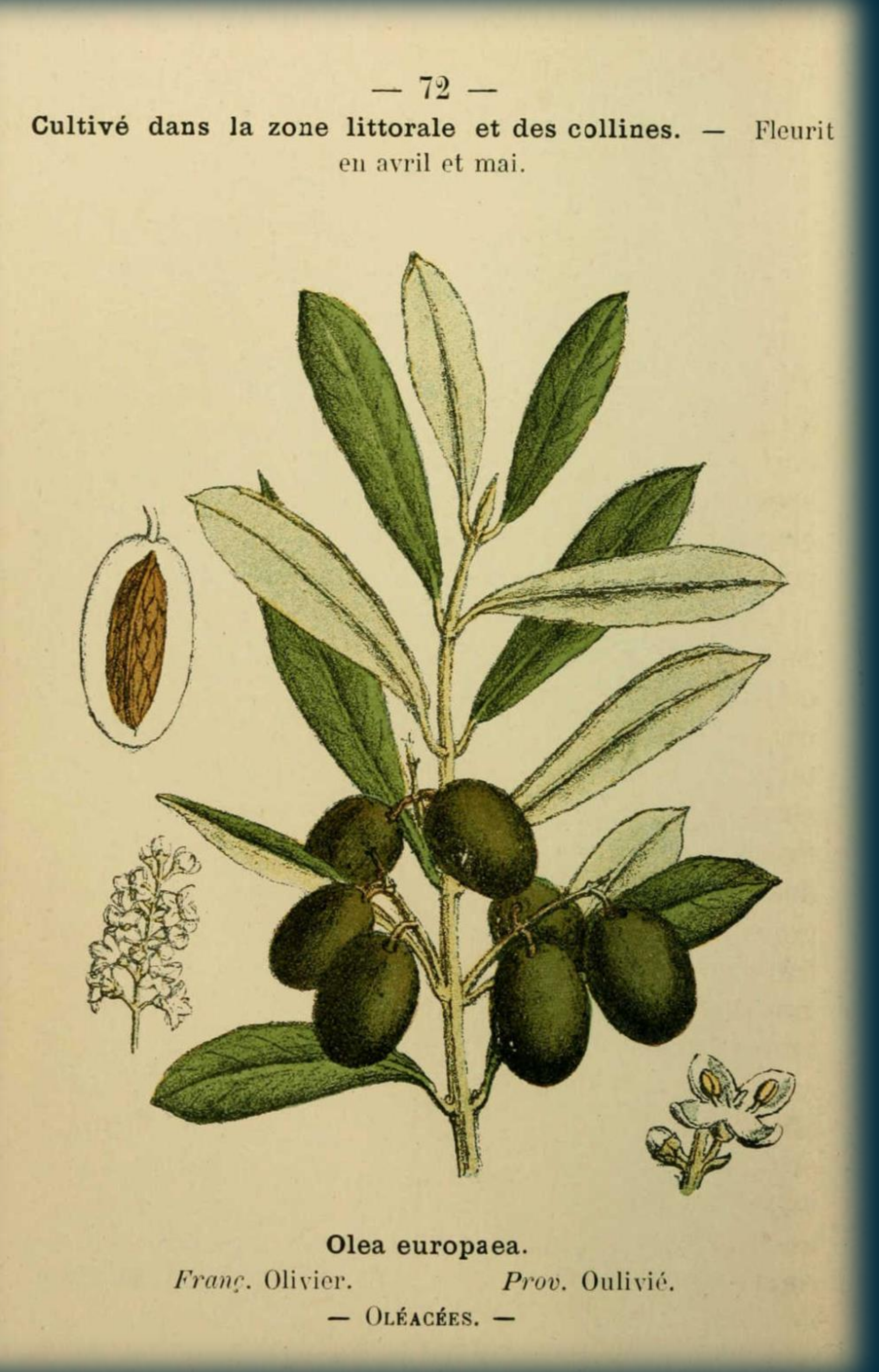


A comparison of modelling solutions for transpiration and yield of olive orchards

"A tree is a tree is a tree is a tree……"

Francisco Villalobos
Omar García
Luca Testi (IAS – CSIC)

UCO – University of Cordoba, Spain

modextreme
agriculture facing extreme climatic events

The carbon assimilation / biomass accumulation of crops is usually been modelled making use of simple but robust relationships between the assimilation of C and a related process.

A "potential" rate of growth is found for a given time step:

Quantification of related process → Relationship → Carbon/biomass

Intercepted radiation $\xrightarrow{\text{RUE}}$ Carbon/biomass

The rate is then reduced with coefficients representing the effect of stressors (lack of water, light, temperature or whatever)

$\left[\text{Transpired water} \xrightarrow{\text{WUE (TE)}} \text{Carbon/biomass} \right]$

OliveCan is a RUE model whose water stress effect is WUE-like driven.

So, what's the problem?

