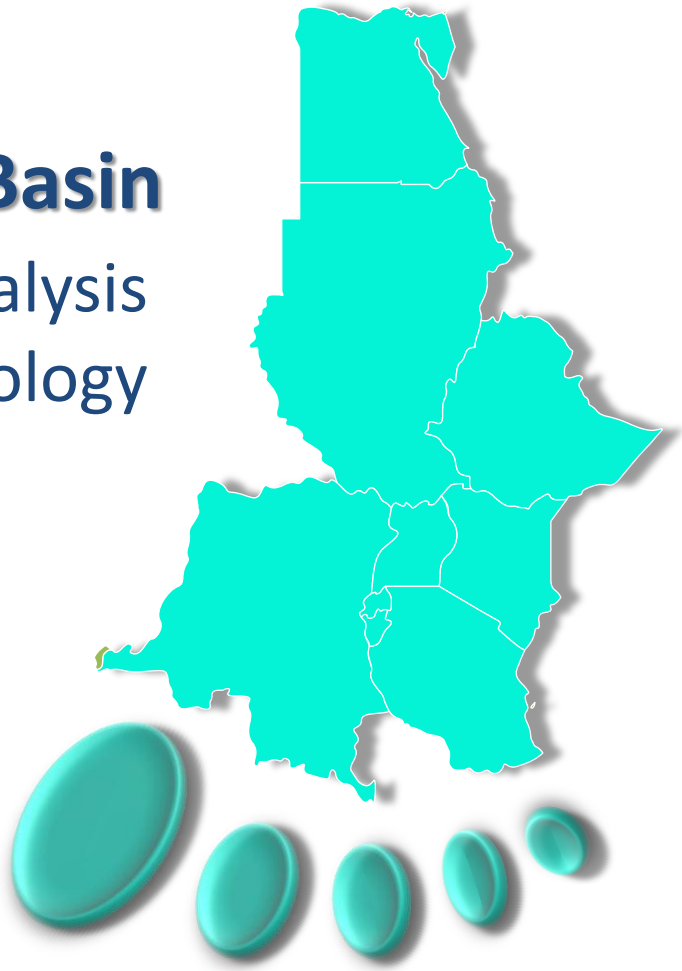
Water Footprint and the Nile Basin

Module 2: Water Footprint Analysis and Methodology



NILE BASIN INITIATIVE
Initiative du Bassin du Nil

PEGASYS
Strategy and Development

Overview of this Module

Part 1: Water Footprint Analysis and Methodology

Part 2: Data Sources & Useful Tools

Part 3: Using CROPWAT

4: Water Footprint Analysis & Methodology
Understanding the Metric

Structure of this session

1. Water Footprint of a Product
2. Detailed Example: Water Footprint of a Crop
3. Detailed Example: Water Footprint of Livestock Products
4. Water Footprint of a Country

A Water Footprint

- The volume of fresh water used to produce the product, summed over the various steps of the production chain.

- When and where the water was used: a water footprint includes a temporal and spatial dimension. Such as:
  - Climate (evapotranspiration)
  - Rainfall
  - Productivity

Elements of Water Footprint

Green water footprint – volume of soil moisture (rainwater) evaporated in crop growth

Blue water footprint – volume of irrigated surface or ground water evaporated or incorporated into a product

Grey water footprint – volume of water required to dilute contamination by waste discharge and return flow

Water Footprint Example: Beer

Crop Cultivation

- *Energy*
- *Fertiliser/ pesticide*
- *Crop Growth (rainfed/ irrigated)*

Crop Processing

- *Transport*
- *Energy*
- *Crop Imports*
- *Direct Water Use*

Brewing

- *Energy*
- *Transport*
- *Packaging*
- *Raw Materials*
- *Waste*
- *Direct Water Use*

Distribution

- *Transport*

Consumer

- *Disposal*
- *Recycling*

Detailed Example: Water Footprint of a Crop

$$WF = \frac{\text{Crop water use } (m^3/ha)}{\text{Crop yield } (ton/ha)}$$

Hoekstra and Chapagain (2008)

Detailed Example: Water Footprint of a Crop

$$WF = \frac{\text{Crop Water Use}_{\text{green}} + \text{Crop Water Use}_{\text{blue}}}{\text{Crop yield (ton/ha)}}$$

Hoekstra and Chapagain (2008)

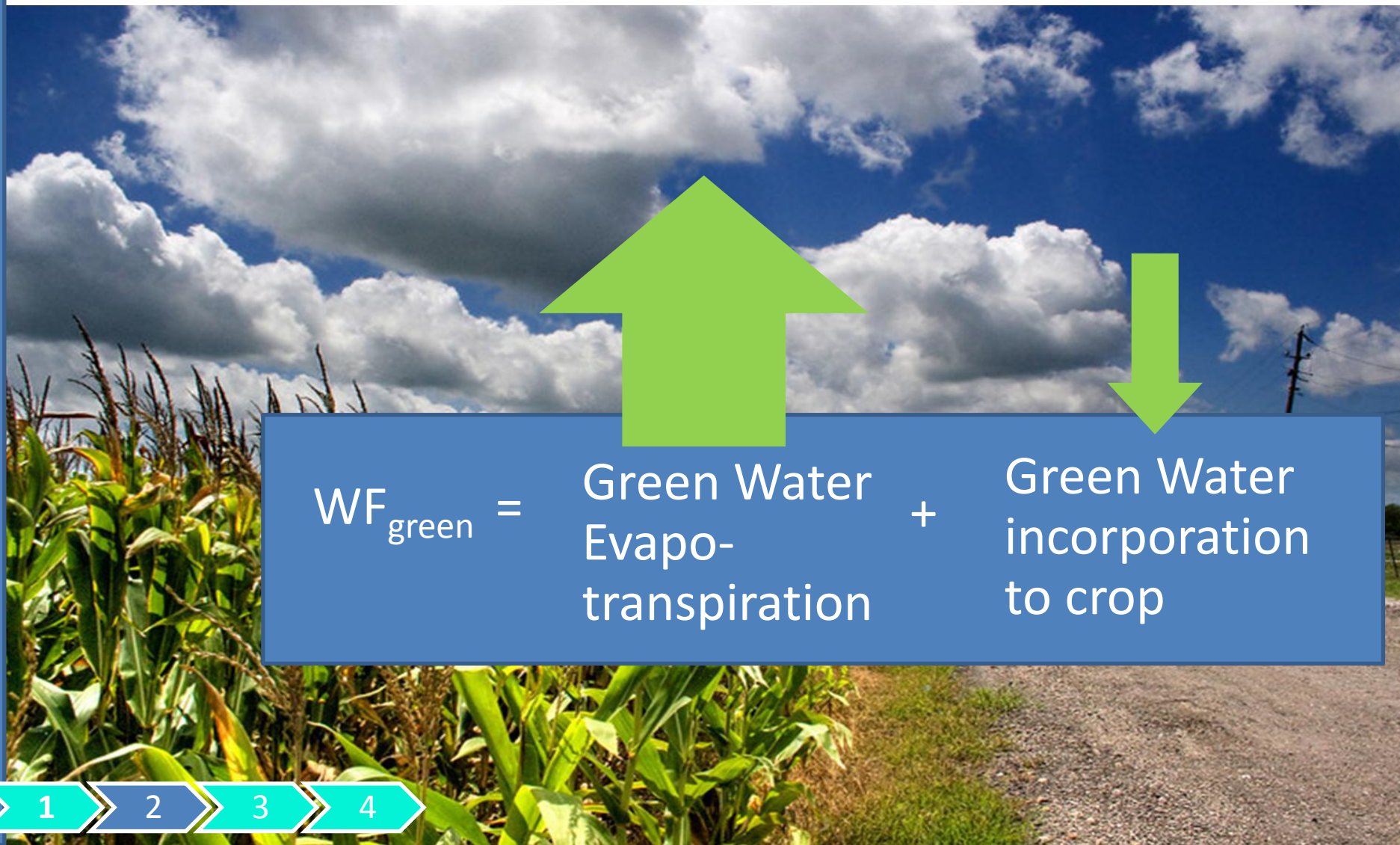
Detailed Example: Water Footprint of a Crop

$$WF = \frac{\text{Crop Water Use}_{green} + \text{Crop Water Use}_{blue}}{\text{Crop yield (ton/ha)}}$$

What is Green Crop Water Use?

Hoekstra and Chapagain (2008)

Water Footprint of a Crop – Green Water



WF_{green} = Green Water Evapo-transpiration + Green Water incorporation to crop

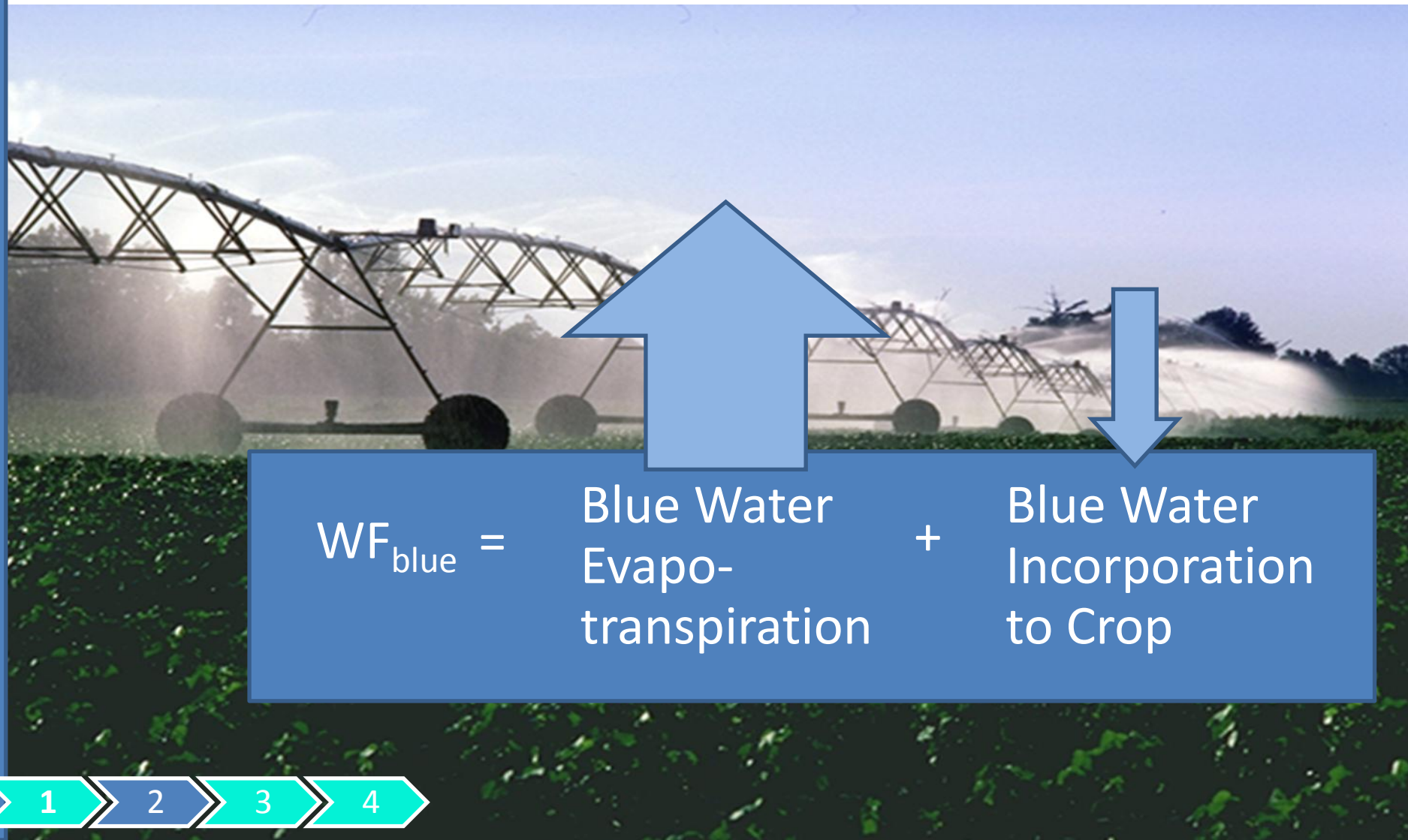
Detailed Example: Water Footprint of a Crop

$$WF = \frac{\text{Crop Water Use}_{green} + \text{Crop Water Use}_{blue}}{\text{Crop yield (ton/h}}$$

What is Blue Crop Water Use?

Hoekstra and Chapagain (2008)

Water Footprint of a Crop – Blue Water



WF_{blue} = Blue Water Evapo-transpiration + Blue Water Incorporation to Crop

CROPWAT Estimation Methods

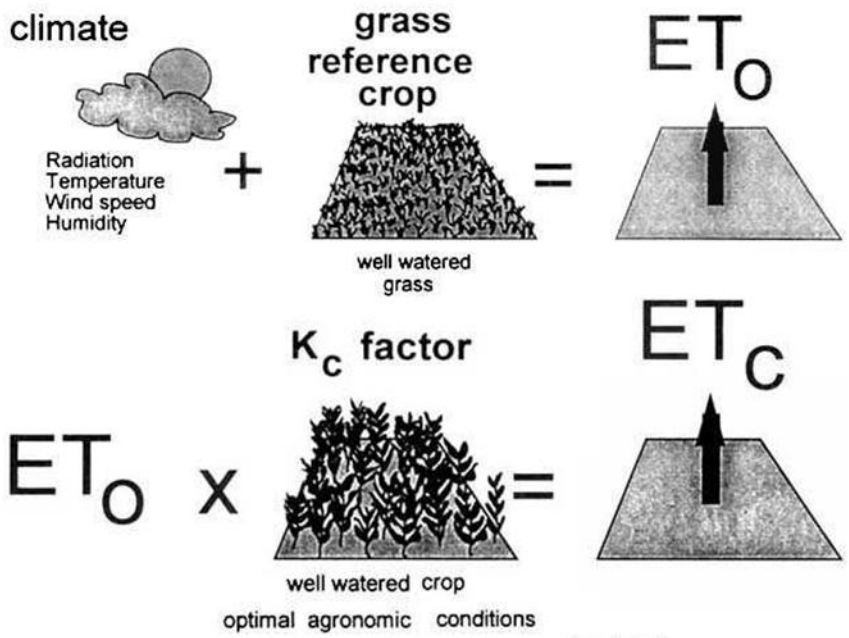
1. CWR option – Optimal conditions
   – Without considering soil water balance
   – Ten-day time step effective rainfall

2. Irrigation schedule option – Non-optimal conditions
   – Considering soil water balance
   – Daily time step soil water balance

For the purposes of this training, we will only be examining CWR Option (further details of the Irrigation Schedule and using CROPWAT can be found in your training pack)

1. CWR Option - Crop Evapotranspiration

FIGURE 4. Reference (ET_o), crop evapotranspiration under standard (ET_c) and non-standard conditions ($ET_{c\ adj}$)



Allen et al. (1998)

Reference crop evapotranspiration

Evapotranspiration rate from a hypothetical grass reference surface, not short of water

Crop evapotranspiration under standard conditions

Evapotranspiration from disease-free, well fertilized crops, grown in large fields, under optimum soil water conditions and achieving full production under the given climatic conditions

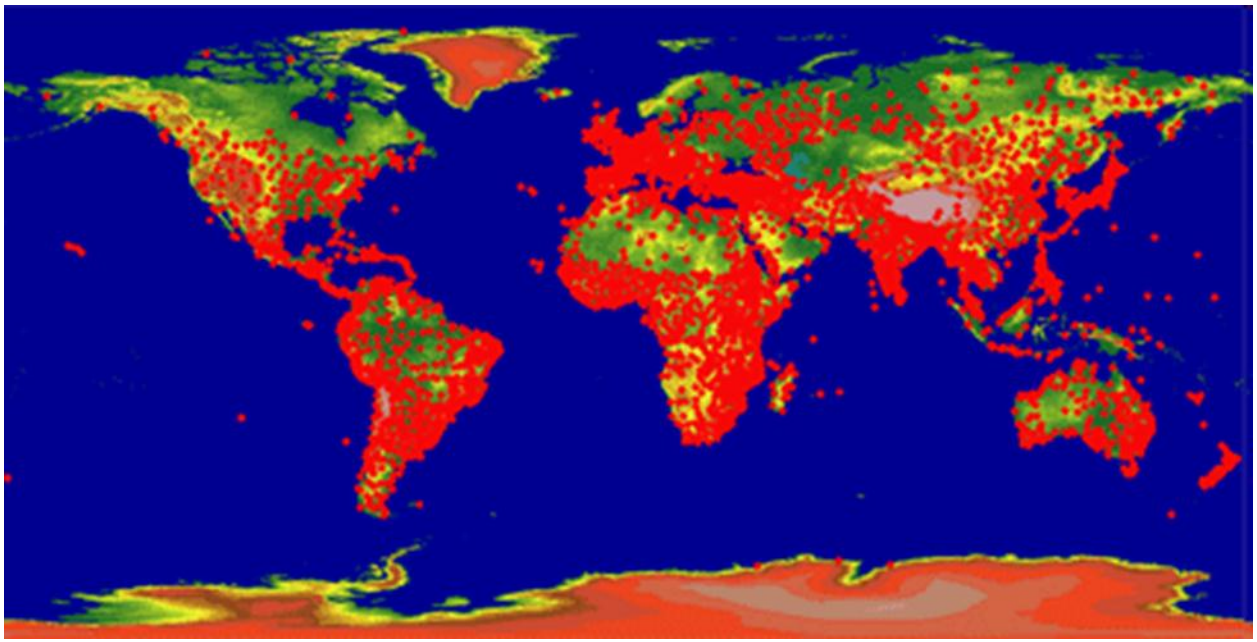
Crop coefficient

Characteristics: Crop height, albedo (reflectance), canopy resistance, evaporation from soil.

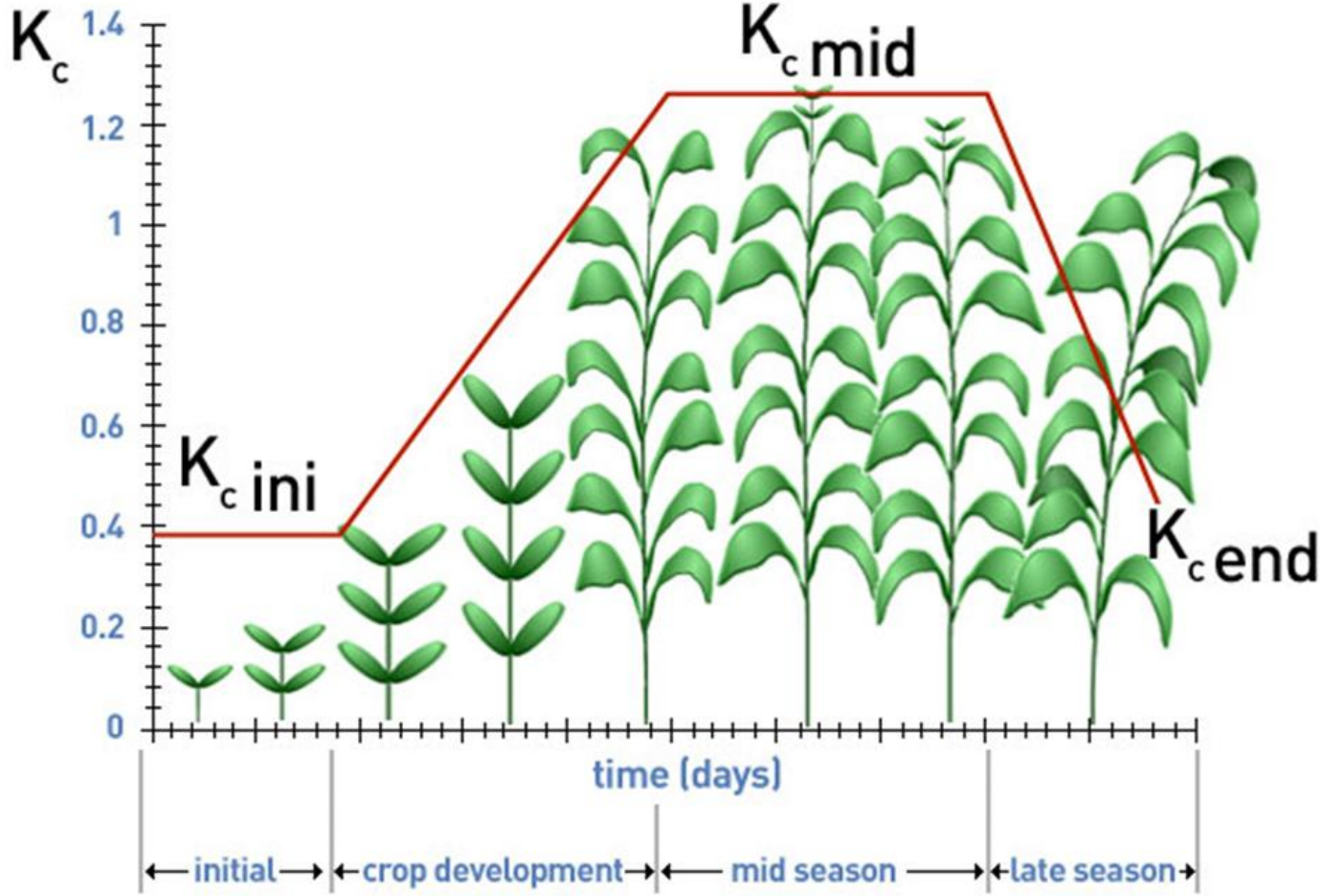
1. CWR Option - Climate Data

Climate data – **CLIMWAT 2.0** database (FAO, 2006)

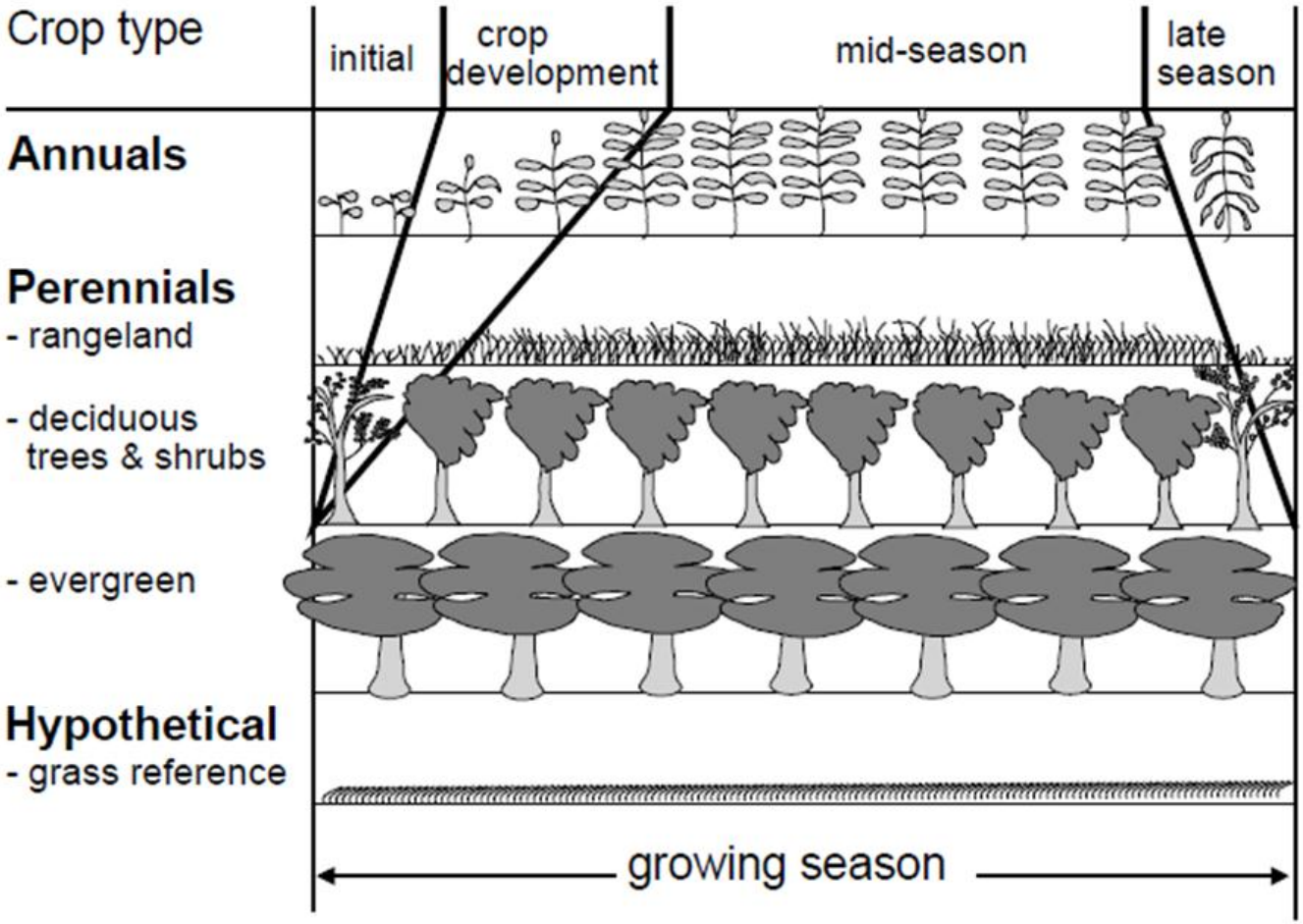
Observed agroclimatic data of over 5000 stations worldwide (tries to cover 1971-2000)



