### Water Footprint and the Nile Basin

Module 2: Water Footprint Analysis and Methodology









### **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





### Detailed Example: Water Footprint of a Crop

### Crop water use (m<sup>3</sup>/ha)

### WF =

### Crop yield (ton/ha)



Hoekstra and Chapagain (2008)



### Detailed Example: Water Footprint of a Crop

# WF = Crop Water Use <sub>green</sub> + Crop Water Use <sub>blue</sub> Crop yield (ton/ha)



Hoekstra and Chapagain (2008)





### Water Footprint of a Crop – Green Water







### Water Footprint of a Crop – Blue Water



Δ



### **CROPWAT Estimation Methods**

### 1. <u>CWR</u>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<sub>0</sub>), crop evapotranspiration under standard (ET<sub>c</sub>) and non-standard conditions (ET<sub>c adj</sub>)



#### 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

Allen et al. (1998)

#### **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 Growth Stages for Different Crops









## Detailed Example: Green Water Footprint of a Crop









# Detailed Example: Blue Water Footprint of a Crop

### **Evapotranspiration**<sub>blue</sub> =

min(crop irrigation requirement, actual irrigation)

# $CWU_{blue} = 10 \text{ x} \sum Evapotran spiration}_{blue}$







Hoekstra and Chapagain (2008)





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





## Water Footprint of a Live Animal

# WF<sub>live animal</sub> = WF<sub>drink</sub> + WF<sub>service</sub> + WF<sub>feed</sub>

- WF <sub>drink</sub> = volume of water drunk by an animal
- WF <sub>service</sub> = volume of water used to service an animal
- WF <sub>feed</sub> = 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 <sub>Feed</sub> = WF<sub>Grass</sub> \* Volume <sub>Grass eaten</sub>



### Water Footprint of a Country







1 2 3 4



## National Water Use Accounting Framework





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









### **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

text only version > print friendly

Topics

Information Resources

Publications & CD-ROMs

Databases & Software

Graphs & Maps

Multimedia

AquaCrop

CropWat

ClimWat

ETo Calculator

Wastewater Projects Hot Issues

Video

helping to build a world without hunger

		NATURAL RESOURCES AND ENVIRONMENT DEPARTMENT
) Fao Water		Participant
FrontPage	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

#### 習 RELATED LINKS

Climate Change and Bioenergy Unit

Revised FAO Methodology for Crop Water Requirements

#### 📩 DOWNLOADS

ClimWat 2.0 for Cropwat

CONTACT US



Our Regional Offices

QUICKLINK TO Databases & Software Publications & CD-ROMs Educational Material



# **Crop Growth and Evapotranspiration Data**

http://www.fao.org/nr/water/infores databases cropwat.html

text only version > print friendly

helping to build a world without hunger

# NATURAL RESOURCES AND ENVIRONMENT DEPARTMENT FrontPage Software

#### Topics Information Resources CropWat Publications & CD-ROMs CROPWAT is a decision support tool developed by the Land and Water Graphs & Maps Development Division of FAO. Multimedia Video CROPWAT 8.0 for Windows is a computer Databases & Software program for the calculation of crop water AquaCrop CropWat ClimWat ETo Calculator Wastewater Projects Hot Issues QUICKLINK TO 🔍 Databases & Software Publications & CD-ROMs

#### Cropwat 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. 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 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

Educational Material

Our Regional Offices

IPTRID



# 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

Goog 🚼	le	×	() FAO: Searc	h result	× ( 💮 F/	40 - Water Dev	elopment a	× 🕥 FAO -	Water Develo	pment : ×)	FAOSTAT	
$\leftarrow \rightarrow$	C 🔇 faostat	.fao.org	g/default.as	ох								
	AOSTA	Т									FOOD AN	D AGRICULT
Home	Production T	rade l	Food Supply	Food Balance S	iheets	Food Security	Prices	Resources	Forestry	Fisheries	Metadata	Support/FAG
logon	want to register	? FAO	STAT videos	Country STAT								

FAOSTAT provides time-series and cross sectional data relating to food and agriculture for some 200 countries.

The national version of FAOSTAT, CountrySTAT, is being developed and implemented in a number of target countries, primarily in sub-saharan Africa. It will offer a two-way data exchange facility between countries and FAO as well as a facility to store data at the national and sub-national levels.

#### FAOSTAT User Dialogue 2010

One of the priorities of the Statistics Division is to involve the producers and custodians of statistics at FAO in a stronger communication with our users, and to gain a better understanding of their needs. Since July 2010 the free FAO data access policy has been implemented. The number of registered users has boomed since then from 400 to over 10 000 as of today.

We are seeking contact with registered users of FAOSTAT to open a qualitative feedback channel. We are looking for your views and experiences in using FAO's statistics as well as specific, technical suggestions. We would very much appreciate receiving your advice. To see the issues please click here.

#### Latest news

The following subject domains have been updated:

- ForesSTAT (August 2011)
- PopSTAT (August 2011)
- ResourceSTAT-Land (July 2011)
- Forestry Trade Flows (July 2011)
- ResourceSTAT-Fertilizers (July 2011)
- ProdSTAT (May 2011)
- ResourceSTAT-Pesticides Consumption (March 2011)
- TradeSTAT-Detailed Trade Matrix (February 2011)
- ResourceSTAT-Machinery (December 2010)
- TradeSTAT-Detailed trade data (November 2010)



# 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



**CROPWAT** (FAO, 2009a)

## Crop water use (m<sup>3</sup>/ha)



Crop yield (ton/ha)

**FAOSTAT** (FAO, 2009b)

### **CROPWAT** estimation methods

- 1. <u>CWR</u> option Optimal conditions
  - Without considering soil water balance
  - Ten-day time step effective rainfall

## 2. <u>Irrigation schedule</u> option – Non-optimal conditions – Considering soil water balance

- Daily time step soil water balance



### 1. CWR option

🛞 CROPWAT -	Session: untitled					_ 🗆 🗙
File Edit Ca	Iculations Char	ts Settings	Window	Language	e Help	
	New Ope	n Save	Close	erint (	Chart Options	
Climate/ETo Rain Pain Crop Sole CWR Schedule Crop Pattern						
ET	o file		Rain file		C	rop file
						//