RUE
glucose

phenology
simulation

a) the water stress effect
as a reduction coefficient of the assimilation

cose a

intercepted radiation (3D)

available PAR energy

$C_6H_{12}O_6$

partition to organs

glucose b
....
glucose n

(P-M)

Tr_{max}

water stress effect: $\frac{A_{act}}{A_{max}} \propto \frac{Tr_{act}}{Tr_{max}}$

Tr_{act} from water balance

biomass a
biomass b
....
biomass n

conversion

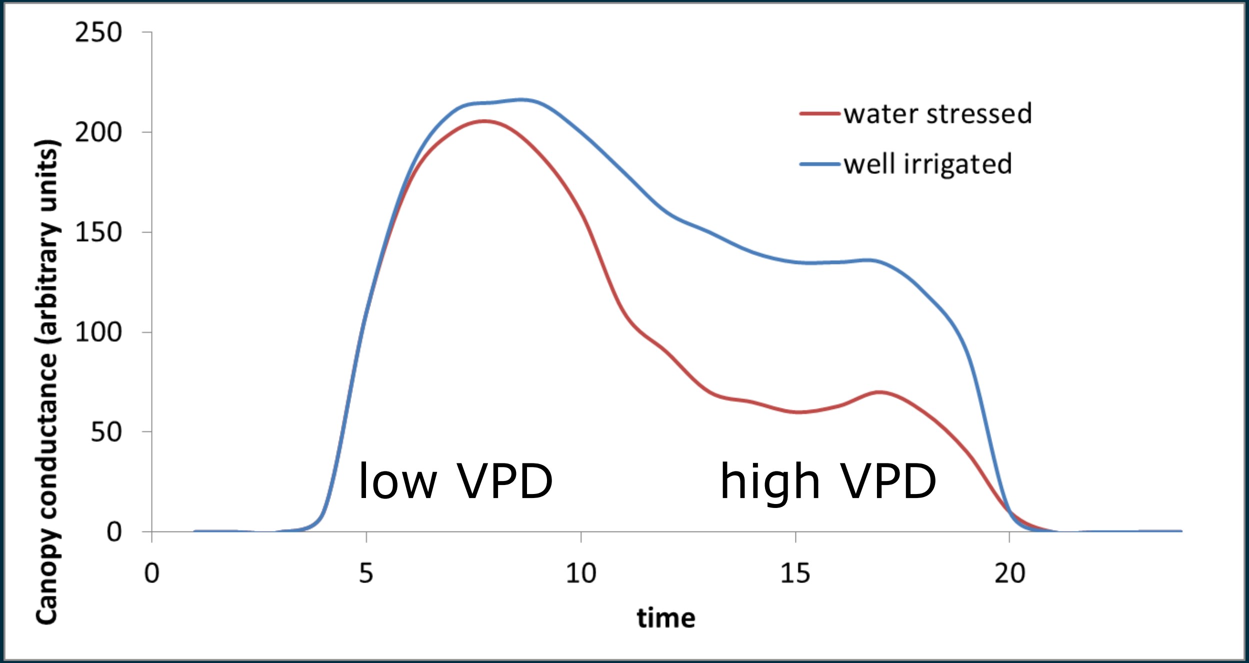
net glucose a
net glucose b
....
net glucose n

respiration a
respiration b
....
respiration n

a) the water stress effect as a reduction coefficient for the assimilation

The coefficient (T_{act} / T_{max}) used in the majority of models ranges from 0 (maximum stress, no assimilation) to 1 (no stress).

Is TE the same in different stress conditions?
The TE of trees changes significantly with water status at day or seasonal level due to different skewness of the stressed and unstressed diurnal conductance curves (Villalobos et al., 2012, Roccuzzo et al, 2014).



So, what's the problem?

RUE glucose

phenology simulation

glucose a

glucose n

intercepted radiation (3D) → available PAR energy

b) the water balance under localised irrigation: how to quantify the stress and Tr_{act}?

(P-M)

