2.21.1b.

Table 2.21.1a – Structure of a Climate file (files with extension CLI)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	The name of the air temperature file (*.TMP)	String of characters
4	The name of the ETo file (*.ETo)	String of characters
5	The name of the rainfall file (*.PLU)	String of characters
6	The name of the CO_2 file (*.CO2)	String of characters

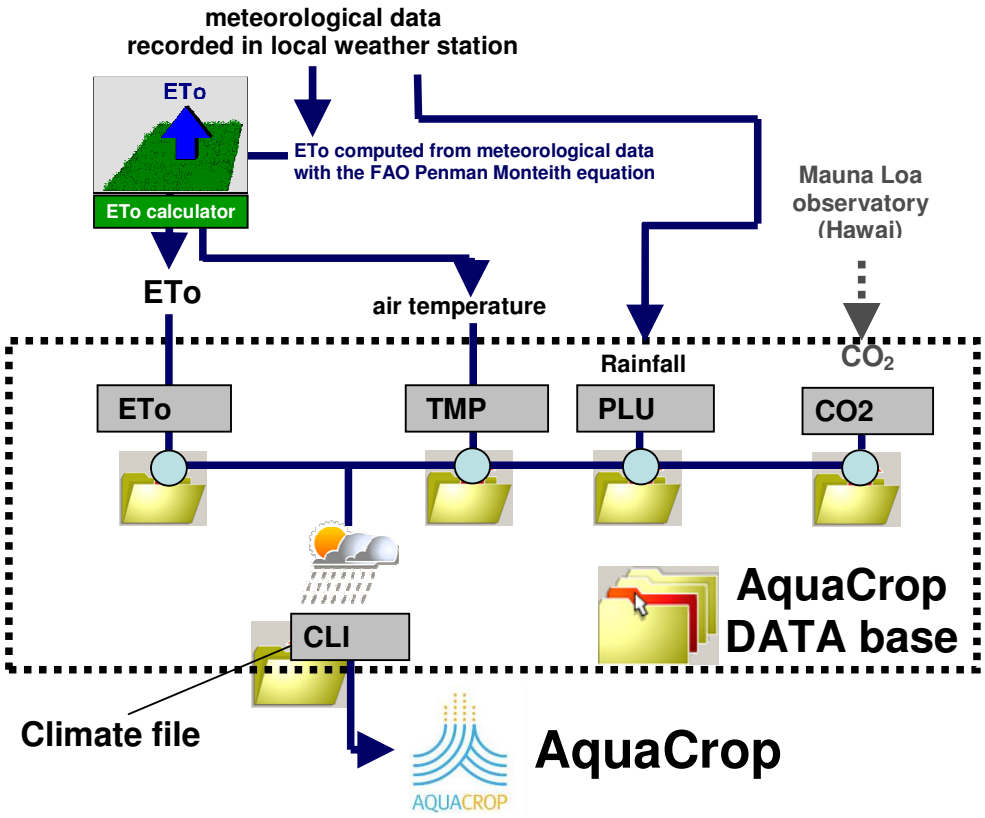


Fig 2.21.1 – Climatic data and Climate file

Table 2.21.1b – Example of a climate file (files with extension CLI)

```
Tunis (Tunisia) climatic data
 4.0   : AquaCrop Version (May 2012)
Tunis.TMP
Tunis.ETo
Tunis7902.PLU
MaunaLoa.CO2
```

2.21.2 Temperature (*.TMP), ETo (*ETo) and rainfall (*.PLU) files

Temperature (*.TMP), ETo (*.ETo) and Rainfall (*.PLU) files contain daily, mean 10-daily or monthly weather data for a number of successive days, 10-day periods or months.

Structure and Examples of TMP, ETo and PLU files

Temperature (Tab. 2.21.2a), ETo (Tab. 2.21.2c) and Rainfall files (Tab. 2.21.2e) have all the same structure which consists of:

- 5 lines containing information required by the program;
- an empty line to separate the information from the records;
- 2 lines for the title of the records;
- list of records (1 line for each daily, 10-daily or monthly record). The records are the daily, mean 10-daily or monthly minimum and maximum air temperature in degrees Celsius, the daily, mean 10-daily or monthly ETo in mm/day and the total daily, 10-daily or monthly rainfall data in mm. The data may consist of integers or real's with 1 digit (1/10 of a degree or a millimeter).

Table 2.21.2a – Structure of an air temperature file (files with extension TMP)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	A number (1 to 3) used as a code to specify the time aggregation of the weather data: 1 : Daily weather data 2 : 10-day weather data 3 : monthly weather data	Integer
4	First day of record (1, 11 or 21 for 10-day or 1 for months)	Integer
5	First month of record	Integer
6	First year of record (1901 if the characteristics are not linked to a specific year)	Integer
7	Empty line	-
8	Title of variables ('Tmin (°C) TMax (°C)')	String of characters
9	Dotted line ('==========')	String of characters
10	For each day 10-day or month of the record: - (average) minimum air temperature (°C) - (average) maximum air temperature (°C)	 Real (1 digit) Real (1 digit)

Table 2.21.2b – Example of an air temperature file (files with extension TMP)

```
Daily air temperature data of  Location (Country)
1         : Daily records (1=daily, 2=10-daily and 3=monthly data)
1         : First day of record (1, 11 or 21 for 10-day or 1 for months)
1         : First month of record
2000      : First year of record (1901 if not linked to a specific year)

  Tmin (°C)   TMax (°C)
========================
    7.0       15.0
    8.0       16.0
    9.0       18.0
   …          ….
```

Table 2.21.2c – Structure of an ETo file (files with extension ETo)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	A number (1 to 3) used as a code to specify the time aggregation of the weather data: 1 : Daily weather data 2 : 10-day weather data 3 : monthly weather data	Integer
4	First day of record (1, 11 or 21 for 10-day or 1 for months)	Integer
5	First month of record	Integer
6	First year of record (1901 if the characteristics are not linked to a specific year)	Integer
7	Empty line	-
8	Title of variables ('Average ETo (mm/day)')	String of characters
9	Dotted line ('==========')	String of characters
10	Average ETo (mm/day) for each day, 10-day or month of the record	Real (1 digit)

Table 2.21.2d – Example of an ETo file (files with extension ETo)

```
Daily reference evapotranspiration (ETo) of  Location (Country)
1        : Daily records (1=daily, 2=10-daily and 3=monthly data)
1        : First day of record (1, 11 or 21 for 10-day or 1 for months)
1        : First month of record
2000     : First year of record (1901 if not linked to a specific year)

Average ETo (mm/day)
========================
      1.0
      1.1
      1.2
       …
       …
```

Table 2.21.2e – Structure of a Rainfall file (files with extension PLU)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	A number (1 to 3) used as a code to specify the time aggregation of the weather data: 1 : Daily weather data 2 : 10-day weather data 3 : monthly weather data	Integer
4	First day of record (1, 11 or 21 for 10-day or 1 for months)	Integer
5	First month of record	Integer
6	First year of record (1901 if the characteristics are not linked to a specific year)	Integer
7	Empty line	-
8	Title of variables ('Total Rain (mm)')	String of characters
9	Dotted line ('==========')	String of characters
10	Total Rain (mm) for each day, 10-day or month of the record	Real (1 digit)

Table 2.21.2f – Example of an Rainfall file (files with extension PLU)

```
Daily rainfall of  Location (Country)
1         : Daily records (1=daily, 2=10-daily and 3=monthly data)
1         : First day of record (1, 11 or 21 for 10-day or 1 for months)
1         : First month of record
2000      : First year of record (1901 if not linked to a specific year)

   Total Rain (mm)
========================
     0.0
     0.0
    16.6
       …
       …
```

Reference evapotranspiration (ETo)

The reference evapotranspiration, denoted as ETo, is used in AquaCrop as a measure of evaporative demand of the atmosphere. It is the evapotranspiration rate from a reference surface, not short of water. A large uniform grass (or alfalfa) field is considered worldwide as the reference surface. The reference crop completely covers the soil, is kept short, well watered and is actively growing under optimal agronomic conditions.

ETo can be derived from weather station data by means of the FAO Penman-Monteith equation, and an ETo calculator is available for that purpose (Table 2.21.2g). In the calculator, the data from a weather station can be specified in a wide variety of units, meteorological data can be imported, and procedures are available to estimate missing climatic data. Climate files (*. ETo and *.TMP) can be exported to AquaCrop (Fig. 2.21.1 and 2.21.2).

Table 2.21.2g – The ETo Calculator (Land and water Digital Media Service N° 36, FAO, 2009).