### Green and blue water footprint of a crop



### 1. CWR option



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

Interpolates where no observations are available







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



#### Green and blue water footprint of a crop



#### **CLIMWAT** database

GRONINGEN-A	AP-EELDE.cli - No at View Helr	tepad				
"GRONINGEN-A 0.21 0.39 0.86 1.58 2.43 2.82 2.75 2.53 1.59 0.83 0.44 0.22	P-EELDE","" 66 45 57 48 57 68 76 66 70 68 70 77 75	," 4",0,0,0 .60 .20 .20 .20 .80 .80 .30 .40 .60 .70 .10 .50	0, 0, 0, 0, 0 59.50 41.93 52.21 44.48 52.45 61.23 66.99 59.35 62.63 61.15 67.59 66.38		*P **(	enman-Monteith metho JSDA Soil Conservatior
ET <sub>0</sub> * (mm/day)	Mon rain (mm/n	thly fall effe nonth) (	Monthly ective rainfa (mm/month)	11**	Se	ervice formula
Eile Edit Eorm	VP-EELDE.pen - N at View Helr	lotepad				_
"Location 7" 3.7 4.5 7.9 11.8 16.6 19.5 20.7 21.2 18.2 13.7 8.3 4.9	,"GRONINGEN -1.5 -1.4 0.5 2.5 6.3 9.3 10.9 10.8 8.7 5.9 2.3 -0.2	AP-EELDE", 95.4 91.9 86.7 81.7 79.1 80.6 83.0 82.5 87.2 90.8 92.5 95.7	4,53.13,"N. 457.9 423.4 449.3 397.4 354.2 345.6 354.2 319.7 337.0 354.2 440.6 449.3	.L.",6.58, 0.45 2.05 2.85 5.01 6.22 6.11 5.71 5.83 4.06 2.45 1.06 0.13	" 01" 2.06 4.60 7.93 13.22 17.06 17.95 16.92 15.05 10.18 5.78 2.77 1.53	0.21 0.39 0.86 1.58 2.43 2.82 2.75 2.53 1.59 0.83 0.44 0.22
Mean daily M maximum temp. (°C) te	/lean daily minimum emp. (ºC) h	Mean relative umidity (%)	Mean wind speed (km/day)	Mean sunshine hours per dav	Mean solar radiation (MJ/m²/day)	ET <sub>0</sub> * (mm/day)

.CLI

.PEN

Climate/ETo



### **ET**<sub>0</sub> Penman-Monteith

ile Edit Ca	culation	s Charts	Settings	Window Langu	uage Help			
	New	• 🗳 Open	- R Save	Close Print	Chart Option	8		
		Climati	ptions e / FTo	Dainfall	Manuina	eres colordulius Ì	Disc colorduling	Land Branstelian (rise)
R		Ciinau	57210	Rainraii	Non-fice	crop scheduling	Rice scheduling	Land Preparation (rice)
Rain		Data set	tings					
			ETo Pe	nman-Monteith	ETo Penman calo	ulated from climatic	data	
• Crop					,			
				Temperature	Minimum / maxim	um temperatures		•
*				Changes to 1	W			
Soil				Changes to	inese settings only	ellect NEW Uata		
45		Units —						
CWR				Humidity	Relative humidity	in %		-
				Windspeed	Kilometers per day	,		•
<u>₩</u>				Sunshine	Hours sunshine			•
Schedule				ETo	mm per day			•
					,			
Crop Pattern								
		Sav	ve as default	Bes	et to FAO defaults			ncel Help
**								
Scheme								
Scheme								





#### Effective rainfall estimation method

🛞 CROPWAT - Sessi	on: untitled				_	
File Edit Calculat	ions Charts Settings Win	dow Language	Help			
New	, Open Save Clo	se Print Ch	art Options			
¥ Climate/ETo	CROPWAT options					
	Climate / ETo	Rainfall	Non-rice crop scheduling	Rice scheduling	Land Preparation (rice)	
Rain	Effective rainfall method for C	WR calculations -		Note: in red are o	correction factors that	
🔶 Crop	C Dependable rain ( Peff = 0.6 * P · 10 / Peff = 0.8 * P · 24	FAO/AGLW form	<b>ula)</b> = 70 <mark>/3</mark> mm	the case of deca data (for effective daily data are agg	es to adjust formulas in de and daily rainfall rainfall calculations gregated per decade)	
100 Soil	C Empirical formula Peff = 0.5 *P	+ -5 /3 fo	or P<= 50 <b>/3</b> mm y P ≥ 50 <b>/3</b> mm			
🛛 👽 🗌	1 01 - 0.1	. 20 70 10	, i / 30 <mark>/ 3</mark> iiiii			
CWR	<ul> <li>USDA soil conser</li> <li>Peff = (P * (125 - 0.</li> </ul>	<b>vation service</b> 2 <b>*3</b> *P))/125	for P <= 250 <mark>/3</mark> mm			
<b>10</b>	Peff = 125 /3 + 0	.1 * P	for P > 250 /3 mm			
Schedule	C Rainfall not consi	dered in irrigation	a calculations (effective	e rainfall = 0)		
Core Dellare						
Crop Fattern	Save as default	Reset to FA	.0 defaults	OK Can	cel Help	
Scheme						
ETo file	Rain	file	Crop file	Soil	file	Pla





#### 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 coefficient curve**



Lenght of growth stages

Allen et al. (1998)



#### **Crop growth stages for different crops**



Allen et al. (1998)

Green and blue water footprint of a crop



## 1. CWR option - input

🛞 CROPWAT	- Session: untitled						,
File Edit C	alculations Charts	s Settings Wind	ow Language	Help			
	New Open	Save Clos	e Print Cl	hart Options			
≠ 💥 Climate/ETo							
≠ 👷 Rain							
🗡 Crop							
1 Soil							
ty CWR							
Market Schedule							
👯 Crop Pattern							
₩ Scheme							
E	To file	Bain	file	Cro	op file	Soil file	Planting date



