Crop Water Requirements and Irrigation Management using Weather Data

Graziano Ghinassi

DEISTAF - University of Florence

graziano.ghinassi@unifi.it

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Field comparison of drip and hose reel irrigation performance results of a three year research project in Italy

11 farms
Sub-humid climate

Field comparison of drip and hose reel irrigation performance results of a three year research project in Italy

Crop	Irrigation System	Crop water requirements (mm)	Effective Rainfall (mm)	Net Irrigation Requirement (mm)	Seasonal Irrigation Supply (mm)	Water surplus (m^3/ha)	Irrigation Efficiency (%)
Onion	Sprinkler	256	64	192	268	760	72
	Drip			192	303	1110	63
Processing Tomato	Sprinkler	272	131	141	160	190	88
	Drip	224		93	115	220	81
Processing Tomato	Sprinkler	231	60	171	194	230	88
	Drip	229	89	140	245	1050	57
Tobacco	Sprinkler	162	0	162	189	270	86
	Drip	154		154	238	840	65
Onion	Sprinkler	498	348	150	224	740	67
	Drip			150	241	910	62
Processing Tomato	Sprinkler	311	211	100	133	330	75
	Drip	296		85	171	860	50
Processing Tomato	Sprinkler	428	334	94	120	260	78
	Drip	414		80	204	1240	39
Tobacco	Sprinkler	343	237	106	125	190	85
	Drip	338		101	129	280	78
Onion	Sprinkler	285	103	182	223	410	82
	Drip	253		150	238	880	63
Processing Tomato	Sprinkler	298	68	230	263	330	87
	Drip	267	71	196	348	1520	56
Tobacco	Sprinkler	217	94	123	188	650	65
	Drip	211		117	144	270	81

Processing Tomato in South Italy (avg season)

Crop water req: 4000-4500 m^3/ha
Net irrigation req: 3000-3500 m^3/ha
Seasonal irrigation: 6000-6500 m^3/ha
Irrigation efficiency: **~50-60%**
Water losses: up to **3000 m^3/ha**

Processing Tomato in South Italy (avg season)

SUMMER 2012
Dams and reservoirs
(nearly) empty

1-There is evidence that:

- users don’t know crop (irrigation) water requirements;
- users don’t know how much water they supply;
- when water is not a limiting factor (availability, cost), water use is inefficient in most cases.

2-There is evidence that:

- water is fundamental for crop production;

Plants use water for three major purposes:

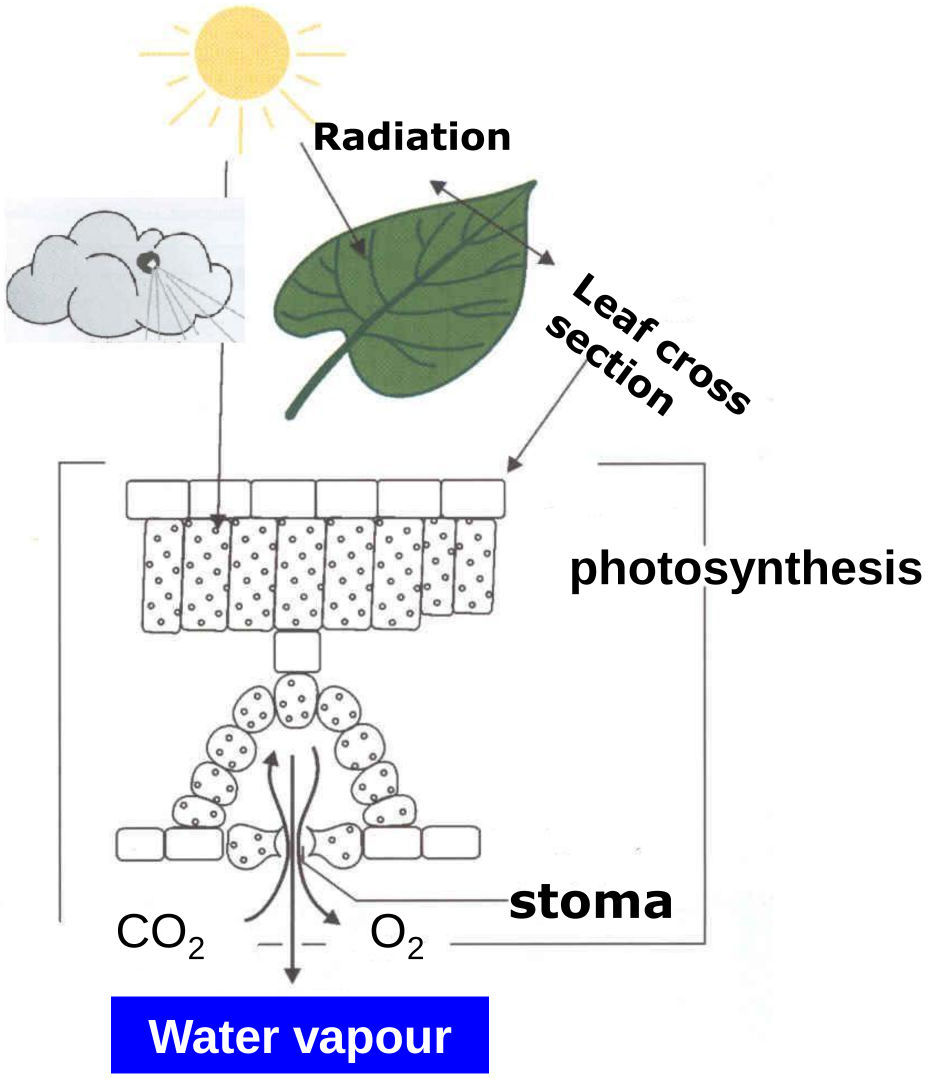
1. to transport dissolved chemicals and minerals (fertilisers) from the plant root hairs to the rest of the plant

2. to control the physical shape and direction of growth of the plant (water pressure in plant cells provides structure)

3. to assist in control of leaf temperature.

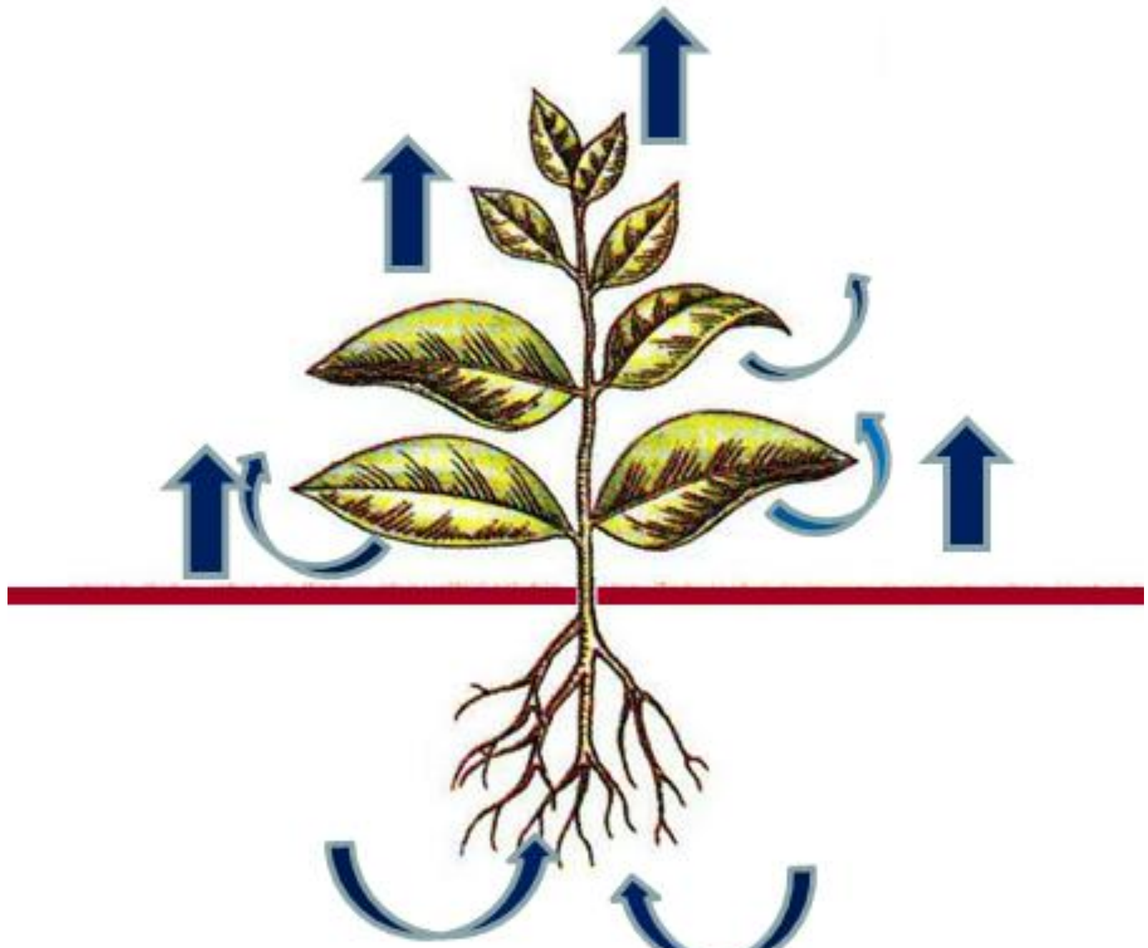
Destination of absorbed water (e.g., annual crops ~98%) is the atmosphere.