The ETo Calculator is public domain software, and an installation disk (1.5 Mb) and a software copy of the Reference Manual can be obtained from:

Land and Water Development Division
FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy
e-mail: Land-and-Water@fao.org

web page: http://www.fao.org/nr/water/ETo.html

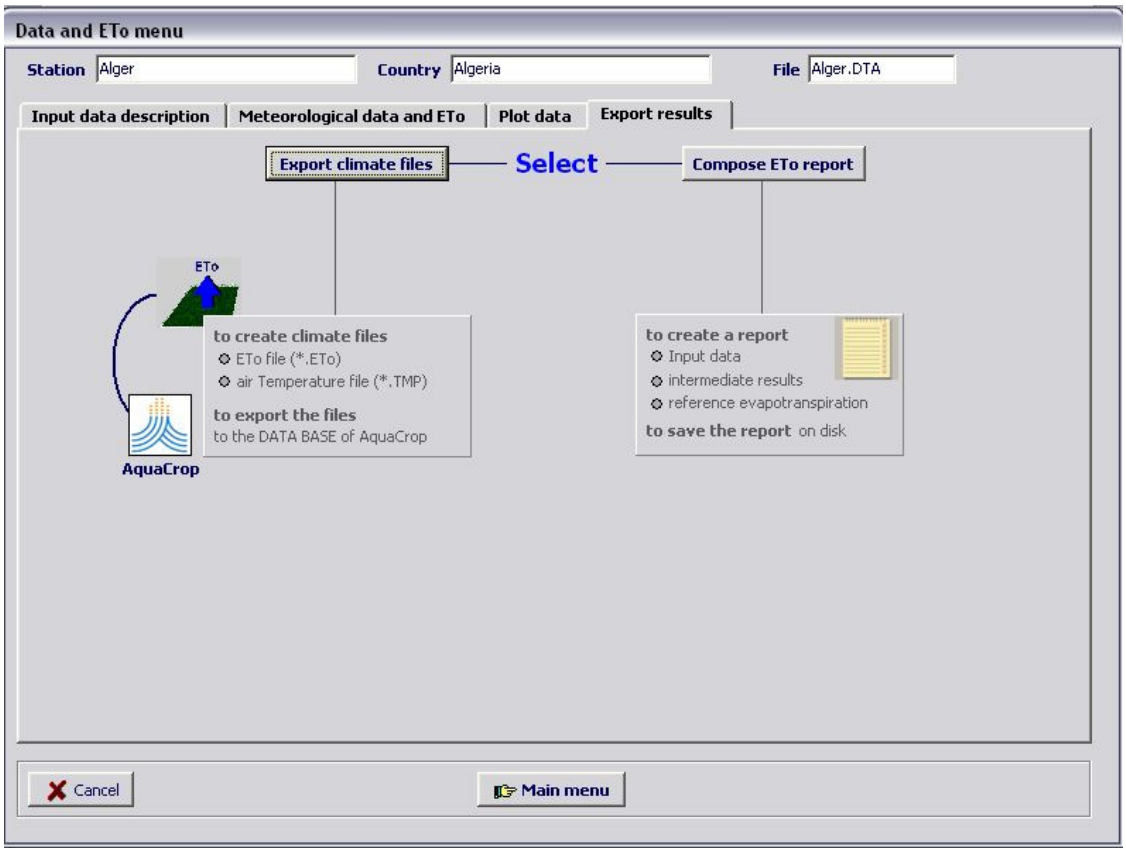


Figure 2.12.2 - Options available in the ETo calculator to export an ETo file (*.ETo) and air temperature (*.TMP) file to AquaCrop.

Daily, 10-day and Monthly weather data

In the absence of daily data, the input (Air Temperature, and/or ETo) may also consists of 10-day or monthly data. At run time an interpolation procedure is used to obtain daily temperature and/or ETo data from the 10-day or monthly means.

For rainfall, with its extremely heterogeneous distribution over time, the use of long-term mean data is not recommended. In case no daily rainfall data is available, 10-day and monthly data can be used as input. Since it is highly unlikely that rainfall is homogenously distributed over all the days of the 10-day period or month, AquaCrop uses at run time procedures to determine the amount of rainfall that is (i) lost by surface runoff, (ii) stored in the top soil as effective rainfall, (iii) lost by deep percolation and (iv) by soil evaporation.

Average weather data

If the meteorological data consists of averages of several years, the data should not be linked to a specific year and the year has not to be specified (Tab. 2.21.2h). Since the weather data is not linked to a specific year, the data can be used for any year.

Table 2.21.2h – Example of an ETo file (file with extension ETo) with mean monthly climatic data not linked to a specific year

```
Mean monthly ETo for Axum (Ethiopia)
   3     : Monthly records (1=daily, 2=10-daily and 3=monthly data)
   1     : First day of record (1, 11 or 21 for 10-day or 1 for months)
   1     : First month of record
1901     : First year of record (1901 if not linked to a specific year)

 Average ETo (mm/day)
=======================
     3.4
     3.5
     4.6
     4.9
     5.4
     4.8
     3.5
     3.2
     4.1
     4.2
     3.4
     3.0
```

2.21.3 CO2 file (*.CO2)

A CO2 file contains mean annual atmospheric CO_2 data (in ppm) for a series of years arranged in chronological order. For years not specified in the file, AquaCrop will derive at run time the CO_2 concentration by linear interpolation between the specified CO_2 values for an earlier and later year. For years out of the listed range, the atmospheric CO_2 concentration is assumed to be equal to the specified value of the first year (for earlier years) or the specified value of the last year (for later years). When creating CO2 file, the structure of the file needs to be respected (Tab. 2.21.3a).

Table 2.21.3a – Structure of a CO2 file (files with extension CO2)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Title of variables ('Year CO2 (ppm by volume)')	String of characters
3	Dotted line ('==========')	String of characters
4 and next	For each record specify: - year - corresponding [CO2] in ppm by volume	 Integer Real (2 digits)

Table 2.21.3b – Example of a CO2 file (files with extension CO2)

```
Default atmospheric CO2 concentration from 1902 to 2099
Year     CO2 (ppm by volume)
============================
  1902  297.4
  1905  298.2
  1912  300.7
  1915  301.3
  1924  304.5
  1926  305.0
  1929  305.2
  1932  307.8
  1934  309.2
  1936  307.9
  1938  310.5
  1939  310.1
  1940  310.5
  1944  309.7
  1948  310.7
  1953  311.9
  1954  314.1
  1958  315.29
  1959  315.98
  1960  316.91
  1961  317.65
  1962  318.45
  1963  318.99
  1964  319.61
  1965  320.03
  1966  321.37
  …       …
  …       …
  2008  385.57
  2009  387.35
  2010  389.78
  2011  391.57
  2020  409.57
  2099  567.57
```

AquaCrop uses as default the data from the MaunaLoa.CO2 (stored in the SIMUL subdirectory) which contains the mean annual atmospheric CO_2 concentration measured at Mauna Loa Observatory since 1958. For earlier years, data obtained from firn and ice samples

close to the coast of Antarctica[1] are used, and for future estimates an increase of 2.0 ppm is assumed (following Pieter Hans (NOAA) - personal communication, December 2007).

Several carbon cycle models for projecting atmospheric CO_2 concentrations are available and used by IPCC (Intergovernmental Panel on Climate Change). The various models consider responses of the carbonate chemistry of terrestrial and ocean components. Various simulated atmospheric CO_2 concentrations for various story lines are available in the data base (subdirectory DATA) of AquaCrop (files: A1B.CO2, A2.CO2, B1.CO2, B2.CO2). The presented **A2, A1B, B2 and B1** storylines describes the future world but different due to dissimilarity in the assumed speed of economic growth, the moment of peak and decline of global population, the introduction of new and more efficient technologies, the changes in economic structures toward a service and information economy, etc.

When the effect of a specific [CO_2] on crop production has to be tested for a number of successive years, the content of the CO2 file can be specified as shown in Table 2.21.3b. In the example it is assumed that the specified CO_2 concentration corresponds to 550 ppm. For all years between and even out of the range 2025 – 2100, AquaCrop will assume that the CO_2 concentration remains constant (550 ppm).

Table 2.21.3c – Example of a CO2 file for a constant CO_2 concentration in a specific period (1980-2010)

```
Constant CO2 concentration (550 ppm) for all years in and outside 2025 - 2100
Year     CO2 (ppm by volume)
============================
2025       550
2100       550
```

[1] David Etheridge et al. (1996), J. Geophys. Research vol. 101, 4115-4128

2.21.4 Crop file (*.CRO)

Crop parameters describing its development, evapotranspiration, production (biomass and yield), and its response to soil water, temperature, salinity and fertility stress, are stored in crop files (files with extension CRO). To assure that there is no conflict in the data, and the data is in the correct range, crop files are best created with the user interface. An example of a crop file is given in Table 2.21.4.

Table 2.21.4 – Example of crop file (Default.CRO)

```
a generic crop
     4.0        : AquaCrop Version (June 2012)
     1          : File not protected
     2          : fruit/grain producing crop
     1          : Crop is sown
     1          : Determination of crop cycle : by calendar days
     1          : Soil water depletion factors (p) are adjusted by ETo
     5.5        : Base temperature (°C) below which crop development does not progress
    30.0        : Upper temperature (°C) above which crop development no longer increases with an increase in temperature
    -9          : Total length of crop cycle in growing degree-days
     0.25       : Soil water depletion factor for canopy expansion (p-exp) - Upper threshold
     0.60       : Soil water depletion factor for canopy expansion (p-exp) - Lower threshold
     3.0        : Shape factor for water stress coefficient for canopy expansion (0.0 = straight line)
     0.50       : Soil water depletion fraction for stomatal control (p - sto) - Upper threshold
     3.0        : Shape factor for water stress coefficient for stomatal control (0.0 = straight line)
     0.85       : Soil water depletion factor for canopy senescence (p - sen) - Upper threshold
     3.0        : Shape factor for water stress coefficient for canopy senescence (0.0 = straight line)
     0          : Sum(ETo) during stress period to be exceeded before senescence is triggered
     0.90       : Soil water depletion factor for pollination (p - pol) - Upper threshold
     5          : Vol% for Anaerobiotic point (* (SAT - [vol%]) at which deficient aeration occurs *)
    50          : Considered soil fertility/salinity stress for calibration of stress response (%)
     2.16       : Shape factor for the response of canopy expansion to soil fertility/salinity stress
     0.79       : Shape factor for the response of maximum canopy cover to soil fertility/salinity stress
     1.67       : Shape factor for the response of crop Water Productivity to soil fertility stress
     1.67       : Shape factor for the response of decline of canopy cover to soil fertility/salinity stress
     2.90       : Shape factor for the response of stomatal closure to soil salinity stress
     8          : Minimum air temperature below which pollination starts to fail (cold stress) (°C)
    40          : Maximum air temperature above which pollination starts to fail (heat stress) (°C)
    11.1        : Minimum growing degrees required for full biomass production (°C - day)
     2          : Electrical Conductivity of soil saturation extract at which crop starts to be affected by soil salinity (dS/m)
    12          : Electrical Conductivity of soil saturation extract at which crop can no longer grow (dS/m)
     0          : Shape factor for soil salinity stress coefficient (0 : linear response)
     1.10       : Crop coefficient when canopy is complete but prior to senescence (KcTr,x)
     0.150      : Decline of crop coefficient (%/day) as a result of ageing, nitrogen deficiency, etc.
     0.30       : Minimum effective rooting depth (m)
     1.00       : Maximum effective rooting depth (m)
```