Green and blue water footprint of a crop



## 1. CWR option - output

🛞 CROPWAT	- Session: untitled					
File Edit (	Calculations Chart	s Settings	Window Language	e Help		
	New Oper	save	Close Print (	<b>禁 『</b> Chart Options		
¥ Climate/E⊺c						
Rain						
🔶 Crop						
Soil						
💙 CWR						
Schedule						
Crop Patterr	1					
Scheme					Jr	
E	To file		Rain file	Crop file	Soil file	Planting date

# -

## 1. CWR option - output

🛞 Crop Water	Requirements						_	
ETo sta	ation GRONIN	GEN-AP-EELD				Сгор	Sugarbeet	
Rain sta	ation GRONIN	GEN-AP-EELD		CWR	F	lanting 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	

> 😲

# -

## 1. CWR option - output

🖻 Crop Water I	Requirements						_	. 🗆
ETo sta	ation GRONIN	GEN-AP-EELD				Сгор	Sugarbeet	
Rain sta	tion GRONIN	GEN-AP-EELD			CWR F	lanting date	10/04	
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Τ
			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	Copy table 🔸	Data only		0.0	
Jun	2	Deve	0.73	2.25	Data and He	aders	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	
Ѕер	2	Late	0.98	1.73	17.3	21.1	0.0	
Ѕер	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



Crop type

Annuals

Perennials - rangeland

 deciduous trees & shrubs
 evergreen
 Hypothetical
 grass reference crop development

**p** 

initial

late

season

The second second

mid-season

growing season

ning nahing hit make the disk and a first and the disk distribution

# Data from CROPWAT

Image: Arrop Develop ment StageCrop Crop Evapo Coefficient Coefficient TranspirationCrop Evapo transpirationEffective tainfallIrrigation RequirementActual rrigationMonthDecadeStageKcFCETcEffective transpirationIrr. Req.Act. Irrig.MonthDecadeStageKcFCETcEffective transpirationIrr. Req.Act. Irrig.Aug1Init0.30.988.85.25.30.0Aug2Init0.30.988.85.25.30.0Aug3Deve0.431.0210.24.270.0Aug3Deve0.431.55175.31280.0Sep1Deve0.72.6726.76.12160.0Sep3Mid1.185.0250.210.44180.0Oct1Mid1.25.6956.914.34460.0	
Develop ment StageGrop Crop Coefficient Coefficie	
mentGropGropCrop EvapoCrop EvapoEffectiveIrrigationActualMonthDecadeStageKcETcETcEff rainIrr. Req.Act. Irrig.MonthDecadeStageKcETcETcEff rainIrr. Req.Act. Irrig.Aug1Init0.30.988.85.25.30.0Aug2Init0.30.988.85.25.30.0Aug2Deve0.431.0210.24.270.0Aug3Deve0.431.551.75.31.280.0Sep1Deve0.72.6726.76.12.10.00.0Sep2Deve0.963.863.8.67.93.270.0Oct1Mid1.185.025.0210.44.4180.0Oct2Mid1.25.6956.914.34.460.0	
MonthDecadeStageCoefficientTranspirationtranspirationRainfallRequirementIrrigationMonthDecadeStageKcETcETcEff rainIrr. Req.Act. Irrig.Aug1Init0.980.988.85.25.80.0Aug2Init0.330.988.85.25.80.0Aug3Deve0.431.0210.24.270.0Aug3Deve0.431.551.75.31.280.0Sep1Deve0.72.6726.76.12.160.0Sep2Deve0.963.8638.67.932.70.00.0Sep3Mid1.185.0250.210.444.80.00.0Oct-1Mid1.25.6956.914.344.60.0Oct-8Mid1.25.6962.619.745.20.0	
MonthDecadeStageKcFTcFfr ainIrr. Req.Act. Irrig.AugIInitcoeffmm/daymm/decmm/decmm/decmm/decmm/decAugIInit0.30.988.85.25.30.0AugIInit0.31.0210.24.20.77AugIDeve0.431.55175.31280.0AugIDeve0.72.6726.76.12160.0SepIDeve0.963.8638.67.93270.0SepIMid1.185.0250.210.44180.0OctIMid1.25.6956.914.34460.0OctBMid1.25.6962.619.74520.0	
Aug         1         Init         0.98         mm/dec	
Aug       1       Init       0.3       0.98       8.8       5.2       5.3       0.0         Aug       2       Init       0.3       1.02       10.2       4.2       7       0.0         Aug       3       Deve       0.43       1.55       17       5.3       12       8       0.0         Sep       1       Deve       0.7       2.67       26.7       6.1       21       6       0.0         Sep       2       Deve       0.96       3.86       38.6       7.9       32       7       0.0         Sep       2       Deve       0.96       3.86       38.6       7.9       32       7       0.0         Sep       3       Mid       1.18       5.02       50.2       10.4       41.8       0.0         Oct       1       Mid       1.2       5.69       56.9       14.3       44       6       0.0         Oct       8       Mid       1.2       5.69       62.6       19.7       45.2       0.0	
Aug       2 Init       0.3       1.02       10.2       4.2       7       0.0         Aug       3 Deve       0.43       1.55       17       5.3       12       8       0.0         Sep       1 Deve       0.7       2.67       26.7       6.1       21       6       0.0         Sep       2 Deve       0.96       3.86       38.6       7.9       32       7       0.0         Sep       3 Mid       1.18       5.02       50.2       10.4       41       8       0.0         Oct       1 Mid       1.2       5.41       54.1       12.4       43       7       0.0         Oct       2 Mid       1.2       5.69       56.9       14.3       44       6       0.0         Oct       B Mid       1.2       5.69       62.6       19.7       45.2       0.0	
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       B Mid       1.2       5.69       62.6       19.7       45.2       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       B Mid       1.2       5.69       62.6       19.7       45       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         B Mid         1.2         5.69         62.6         19.7         45.2         0	
Sep         3 Mid         1.18         5.02         50.2         10.4         41.8         60           Oct         1 Mid         1.2         5.41         54.1         12.4         43         7         60           Oct         2 Mid         1.2         5.69         56.9         14.3         44         6         60           Oct         8 Mid         1.2         5.69         62.6         19.7         45.2         60	
Oct         1 Mid         1.2         5.41         54.1         12.4         43 7         00           Oct         2 Mid         1.2         5.69         56.9         14.3         44 6         00           Oct         B Mid         1.2         5.69         62.6         19.7         45 2         00	
Oct         2 Mid         1.2         5.69         56.9         14.3         44 6         0           Oct         8 Mid         1.2         5.69         62.6         19.7         45 2         0	
Oct B Mid 1.2 5.69 62.6 19.7 45.2 0	
Nov 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	
$K_{c^{14}}$ $K_{cmid}$ 165.2 297.5	