1. CWR Option
- Crop Coefficient Curve



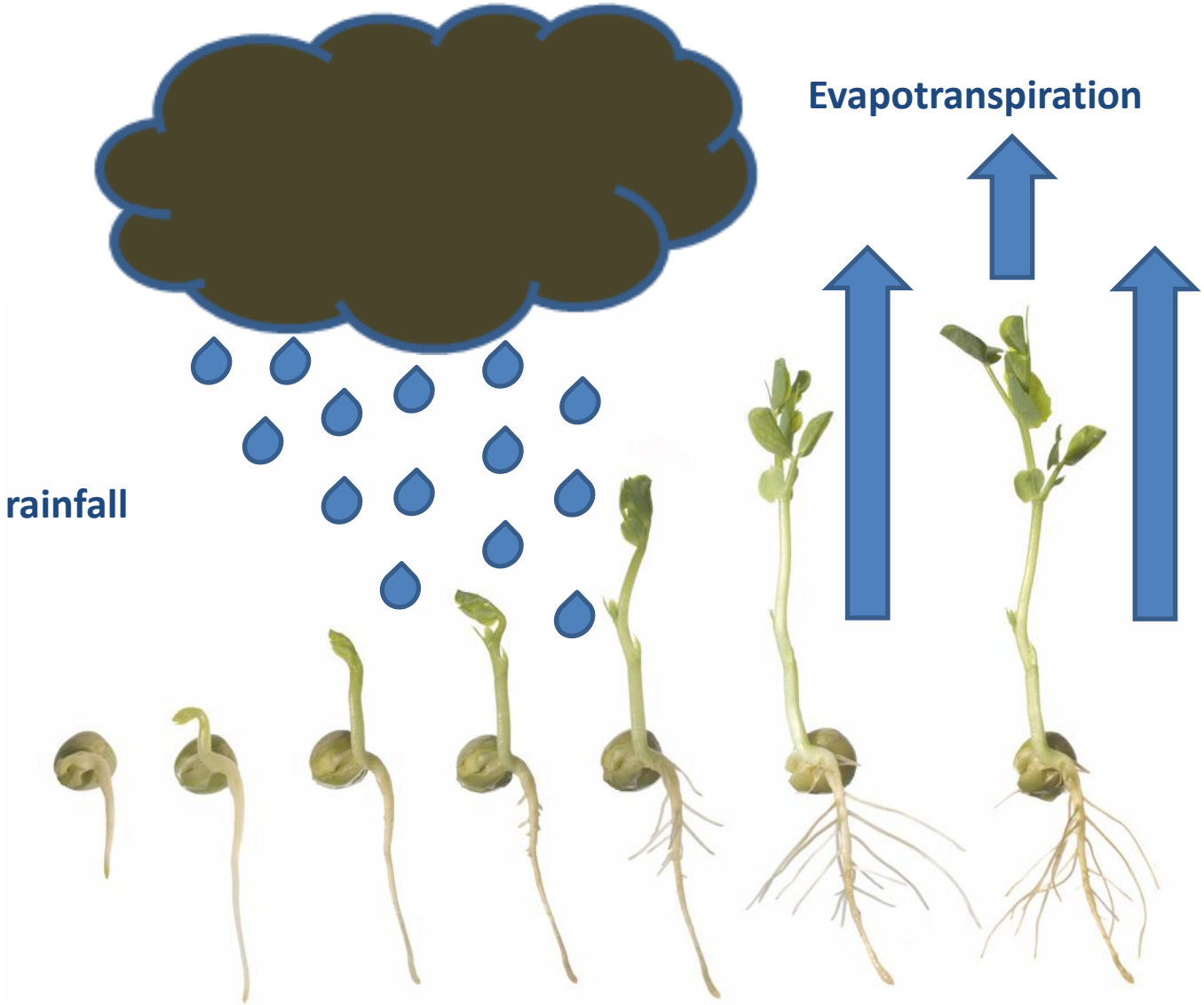
1. CWR Option
- Crop Growth Stages for Different Crops



Planting date

Green up date

Detailed example of green Crop Water Use



Summed over the entire growing period

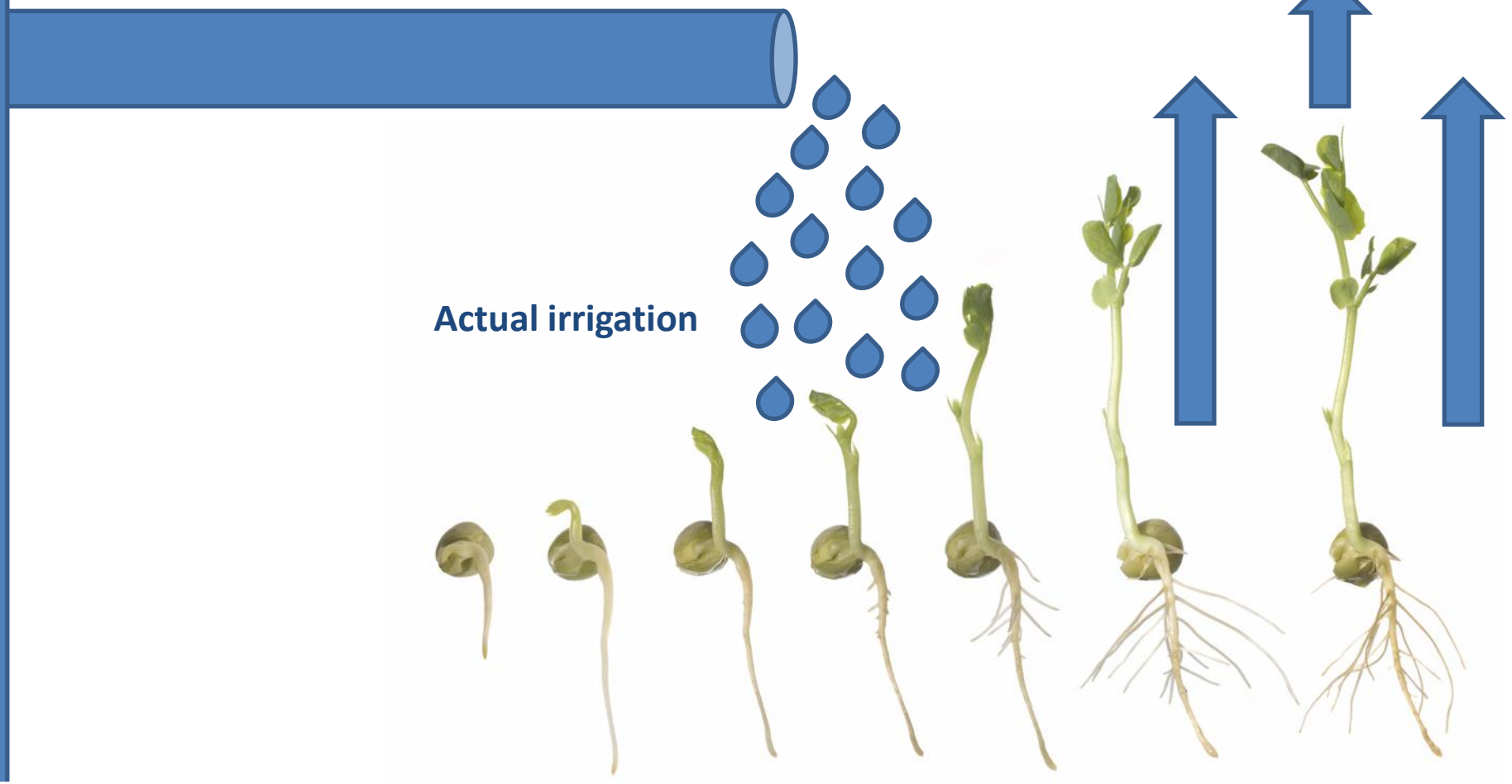
Detailed Example: Green Water Footprint of a Crop

$$\text{Evapotranspiration}_{green} = \min(\text{crop evapotranspiration, effective rainfall})$$

$$\text{CWU}_{green} = 10 \times \sum \text{Evapotranspiration}_{green}$$

$$\text{WF} = \frac{\text{Crop water use } (m^3/ha)}{\text{Crop yield (ton/ha)}}$$

Detailed example of blue Crop Water Use



Summed over the entire growing period

Detailed Example: Blue Water Footprint of a Crop

$$\text{Evapotranspiration}_{blue} = \min(\text{crop irrigation requirement, actual irrigation})$$

$$\text{CWU}_{blue} = 10 \times \sum \text{Evapotranspiration}_{blue}$$

$$\text{WF} = \frac{\text{Crop water use } (m^3/ha)}{\text{Crop yield (ton/ha)}}$$

Hoekstra and Chapagain (2008)

Detailed Example: Water Footprint of a Crop

$$WF = \frac{\text{Crop water use } (m^3/ha)}{\text{Crop yield (ton/ha)}}$$

Crop yield = crop production per unit area of land under cultivation

Hoekstra and Chapagain (2008)

What influences Water Footprint?

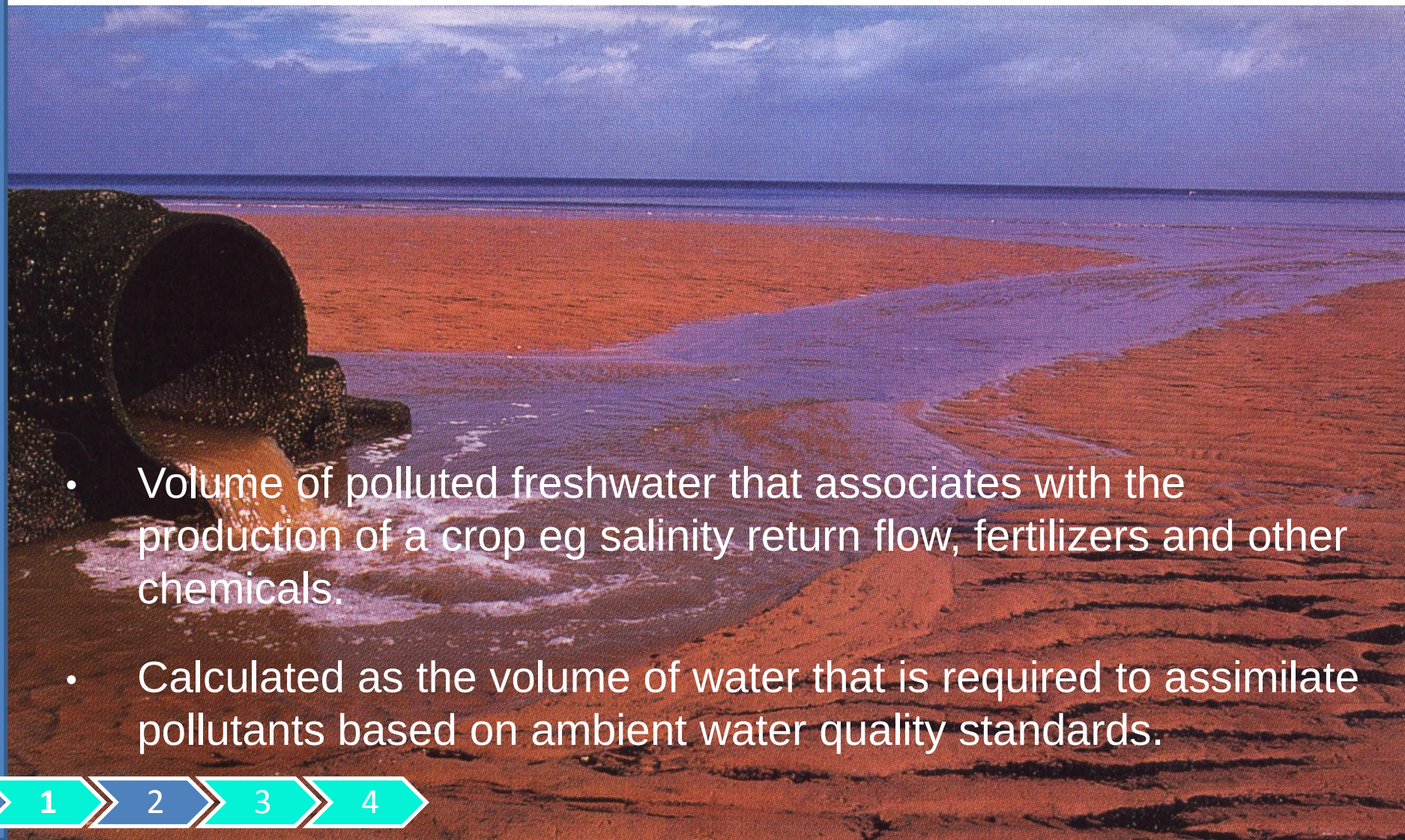
Type of crop/product
Crop Evapotranspiration: climate

$$WF = \frac{\text{Crop water use } (m^3/ha)}{\text{Crop yield (ton/ha)}}$$

Fertilizer use
Irrigation practices
Not receiving optimal water
Soil

Hoekstra and Chapagain (2008)

Water Footprint of a Crop – Grey Water



- Volume of polluted freshwater that associates with the production of a crop eg salinity return flow, fertilizers and other chemicals.
- Calculated as the volume of water that is required to assimilate pollutants based on ambient water quality standards.

Detailed Example: Water Footprint of a Livestock Product

Water Footprint Example: a Live Animal

Feed Cultivation

- *Energy*
- *Fertiliser/ pesticide*
- *Crop Growth (rainfed/ irrigated)*

Animal Rearing

- *Crop Imports*
- *Direct Water Use*

Processing

- *Energy*
- *Transport*
- *Packaging*
- *Raw Materials*
- *Waste*
- *Direct Water Use*

Distribution

- *Transport*

Consumer

- *Disposal*
- *Recycling*

Water Footprint of a Live Animal

$$WF_{live\ animal} = WF_{drink} + WF_{service} + WF_{feed}$$

- WF_{drink} = volume of water drunk by an animal
- $WF_{service}$ = volume of water used to service an animal
- WF_{feed} = water embedded in the crops used to make up the feed

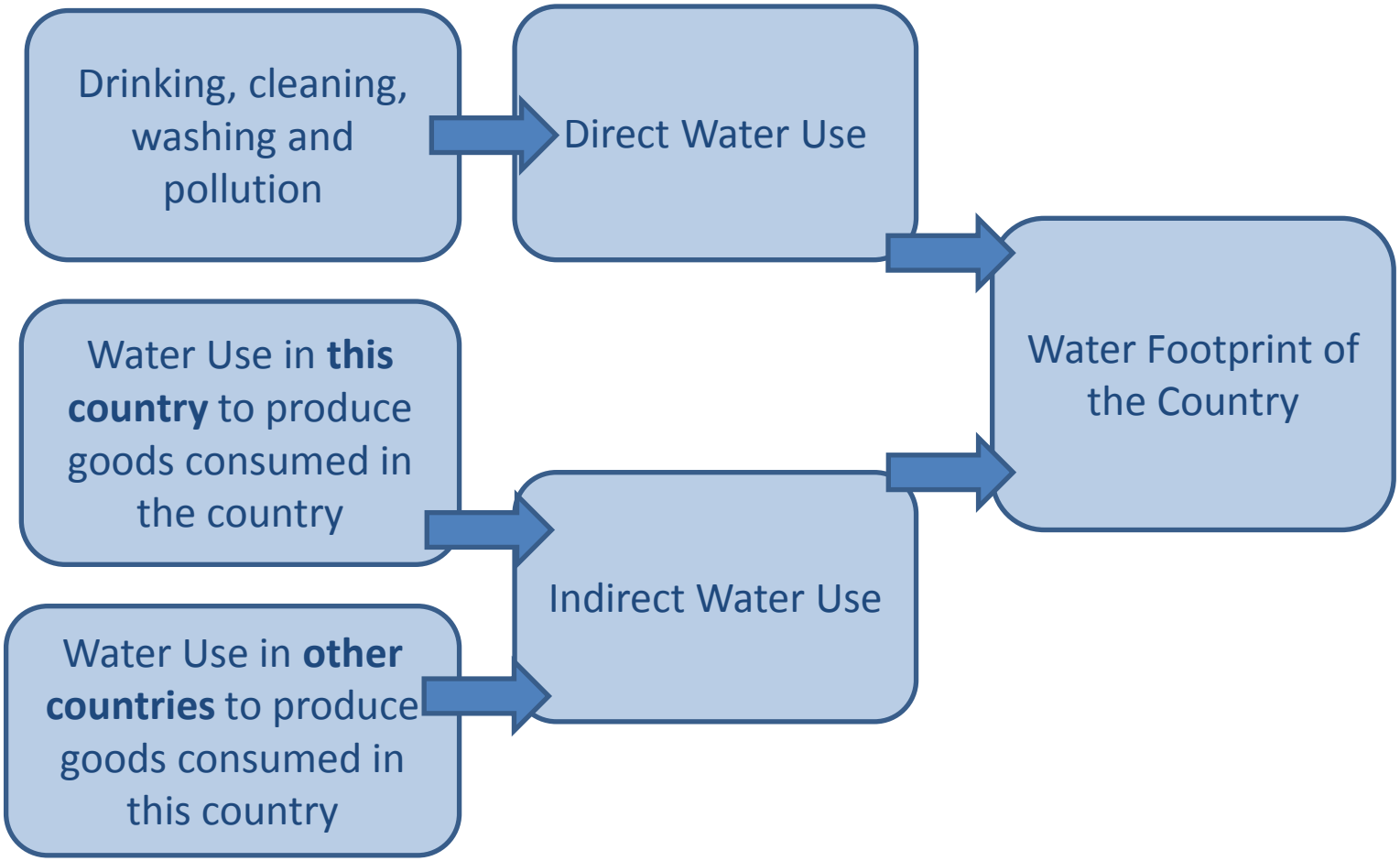
Water Footprint of a Live Animal - Water Footprint of Feed

- Water Footprint of Grass (m3/ton)
- Volume of grass eaten by an animal (ton)

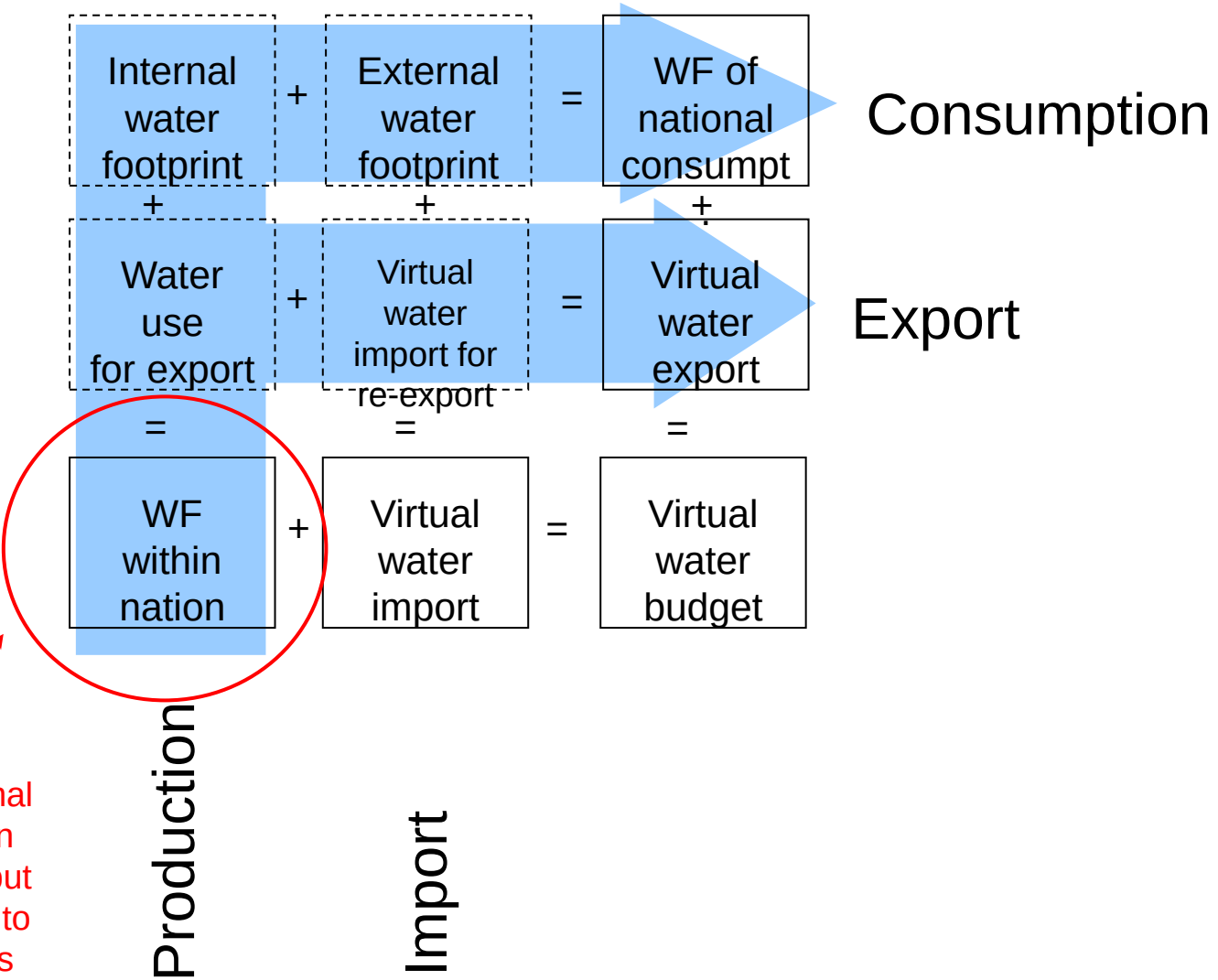
$$WF_{Feed} = WF_{Grass} * Volume_{Grass\ eaten}$$

Water Footprint of a Country

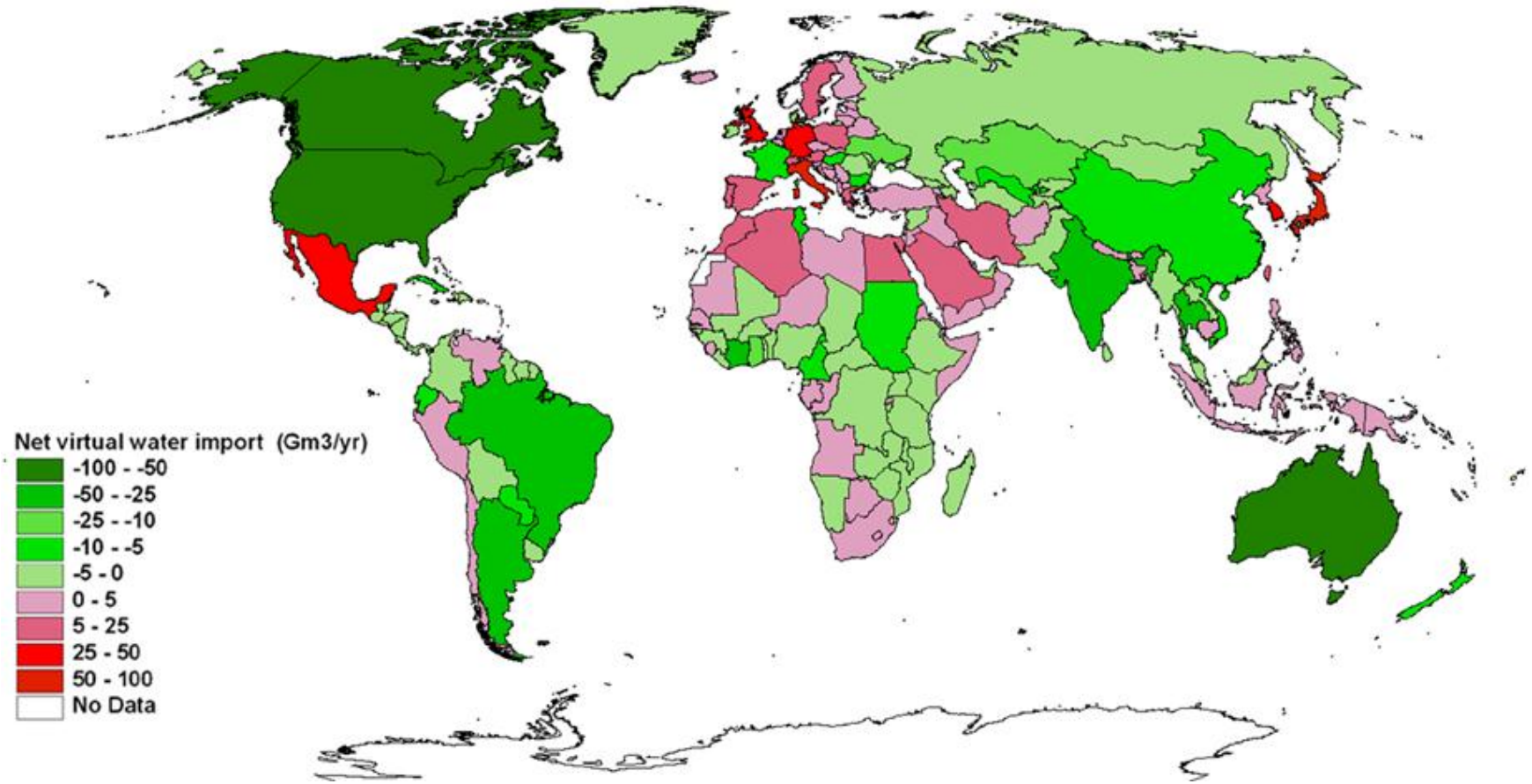
Water Footprint of a Country



National Water Use Accounting Framework



Net Water Importers and Exporters



National virtual water balances related to the international trade of products. Period 1997-2001. Net exporters are shown in green and net importers in red

Data Sources and Useful Tools

Doing your own Water Footprint analysis

Basic Data required:

- Rainfall and evaporation data
- Crop growth and evapotranspiration data
- Irrigation practices
- Crop yield

Additional information:

- Production volumes
- Trade volumes
- Jobs associated with production
- Contribution to the GDP
- Other information of interest.

Doing your own Water Footprint analysis

Useful information from non-governmental sources, include the following sources and tools:

Rainfall and Evaporation Data

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

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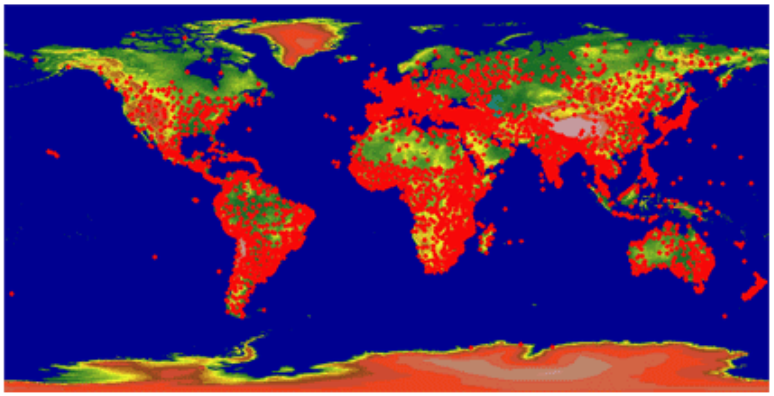
Databases

CLIMWAT 2.0 for CROPWAT

CLIMWAT is a climatic database to be used in combination with the computer program CROPWAT. and allows the calculation of crop water requirements, irrigation supply and irrigation scheduling for various crops for a range of climatological stations worldwide.

CLIMWAT 2.0 for CROPWAT is a joint publication of the **Water Development and Management Unit** and the **Climate Change and Bioenergy Unit** of FAO.

CLIMWAT 2.0 offers observed agroclimatic data of over 5000 stations worldwide distributed as shown below.



Location of stations included in CLIMWAT 2.0.

