Introduction to AquaCrop

Concepts and Structure

TOMÁS ROQUETTE TENREIRO
IAS-CSIC and University of Cordoba

European Commission

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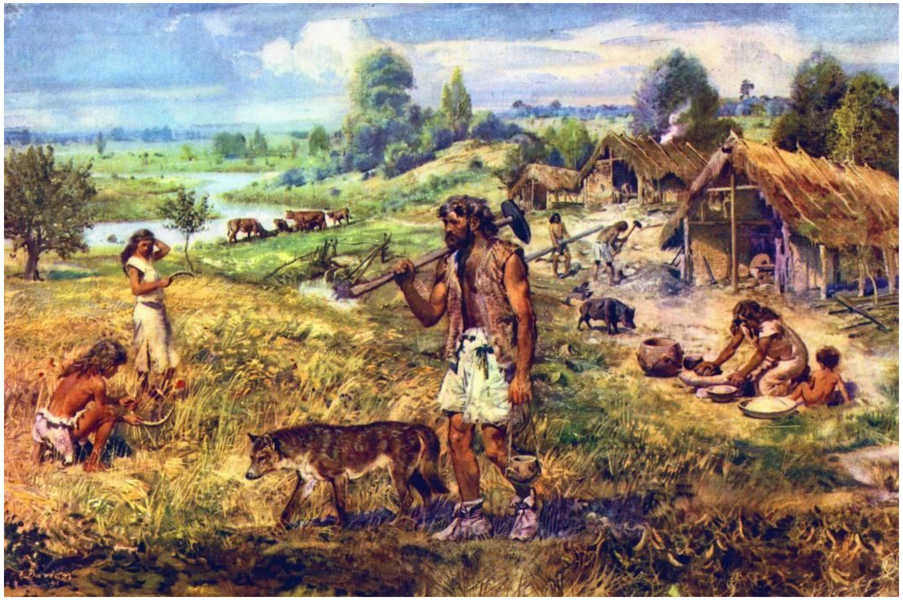

FROM THE BEGINNING OF AGRICULTURE, MAN HAS BEEN TRYING TO UNDERSTAND HOW CROPS FUNCTION, HOW THEY GROW, DEVELOP, AND PRODUCE

For the last 150 years, **FIELD EXPERIMENTS** have led to improved varieties, better agricultural practices and better understanding of how agricultural systems function through ecophysiological studies

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AS WE HAVE ADVANCED OUR KNOWLEDGE, WE WOULD LIKE TO ANSWER QUESTIONS SUCH AS: CAN WE PREDICT YIELD?

FIELD EXPERIMENTATION: SITE-SPECIFIC, LENGTHY AND COSTLY

IS THERE ANOTHER WAY?

A CROP SIMULATION MODEL

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WHAT IS A CROP SIMULATION MODEL?

LET'S LOOK AT AN EARLY VERSION

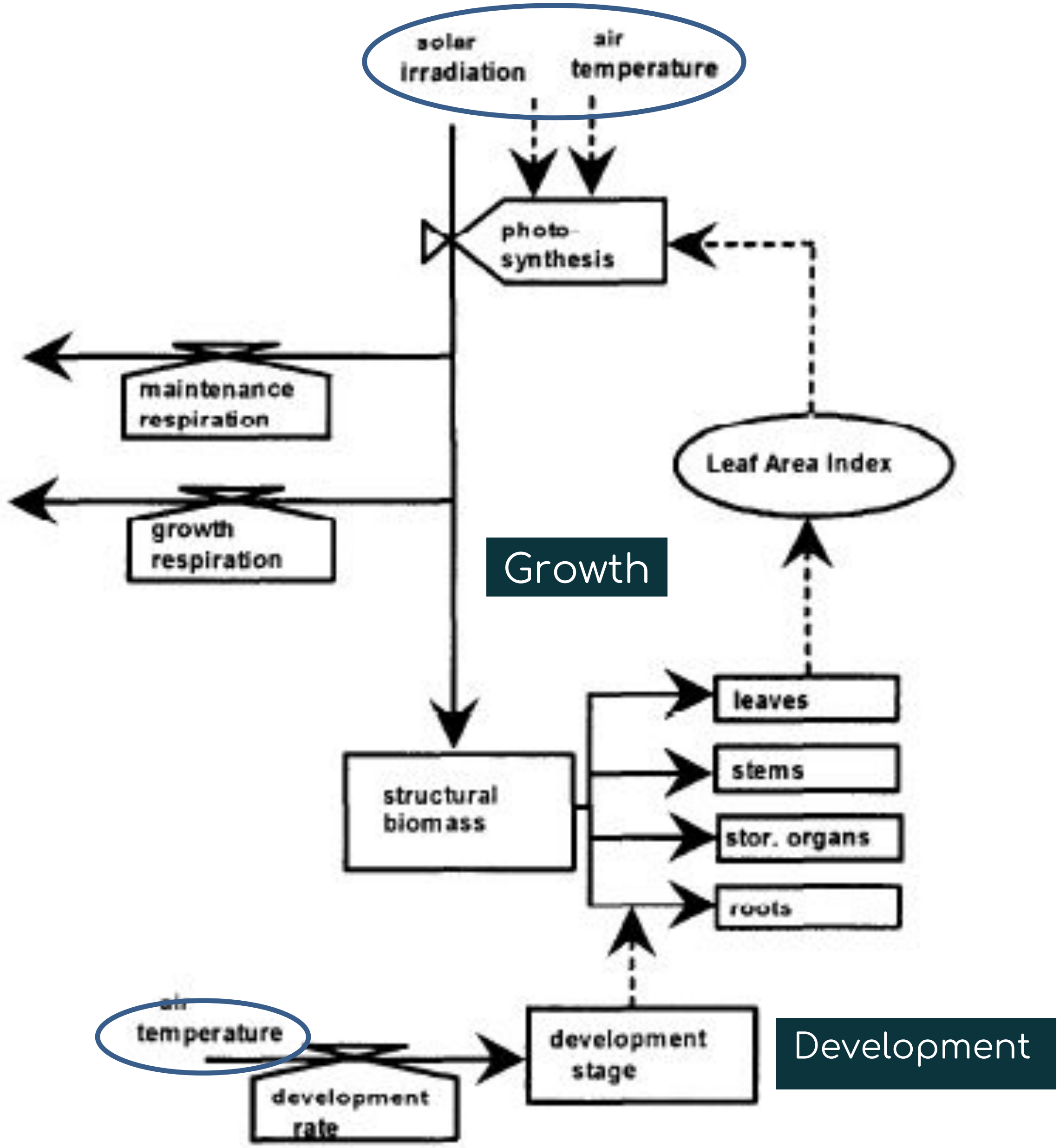


Fig. 2. Diagram of the relations in a typical "School of de Wit" crop growth model (SUCROS) for potential production. Boxes indicate state variables, valves rate variables, circles auxiliary variables, solid lines (arrows) the flow of matter and dotted lines the flow of information.

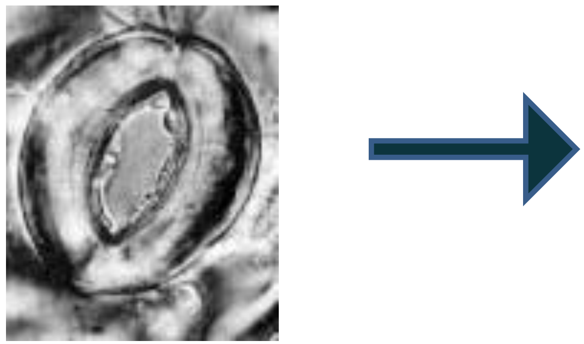
Many models use this principle (DSSAT, APSIM, WOFOST, etc.)

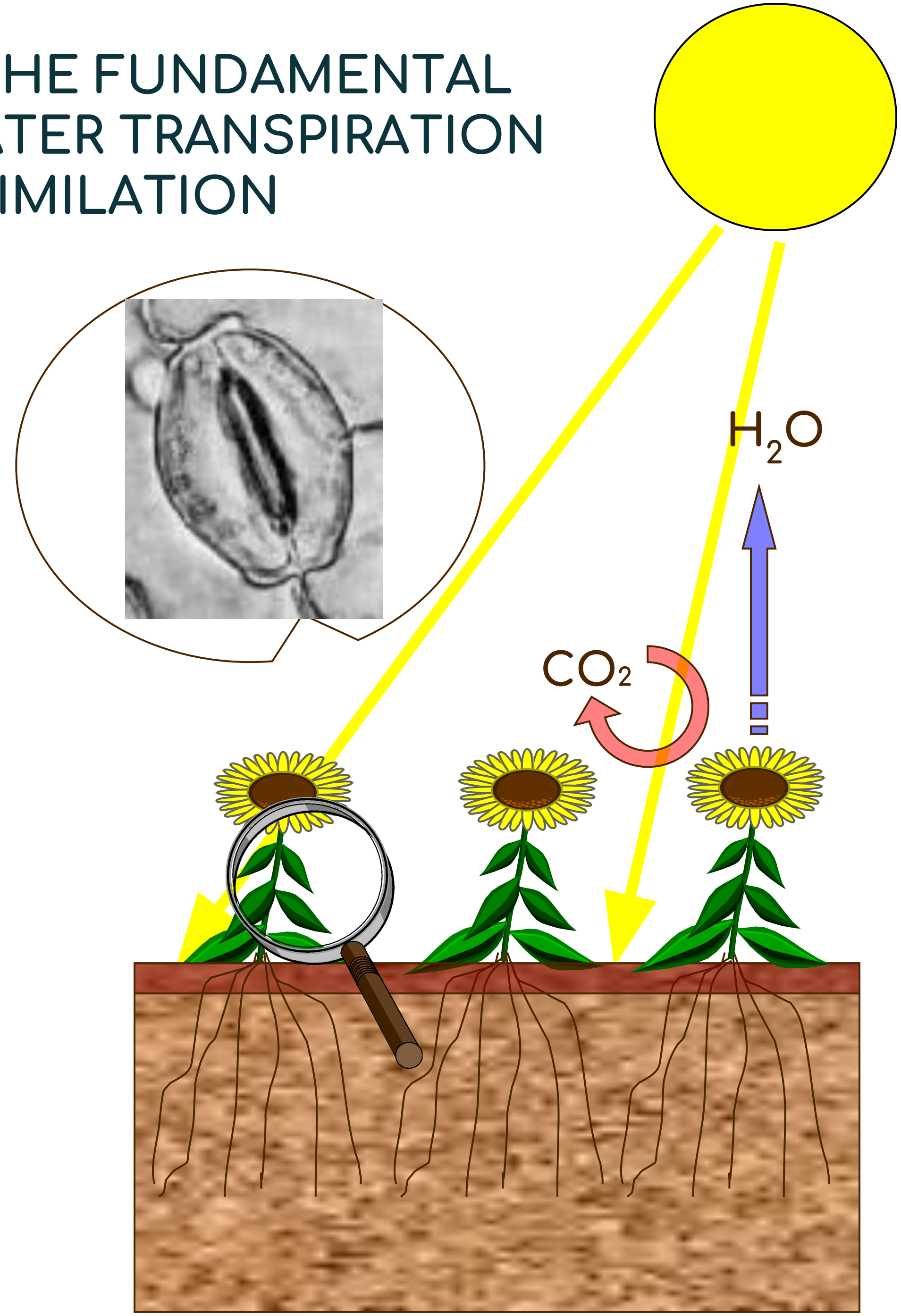
Climate and the Efficiency of Crop Production in Britain, JL Monteith, 1977