Table 2.21.4 – Example of crop file … *continued*

```
    15          : Shape factor describing root zone expansion
     0.024      : Maximum root water extraction (m3water/m3soil.day) in top quarter of root zone
     0.006      : Maximum root water extraction (m3water/m3soil.day) in bottom quarter of root zone
    50          : Effect of canopy cover in reducing soil evaporation in late season stage
```

```
     6.50      : Soil surface covered by an individual seedling at 90 % emergence (cm2)
   185000      : Number of plants per hectare
     0.15000   : Canopy growth coefficient (CGC): Increase in canopy cover (fraction soil cover per day)
    -9         : Maximum decrease of Canopy Growth Coefficient in and between seasons - Not Applicable
    -9         : Number of seasons at which maximum decrease of Canopy Growth Coefficient is reached - Not Applicable
    -9.0       : Shape factor for decrease Canopy Growth Coefficient - Not Applicable
     0.80      : Maximum canopy cover (CCx) in fraction soil cover
     0.12750   : Canopy decline coefficient (CDC): Decrease in canopy cover (in fraction per day)
     5         : Calendar Days: from sowing to emergence
   100         : Calendar Days: from sowing to maximum rooting depth
   110         : Calendar Days: from sowing to start senescence
   125         : Calendar Days: from sowing to maturity (length of crop cycle)
    70         : Calendar Days: from sowing to flowering
    10         : Length of the flowering stage (days)
     1         : Crop determinancy linked with flowering
    50         : Excess of potential fruits (%)
    50         : Building up of Harvest Index starting at flowering (days)
    17.0       : Water Productivity normalized for ETo and CO2 (WP*) (gram/m2)
   100         : Water Productivity normalized for ETo and CO2 during yield formation (as % WP*)
    50         : Crop performance under elevated atmospheric CO2 concentration (%)
    50         : Reference Harvest Index (HIo) (%)
     5         : Possible increase (%) of HI due to water stress before flowering
    10.0       : Coefficient describing positive impact on HI of restricted vegetative growth during yield formation
     8.0       : Coefficient describing negative impact on HI of stomatal closure during yield formation
    15         : Allowable maximum increase (%) of specified HI
    -9         : GDDays: from sowing to emergence
    -9         : GDDays: from sowing to maximum rooting depth
    -9         : GDDays: from sowing to start senescence
    -9         : GDDays: from sowing to maturity (length of crop cycle)
    -9         : GDDays: from sowing to flowering
    -9         : Length of the flowering stage (growing degree days)
    -9.000000  : CGC for GGDays: Increase in canopy cover (in fraction soil cover per growing-degree day)
    -9.000000  : CDC for GGDays: Decrease in canopy cover (in fraction per growing-degree day)
    -9         : GDDays: building-up of Harvest Index during yield formation
```

2.21.5 Irrigation file (*.IRR)

The irrigation method, the percentage of the soil surface wetted by the irrigation, and (i) the timing, net application depth and water quality of the irrigation events or (ii) rules to generate irrigation events, or (iii) rules to determine net irrigation requirement, are specified in an irrigation file (files with extension IRR). Various irrigation modes are considered in AquaCrop:

(i) specification of irrigation events (example Tab. 2.21.5c);
(ii) generation of an irrigation schedule (example Tab. 2.21.5d);
(iii) determination of net irrigation water requirement (example Tab. 2.21.5e).

Each mode requires particular data that need to be specified (Table 2.21.5a).

In the absence of an irrigation file, rainfed cropping is assumed when running a simulation.

Table 2.21.5a – Structure of the irrigation file (files with extension IRR)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	A number (1 to 5) used as a code to specify the irrigation method: 1 : Sprinkler irrigation 2 : Surface irrigation: Basin 3 : Surface irrigation: Border 4 : Surface irrigation: Furrow 5 : Drip irrigation Default = 1	Integer
4	Percentage of soil surface wetted by irrigation. This percentage is generally closely linked with the irrigation method. Indicative values for the percentage of soil surface wetted for various irrigation methods are presented in Table 2.21.5b. Default = 100	Integer
5	A number (1 to 3) used as a code to specify the irrigation mode: 1 : Specification of irrigation events; 2 : Generation of an irrigation schedule; 3 : Determination of net irrigation water requirement;	Integer
	Code = 1 (in line 5): Specification of irrigation events (Example Table 2.21.5c)	
6	Empty line	-
7	Title ('Day Depth (mm) ECw (dS/m)')	String of characters
8	Dotted line ('==========')	String of characters
9	For the 1st irrigation event: – The number of days after sowing/planting – The net irrigation application depth (mm) – The Electrical Conductivity (dS/m) of the irrigation water The net irrigation application depth refers to the net	 Integer Integer Real (1 digit)

	irrigation amount. Extra water applied to the field to account for conveyance losses or the uneven distribution of irrigation water on the field should not be added.	
10..	Repeat for each successive irrigation event	
	Code = 2 (in line 5): Generation of an irrigation schedule (Example Table 2.21.5d)	
6	A number (1 to 3) used as a code to specify the time criterion: 1 : Fixed interval; 2 : Allowable depletion (mm water); 3 : Allowable depletion (% of RAW).	Integer
7	A number (1 to 2) used as a code to specify the depth criterion: 1 : Back to Field Capacity; 2 : Fixed net application depth.	Integer
8	Empty line	-
9	Title ('From day … ECw (dS/m)')	String of characters
10	Dotted line ('==========')	String of characters
11	For the 1st rule: – The number of days after sowing/planting from which the rule is valid (has to be 1 for the 1st rule); – Value linked with the time criterion: o the fixed interval (days) between irrigations (for example 10 days); o the amount of water (mm) that can be depleted from the root zone (the reference is soil water content at field capacity) before an irrigation has to be applied (for example 30 mm); or o the percentage of RAW that can be depleted before irrigation water has to be applied (for example 100 %). – Value linked with the depth criterion: o Extra water on top of the amount of irrigation water required to bring the root zone back to Field Capacity. The specified value can be zero (exact back to FC), positive (an over-irrigation) or negative (an under-irrigation); or o The fixed net irrigation application depth. – The Electrical Conductivity (dS/m) of the irrigation water. The fixed net irrigation application depth refers to the net irrigation amount. Extra water applied to the field to account for conveyance losses or the uneven distribution of irrigation water on the field should not be added. The values specified remain valid till the date for which a new rule (in the next line) is specified or to the end of the	Integer Integer Integer Real (1 digit)

	cropping period when no values at later dates are specified	
12..	If applicable specifies values for 2nd , 3rd , 4th , .. rule	
	Code = 3 (in line 5): Determination of net irrigation requirement. (Example Table 2.21.5e)	
6	The depletion (% RAW) below which the soil water content in the root zone may not drop (0 % RAW corresponds to Field Capacity). The total amount of irrigation water required to keep the water content in the soil profile above the specified threshold is the net irrigation water requirement for the period. The net requirement does not consider extra water that has to be applied to the field to account for conveyance losses or the uneven distribution of irrigation water on the field.	Integer

Table 2.21.5b – Indicative values for soil surface wetted for various irrigation methods

Irrigation method	Soil surface wetted (%)
Sprinkler irrigation	100
Basin irrigation	100
Border irrigation	100
Furrow irrigation (every furrow), narrow bed	60 – 100
Furrow irrigation (every furrow), wide bed	40 – 60
Furrow irrigation (alternated furrows)	30 – 50
Trickle/Drip - Micro irrigation	15 – 40
Subsurface drip irrigation	0

Table 2.21.5c – Example of an irrigation file (file with extension IRR) in which irrigation events of an irrigation schedule are specified

```
Given irrigation schedule
   4.0   : AquaCrop Version (June 2012)
   1     : Sprinkler irrigation
 100     : Percentage of soil surface wetted by irrigation
   1     : Irrigation schedule

   Day    Depth (mm)   ECw (dS/m)
====================================
    10        50          1.0
    20        50          1.0
    30        50          1.0
    40        50          1.2
    50        50          1.4
    60        50          1.6
    80        50          1.8
```