SEARCH

RELATED LINKS

- Climate Change and Bioenergy Unit
- Revised FAO Methodology for Crop Water Requirements

DOWNLOADS

- ClimWat 2.0 for Cropwat

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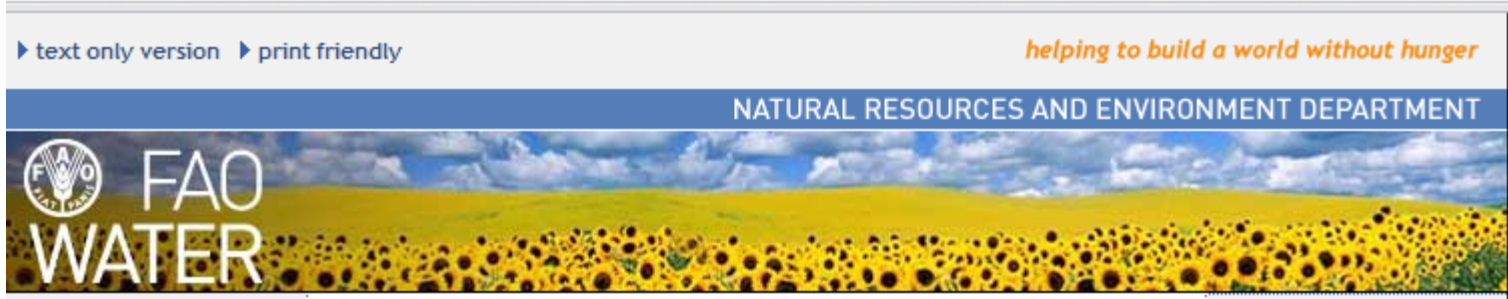
Crop Growth and Evapotranspiration Data

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



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CropWat

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO.

CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions.

CROPWAT 8.0

All calculation procedures used in CROPWAT 8.0 are based on the two FAO publications of the Irrigation and Drainage Series, namely, No. 56 "**Crop Evapotranspiration - Guidelines for computing crop water requirements**" and No. 33 titled "**Yield response to water**".

As a starting point, and only to be used when local data are not available, CROPWAT 8.0 includes standard crop and soil data. When local data are available, these data files can be easily modified or new ones can be created. Likewise, if local climatic data are not available, these can be obtained for over 5,000 stations worldwide from CLIMWAT, the associated climatic database. The development of irrigation schedules in

SEARCH

RELATED LINKS

Revised methodology for crop water requirements
Topics: Irrigation
Topics: Water Productivity
Publications: Irrigation
Publications: Productivity

DOWNLOADS

CropWat 8.0
Example of CropWat 8.0 use

CONTACT US

Irrigation practices and Crop Yields

http://www.fao.org/ag/agl/fertistat/fst_fubc_en.asp

Production and Trade Volumes

http://faostat.fao.org/default.aspx

Water Footprint Network

http://www.waterfootprint.org

Useful Additional References

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998) Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56. Food and Agriculture Organization. Rome. Available from: http://www.fao.org/docrep/X0490E/X0490E00.htm

Chapagain, A.K. and Hoekstra, A.Y. (2004) Water footprints of nations. Value of Water Research Report Series No. 16, UNESCO-IHE, Delft, the Netherlands. Available from: http://www.waterfootprint.org/?page=files/Research%20data

Mekonnen, M.M. and Hoekstra, A.Y. (2011) The green, blue and grey water footprint of crops and derived crop products, Hydrology and Earth System Sciences, 15(5): 1577-1600. Available from:

http://www.waterfootprint.org/?page=files/Publications

Chapagain, A.K. and Hoekstra, A.Y. (2003) 'Virtual water flows between nations in relation to trade in livestock and livestock products' ,Value of Water Research Report Series No.13, UNESCO-IHE.

http://www.waterfootprint.org/?page=files/Publications

FAO (2003) Technical Conversion Factors for Agricultural Commodities. Food and Agriculture Organization of the United Nations, Rome. Online available: www.fao.org/WAICENT/FAOINFO/ECONOMIC/ESS/pdf/tcf.pdf

Hoekstra, A.Y. and Chapagain, A.K. (2008) Globalization of water: Sharing the planet's freshwater resources. Blackwell Publishing. Oxford, UK.

Monfreda, C., Ramankutty, N. and Foley, J.A. (2008) Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000, Global Biogeochemical Cycles, Vol. 22, GB1022, doi:10.1029/2007GB002947. Available from: http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html

4: Using CROPWAT

Green and blue water footprint of a crop

$$WF = \frac{\text{Crop water use } (m^3/ha)}{\text{Crop yield } (ton/ha)}$$

CROPWAT
(FAO, 2009a)

FAOSTAT
(FAO, 2009b)

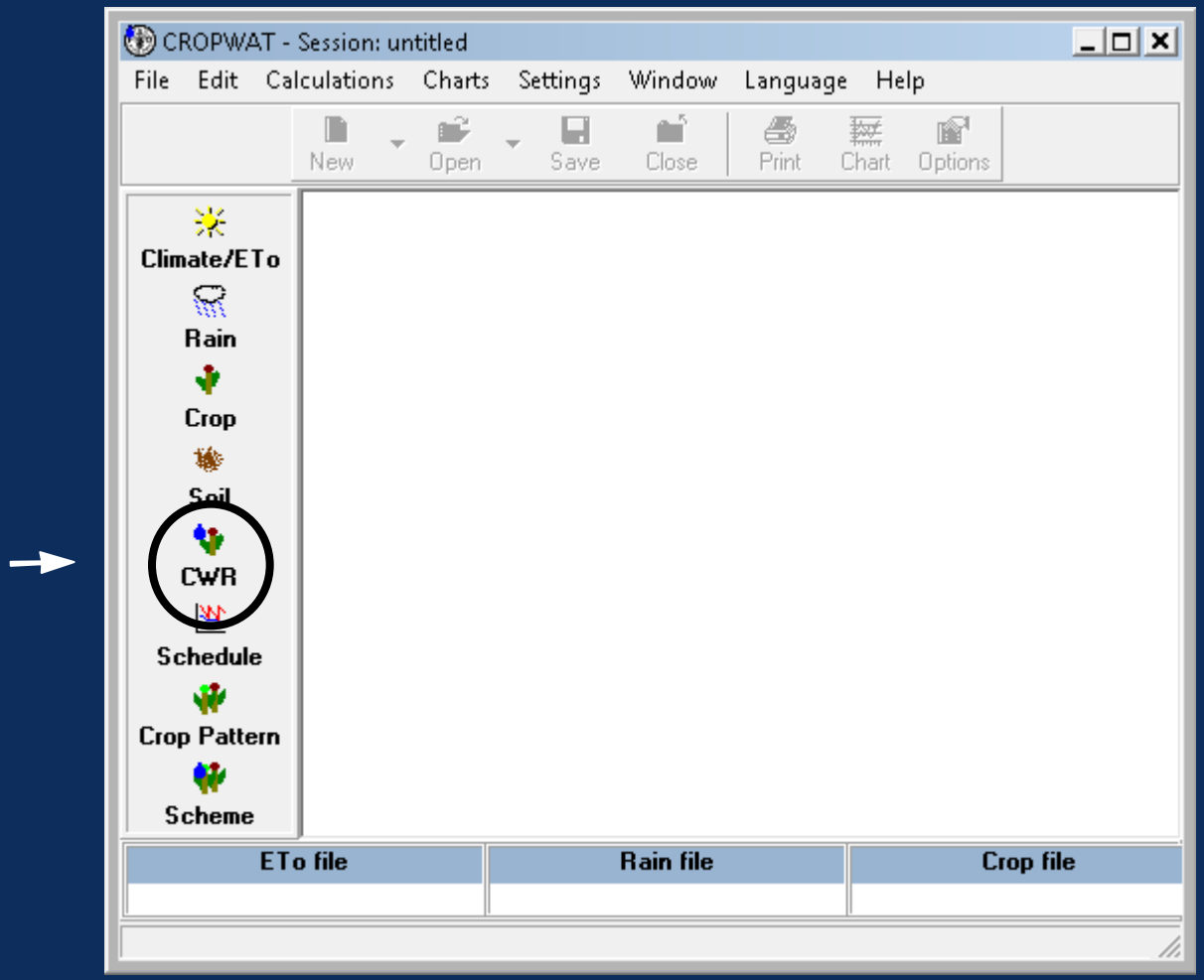
Hoekstra and Chapagain (2008)

CROPWAT estimation methods

1. CWR option – Optimal conditions
   – Without considering soil water balance
   – Ten-day time step effective rainfall

2. Irrigation schedule option – Non-optimal conditions
   – Considering soil water balance
   – Daily time step soil water balance

1. CWR option


CROPWAT - Session: untitled
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Print
Chart
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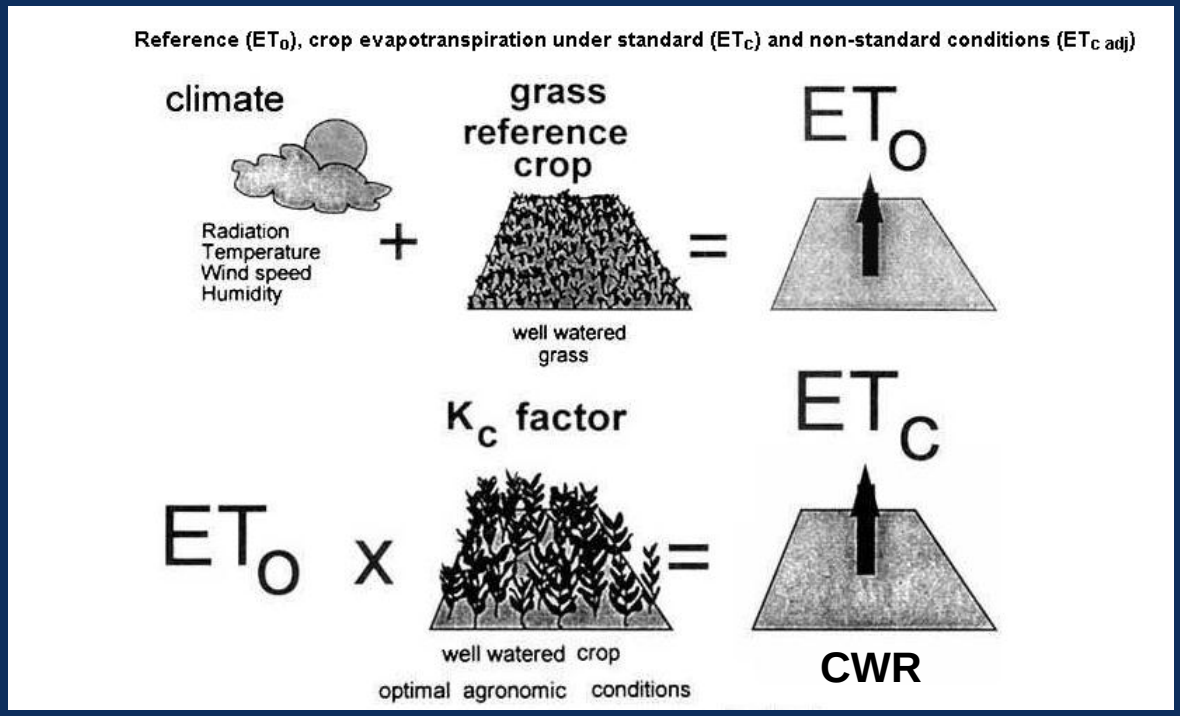
Crop
Soil
CWR
Schedule
Crop Pattern
Scheme
ETo file
Rain file
Crop file

1. CWR option



Allen et al. (1998)

Reference crop evapotranspiration

Evapotranspiration rate from a hypothetical grass reference surface, not short of water

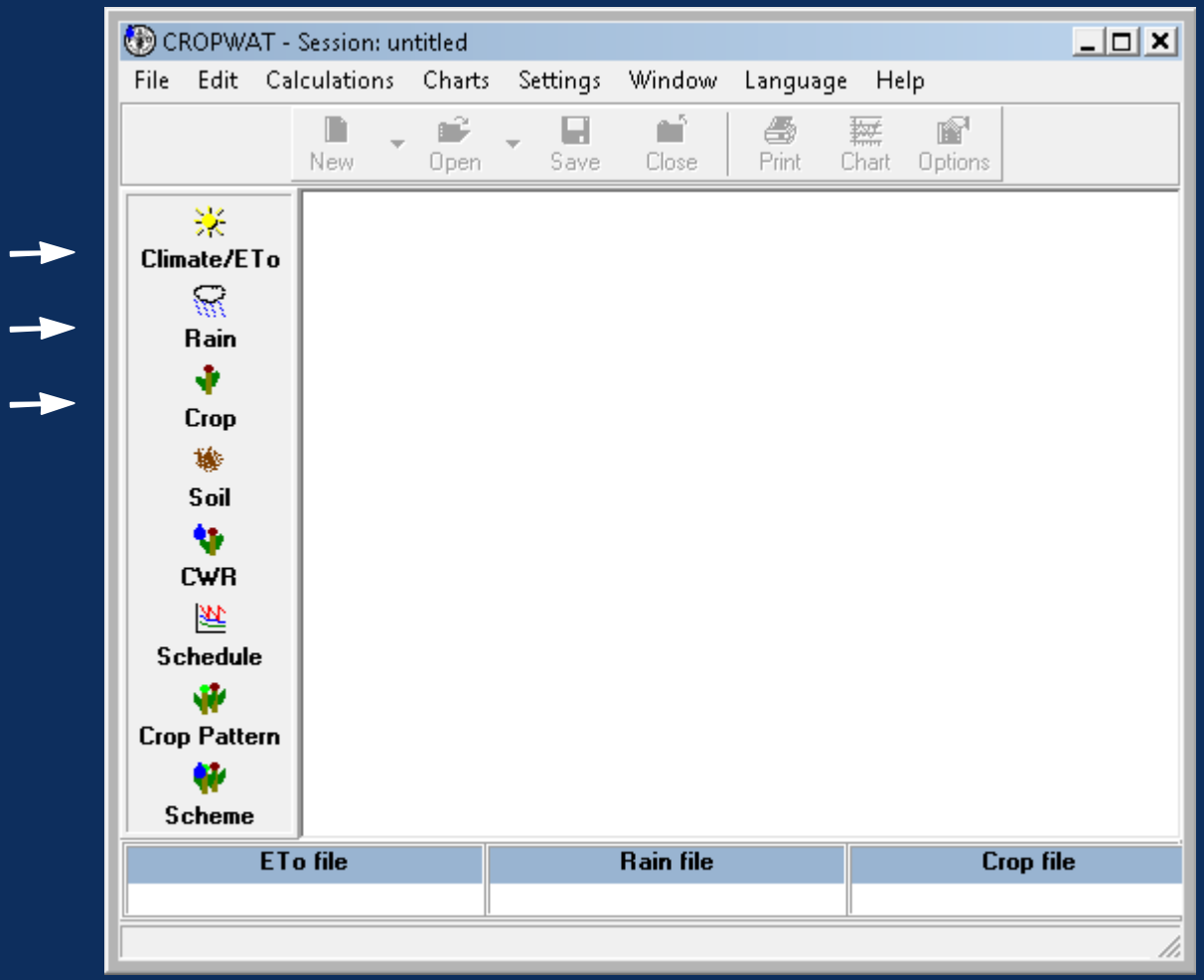
Crop evapotranspiration under standard conditions

Evapotranspiration from disease-free, well fertilized crops, grown in large fields, under optimum soil water conditions and achieving full production under the given climatic conditions

Crop coefficient

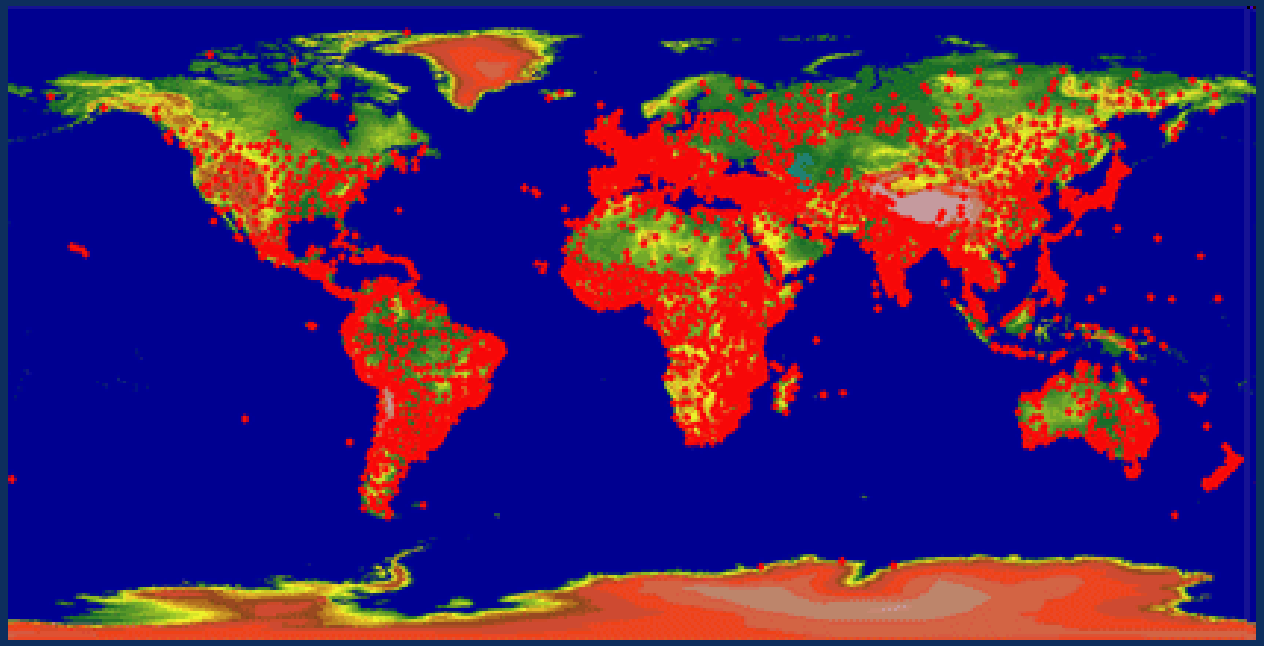
Characteristics: Crop height, albedo (reflectance), canopy resistance, evaporation from soil.

1. CWR option – Input



Climate data – **CLIMWAT 2.0** database (FAO, 2006)

Observed agroclimatic data of over 5000 stations worldwide (tries to cover 1971-2000)

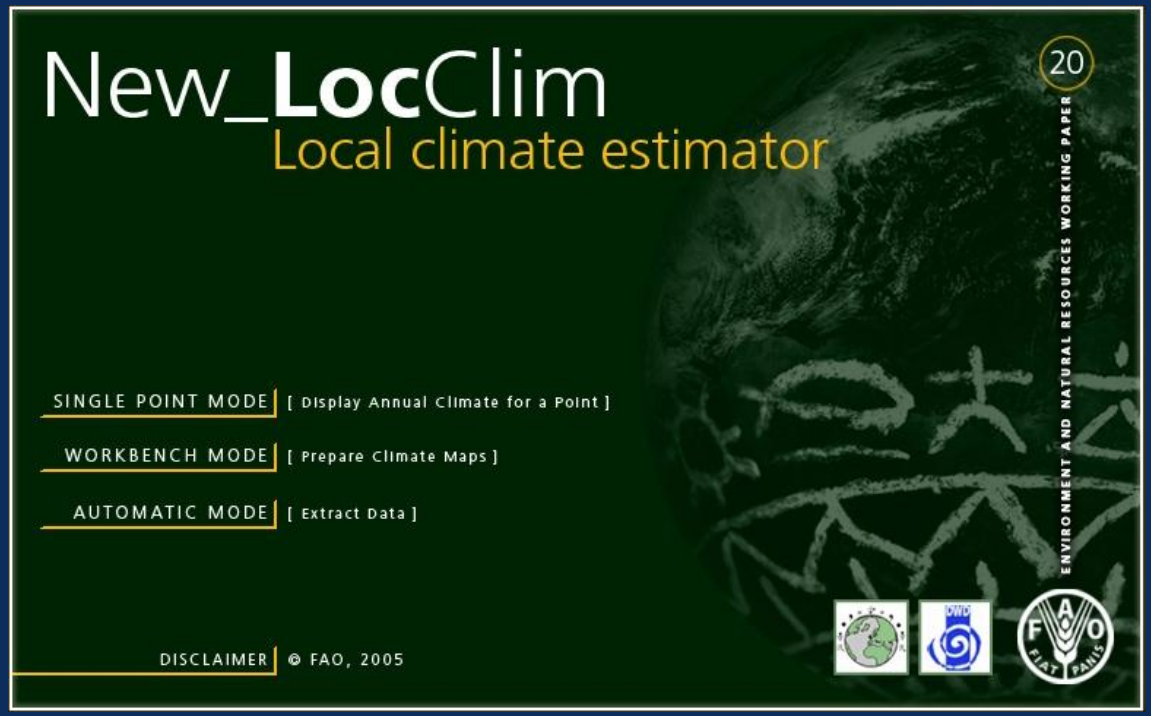


Climate/ETo

Rain

Climate data – **New LocClim** 1.10 database (FAO, 2005)

Interpolates where no observations are available



Climate/ETo

Rain

Climate data – Local Data can be added by hand to CROPWAT

CLIMWAT database

.CLI

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File Edit Format View Help

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      2.43            57.80            52.45
      2.82            68.80            61.23
      2.75            76.30            66.99
      2.53            66.40            59.35
      1.59            70.60            62.63
      0.83            68.70            61.15
      0.44            77.10            67.59
      0.22            75.50            66.38
```

ET_0* (mm/day)	Monthly rainfall (mm/month)	Monthly effective rainfall** (mm/month)

*Penman-Monteith method
**USDA Soil Conservation Service formula

.PEN

GRONINGEN-AP-EELDE.pen - Notepad

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       7.9       0.5      86.7     449.3      2.85       7.93      0.86
      11.8       2.5      81.7     397.4      5.01      13.22      1.58
      16.6       6.3      79.1     354.2      6.22      17.06      2.43
      19.5       9.3      80.6     345.6      6.11      17.95      2.82
      20.7      10.9      83.0     354.2      5.71      16.92      2.75
      21.2      10.8      82.5     319.7      5.83      15.05      2.53
      18.2       8.7      87.2     337.0      4.06      10.18      1.59
      13.7       5.9      90.8     354.2      2.45       5.78      0.83
       8.3       2.3      92.5     440.6      1.06       2.77      0.44
       4.9      -0.2      95.7     449.3      0.13       1.53      0.22
```
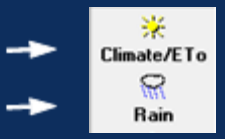
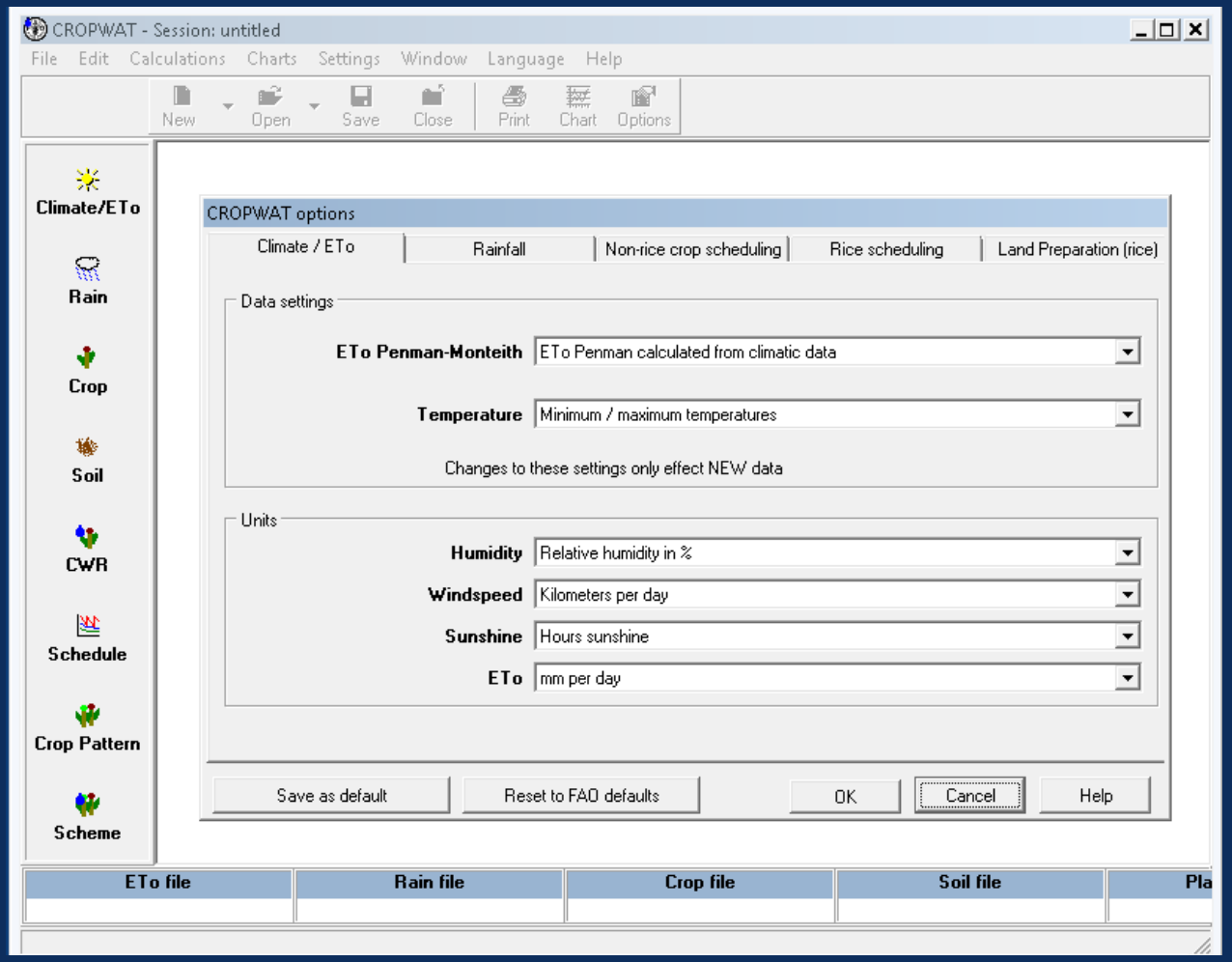
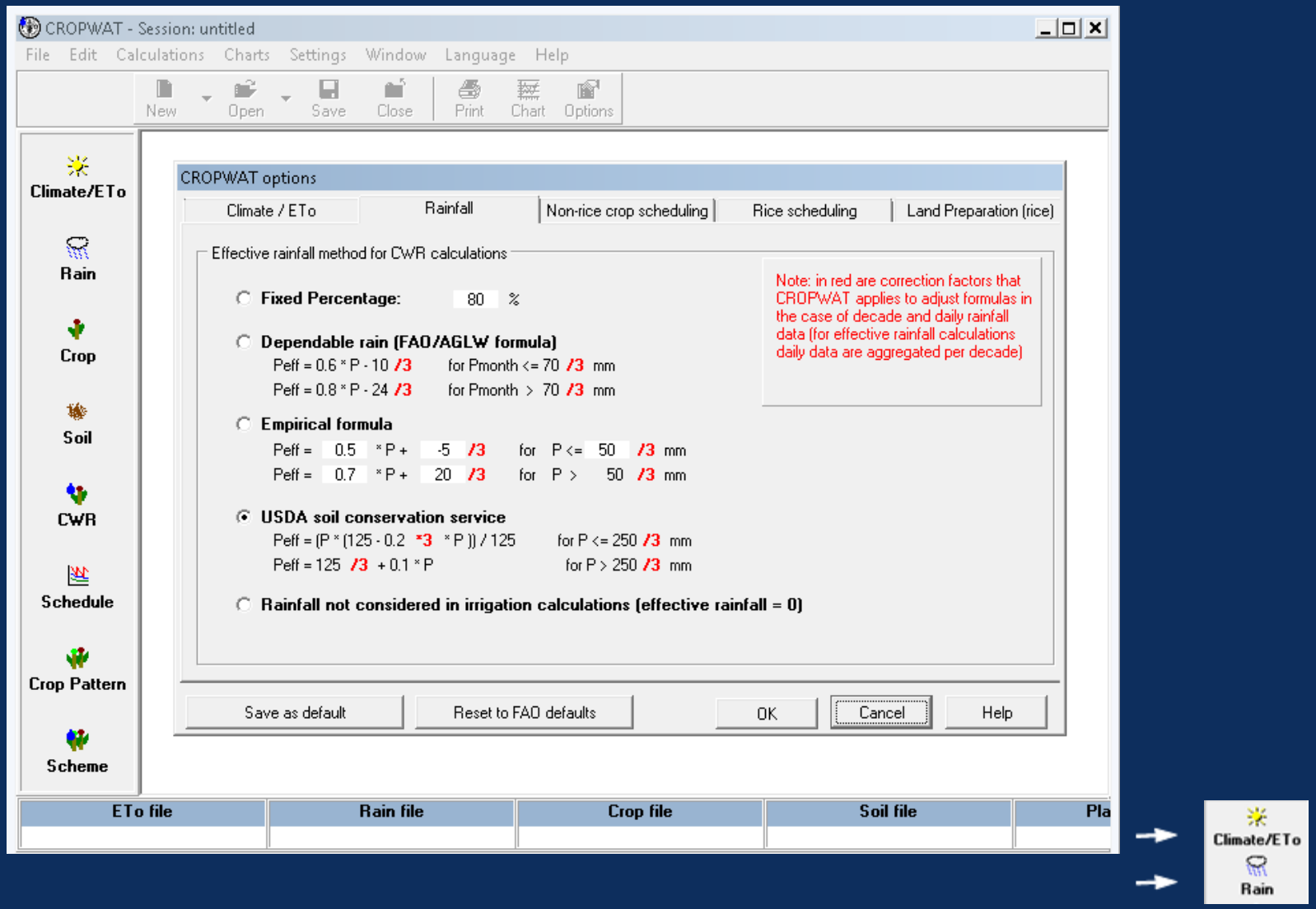