Water transfer from the root system to the atmosphere is called TRANSPIRATION



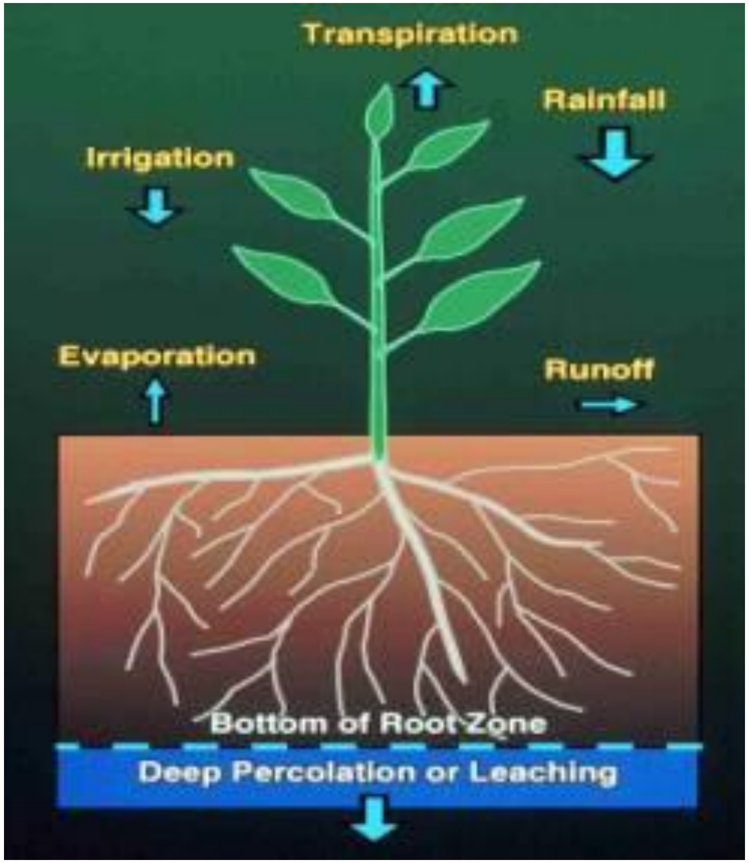
Irrigation, Cemagref

When evaporation from the soil is computed, the combined condition is called EVAPOTRANSPIRATION.



Analysis of crop water use

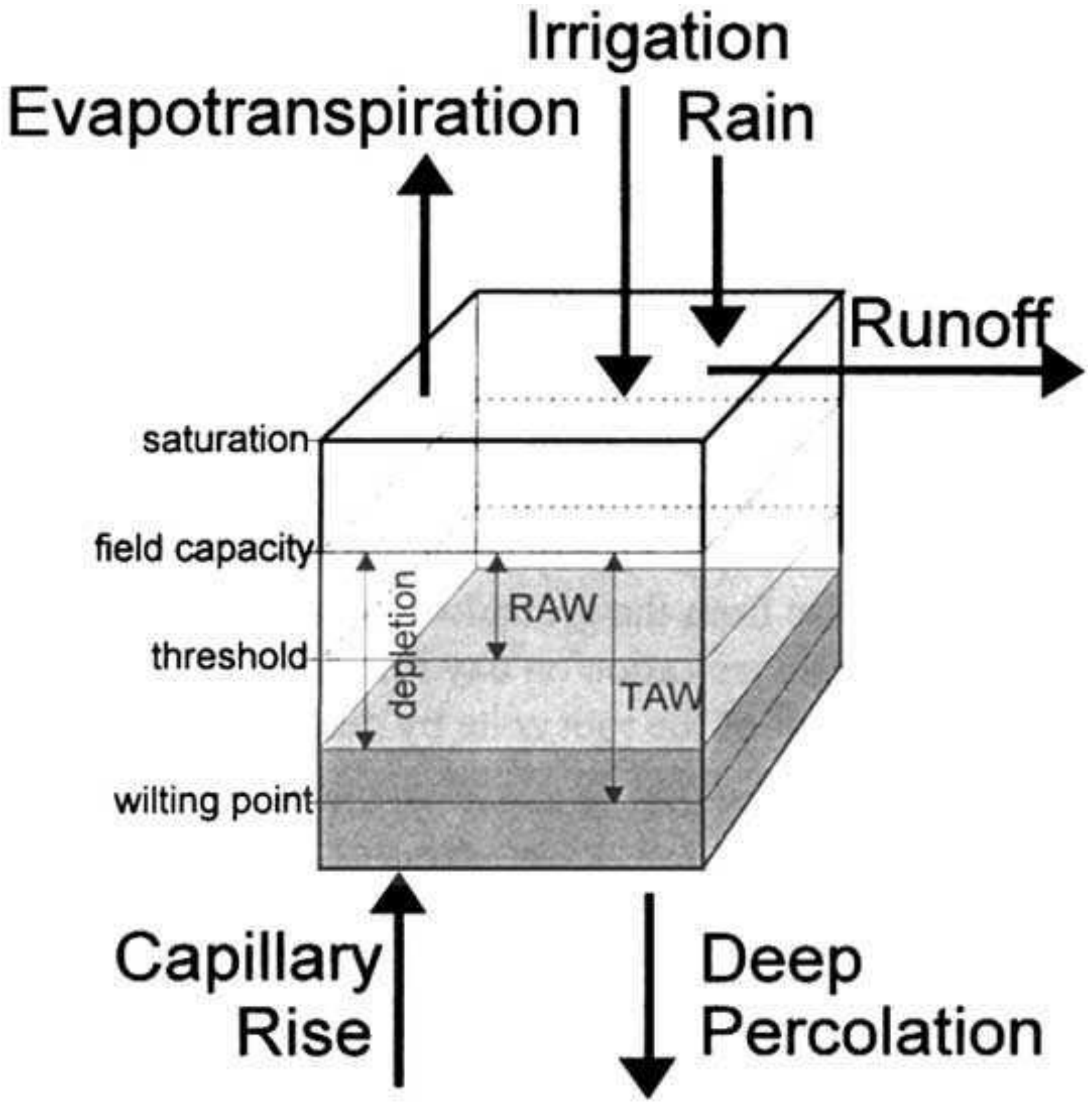
- Water for crop ET is stored in the soil;
- upward water flow starts in the soil;
- understanding soil water balance.



Water balance

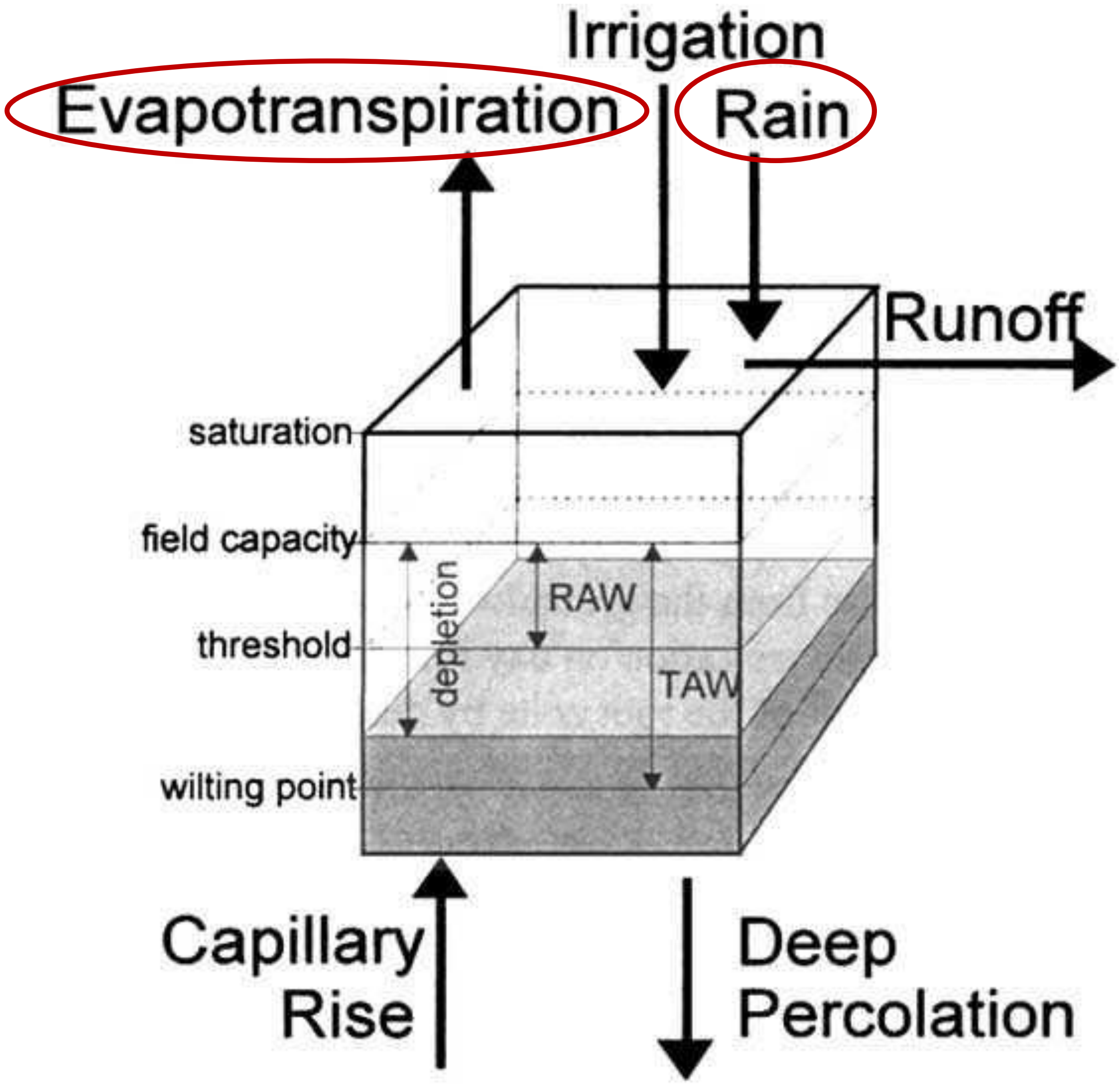
The water balance estimates the volume of water moving into a defined area (e.g., volume of soil, which has defined **vertical and horizontal boundaries)**, the change in volume of water in the area and the volume of water moving out of the area during a given **time period**.