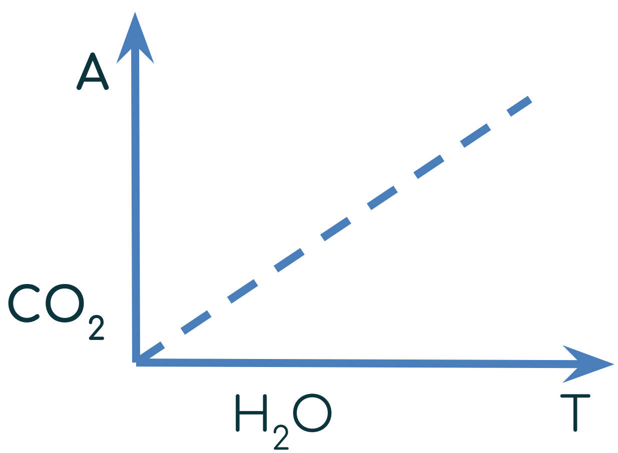
Total optimal production of dry matter in most of C-3 crop species varies from 2.5 to 3.5 g/MJ PAR intercepted.

BUT AQUACROP IS BASED ON A DIFFERENT PRINCIPLE

AQUACROP IS BASED ON THE FUNDAMENTAL CONNECTION BETWEEN WATER TRANSPIRATION AND CARBON ASSIMILATION







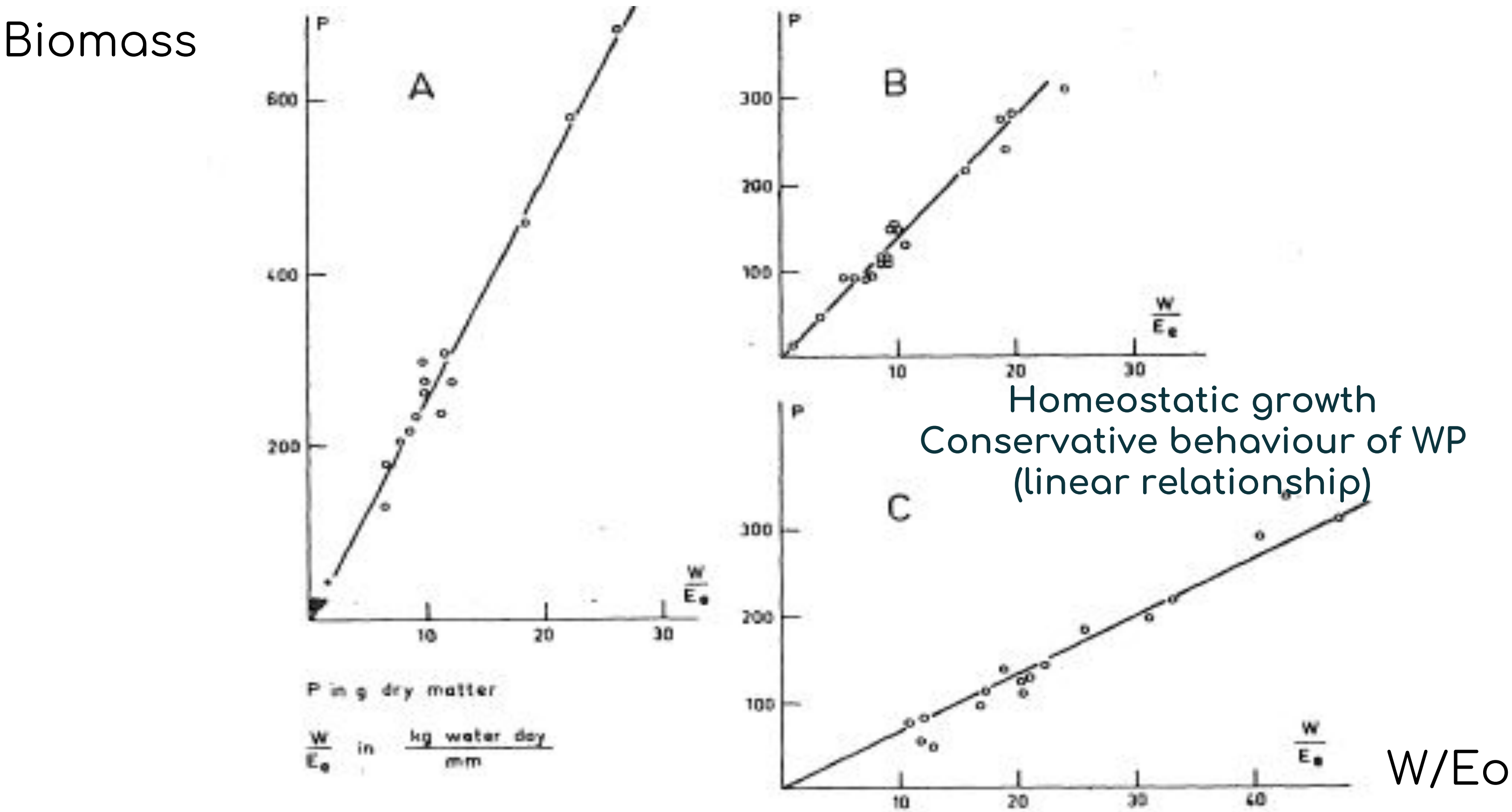


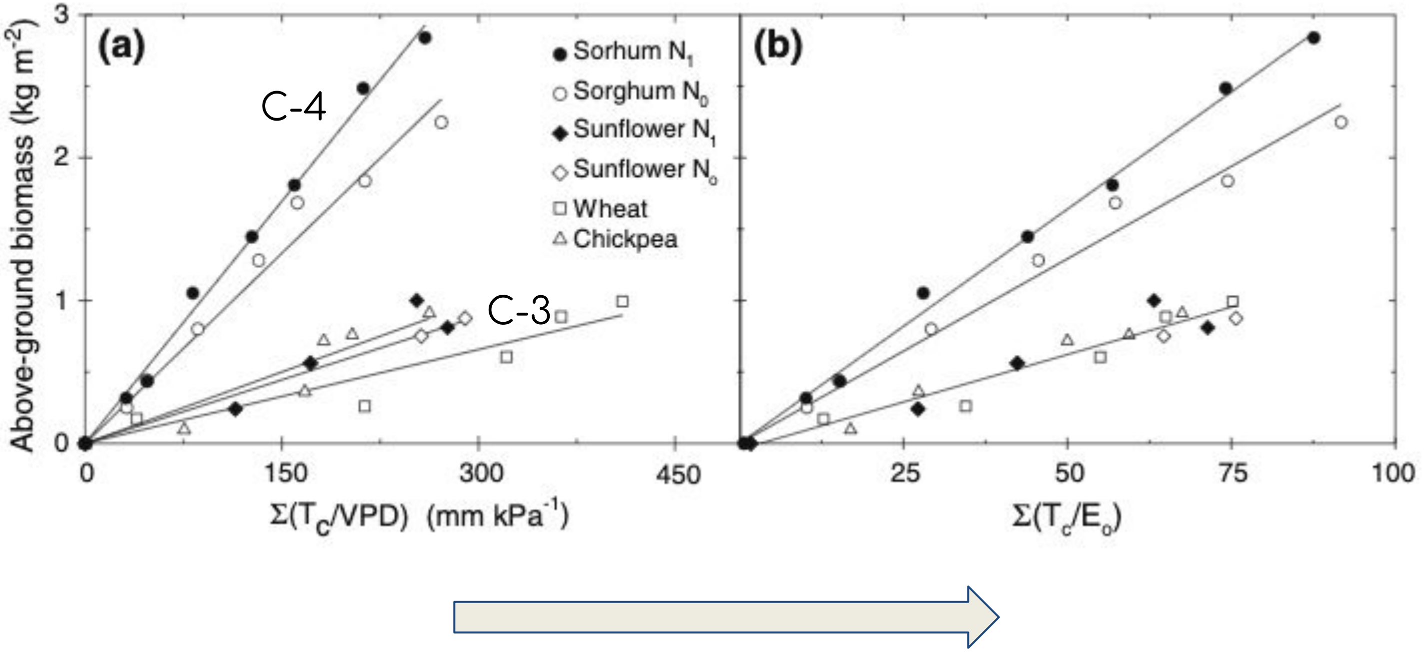
FIG. 24. Diagrams, showing the relation between production per container – P – and the ratio WE_e^{-1} between transpiration per container – W –, and pan evaporation – E_e –. The data are from table 6 and the same as used in the diagrams of figure 22 and 23. There exists a straight line relationship of the form: $P = m_e WE_e^{-1}$.
Graph A: sorghum; B: Kubanka wheat; C: alfalfa.