Mean daily maximum temp. (ºC)	Mean daily minimum temp. (ºC)	Mean relative humidity (%)	Mean wind speed (km/day)	Mean sunshine hours per day	Mean solar radiation (MJ/m^2/day)	ET_0* (mm/day)



ET_0 Penman-Monteith



Effective rainfall estimation method



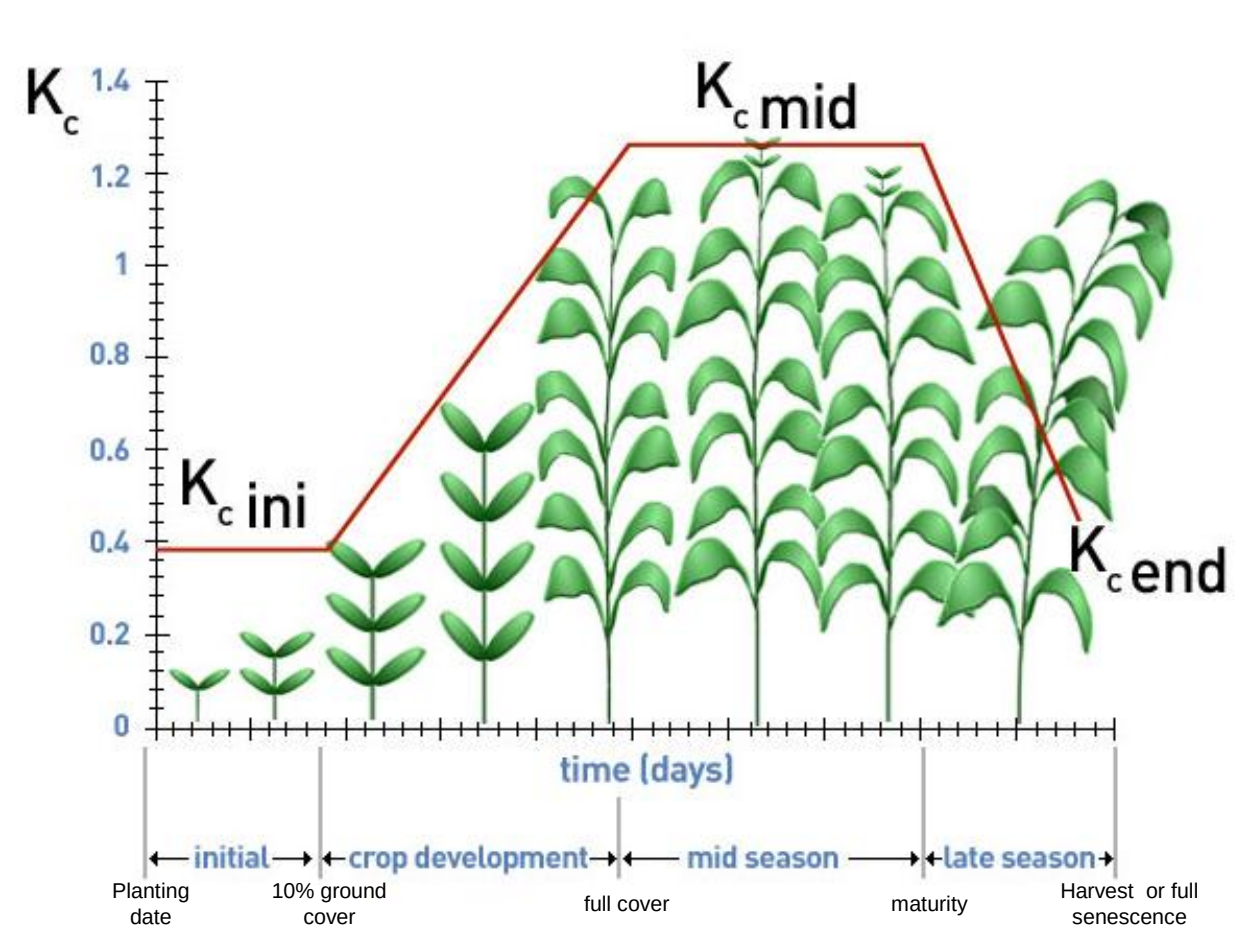
Crop parameters

- Crop coefficients (Kc)
  - Global → CROPWAT (FAO, 2009a)
  - Regional → Table 12 in Allen et al. (1998)
  - Climate region → Chapagain and Hoekstra (2004) (App. VI)
  - Local → Agricultural research stations, farmers

- Crop growing period (planting/green up date)
  - Global → CROPWAT (FAO, 2009a)
  - Regional → Table 11 in Allen et al. (1998)
  - Climate region → Chapagain and Hoekstra (2004) (App. VI)
  - Local → Agricultural research stations, farmers

→ Crop

Crop coefficient curve



Lenght of growth stages

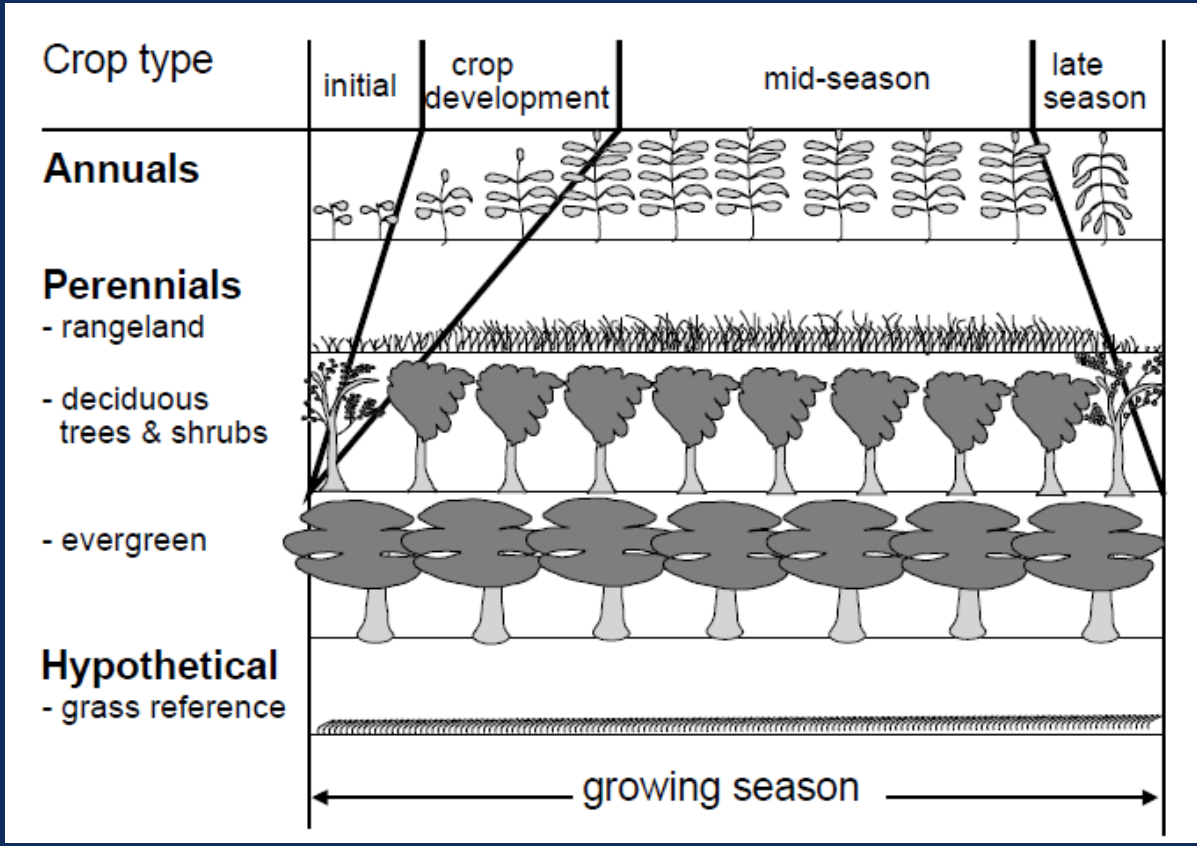
Allen et al. (1998)

Crop

Crop growth stages for different crops

Planting date

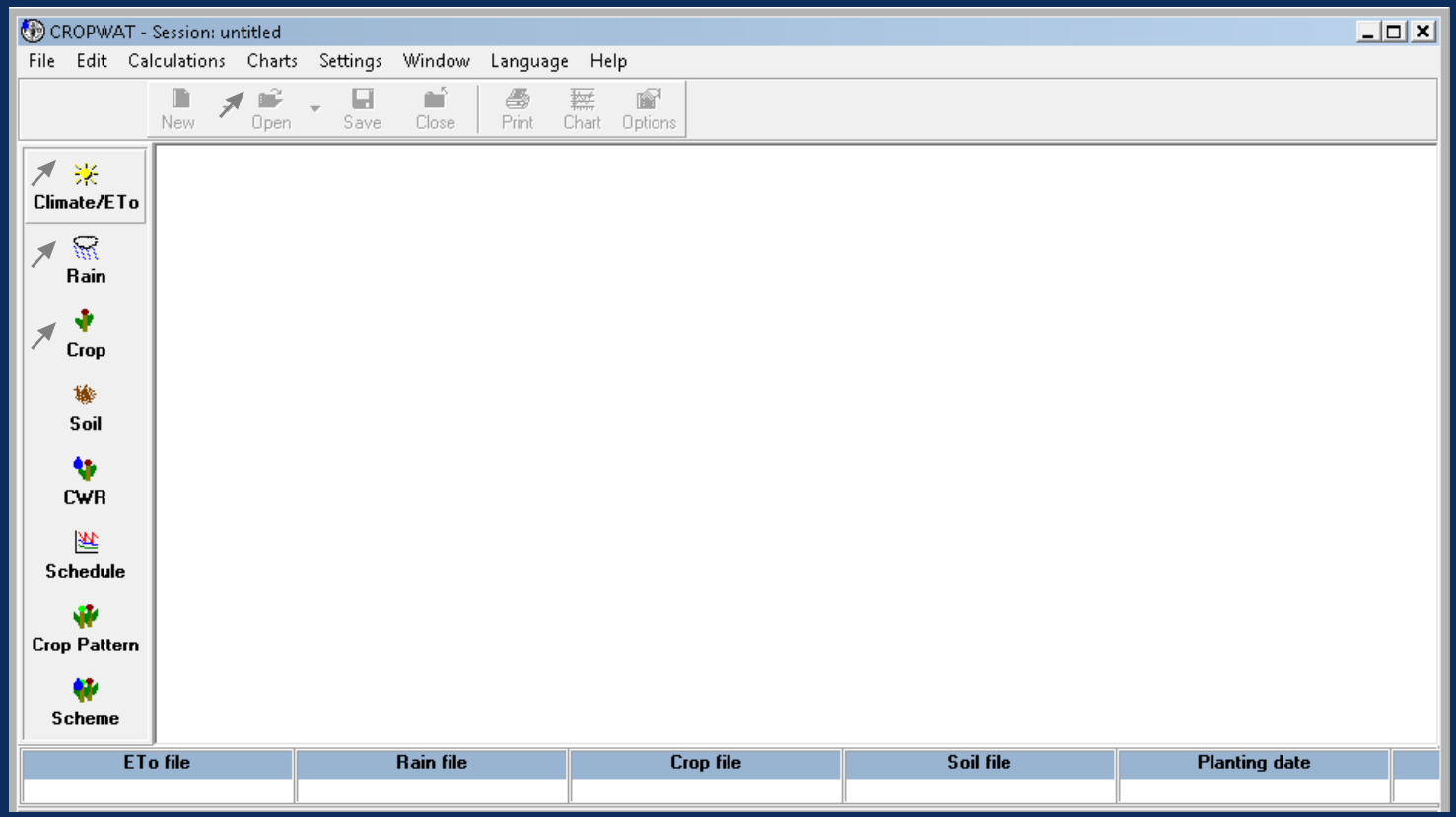
Green up date



Allen et al. (1998)

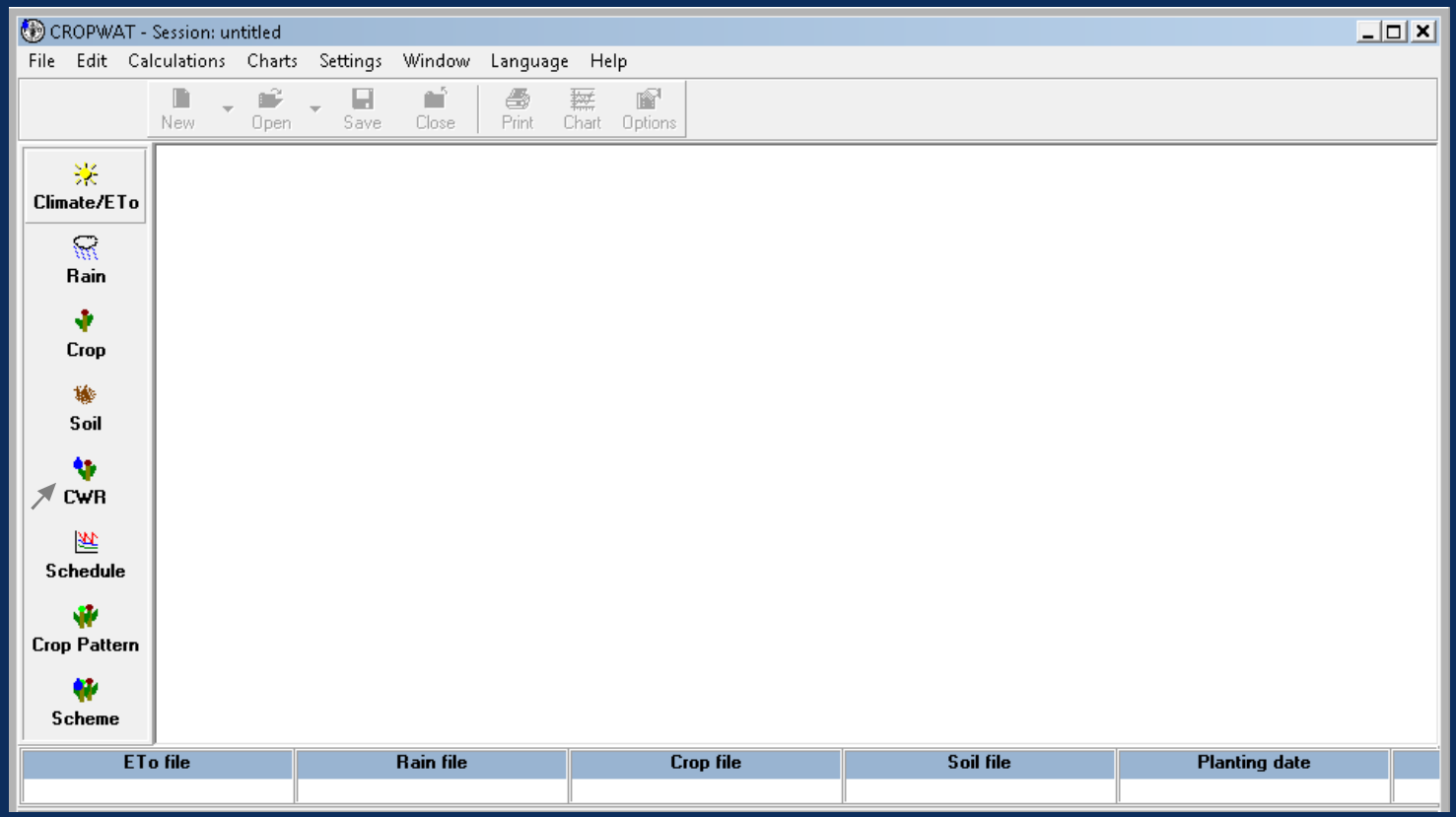
Crop

1. CWR option - input



CWR

1. CWR option - output



CWR

1. CWR option - output

Crop Water Requirements

ETo station: GRONINGEN-AP-EELD
Rain station: GRONINGEN-AP-EELD
Crop: Sugarbeet
Planting date: 10/04

CWR

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.35	0.52	0.5	1.5	0.5
Apr	2	Init	0.35	0.62	6.2	14.1	0.0
Apr	3	Init	0.35	0.72	7.2	15.2	0.0
May	1	Init	0.35	0.83	8.3	16.6	0.0
May	2	Init	0.35	0.93	9.3	17.5	0.0
May	3	Deve	0.36	1.00	11.0	18.5	0.0
Jun	1	Deve	0.51	1.51	15.1	19.5	0.0
Jun	2	Deve	0.73	2.25	22.5	20.5	2.0
Jun	3	Deve	0.95	2.90	29.0	21.1	7.9
Jul	1	Mid	1.17	3.52	35.2	22.1	13.1
Jul	2	Mid	1.23	3.67	36.7	22.9	13.8
Jul	3	Mid	1.23	3.59	39.5	21.9	17.6
Aug	1	Mid	1.23	3.50	35.0	20.3	14.7
Aug	2	Mid	1.23	3.41	34.1	19.3	14.8
Aug	3	Late	1.22	2.97	32.7	19.8	12.9
Sep	1	Late	1.11	2.33	23.3	20.6	2.7
Sep	2	Late	0.98	1.73	17.3	21.1	0.0
Sep	3	Late	0.86	1.27	12.7	20.8	0.0
Oct	1	Late	0.76	0.91	5.5	12.2	0.0
					381.2	**345.6**	**100.1**

CWR

1. CWR option - output

Crop Water Requirements

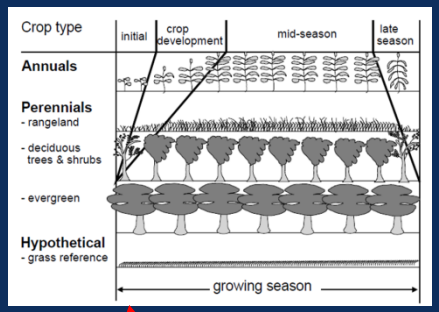
ETo station: GRONINGEN-AP-EELD
Crop: Sugarbeet
Rain station: GRONINGEN-AP-EELD
Planting date: 10/04

CWR

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.35	0.52	0.5	1.5	0.5
Apr	2	Init	0.35	0.62	6.2	14.1	0.0
Apr	3	Init	0.35	0.72	7.2	15.2	0.0
May	1	Init	0.35	0.83	8.3	16.6	0.0
May	2	Init	0.35	0.93	9.3	17.5	0.0
May	3	Deve	0.36	1.00	11.0	18.5	0.0
Jun	1	Deve	0.51				0.0
Jun	2	Deve	0.73	2.25			2.0
Jun	3	Deve	0.95	2.90	29.0	21.1	7.9
Jul	1	Mid	1.17	3.52	35.2	22.1	13.1
Jul	2	Mid	1.23	3.67	36.7	22.9	13.8
Jul	3	Mid	1.23	3.59	39.5	21.9	17.6
Aug	1	Mid	1.23	3.50	35.0	20.3	14.7
Aug	2	Mid	1.23	3.41	34.1	19.3	14.8
Aug	3	Late	1.22	2.97	32.7	19.8	12.9
Sep	1	Late	1.11	2.33	23.3	20.6	2.7
Sep	2	Late	0.98	1.73	17.3	21.1	0.0
Sep	3	Late	0.86	1.27	12.7	20.8	0.0
Oct	1	Late	0.76	0.91	5.5	12.2	0.0
					381.2	**345.6**	**100.1**

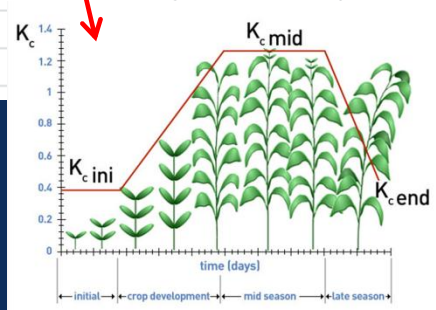
Copy table
Data only
Data and Headers

CWR



Data from CROPWAT

Month	Decade	Crop Development Stage	Crop Coefficient	Crop Evapo Transpiration	Crop Evapo transpiration	Effective Rainfall	Irrigation Requirement	Actual Irrigation
		Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Act. Irrig.
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec
Aug	1	Init	0.3	0.98	8.8	5.2	5.3	0
Aug	2	Init	0.3	1.02	10.2	4.2	7	0
Aug	3	Deve	0.43	1.55	17	5.3	12.8	0
Sep	1	Deve	0.7	2.67	26.7	6.1	21.6	0
Sep	2	Deve	0.96	3.86	38.6	7.9	32.7	0
Sep	3	Mid	1.18	5.02	50.2	10.4	41.8	0
Oct	1	Mid	1.2	5.41	54.1	12.4	43.7	0
Oct	2	Mid	1.2	5.69	56.9	14.3	44.6	0
Oct	3	Mid	1.2	5.69	62.6	19.7	45.2	0
Nov	1	Late	1.14	5.41	54.1	25.3	30.3	0
Nov	2	Late	0.88	4.14	41.4	31.9	12.5	0
Nov	3	Late	0.59	2.78	33.7	30	0	0
Dec	1	Late	0.39	1.83	9.3	12.5	0	0
					165.2	297.5		0



1. CWR option - output

$ET = ET_c$

$ET_g = \min (ET_c, P_{eff})$

$ET_b = \max (0, ET_c - P_{eff})$* Irr. Fraction (ie the volume of irrigation in reality)