Components of soil water balance



FAO, I&D paper 56

Components of soil water balance



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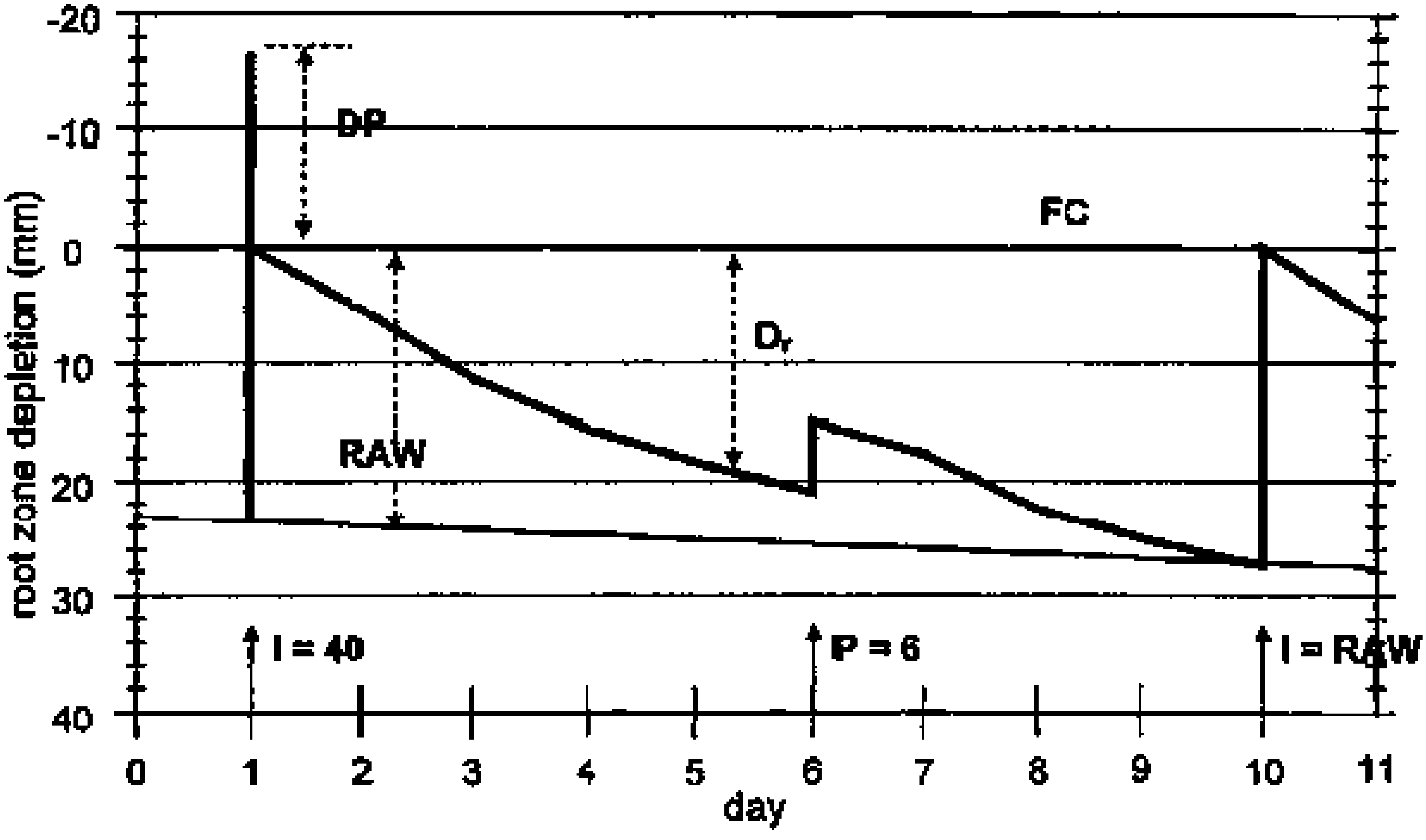
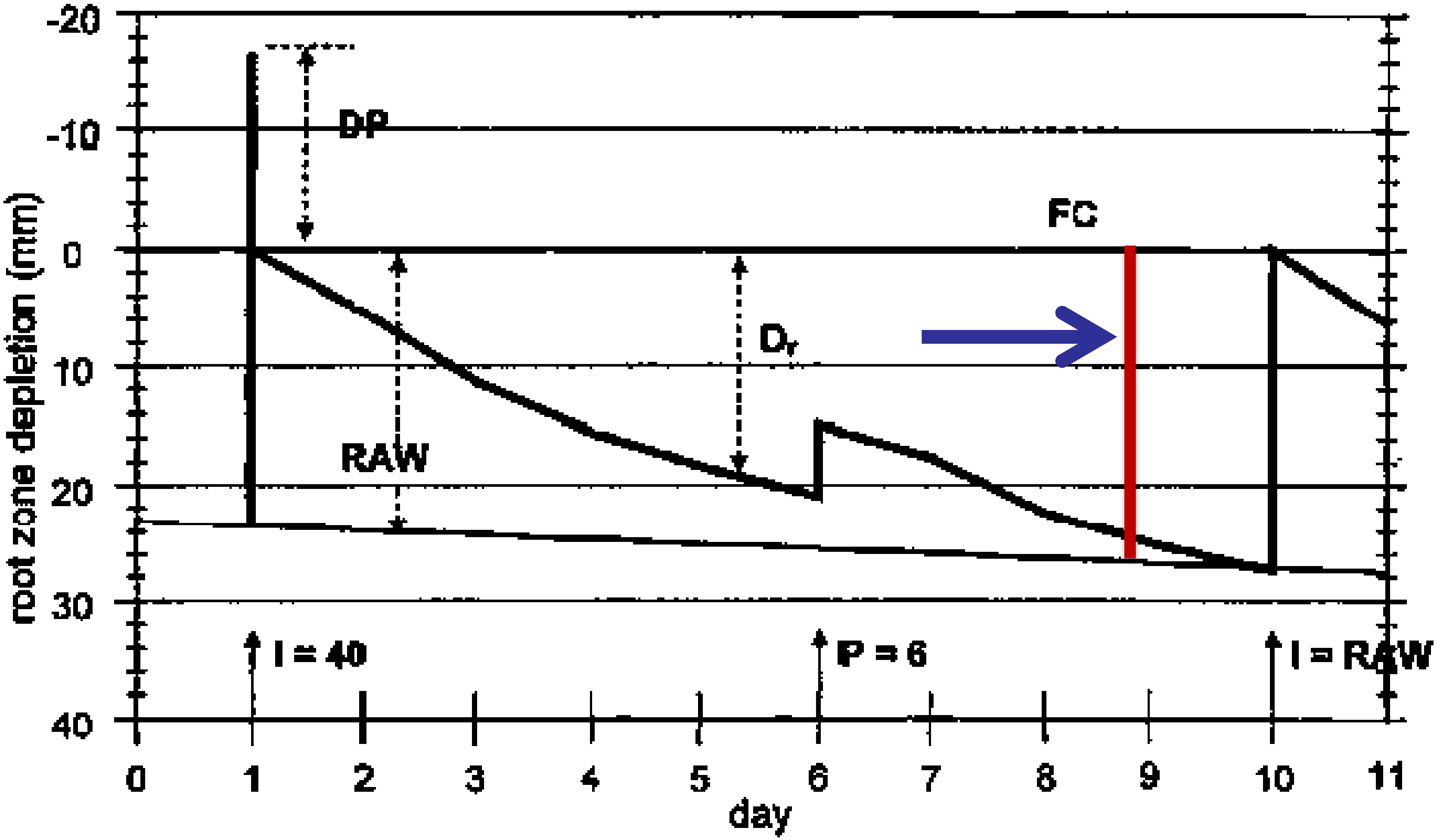
Evolution of soil water content



Evolution of soil water content



The water lost in the evapotranspiration process is the

net crop water requirement

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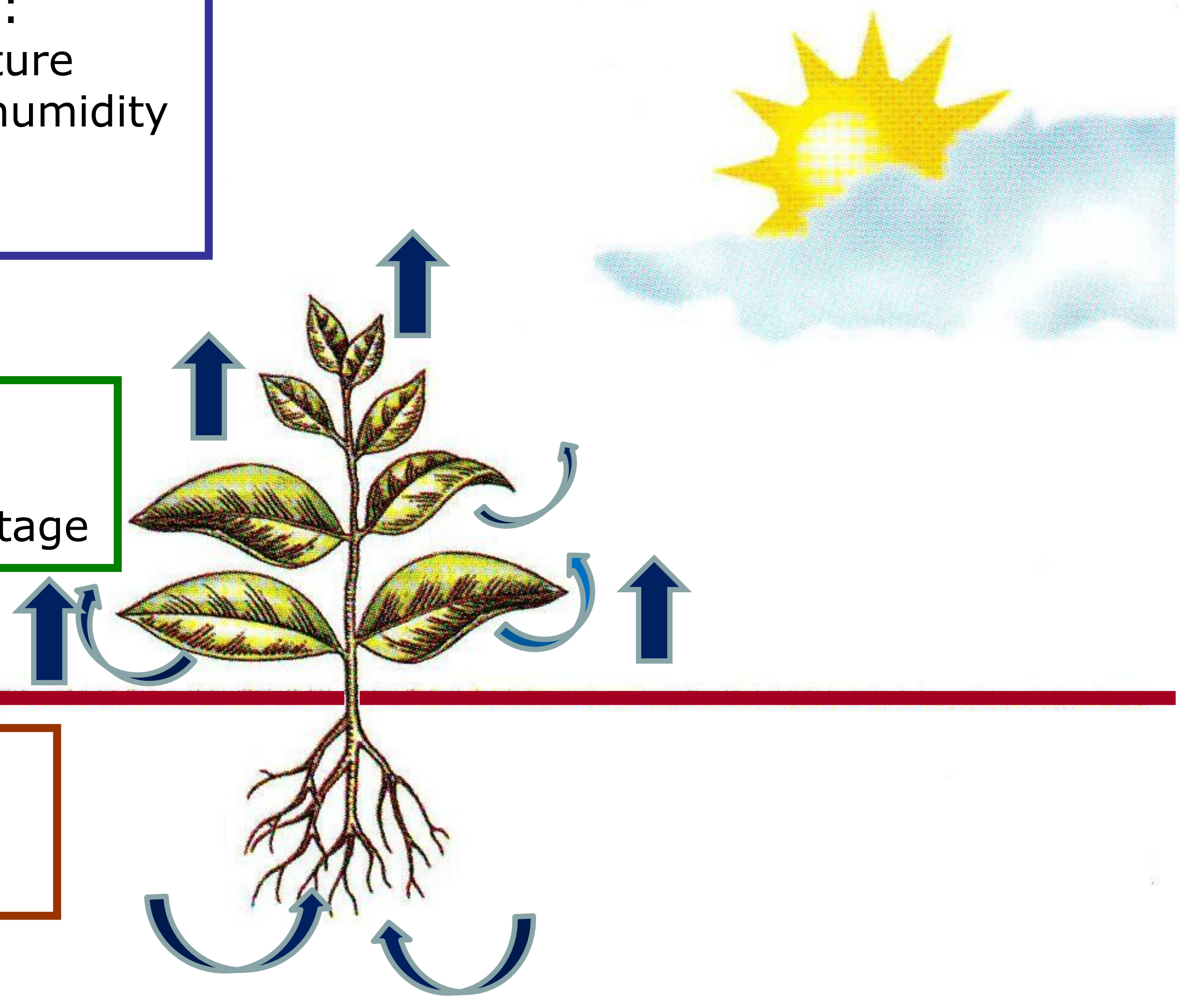
- When adequate moisture is available to the plant there is a continuous flow of water from the root hairs up to the leaves.
- If inadequate moisture is present in the soil, then water related stress happens.
- Too much water in the rootzone for long periods can also be damaging to plants due to a reduction in oxygen in the area around the root hairs. This can occur when irrigation is performed too frequently or in too great amount for the plant to remove and use.