Table 2.21.5d – Example of an irrigation file (file with extension IRR) in which rules for the generation of an irrigation schedule are specified

```
Generation of irrigation schedule
   4.0   : AquaCrop Version (June 2012)
   1     : Sprinkler irrigation
 100     : Percentage of soil surface wetted by irrigation
   2     : Generate irrigation schedule
   1     : Time criterion = fixed intervals
   2     : Fixed application depth

  From day    Interval (days)    Application depth (mm)    ECw (dS/m)
=========================================================================
       1             40                   40                   0.4
      41              7                   40                   0.6
     116            100                   40                   0.8
```

Generated irrigation schedules as defined in above Table:

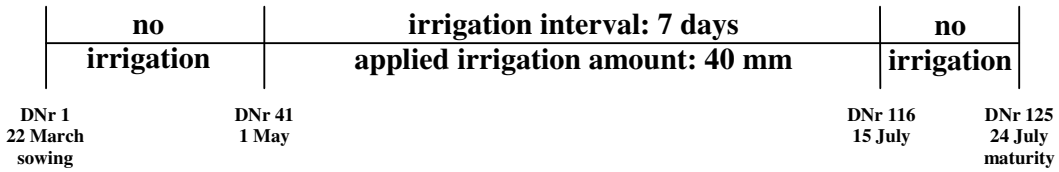


Table 2.21.5.e – Example of an irrigation file (file with extension IRR) in which the request for the determination of the Net irrigation water requirement is specified

```
Determination of Net irrigation requirement
   4.0   : AquaCrop Version (June 2012)
   1     : Sprinkler irrigation
 100     : Percentage of soil surface wetted by irrigation
   3     : Determination of Net Irrigation requirement
  50     : Allowable depletion of RAW (%)
```

2.21.6 Field management file (*.MAN)

The type of mulches and the fraction of soil surface covered by the mulches, the soil fertility level and practices that affect the surface run-off (soil bunds and field surface practices) are specified in the field management file (files with extension MAN). The content of the field management file is given in Table 2.21.6a, and an example in Table 2.21.6c.

In the absence of a field management file, no specific field management conditions are considered. It is assumed that soil fertility is unlimited, and that field surface practices do not affect soil evaporation or surface run-off

Table 2.21.6a – Structure of the field management file (files with extension 'MAN')

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	Percentage (%) of ground surface covered by mulches in the growing period	Integer
4	Effect (%) of mulches on the reduction of soil evaporation, which depends on the type of mulches (see Table 2.21.6b)	Integer
5	Degree of soil fertility stress (%) The effect of the selected soil fertility stress on crop production depends on calibration since the biomass – stress relationship (calibrated in the ***Crop characteristic*** menu), determines the corresponding biomass production that can be expected under well watered conditions for the selected soil fertility stress (Fig. 2.21.6). The expected biomass production is expressed as a percentage of the maximum biomass production for unlimited soil fertility. In the absence of a calibration, the adjustment of biomass production to the specified soil fertility stress will not be simulated.	Integer
6	Height (m) of soil bunds	Real (2 digits)
7	A number (0 to 1) used as a code to specify if surface runoff is prevented by field surface practices: 0 : surface runoff is not prevented 1 : prevention of surface runoff (Default = 0)	Integer

Table 2.21.6b – Effect of mulches on the reduction of soil evaporation

Type of mulches	Effect on reduction of soil evaporation
Synthetic plastic mulches (completely reducing the evaporation of water from the soil surface)	100 %
Organic mulches, which consists of unincorporated plant residues or foreign material imported to the field such as a straw	50 %
User specified mulches	10 … 100 %

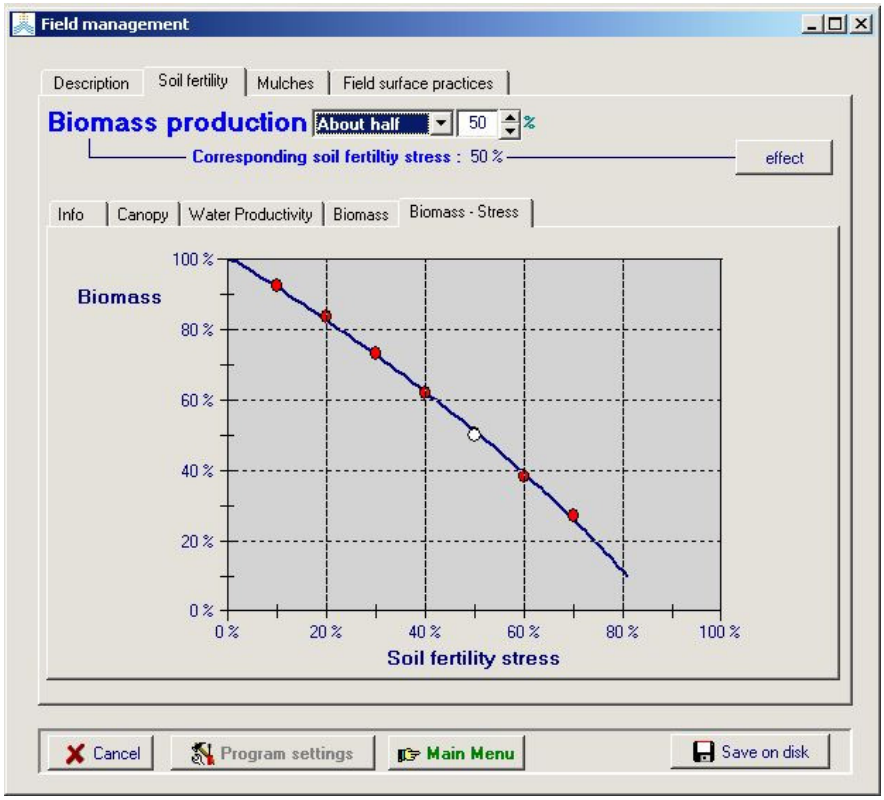


Figure 2.21.6 – Display of the calibrated Biomass - stress relationship in the *Field management* menu

Table 2.21.6c – Example of field management file

```
Moderate soil fertility, organic mulches and practices affecting runoff
 4.0  : AquaCrop Version (June 2012)
80    : percentage (%) of ground surface covered by mulches
50    : effect (%) of mulches on reduction of soil evaporation
41    : Degree of soil fertility stress (%) - Effect is crop specific
 0.00 : height (m) of soil bunds
 1    : surface runoff prevented by field surface practices
```

2.21.7 Soil profile file (*.SOL)

Major physical characteristics of the successive soil horizons of the soil profile are specified in a soil profile file (files with extension 'SOL'). Up to 5 soil horizons can be specified.

Structure and Example of SOL files

The structure and an example of a SOL file are given in Tables 2.21.7a and 2.21.7b.

Table 2.21.7a – Structure of the Soil profile file (files with extension SOL)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	CN: the Curve Number (dimensionless)	Integer
4	REW: The Readily evaporable water from top layer (mm)	Integer
5	Number of soil horizons	Integer
6	Depth (m) of restrictive soil layer inhibiting root zone expansion	Real (2 digits) - 9.00 if none
7	Line with symbols for the soil physical characteristics	
8	Line with units for the soil physical characteristics	
9	Soil physical characteristics for soil horizon 1: - thickness of the soil horizon (m) - soil water content at saturation (vol%) - soil water content at Field Capacity (vol%) - soil water content at Permanent Wilting Point (vol%) - saturated hydraulic conductivity (mm/day) - parameter 'a' for estimation of capillary rise - parameter 'b' for estimation of capillary rise - description	 Real (2 digits) Real (1 digit) Real (1 digit) Real (1 digit) Real (1 digit) Real (6 digits) Real (6 digits) String of characters
10	Soil physical characteristics for soil horizon 2 (if present)	as for line 9
11	Soil physical characteristics for soil horizon 3 (if present)	as for line 9
12	Soil physical characteristics for soil horizon 4 (if present)	as for line 9
13	Soil physical characteristics for soil horizon 5 (if present)	as for line 9

Table 2.21.7b – Example of soil profile file with 3 horizons

```
Three layered loamy soil
 4.0      : AquaCrop Version (June 2012)
65        : CN (Curve Number)
 7        : Readily evaporable water from top layer (mm)
 3        : number of soil horizons
-9.00     : Depth (m) of restrictive soil layer inhibiting root zone expansion - None
  Thickness  Sat   FC    WP     Ksat       CRa       CRb           description
  ---(m)-   ----(vol %)-----  (mm/day)  ------------------------------------------------
    0.30    41.0  22.0  10.0   500.0    -0.316200  0.007849        sandy loam
    0.50    46.0  31.0  15.0   250.0    -0.476100  0.506154             loam
    2.00    46.0  33.0  13.0   150.0    -0.485100  0.262082         silt loam
```

Guidelines for determining the required soil physical characteristics

- **Soil water content (volume %)**
  - SAT: Soil water content (vol%) at saturation. When the total pore volume is filled with water, the soil water content is at saturation;
  - FC: Soil water content (vol%) at field capacity is the quantity of water that a well-drained soil layer would hold against the gravitational forces; The soil water content at the drained upper limit (DUL) is similar to the soil water content at Field Capacity;
  - PWP: Soil water content (vol%) at permanent wilting point is the soil water content at which plants stop extracting water and will permanently wilt. The soil water content at the drained lower limit (DLL) is similar to the soil water content at Permanent Wilting Point;

The soil water contents (SAT, FC or DLL, and PWP or DUL) for each of the soil horizons are given as input or can be derived from soil texture (see e.g. equations in the Hydraulic Properties Calculator: http://hydrolab.arsusda.gov/soilwater/Index.htm). If only the soil texture class is available, default values in Table 2.21.7c can be used.