## 1. CWR option - output

$ET = ET_c$
ET <sub>g</sub> = min (ET <sub>c</sub> , P <sub>eff</sub> )
$ET_{b} = max (0, ET_{c} - P_{eff})^{*}$ Irr. Fraction (ie the

volume of irrigation in reality)

					0111					
Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	ET	ΕTg	ЕTь
			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

**OVA / F** 

Growing period



### 2. Irrigation schedule option

🛞 CI	ROPWA	<b>\</b> Τ -	Session	i: un	titled							
File	Edit	Ca	lculatio	ns	Charts	Se	ettings	Window	Languag	ge He	lp	
			New	Ŧ	Dpen	Ŧ	Save	Close	🗂 Print	Chart	Options	
	⋇	_										
Clim	ate/L	10										
	III -											
	Rain											
	<b>*</b>											
	Сгор											
	橡											
	Soil											
	۹.											
Sc Crop	hedula Patte											
ETo file								Rain file			Cr	op file



### 2. Irrigation schedule option





## 2. Irrigation schedule option input

New Open Save Close Print Chart Options	– File Edit	Cal	culatio	ns	Charts	Se	ettings	Window	Langua	iqe He	lp	_
Kinate/E To   Rain   Rain   Image: Crop   Image: Soil   I			New	Ŧ	Dpen	Ŧ	Save	Close	e Print	Chart	Options	
Cimate/E To Rain Rain Crop Soil Soil CWR CWR Schedule CWR CWR CWR												
Rain   Rain   Rain   Crop   Soil   Soil   CWR   Schedule   Schedule   Schedule   Schedule   Schedule	Climate/E	То										
Rain   Pain   Pain   Crop   Soil   Soil   CWR   Pain   Schedule   Pain   Pain   Pain	R											
<pre></pre>	Rain											
Crop   ion   Soil   ion   ion   ion   ion   ion   ion   ion   ion   ion	- <b>*</b>											
Soil Soil CWR Schedule Crop Pattern	Crop											
Soli CWR Execute Schedule Crop Pattern ♥	Soil											
CWR Schedule Crop Pattern	30ii 13											
Erop Pattern	CWR											
Schedule V Crop Pattern	<u>18</u>											
Crop Pattern	Schedu	e										
Crop Pattern												
	Crop Patt	ern										
Cohomo -	Cohom:											
	Schem	; гт.						Duin Gla			<b>C</b> .	61-
E l'u file Hain file Crop file	ETo file							n airi file				op nie



## Soil data (FAO, 2009a)

🚯 Soil - C:\ProgramData\CROPWAT\data\soils\FAO\/	MEDIUM.SOI			_ 🗆 🗙
Soil name	fedium (loam)			
General soil data				
Total available soil moisture	e (FC - WP)	290.0	mm/meter	
Maximum rain infi	Itration rate	40	mm/day	
Maximum ro	oting depth	900	centimeters	
Initial soil moisture depletion	(as % TAM)	0	%	
Initial available s	oil moisture	290.0	mm/meter	





## 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 water balance







### 2. Irrigation schedule option – input

🛞 c	ROPWA	ΔT -	Session	n: un	titled							_	. <b>.</b> .
File	Edit	Cal	culatio	ns	Charts	Settir	ngs	Window	Languag	je He	elp		
			New	Ŧ	Dpen	- Sa	ive	Close	e Print	tait Chart	Options		
Image: A state     Imag	rate/E Rain ₹ Crop Soil	Το											
So Cro S	CWR Echedule Patte Cheme	e ern	o file					Rain file			C	rop file	
		2.11	5 mc								U.	тор ше	
													//.




🛞 CI	ROPWA	ΔT -	Session	i: un	titled					_ 🗆 🗙
File	Edit	Cal	lculatio	ns	Charts	Settings	Window	Language	Help	
			New	Ŧ	Dpen	- Save	Close	es Print C	🗮 🖬 Chart Options	;
Clim	inate/E Rain ₽ Crop	Το								
× So	Soil V CWR M hedulo	e								
Crop	p Patte W cheme	ern								
		ET	o file				Rain file		(	Crop file





🕖 Crop irri	igation sc	hedule									>
ETo	station 🖡	GRONINGE	N-AP-EELD	Cro	p Sugarbe	et		Planting	date 10/0	)4	Yield red.
Rain	station	GRONINGE	N-AP-EELD	So	il Medium	(loam)		Harvest	date 06/1	0	0.0 %
Table form C Irriga O Daily	nat ntion sche soil mois	edule sture balar	nce	1 Applie Fie	iming: In cation: F eld eff. 7	rigate at crit tefill soil to fi 0 <b>%</b>	ical depletic ield capacity	in J			
Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	<b>^</b>
			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	-
10 4		13	00	1.00	00	-	0.0	10	0.0	0.0	
Totals	Ac Poter Efficier Deficier	Total gr Total Total irrig tual water ntial water ncy irrigati ncy irrigati	oss irrigati net irrigati gation loss use by cri use by cri ion schedu	on 0.0 on 0.0 es 0.0 op 380 op 380 ule - ule 0.0	mm mm .3 mm .3 mm %		Moi: Actual irr	Tot Effectiv Tota st deficit a igation rea Effici	al rainfall ve rainfall I rain loss at harvest quirement ency rain	383.0 319.5 63.4 60.8 60.8 83.4	mm mm mm mm %
- Yield ı	eduction	s ———	Stagelabe	I A		В	С	Γ	) s	eason	•