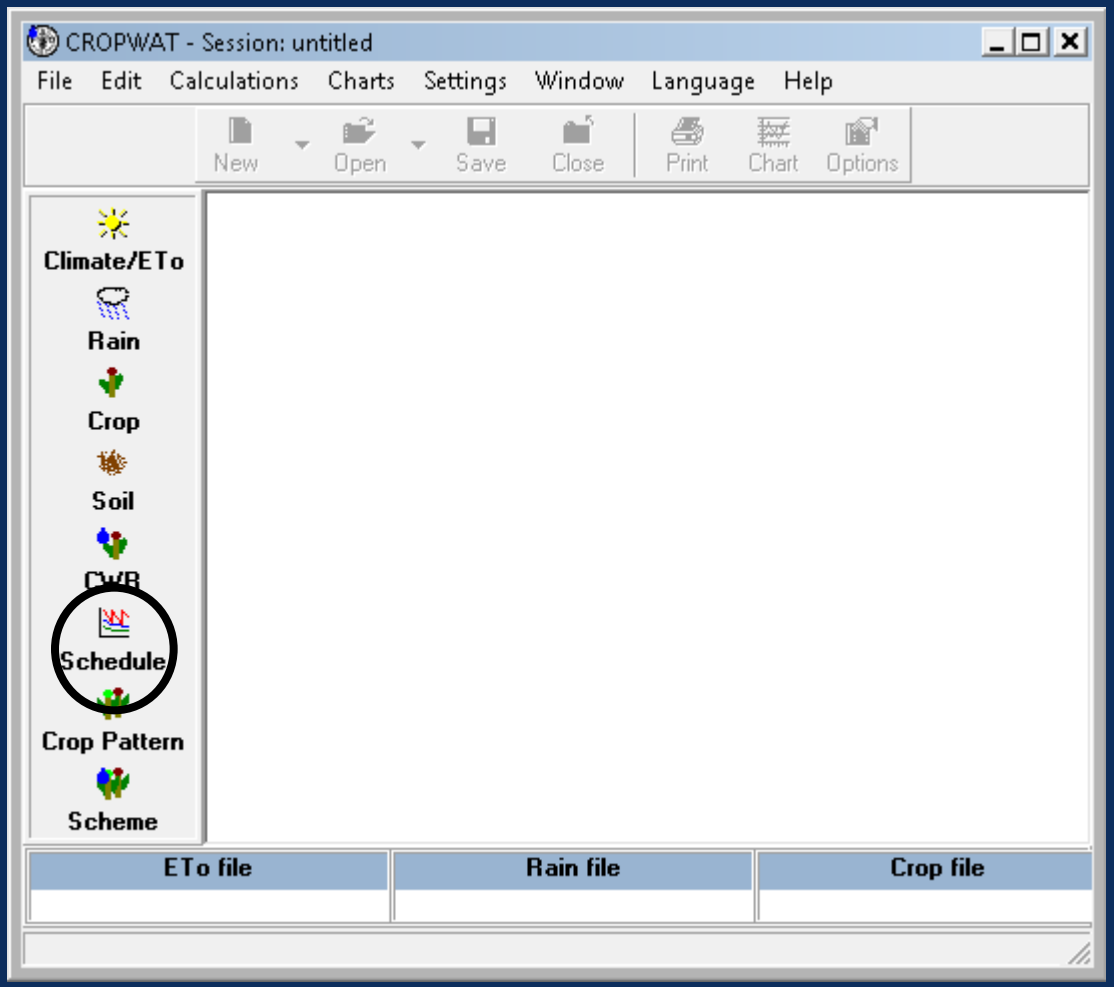
CWR

Growing period

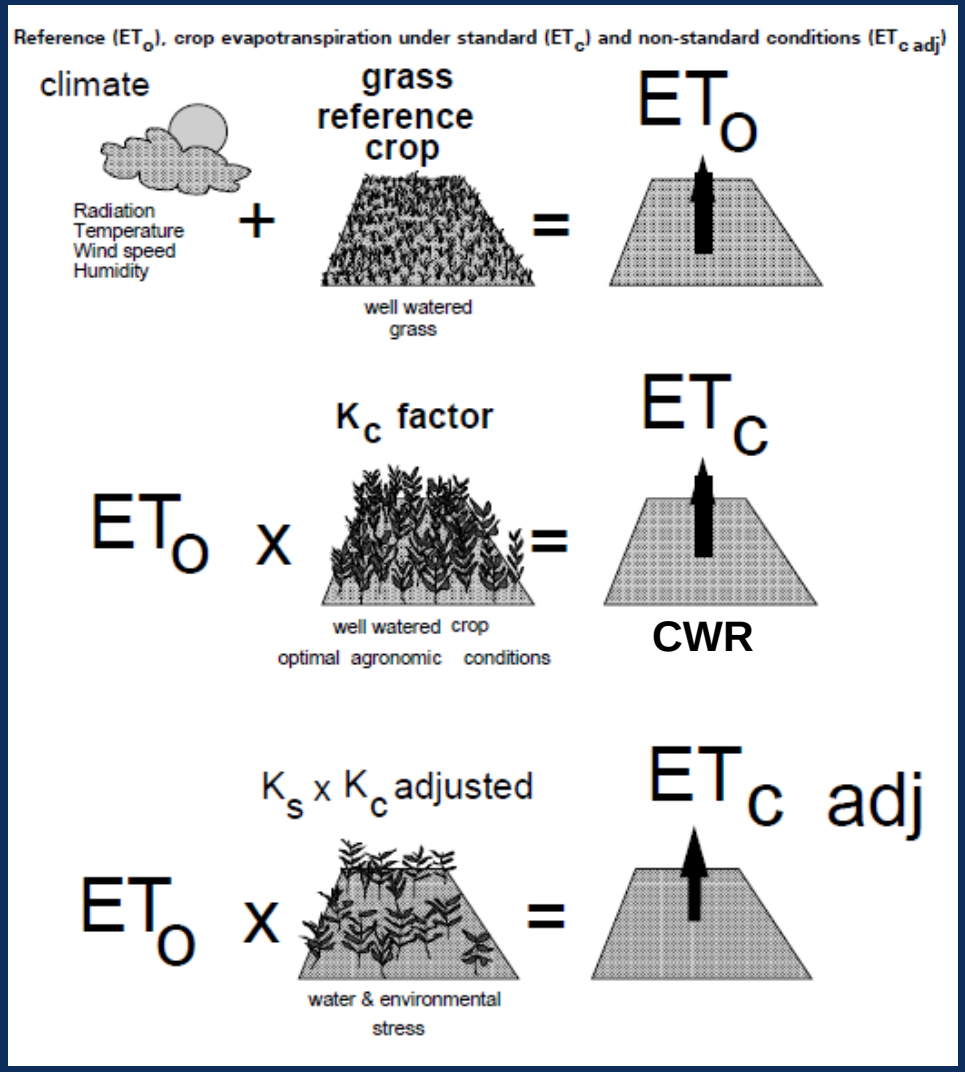
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	ET	ET_g	ET_b
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.35	0.52	0.5	1.5	0.5	0.5	0.5	0
Apr	2	Init	0.35	0.62	6.2	14.1	0	6.2	6.2	0
Apr	3	Init	0.35	0.72	7.2	15.2	0	7.2	7.2	0
May	1	Init	0.35	0.83	8.3	16.6	0	8.3	8.3	0
May	2	Init	0.35	0.93	9.3	17.5	0	9.3	9.3	0
May	3	Deve	0.36	1	11	18.5	0	11	11	0
Jun	1	Deve	0.51	1.51	15.1	19.5	0	15.1	15.1	0
Jun	2	Deve	0.73	2.25	22.5	20.5	2	22.5	20.5	2
Jun	3	Deve	0.95	2.9	29	21.1	7.9	29	21.1	7.9
Jul	1	Mid	1.17	3.52	35.2	22.1	13.1	35.2	22.1	13.1
Jul	2	Mid	1.23	3.67	36.7	22.9	13.8	36.7	22.9	13.8
Jul	3	Mid	1.23	3.59	39.5	21.9	17.6	39.5	21.9	17.6
Aug	1	Mid	1.23	3.5	35	20.3	14.7	35	20.3	14.7
Aug	2	Mid	1.23	3.41	34.1	19.3	14.8	34.1	19.3	14.8
Aug	3	Late	1.22	2.97	32.7	19.8	12.9	32.7	19.8	12.9
Sep	1	Late	1.11	2.33	23.3	20.6	2.7	23.3	20.6	2.7
Sep	2	Late	0.98	1.73	17.3	21.1	0	17.3	17.3	0
Sep	3	Late	0.86	1.27	12.7	20.8	0	12.7	12.7	0
Oct	1	Late	0.76	0.91	5.5	12.2	0	5.5	5.5	0
Total					381	346	100	381	282	100

CWR

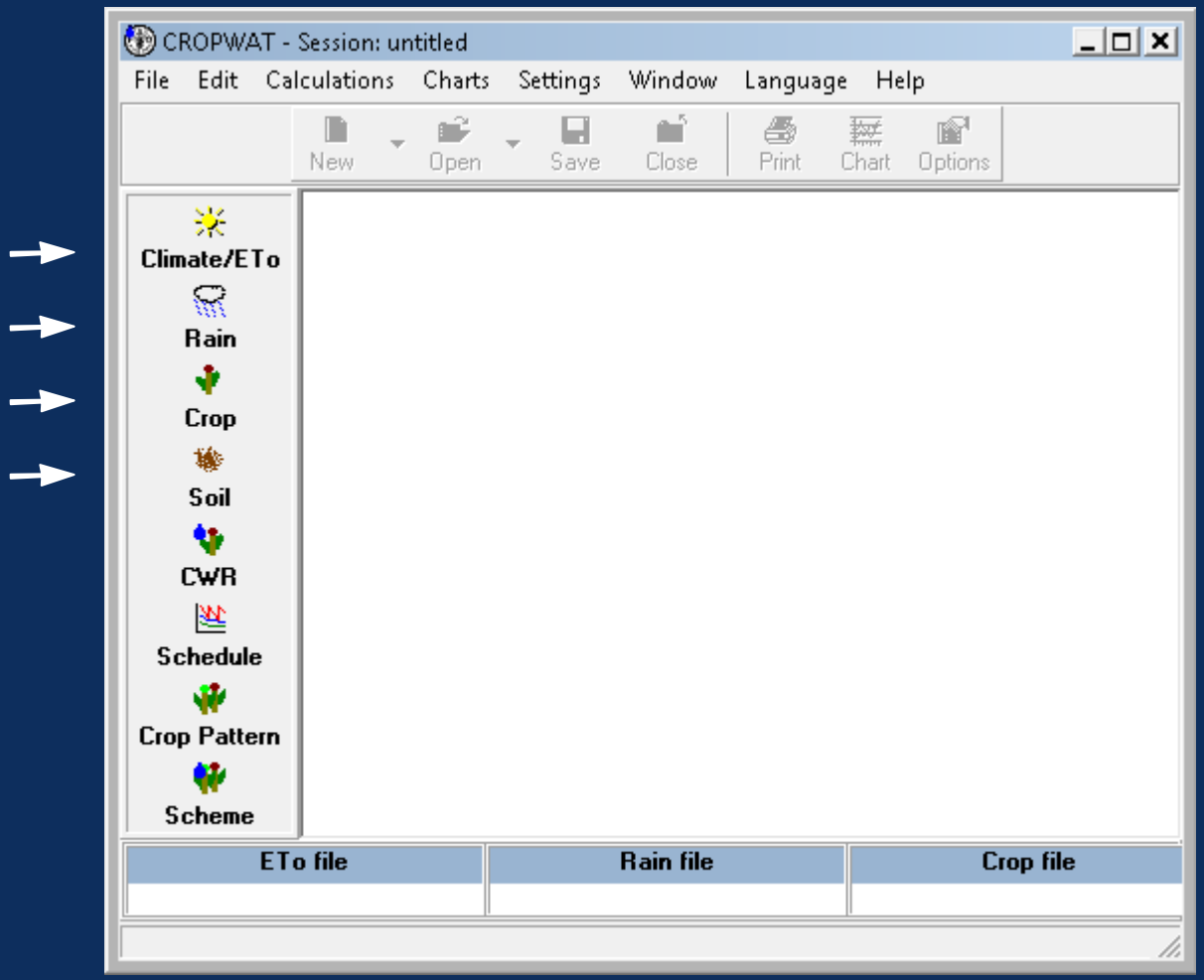
2. Irrigation schedule option



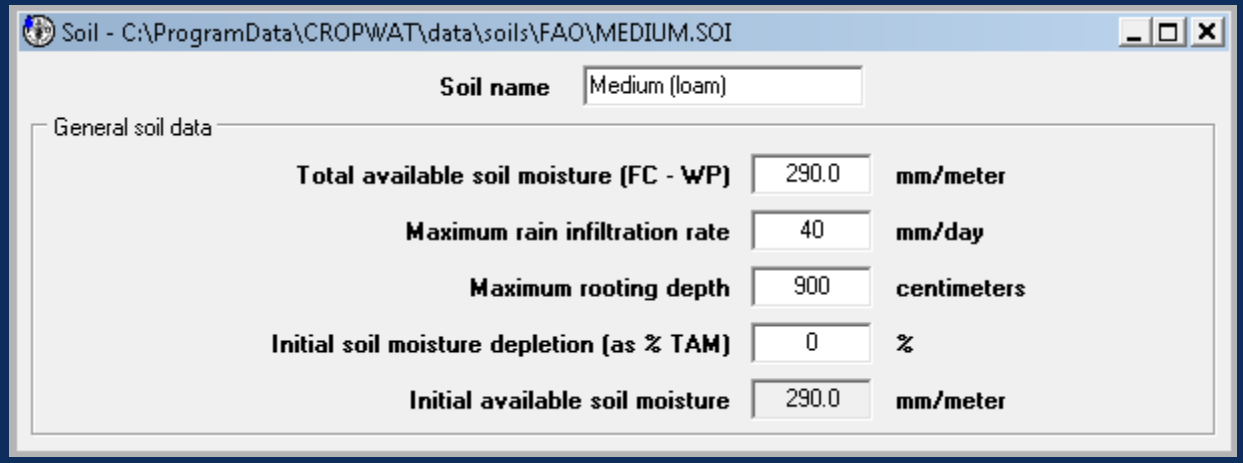
2. Irrigation schedule option



2. Irrigation schedule option input



Soil data (FAO, 2009a)



Soil data (FAO, 2009a)

Field Capacity (FC)

-The amount of moisture that remains in the soil after the excess water has drained away.

- FC varies with soil type

Wilting Point (WP)

-The minimum amount of soil moisture required for a plant to remain upright.

- If soil contains less moisture than the wilting point for that plant, it will wilt, but can recover.

Total Available Water

- Water held in the soil available to plants

- Difference between the water content at field capacity and wilting point

Readily Available Water

- Fraction of TAW that a crop can extract from the root zone without suffering water stress

Soil

Actual evapotranspiration

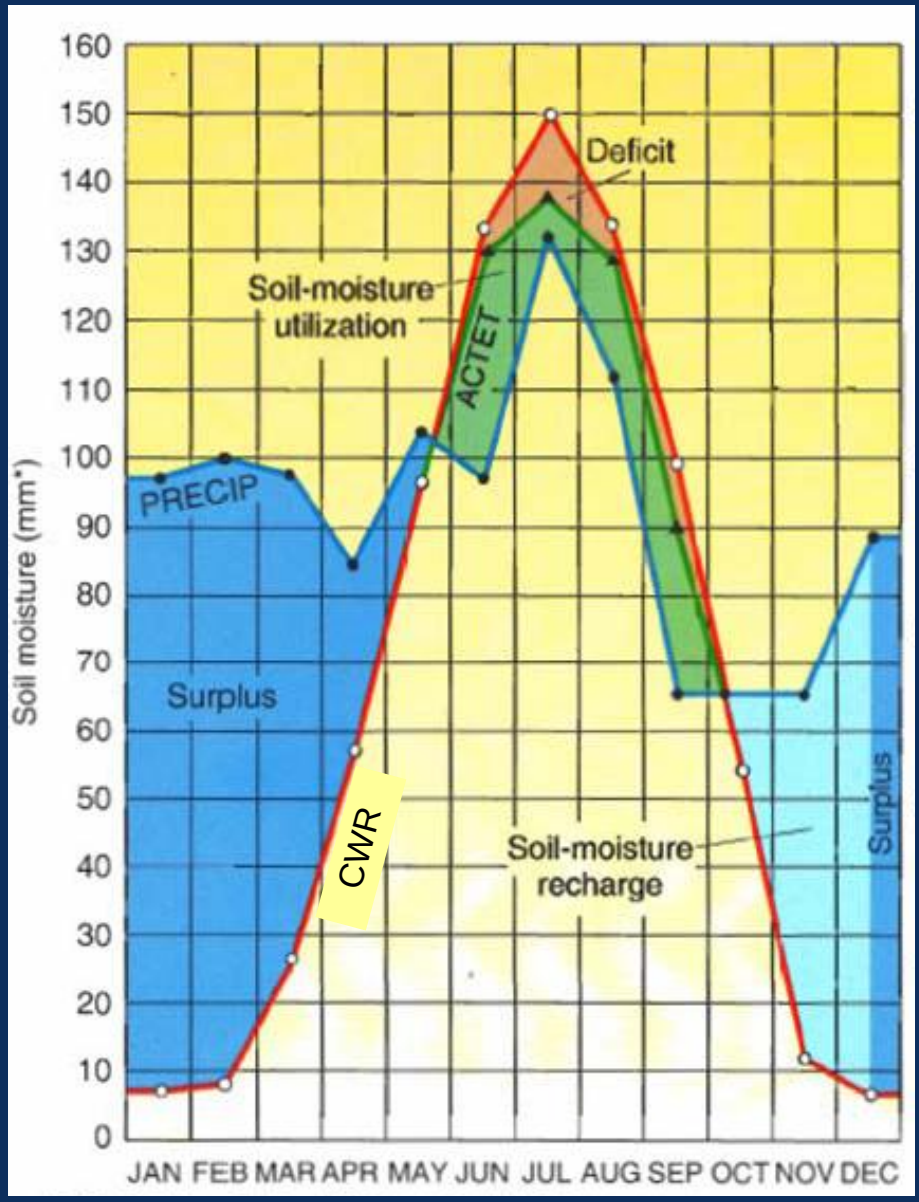
Reference evapotranspiration
ET_o

↓

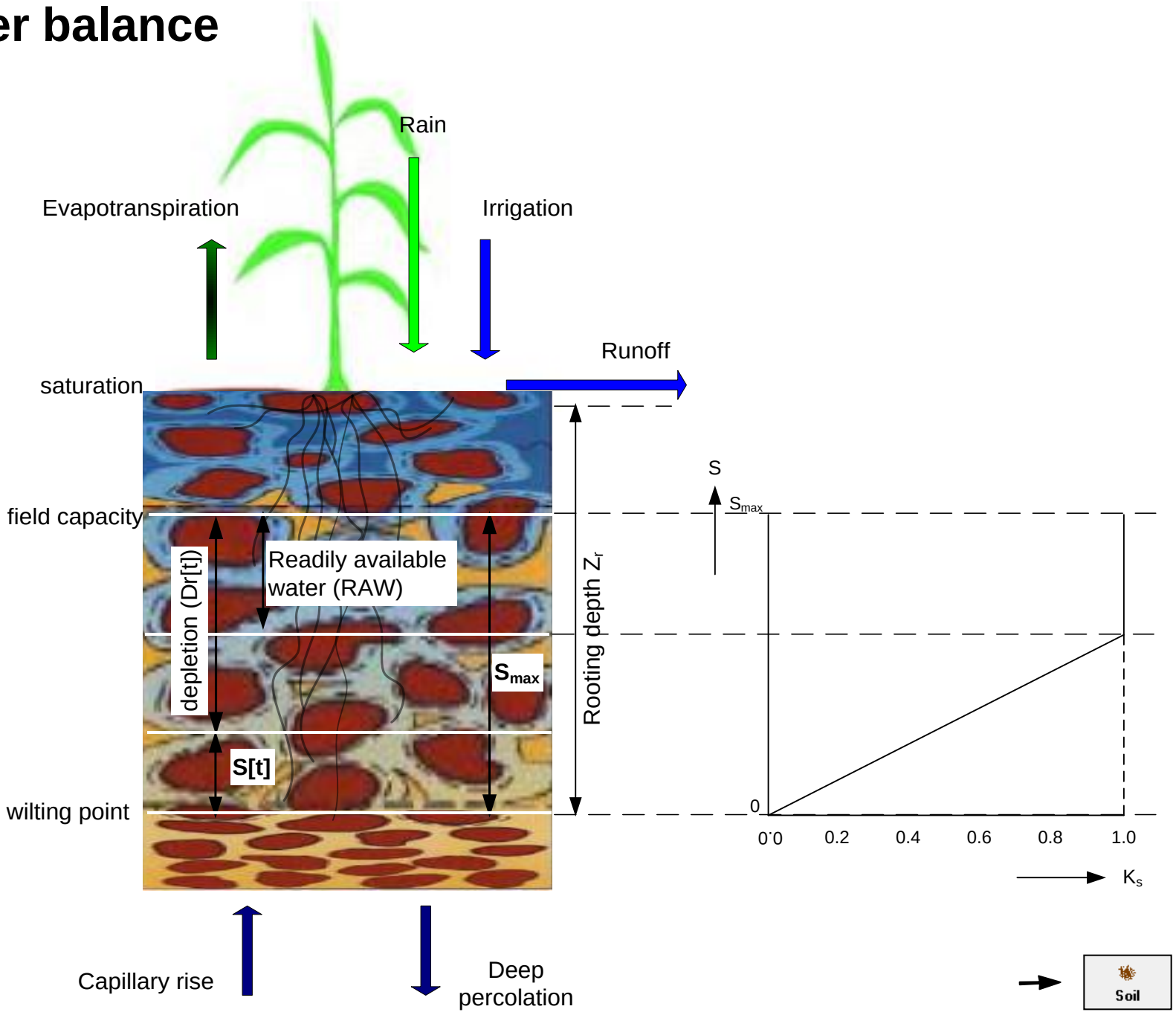
Crop water requirement
CWR
$CWR = ET_o \times K_c$

↓

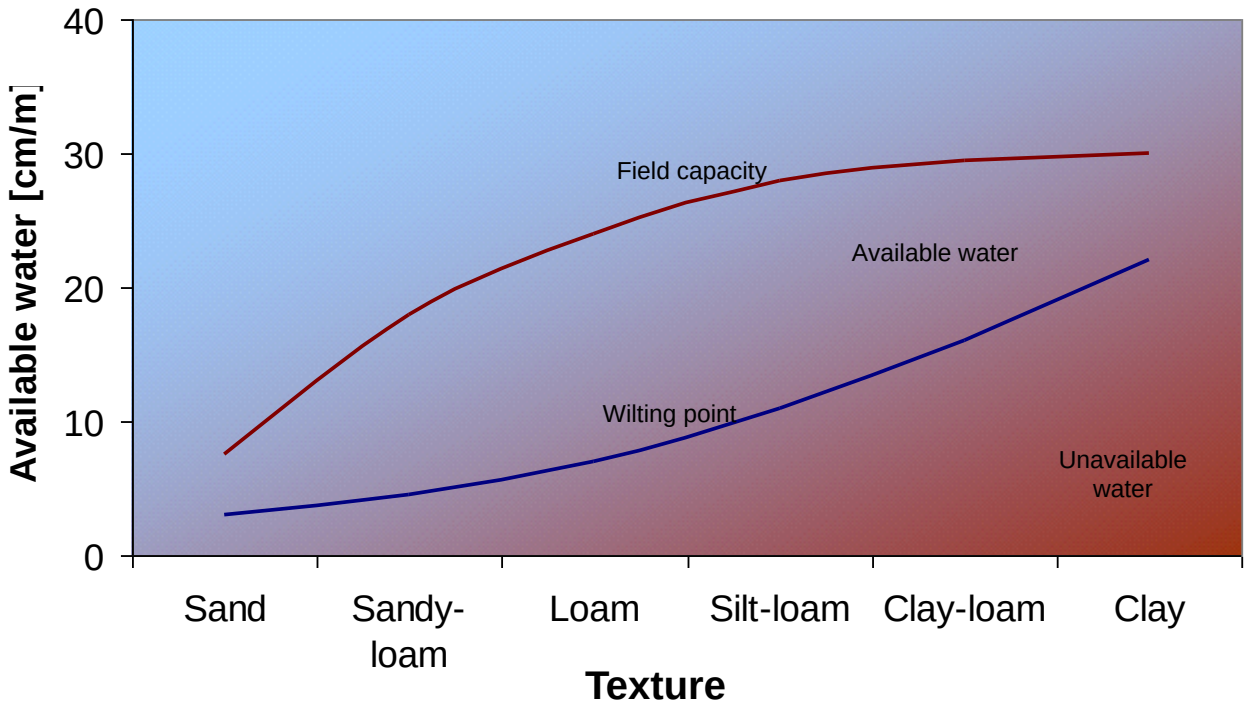
Actual evapotranspiration ET_a
$ET_a = CWR \times K_s$



