Food and Agriculture Organizatio
of the United Nations

WATER
Efficiency, Productivity,
and Sustainability
in the Near East and North Africa countries

Sweden
Sverige

مقدمة الى النموذج الرياضي
AquaCrop

د. إيهاب جناد

مدير إدارة المياه-اكساد

ihjnad@yahoo.com

المركز العربي لدراسات المناطق الجافه و الأراضي القاحلة

(ACSAD)

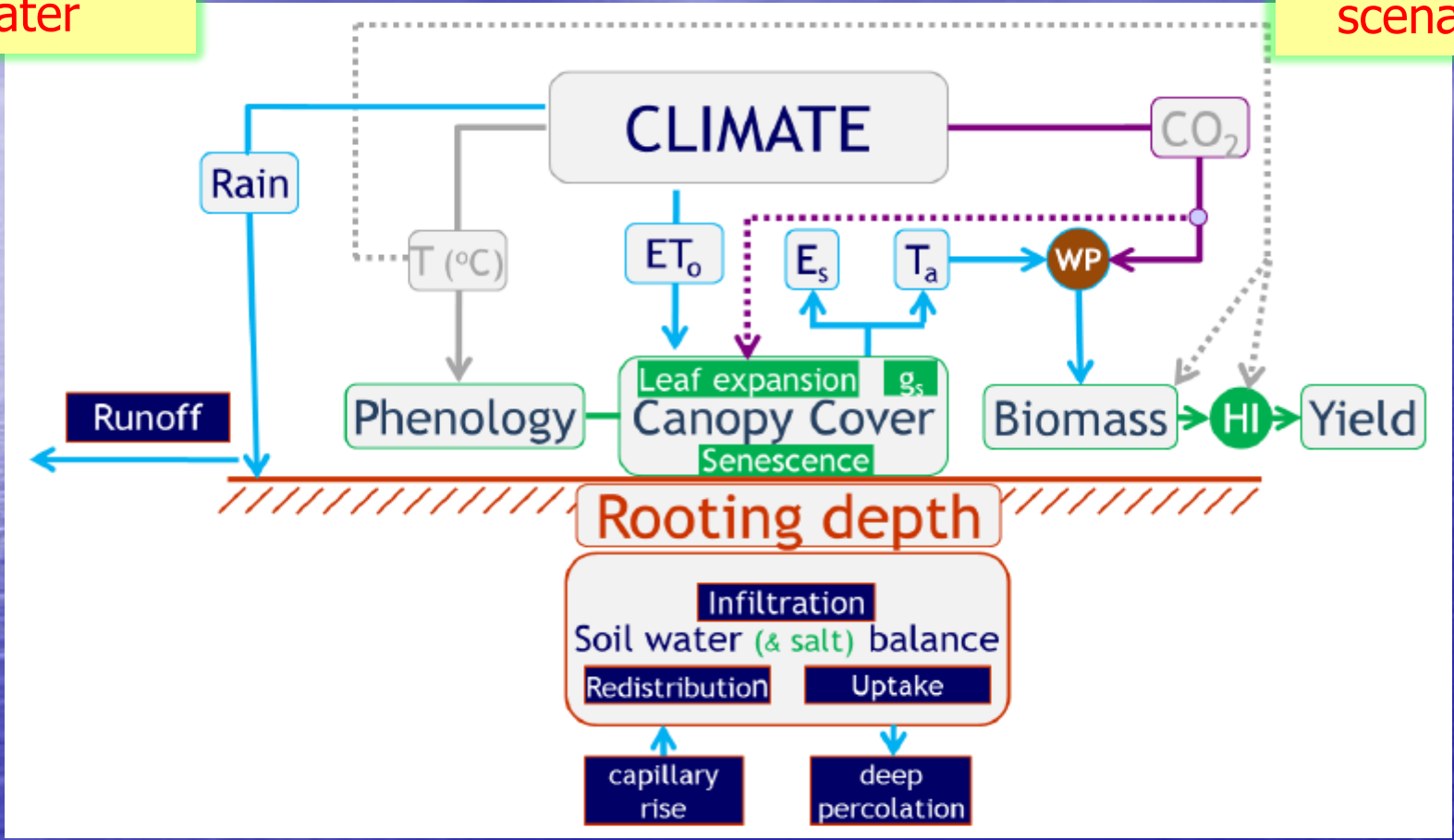
Crop growth models

DSSAT, EPIC, WOFOST, AQUACROP,
FASSET, HERMES, CROPSYST)

AquaCrop model simulate yield response to water

AquaCrop model

AquaCrop predict yield under climate change scenarios



Developed by FAO

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

استخدامات النموذج الرياضي AquaCrop

- إدارة مياه الري
  - تحديد الاحتياجات المائية
  - جدولة الري
  - دراسة العلاقة بين كمية مياه الري المضافة و إنتاجية المحاصيل الزراعيه
- تقدير إنتاجية المحاصيل الزراعية
- تحديد الإنتاجية المائية

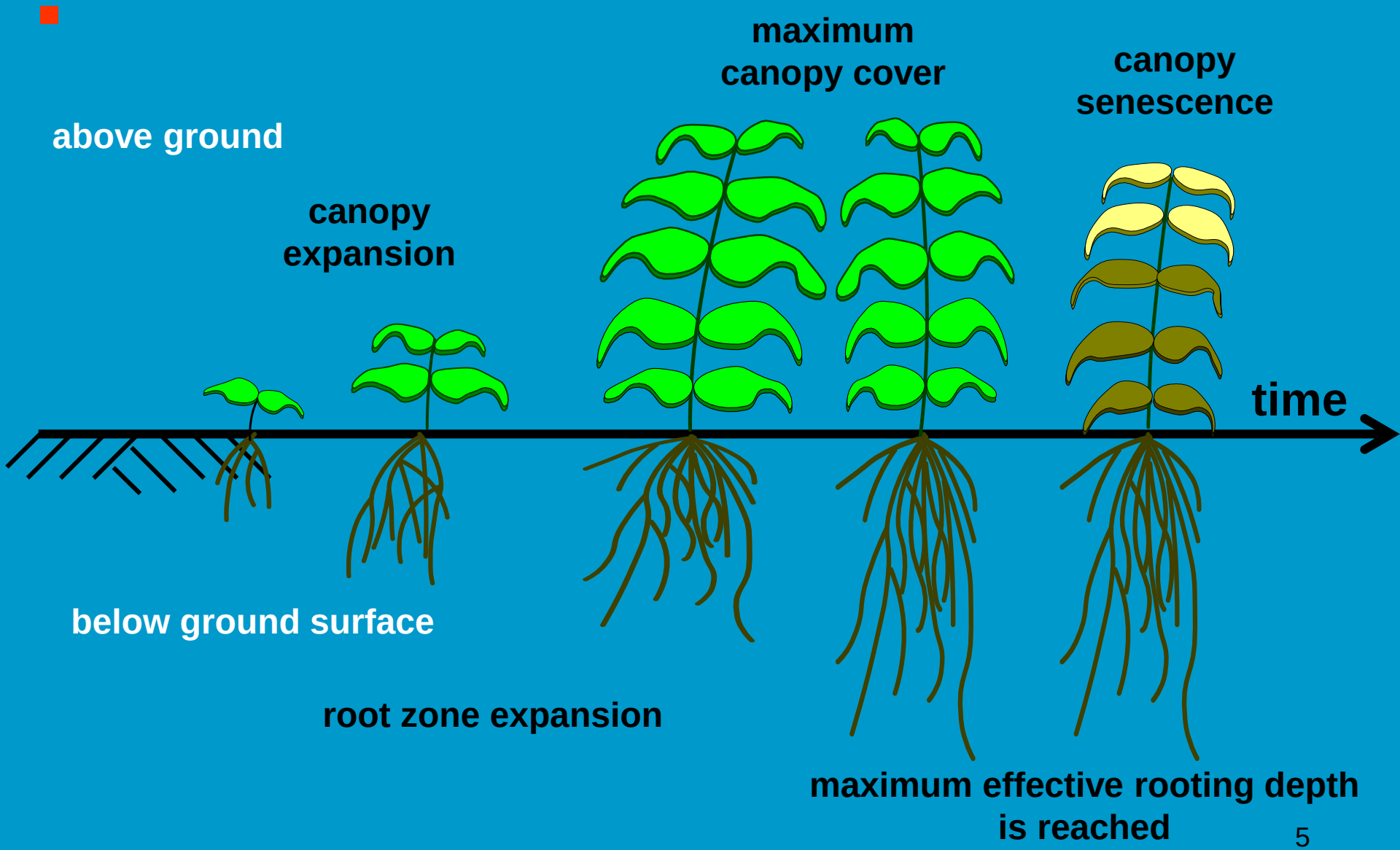
Performance indicator:

$$WP_{ET} = \frac{\text{kg (yield)}}{\text{m}^3\text{ (ET)}}$$

(ET water productivity)

- تقييم اثر التغيرات المناخية على المحاصيل الزراعية

Aquacrop المخطط الحسابي للنموذج الرياضي



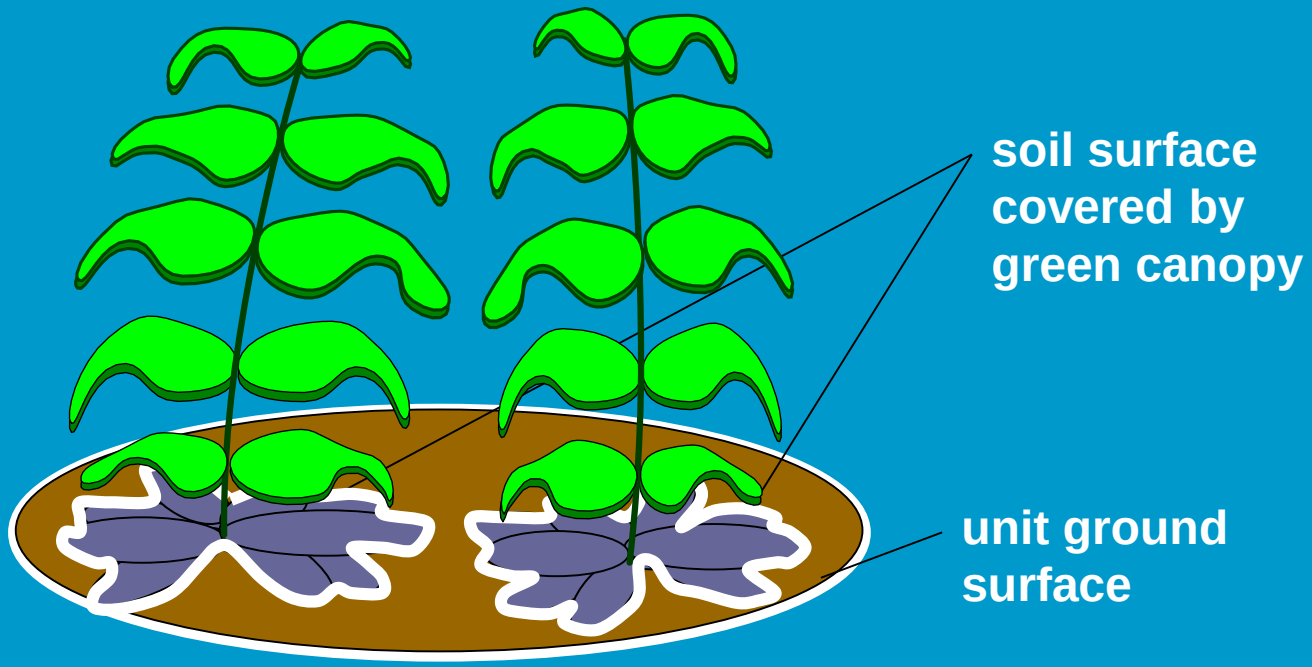
Instead of Leaf Area Index (LAI)

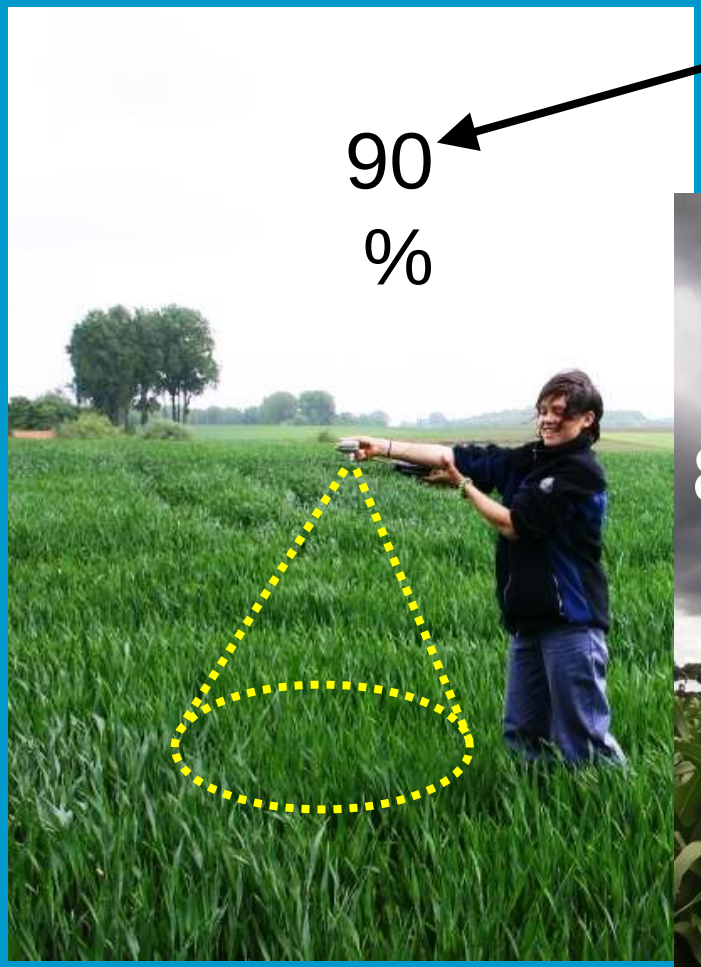
AquaCrop uses **green canopy cover (CC)**

$$CC = \frac{\text{soil surface covered by the green canopy}}{\text{unit ground surface area}}$$