water stress effect: $\frac{A_{act}}{A_{max}} \propto \frac{Tr_{act}}{Tr_{max}}$

Tr_{max}

Tr_{act} from water balance

biomass a
biomass b
....
biomass n

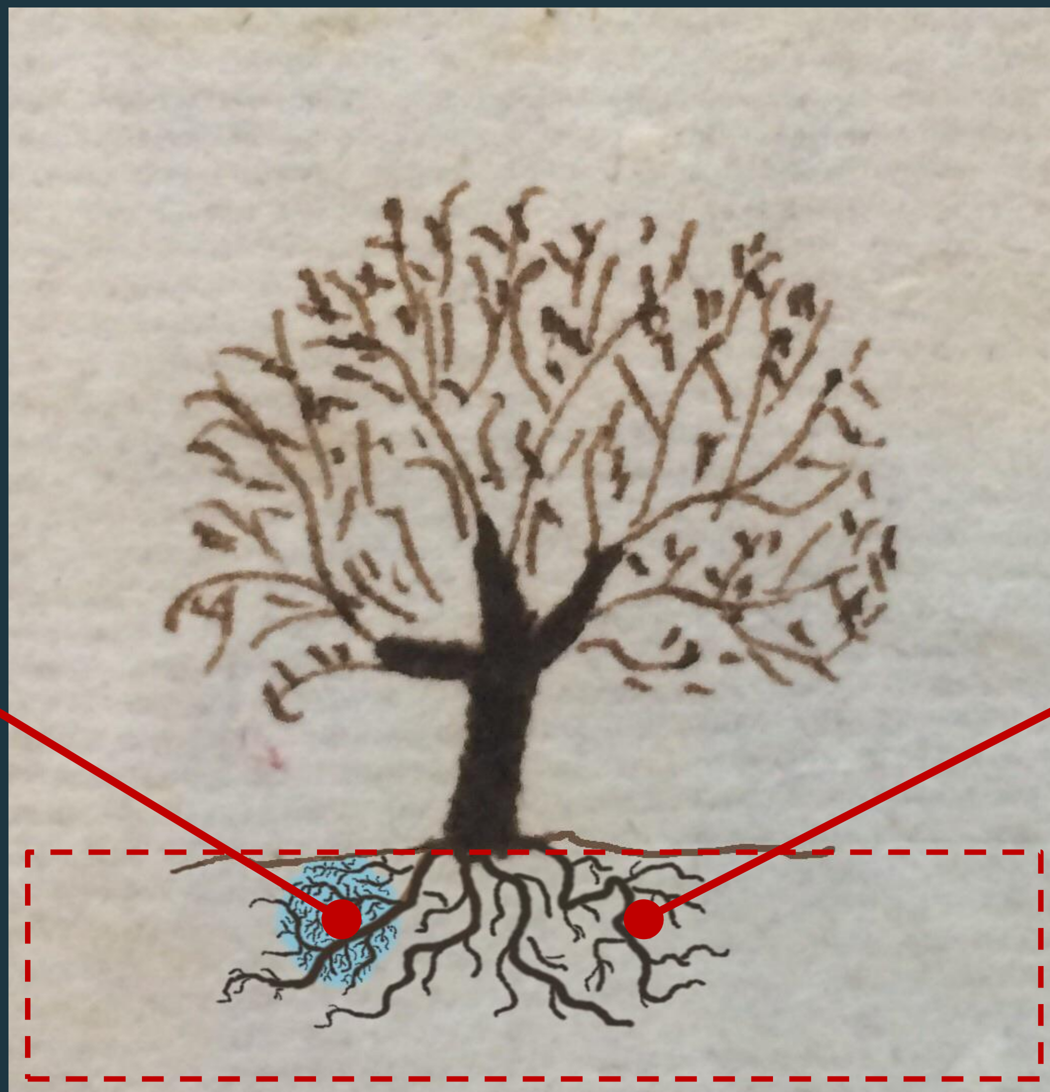
conversion

net glucose a
net glucose b
....
net glucose n

respiration a
respiration b
....
respiration n

b): the water balance under localised irrigation: how to quantify T_{act} and the overall impact of water stress?

How much water comes from the wet bulb?



How much from the rest of the soil?

The average water content or potential is useless

So, what's the problem?

RUE

glucose

phenology simulation

glucose a

se b

glucose n

c) the change in atmospheric CO_2 concentration will necessary change the RUE and the stomatal response to water stress

intercepted radiation (3D)

energy

(P-M)

water stress effect: $\frac{A_{act}}{A_{max}} \propto \frac{T_{act}}{T_{max}}$

T_{max}

T_{act} from water balance

biomass a

biomass b

....

biomass n

conversion

net glucose a

net glucose b

....

net glucose n

respiration a

respiration b

....

respiration n

OliveCan 2.0

OliveCan 2.0 new features:

- photosynthesis is calculated starting with the complete Farquhar model
- the leaf area is distributed real-time between sun and shade categories
- instead of reducing the "potential" assimilation by a water stress function, the stomatal conductance is directly calculated from leaf water potential (Tuzet et al, 2003). The assimilation and transpiration are calculated with the conductance that satisfies the balance

$$\Psi_{\text{leaves(sun, sh)}} \rightarrow G_{\text{leaves(sun, sh)}} \rightarrow \begin{cases} A_{\text{(sun, sh)}} \\ E_{\text{(sun, sh)}} \end{cases}$$

OliveCan 2.0 new features:

- instead of calculating a demand (atmosphere and leaves) and a supply (roots and soil), the water movement through the plant is now simulated with a SPAC model, like a complex electric circuit, driven by water potential and resistances

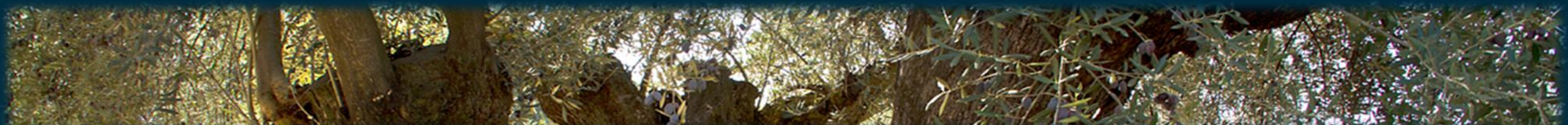
$$\Psi_{\text{soil (irr, noirr)}} \rightarrow \Psi_{\text{root (irr, noirr)}} \rightarrow \Psi_{\text{leaves(sun, sh)}} \rightarrow E_{\text{(sun, sh)}}$$

$$\Psi_{\text{leaves(sun, sh)}} \leftrightarrow G_{\text{leaves(sun, sh)}}$$

- two compartments of the soil (irrigated and non-irrigated) wired in parallel (each one with a water potential, a root density, a temperature, all distributed over a depth profile) contribute together to the flux. A third soil compartment hosts the roots of the cover crop when present.