Factors affecting evapotranspiration

CLIMATE:
- temperature
- relative humidity
- radiation
- wind

PLANT:
- type
- growth stage

SOIL:
- texture
- structure



Climate

and

Evapotranspiration

Sunlight (solar radiation).
Sunlight provides most of the **energy** used in the **evaporation** of water **from the soil** and in the process of **plant transpiration**, which **is the transformation of water in the soil to the water vapour** that leaves the plant through leaf surfaces.
Sunlight is measured in terms of its **intensity** and **duration** and is influenced by cloud cover, altitude and the shading of nearby plants, structures, or terrain.

Wind.

Wind moves air across leaf and soil surfaces and increases the amount of water vapour removed from the landscape. Wind is measured in terms of its velocity, direction and duration and may be slightly influenced by trees and other crops.

Air Temperature.

Temperature influences the rates of transpiration from the plant and evaporation from the soil. Higher temperatures result in more rapid removal of water from the landscape.

Humidity.
Humidity is a measure of the water vapour content of the air. Lower humidity (dry air) provides a greater differential between the moist leaf surface and the air, which increases the rate of water loss from the plant. Humidity is typically quantified in terms of relative humidity (relative to completely saturated air).

The influence of meteorological parameters on crop water requirements is summarized by the FAO approach into the
reference evapotranspiration (ETo)

FAO definition for the reference surface:

"A hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m^{-1} and an albedo of 0.23."

The reference surface closely resembles an extensive surface of green grass of uniform height, actively growing, completely shading the ground and with adequate water. The requirements that the grass surface should be extensive and uniform result from the assumption that all fluxes are one-dimensional upwards.

FAO, I&D paper 56

The FAO ***Penman-Monteith method*** *is selected as the method by which the evapotranspiration of this reference surface (ET_o) can be unambiguously determined, and as the method which* ***provides consistent ET_o values in all regions and climates****.*

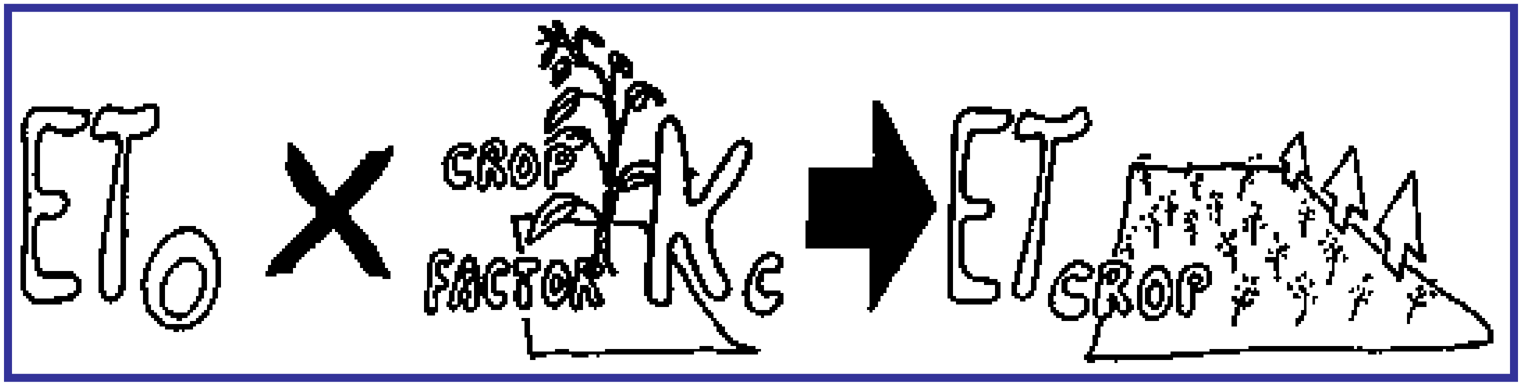
FAO, I&D paper 56

FAO Penman-Monteith

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

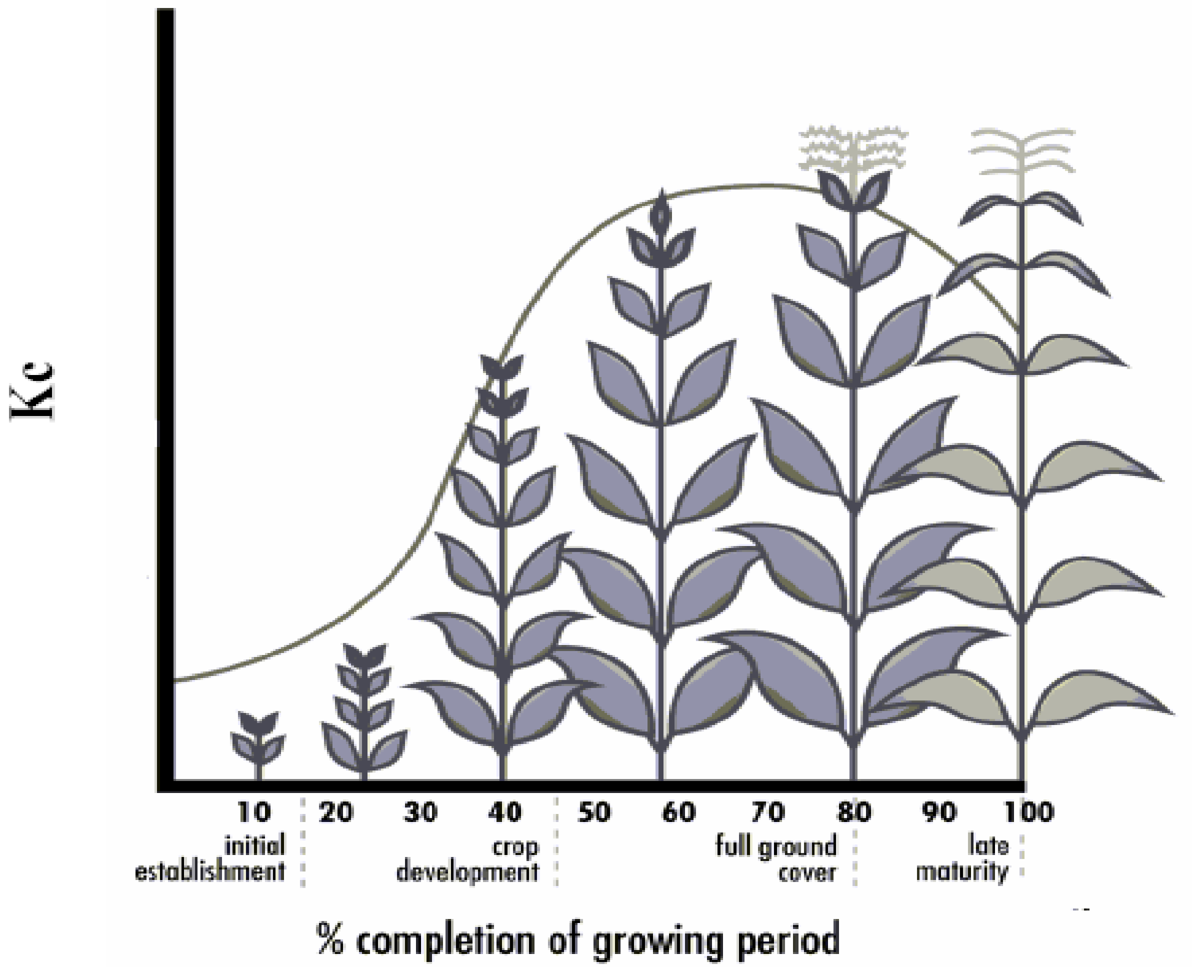
ET_o	reference evapotranspiration [mm day^{-1}],
R_n	net radiation at the crop surface [MJ m^{-2} day^{-1}],
G	soil heat flux density [MJ m^{-2} day^{-1}],
T	mean daily air temperature at 2 m height [°C],
u_2	wind speed at 2 m height [m s^{-1}],
e_s	saturation vapour pressure [kPa],
e_a	actual vapour pressure [kPa],
e_s-e_a	saturation vapour pressure deficit [kPa],
Δ	slope vapour pressure curve [kPa °C^{-1}],
γ	psychrometric constant [kPa °C^{-1}].