🐌 CI	ROPWA	AT - Se	ssion: un	ititled										
File	Edit	Calcu	lations	Charts S	ettings W	/indow L	anguage	Help						
		N	lew -	😅 🗸	<b>₽</b> Save	Close	Print Ch	⊈ 😭 art Option	s					
			🕖 Crop	irrigation s	chedule									
	×		ET	o station	GRONINGE	N-AP-EELD	Cro	p Sugarbe	et		Planting	date 10/0	14	Yield red.
Clin	nate/E1	To	Rai	in station	GRONINGE	N-AP-EELD	So	il Medium	(loam)		Harvest	date 06/1	0	0.0 %
		- 1	 ⊏_ Table fi	ormat	,			,				,		
	R	- 1	O Irri	igation sch	edule			Timing: Ir	rigate at cri	tical depletio	n			
	Rain		⊙ Da	ily soil moi	isture balar	nce	Applı Fie	cation: H eld eff. 7	ehill soil to f 0 %	neld capacity				
	_		Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	<b>_</b>
	<b>*</b>	- 1				mm	fract.	mm/day	%	mm	mm	mm	mm	
	Crop	- 1	10 Ap	r 1	Init	0.0	1.00	0.5	1	0.0	0.5	0.0	0.0	
		- 1	11 Ар	r 2	Init	0.0	1.00	0.6	1	0.0	1.1	0.0	0.0	
	1	- 1	12 Ap	r 3	Init	0.0	1.00	0.6	2	0.0	1.8	0.0	0.0	
	Soil	- 1	13 Ар	r 4	Init	7.6	1.00	0.6	1	0.0	0.6	0.0	0.0	
		- 1	14 Ap	r 5	Init	0.0	1.00	0.6	1	0.0	1.2	0.0	0.0	
		- 1	15 Ap	r 6	Init	0.0	1.00	0.6	2	0.0	1.8	0.0	0.0	
	<b>\</b>	- 1	16 Ap	r 7	Init	0.0	1.00	0.6	2	0.0	2.5	0.0	0.0	
	C₩R	- 1	17 Ap	r 8	Init	7.6	1.00	0.6	1	0.0	0.6	0.0	0.0	<b>_</b>
		-1	10 4		l Luis	00	1.00	00	- 1	0.0	10	- 00	00	
So	Market Chedule	e	– Tota	als ———	Total gr Total Total irrig	oss irrigat net irrigat gation los:	ion 0.0 ion 0.0 ses 0.0	MM MM MM			Tot Effectiv Tota	al rainfall ve rainfall   rain loss	383.0 319.5 63.4	mm mm mm
6	*			A Pote	ctual water ential water	ruse by cr ruse by cr	rop 380 rop 380	1.3 mm 1.3 mm		Moi: Actual irr	st deficit a igation rec	nt harvest quirement	60.8 60.8	mm mm
Cro	p Patte	sin		Deficie	ency irrigati ency irrigati	ion sched ion sched	ule - ule 0.0	%			Ethc	ency rain	83.4	<u>6</u>
s	👯 cheme			d reduction	ns	Stagelabe	a A		B	C	[	) S	eason	•





#### **Rainfed conditions**

$$ET_{qreen}$$
 (*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)

CROPWAT options	
Non-rice crop scheduling	
Scheduling criteria for non-tice crops	
Irrigation timing	
No irrigation (rainfed)	
No irrigation (only rainfall)	
Inigation application	
Refill soil to field capacity	
Irrigation efficiency 70 %	
Save as default Reset to FAO defaults OK Cancel Help	

#### Irrigated scenario (*irr* = 1)

CROPWAT options
Non-rice crop scheduling
C Scheduling criteria for non-rice crops
Irrigation timing
Irrigate at critical depletion
Irrigation at 100 % critical depletion
Irrigation application
Refill soil to field capacity
Refill soil moisture content to 100% field capacity
Irrigation efficiency
Save as default Reset to FAD defaults OK Cancel Help



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



\_ **D** ×

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

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

#### 🞲 CLIMWAT 2.0 - Local Station Distribution

Exit Export New Location Stations Display Zoom In Zoom Out Export Selected Stations Colors Disclaimer About



Nr.	Lon [°]	Lat [°]	Alt	[m]	Name	Country
1	5.78	50.91		116	MAASTRICHT-AP-ZUID-LIMBU	NETHERLAN
2	3.6	51.45		10	VLISSINGEN	NETHERLAN
3	5.41	51.45		28	EINDHOVEN	NETHERLAN
4	4.78	52.91		14	DE-KOOY	NETHERLAN
5	5.18	52.1		15	DE-BILT	NETHERLAN
6	6.9	52.26		57	TWENTHE	NETHERLAN
7	6.58	53.13		4	GRONINGEN-AP-EELDE	NETHERLAN