OliveCan 2.0 new features:

- root conductance is calculated as a function of soil temperature
- the conductance of the soil surrounding the root elements is a function of soil texture and humidity and root diameter
- all the solutions of OliveCan 1.0 (RUE, assimilation reduction by WUE approach, etc.) are retained as simulation options



OliveCan 2.0 examples of responses

(those that we couldn't get before)

simulation conditions:

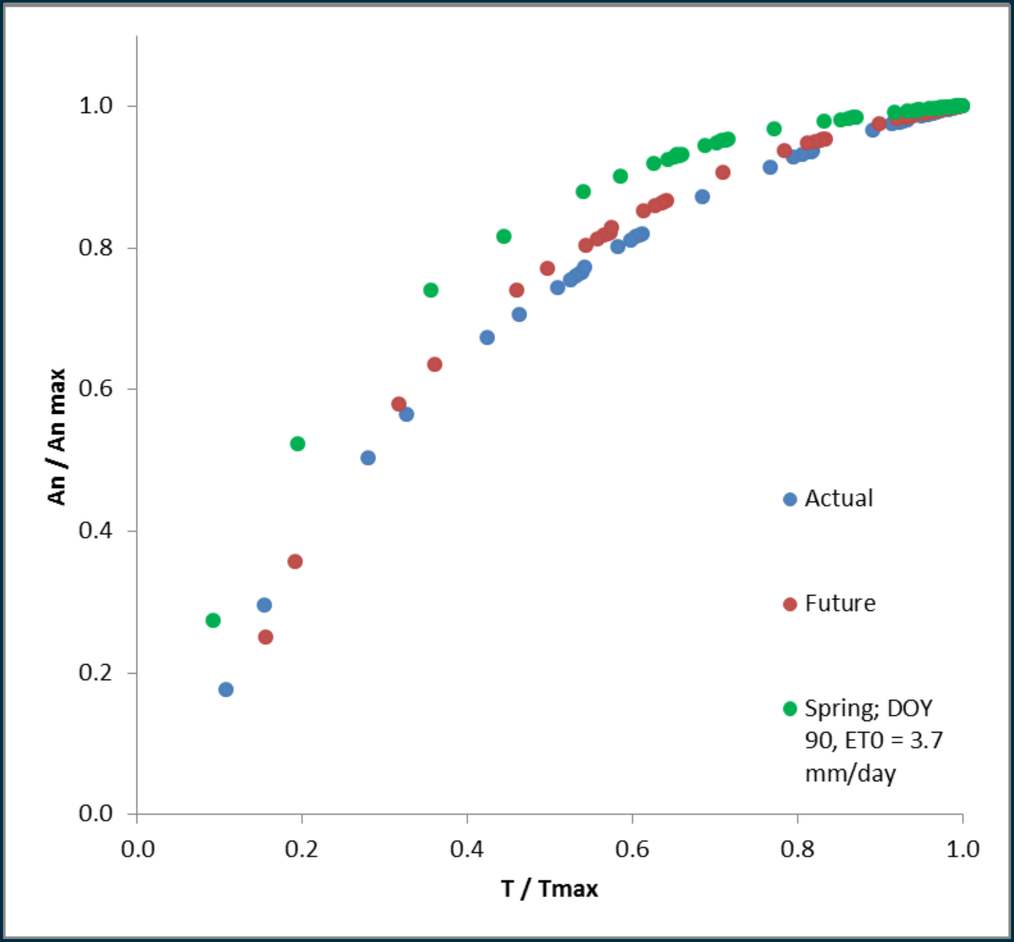
full July day in Cordoba
Tmax=37.6 ºC
Tmin=19.6 ºC
ET0 = 7 mm day^{-1}
390 ppm [CO_2]

adult, 7x3.5 m
38% soil cover
Lv wet bulb = 1.5 cm cm^{-3}
Lv rest of soil = 0.5 cm cm^{-3}
rooting depth: 1 m