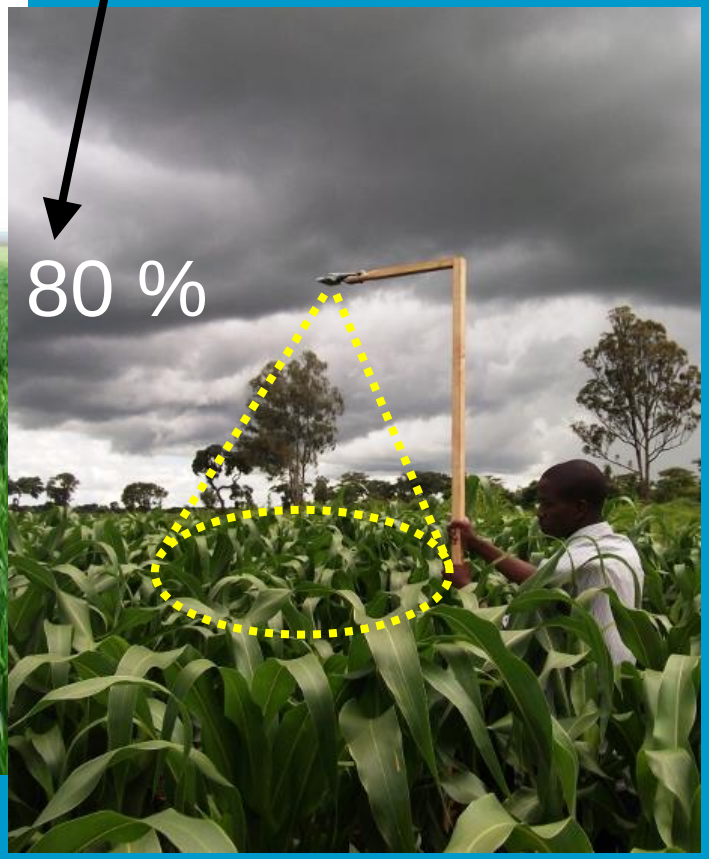
ranges from 0 (bare soil) to 1 (full canopy cover)

0 % → 100 %





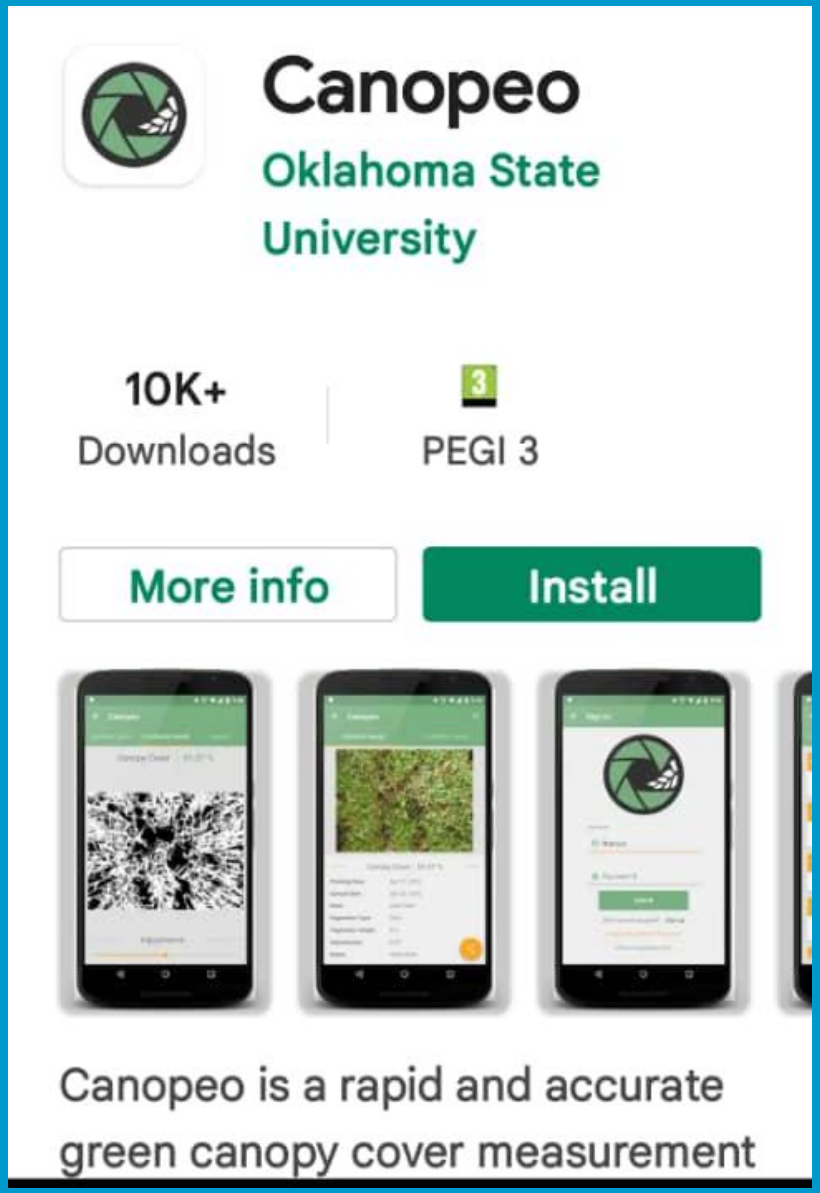
assess CC from picture (software)



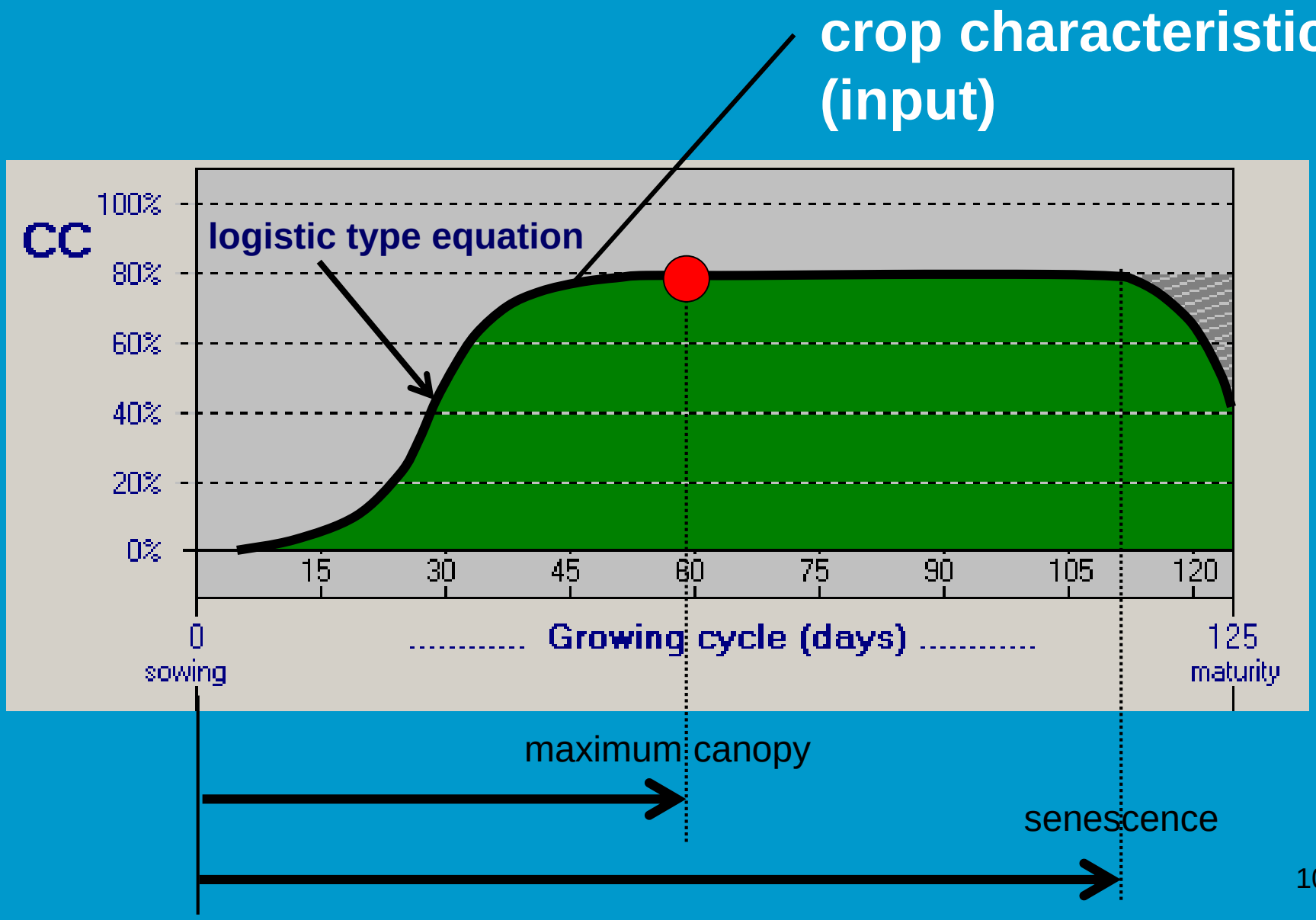
Green Canopy Cover (CC)

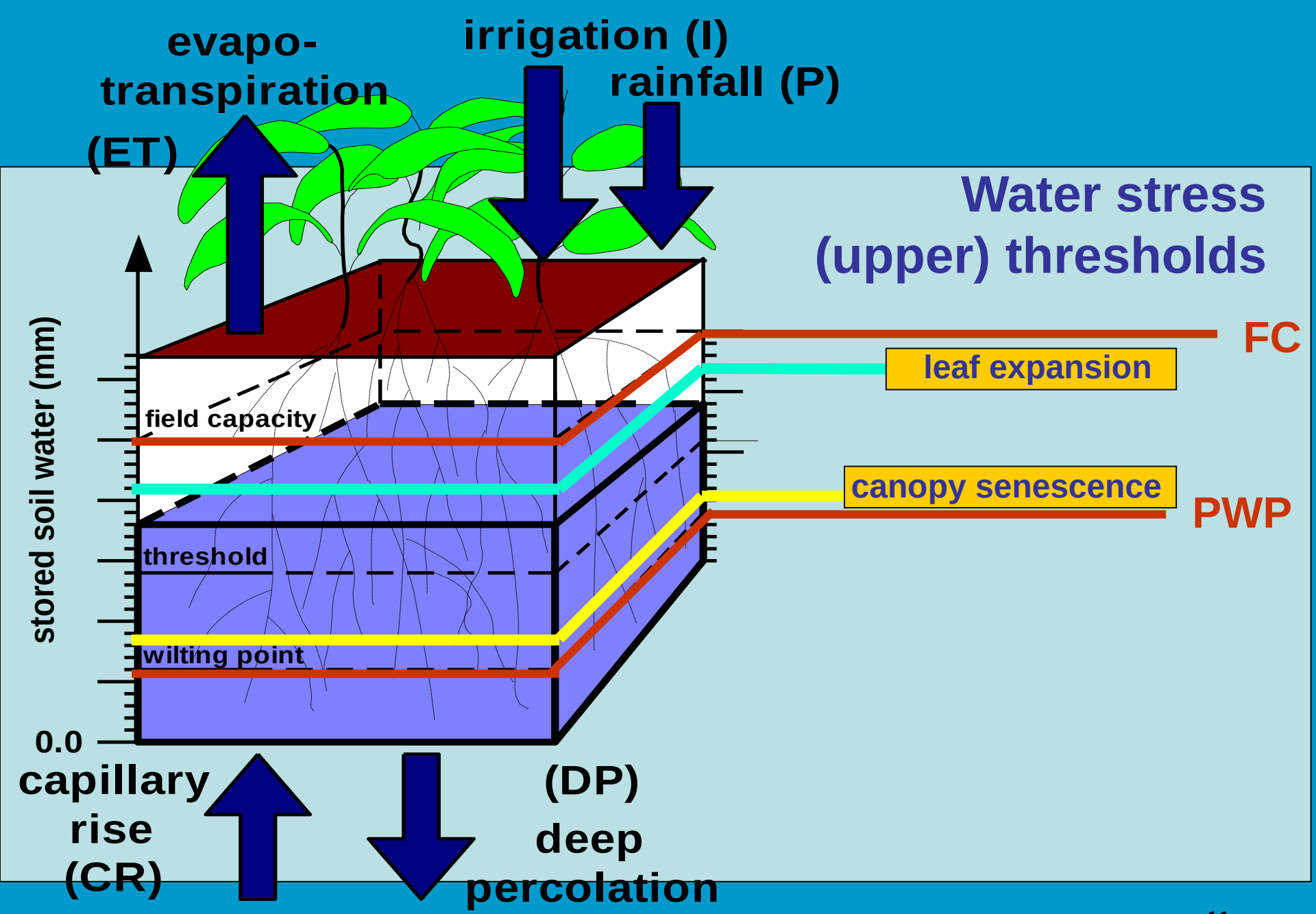
Winter wheat
(Walshoutem, Belgium)