Table 2.21.7c –Default values for the saturated hydraulic conductivity (Ksat) and the soil water content at saturation (SAT), field capacity (FC), permanent wilting point (PWP), and at the drained upper (DUL) and lower (DLL) limit for various soil texture classes.

Soil textural class	Soil water content			Saturated hydraulic conductivity Ksat
	SAT	FC (DUL)	PWP (DLL)	
	vol %			mm/day
Sand	36	13	6	1500
Loamy sand	38	16	8	800
Sandy loam	41	22	10	500
Loam	46	31	15	250
Silt loam	46	33	13	150
Silt	43	33	9	50
Sandy clay loam	47	32	20	125
Clay loam	50	39	23	100
Silty clay loam	52	44	23	120
Sandy clay	50	39	27	75
Silty clay	54	50	32	15
Clay	55	54	39	2

The total porosity (assumed to be similar to the soil water content at saturation SAT) can also be derived from the soil bulk density of the soil horizon:

$$SAT = 100\frac{(\rho_p - \rho_b)}{\rho_p} \qquad \text{(Eq. 2.21.7a)}$$

where SAT soil water content at saturation [vol%]
ρ_p particle density [2.65 Mg/m^3]
ρ_b bulk density of the soil [Mg/m^3]

- **Saturated hydraulic conductivity (mm/day)**

The hydraulic conductivity expresses the property of the soil horizon to conduct water through a soil. It is given as input or can be derived from soil texture (see e.g. equations in the Hydraulic Properties Calculator: http://hydrolab.arsusda.gov/soilwater/Index.htm). If only the soil texture class is available, default values in Table 2.21.7c can be used.

If values for the soil water content at SAT, FC and PWP are available derive (i) first the soil class from Table 2.21.7e, and use the default values of Table 2.21.7d.

Table 2.21.7d – Default saturated hydraulic conductivity (Ksat) for each of the 4 soil classes determined in Tab. 2.21.7e.

Soil class number	Description	Default Ksat [mm/day]
I	Sandy soil	1500
II	Loamy soil	250
III	Sandy Clayey soil	75
IV	Silty clayey soil	15

- **'a' and 'b' parameters for estimating capillary rise**

The maximum possible capillary rise for each soil horizon is calculated with an exponential equation. The default 'a' and 'b' parameters, describing the capillary rise, are obtained by (i) considering the class of the soil type and (ii) the saturated hydraulic conductivity:

1. The class of the soil type for each of the soil horizons is obtained by comparing the volumetric water content at saturation (SAT), field capacity (FC) and permanent wilting point (PWP) of the soil horizon with the expected ranges of those soil water contents (Table 2.21.7e). Four classes are distinguished: I. sandy soils; II. Loamy soils; III Sandy clayey soils; and IV Silty clayey soils;
2. The a and b soil parameters for each soil horizon are obtained with Eq. 2a and 2b by considering (i) the soil class of the soil horizon and (ii) the saturated hydraulic conductivity (Ksat in mm/day) for that soil horizon (Table 2.21.7f and 2.21.7g).

Table 2.21.7e – Calculation procedure for the soil class

```
IF (SATvolPro <= 55)
   THEN BEGIN
        IF (PWPvolPro >= 20)
           THEN BEGIN
                IF ((SATvolPro >= 49) AND (FCvolPro >= 40))
                   THEN NumberSoilClass := 4  // silty clayey soils
                   ELSE NumberSoilClass := 3  // sandy clayey soils
                END
           ELSE BEGIN
                IF (FCvolPro < 23)
                   THEN NumberSoilClass := 1 // sandy soils
                   ELSE BEGIN
                        IF ((PWPvolPro > 16) AND (Ksatmm < 100))
                           THEN NumberSoilClass := 3 // sandy clayey soils
                           ELSE BEGIN
                                IF ((PWPvolPro < 6) AND (FCvolPro < 28)
                                   AND (Ksatmm >750))
                                   THEN NumberSoilClass := 1 // sandy soils
                                   ELSE NumberSoilClass := 2  // loamy soils
                                END;
                        END;
                END;
        END
   ELSE NumberSoilClass := 4; // silty clayey soils
```

Table 2.21.7f – Equation 2a and 2b for the 4 soil Classes with indication of the considered range for the saturated hydraulic conductivity (K_{sat})

Soil Class	Range K_{sat} $mm.day^{-1}$	a (Eq. 2a)	b (Eq. 2b)
I. Sandy soils sand, loamy sand, sandy loam	200 to 2000	$-0.3112 - 10^{-5} K_{sat}$	$-1.4936 + 0.2416 \ln(K_{sat})$
II. Loamy soils loam, silt loam, silt	100 to 750	$-0.4986 + 9 (10^{-5}) K_{sat}$	$-2.1320 + 0.4778 \ln(K_{sat})$
III. Sandy clayey soils sandy clay, sandy clay loam, clay loam	5 to 150	$-0.5677 - 4 (10^{-5}) K_{sat}$	$-3.7189 + 0.5922 \ln(K_{sat})$
IV. Silty clayey soils silty clay loam, silty clay, clay	1 to 150	$-0.6366 + 8 (10^{-4}) K_{sat}$	$-1.9165 + 0.7063 \ln(K_{sat})$

Table 2.21.7g – Calculation procedure for 'a' and 'b' parameters for the 4 soil classes

```
CASE SoilClass OF
        1 : BEGIN  // sandy soils
            aParam := -0.3112 - KsatMM/100000;
            bParam := -1.4936 + 0.2416*LN(KsatMM);
            END;
        2 : BEGIN // loamy soils
            aParam := -0.4986 + 9*KsatMM/100000;
            bParam := -2.1320 + 0.4778*LN(KsatMM);
            END;
        3 : BEGIN // sandy clayey soils
            aParam := -0.5677 - 4*KsatMM/100000;
            bParam := -3.7189 + 0.5922*LN(KsatMM);
            END;
       else BEGIN // silty clayey soils
            aParam := -0.6366 + 8*KsatMM/10000;
            bParam := -1.9165 + 0.7063*LN(KsatMM);
            END;
       end;
```

Guidelines for determining the characteristics of the soil surface layer

- **CN: Curve number (dimensionless)**

The Curve Number (CN) is required for the simulation of the surface runoff and its value refers to the value for antecedent moisture class II (AMC II).

The Curve Number of a soil is a function of its type, slope, land use, cover and the relative wetness of the top soil. If not given as input it can be derived from the saturated hydraulic conductivity (Ksat) of the top soil horizon (Tab. 2.21.7h and 2.21.7i).

Table 2.21.7h – Default CN values for various saturated hydraulic conductivities of the top soil horizon

Saturated hydraulic conductivity (K_{sat}) mm/day	CN default value for AMC II
> 250	65
250 – 50	75
50 – 10	80
< 10	85

Table 2.21.7i – Calculation procedure for CN

```
IF (KsatMM >= 250)
   THEN CN2 := 65
   ELSE IF (KsatMM >= 50)
            THEN CN2 := 75
            ELSE IF (KsatMM >= 10)
                     THEN CN2 := 80
                     ELSE CN2 := 85;
```

- **REW: Readily Evaporable Water (mm)**

REW expresses the maximum amount of water (mm) that can be extracted by soil evaporation from a thinly soil surface layer in stage I.

REW is derived from the soil water content at Field Capacity (FC) and Permanent Wilting Point (PWP) of the top soil horizon (both expressed as volume %):

$$0 \leq REW = 10\,(FC - PWP/2)\,Z_{e,surf} \leq 15 \qquad \text{(Eq. 2.21.7c)}$$

where FC volume water content at field capacity [vol%];
PWP volume water content at permanent wilting point [vol%];
$Z_{e,surf}$ thickness of the evaporating soil surface layer in direct contact with the atmosphere [0.040 m].

The calculation procedure is presented in Table 2.21.7j.

Table 2.21.7j – Calculation procedure for REW

```
CONST Zsurflayer = 0.04; // meter

REW := ROUND(10 * (FC-(PWP/2)) * Zsurflayer);
IF (REW < 0) THEN REW := 0;    // minimum value
IF (REW > 15) THEN REW := 15;  // maximum value
```

2.21.8 Groundwater file (*.GWT)

Characteristics of the groundwater table are specified in the groundwater file (files with extension GWT). The considered characteristics of the groundwater table are (i) its depth below the soil surface and (2) its salinity. The characteristics can be constant or vary throughout the year. The description of the content and examples are given in Table 2.21.8a to 2.21.8d.

In the absence of a groundwater file, no shallow groundwater table is assumed when running a simulation.

Table 2.21.8a – Structure of the Groundwater file (files with extension GWT)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	A number (0, 1 or 2) used as a code to specify the presence and its variation in time of the groundwater table: 0: code indicating that there is no groundwater table; 1: code indicating that the characteristics are constant 2: code indicating that the characteristics are variable	Integer
	Code = 0 (in line 3): No groundwater table no further lines are required (Example Table 2.21.8b)	
	Code = 1 (in line 3): Groundwater table at fixed depth and with constant salinity 4 extra lines are required (Example Table 2.21.8c)	
4	Empty line	-
5	Title of variables (‘`Day  Depth (m)  ECw (dS/m)`’)	String of characters
6	Dotted line (‘`==========`’)	String of characters
7	– The day number from which the characteristics of the groundwater table are valid (has to be from the first day since the characteristics are constant); – The depth (m) of the groundwater table below the soil surface; – The salinity of the groundwater table expressed by the electrical conductivity of the water (ECw) in deciSiemens per meter (dS/m).	Integer Real (2 digits) Real (1 digit)
	Code = 2 (in line 3): Variable groundwater table extra lines are required (Example Table 2.21.8d)	
4	first day of observations	Integer
5	first month of observations	Integer
6	first year of observations (1901 if the characteristics are not linked to a specific year)	Integer
7	Empty line	-
8	Title of variables (‘`Day  Depth (m)  ECw (dS/m)`’)	String of characters
9	Dotted line (‘`==========`’)	String of characters
10	Specify for the first observation:	Integer

	– The day number from which the characteristics of the groundwater table are valid (with reference to the date specified in line 4 (DD), 5 (MM) and 6 (YYYY)); – The depth (m) of the groundwater table below the soil surface; – The salinity of the groundwater table expressed by the electrical conductivity of the water (ECw) in deciSiemens per meter (dS/m).	Real (2 digits) Real (1 digit)
11	Specify for the next observation: – The day number; – The depth (m); – The salinity (dS/m).	Integer Real (2 digits) Real (1 digit)
12..	Etc.	