FAO methodology to calculate ET crop from ETo



FAO methodology to calculate ET crop from ETo

Crop water use will vary with climate, weather conditions and stage of crop development. To relate crop water use to Reference Evapotranspiration (ETo), crop coefficients (Kc) have been developed for most crops.



FAO methodology to calculate ET crop from ETo

ETo represents an index of climatic demand

Kc varies predominately with the specific crop characteristics and only to a limited extent with climate.

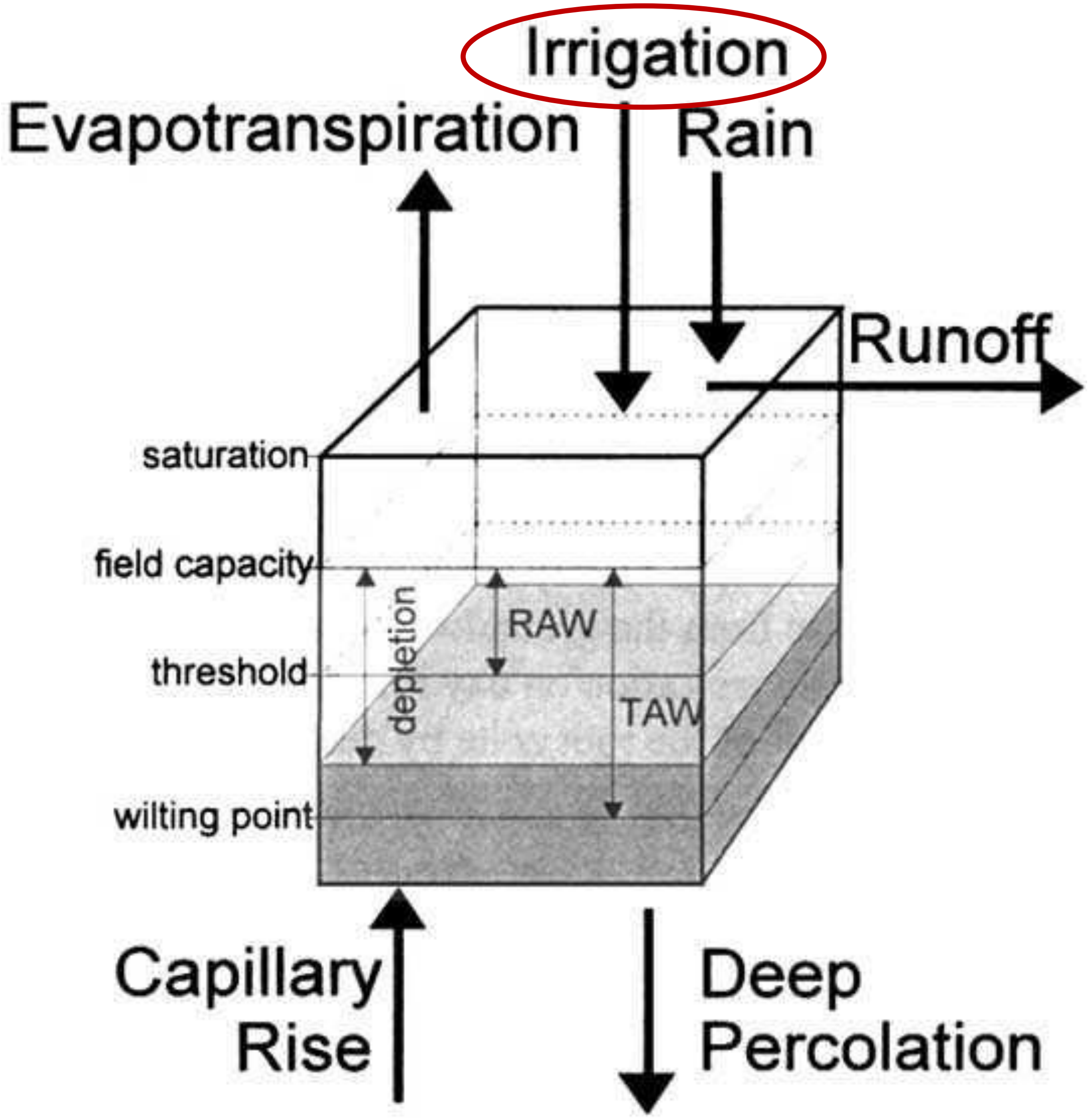
This enables the transfer of standard values for Kc between locations and between climates.

Crop

and

Irrigation

Components of soil water balance



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Crop and irrigation

A crop develops under optimal conditions when the water need is met during the growing time.

- **Irrigation** is (1) the human activity that results in supplying water, in addition to **precipitation**, to encourage crop **growth** (ICID).
- **Irrigation** is (2) the application of water supplementary to that supplied directly by **precipitation** for the **production** of crops (Proceedings of the Consultation on Irrigation in Africa, Lomé, Togo, 1997).

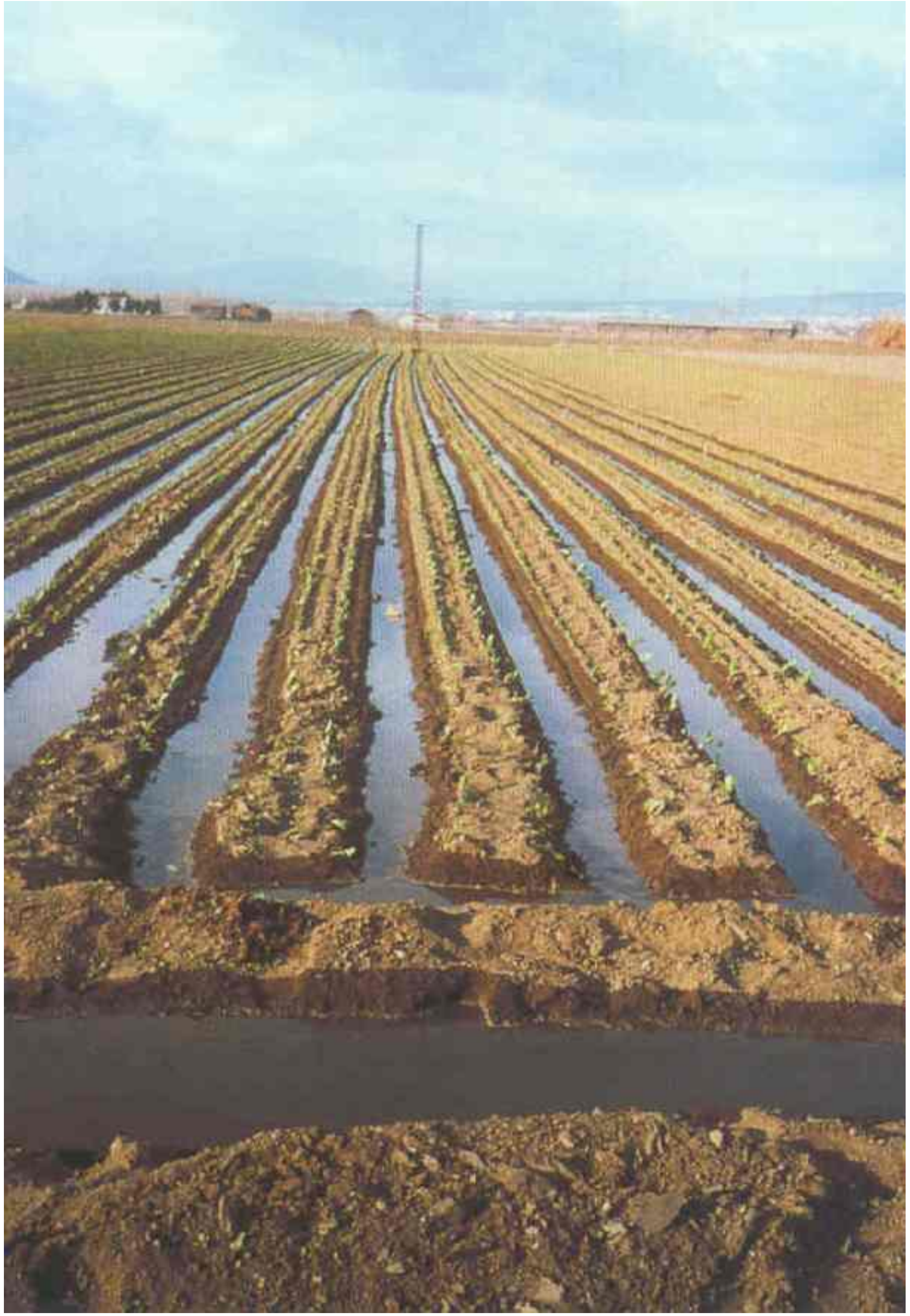
Crop and irrigation

Irrigation water is supplied to the soil by using different systems and according to different strategies (management).

Irrigation Management aims to manipulate soil water content in order to achieve specific objectives (e.g., crop yield, quality).