De Wit normalized the water consumption by the evaporative demand, thus demonstrating the uniqueness of the B-T relation, and how the environment determines crop water use **(De Wit. 1958. Transpiration and Crop Yields)**

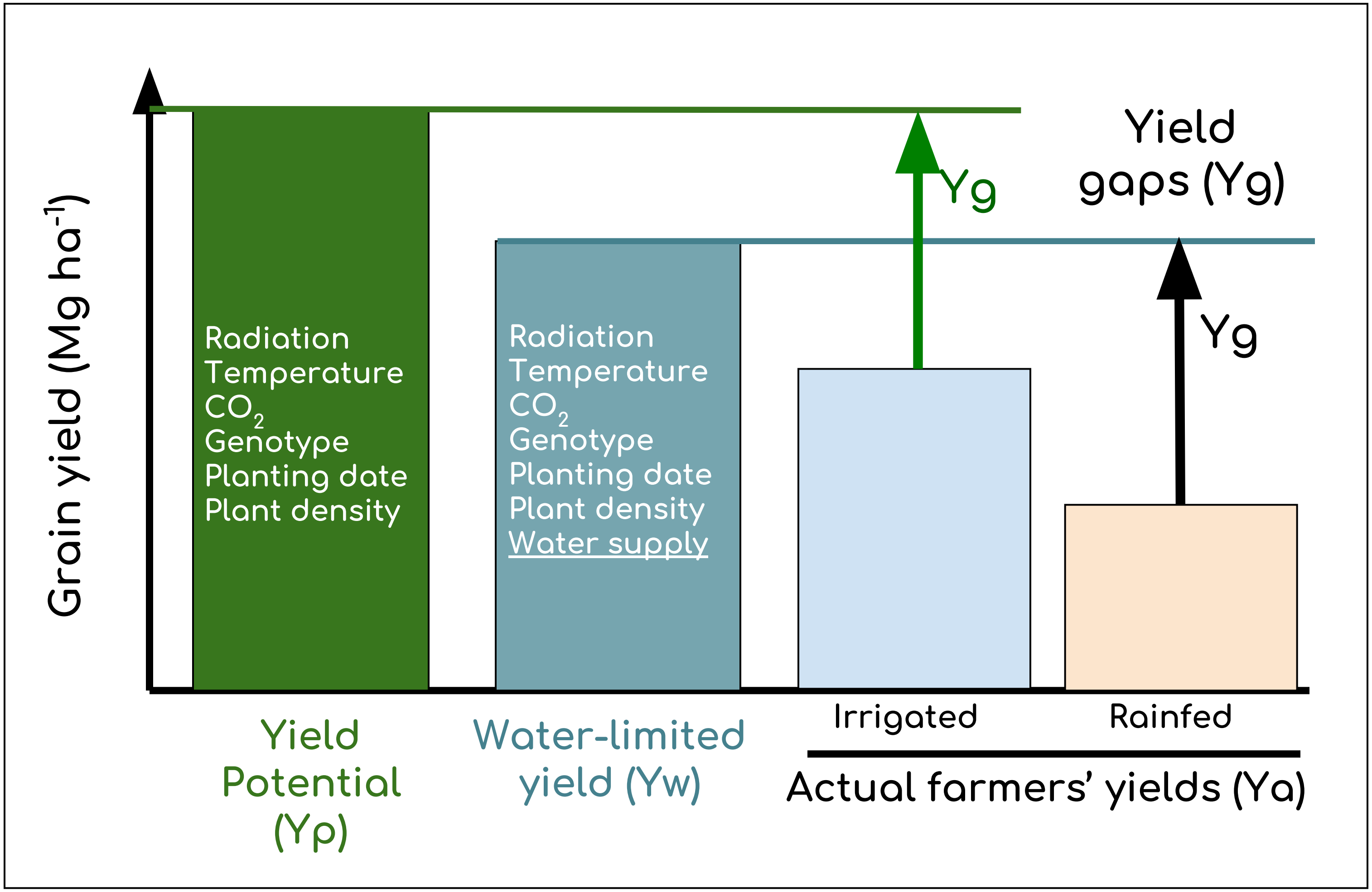
Periodic assessments of the relation between biomass and water use

Tanner & Sinclair. (1983); Steduto et al. (2007)

Normalization can be done using Reference Evapotranspiration (ETo)



AQUACROP SIMULATES Yp AND Yw



Modified from Cassman *et al.* (2003)

P. Steduto, D. Raes, T.C. Hsiao & E. Fereres

A MODEL FOR SIMULATING WATER-LIMITED YIELD

AQUACROP

crop production simulator

www.fao.org/nr/water

Background

- Revision of the 1979 FAO I & D Paper no.33, *"Yield Response to Water"*

- A simulation model for field-crops:

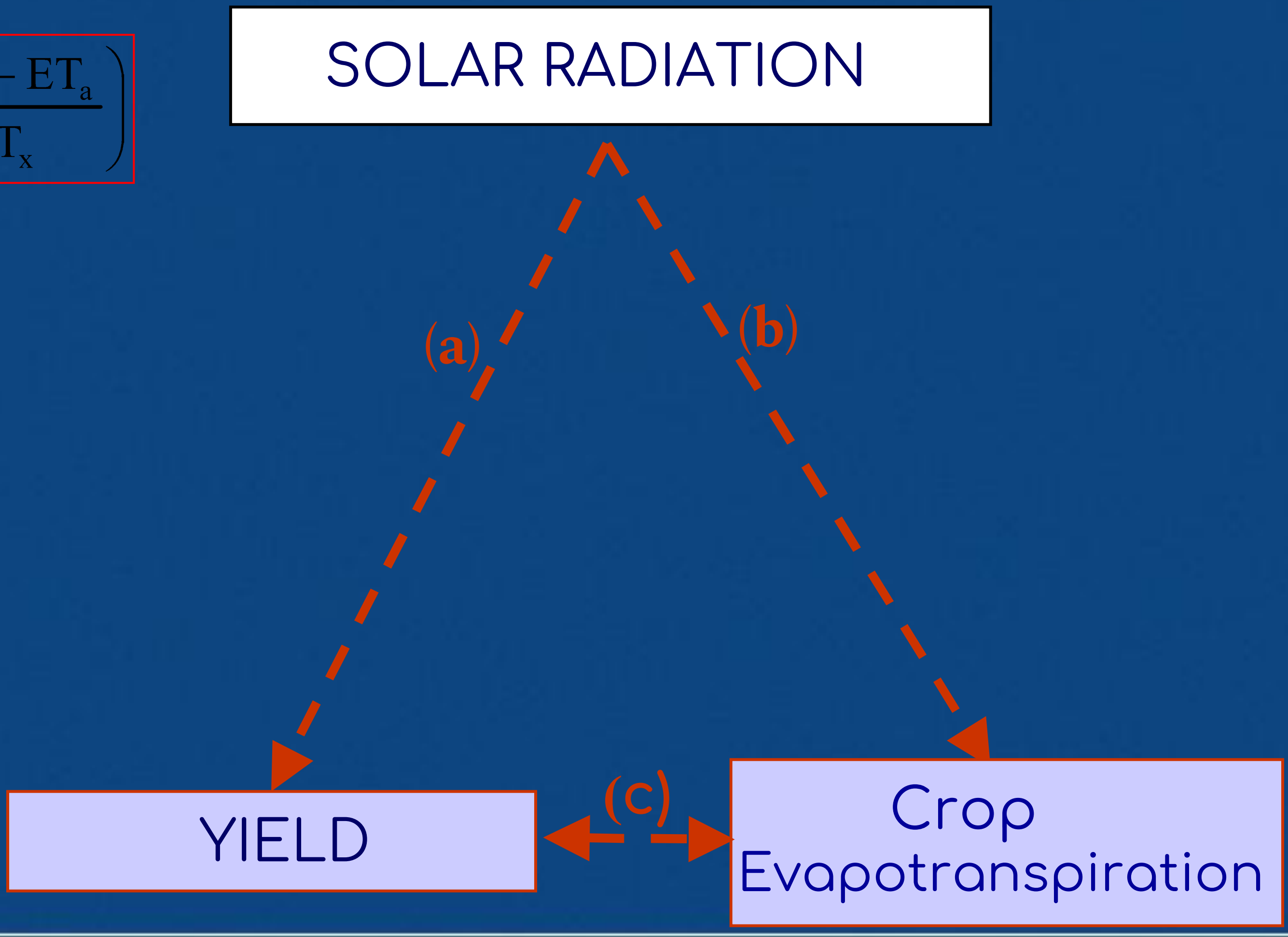
  AquaCrop

Continuously improving process

Evolution from FAO Paper 33

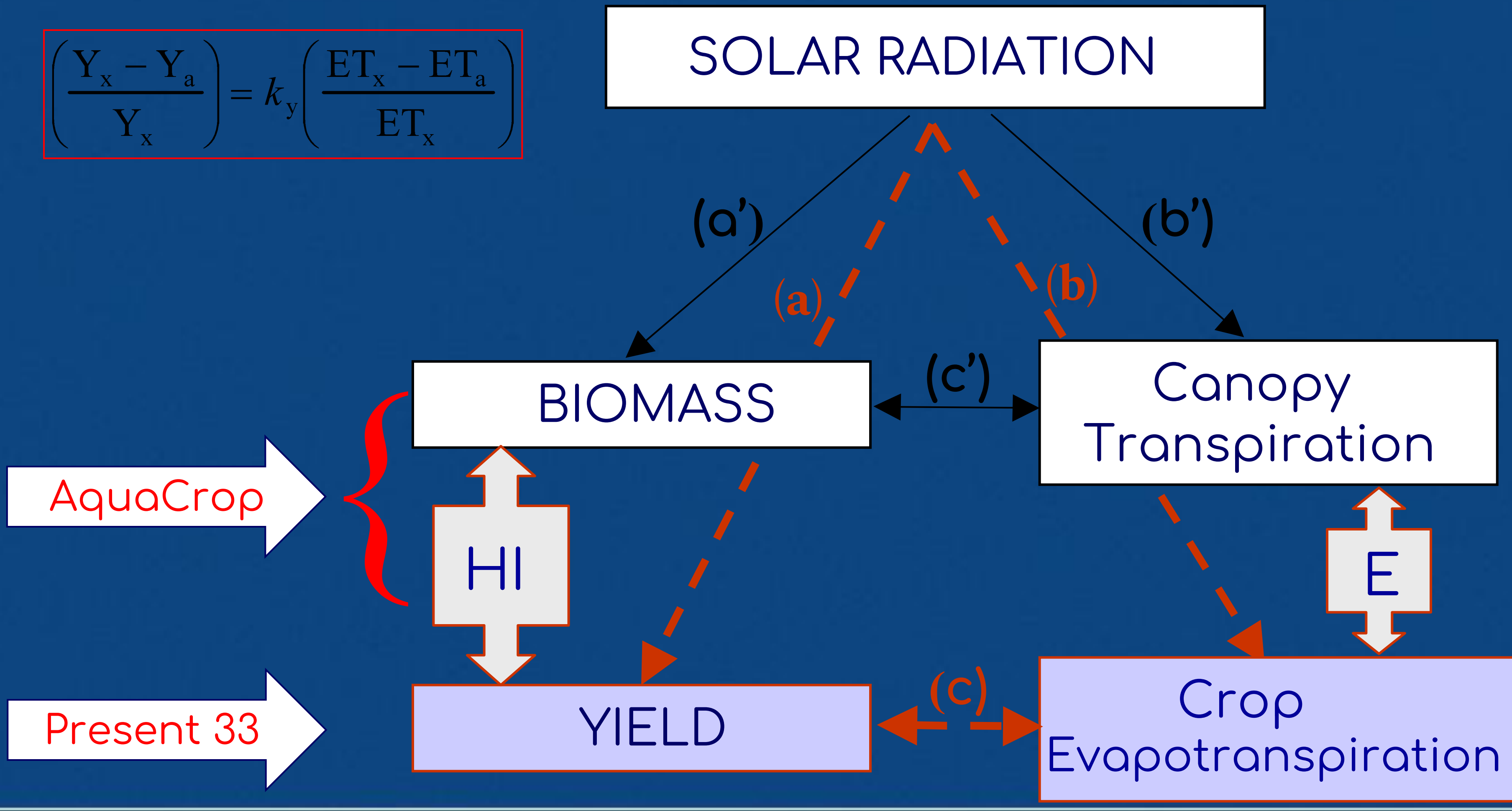
$$\left(\frac{Y_x - Y_a}{Y_x}\right) = k_y\left(\frac{ET_x - ET_a}{ET_x}\right)$$

FAO - 33

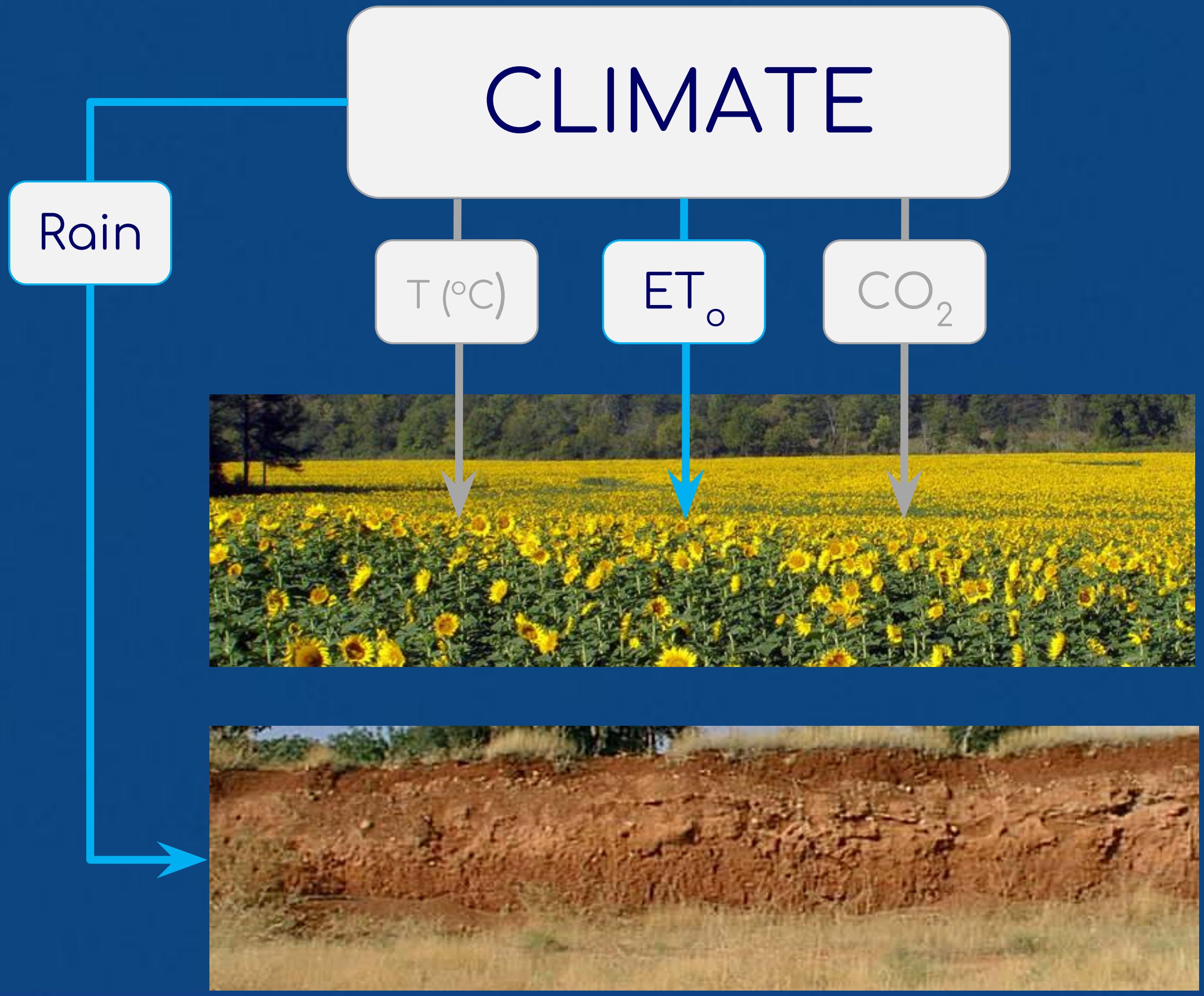


Evolution from FAO Paper 33

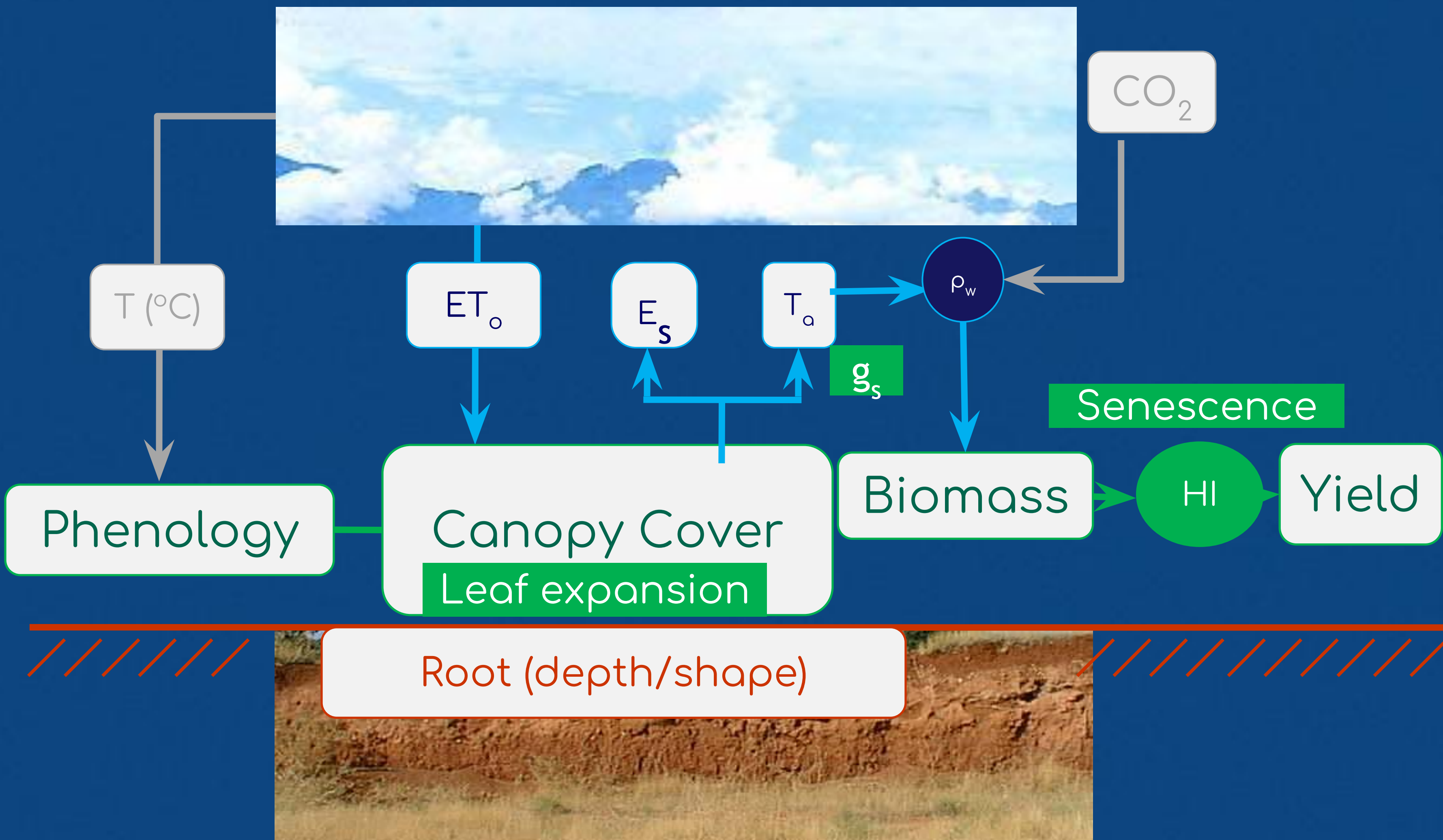
$$\left(\frac{Y_x - Y_a}{Y_x}\right) = k_y\left(\frac{ET_x - ET_a}{ET_x}\right)$$