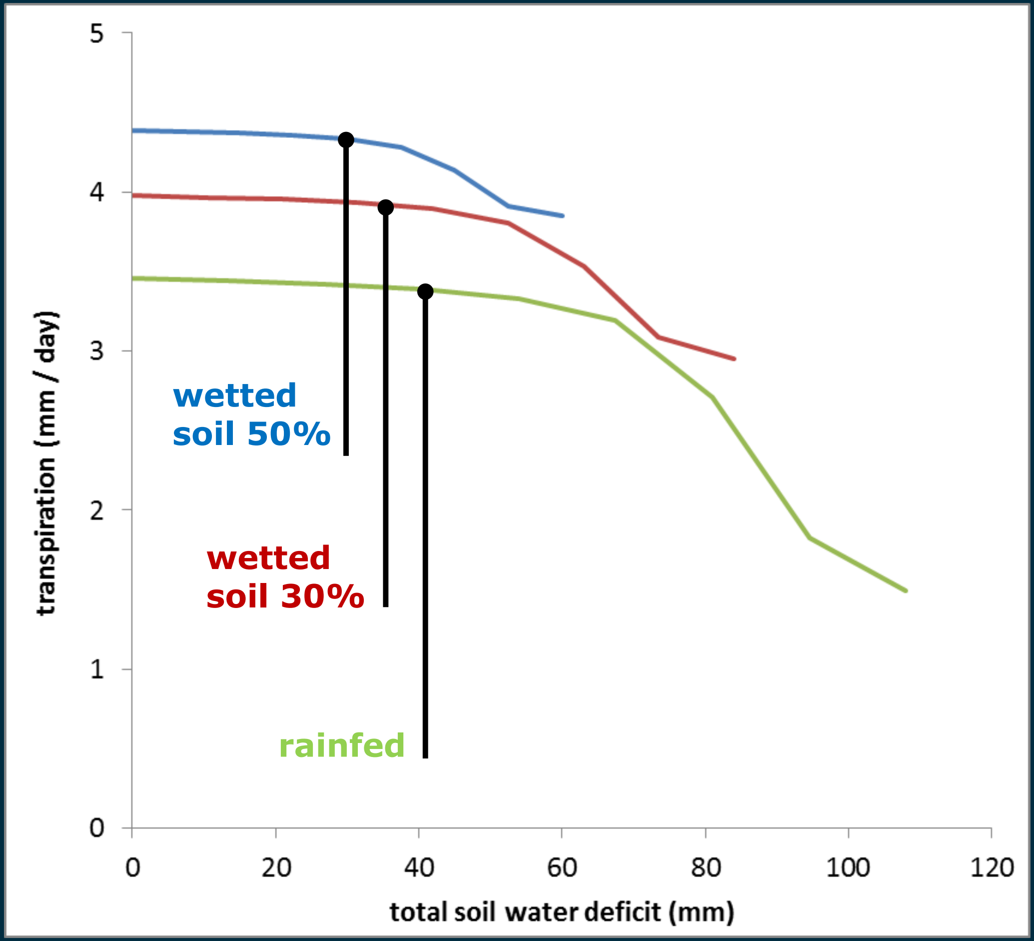
lower limit = 0.08
upper limit = 0.24
water content varying between UL and LL
irrigated compartment volume
varies between 10 and 50%

Future conditions: [CO_2] = 780 ppm, Tmax = 41.6, Tmin= 21.6, ET0=8 mm day^{-1}

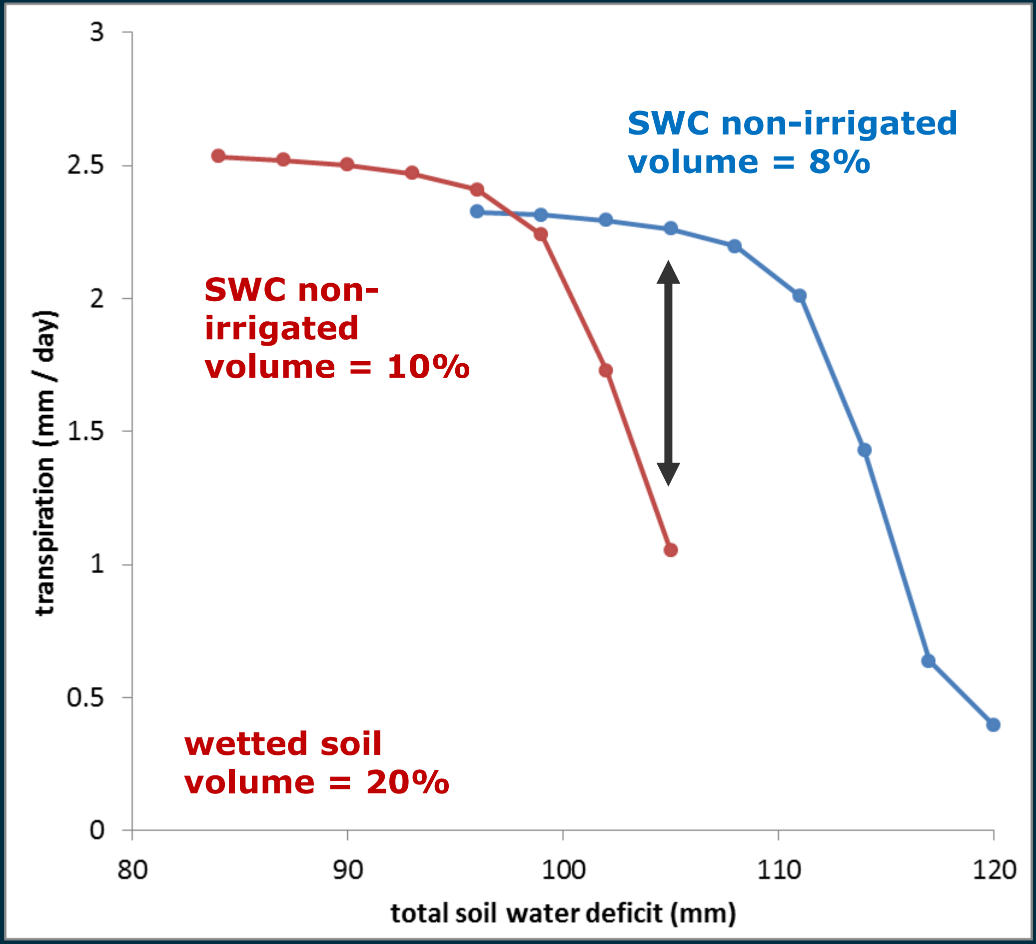
Relationship between transpiration and assimilation:



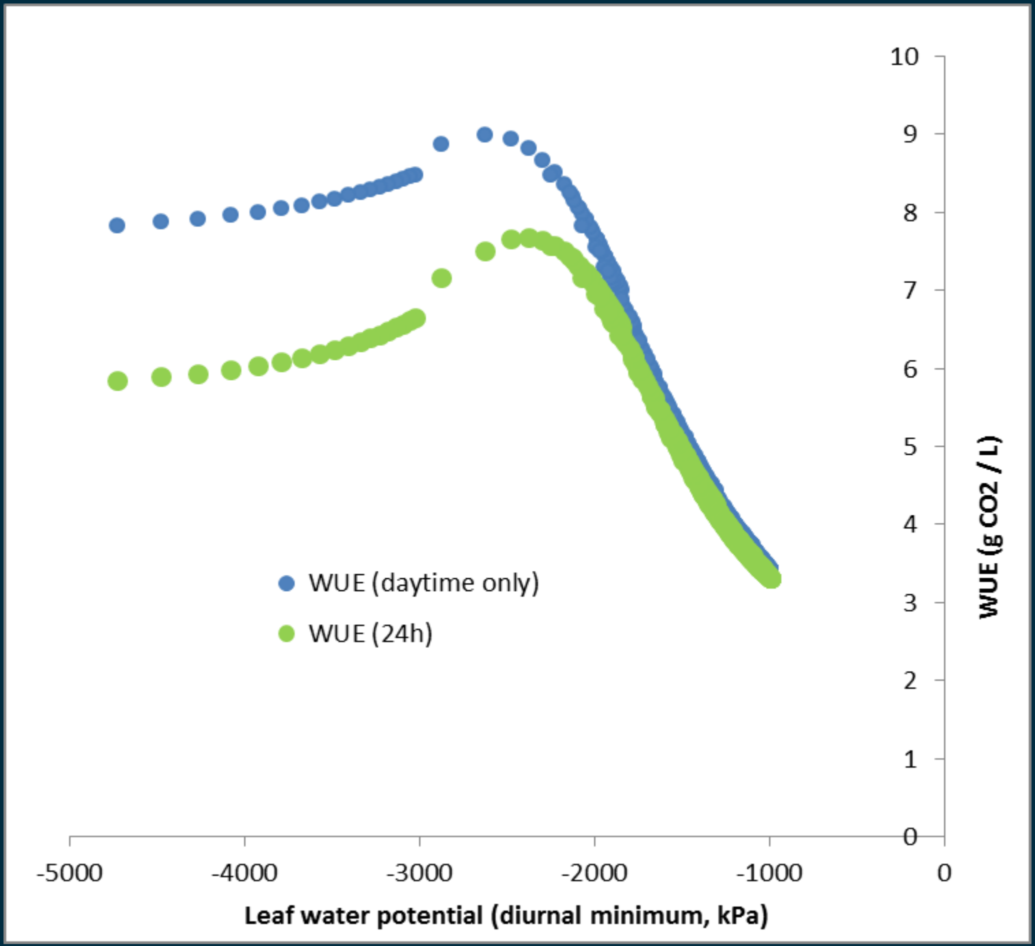
Transpiration is not only dependent on leaf area and soil water content, but depends also on wetted soil volume