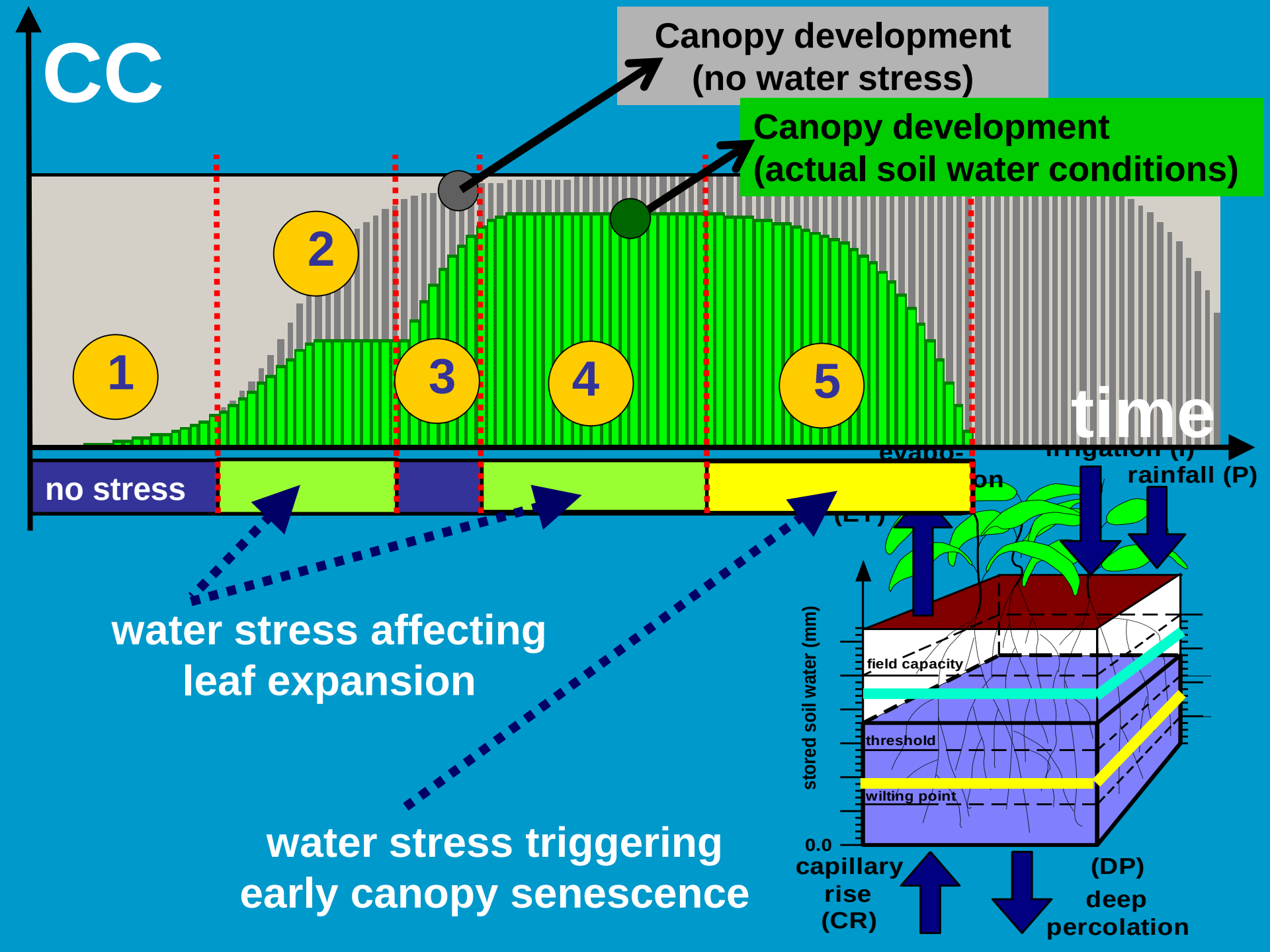
Canopeo software



Canopy development (non-limiting conditions)




evapo-
transpiration
(ET)
irrigation (I)
rainfall (P)
Water stress
(upper) thresholds
FC
leaf expansion
canopy senescence
PWP
field capacity
threshold
wilting point
stored soil water (mm)
0.0
capillary
rise
(CR)
(DP)
deep
percolation


CC
Canopy development
(no water stress)
Canopy development
(actual soil water conditions)
1
2
3
4
5
time
no stress
water stress affecting
leaf expansion
water stress triggering
early canopy senescence
rainfall (P)
field capacity
threshold
wilting point
stored soil water (mm)
0.0
capillary
rise
(CR)
(DP)
deep
percolation

3. Calculation scheme of AquaCrop

- Crop development
- Crop transpiration

CC

Transpiration

weather conditions

characteristics of
the transpiring crop

crop coefficient

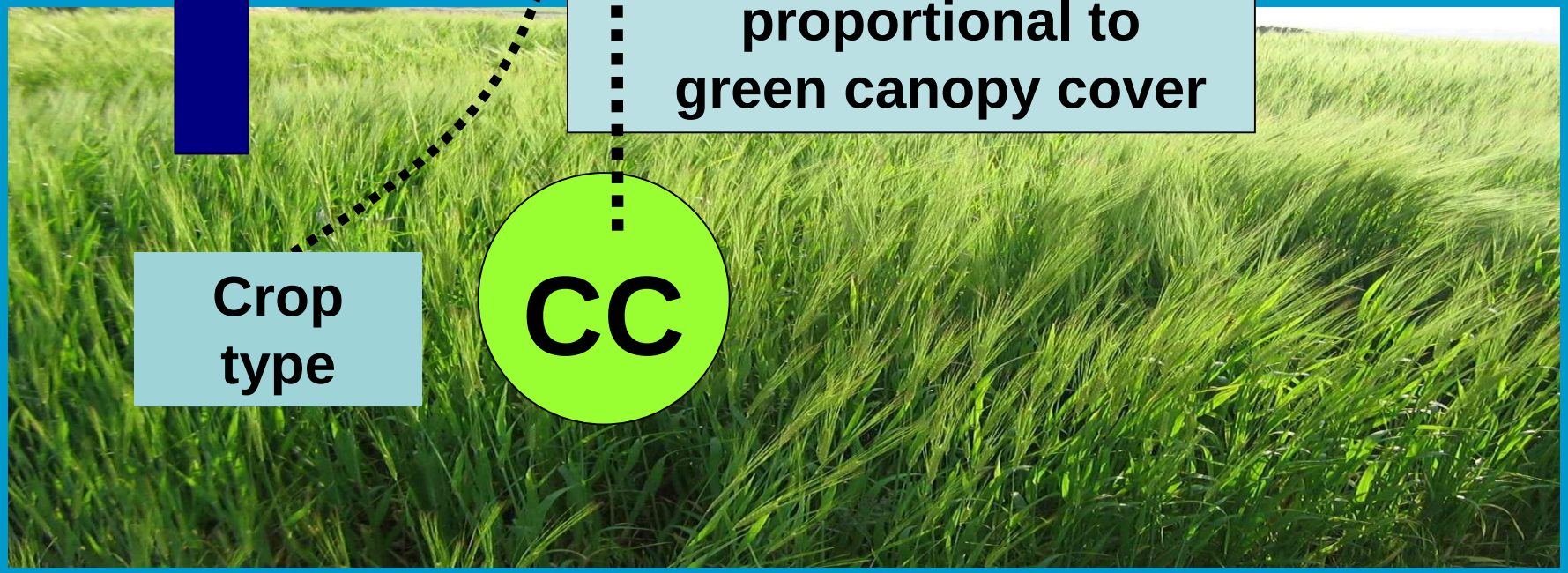
reference evapotranspiration
evaporative power of
the atmosphere

Transpiration = Kc_{Tr} x ETo

proportional to
green canopy cover

Crop
type

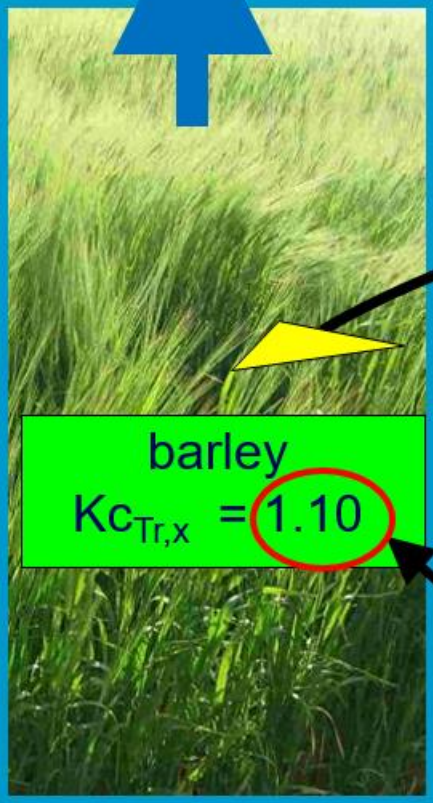
CC



no water stress

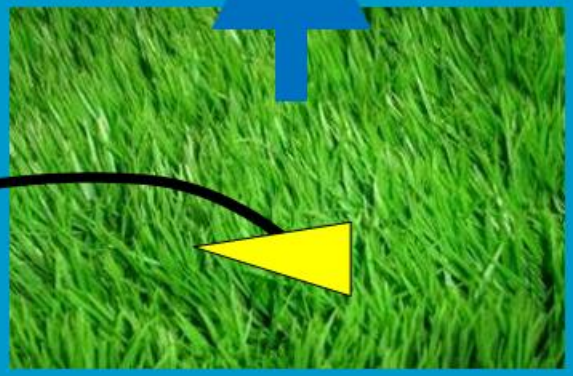
CC = 1 (full canopy cover)

$Trx = Kc_{Tr,x}\ CC\ ETO$



barley

$Kc_{Tr,x}$ = 1.10

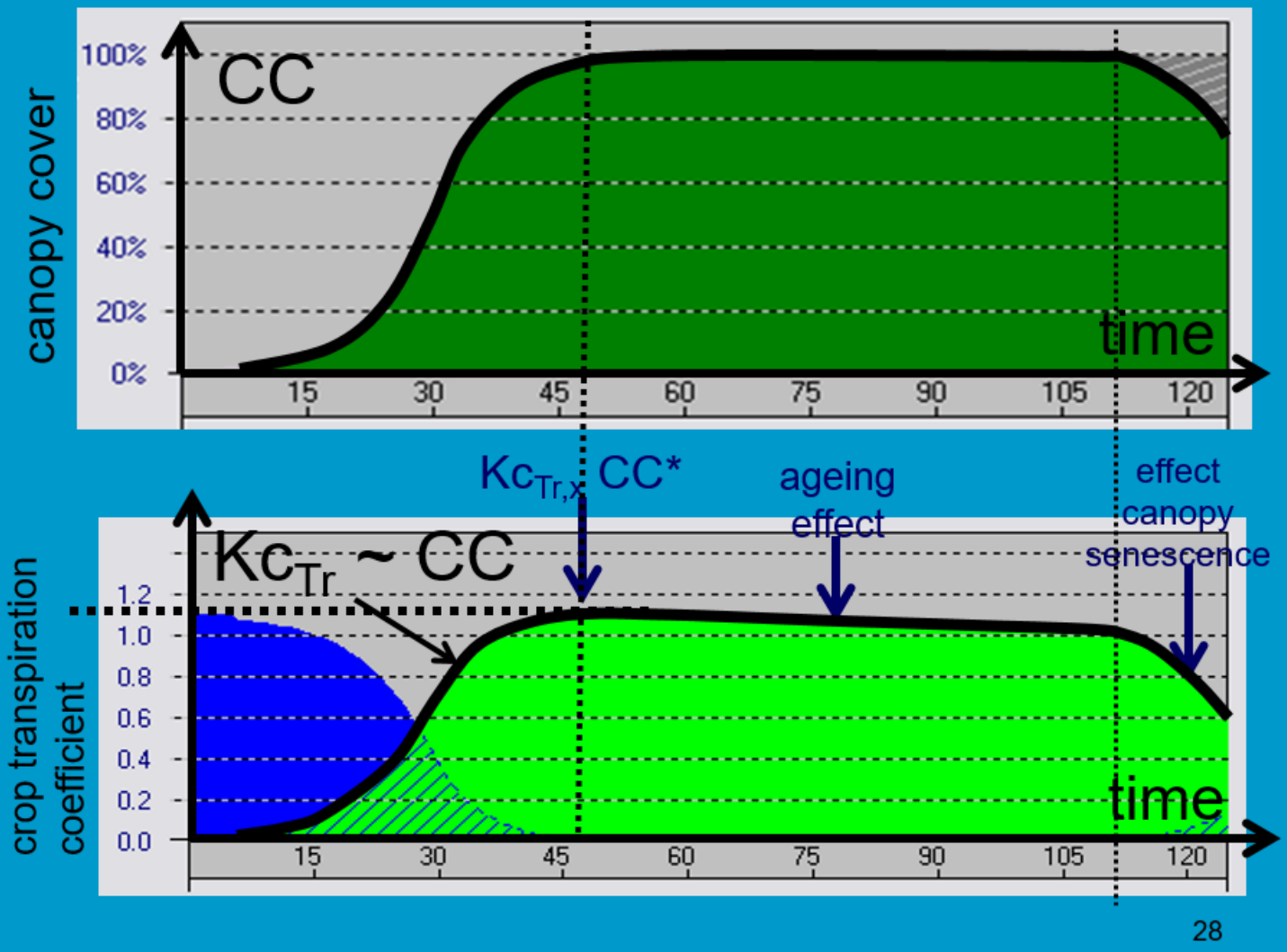


reference surface (grass)