Management is described by the irrigation parameters

Furrows

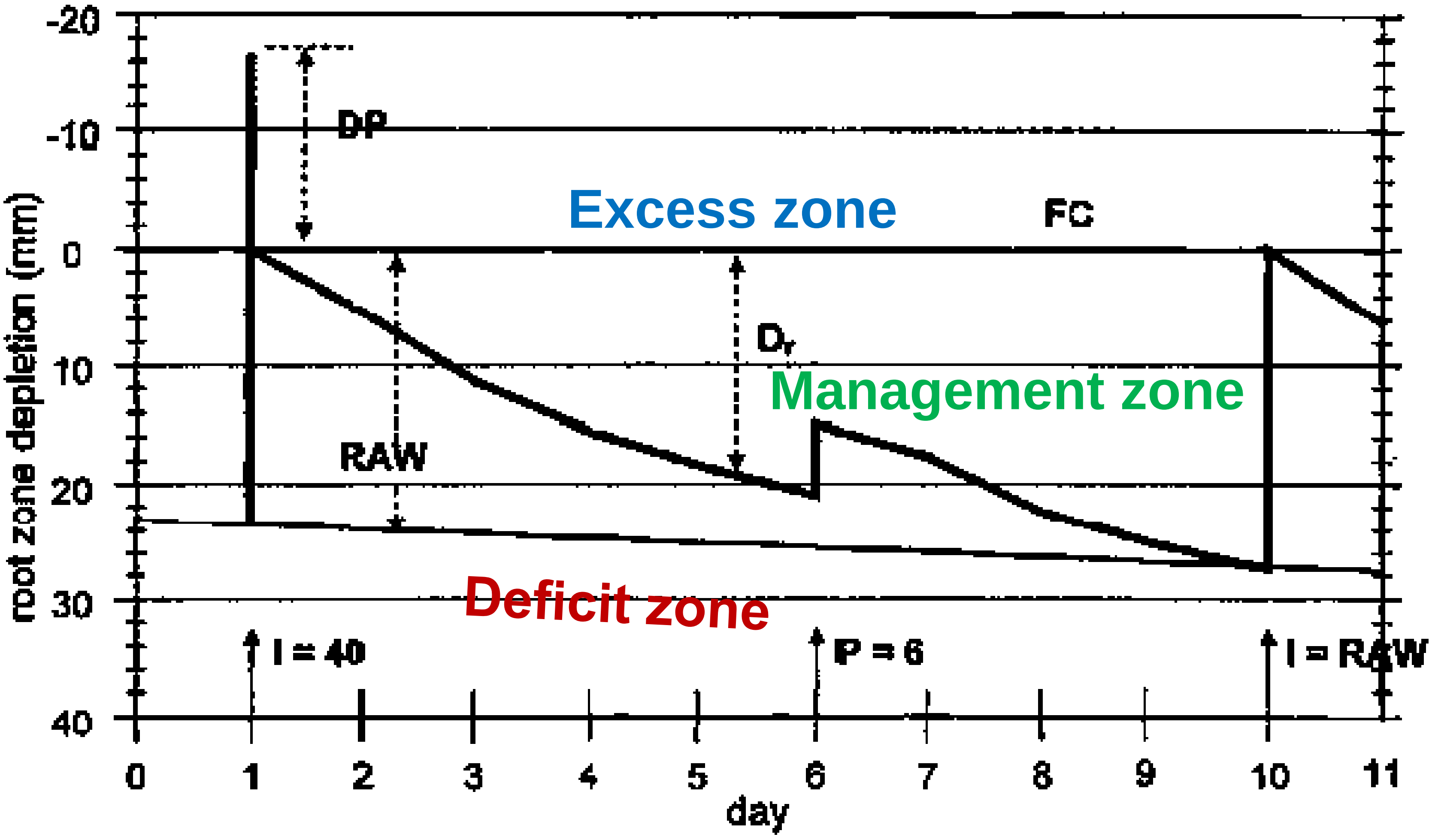


Sprinkler

Micro

Management example

Strategy: *keep soil water content in a range to avoid both water deficit and excess*



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Irrigation parameters

-Irrigation requirement (net to gross);

-Irrigation time;

-Irrigation Interval or Frequency.

Irrigation requirement (IR)

-Net IR = Etc;

-Gross IR (to be supplied) = Etc/system efficiency

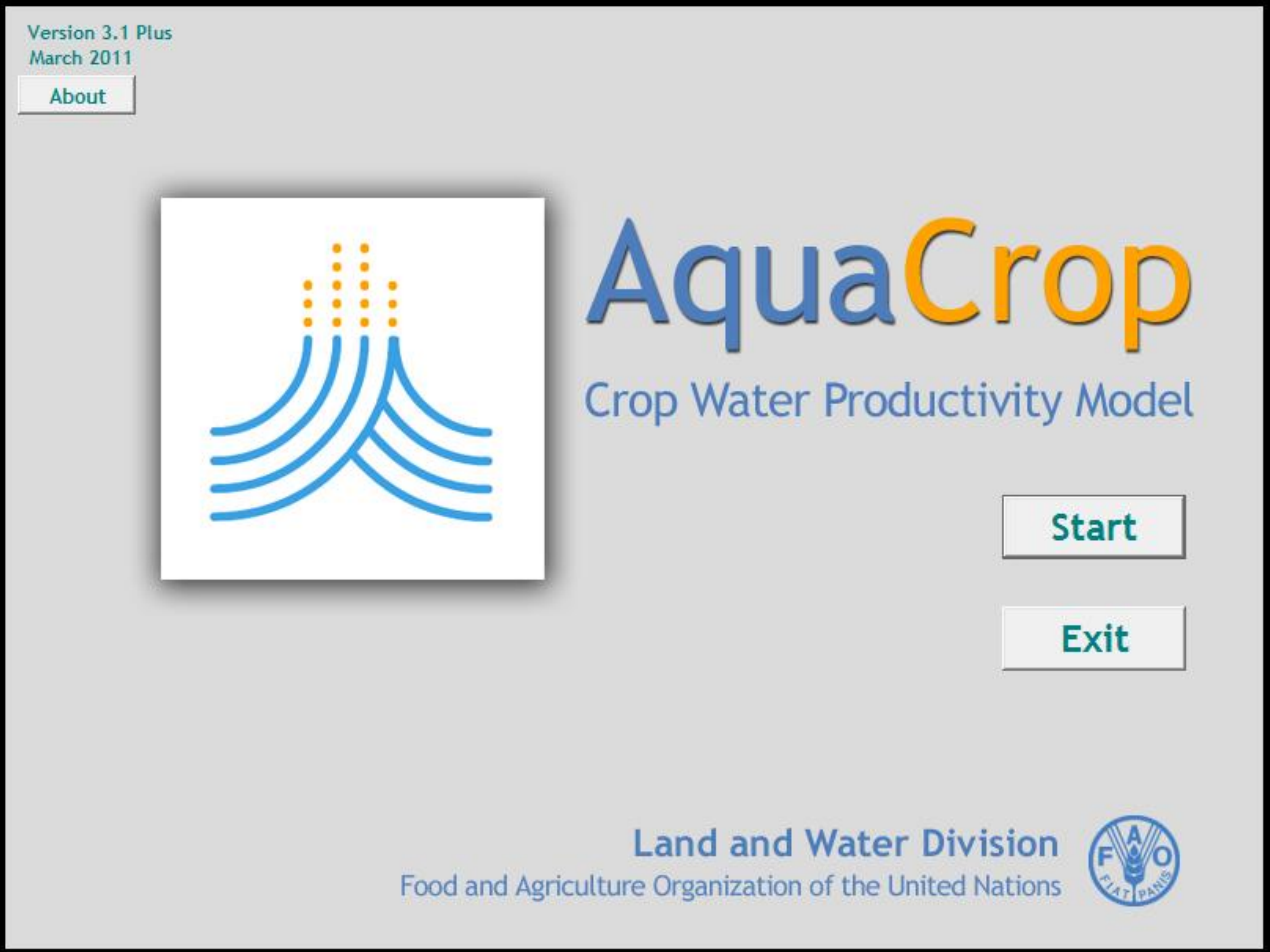
Irrigation time

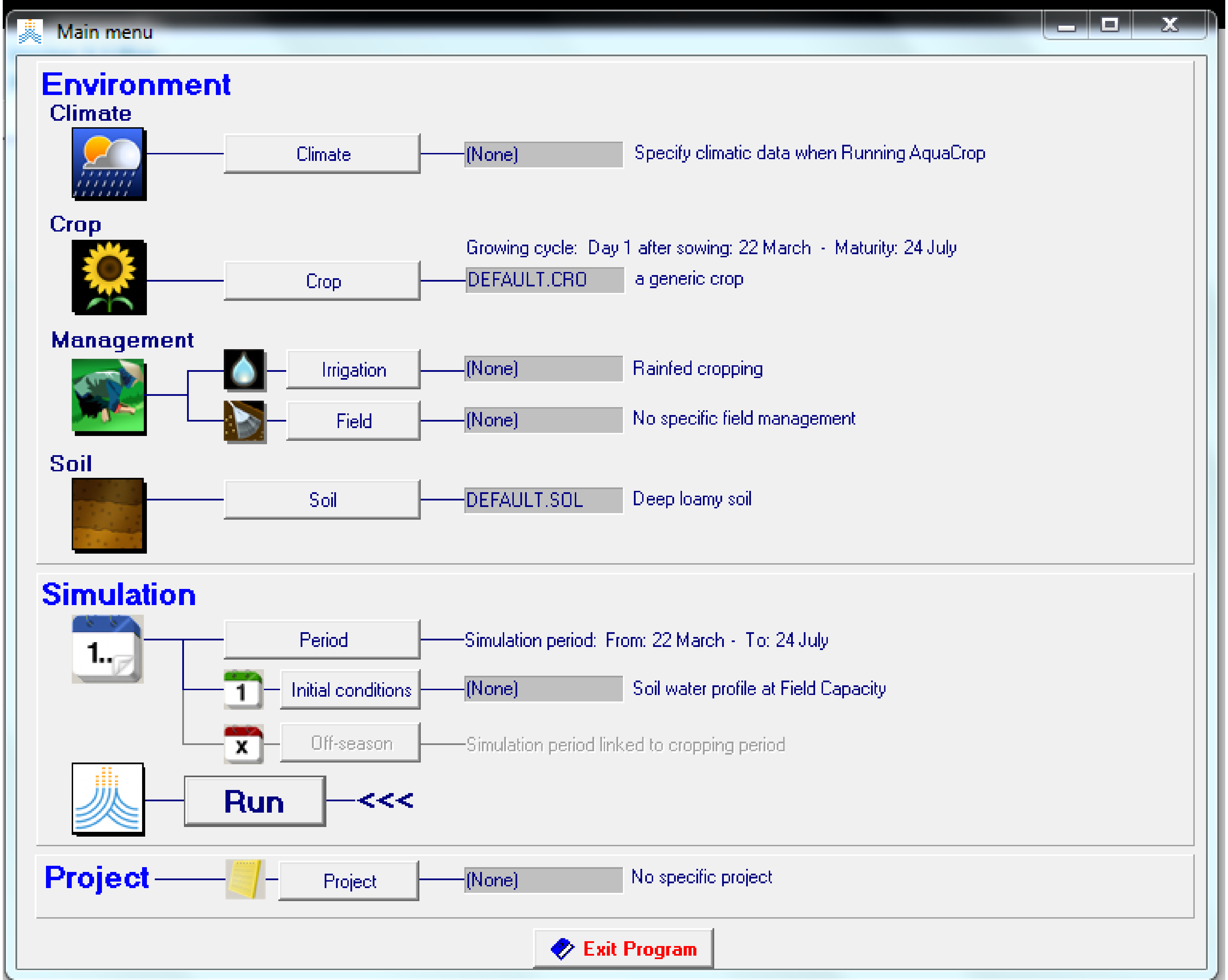
-Irrigation time = duration of an irrigation event