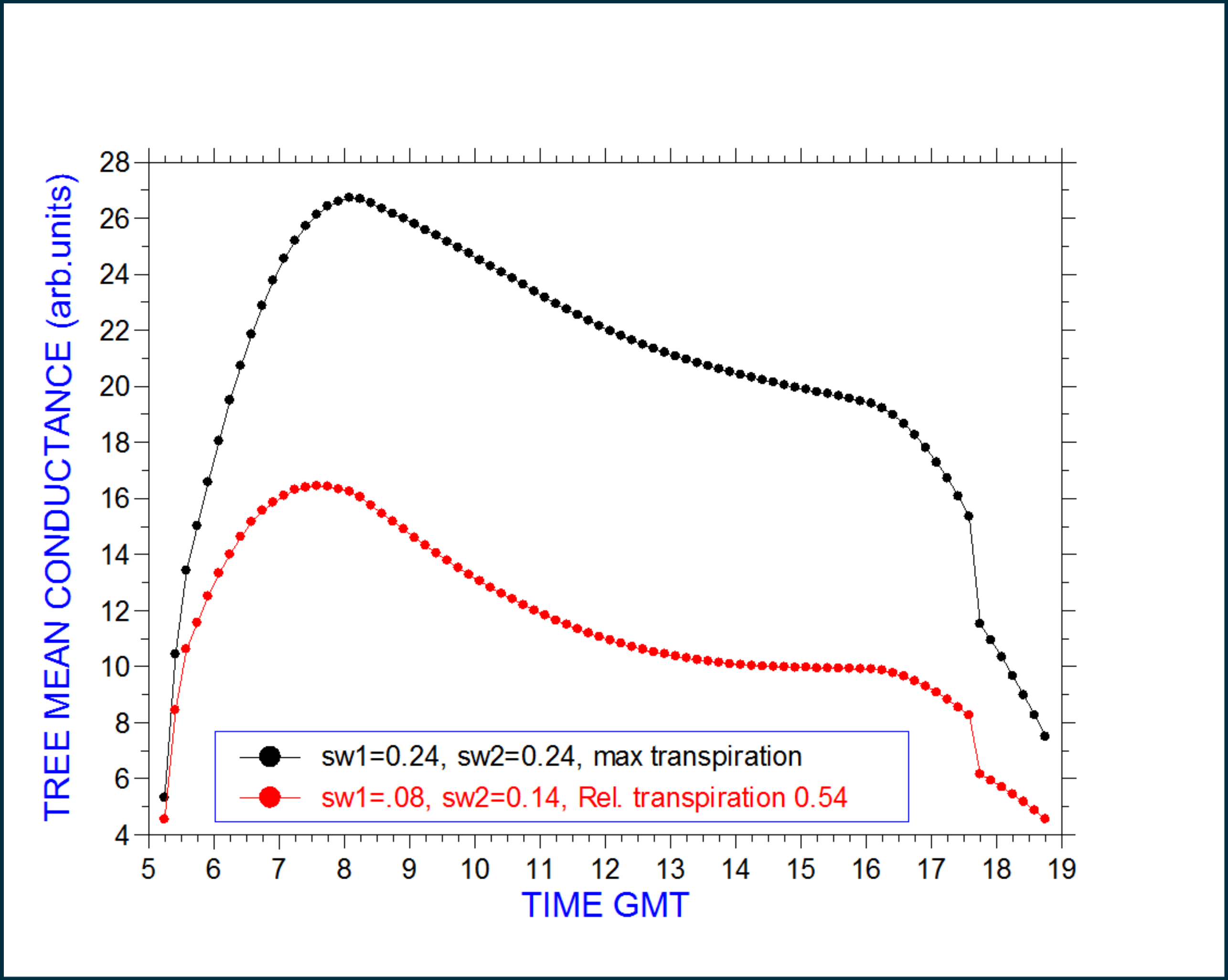
For a given wetted soil volume, the combination of water content in the compartments makes a lot of difference



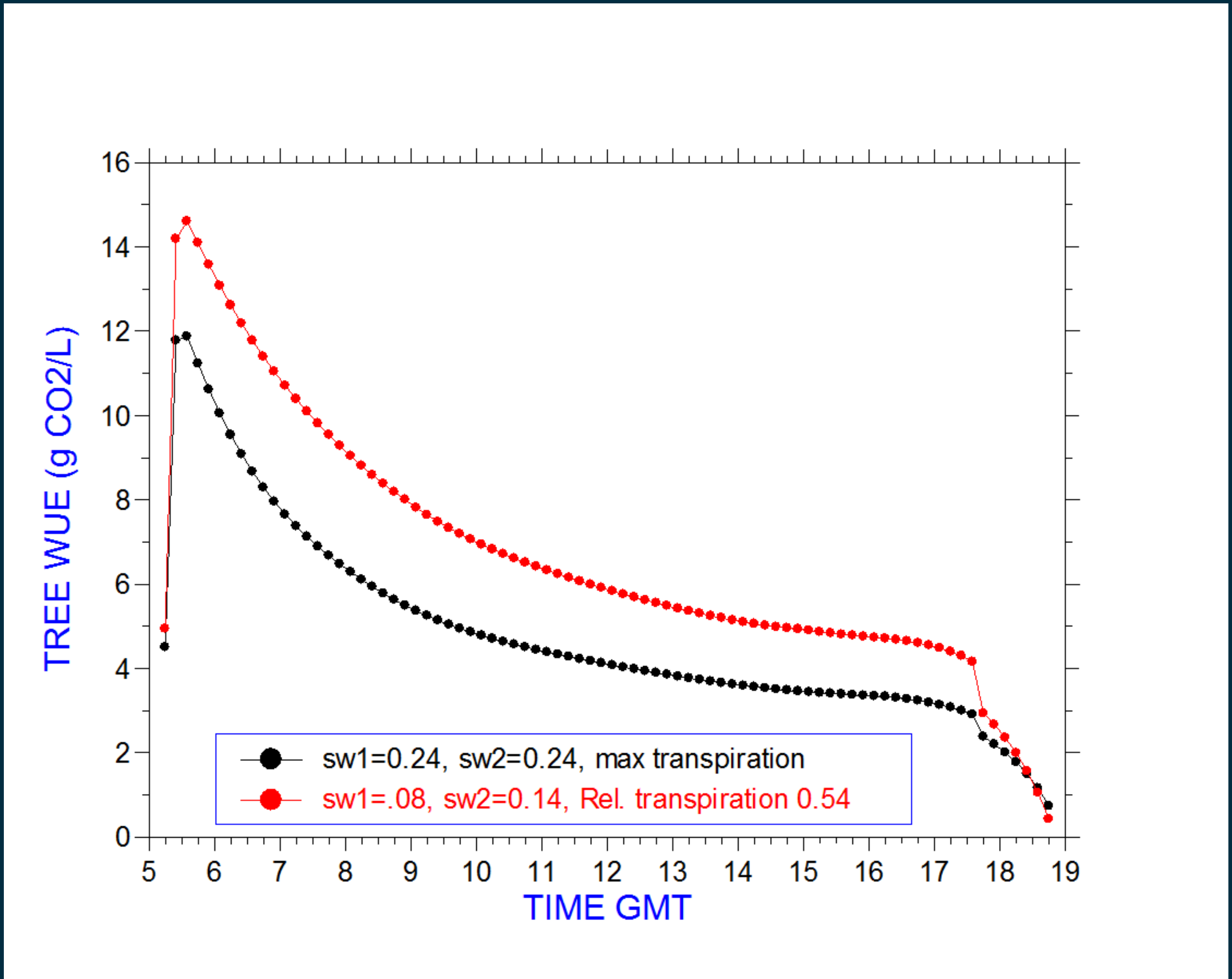
The water use efficiency relationship with plant water status