Soil water balance

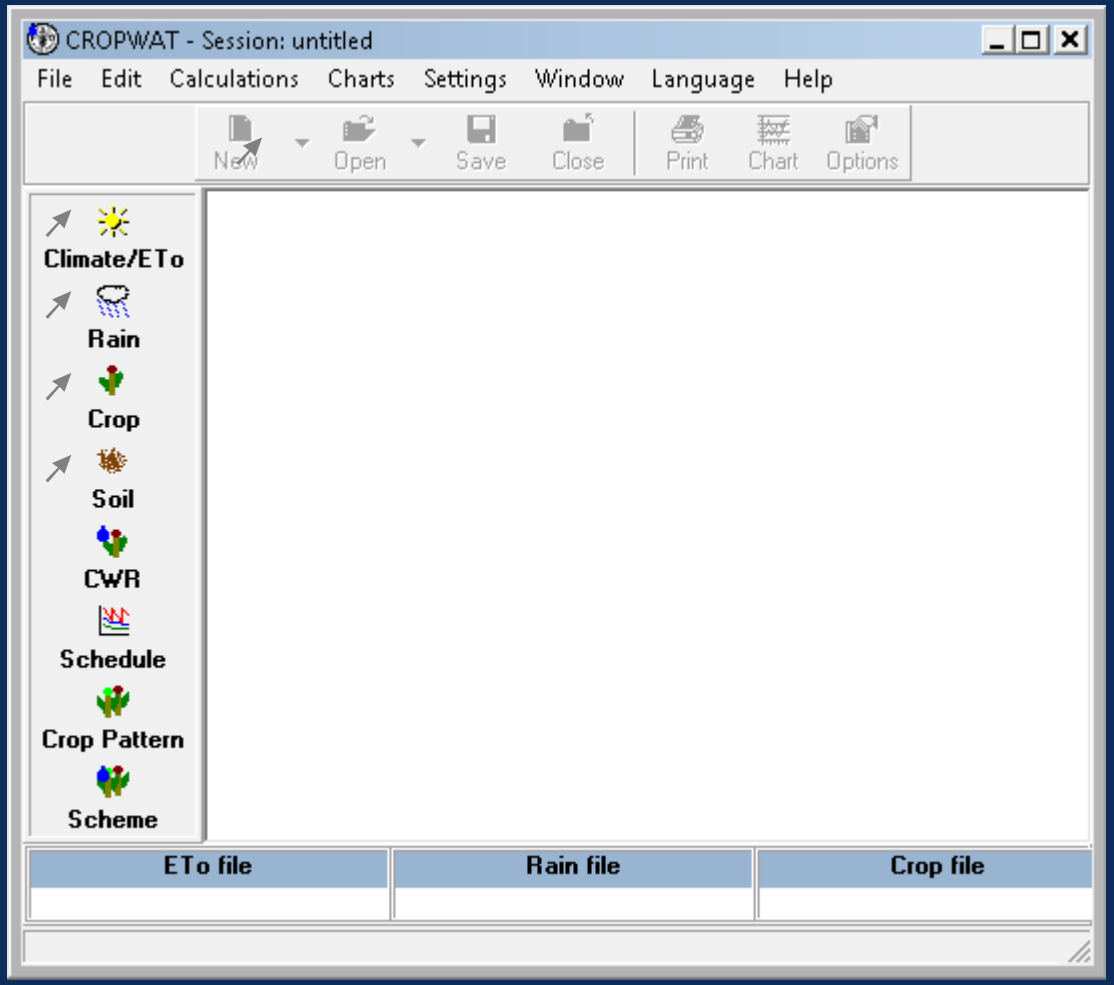


Soil water balance



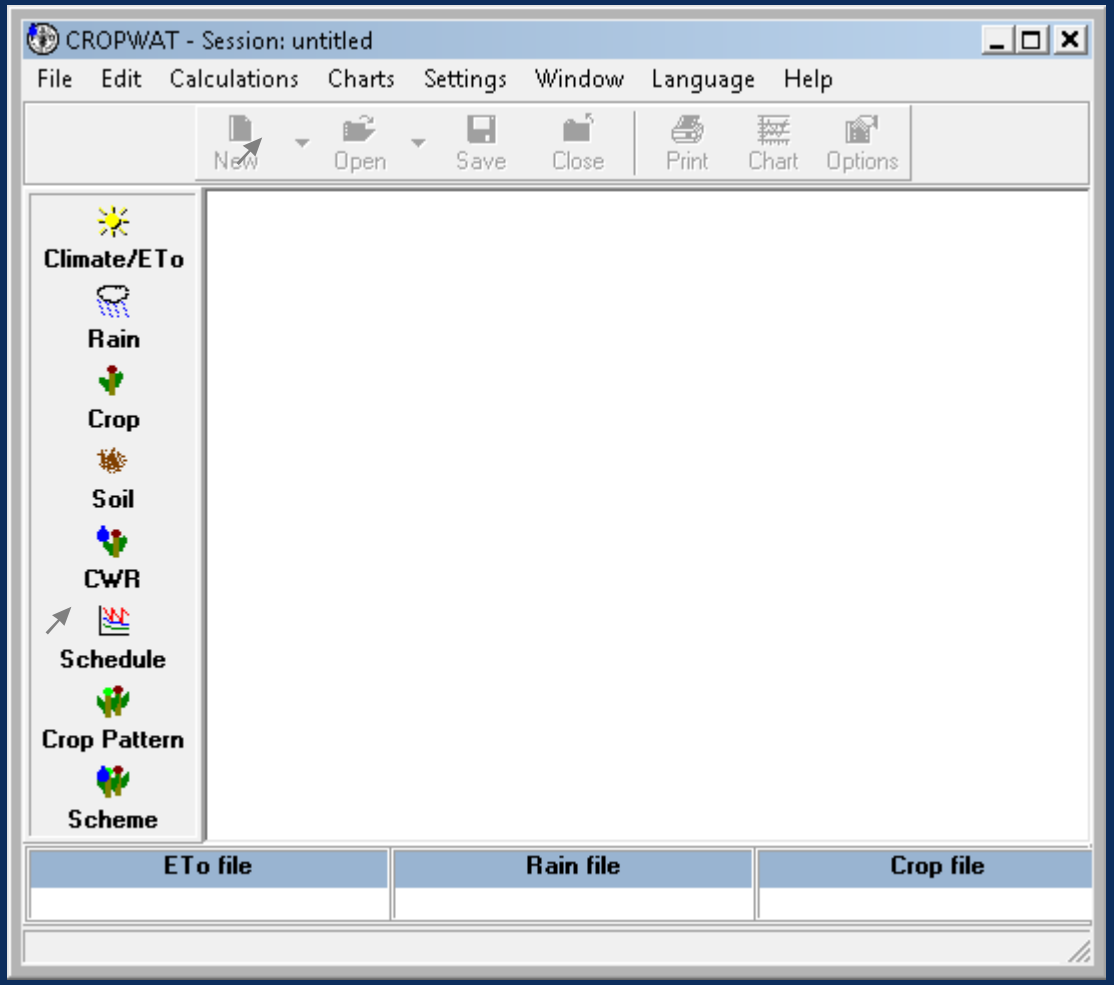
Soil

2. Irrigation schedule option – input



Schedule

2. Irrigation schedule option – output



Schedule

2. Irrigation schedule option - output

Crop irrigation schedule

ETo station: GRONINGEN-AP-EELD | Crop: Sugarbeet | Planting date: 10/04 | Yield red.: 0.0 %

Rain station: GRONINGEN-AP-EELD | Soil: Medium (loam) | Harvest date: 06/10

Table format
- Irrigation schedule
- Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff.: 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr
			mm	fract.	mm/day	%	mm	mm	mm	mm
10 Apr	1	Init	0.0	1.00	0.5	1	0.0	0.5	0.0	0.0
11 Apr	2	Init	0.0	1.00	0.6	1	0.0	1.1	0.0	0.0
12 Apr	3	Init	0.0	1.00	0.6	2	0.0	1.8	0.0	0.0
13 Apr	4	Init	7.6	1.00	0.6	1	0.0	0.6	0.0	0.0
14 Apr	5	Init	0.0	1.00	0.6	1	0.0	1.2	0.0	0.0
15 Apr	6	Init	0.0	1.00	0.6	2	0.0	1.8	0.0	0.0
16 Apr	7	Init	0.0	1.00	0.6	2	0.0	2.5	0.0	0.0
17 Apr	8	Init	7.6	1.00	0.6	1	0.0	0.6	0.0	0.0

Totals

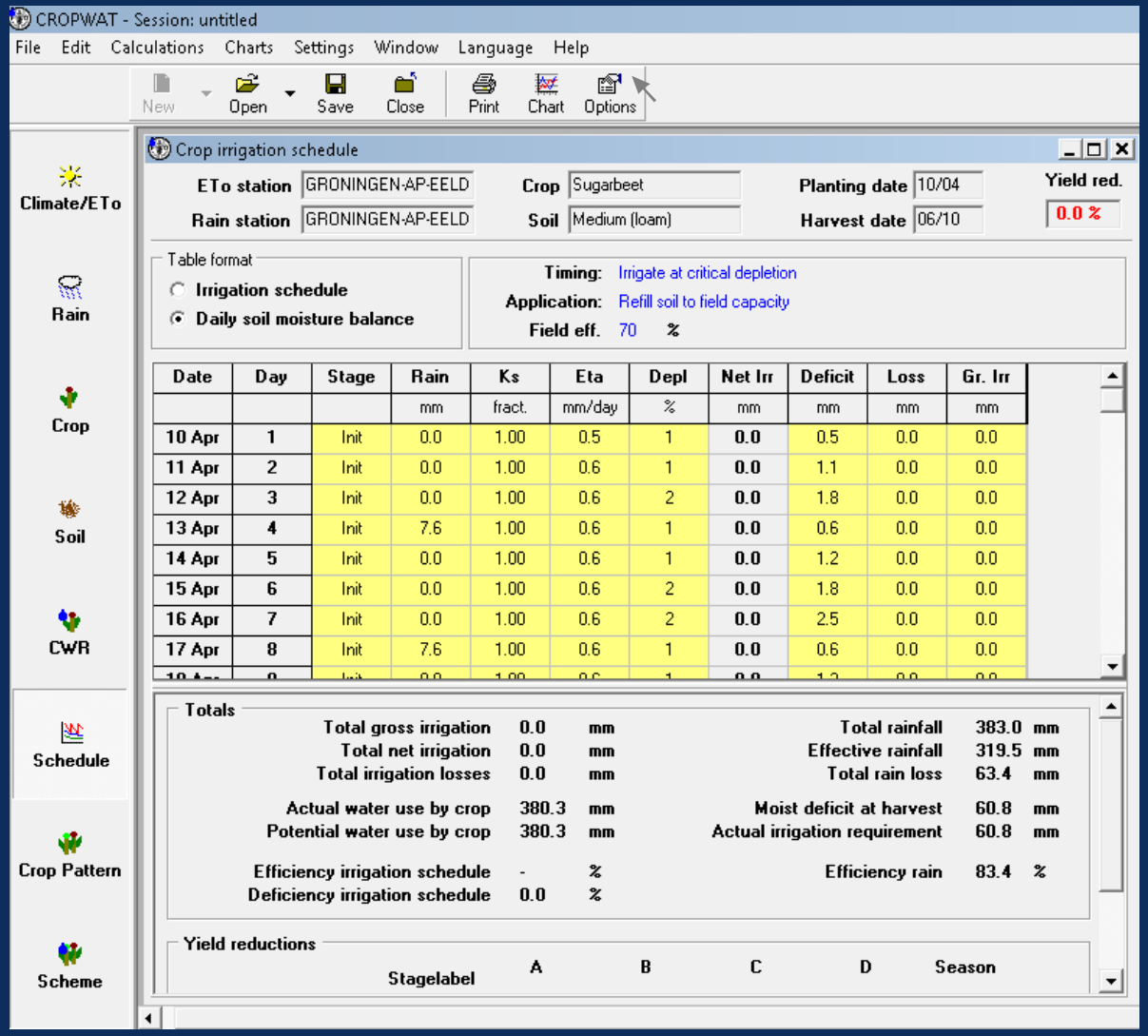
Total gross irrigation	0.0	mm	Total rainfall	383.0	mm
Total net irrigation	0.0	mm	Effective rainfall	319.5	mm
Total irrigation losses	0.0	mm	Total rain loss	63.4	mm
Actual water use by crop	380.3	mm	Moist deficit at harvest	60.8	mm
Potential water use by crop	380.3	mm	Actual irrigation requirement	60.8	mm
Efficiency irrigation schedule	-	%	Efficiency rain	83.4	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season

Schedule

2. Irrigation schedule option - output



2. Irrigation schedule option - output

Rainfed conditions

ET_{green} (irr = 0) = ET_{tot} (irr = 0)

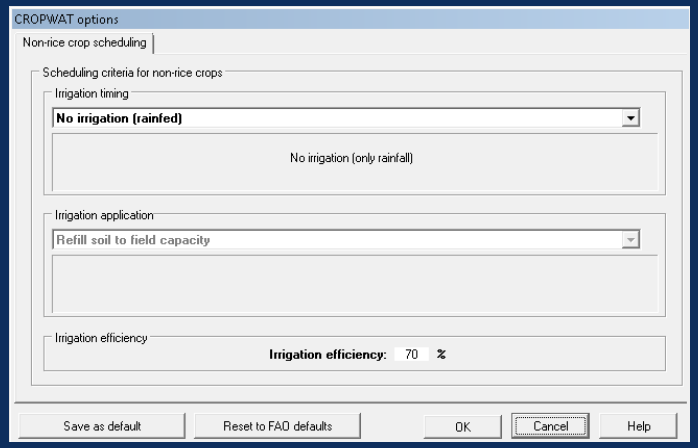
ET_{blue} (irr = 0) = 0

Irrigated conditions

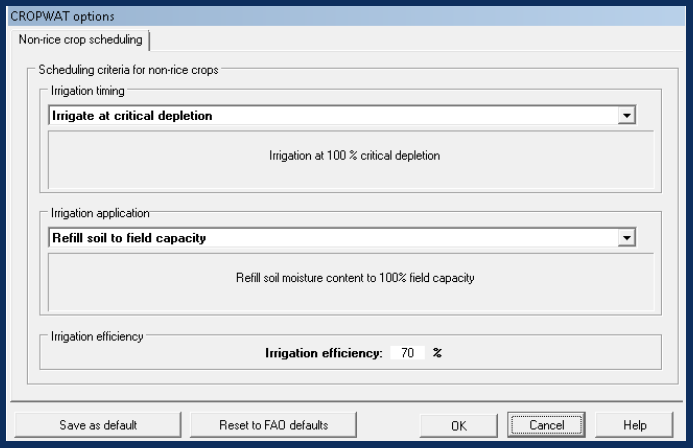
ET_{green} (irr = 1) = ET_{green} (irr = 0)

ET_{blue} (irr = 1) = ET_{tot} (irr = 1) – ET_{green} (irr = 0)

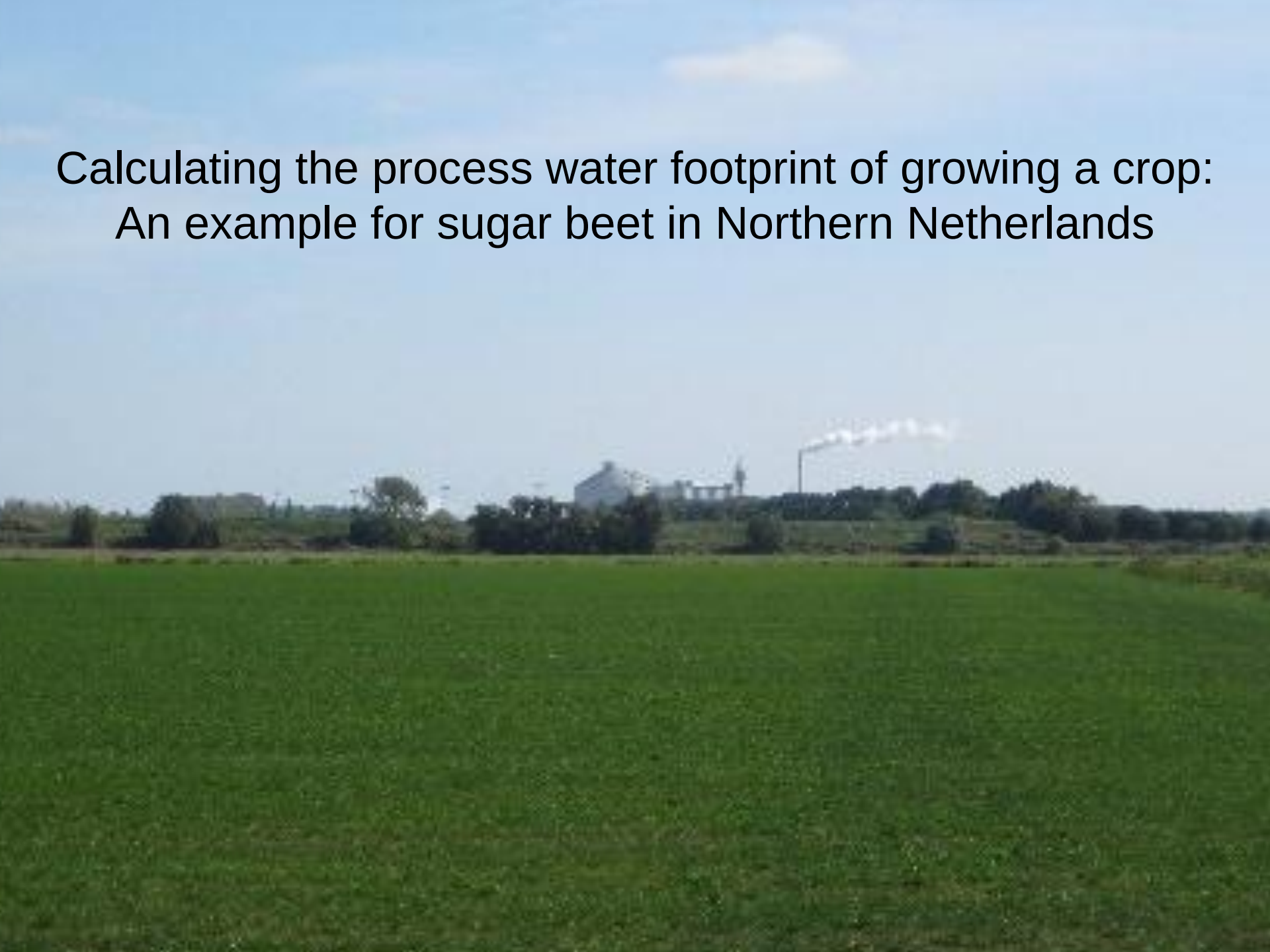
Rainfed scenario (irr = 0)



Irrigated scenario (irr = 1)

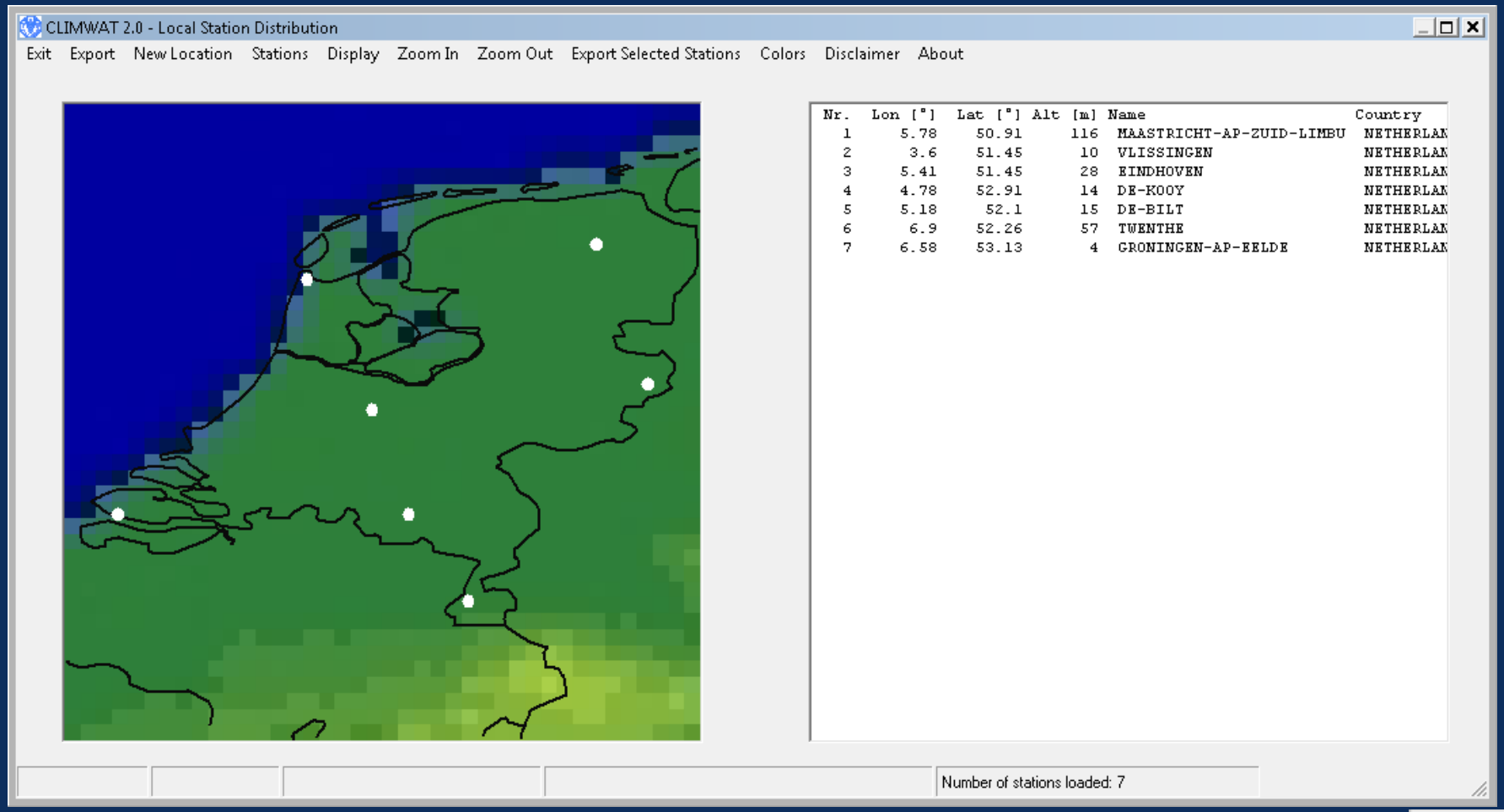


Calculating the process water footprint of growing a crop: An example for sugar beet in Northern Netherlands



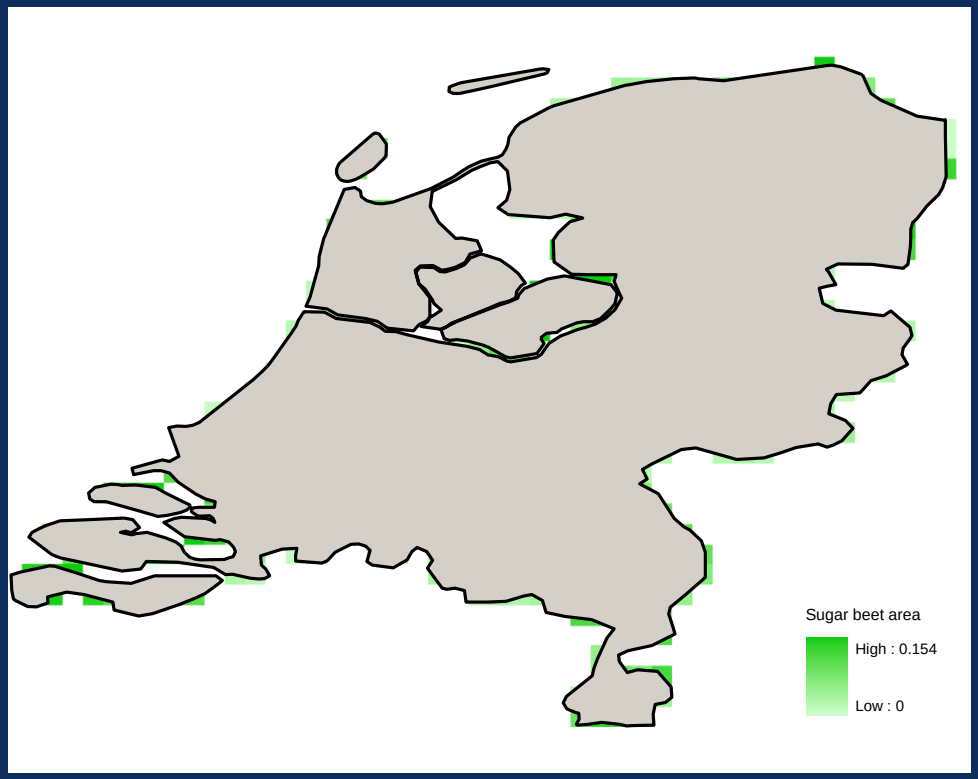
Climate data - **CLIMWAT** database (FAO, 2006)

Observed agroclimatic data of over 5000 stations worldwide (tries to cover 1971-2000)



Climate/ETo
Rain

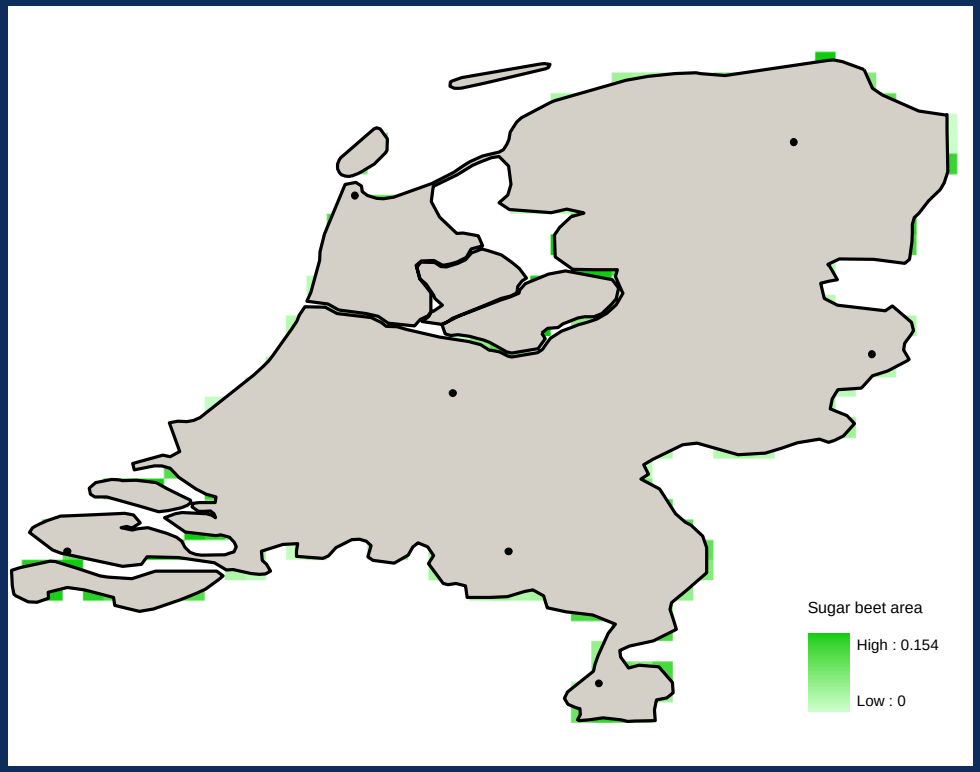
Crop distribution maps



Sugar beet harvested area in the Netherlands
(unit: proportion of grid cell area) Source: Monfreda et al. (2008)

Climate/ETo
Rain

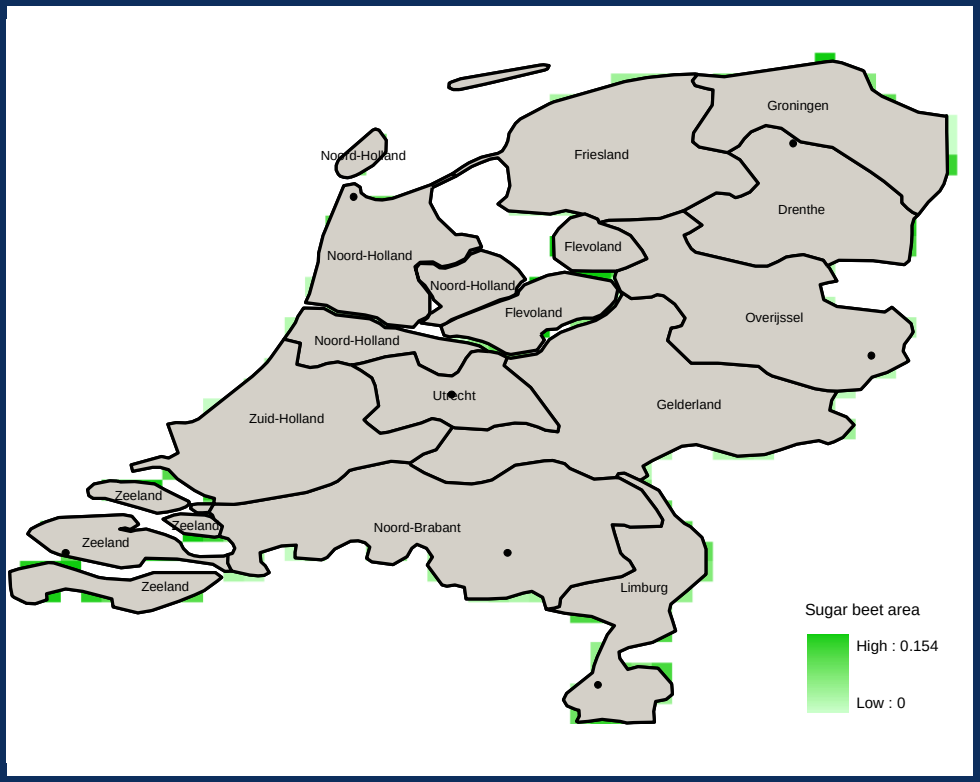
Crop distribution maps – Climate data



Climate stations (dots) and sugar beet harvested area in the Netherlands
(unit: proportion of grid cell area) Source: FAO (2006) Monfreda et al. (2008)