In a groundwater file, the user can specify explicitly that there is no groundwater table or too deep to result in capillary rise to the top soil (as in the example presented in Table 2.21.8b). However, there is no need to create such a file, since in the absence of a groundwater file, AquaCrop will ignore the effect of the groundwater table when running a simulation.

Table 2.21.8b – Example of No groundwater table

```
no shallow groundwater table
     4.0   : AquaCrop Version (June 2012)
     0     : no groundwater table
```

Table 2.21.8c – Example of a groundwater table at fixed depth and with constant salinity

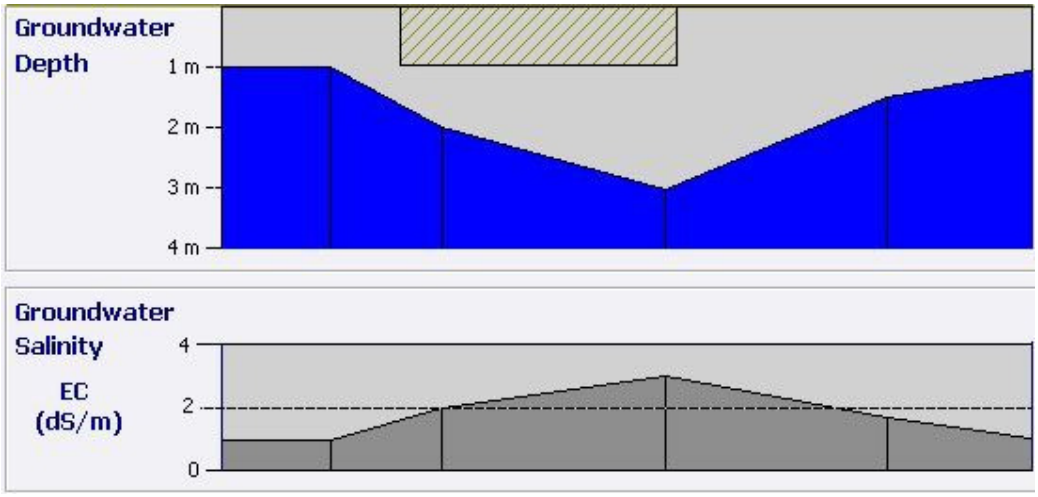
```
constant groundwater table at 1.50 m and with salinity level of 1.5 dS/m
     4.0   : AquaCrop Version (March 2012)
     1     : groundwater table at fixed depth and with constant salinity

   Day    Depth (m)    ECw (dS/m)
=====================================
     1      1.50          1.5
```

Table 2.21.8d – Example of a ground water table with variable depth and/or variable soil salinity

```
variable groundwater table for year 2000
     4.0   : AquaCrop Version (March 2012)
     2     : variable groundwater table
     1     : first day of observations
     1     : first month of observations
  2000     : first year of observations (1901 if not linked to a specific year)

   Day     Depth (m)     ECw (dS/m)
=====================================
    50       1.00           1.0
   100       2.00           2.0
   200       3.00           3.0
   300       1.50           1.7
   400       0.80           0.7
   500       1.50           0.5
```



The characteristics of the groundwater table for days between specified day numbers will be obtained at run time by means of linear interpolation.

2.21.9 File with initial conditions (*.SW0)

The soil water content and soil salinity in the soil profile at the start of the simulation run are specified in the files with the initial conditions (files with extension SW0). If the field is surrounded by soil bunds the depth of the water layer on top of the soil surface and its water quality at the start of the simulation run are specified as well in the SW0 file. The soil salinity is given by the Electrical Conductivity of the saturated soil-paste extract (ECe). The quality of the water between the soil bunds is given by its Electrical Conductivity (ECw). Both ECe and ECw are expressed in dS/m. The structure and examples of SW0 files are given in Table 2.21.9a to 2.21.9d.

In the absence of a file with initial conditions, it is assumed that in the soil profile (i) the soil water content is at field capacity and (ii) salts are absent at the start of the simulation.

Table 2.21.9a – Structure of the file with initial conditions (files with extension SW0)

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	Water layer (mm) stored between soil bunds (if present)	Real (1 digit)
4	Electrical conductivity (dS/m) of water layer stored between soil bunds (if present)	Real (2 digits)
5	A number (0 or 1) used as a code to specify if the initial conditions are specified for specific layers, or at particular depths of the soil profile: 0: code indicating that the data are specified for specific layers (Example Table 2.21.9b and 2.21.9c); 1: code indicating that the data are specified at particular depths of the soil profile (Example Table 2.21.9d).	Integer
6	Number of different layers/depth considered (Maximum = 12)	Integer
7	Empty line	-
8	Title (list of parameters)	String of characters
9	Dotted line ('==========')	String of characters
	Code = 0 (in line 5): For specific soil layers (Example Table 2.21.9b and 2.21.9c)	
10	For the 1st soil layer: – Thickness of the soil layer in meter – Soil water content in volume % – Soil salinity (ECe) in dS/m	 Real (2 digits) Real (2 digits) Real (2 digits)
11 ..	Repeat for each soil layer	
	Code = 1 (in line 5): At particular soil depths (Example Table 2.21.9d)	
10	At the 1st soil depth: – Soil depth in meter – Soil water content in volume % – Soil salinity (ECe) in dS/m	 Real (2 digits) Real (2 digits) Real (2 digits)
11 ..	Repeat for each soil depth	

Table 2.21.9b – Example of initial conditions specified for specific soil layers

```
initial conditions for specific layers in Field AZ123 on 21 March 2010
    4.0    : AquaCrop Version (June 2012)
    0.0    : water layer (mm) stored between soil bunds (if present)
    0.00   : electrical conductivity (dS/m) of water layer between bunds
    0      : soil water content specified for specific layers
    3      : number of layers considered

Thickness layer (m)     Water content (vol%)     ECe(dS/m)
============================================================
         0.40                  30.00                 1.00
         0.40                  20.00                 2.00
         0.40                  18.00                 2.50
```