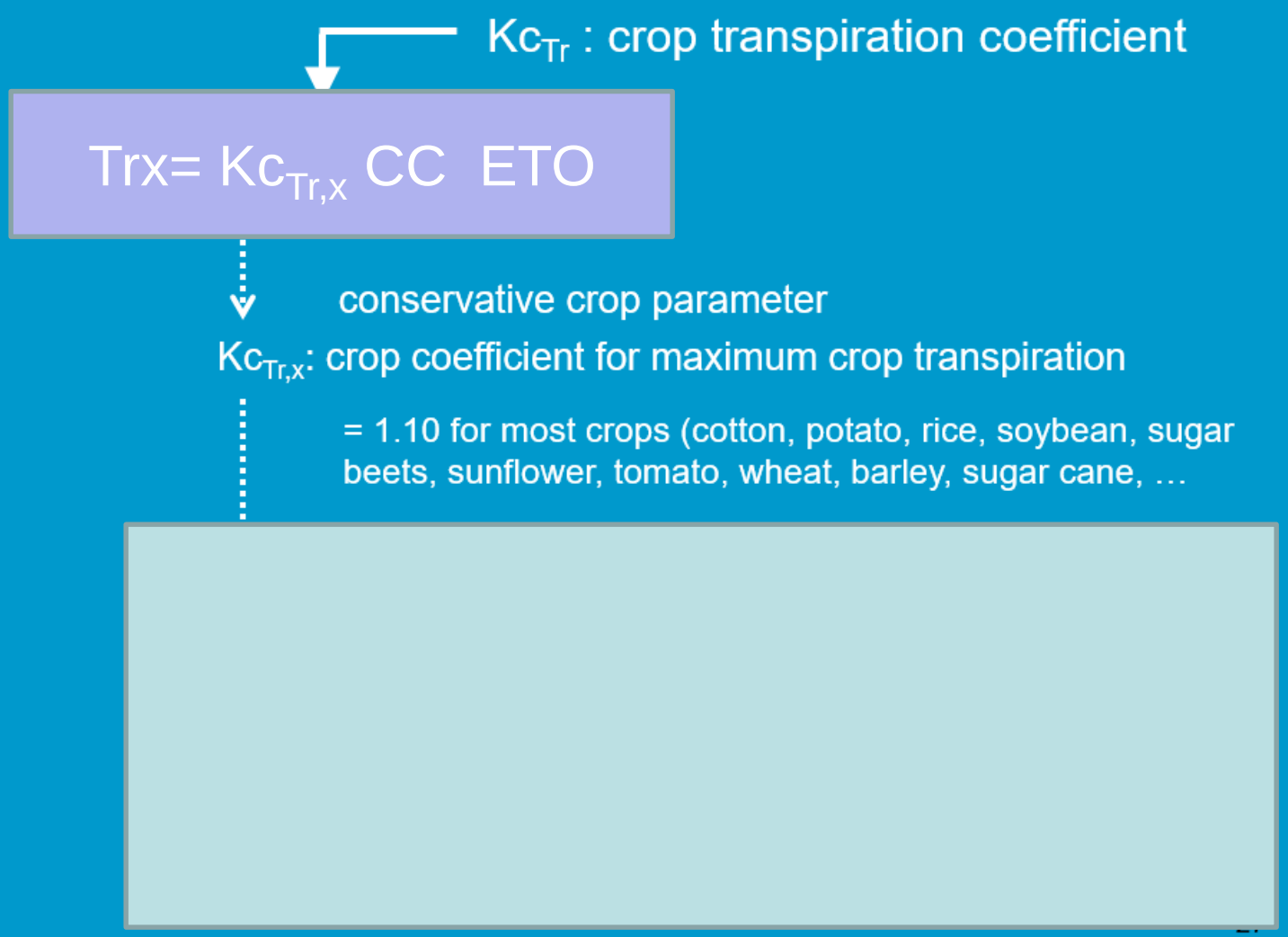
$Kc_{Tr,x}$ = 1.00

integration of the effects of the characteristics that distinguish the crop with a complete canopy from reference grass

26

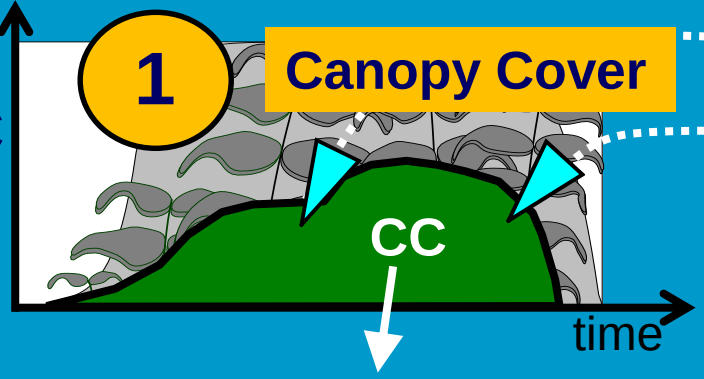

canopy cover
100%
80%
60%
40%
20%
0%
CC
time
15
30
45
60
75
90
105
120
$Kc_{Tr,x}$
CC*
ageing effect
effect canopy senescence
crop transpiration coefficient
Kc_{Tr} ~ CC
1.2
1.0
0.8
0.6
0.4
0.2
0.0
time
15
30
45
60
75
90
105
120

28


Kc_{Tr} : crop transpiration coefficient
$Trx = Kc_{Tr,x}$ CC ETO
conservative crop parameter
$Kc_{Tr,x}$: crop coefficient for maximum crop transpiration
= 1.10 for most crops (cotton, potato, rice, soybean, sugar beets, sunflower, tomato, wheat, barley, sugar cane, …