Climate/ETo
Rain

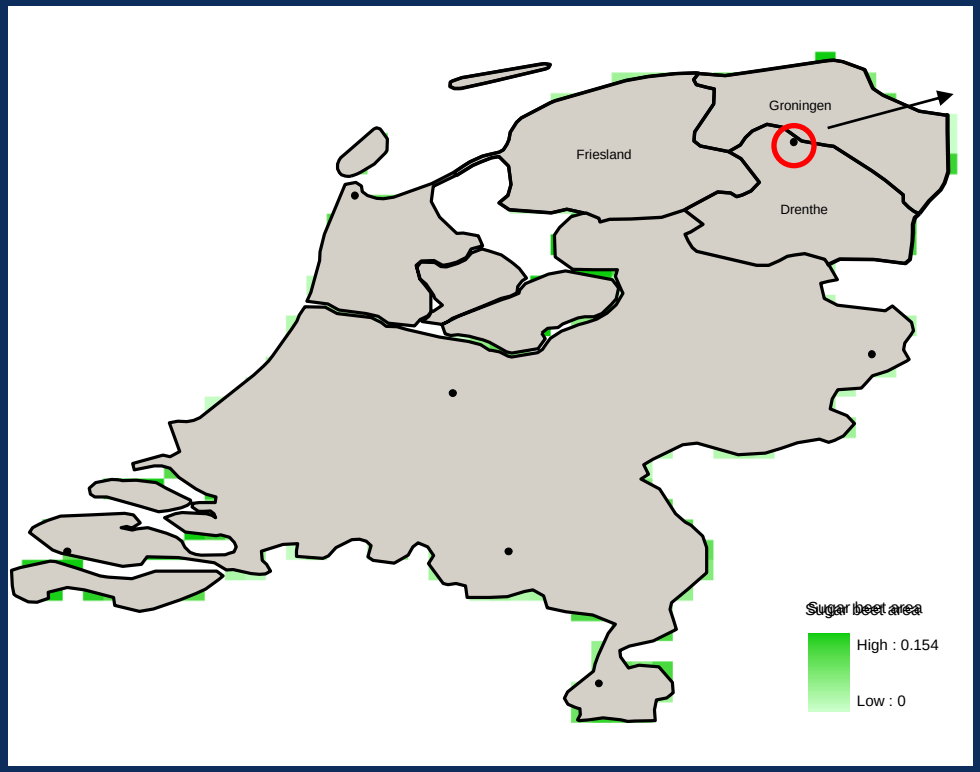
Crop distribution maps – Climate data



Climate stations (dots) and sugar beet harvested area in the Netherlands
(unit: proportion of grid cell area) Source: FAO (2006) Monfreda et al. (2008)

Climate/ETo
Rain

Crop distribution maps – Climate data



Groningen Ap Eelde

Climate stations (dots) and sugar beet harvested area in the Netherlands
(unit: proportion of grid cell area) Source: FAO (2006) Monfreda et al. (2008)

Climate/ETo
Rain

Climate data - CLIMWAT

.CLI

GRONINGEN-AP-EELDE.cli - Notepad

File Edit Format View Help

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      0.39            45.20            41.93
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      2.43            57.80            52.45
      2.82            68.80            61.23
      2.75            76.30            66.99
      2.53            66.40            59.35
      1.59            70.60            62.63
      0.83            68.70            61.15
      0.44            77.10            67.59
      0.22            75.50            66.38
```

ET_0* (mm/day)	Monthly rainfall (mm/month)	Monthly effective rainfall** (mm/month)

*Penman-Monteith method

**USDA Soil Conservation Service formula

.PEN

GRONINGEN-AP-EELDE.pen - Notepad

File Edit Format View Help

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       4.5        -1.4        91.9       423.4        2.05        4.60        0.39
       7.9         0.5        86.7       449.3        2.85        7.93        0.86
      11.8         2.5        81.7       397.4        5.01       13.22        1.58
      16.6         6.3        79.1       354.2        6.22       17.06        2.43
      19.5         9.3        80.6       345.6        6.11       17.95        2.82
      20.7        10.9        83.0       354.2        5.71       16.92        2.75
      21.2        10.8        82.5       319.7        5.83       15.05        2.53
      18.2         8.7        87.2       337.0        4.06       10.18        1.59
      13.7         5.9        90.8       354.2        2.45        5.78        0.83
       8.3         2.3        92.5       440.6        1.06        2.77        0.44
       4.9        -0.2        95.7       449.3        0.13        1.53        0.22
```

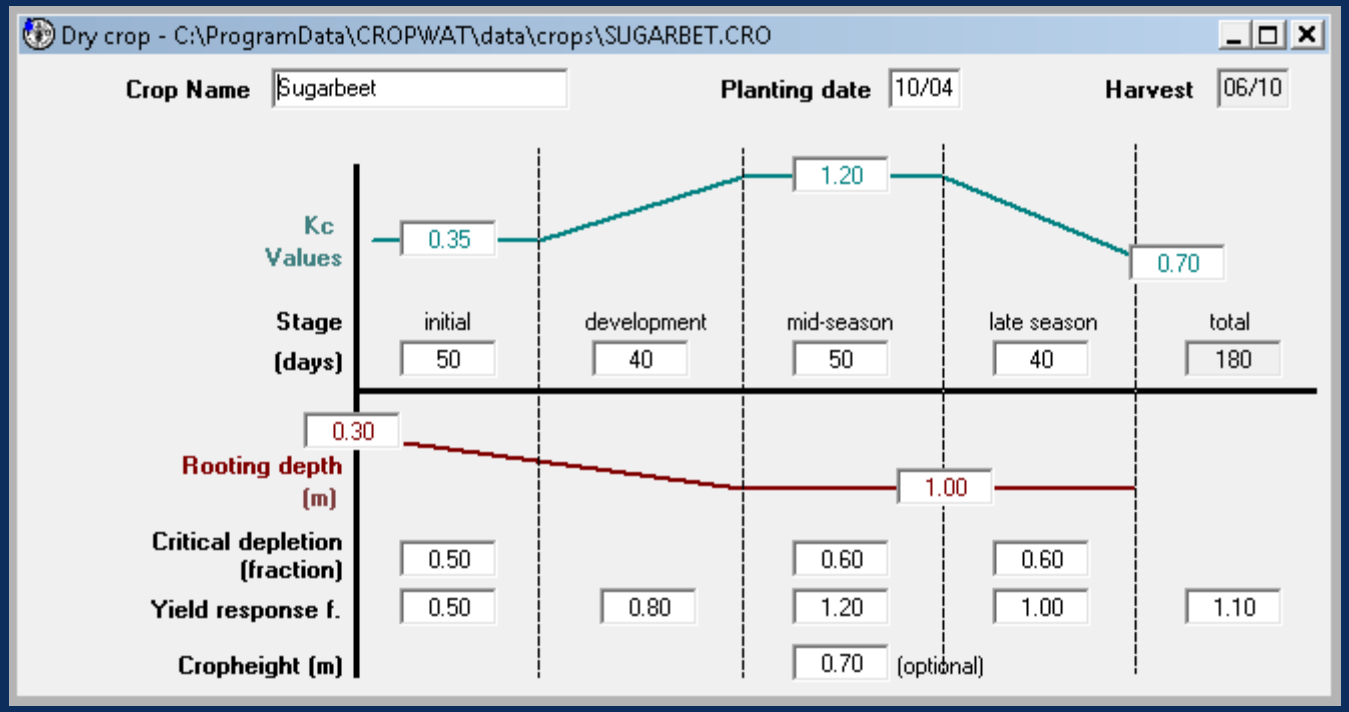
Mean daily maximum temp. (ºC)	Mean daily minimum temp. (ºC)	Mean relative humidity (%)	Mean wind speed (km/day)	Mean sunshine hours per day	Mean solar radiation (MJ/m^2/day)	ET (mm/

Crop parameters for sugar beet

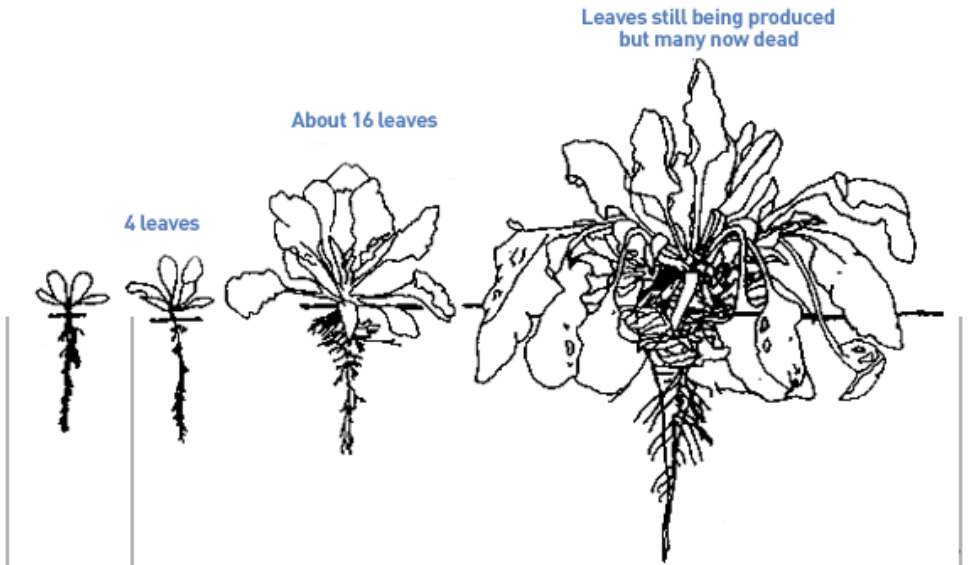
Source	Level	Kc ini	Kc mid	Kc end	Initial stage	Dev stage	Mid stage	Late stage	Planting/ Green up date	Rooting depth (m)	Critical depletion level (p)	Yield response factor (Ky)
Chapagain and Hoekstra (2004)	Per Climate Region	0.35	1.20	0.70	50	40	50	40	1 April			
Allen et al. (1998)	Per region	0.35	1.20	0.70	50	40	50	40	April			
CROPWAT (FAO, 2009a)	Global	0.35	1.20	0.70	25	35	50	50		0.3-1	0.5-0.6-0.6	0.5-0.8-1.2-1-1.1
IRS (2009)*	Local								10 April			

**Institute of Sugar Beet Research in the Netherlands*

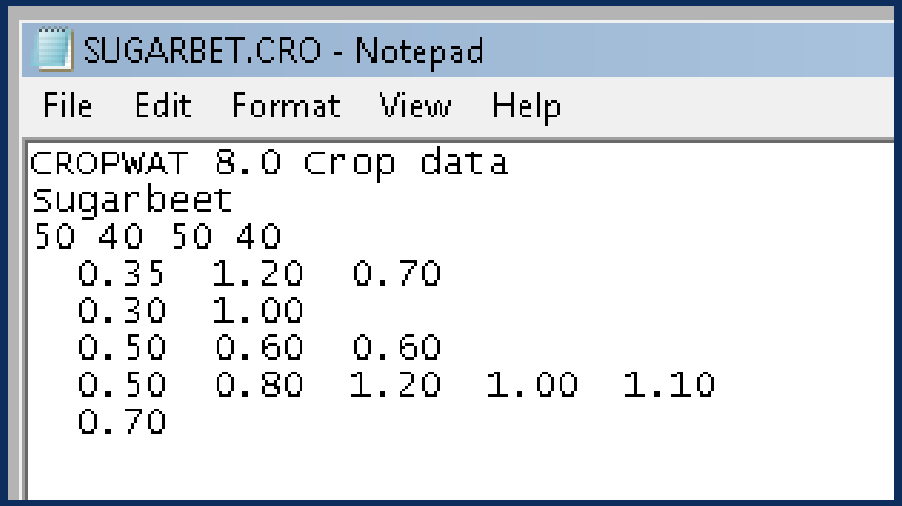
Crop parameters for sugar beet



Crop parameters for sugar beet

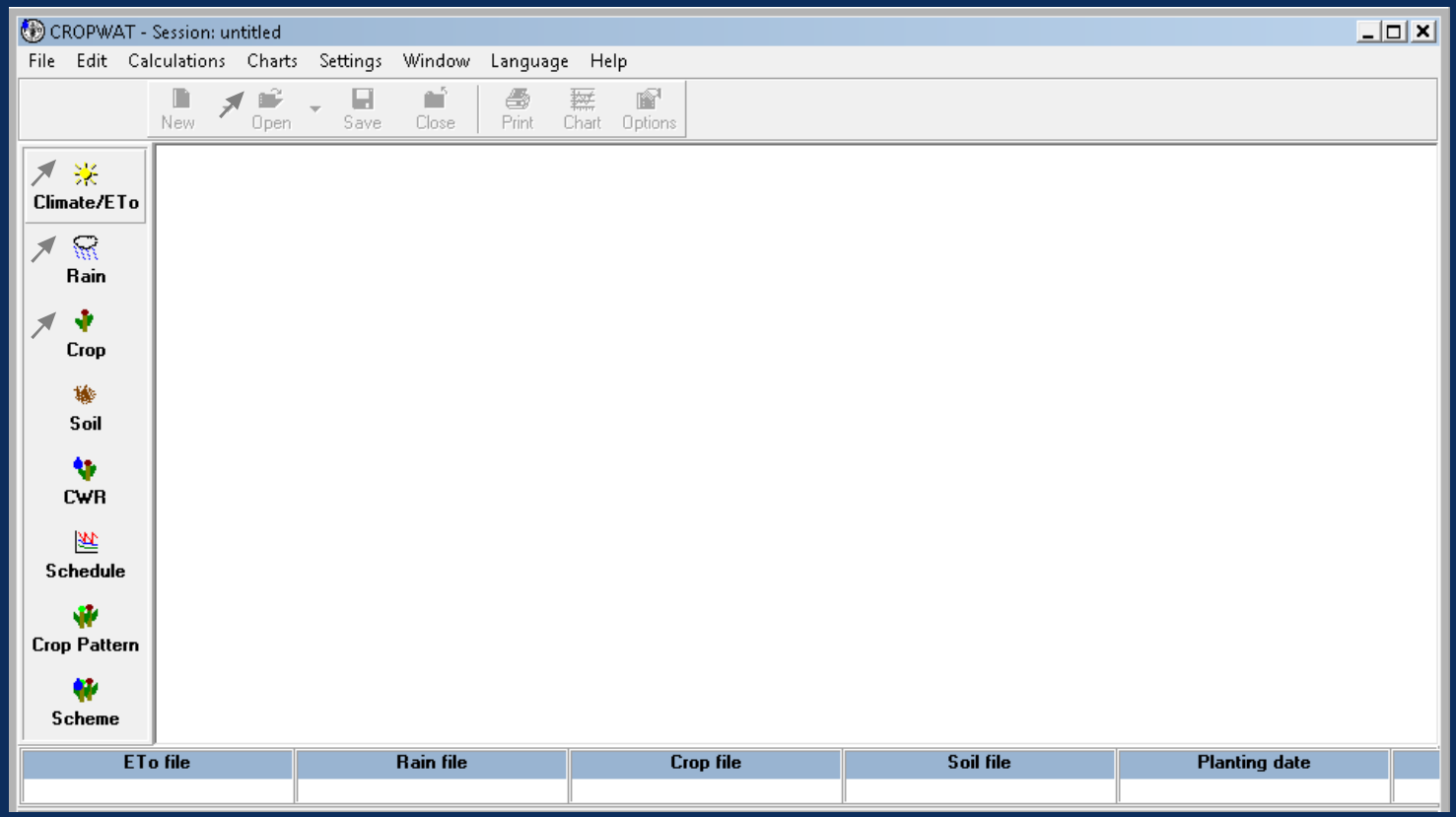


Crop parameters for sugarbeet

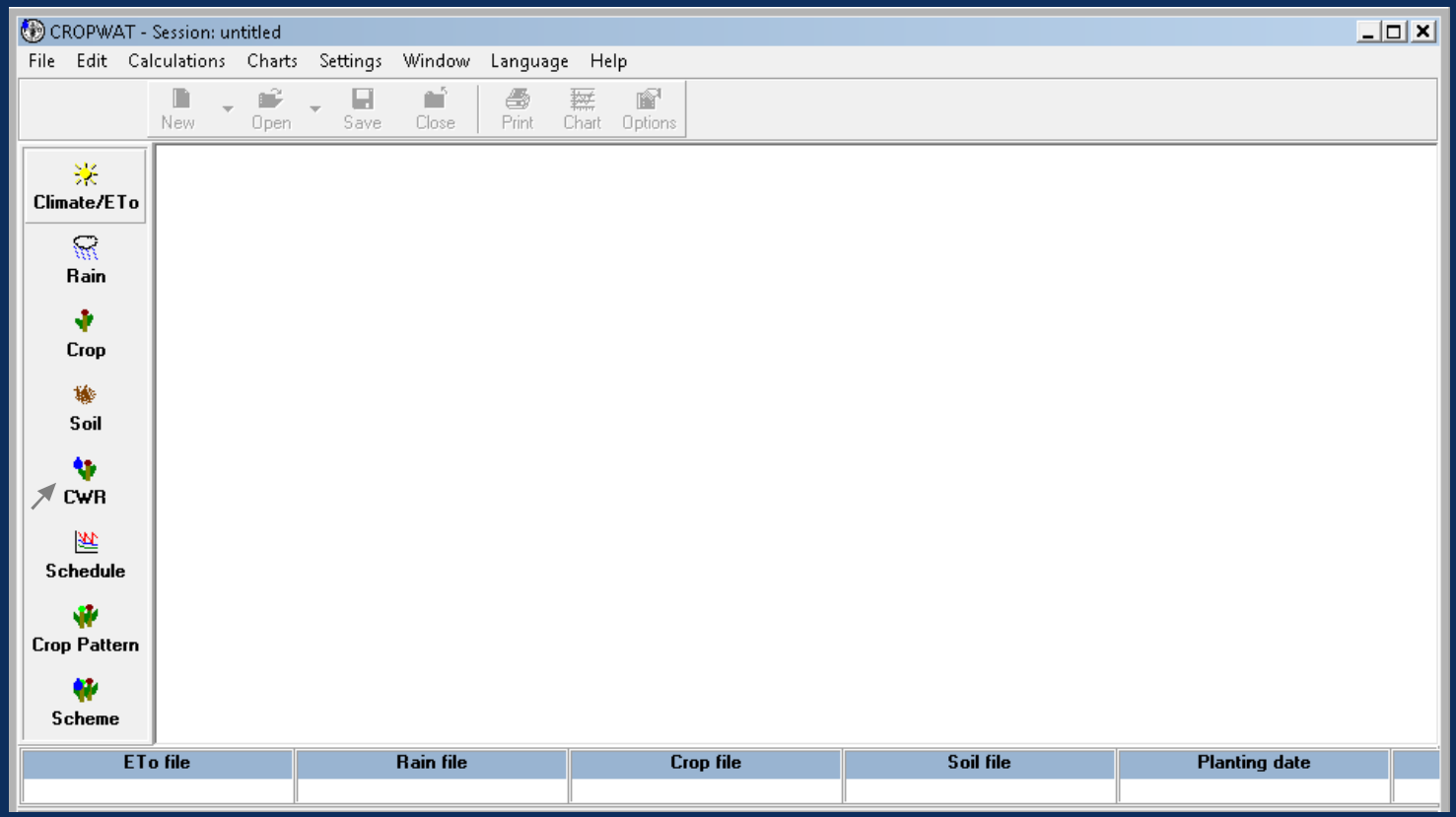


- Crop length of the growing season
- Crop coefficients (Kc init, Kc mid, Kc end)
- Rooting depth (m)
- Critical depletion level (P)
- Yield response factor (Ky)
- Height (provide if available)

1. CWR option - input



1. **CWR option** - output



1. CWR option - output

Crop Water Requirements

ETo station: GRONINGEN-AP-EELD
Rain station: GRONINGEN-AP-EELD
Crop: Sugarbeet
Planting date: 10/04

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.35	0.52	0.5	1.5	0.5
Apr	2	Init	0.35	0.62	6.2	14.1	0.0
Apr	3	Init	0.35	0.72	7.2	15.2	0.0
May	1	Init	0.35	0.83	8.3	16.6	0.0
May	2	Init	0.35	0.93	9.3	17.5	0.0
May	3	Deve	0.36	1.00	11.0	18.5	0.0
Jun	1	Deve	0.51	1.51	15.1	19.5	0.0
Jun	2	Deve	0.73	2.25	22.5	20.5	2.0
Jun	3	Deve	0.95	2.90	29.0	21.1	7.9
Jul	1	Mid	1.17	3.52	35.2	22.1	13.1
Jul	2	Mid	1.23	3.67	36.7	22.9	13.8
Jul	3	Mid	1.23	3.59	39.5	21.9	17.6
Aug	1	Mid	1.23	3.50	35.0	20.3	14.7
Aug	2	Mid	1.23	3.41	34.1	19.3	14.8
Aug	3	Late	1.22	2.97	32.7	19.8	12.9
Sep	1	Late	1.11	2.33	23.3	20.6	2.7
Sep	2	Late	0.98	1.73	17.3	21.1	0.0
Sep	3	Late	0.86	1.27	12.7	20.8	0.0
Oct	1	Late	0.76	0.91	5.5	12.2	0.0
					381.2	**345.6**	**100.1**

$IR = ETc - P_{eff}$

CWR

1. CWR option - output

Crop Water Requirements

ETo station: GRONINGEN-AP-EELD
Rain station: GRONINGEN-AP-EELD
Crop: Sugarbeet
Planting date: 10/04

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.35	0.52	0.5	1.5	0.5
Apr	2	Init	0.35	0.62	6.2	14.1	0.0
Apr	3	Init	0.35	0.72	7.2	15.2	0.0
May	1	Init	0.35	0.83	8.3	16.6	0.0
May	2	Init	0.35	0.93	9.3	17.5	0.0
May	3	Deve	0.36	1.00	11.0	18.5	0.0
Jun	1	Deve	0.51				0.0
Jun	2	Deve	0.73	2.25			2.0
Jun	3	Deve	0.95	2.90	29.0	21.1	7.9
Jul	1	Mid	1.17	3.52	35.2	22.1	13.1
Jul	2	Mid	1.23	3.67	36.7	22.9	13.8
Jul	3	Mid	1.23	3.59	39.5	21.9	17.6
Aug	1	Mid	1.23	3.50	35.0	20.3	14.7
Aug	2	Mid	1.23	3.41	34.1	19.3	14.8
Aug	3	Late	1.22	2.97	32.7	19.8	12.9
Sep	1	Late	1.11	2.33	23.3	20.6	2.7
Sep	2	Late	0.98	1.73	17.3	21.1	0.0
Sep	3	Late	0.86	1.27	12.7	20.8	0.0
Oct	1	Late	0.76	0.91	5.5	12.2	0.0
					381.2	**345.6**	**100.1**

Copy table ▸ Data only / Data and Headers

CWR

1. CWR option - output

$ET = ET_c$

$ET_g = \min (ET_c, P_{eff})$

$ET_b = \max (0, ET_c - P_{eff}) *$ Irr. fraction

Growing period

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	ET	ET_g	ET_b
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.35	0.52	0.5	1.5	0.5	0.5	0.5	0
Apr	2	Init	0.35	0.62	6.2	14.1	0	6.2	6.2	0
Apr	3	Init	0.35	0.72	7.2	15.2	0	7.2	7.2	0
May	1	Init	0.35	0.83	8.3	16.6	0	8.3	8.3	0
May	2	Init	0.35	0.93	9.3	17.5	0	9.3	9.3	0
May	3	Deve	0.36	1	11	18.5	0	11	11	0
Jun	1	Deve	0.51	1.51	15.1	19.5	0	15.1	15.1	0
Jun	2	Deve	0.73	2.25	22.5	20.5	2	22.5	20.5	2
Jun	3	Deve	0.95	2.9	29	21.1	7.9	29	21.1	7.9
Jul	1	Mid	1.17	3.52	35.2	22.1	13.1	35.2	22.1	13.1
Jul	2	Mid	1.23	3.67	36.7	22.9	13.8	36.7	22.9	13.8
Jul	3	Mid	1.23	3.59	39.5	21.9	17.6	39.5	21.9	17.6
Aug	1	Mid	1.23	3.5	35	20.3	14.7	35	20.3	14.7
Aug	2	Mid	1.23	3.41	34.1	19.3	14.8	34.1	19.3	14.8
Aug	3	Late	1.22	2.97	32.7	19.8	12.9	32.7	19.8	12.9
Sep	1	Late	1.11	2.33	23.3	20.6	2.7	23.3	20.6	2.7
Sep	2	Late	0.98	1.73	17.3	21.1	0	17.3	17.3	0
Sep	3	Late	0.86	1.27	12.7	20.8	0	12.7	12.7	0
Oct	1	Late	0.76	0.91	5.5	12.2	0	5.5	5.5	0
Total					381	346	100	381	282	100