The water use efficiency varies during the day also because of the skewed conductance



The water use efficiency varies during the day also because of the skewed conductance



Simulation of yield: alternatives for annual crops

1) fixed harvest index*
2) linear increase in harvest index*
3) yield components
   a) seed number (affected by plant size and stress)
   b) single seed growth (affected by C supply and stress)

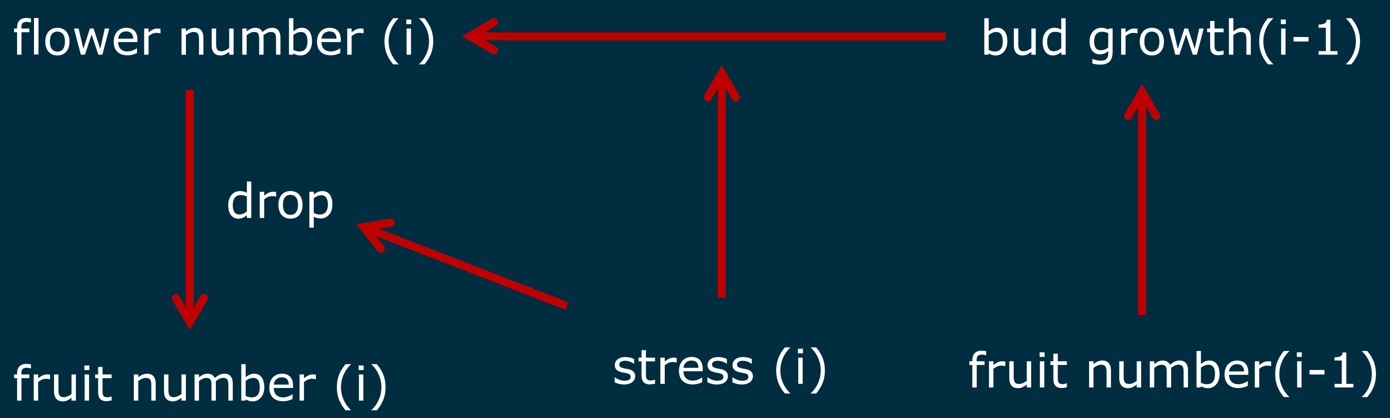
* modifiable by stressors

what about trees???

OliveCan 2.0

Uses yield components (or fixed HI, user decides)

YC approach allows to account for the dynamic nature of the fruit number (alternate bearing)



Relevance for quantifying the impact of extreme drought events

- The biomass (and yield) reduction due to water deprivation is now explicitly calculated.
- Under extreme water stress the WUE varies and this variation is now accounted for (without simulating WUE itself).
- The water stress over the whole plant is now correctly estimated from water balance in the different compartments; this is paramount in very dry environments.
- The effect of drought on the assimilated carbon / biomass now considers the CO_2 concentration explicitly with all its effects on leaf conductance and assimilation. Future olive performance can now be simulated with a new level of confidence.
- The effect of drought in an actual year could be masked by the effect of fruit charge, which is now accounted for.

"Rose is a rose is a rose is a rose."

Gertrude Stein, *Sacred Emily*, 1913.

"A rose tree may be a rose tree may be a rosy rose tree if watered."

Gertrude Stein, *Alphabets and Birthdays*, 1957.

thanks for your attention.