Number of stations loaded: 7





#### Crop distribution maps



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





#### 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)





#### 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)





#### 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)



### Green and blue water footprint of a crop



#### Climate data - CLIMWAT

📃 GRONINGEN-A	AP-EELDE.cli - N	lotepad						
File Edit Form	nat View He	lp						
"GRONINGEN-A 0.21 0.39 0.86 1.58 2.43 2.82 2.75 2.53 1.59 0.83 0.44 0.22	P-EELDE"," 6 4 5 4 5 6 7 6 7 7 7 7 7 7 7	"," 4",0,0,0 6.60 5.20 7.50 8.20 7.80 8.80 6.30 6.30 6.40 0.60 8.70 7.10 5.50	0,0,0,0,0,0 59.50 41.93 52.21 44.48 52.45 61.23 66.99 59.35 62.63 61.15 67.59 66.38		۴P	enman-Mor	nteith meth	nod
ET <sub>o</sub> * (mm/day)	Mo rai (mm/i	nthly nfall effe month) (	Monthly ective rainfal (mm/month)	<b> </b> **	**  Se	USDA Soil ( ervice formu	Conservati Ia	on
🔄 GRONINGEN-A	VP-EELDE.pen -	Notepad						
File Edit Form	iat View He	lp						
"Location 7" 3.7 4.5 7.9 11.8 16.6 19.5 20.7 21.2 18.2 13.7 8.3 4.9	,"GRONINGE -1.5 -1.4 0.5 2.5 6.3 9.3 10.9 10.8 8.7 5.9 2.3 -0.2	N-AP-EELDE", 95.4 91.9 86.7 81.7 79.1 80.6 83.0 82.5 87.2 90.8 92.5 95.7	4,53.13,"N. 457.9 423.4 397.4 354.2 345.6 354.2 319.7 337.0 354.2 440.6 449.3	L.",6.58, 0.45 2.05 2.85 5.01 6.22 6.11 5.71 5.83 4.06 2.45 1.06 0.13	" 01" 2.06 4.60 7.93 13.22 17.06 17.95 16.92 15.05 10.18 5.78 2.77 1.53	0.21 0.39 0.86 1.58 2.43 2.82 2.75 2.53 1.59 0.83 0.44 0.22		
Mean daily M maximum	Alean daily minimum	Mean relative	Mean wind speed	Mean sunshine hours per	Mean solar radiation	ET (mm,	+	Climate/El

.CLI

.PEN



#### 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

#### SUGARBET.CRO - Notepad

File Edit Format View Help

CROPWAT 8.0 Crop data Suqarbeet 50 40 50 40 0.70 0.35 1.20 0.30 1.00 0.50 0.60 0.60 1.20 1.00 1.10 0.50 0.80 0.70

- 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)



Green and blue water footprint of a crop



# 1. CWR option - input

🛞 CROPWAT -	Session: untitled							_ 🗆 🗙
File Edit Ca	Iculations Charts	Settings Wind	ow Language	Help				
	New Øpen	Save Close	e Print C	hart Options				
🚿 🔆 Climate/ETo								
🗡 🕅 Rain								
🗡 🍦 Crop								
<b>ii</b> Soil								
V CWR								
₩ Schedule								
👯 Crop Pattern								
Scheme								
ET	o file	Rain f	ile	Cri	op file	Soil file	Planting date	

Green and blue water footprint of a crop



# 1. CWR option - output

🛞 CROPWAT	- Session: untitled				
File Edit Ca	alculations Charts	Settings Window La	anguage Help		
	New Open	Save Close	😂 🧱 🖬 Print Chart Options		
¥ Climate/E⊺o					
Rain					
🔶 Crop					
1 Soil					
X CWR					
Schedule					
辩 Crop Pattern					
Scheme					
E	To file	Rain file	Crop file	Soil file	Planting date



# 1. CWR option - output

🐌 Crop Water	Requirements							
ETo sta	ation GRONIN	GEN-AP-EELD				Сгор	Sugarbeet	
Rain sta	ation GRONIN	GEN-AP-EELD			F	lanting 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	



# 1. CWR option - output

🕑 Crop Water F	Requirements						_	- [
ETo sta	tion GRONIN	GEN-AP-EELD				Сгор	Sugarbeet	
Rain sta	tion GRONIN	GEN-AP-EELD			P	lanting 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	Copy table 🕒	Data only		0.0	
Jun	2	Deve	0.73	2.25	Data and He	aders	2.0	
Jun	3	Deve	0.95	2.90	29.0	ZI.T	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	
Ѕер	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	



# 1. CWR option - output

$ET = ET_{c}$
$ET_g = min (ET_c, P_{eff})$
$ET_{b} = max (0, ET_{c} - P_{eff})^{*}$ Irr. fraction

	Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	ET	ЕТg	ЕТь
				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
$\sim$	Oct	1	Late	0.76	0.91	5.5	12.2	0	5.5	5.5	0
	Total					381	346	100	381	282	100

Growing period



# 1. CWR option

## Water footprint estimation

ETg	EТь	ET	CWUg	CWU <sub>b</sub>	CWU	Y≭	WF <sub>proc,green</sub>	$\textbf{WF}_{proc,blue}$	$\textbf{WF}_{proc}$	
	mm/period			m <sup>3</sup> /ha		ton/ha		m <sup>3</sup> /ton		
282	100	381	2816	995	3811	59	48	17	65	
*IRS (1999	IRS (1999-2006) for Northern Netherlands									





🛞 c	ROPWA	AT - 3	Session	i: un	titled						
File	Edit	Cal	culatio	ns	Charts	Setting	gs Windov	w Langua	ge He	lp	
			New	Ŧ	Dpen	Sav	ye Close	Print	₩. Chart	Options	
X Clin X X So Cro	Rain Rain Crop Soil Soil CWR WE chedule P Patte W	e ern									
		ETo	) file				Rain file	•		C	rop file





🛞 CI	ROPWA	AT -	Session	n: un	titled					
File	Edit	Cal	lculatio	ns	Charts	Settings	Window	Language	Help	
			New	Ŧ	Dpen	- Save	Close	esta de la composición de la c	hart Options	
Clim	inate/E Rain ₽ Crop ₩ Soil	Το								
Sc	CWR E hedula Patte	e								
S	💔 cheme	•								
		ET	o file				Rain file		C	rop file