Irrigation interval

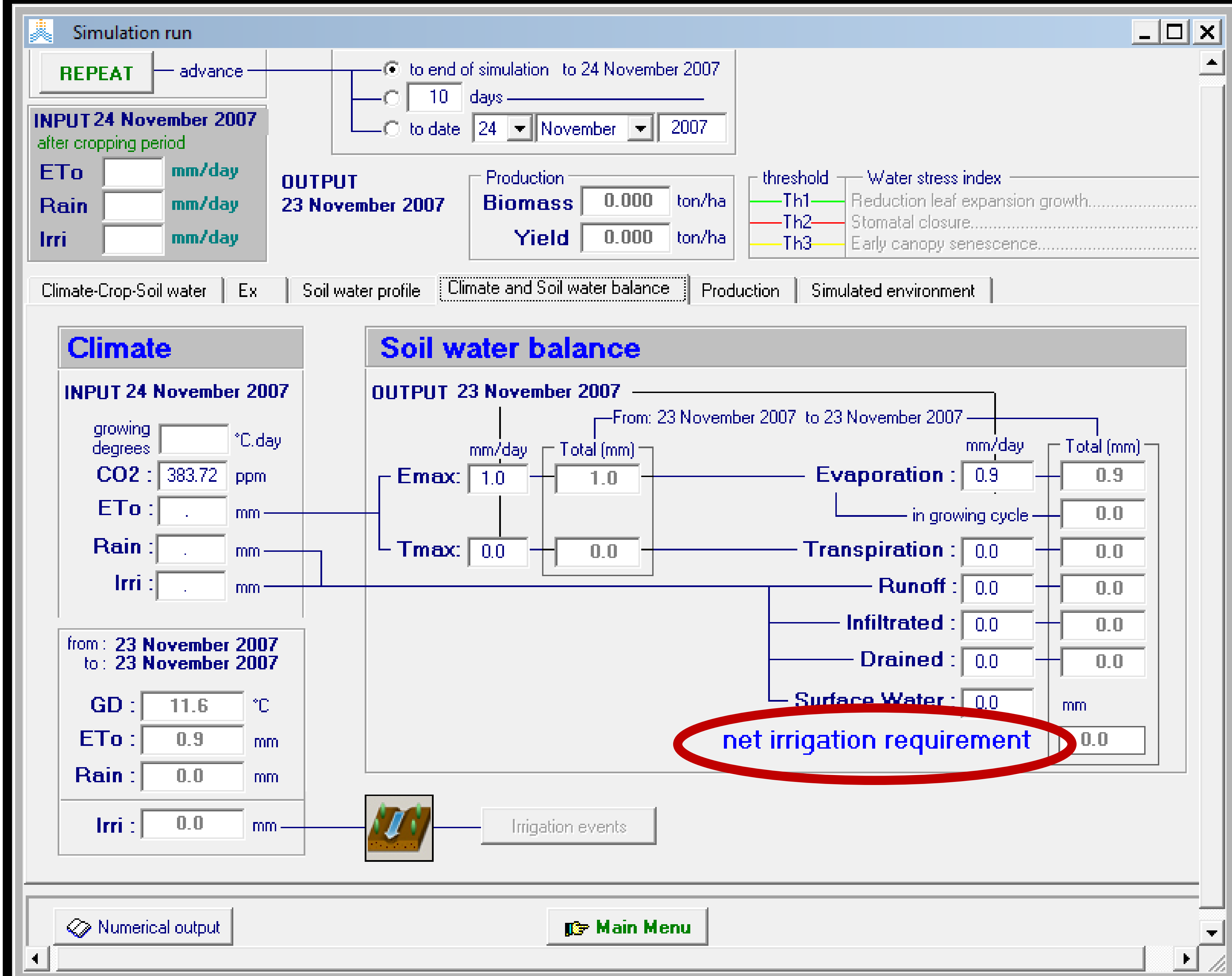
-Irrigation Interval or Frequency = time from the start of two subsequent irrigations

- Assessment of crop water requirements and irrigation management is quite complex.


Version 3.1 Plus
March 2011
About
AquaCrop
Crop Water Productivity Model
Start
Exit
Land and Water Division
Food and Agriculture Organization of the United Nations
FAO
FIAT PANIS



Main menu
Environment
Climate
Climate
(None)
Specify climatic data when Running AquaCrop
Crop
Growing cycle: Day 1 after sowing: 22 March - Maturity: 24 July
Crop
DEFAULT.CRO
a generic crop
Management
Irrigation
(None)
Rainfed cropping
Field
(None)
No specific field management
Soil
Soil
DEFAULT.SOL
Deep loamy soil
Simulation
1..
Period
Simulation period: From: 22 March - To: 24 July
1
Initial conditions
(None)
Soil water profile at Field Capacity
x
Off-season
Simulation period linked to cropping period
Run
<<<
Project
Project
(None)
No specific project
Exit Program


Simulation run
REPEAT
advance
to end of simulation to 24 November 2007
10 days
to date 24 November 2007
INPUT 24 November 2007
after cropping period
ETo mm/day
Rain mm/day
Irri mm/day
OUTPUT
23 November 2007
Production
Biomass 0.000 ton/ha
Yield 0.000 ton/ha
threshold
Th1
Th2
Th3
Water stress index
Reduction leaf expansion growth
Stomatal closure
Early canopy senescence
Climate-Crop-Soil water
Ex
Soil water profile
Climate and Soil water balance
Production
Simulated environment
Climate
INPUT 24 November 2007
growing degrees °C.day
CO2 : 383.72 ppm
ETo : mm
Rain : mm
Irri : mm
from : 23 November 2007
to : 23 November 2007
GD : 11.6 °C
ETo : 0.9 mm
Rain : 0.0 mm
Irri : 0.0 mm
Irrigation events
Soil water balance
OUTPUT 23 November 2007
From: 23 November 2007 to 23 November 2007
mm/day
Total (mm)
Emax: 1.0 1.0
Tmax: 0.0 0.0
Evaporation : 0.9 0.9
in growing cycle 0.0
Transpiration : 0.0 0.0
Runoff : 0.0 0.0
Infiltrated : 0.0 0.0
Drained : 0.0 0.0
Surface Water : 0.0 mm
net irrigation requirement 0.0
Numerical output
Main Menu

Output NET IRRIGATION REQUIREMENT can be manage by design support tools, able to assess

- Gross Irrigation Application Depth;
- Irrigation Time;
- Water losses;
- Energy requirements.

ARSIA - *Agenzia Regionale per lo Sviluppo e l'innovazione nel settore Agricolo-forestale*

Ve.Pro.L.G. s 2008

Laboratorio Nazionale dell'Irrigazione

VeProLG s

File View Insert Tools ?

RANKING OF DRIP LINE ACCORDING TO UNIFORMITY

INPUTS

Lunghezza 200 m Slope 0 %

RESULTS

Drip lines model	Spacing. m	Press. head m c.a.	Q ave. l/hm	Intensity mm/hour	E distrib. Wh/m³	EU %
Uniram CNL d.16 q.2.3 s. 0.8 autocomp. (2005)	0.8	17.7	2.90	2.9	49.052	**98.1**
NAANPC d.16 q.1.6 s.0.8 autocomp. (2005)	0.8	13.5	2.05	2.1	37.649	**97.8**
RA'AM d.17 q.2,3 s.0,5 autocomp. (1997)	0.5	27.5	4.55	4.6	76.618	**97.6**
Uniram CNL d.16 q.2.3 s. 0.6 autocomp. (2004)	0.6	28.3	3.84	3.8	78.897	**97.6**
Uniwine d.16 q.1.6 s.0.8 autocomp. (2004)	0.8	12.2	2.12	2.1	34.120	**97.5**
RAAM d.16 q.1.6 s.0.8 autocomp. (2004)	0.8	11.3	2.04	2.0	31.553	**97.4**
Dripnet PC 16390 d.16 q.1.6 s.0.6 autocomp. (2005)	0.6	13.6	2.68	2.7	38.246	**97.0**
Python d.22 q.0.84 s.0.3 (2004)	0.3	6.0	2.61	2.6	16.836	**97.0**
Tif 16/2.1 PC d.16 q.2.1 s.0.8 autocomp. (2004)	0.8	19.9	2.74	2.7	56.096	**96.7**
RA'AM d.17 q.2,3 s.0,6 autocomp. (1997)	0.6	20.5	3.76	3.8	57.706	**96.6**