Canopy development

CC

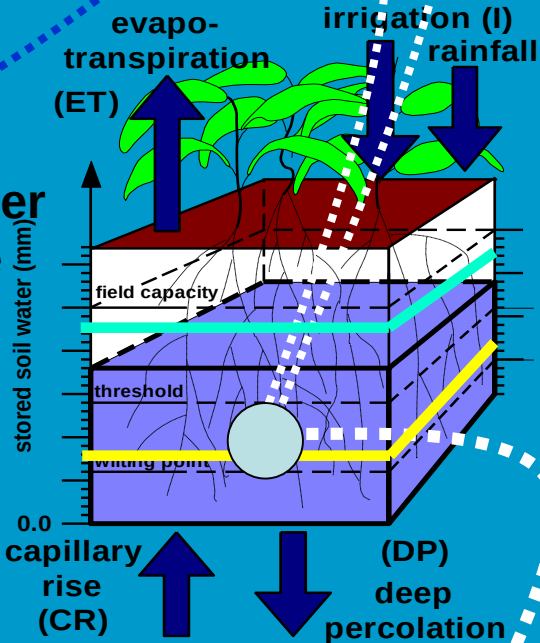


leaf expansion

canopy senescence

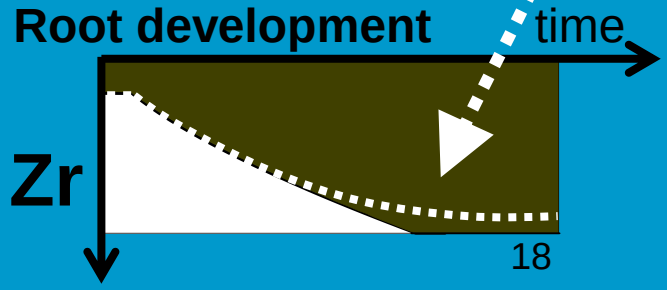
$$Tr = Kc_{Tr} \; ETo$$

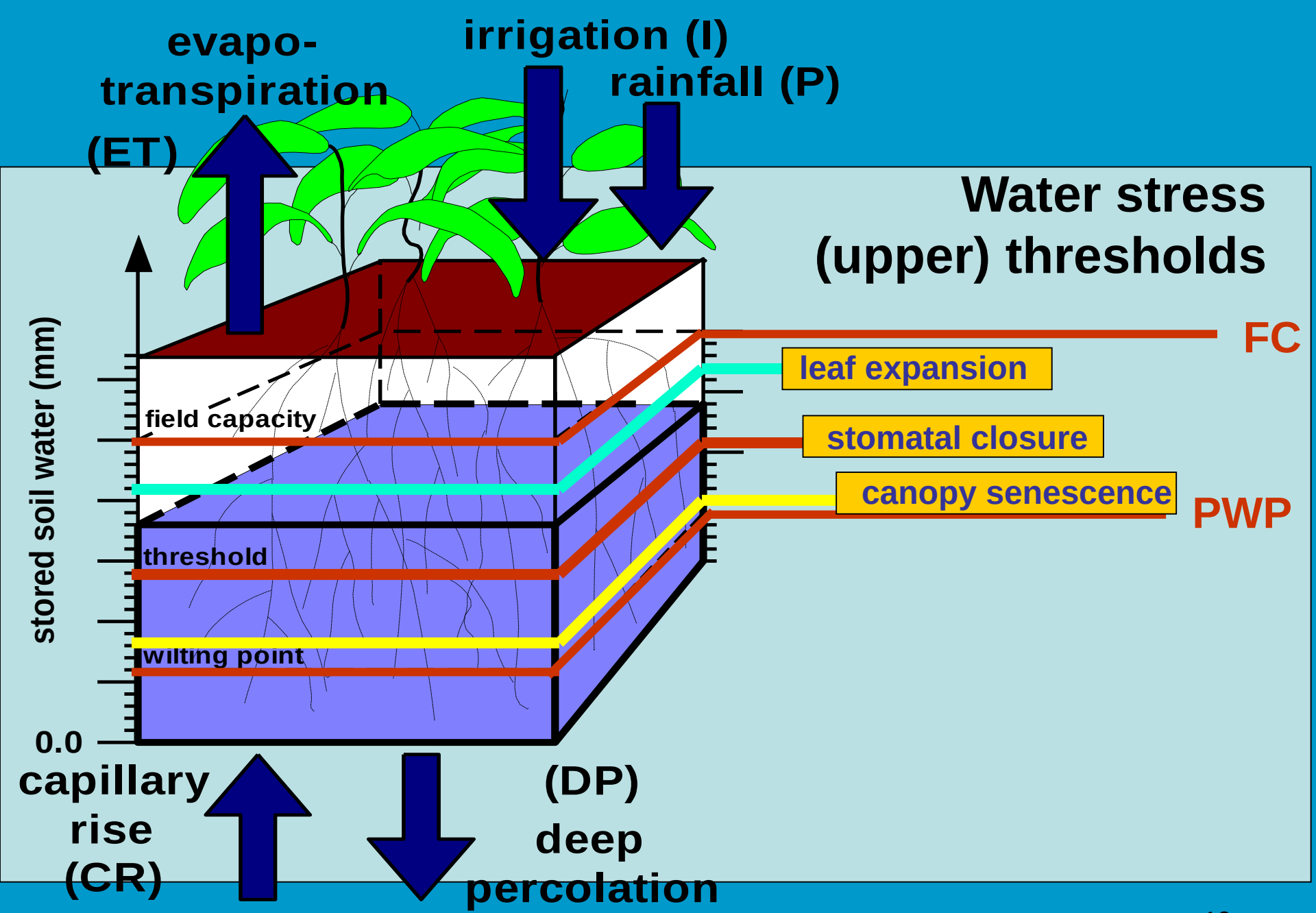
soil water balance

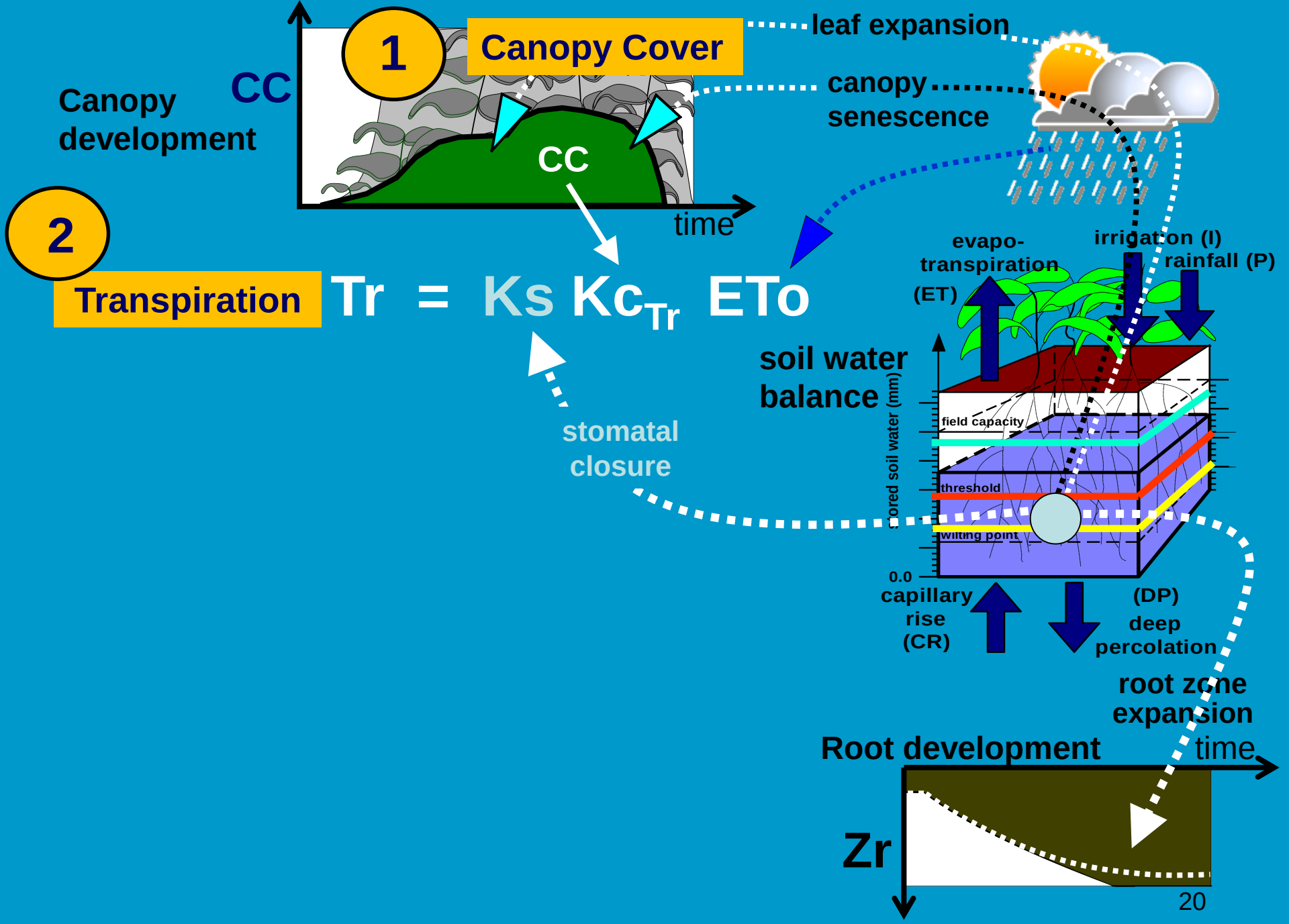


root zone expansion

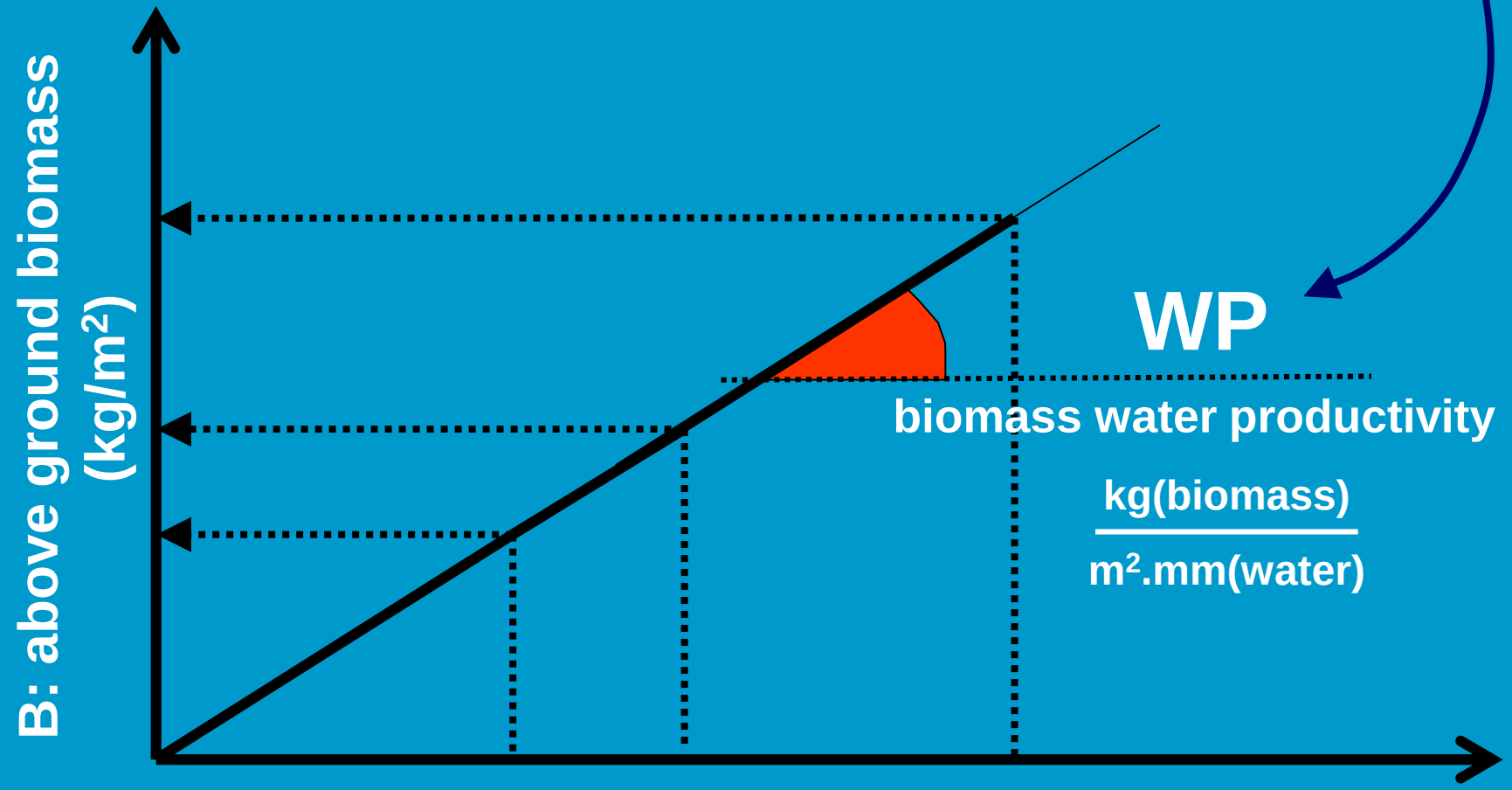
Root development



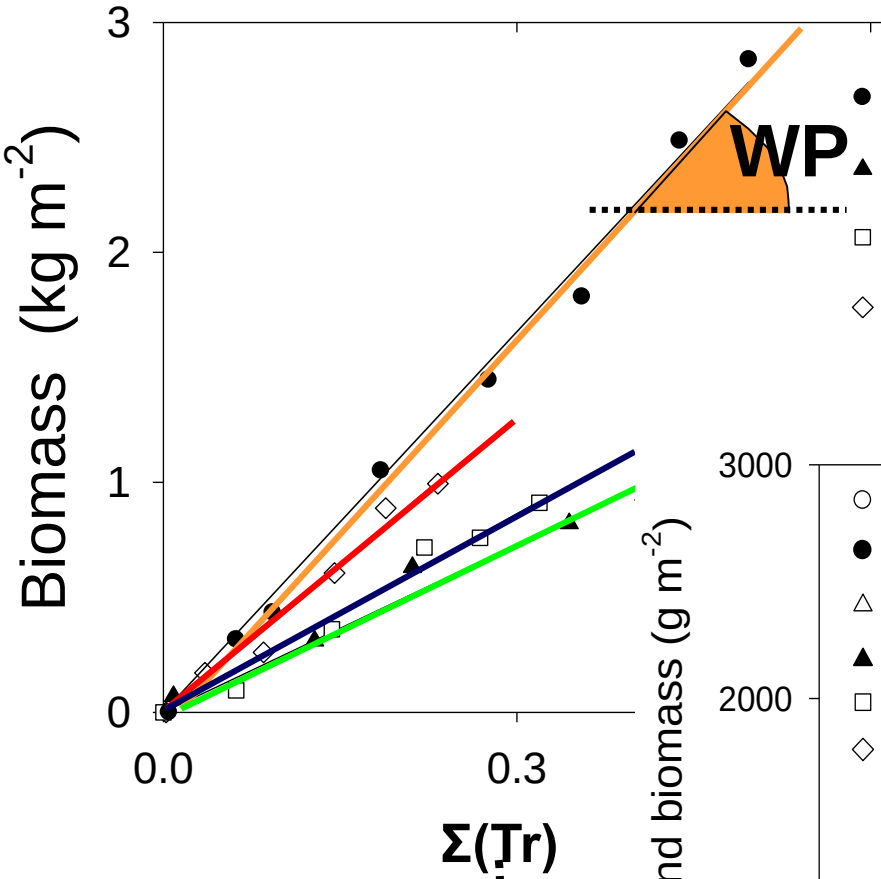

evapo-
transpiration
(ET)
irrigation (I)
rainfall (P)
Water stress
(upper) thresholds
FC
leaf expansion
stomatal closure
canopy senescence
PWP
field capacity
threshold
wilting point
stored soil water (mm)
0.0
capillary
rise
(CR)
(DP)
deep
percolation


1
Canopy Cover
CC
Canopy development
CC
time
leaf expansion
canopy senescence
2
Transpiration
Tr = Ks Kc$_{Tr}$ ETo
stomatal closure
soil water balance
evapo-transpiration (ET)
irrigation (I)
rainfall (P)
field capacity
threshold
wilting point
stored soil water (mm)
0.0
capillary rise (CR)
(DP) deep percolation
root zone expansion
Root development
time
Zr

There exists a stable & conservative nature between
- Biomass (B) and
- Cumulative transpiration (Σ(Tr))



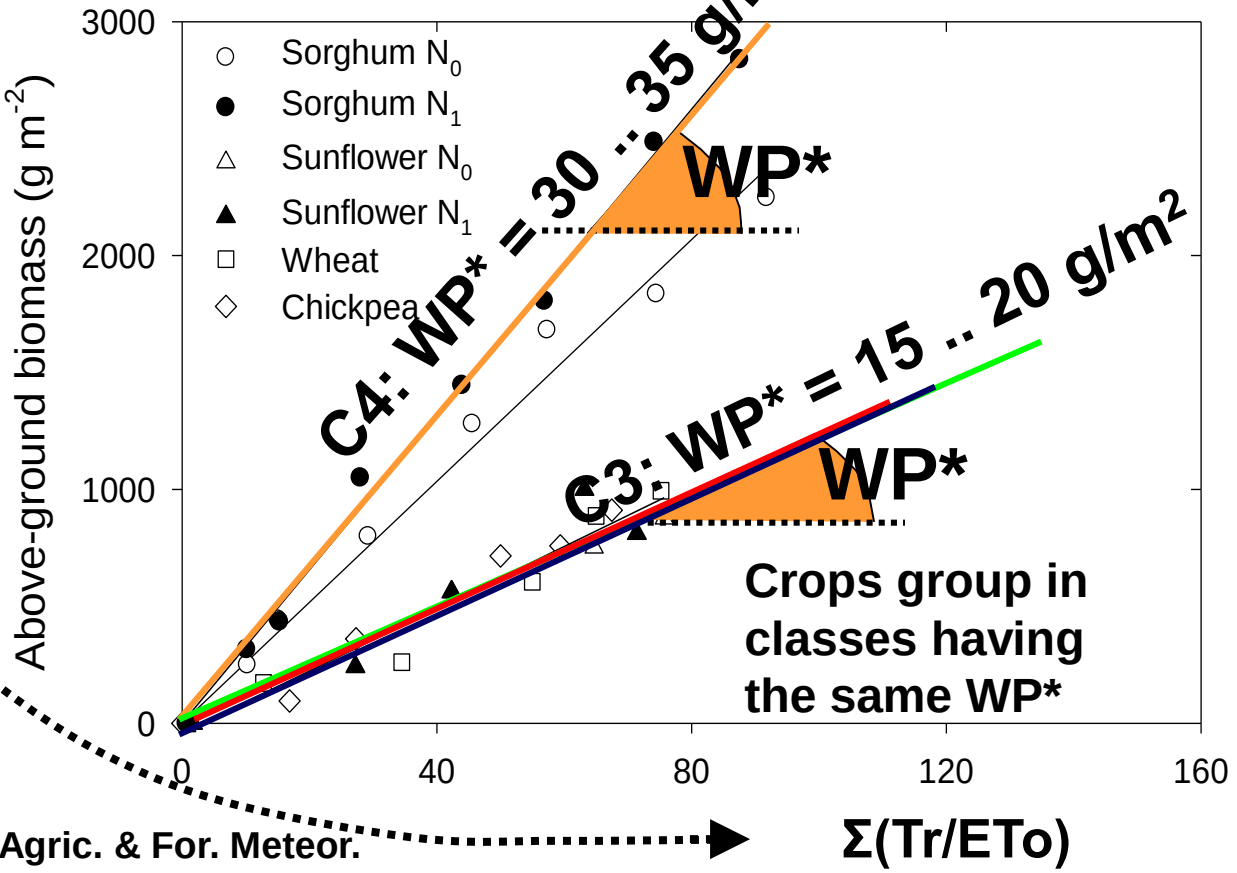
For given climatic conditions



by dividing Tr by ETo

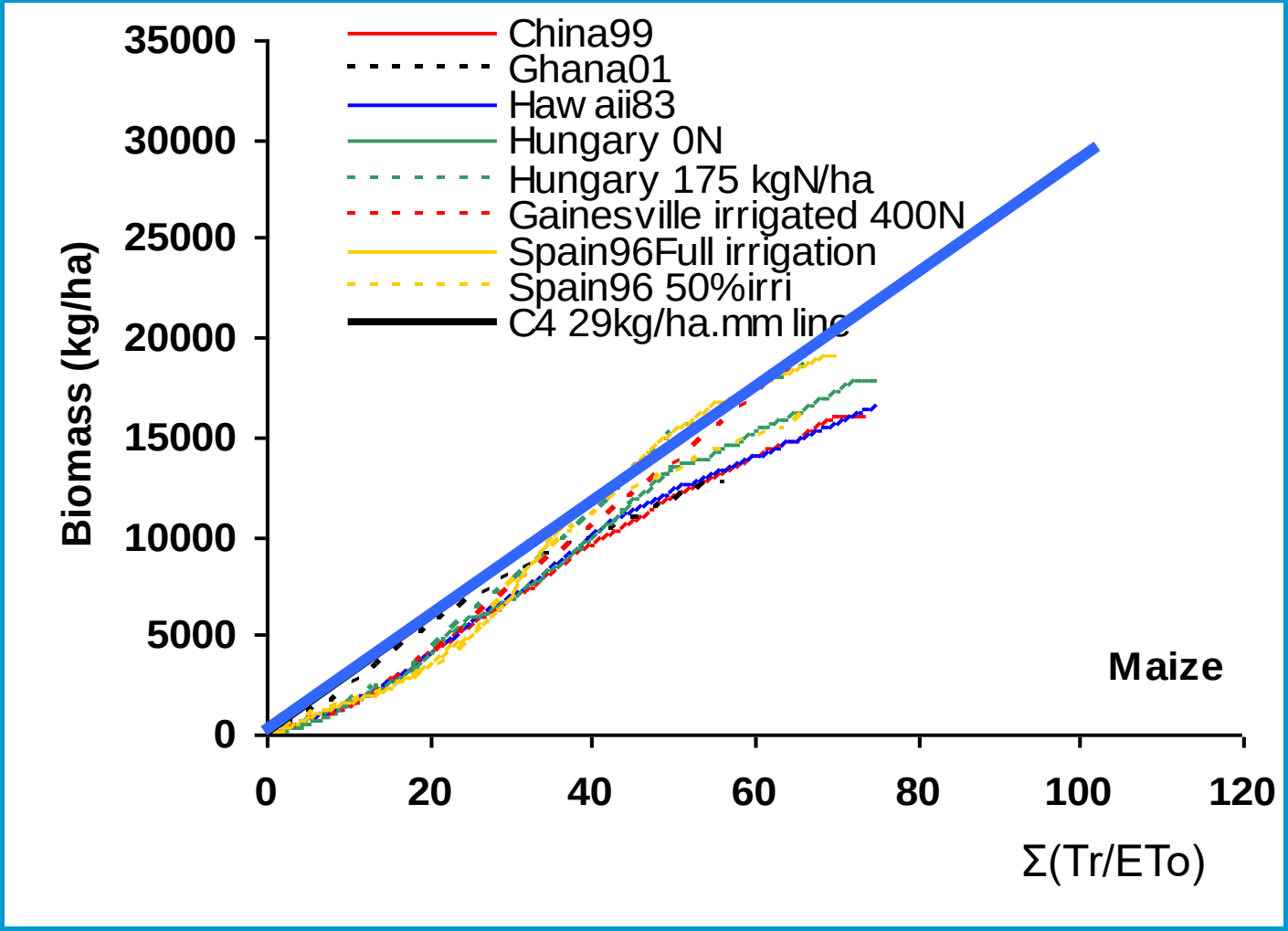
WP is normalized for clima

WP → WP*



Data from Steduto & Albrizio, 2005, Agric. & For. Meteor.