🚯 Crop irr	igation scl	hedule									_ 🗆 🗙
ETo	station 🛛	GRONINGE	N-AP-EELD	Cro	p Sugarbe	et		Planting	date 10/0	)4	Yield red.
Rain	station	GRONINGE	N-AP-EELD	So	il Medium	(loam)		Harvest	0	0.0 %	
⊂ Table form C Irriga ⊙ Daily	Table format Table format Trigation schedule Daily soil moisture balance				Timing:Irrigate at critical depletionApplication:Refill soil to field capacityField 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	-
10 4	0	1a	00	1.00	00	-	0.0	10	- 00	00	
Totals	Ac Poter Efficier Deficier	Total gr Total Total irrig tual water ntial water ncy irrigat	oss irrigati net irrigati jation loss use by cr use by cr on schedu	on 0.0 on 0.0 es 0.0 op 380 op 380 ule - ule 0.0	mm mm .3 mm .3 mm % %		Moi: Actual irr	Tot Effectiv Total st deficit a igation rec Effici	al rainfall ve rainfall rain loss tharvest quirement ency rain	383.0 319.5 63.4 60.8 60.8 83.4	mm   mm   mm   mm   mm   x
Yield 1	reduction	\$	Stagelabe	, A		В	С	C	) S	eason	-



# ?

### 2. Irrigation schedule option - output

🐌 CI	) CROPWAT - Session: untitled													
File	Edit	Calculatio	ons	Charts S	ettings W	'indow L	anguage	Help						
		New	Ŧ	Dpen 🕇	<b>L</b> Save	Close	Print Ch	∉ 😭 art Option	IS					
			Crop i	irrigation so	chedule									
	×		ET	o station	GRONINGE	N-AP-EELD	Cra	p Sugarbe	et		Planting	date 10/0	14	Yield red.
Clim	nate/ET	ο	Bai	n station	, GRONINGE	N-AP-EELD		il Medium	(loam)		Harvest	, date 06/1	0	0.0 %
				·										
	0		able ro	ormat 				Timing: Ir	rigate at cri	tical depletio	n			
	Bain		i mig Si Di si	gation sch ilu soil moi	equie istura balar		Application: Refill soil to field capacity							
			· Da	ny son moi	sture Dalai	ice	Fie	eld eff. 7						
	_		)ate	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	<b>_</b>
	<u>*</u>					mm	fract.	mm/day	%	mm	mm	mm	mm	
	Crop	10	0 Apr	1	Init	0.0	1.00	0.5	1	0.0	0.5	0.0	0.0	
		11	1 Apr	2	Init	0.0	1.00	0.6	1	0.0	1.1	0.0	0.0	
	140	12	2 Apr	3	Init	0.0	1.00	0.6	2	0.0	1.8	0.0	0.0	
	Soil	13	3 Apr	4	Init	7.6	1.00	0.6	1	0.0	0.6	0.0	0.0	
		14	4 Apr	5	Init	0.0	1.00	0.6	1	0.0	1.2	0.0	0.0	
		1	5 Apr	6	Init	0.0	1.00	0.6	2	0.0	1.8	0.0	0.0	
	<b>\$</b>	16	6 Apr	7	Init	0.0	1.00	0.6	2	0.0	2.5	0.0	0.0	
	C₩R	17	7 Apr	8	Init	7.6	1.00	0.6	1	0.0	0.6	0.0	0.0	-
		-  =	• •	1 0	13	0.0	1.00	00	- 1	0.0	10	00	0.0	
Sc	) Kedule	,	Tota	ls ———	Total gr Total Total irrig	oss irrigat net irrigat gation loss	ion 0.0 ion 0.0 ses 0.0	MM MM			Tot Effectiv Total	al rainfall ve rainfall Frain loss	383.0 319.5 63.4	mm mm mm
Grou	e anticia de la compañía de la compa			Ad Pote	ctual water Intial water	use by cr use by cr	rop 380 rop 380 la	).3 mm ).3 mm		Moi: Actual irr	st deficit a igation rec rcc:-:	nt harvest quirement	60.8 60.8	mm mm
CIU	p r aue	"		Deficie	ency irrigati	ion sched	ule 0.0	* %			EINC	ency rain	03.4	* 
S	辩 Scheme		Yield	l reduction	18	Stagelabe	e A		B	C	C	) S	eason	•





#### **Rainfed conditions**

$$ET_{qreen}$$
 (*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)

CROPWAT options										
Non-rice crop scheduling										
Scheduling criteria for non-rice crops	-									
Irrigation timing										
No irrigation (rainfed)										
No irrigation (only rainfall)										
Ingation application										
Refill soil to field capacity										
Inigation efficiency Inigation efficiency: 70 %	]									
Save as default Reset to FAO defaults OK Cancel Help										

#### Irrigated scenario (*irr* = 1)

CROPWAT options
Non-rice crop scheduling
C Scheduling criteria for non-rice crops
Irrigation timing
Irrigate at critical depletion
Irrigation at 100 % critical depletion
Irrigation application
Refill soil to field capacity
Refill soil moisture content to 100% field capacity
Irrigation efficiency
Save as default Reset to FAD defaults OK Cancel Help





# 2. Irrigation schedule option – output – Medium soil

#### Rainfed scenario (*irr* = 0)

🔊 Crop irr	igation sc	hedule									_ 🗆
ETo	station 🛛	GRONINGE	N-AP-EELD	Cro	p Sugarbe	eet		Planting date 10/04			
Rain	station 🛛	GRONINGE	N-AP-EELD	So	il Medium	(loam)		Harvest	date 06/1	10	0.0 %
Table forn O Trriga O Daily	nat ntion sche soil mois	edule sture balar	ice	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	Ac Poter Efficier Deficier	Total gro Total i Total irrig tual water ntial water ncy irrigati ncy irrigati	oss irrigationet irrigation net irrigation lation losso use by cro use by cro on schedu on schedu	on 0.0 on 0.0 es 0.0 op 380 op 380 le - le 0.0	mm mm .3 mm .3 mm 2 %		Moi Actual in	Tol Effectiv Tota st deficit a igation re Effici	al rainfall ve rainfall I rain loss at harvest quirement iency rain	383.0 319.5 63.4 60.8 60.8 83.4	nm nm nm nm mm %
Yield ı	eduction	\$	Stagelabel	A		В	C	[	) S	eason	