AquaCrop Conceptual Framework (ATMOSPHERE)

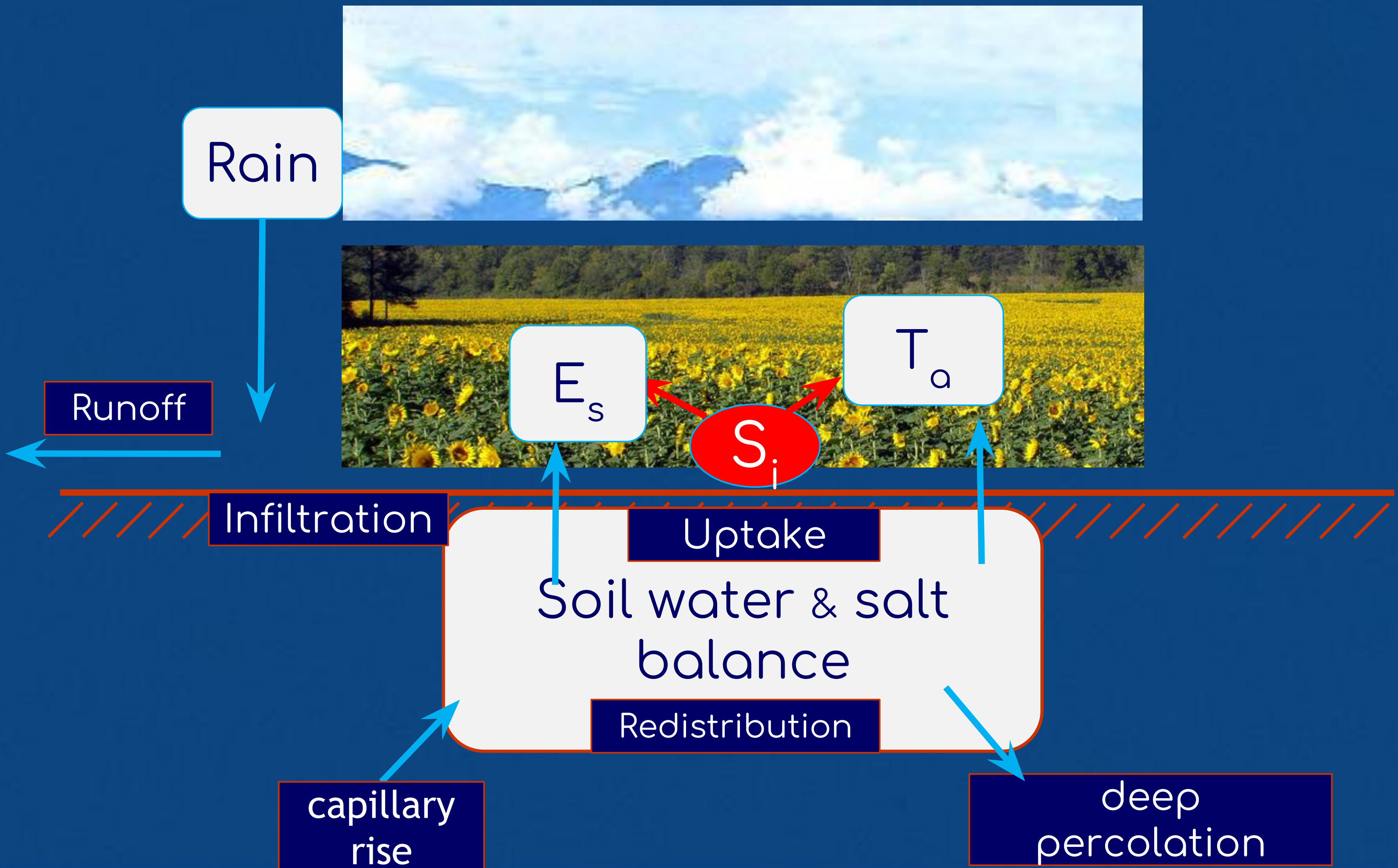


AquaCrop Conceptual Framework (CROP)



FAO WATER

AquaCrop Conceptual Framework (SOIL)



AquaCrop Conceptual Framework (MANAGEMENT)

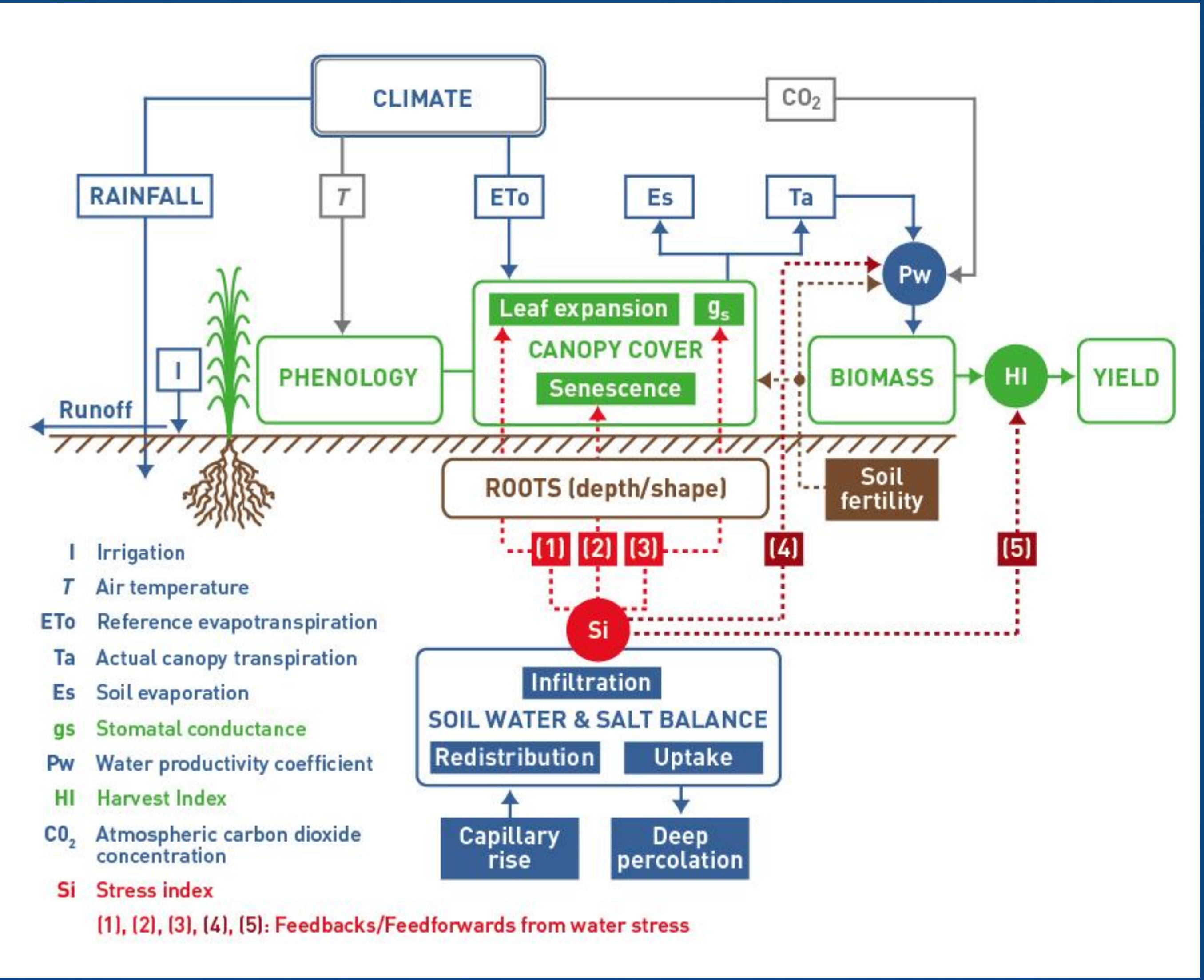
Field Management

- **Fertility level** (non-limiting; moderate; poor)
- **Field-surface practices** (mulching)

Irrigation water Management

- **User defined schedule** (timing and depth)
- **Model-generated schedule** (fixed interval; fixed depth; % of root available water)
- **Irrigation method** (drip; sprinkler; surface)