WP* for maize

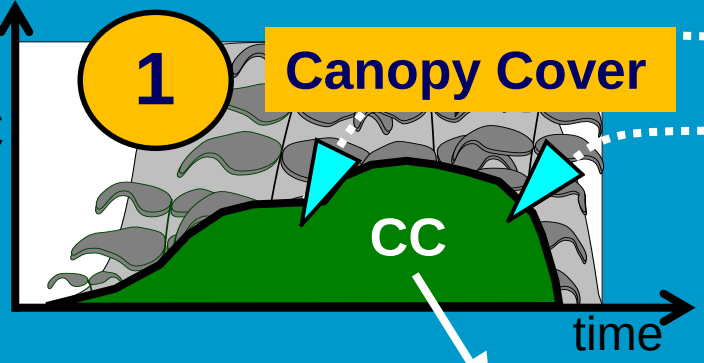


Data from ICASA, IAEA & UniMelb

1 **Canopy Cover**

Canopy development

CC



leaf expansion

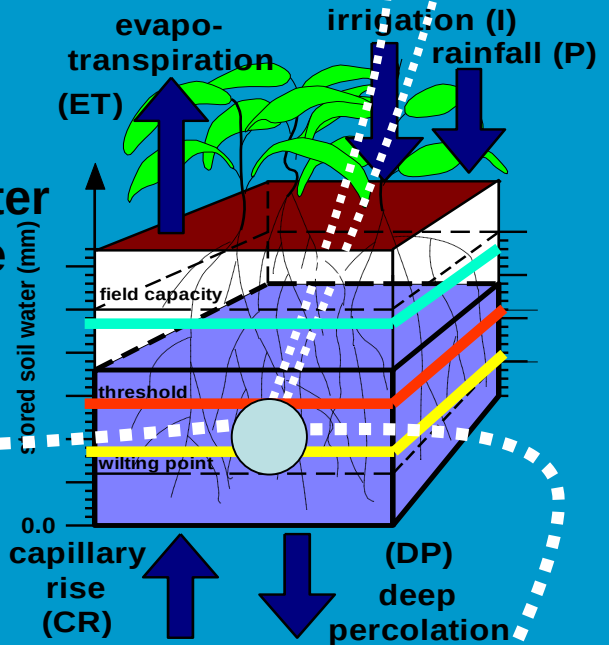
canopy senescence

2 **Transpiration**

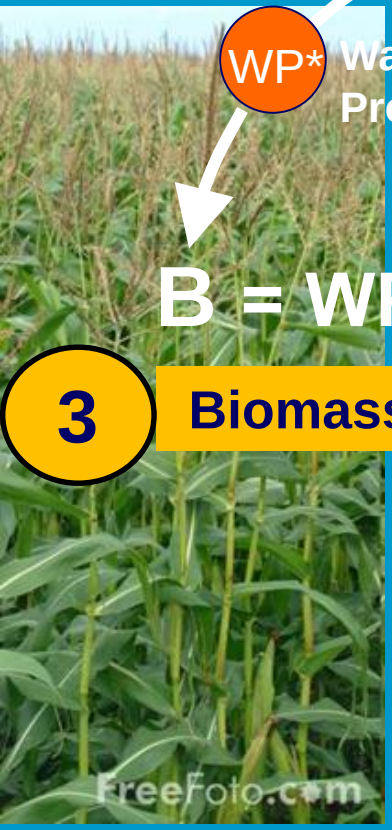
$$Tr = Ks\ Kc_{Tr}\ ETo$$

stomatal closure

soil water balance



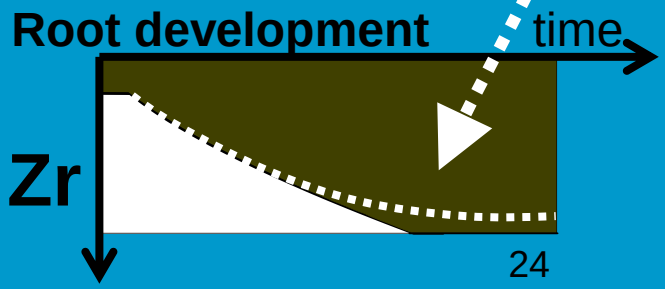
WP* Water Productivity



$$B = WP^* \times \Sigma \left(\frac{Tr}{ETo}\right)$$

3 **Biomass**

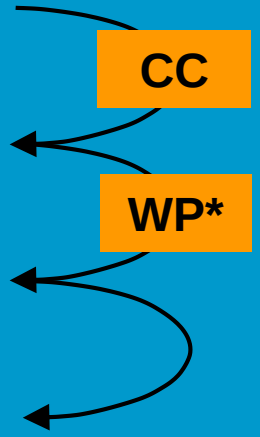
root zone expansion



Biomass

4. Calculation scheme of AquaCrop

- Crop development
- Crop transpiration
- Biomass production
- Yield formation

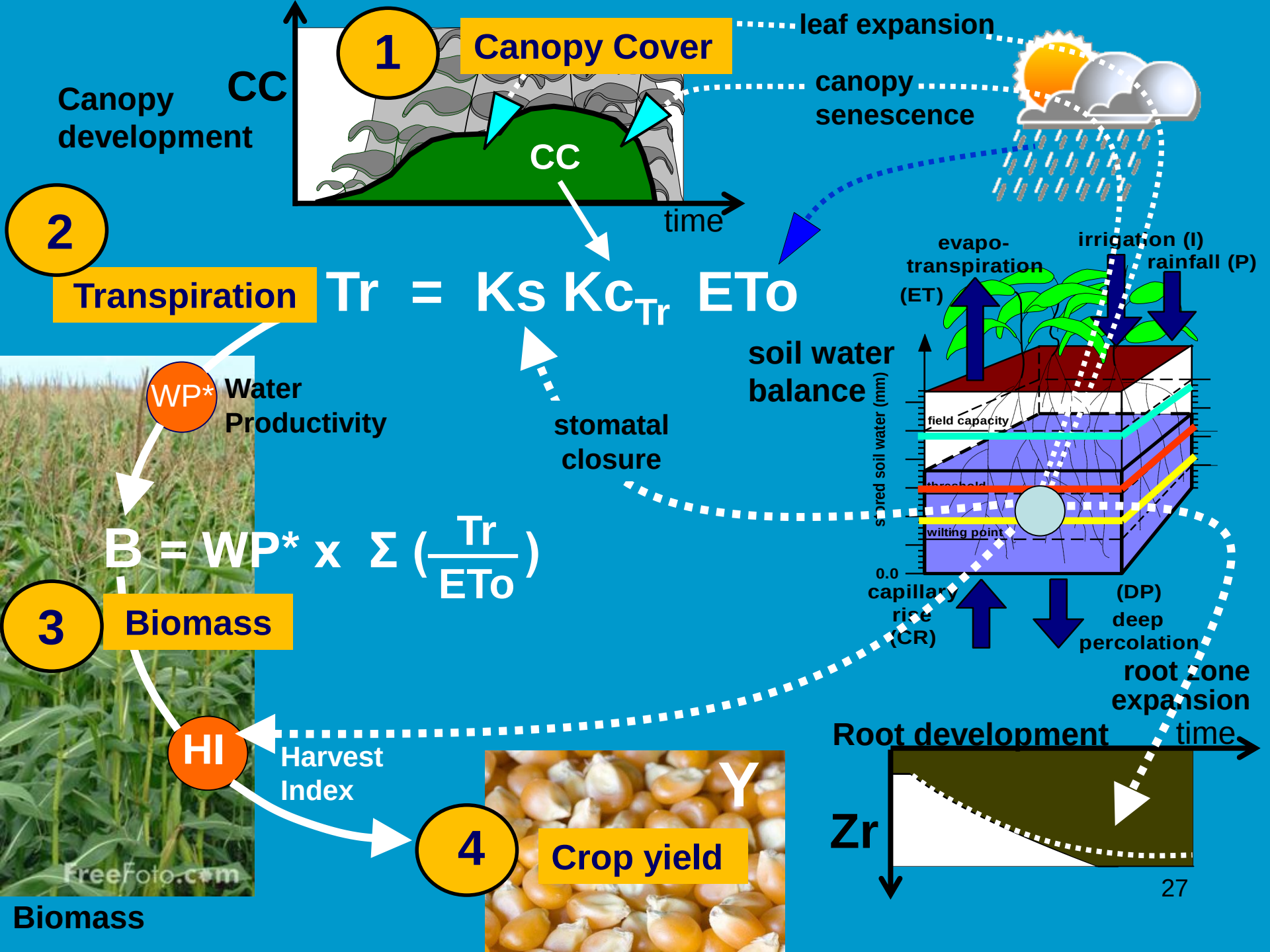


Biomass

B = total above-ground biomass
stem, leaves, flowers, grains, …

Harvest Index (HI) =
fraction of B that is the
harvestable product

Y


1
Canopy Cover
CC
Canopy development
CC
time
leaf expansion
canopy senescence
2
Transpiration
Tr = Ks Kc$_{Tr}$ ETo
WP*
Water Productivity
stomatal closure
soil water balance
evapo-transpiration (ET)
irrigation (I)
rainfall (P)
stored soil water (mm)
field capacity
threshold
wilting point
0.0
capillary rise (CR)
(DP)
deep percolation
root zone expansion
B = WP* x Σ (Tr / ETo)
3
Biomass
HI
Harvest Index
Root development
time
Zr
4
Crop yield
Y
Biomass
FreeFoto.com
27

B

(biomass)

Harvest Index

HI

Y (yield)

$$Y = HI \times B$$

Required data

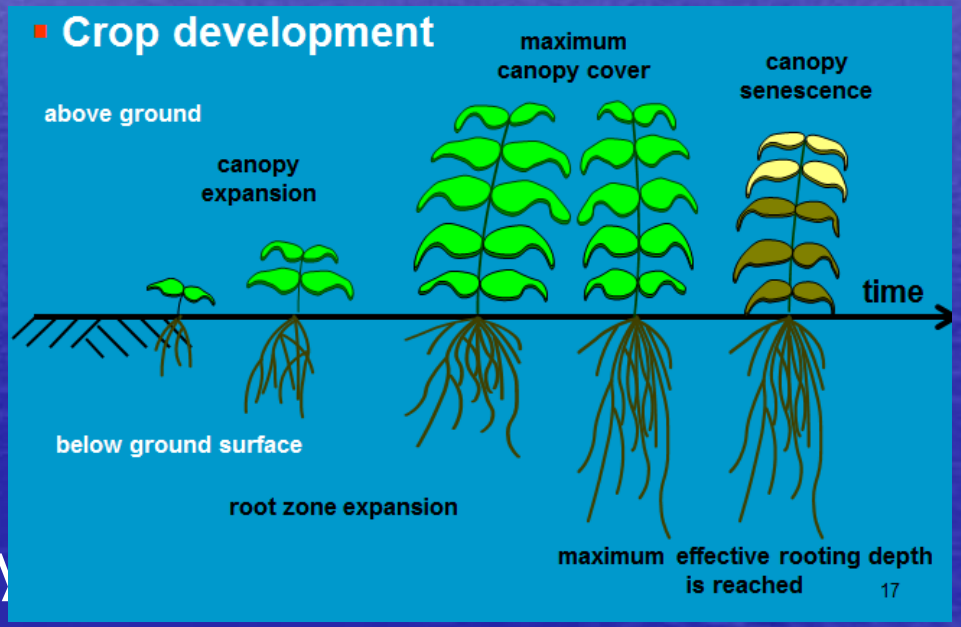
- Climate data:
  - Precipitation
  - Temperature
  - ET
  - Concentration of CO2
-

البيانات المطلوبه

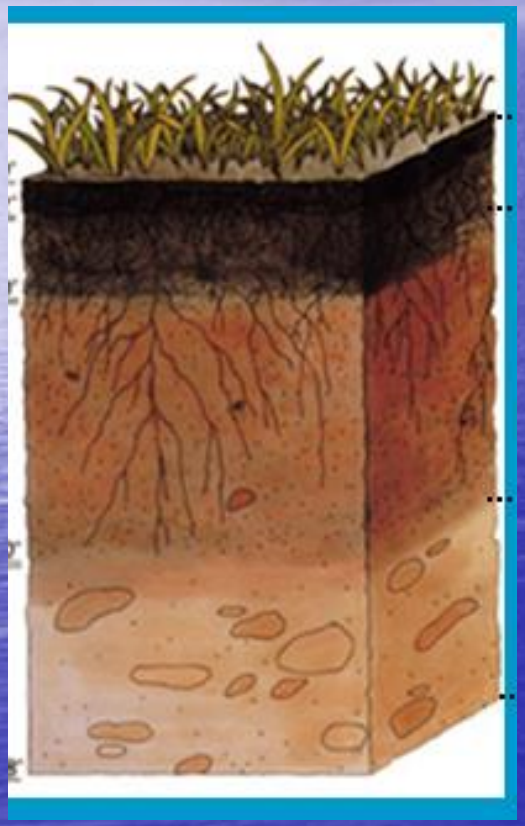
- البيانات المناخيه:
  - الهطولات المطريه
  - درجات الحراره العظمى
  - درجات الحراره الصغرى
  - تركيز CO2