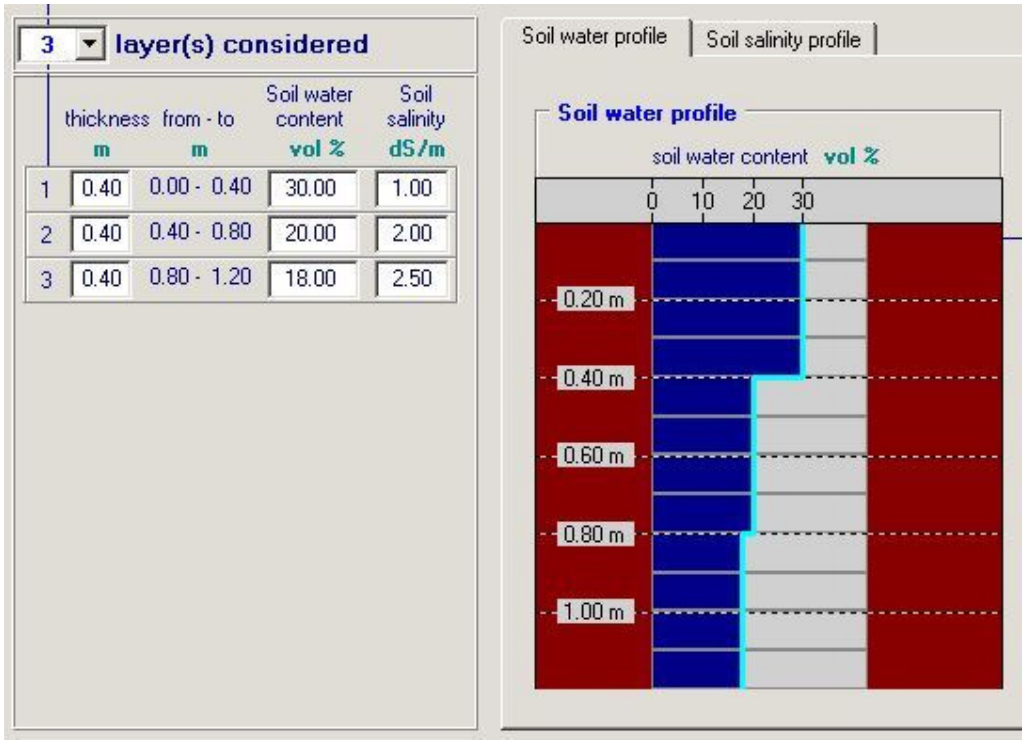


Table 2.21.9c – Example for water stored between bunds

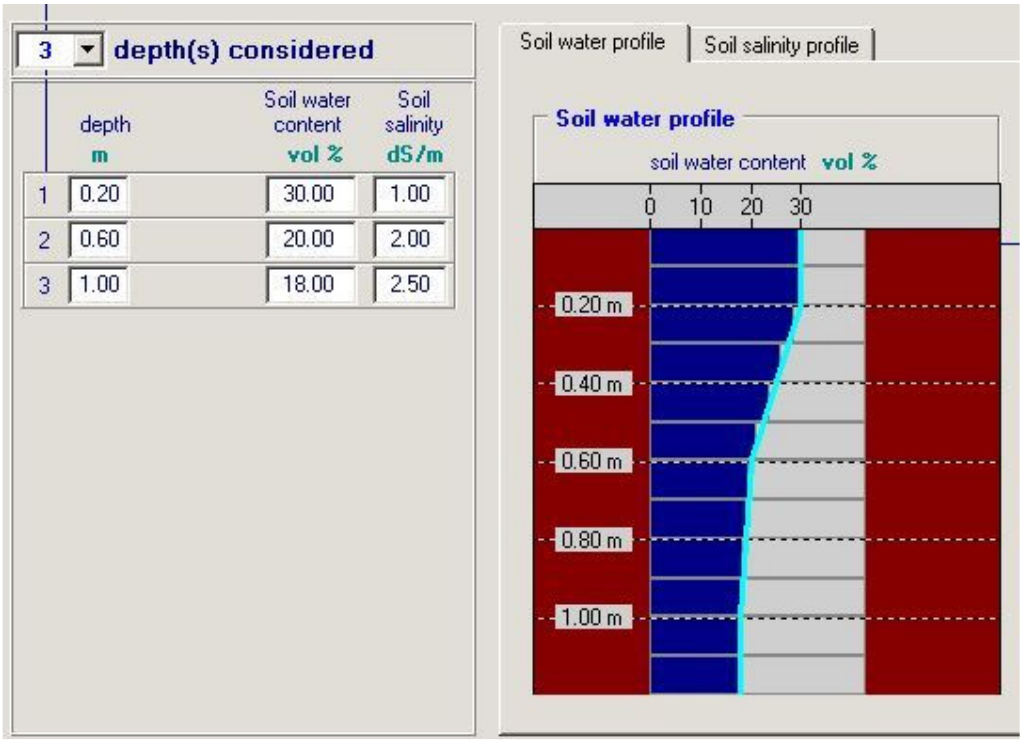
```
Uniform silty soil at Field capacity with soil bunds
    4.0   : AquaCrop Version (June 2012)
  150.0   : water layer (mm) stored between soil bunds (if present)
    0.00  : electrical conductivity (dS/m) of water layer between bunds
    0     : soil water content specified for specific layers
    1     : number of layers considered

Thickness layer (m)     Water content (vol%)     ECe(dS/m)
============================================================
         4.00                 33.00                  0.00
```

Table 2.21.9d – Example of initial conditions specified at particular soil depths

```
initial conditions at particular depths in Field AZ123 on 21 March 2010
    4.0   : AquaCrop Version (June 2012)
    0.0   : water layer (mm) stored between soil bunds (if present)
    0.00  : electrical conductivity (dS/m) of water layer between bunds
    1     : soil water content specified at particular depths
    3     : number of soil depths considered

     Soil depth (m)     Water content (vol%)     ECe (dS/m)
============================================================
         0.20                 30.00                  1.00
         0.60                 20.00                  2.00
         1.00                 18.00                  2.50
```



2.21.10 File with off-season conditions (*.OFF)

A file with off-season conditions (Tab. 2.21.10a and 2.21.10d) contains field management (the presence of mulches) and irrigation management conditions (irrigation events and the quality of the irrigation water) in the off-season (i.e. before and after the growing cycle).

In the absence of a file with off-season conditions, no mulches and irrigation events are considered before and after the growing cycle.

Table 2.21.10a – Structure of the file with off-season conditions

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	Percentage (%) of ground surface covered by mulches before the growing period	Integer
4	Percentage (%) of ground surface covered by mulches after the growing period	Integer
5	Effect (%) of mulches on the reduction of soil evaporation, which depends on the type of mulches (see Table 2.21.10b)	Integer
6	Number of irrigation events before the growing period (Maximum = 5)	Integer
7	The Electrical Conductivity (dS/m) of the irrigation water before the growing period	Real (1 digit)
8	Number of irrigation events after the growing period (Maximum = 5)	Integer
9	The Electrical Conductivity (dS/m) of the irrigation water after the growing period	Real (1 digit)
10	Percentage of soil surface wetted by irrigation in the off-season. This percentage is generally closely linked with the irrigation method. Indicative values for the percentage of soil surface wetted for various irrigation methods are presented in Table 2.21.10c. Default = 100	Integer
11	Empty line	-
12	Title ('Day Depth(mm) When')	String of characters
13	Dotted line ('==========')	String of characters
14 and next	For the 1st irrigation event (if any) before the growing period: - The number of days after the start of the simulation period - The net irrigation application depth (mm) - String of characters stating that the event occurred before the growing period Repeat for each successive irrigation event before the growing period (if any)	 Integer Integer String of characters

	For the 1st irrigation event (if any) after the growing period: - The number of days after the end of the growing period - The net irrigation application depth (mm) - String of characters stating that the event occurred after the growing period Repeat for each successive irrigation event after the growing period (if any) The net irrigation application depth refers to the net irrigation amount. Extra water applied to the field to account for conveyance losses or the uneven distribution of irrigation water on the field should not be added.	Integer Integer String of characters

Table 2.21.10b – Effect of mulches on the reduction of soil evaporation

Type of mulches	Effect on reduction of soil evaporation
Synthetic plastic mulches (completely reducing the evaporation of water from the soil surface)	100 %
Organic mulches, which consists of unincorporated plant residues or foreign material imported to the field such as a straw	50 %
User specified mulches	10 … 100 %

Table 2.21.10c – Indicative values for soil surface wetted for various irrigation methods

Irrigation method	Soil surface wetted (%)
Sprinkler irrigation	100
Basin irrigation	100
Border irrigation	100
Furrow irrigation (every furrow), narrow bed	60 – 100
Furrow irrigation (every furrow), wide bed	40 – 60
Furrow irrigation (alternated furrows)	30 – 50
Trickle/Drip - Micro irrigation	15 – 40
Subsurface drip irrigation	0

Table 2.21.10d – Example of a file with off-season conditions

```
Field and irrigation management conditions in the off-season
     4.0       : AquaCrop Version (June 2012)
     0         : percentage (%) of ground surface covered by mulches BEFORE growing period
    70         : percentage (%) of ground surface covered by mulches AFTER growing period
    50         : effect (%) of mulches on reduction of soil evaporation
     1         : number of irrigation events BEFORE growing period
     1.5       : quality of irrigation water BEFORE growing period (dS/m)
     0         : number of irrigation events AFTER growing period
     3.0       : quality of irrigation water AFTER growing period (dS/m)
   100         : percentage (%) of soil surface wetted by off-season irrigation

   Day    Depth(mm)    When
   ================================
    10        40       before season
```

2.21.11 Single and Multiple run Project files (*.PRO and *.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).

Structure and Examples of Project files (extension 'PRO' or 'PRM')

A project file contains (Table 2.21.11a):

- 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).

Table 2.21.11a – 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 2.21.11e 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

Table 2.21.11a – Structure and example of project file … *continued*

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\`

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 …)*
…. …. …. ….

In the absence of climate, irrigation management, field management, groundwater, initial and off-season conditions files, the default settings are assumed when running the simulation (Tab. 2.21.11b).

Table 2.21.11b – Default settings assumed at the start of a simulation in the absence of climate, irrigation management, field management, groundwater, initial and/or off-season conditions file

Environment	**File**	**Remarks**
Climate	(None)	A default minimum and maximum air temperature (see Climate), an ETo of 5 mm/day, no rainfall and an average atmospheric CO_2 concentration of 369.47 ppm are assumed throughout the growing cycle. When running a simulation without a climate file, the user has still the option to specify other than the default ETo and rainfall data. This climatic data can be specified for each day of the simulation period in the Input panel of the ***Simulation run*** menu
Irrigation management	(None)	Rainfed cropping is assumed. When running a simulation in this mode, irrigation can still be scheduled. The quality of the irrigation water and the irrigation application amount can be specified for each day of the simulation period in the Input panel of the ***Simulation run*** menu
Field management	(None)	No specific field management conditions are considered. It is assumed that soil fertility is unlimited, and that field surface practices do not affect soil evaporation or surface run-off
Groundwater	(None)	Absence of a shallow groundwater table
Simulation	**File**	**Remarks**
Initial conditions	(None)	At the start of the simulation it is assumed that in the soil profile (i) the soil water content is at field capacity and (ii) salts are absent
Off-season conditions	(None)	No specific field management conditions are considered outside the growing period. When running a simulation there are no irrigation events and mulches do not cover the field surface in the off-season

An example of a single project (WheatTunis.PRO) and a multiple project file (TunisWheat.PRM) are given in Table 2.21.11c and Table 2.21.11d.