AquaCrop simulation scheme

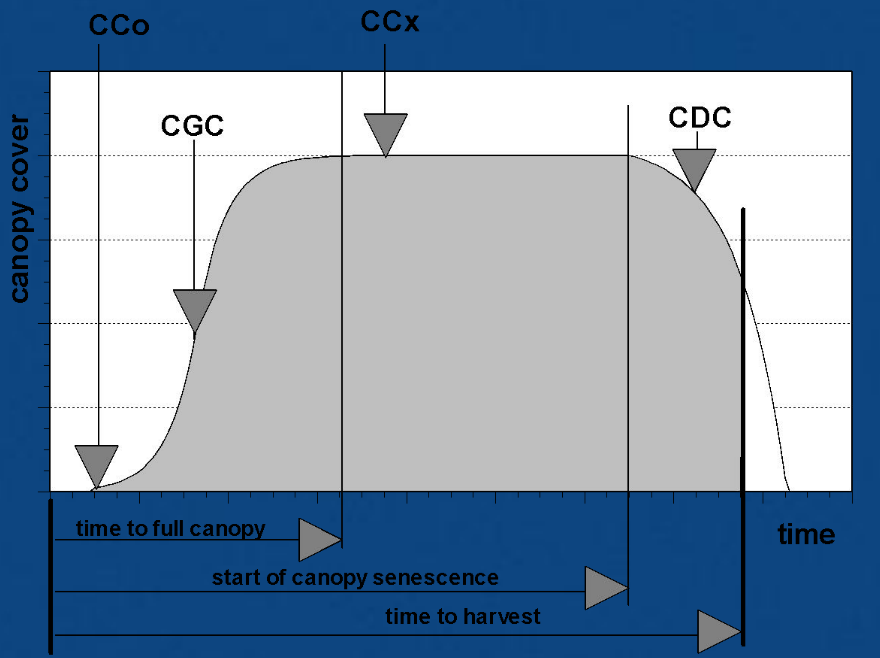


Phenology

- the time required to reach a particular stage is expressed in GDD (°C days)
- the GDD calculation accounts for an upper temperature threshold ($T_{ceiling}$) above which temperature does not affect crop development
- the GDD calculation follows the procedure reported by McMaster and Wilhelm (1997)

Canopy Cover (CC)

- CC follows an exponential growth during the first half of the full development (Eq. 1) and an exponential decay during the second half of the full development (Eq. 2)



$$CC = CC_o e^{CGC \cdot t}$$

$$CC = CC_x - (CC_x - CC_o) \cdot e^{-CGC \cdot t}$$

- the initial canopy cover (CC_o at emergence or transplanting) can be derived from 'sowing density' or 'planting density'

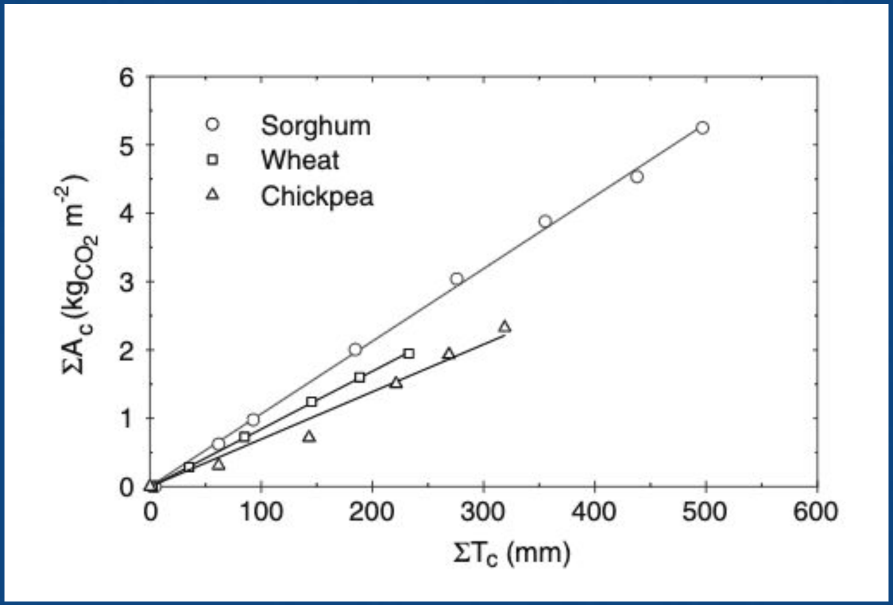
WUE (ρ_w)

$$p_w = \frac{Biomass}{\sum T}$$

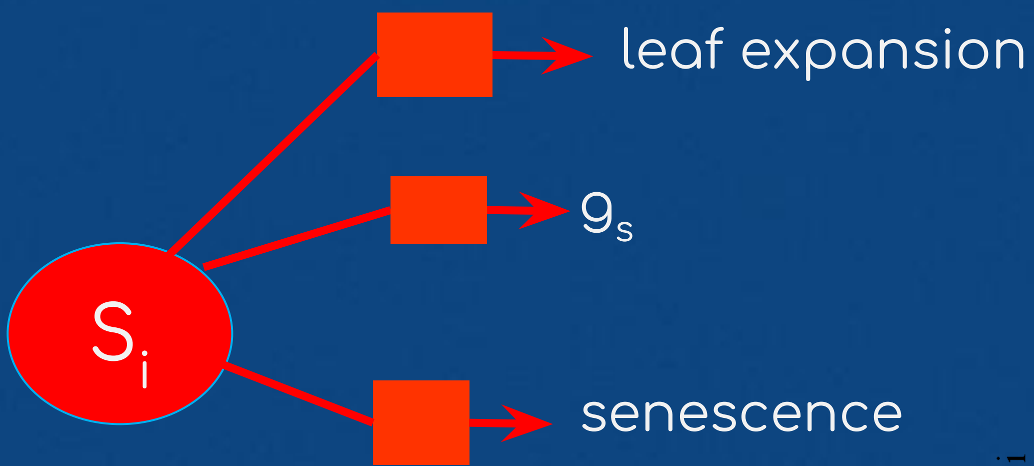
(g m^{-2} mm^{-1})

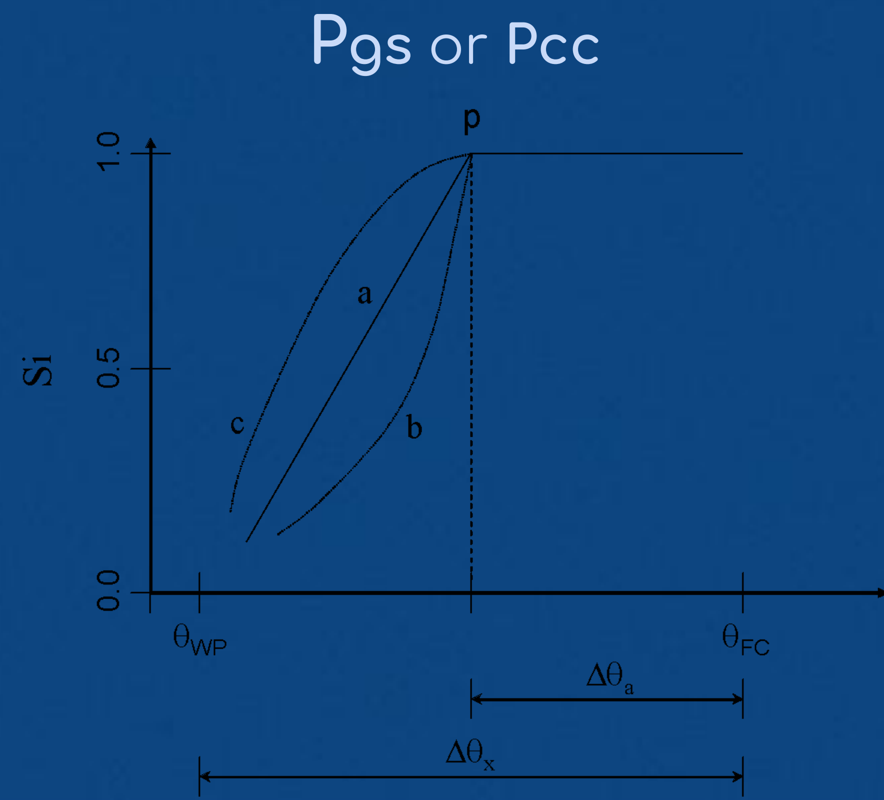
$$p_w^* = \left[\frac{Biomass}{\sum \left(\frac{T_c}{ET_o} \right)} \right]_{CO_2 (2000)}$$

(g m^{-2})