بيانات المحصول

- :
  - Planting date;تاريخ الزراعه
  - Plant density;كثافة الزراعه
  - Maximum canopy cover (CCx);الغطاء النباتي الاعظمي
  - المراحل الفينولوجيه
  - Time to crop emergence, flowering, start of canopy senescence and to maturity (length of crop cycle);
  - عمق الجذور الاعظمي



بيانات التربه



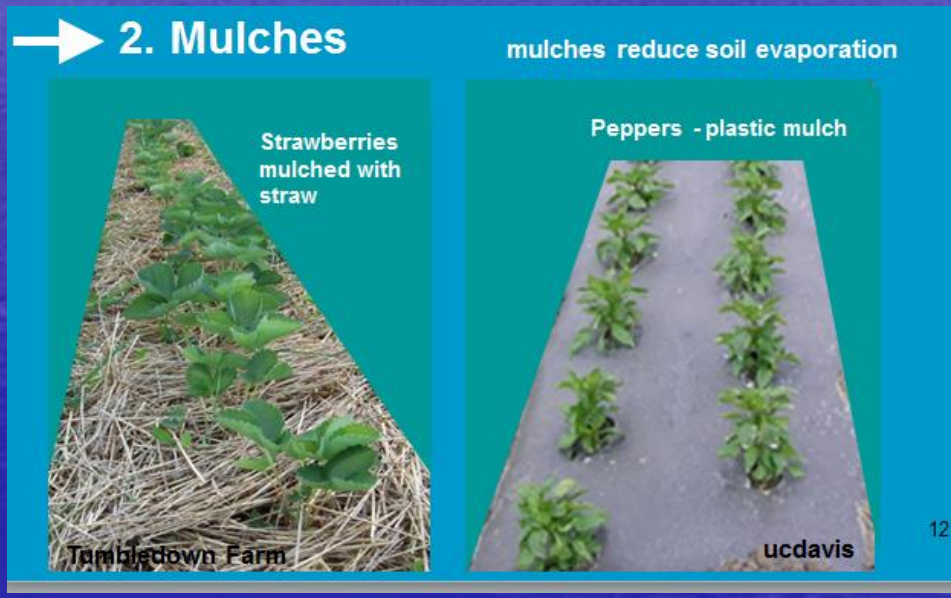
- الخواص الفيزيائيه للتربه :

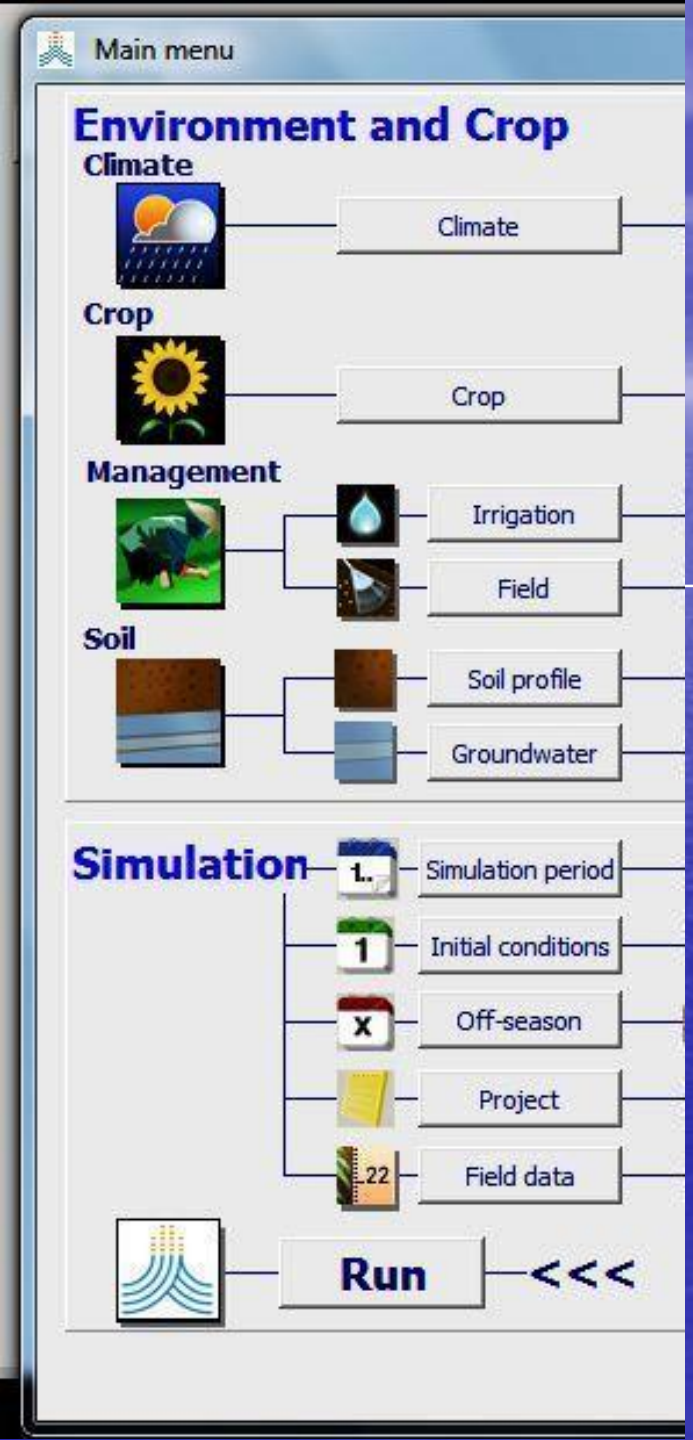
السعه الحقليه ، قوام التربه ،
رطوبة الاشباع ، الناقليه
الهيدروليكيه المشبعة

- عمق الطبقه الكتيمه ان وجدت

بيانات عن ادارة الحقل

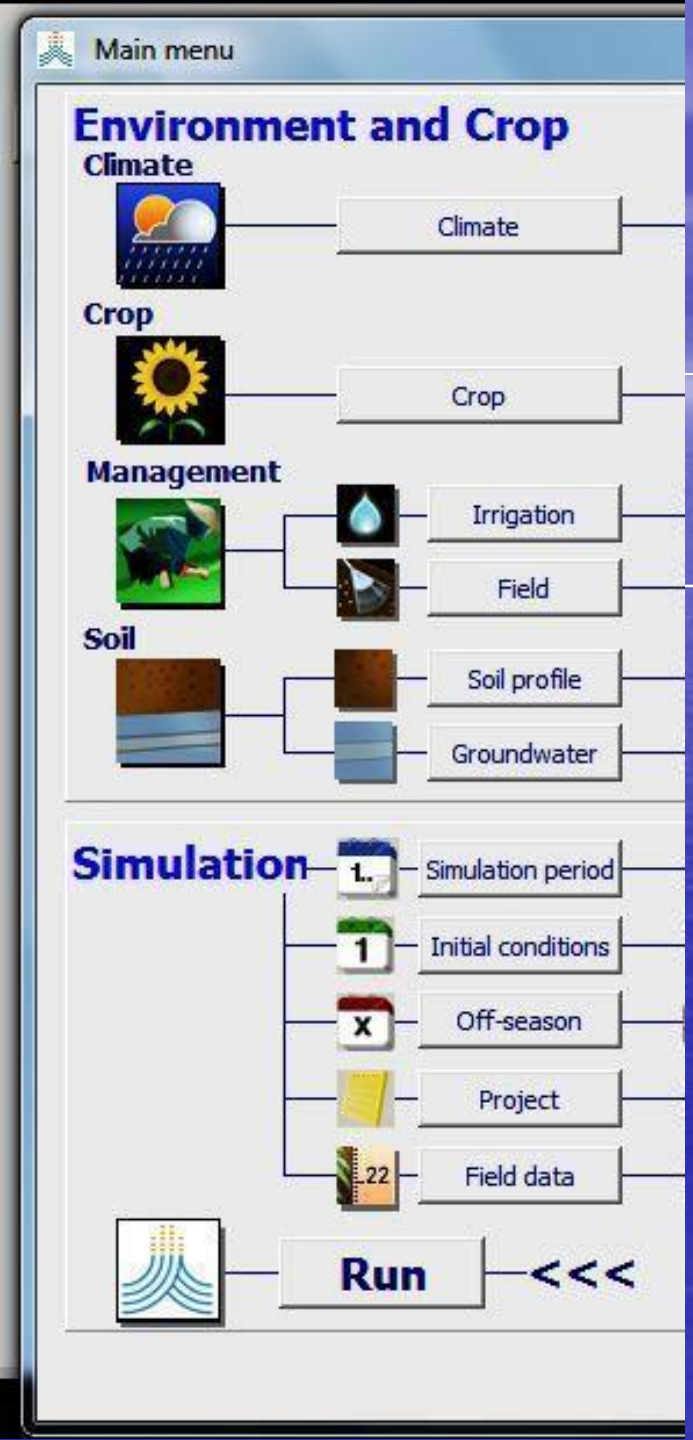
- Parameters describing field management practices:
  - Cover and type of soil mulches;
  - Height of soil bunds;
  - Surface runoff: ON/OFF



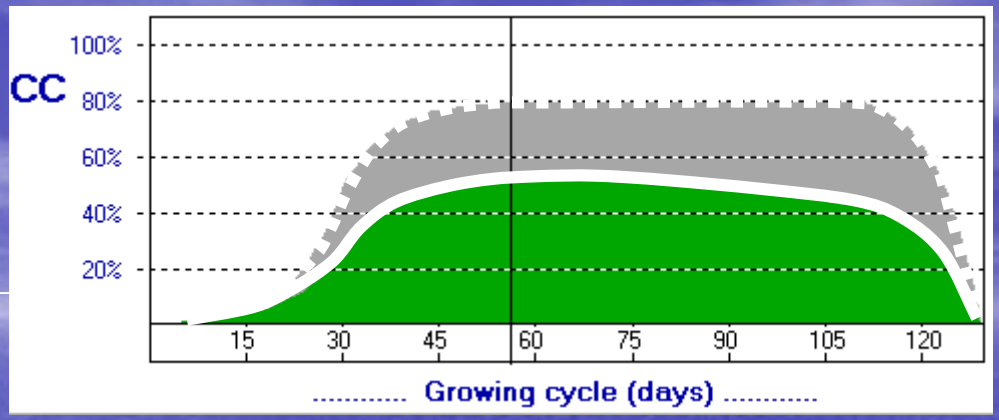


Field management

- **Field surface practices**



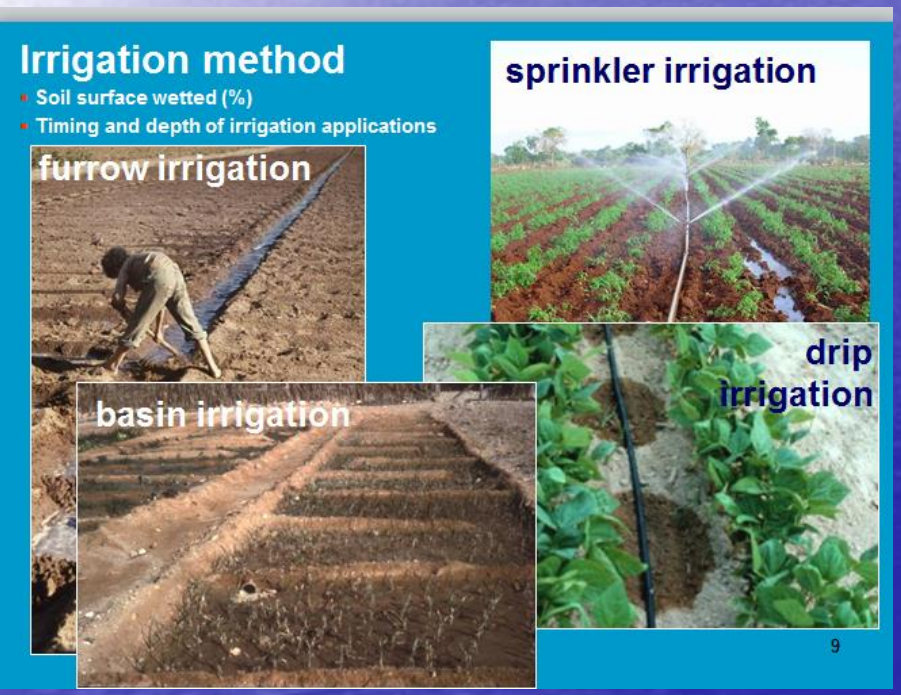
Automatic adjustment of crop development