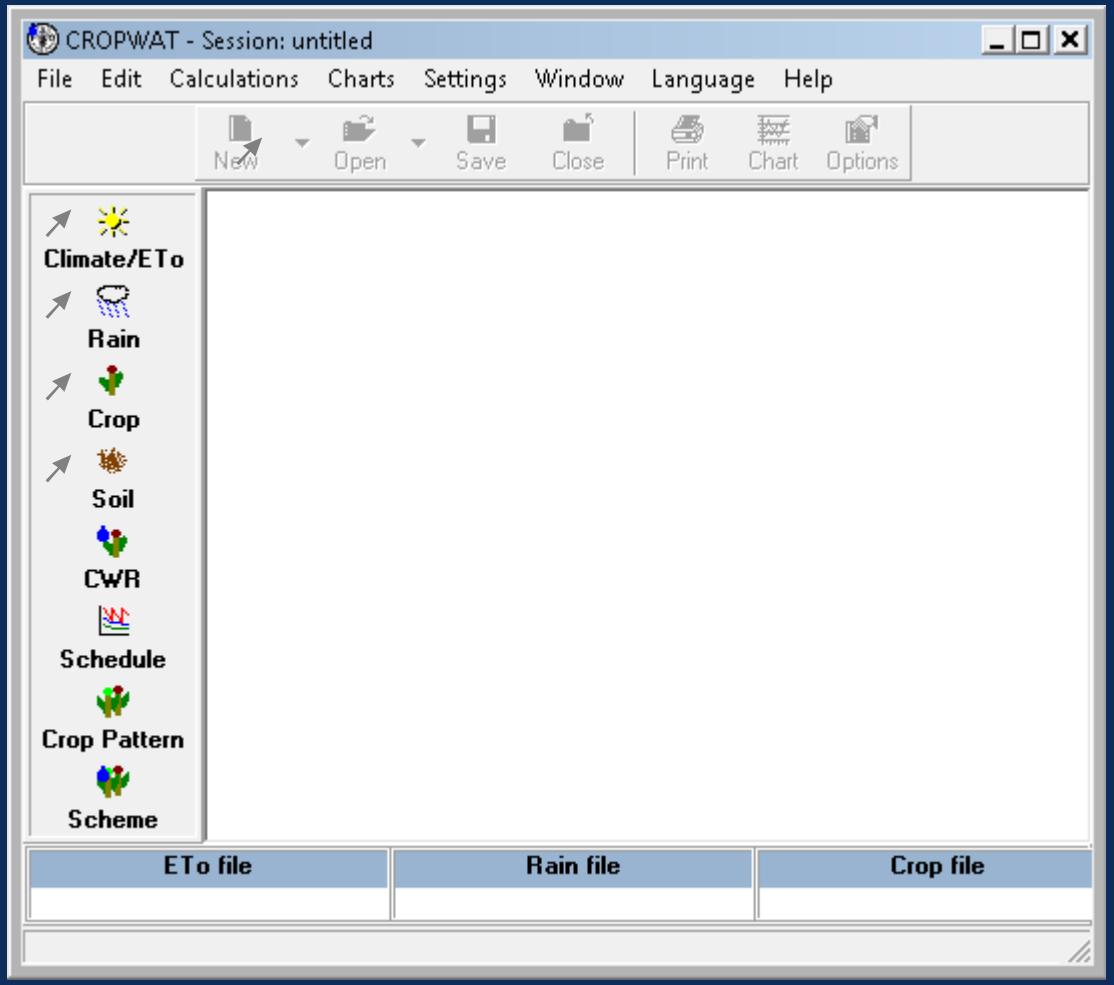
1. CWR option

Water footprint estimation

ET_g	ET_b	ET	CWU_g	CWU_b	CWU	Y*	$WF_{proc,green}$	$WF_{proc,blue}$	WF_{proc}
mm/period			m^3/ha			ton/ha	m^3/ton		
282	100	381	2816	995	3811	59	48	17	65

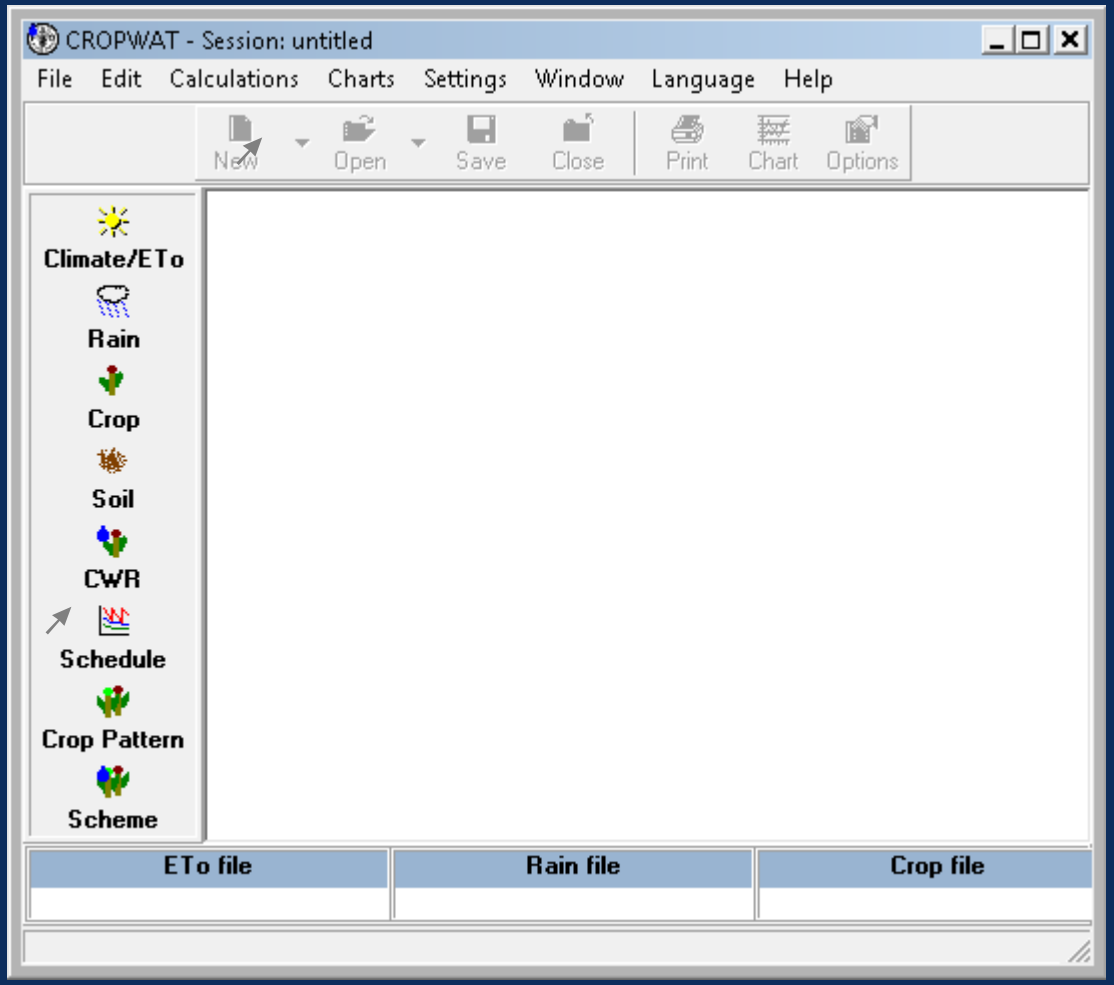
*IRS (1999-2006) for Northern Netherlands

2. Irrigation schedule option – input



Schedule

2. Irrigation schedule option – output



Schedule

2. Irrigation schedule option - output

Crop irrigation schedule

ETo station	GRONINGEN-AP-EELD	Crop	Sugarbeet	Planting date	10/04	Yield red.	0.0 %
Rain station	GRONINGEN-AP-EELD	Soil	Medium (loam)	Harvest date	06/10		

Table format
- Irrigation schedule
- Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr
			mm	fract.	mm/day	%	mm	mm	mm	mm
10 Apr	1	Init	0.0	1.00	0.5	1	0.0	0.5	0.0	0.0
11 Apr	2	Init	0.0	1.00	0.6	1	0.0	1.1	0.0	0.0
12 Apr	3	Init	0.0	1.00	0.6	2	0.0	1.8	0.0	0.0
13 Apr	4	Init	7.6	1.00	0.6	1	0.0	0.6	0.0	0.0
14 Apr	5	Init	0.0	1.00	0.6	1	0.0	1.2	0.0	0.0
15 Apr	6	Init	0.0	1.00	0.6	2	0.0	1.8	0.0	0.0
16 Apr	7	Init	0.0	1.00	0.6	2	0.0	2.5	0.0	0.0
17 Apr	8	Init	7.6	1.00	0.6	1	0.0	0.6	0.0	0.0

Totals

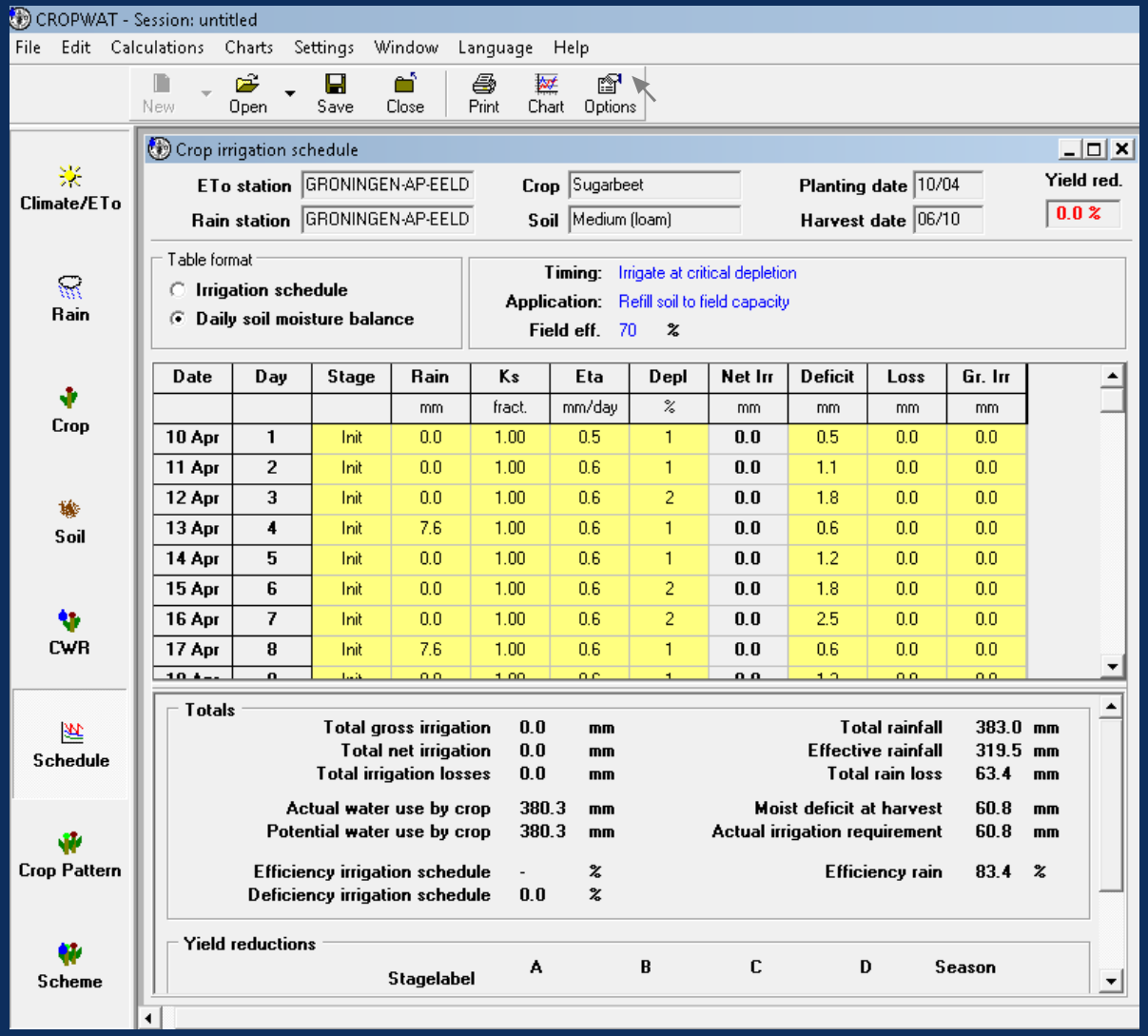
Total gross irrigation	0.0	mm	Total rainfall	383.0	mm
Total net irrigation	0.0	mm	Effective rainfall	319.5	mm
Total irrigation losses	0.0	mm	Total rain loss	63.4	mm
Actual water use by crop	380.3	mm	Moist deficit at harvest	60.8	mm
Potential water use by crop	380.3	mm	Actual irrigation requirement	60.8	mm
Efficiency irrigation schedule	-	%	Efficiency rain	83.4	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season

Schedule

2. Irrigation schedule option - output



Schedule

2. Irrigation schedule option - output

Rainfed conditions

ET_{green} (irr = 0) = ET_{tot} (irr = 0)

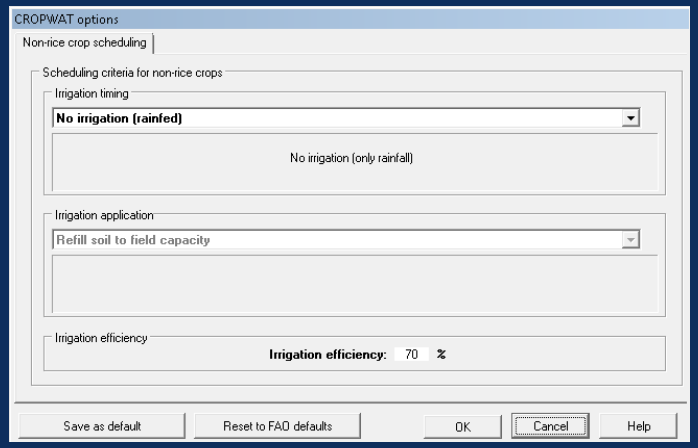
ET_{blue} (irr = 0) = 0

Irrigated conditions

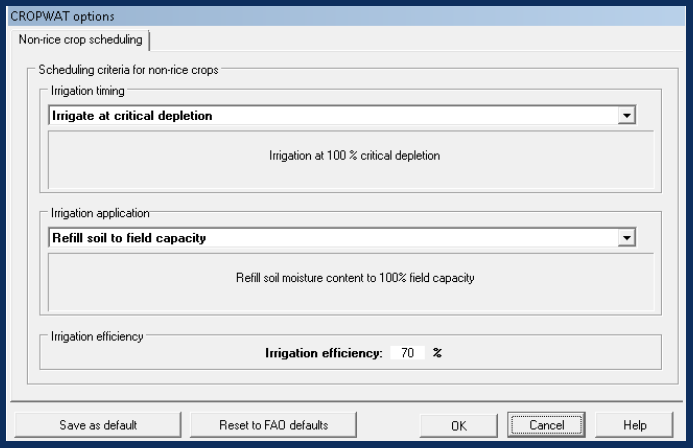
ET_{green} (irr = 1) = ET_{green} (irr = 0)

ET_{blue} (irr = 1) = ET_{tot} (irr = 1) – ET_{green} (irr = 0)

Rainfed scenario (irr = 0)



Irrigated scenario (irr = 1)



Schedule

2. Irrigation schedule option – output – Medium soil

Rainfed scenario (*irr* = 0)

Crop irrigation schedule

ETo station: GRONINGEN-AP-EELD | Crop: Sugarbeet | Planting date: 10/04 | Yield red.: 0.0 %
Rain station: GRONINGEN-AP-EELD | Soil: Medium (loam) | Harvest date: 06/10

Table format: Irrigation schedule / Daily soil moisture balance

Timing: No irrigation (rainfed)
Application: -
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr
			mm	fract.	mm/day	%	mm	mm	mm	mm
29 Sep	173	End	0.0	1.00	1.3	23	0.0	66.3	0.0	0.0
30 Sep	174	End	0.0	1.00	1.3	23	0.0	67.6	0.0	0.0
1 Oct	175	End	0.0	1.00	0.9	24	0.0	68.5	0.0	0.0
2 Oct	176	End	0.0	1.00	0.9	24	0.0	69.4	0.0	0.0
3 Oct	177	End	11.4	1.00	0.9	20	0.0	58.9	0.0	0.0
4 Oct	178	End	0.0	1.00	0.9	21	0.0	59.9	0.0	0.0
5 Oct	179	End	0.0	1.00	0.9	21	0.0	60.8	0.0	0.0
6 Oct	End	End	0.0	1.00	0.0	21				

Totals

Total gross irrigation	0.0	mm	Total rainfall	383.0	mm
Total net irrigation	0.0	mm	Effective rainfall	319.5	mm
Total irrigation losses	0.0	mm	Total rain loss	63.4	mm
Actual water use by crop	380.3	mm	Moist deficit at harvest	60.8	mm
Potential water use by crop	380.3	mm	Actual irrigation requirement	60.8	mm
Efficiency irrigation schedule	-	%	Efficiency rain	83.4	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season

Rainfed conditions

ET_{green} (*irr* = 0) = ET_{tot} (*irr* = 0)

ET_{blue} (*irr* = 0) = 0

Schedule

2. Irrigation schedule option – output – Medium soil

Irrigated scenario (*irr* = 1)

Crop irrigation schedule

ETo station: GRONINGEN-AP-EELD | Crop: Sugarbeet | Planting date: 10/04 | Yield red.: 0.0 %
Rain station: GRONINGEN-AP-EELD | Soil: Medium (loam) | Harvest date: 06/10

Table format: Irrigation schedule / Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr
			mm	fract.	mm/day	%	mm	mm	mm	mm
29 Sep	173	End	0.0	1.00	1.3	23	0.0	66.3	0.0	0.0
30 Sep	174	End	0.0	1.00	1.3	23	0.0	67.6	0.0	0.0
1 Oct	175	End	0.0	1.00	0.9	24	0.0	68.5	0.0	0.0
2 Oct	176	End	0.0	1.00	0.9	24	0.0	69.4	0.0	0.0
3 Oct	177	End	11.4	1.00	0.9	20	0.0	58.9	0.0	0.0
4 Oct	178	End	0.0	1.00	0.9	21	0.0	59.9	0.0	0.0
5 Oct	179	End	0.0	1.00	0.9	21	0.0	60.8	0.0	0.0
6 Oct	End	End	0.0	1.00	0.0	21				

Totals

Total gross irrigation	0.0	mm	Total rainfall	383.0	mm
Total net irrigation	0.0	mm	Effective rainfall	319.5	mm
Total irrigation losses	0.0	mm	Total rain loss	63.4	mm
Actual water use by crop	380.3	mm	Moist deficit at harvest	60.8	mm
Potential water use by crop	380.3	mm	Actual irrigation requirement	60.8	mm
Efficiency irrigation schedule	-	%	Efficiency rain	83.4	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel	A	B	C	D	Season

Irrigated conditions

ET_{green} (*irr* = 1) = ET_{green} (*irr* = 0)

ET_{blue} (*irr* = 1) = ET_{tot} (*irr* = 1) – ET_{green} (*irr* = 0)

Schedule

2. Irrigation schedule option - output – Soil comparison

Light

Totals

Total gross irrigation	110.4	mm	Total rainfall	383.0	mm
Total net irrigation	77.2	mm	Effective rainfall	300.0	mm
Total irrigation losses	0.0	mm	Total rain loss	83.0	mm
Actual water use by crop	380.3	mm	Moist deficit at harvest	3.1	mm
Potential water use by crop	380.3	mm	Actual irrigation requirement	80.4	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	78.3	%
Deficiency irrigation schedule	0.0	%			

Medium

Totals

Total gross irrigation	0.0	mm	Total rainfall	383.0	mm
Total net irrigation	0.0	mm	Effective rainfall	319.5	mm
Total irrigation losses	0.0	mm	Total rain loss	63.4	mm
Actual water use by crop	380.3	mm	Moist deficit at harvest	60.8	mm
Potential water use by crop	380.3	mm	Actual irrigation requirement	60.8	mm
Efficiency irrigation schedule	-	%	Efficiency rain	83.4	%
Deficiency irrigation schedule	0.0	%			

Heavy

Totals

Total gross irrigation	0.0	mm	Total rainfall	383.0	mm
Total net irrigation	0.0	mm	Effective rainfall	319.5	mm
Total irrigation losses	0.0	mm	Total rain loss	63.4	mm
Actual water use by crop	380.3	mm	Moist deficit at harvest	60.8	mm
Potential water use by crop	380.3	mm	Actual irrigation requirement	60.8	mm
Efficiency irrigation schedule	-	%	Efficiency rain	83.4	%
Deficiency irrigation schedule	0.0	%			

Schedule

2. Irrigation schedule option - output – Soil comparison

CROPWAT option	ET_{green}	ET_{blue}	ET	CWU_{green}	CWU_{blue}	CWU	Y*	$WF_{proc,green}$	$WF_{proc,blue}$	WF_{proc}
	mm/period			m^3/ha			ton/ha	m^3/ton		
Light	336	44	380	3364	440	3803	59	57	7	64
Medium	380	0	380	3803	0	3803	59	64	0	64
Heavy	380	0	380	3803	0	3803	59	64	0	64

*IRS (1999-2006) for Northern Netherlands

Schedule

Water footprint estimation

1. CWR option

ET_g	ET_b	ET	CWU_g	CWU_b	CWU	Y*	$WF_{proc,green}$	$WF_{proc,blue}$	WF_{proc}
mm/period			m^3/ha			ton/ha	m^3/ton		
282	100	381	2816	995	3811	59	48	17	65

*IRS (1999-2006) for Northern Netherlands

2. Irrigation schedule option

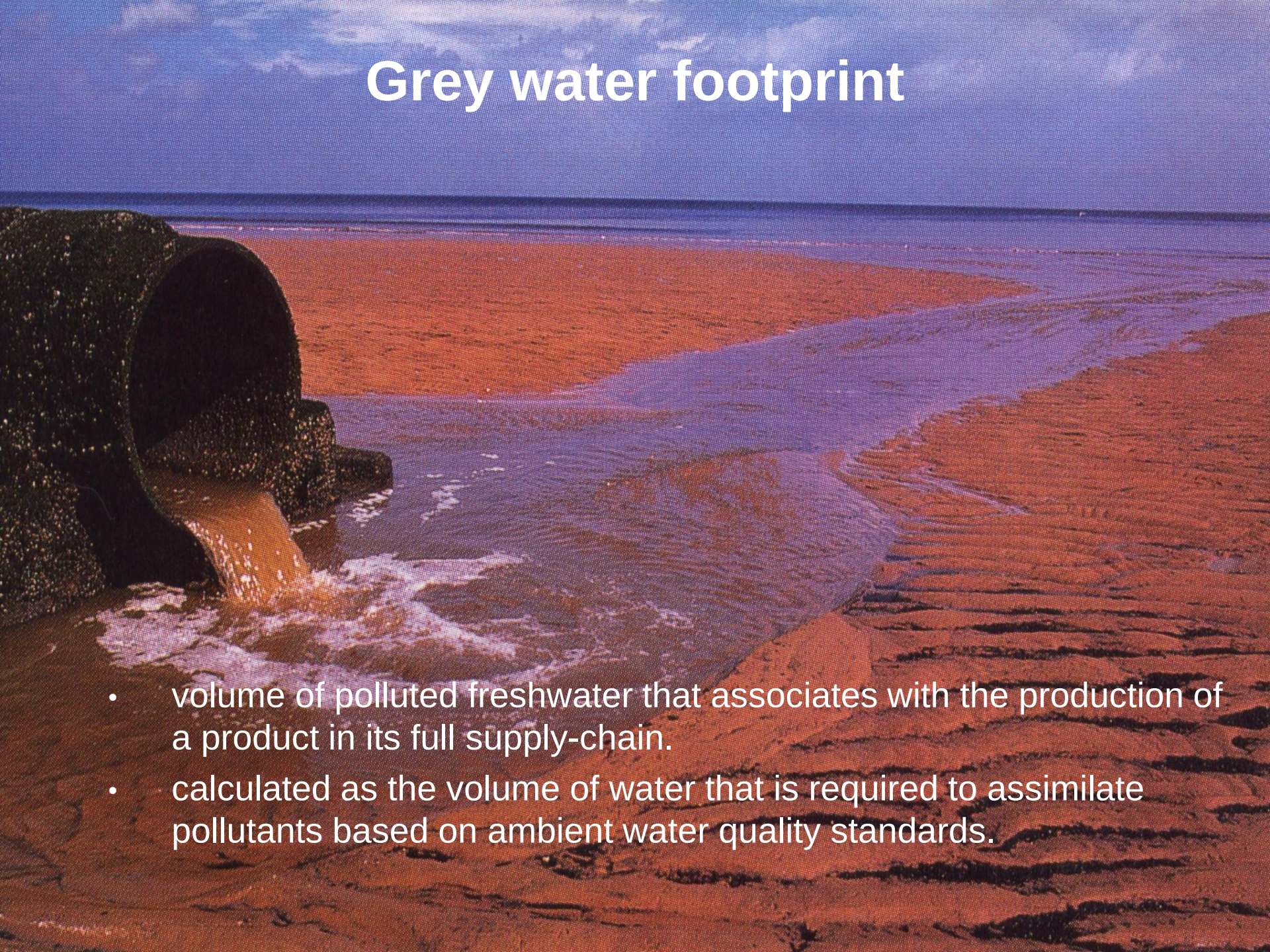
CROPWAT option	ET_{green}	ET_{blue}	ET	CWU_{green}	CWU_{blue}	CWU	Y*	$WF_{proc,green}$	$WF_{proc,blue}$	WF_{proc}
	mm/period			m^3/ha			ton/ha	m^3/ton		
Light	336	44	380	3364	440	3803	59	57	7	64
Medium	380	0	380	3803	0	3803	59	64	0	64
Heavy	380	0	380	3803	0	3803	59	64	0	64

*IRS (1999-2006) for Northern Netherlands

Average irrigated area varies from 1 to 19% (IIRB, 2004)

→ CWR
→ Schedule

Grey water footprint



- volume of polluted freshwater that associates with the production of a product in its full supply-chain.
- calculated as the volume of water that is required to assimilate pollutants based on ambient water quality standards.

Grey water footprint of a crop

- $WF_{proc,grey}\ (m^3) = \dfrac{L}{(c_{max} - c_{nat})}$

- $WF_{proc,grey}\ (m^3/ton) = \dfrac{L\ /\ (c_{max} - c_{nat})}{Prod}$

L – Load of pollutants entering the water system (g/day)
c_{max} – Ambient water quality standard for the pollutant considered (g/m^3)
c_{nat} – Natural concentration in the receiving water body (g/m^3)
Prod – Production (ton/yr)

Grey water footprint

Source: Fertistat (FAO, 2009c)

Grey water footprint

Source: Fertistat (FAO, 2009c)

Grey component of the process water footprint for sugarbeet within the Northern Netherlands

Average fertilizer application rate*	Area**	Total fertilizer applied	Nitrogen leached to the water bodies 10%	US EPA (2009)	Total $WF_{proc,grey}$ sugar beet	Production**	$WF_{proc,grey}$ sugar beet
kg/ha	ha	ton/year	ton/year	mg/l	10^6 m^3/year	ton	m^3/ton
108	10887	1176	118	10	12	647176	18
*Fertistat (FAO, 2009c)							
**IRS (1999-2006) for Northern Netherlands							

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