Table 2.21.11c – Example of a single Project file (files with extension 'PRO')
File: WheatTunis.PRO

```
1 year project for wheat (22 November 1979 - 23 May) cultivated in Tunis region on sandy loam
      4.0       : AquaCrop Version (August 2012)
  28815         : First day of simulation period - 22 November 1979
  28998         : Last day of simulation period - 23 May 1980
  28815         : First day of cropping period - 22 November 1979
  28998         : Last day of cropping period - 23 May 1980
      4         : Evaporation decline factor for stage II
      1.10      : Ke(x) Soil evaporation coefficient for fully wet and non-shaded soil surface
      5         : Threshold for green CC below which 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 top soil for germination (% TAW)
      1.0       : Adjustment factor for FAO-adjustment soil water depletion (p) by ETo
      3         : Number of days after which deficient aeration is fully effective
      1.00       : Exponent of senescence factor adjusting drop in photosynthetic activity of
dying crop
     12         : Decrease of p(sen) once early canopy senescence is triggered (% of p(sen))
      1            : Thresholds for water stress for stomatal closure are affected by soil
salinity stress
     30         : Depth [cm] of soil profile affected by water extraction by soil evaporation
      0.30       : Considered depth (m) of soil profile for calculation of mean soil water
content for CN adjustment
      1         : CN is adjusted to Antecedent Moisture Class
     20         : salt diffusion factor (capacity for salt diffusion in micro pores) [%]
    100         : salt solubility [g/liter]
     16         : shape factor for effect of soil water content gradient on capillary rise
     12.0       : Default minimum temperature (°C) if no temperature file is specified
     28.0       : Default maximum temperature (°C) if no temperature file is specified
      3         : Default method for the calculation of growing degree days
-- 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\
-- 2. Crop (CRO) file
   WheatGDD.CRO
   C:\FAO\AquaCrop\DATA\
-- 3. Irrigation (IRR) file
   (None)
   (None)
-- 4. Management (MAN) file
   (None)
   (None)
-- 5. Soil profile (SOL) file
   SANDYLOAM.SOL
   C:\FAO\AquaCrop\DATA\
-- 6. Groundwater (GWT) file
   (None)
   (None)
-- 7. Initial conditions (SW0) file
   (None)
   (None)
-- 8. Off-season conditions (OFF) file
   (None)
   (None)
```

Table 2.21.11d – Example of a multiple Project file (files with extension 'PRM')
File: TunisWheat.PRM

```
23 year project for wheat cultivated in Tunis region on sandy loam: 23 successive years
      4.0       : AquaCrop Version (August 2012)
  28815         : First day of simulation period - 22 November 1979
  28998         : Last day of simulation period - 23 May 1980
  28815         : First day of cropping period - 22 November 1979
  28998         : Last day of cropping period - 23 May 1980
      4         : Evaporation decline factor for stage II
      1.10      : Ke(x) Soil evaporation coefficient for fully wet and non-shaded soil surface
      5         : Threshold for green CC below which 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 top soil for germination (% TAW)
      1.0       : Adjustment factor for FAO-adjustment soil water depletion (p) by ETo
      3         : Number of days after which deficient aeration is fully effective
      1.00       : Exponent of senescence factor adjusting drop in photosynthetic activity of
dying crop
     12         : Decrease of p(sen) once early canopy senescence is triggered (% of p(sen))
     -9         : dummy (not yet assinged)
     30         : Depth [cm] of soil profile affected by water extraction by soil evaporation
      0.30        : Considered depth (m) of soil profile for calculation of mean soil water
content for CN adjustment
      1         : CN is adjusted to Antecedent Moisture Class
     20         : salt diffusion factor (capacity for salt diffusion in micro pores) [%]
    100         : salt solubility [g/liter]
     16         : shape factor for effect of soil water content gradient on capillary rise
     12.0       : Default minimum temperature (°C) if no temperature file is specified
     28.0       : Default maximum temperature (°C) if no temperature file is specified
      3         : Default method for the calculation of growing degree days
-- 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\
-- 2. Crop (CRO) file
   WheatGDD.CRO
   C:\FAO\AquaCrop\DATA\
-- 3. Irrigation (IRR) file
   (None)
   (None)
-- 4. Management (MAN) file
   (None)
   (None)
-- 5. Soil profile (SOL) file
   SANDYLOAM.SOL
   C:\FAO\AquaCrop\DATA\
-- 6. Groundwater (GWT) file
   (None)
   (None)
-- 7. Initial conditions (SW0) file
   (None)
   (None)
-- 8. Off-season conditions (OFF) file
   (None)
   (None)
```

Table 2.21.11d – Example of a multiple Project file … *continued*

```
  29181         : First day of simulation period - 22 November 1980
  29363         : Last day of simulation period - 23 May 1981
  29181         : First day of cropping period - 22 November 1980
  29363         : Last day of cropping period - 23 May 1981
-- 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\
-- 2. Crop (CRO) file
   WheatGDD.CRO
   C:\FAO\AquaCrop\DATA\
-- 3. Irrigation (IRR) file
   (None)
   (None)
-- 4. Management (MAN) file
   (None)
   (None)
-- 5. Soil profile (SOL) file
   SANDYLOAM.SOL
   C:\FAO\AquaCrop\DATA\
-- 6. Groundwater (GWT) file
   (None)
   (None)
-- 7. Initial conditions (SW0) file
   (None)
   (None)
-- 8. Off-season conditions (OFF) file
   (None)
   (None)
  29546         : First day of simulation period - 22 November 1981
  29722         : Last day of simulation period - 17 May 1982
  29546         : First day of cropping period - 22 November 1981
  29722         : Last day of cropping period - 17 May 1982
-- 1. Climate (CLI) file
   Tunis.CLI
   C:\FAO\AquaCrop\DATA\
   1.1 Temperature (TMP) file
…
…
…
…
```

Day numbers

AquaCrop uses day numbers to specify the start and end of the simulation period and of the growing cycle. The day number refers to the days elapsed since 0th January 1901 at 0 am. The calculation procedure is given in Table 2.21.11e and the code in Table 2.21.11f.

Table 2.21.11e – 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

Table 2.21.11f – Calculation code to derive a day-number from a given date (day/month/year)

```
CONST ElapsedDays :
ARRAY[1..12] of double = (0,31,59.25,90.25,120.25,151.25,181.25,
212.25,243.25,273.25,304.25,334.25);

INPUT: Dayi   : DD (Integer); Monthi : MM (Integer); Yeari   : YYYY (Integer);

OUTPUT:   DayNr (LongInt);

PROCEDURE DetermineDayNr (Dayi,Monthi,Yeari : INTEGER;
                                          VAR DayNr : Longint);
BEGIN
DayNr := TRUNC((Yeari - 1901)*365.25 + ElapsedDays[Monthi] + Dayi + 0.05);
END; (* DetermineDayNr *)
```

2.21.12 File with field data (*.OBS)

A file with field data (Tab. 2.21.12a and 2.21.12b) contains observed field data which can consists of observed green canopy cover (CC), dry above ground biomass (B) and/or soil water content (SWC) collected at a number of specific days. The mean value together with its standard deviation can be specified if various observations were made during the sampling at a specific day. The soil water content is the total water content in a well defined zone (e.g. root zone). Therefore the soil depth, for which soil water contents were calculated, has to be specified.

Table 2.21.12a – Structure of a file with field data

Line	Description	Format
1	First line is a description of the file content	String of characters
2	Version number of AquaCrop	Real (1 digit)
3	The depth (m) of the sampled profile (for soil water content)	Real (2 digits)
4	First day of field data	Integer
5	First month of field data	Integer
6	First year of record (1901 if not linked to a specific year)	Integer
7	Empty line	-
8	Title ('Day Canopy Cover …')	String of characters
9	Title ('Mean Std …')	String of characters
10	Dotted line ('==========')	String of characters
11 and next	For the first day of observation specify	
	- The day number at which the observation was made (with reference to the date specified in line 4 (DD), 5 (MM) and 6 (YYYY));	Integer
	- The mean value of sampled green Canopy Cover (%) on that day (-9.0 if no field data was collected)	Real (1 digit)
	- The standard deviation (%) for the various CC observations made during the sampling on that day (-9.0 if not available or non applicable)	Real (1 digit)
	- The mean value of sampled dry above ground biomass (ton/ha) on that day (-9.0 if no field data was collected)	Real (3 digits)
	- The standard deviation for the various B observations made during the sampling on that day (-9.0 if not available or non applicable)	Real (1 digit)
	- The mean value of sampled total soil water content (mm) in the well defined zone on that day (-9.0 if no field data was collected)	Real (1 digit)
	- The standard deviation for the various SWC observations made during the sampling on that day (-9.0 if not available or non applicable)	Real (1 digit)
	Repeat for each successive day with observations	

Table 2.21.12b – Example of a file with field data.

```
measurements of CC, B and SWC at particular days
     4.0   : AquaCrop Version (May 2012)
     1.00  : depth of sampled soil profile
    22     : first day of observations
     3     : first month of observations
  1901     : first year of observations (1901 if not linked to a specific year)

   Day    Canopy cover (%)    dry Biomass (ton/ha)    Soil water content (mm)
            Mean     Std         Mean       Std          Mean      Std
================================================================================
    11       5.0     3.0       -9.000     -9.0          300.0     20.0
    30      30.0     5.0        1.000      0.3           -9.0     -9.0
    40      50.0    -9.0       -9.000     -9.0          250.0     25.0
    50      60.0     5.0       -9.000     -9.0           -9.0     -9.0
    72      -9.0    -9.0        4.000      0.2          150.0     30.0
    90      -9.0    -9.0        4.400      0.3           -9.0     -9.0
   110      45.0     6.0        5.000      0.5          100.0     10.0
   120      -9.0    -9.0        5.500      0.5          100.0     10.0
```