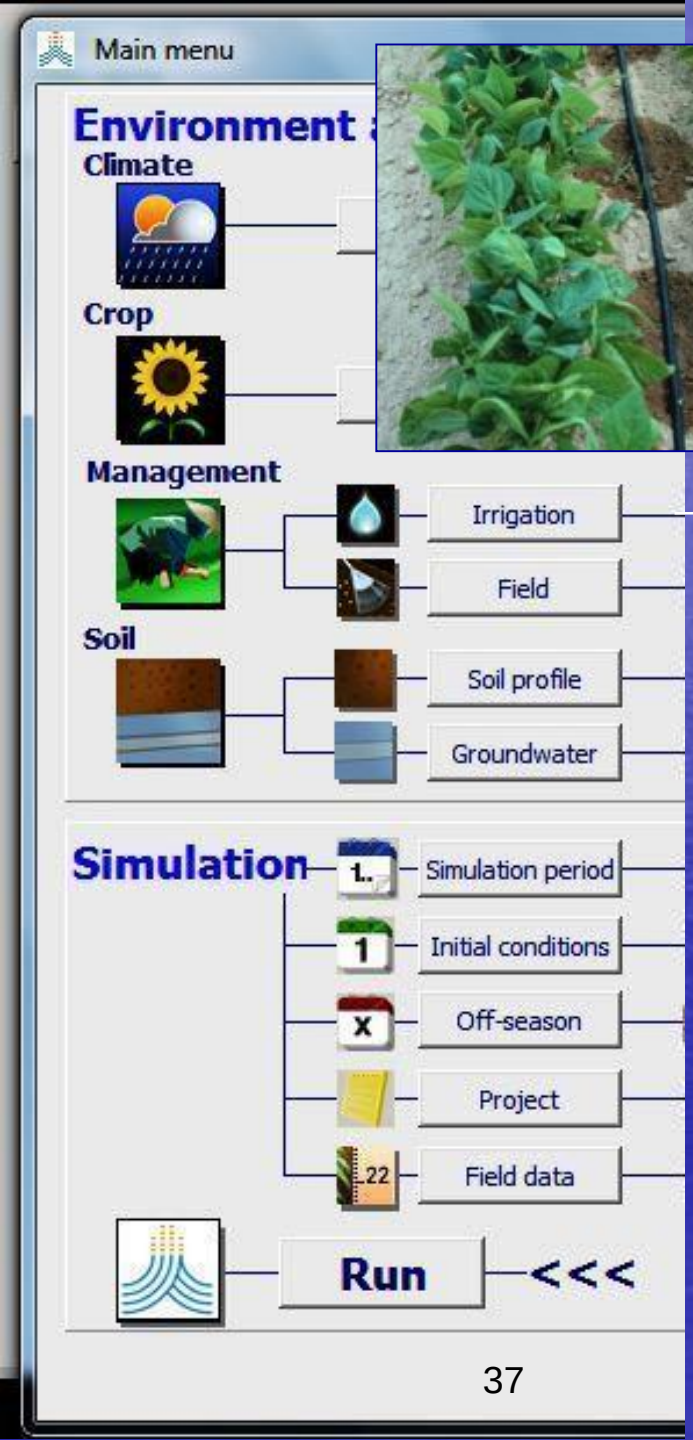
Field management

- Field surface practices
- Mulches
- Weed management
  - competition for light, water and nutrients
- Level of soil fertility

بيانات عن الري



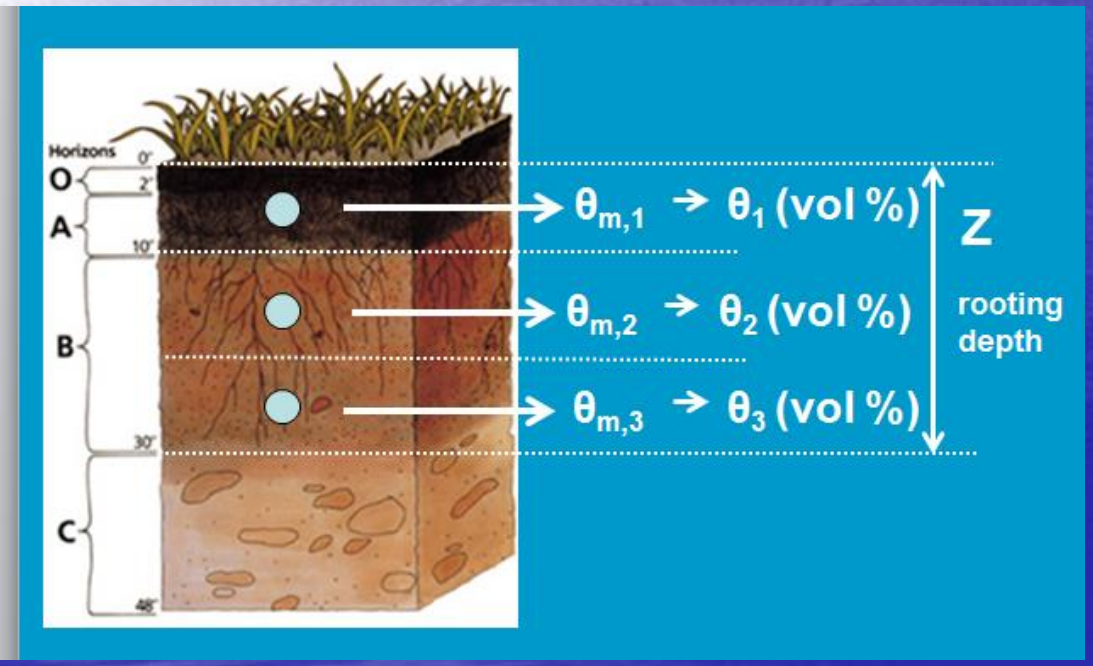
- طريقة الري
- مقنن الري
- مواعيد اضافة الريات
- ملوحة مياه الري.



Irrigation management

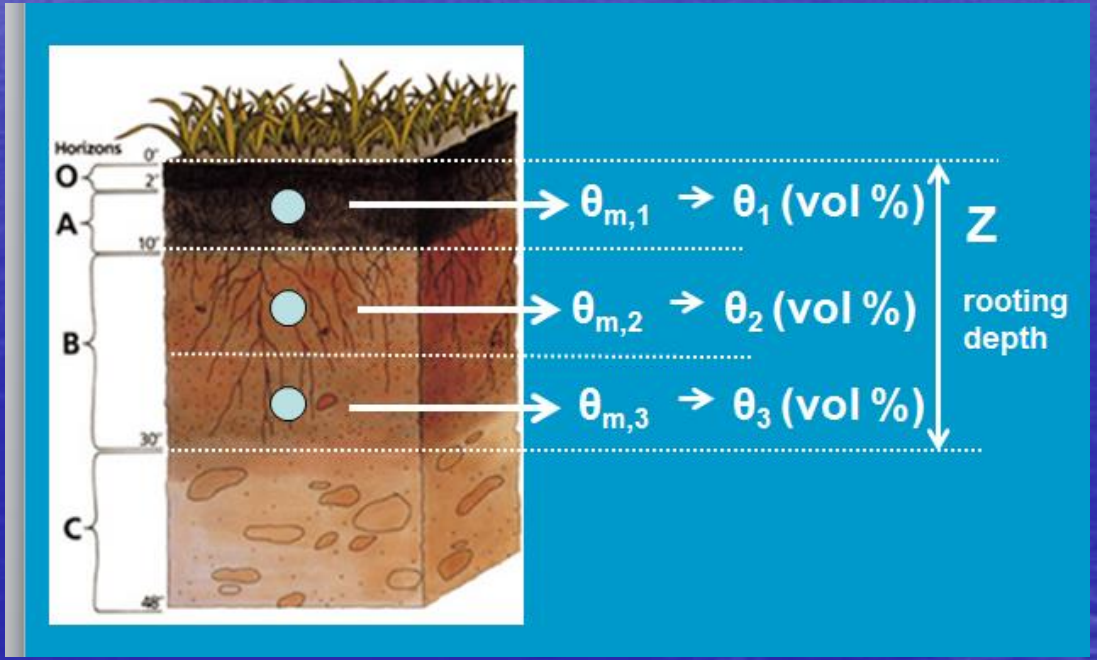
- Irrigation method
- Irrigation schedule
  - when
  - how much
  - water quality
- Generate irrigation schedule
  - when = time criterion
  - how much = depth criterion

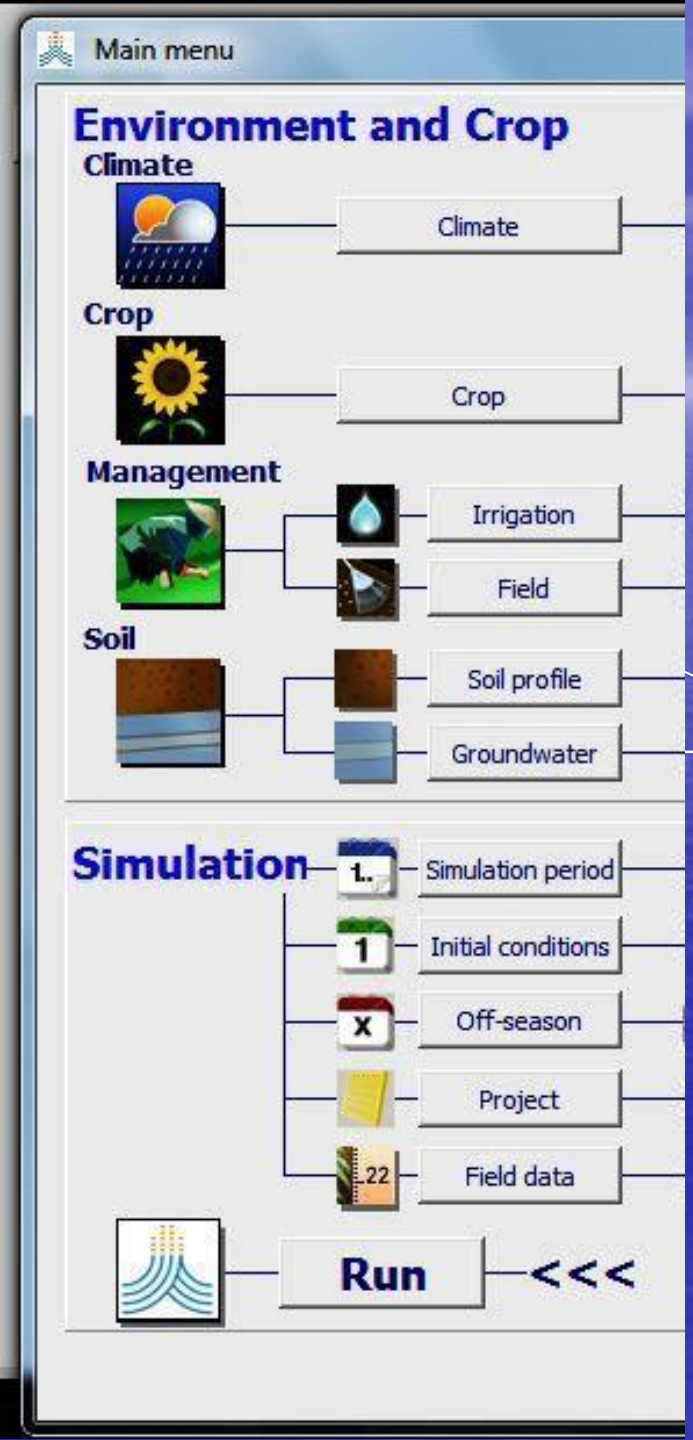
الشروط الابتدائيه

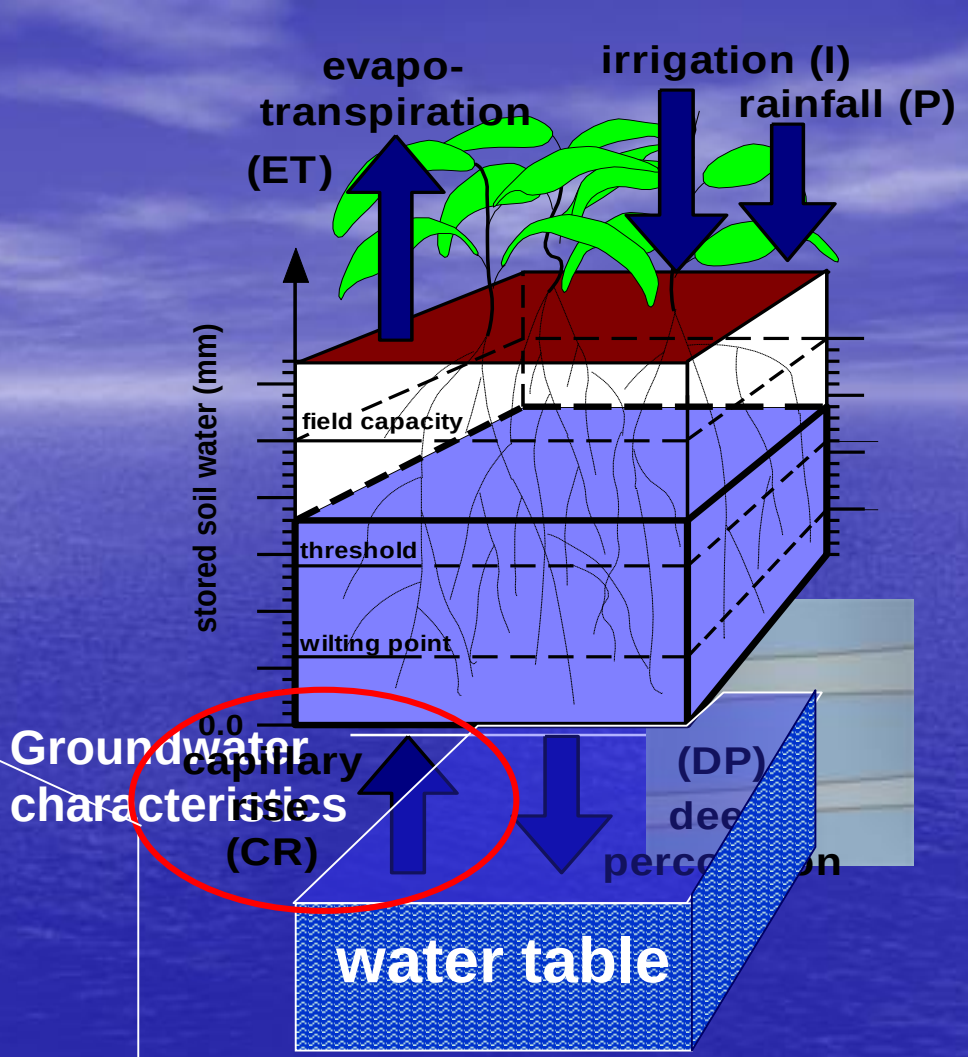


- الرطوبة الابتدائيه عند اعماق مختلفه
- ملوحه التربه عند اعماق مختلفه

- Parameters describing initial conditions at start of simulation period:
- Initial soil water content and soil salinity at various depths in the soil profile







Groundwater characteristics

- Depth of the groundwater table
- Water quality (salinity)

Thanks