Design drip line

Drip line — EU / η / H

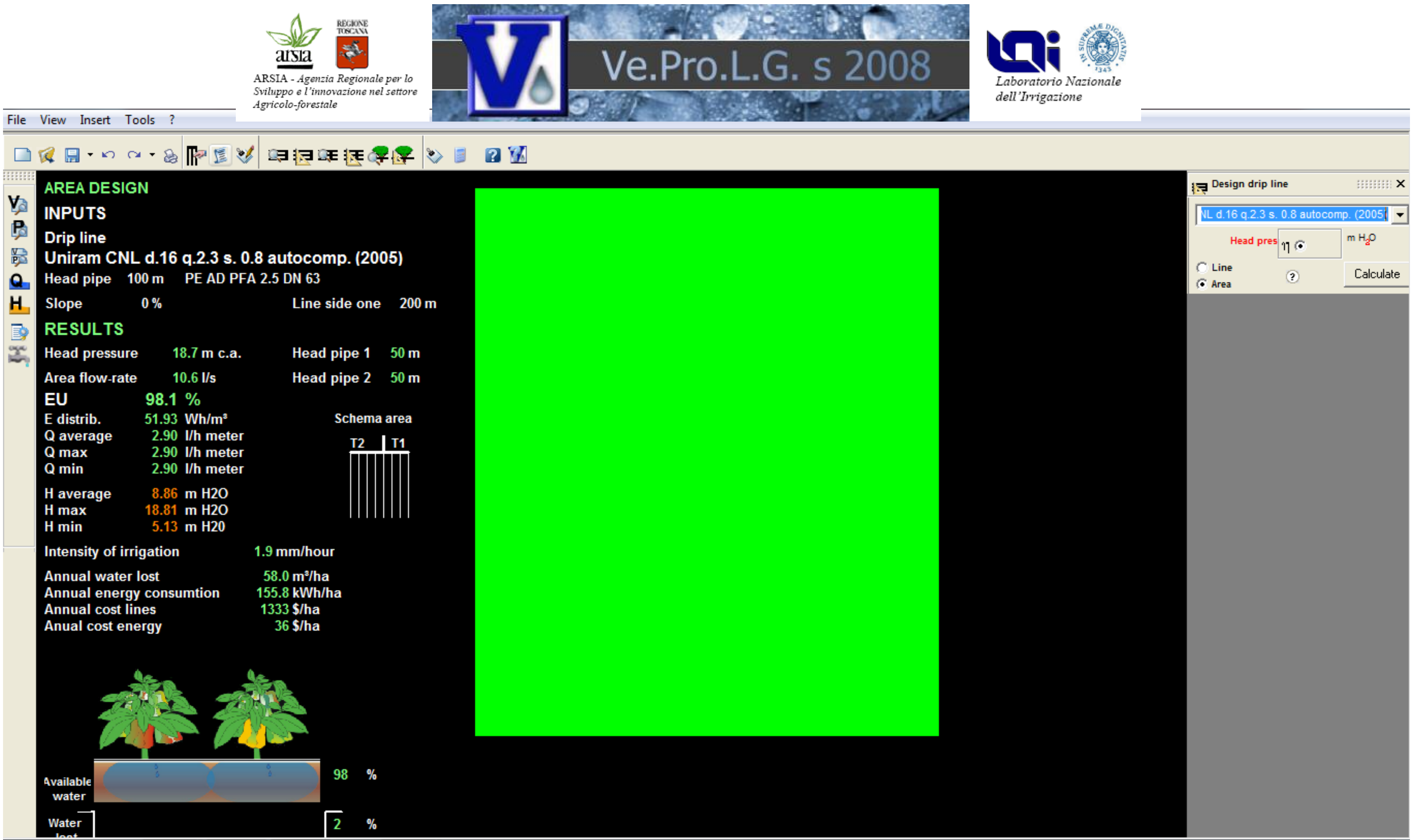
Lenght m 200

Head pres. m H_2O

Slope % 0

Line / Area

Calculate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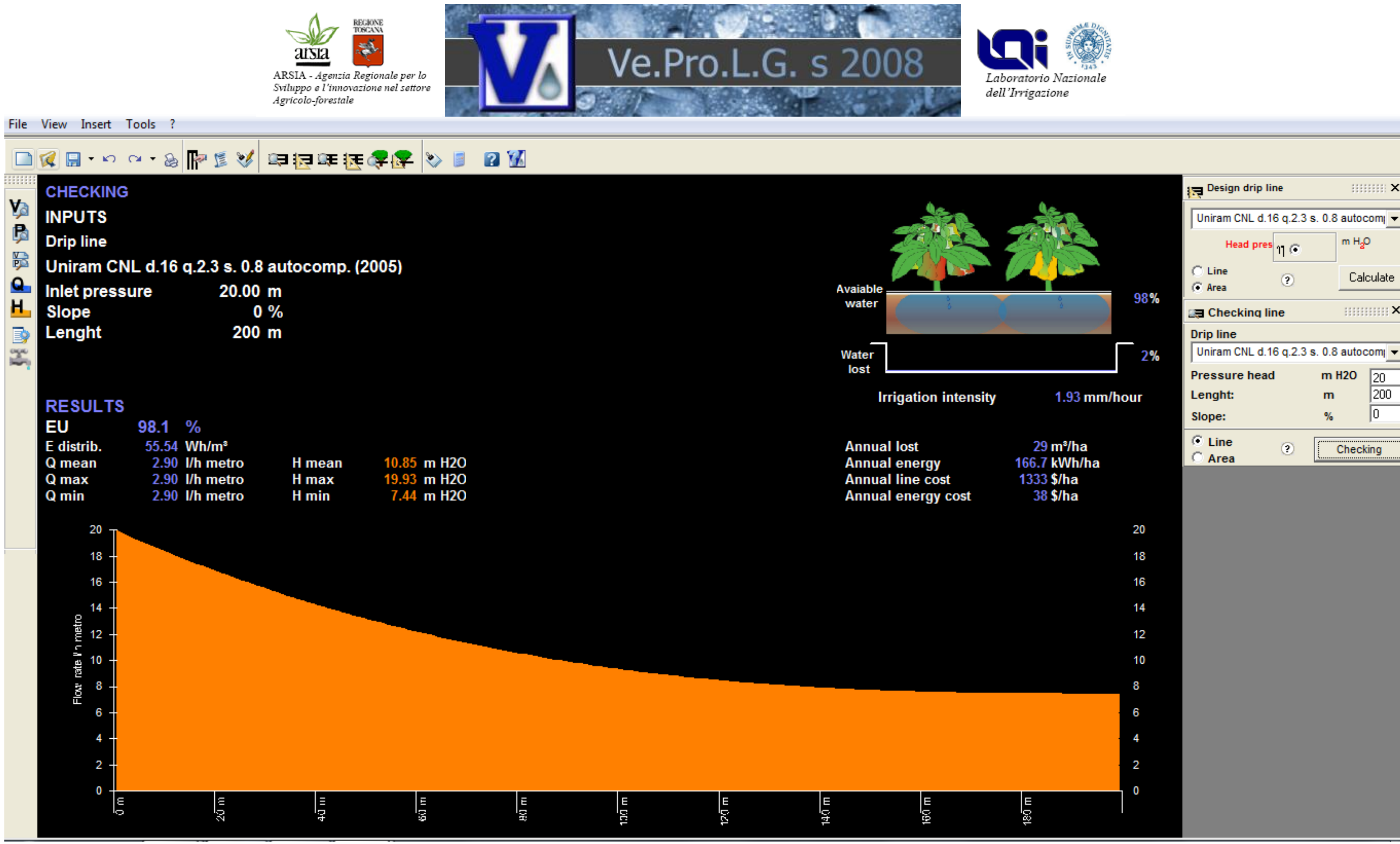
REGIONE TOSCANA
Ve.Pro.L.G. s 2008
Laboratorio Nazionale dell'Irrigazione
File View Insert Tools ?
AREA DESIGN
INPUTS
Drip line
Uniram CNL d.16 q.2.3 s. 0.8 autocomp. (2005)
Head pipe 100 m PE AD PFA 2.5 DN 63
Slope 0 %
Line side one 200 m
RESULTS
Head pressure 18.7 m c.a.
Head pipe 1 50 m
Area flow-rate 10.6 l/s
Head pipe 2 50 m
EU 98.1 %
E distrib. 51.93 Wh/m³
Q average 2.90 l/h meter
Q max 2.90 l/h meter
Q min 2.90 l/h meter
H average 8.86 m H2O
H max 18.81 m H2O
H min 5.13 m H20
Schema area
T2 T1
Intensity of irrigation 1.9 mm/hour
Annual water lost 58.0 m³/ha
Annual energy consumtion 155.8 kWh/ha
Annual cost lines 1333 $/ha
Anual cost energy 36 $/ha
Available water 98 %
Water lost 2 %
Design drip line
NL d.16 q.2.3 s. 0.8 autocomp. (2005)
Head pres
m H2O
Line
Area
Calculate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REGIONE TOSCANA
Ve.Pro.L.G. s 2008
Laboratorio Nazionale dell'Irrigazione
File View Insert Tools ?
CHECKING
INPUTS
Drip line
Uniram CNL d.16 q.2.3 s. 0.8 autocomp. (2005)
Inlet pressure 20.00 m
Slope 0 %
Lenght 200 m
Avaiable water
98%
Water lost
2%
Irrigation intensity 1.93 mm/hour
RESULTS
EU 98.1 %
E distrib. 55.54 Wh/m³
Q mean 2.90 l/h metro
Q max 2.90 l/h metro
Q min 2.90 l/h metro
H mean 10.85 m H2O
H max 19.93 m H2O
H min 7.44 m H2O
Annual lost 29 m³/ha
Annual energy 166.7 kWh/ha
Annual line cost 1333 $/ha
Annual energy cost 38 $/ha
Flow rate l/h metro
0 m
20 m
40 m
60 m
80 m
100 m
120 m
140 m
160 m
180 m
Design drip line
Uniram CNL d.16 q.2.3 s. 0.8 autocom
Head pres
m H2O
Line
Area
Calculate
Checking line
Drip line
Uniram CNL d.16 q.2.3 s. 0.8 autocom
Pressure head m H2O 20
Lenght: m 200
Slope: % 0
Line
Area
Checking

Future perspectives

- Sustainable water use in agriculture is achievable
- Importance to strenghten the role of Met services to supply Eto information and take care of data quality
- Agrometeorological networks to support irrigation practice under different conditions of water avalaibility
- Support the participation of Water users associations and Agric Extension services in the framework of the CAMI project objectives.


Thank you!