#### **Rainfed conditions**

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

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





# 2. Irrigation schedule option – output – Medium soil

🖲 Crop irr	igation sc	hedule										
ETo	station [	GRONINGE	N-AP-EELD	Cro	p Sugarbe	eet		Planting date 10/04				
Rain	station	GRONINGE	N-AP-EELD	Soi	il Medium	(loam)		Harvest date 06/10			0.0 %	
Table forr O Irriga O Daily	nat ation scho v soil moi:	edule sture balar	ice	T Applio Fie	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	Ac Pote Efficie Deficie	Total gro Total i Total irrig tual water ntial water ncy irrigati ncy irrigati	oss irrigatio net irrigatio jation loss use by cro use by cro on schedu	on 0.0 on 0.0 es 0.0 op 380. op 380. le - le 0.0	mm mm 3 mm 3 mm % %		Moi Actual irr	Tot Effectiv Tota st deficit a igation re Effici	al rainfall ve rainfall I rain loss at harvest quirement iency rain	383.0 319.5 63.4 60.8 60.8 83.4	mm mm mm mm %	
Yield	reduction	s	Stagelabel	A		В	С	[	) 5	eason		

#### Irrigated scenario (*irr* = 1)

#### **Irrigated conditions**

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

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



### Green and blue water footprint of a crop



### 2. Irrigation schedule option - output – Soil comparison

	— T-1-1-						
Light	Totais	Total gross irrigation Total net irrigation Total irrigation losses Actual water use by crop Potential water use by crop Efficiency irrigation schedule Deficiency irrigation schedule	110.4 77.2 0.0 380.3 380.3 100.0 0.0	mm mm mm mm % %	Total rainfall Effective rainfall Total rain loss Moist deficit at harvest Actual irrigation requirement Efficiency rain	383.0 300.0 83.0 3.1 80.4 78.3	mm mm mm mm %
	— Totale						
	I ULAIS	Total gross irrigation	0.0	mm	Total rainfall	383.0	mm
		Total net irrigation	0.0	mm	Effective rainfall	319.5	mm
edium		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	%		00.1	
	– Totals						
		Total gross irrigation	0.0	mm	Total rainfall	383.0	mm
		l otal net irrigation	0.0	mm	Effective rainfall	319.5	mm
eavv		l otal irrigation losses	0.0	mm	i otal rain loss	63.4	mm
loavy		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	%			

N





# 2. Irrigation schedule option - output – Soil comparison

CROPWAT	ETgreen	ET <sub>blue</sub>	ET	<b>CWU</b> green	$\textbf{CWU}_{\text{blue}}$	CWU	Y≭	WF <sub>proc,green</sub>	WF <sub>proc,blue</sub>	$\mathbf{WF}_{proc}$
option	mm/period			m <sup>3</sup> /ha			ton/ha	m³/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





## Water footprint estimation

### 1. CWR option

ETg	ЕТ <sub>ь</sub>	ET	CWUg	CWU <sub>b</sub>	CWU	Y*	WF <sub>proc,green</sub>	WF <sub>proc,blue</sub>	WFprod	
mm/period			m³/ha			ton/ha	m <sup>3</sup> /ton			
282	100	381	2816	995	3811	59	48	17	65	

\*IRS (1999-2006) for Northern Netherlands

### 2. Irrigation schedule option

CROPWAT	ETgreen	ET <sub>blue</sub>	ET	<b>CWU</b> green	$\textbf{CWU}_{\text{blue}}$	CWU	<b>Y</b> *	WF <sub>proc,green</sub>	WF <sub>proc,blue</sub>	WF <sub>proc</sub>
option		mm/period			m³/ha		ton/ha		m <sup>3</sup> /ton 7 0 0	
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)



# **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





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

### Grey water footprint of a crop



## Grey water footprint Source: Fertistat (FAO, 2009c)

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS helping to build a world without hunger

Plant Production and Protection Division

#### FertiStat Fertilizer Use Statistics

- Home
- Fertilizer Use Statistics
- Download dataset
- Publications
- Related Sites
- Contact

**Fertilizer Use Statistics** 

English | Français | Español

This page provides 3 criteria for the selection of fertilizer use statistics. You may select more than one country by holding down the Ctrl key and clicking on the countries. FertiStat is still growing - if there is no data for the country-crop-year combination selected, please retry by dropping one of the selection criteria.

#### Country

Moldova, Republic of Morocco Myanmar Netherlands

#### Commodity





All years 👻





## 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 <sub>proc.grey</sub> sugar beet	Production**	WF <sub>prod,grey</sub> sugar beet				
kg/ha	ha	ton/year	ton/year	mg/l	10 <sup>6</sup> m <sup>3</sup> /year	ton	m <sup>3</sup> /ton				
108	10887	1176	118	10	12	647176	18				
*Fertistat (FAO, 2009c)											
**IRS (1999-2006) for Northern Netherlands											

#### 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: <u>http://www.fao.org/docrep/X0490E/X0490E00.htm</u>

**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

**EPA (2009)** Drinking Water Contaminants. US Environmental Protection Agency. Available from: <u>http://www.epa.gov/safewater/contaminants/index.html</u>

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

**FAO (2005)** New LocClim 1.10 database. Food and Agriculture Organization of the United Nations, Rome, Available from: <u>http://www.fao.org/nr/climpag/pub/en3\_051002\_en.asp</u>

**FAO (2006)** CLIMWAT Database. Food and Agriculture Organization, Rome. Available from: <u>http://www.fao.org/nr/water/infores\_databases\_climwat.html</u>

**FAO (2009a)** CROPWAT Model. Food and Agriculture Organization, Rome. Available from: <u>http://www.fao.org/nr/water/infores\_databases\_cropwat.html</u>

**FAO (2009b)** FAOSTAT Database. Food and Agriculture Organization. Rome. Available from: <u>http://faostat.fao.org</u>

**FAO (2009c)** FERTISTAT Database. Food and Agriculture Organization, Rome. Available from: <u>http://www.fao.org/ag/agl/fertistat/fst\_fubc\_en.asp</u>

**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