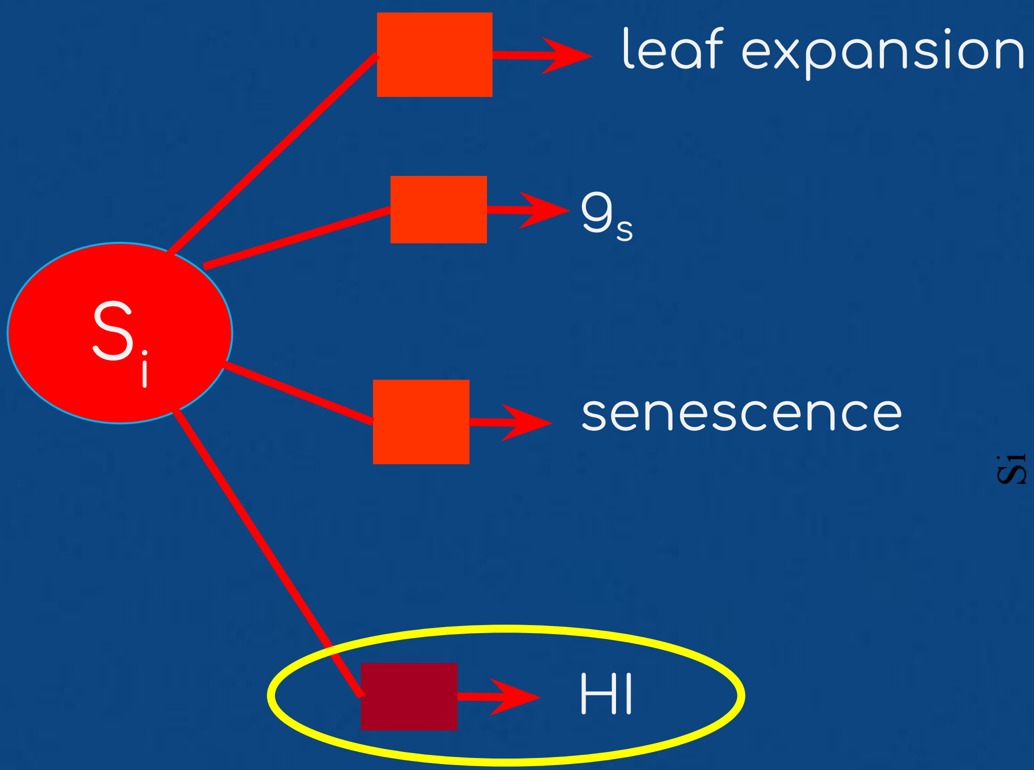


Stress effects on CC and Transpiration

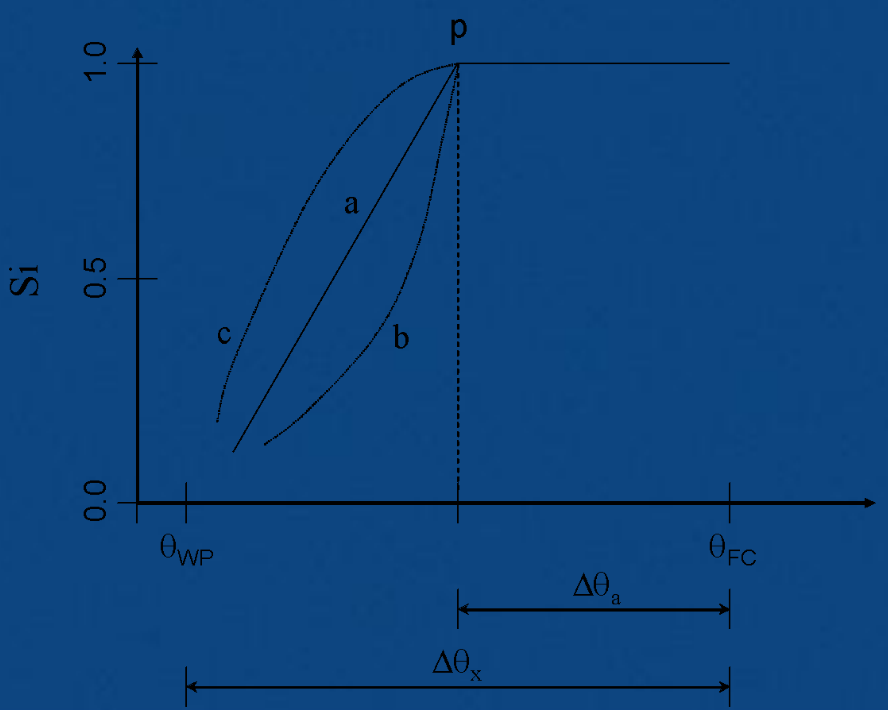


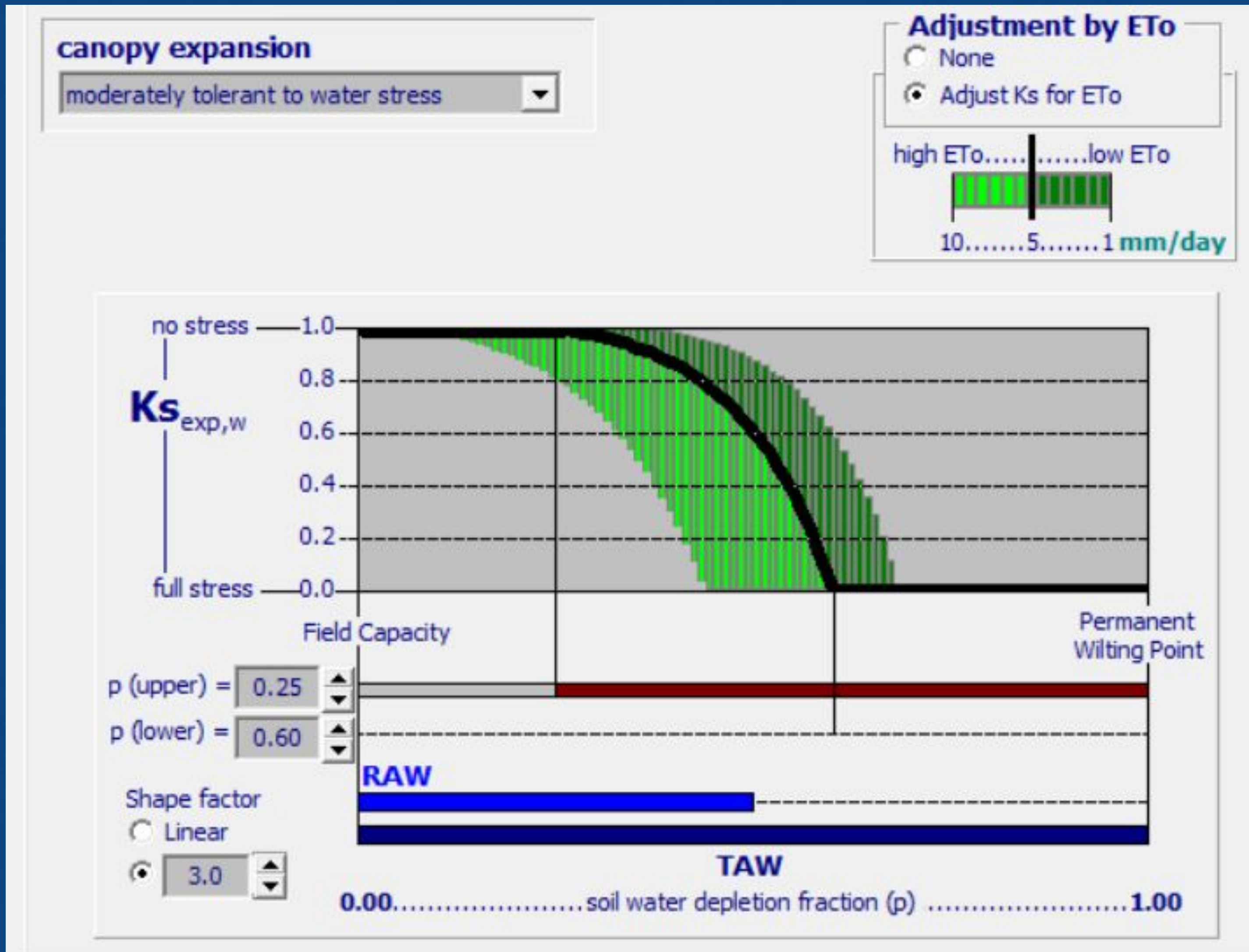


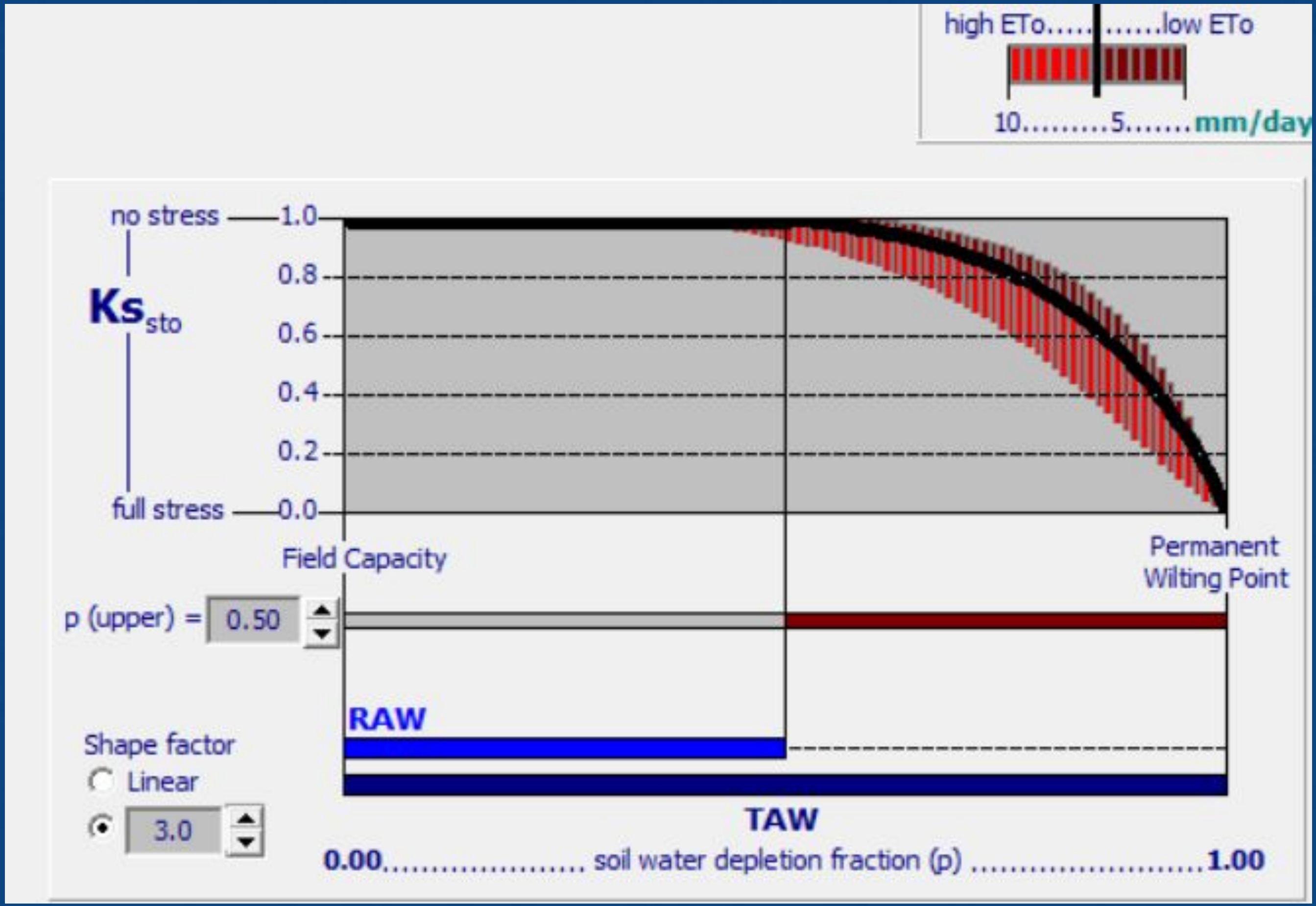
Stress effects on HI

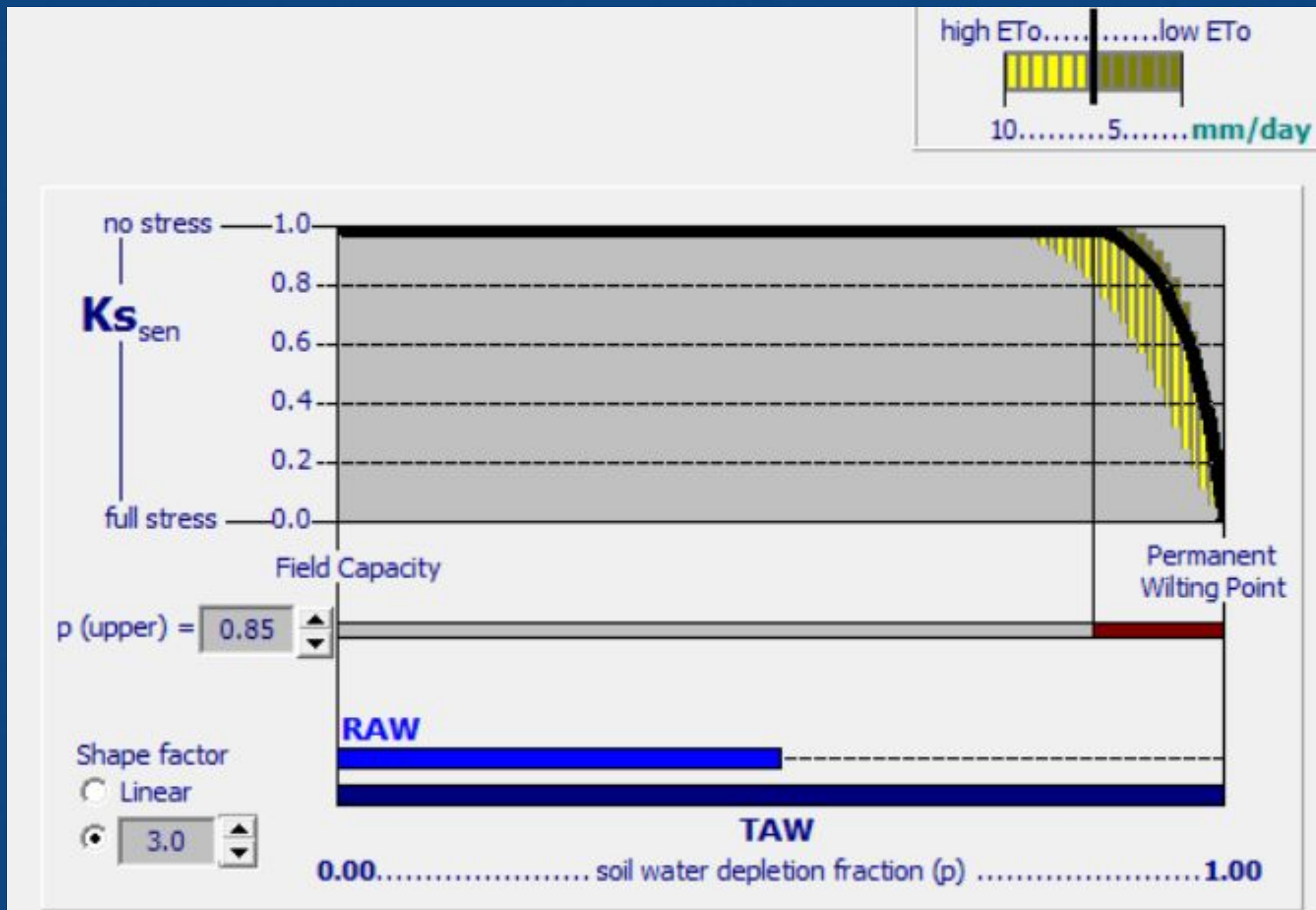


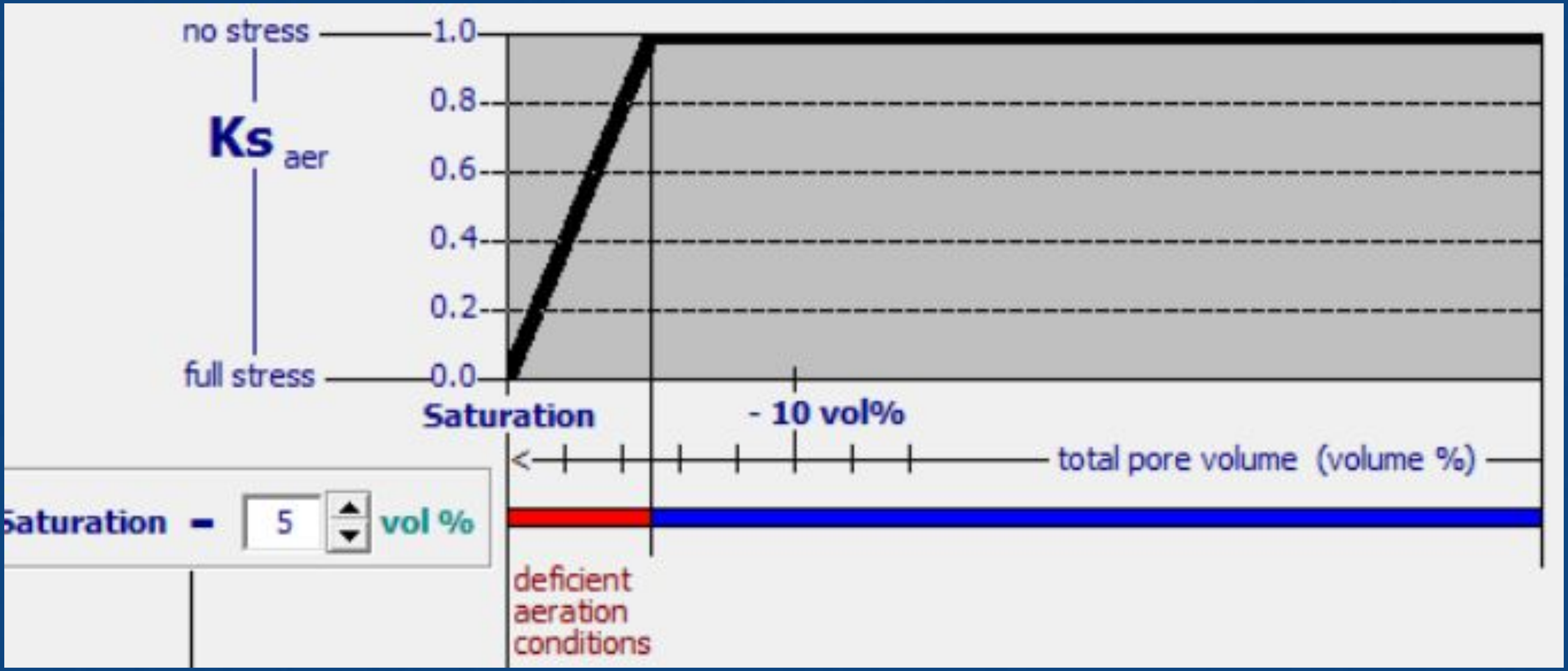
P_{gs} or P_{cc}




canopy expansion
moderately tolerant to water stress
Adjustment by ETo
None
Adjust Ks for ETo
high ETo...........low ETo
10.......5.......1 mm/day
no stress
full stress
Ks exp,w
1.0
0.8
0.6
0.4
0.2
0.0
Field Capacity
Permanent Wilting Point
p (upper) = 0.25
p (lower) = 0.60
RAW
Shape factor
Linear
3.0
TAW
0.00.......................soil water depletion fraction (p) 1.00


high ETo...........low ETo
10.........5.......mm/day
no stress
1.0
0.8
Ks$_{sto}$
0.6
0.4
0.2
full stress
0.0
Field Capacity
Permanent Wilting Point
p (upper) = 0.50
RAW
Shape factor
Linear
3.0
TAW
0.00.................... soil water depletion fraction (p) 1.00


high ETo.........low ETo
10.........5.......mm/day
no stress
full stress
Ks sen
1.0
0.8
0.6
0.4
0.2
0.0
Field Capacity
Permanent Wilting Point
p (upper) = 0.85
RAW
Shape factor
Linear
3.0
TAW
0.00...................... soil water depletion fraction (p) 1.00


no stress
full stress
Ks aer
1.0
0.8
0.6
0.4
0.2
0.0
Saturation
- 10 vol%
total pore volume (volume %)
Saturation - 5 vol %
deficient
aeration
conditions

EFFECTS OF WATER DEFICITS ON HI:

Negative (or Null)
WHEN SWC IS BETWEEN Pgl AND PWP
e.g. maize

Positive (or NULL)
WHEN SWC IS BETWEEN Pcc and Pgl
e.g. cotton

Conclusions

- AquaCrop maintains an optimum balance between simplicity, accuracy and robustness

- AquaCrop distinguishes itself from other models for its relatively small number of parameters (explicit and mostly intuitive)

- AquaCrop addresses mainly practitioner type of end-user, such as those working for extension services, governmental agencies, NGOs and various kinds of farmers associations

- AquaCrop is also particularly suited for perspective studies (e.g., future water policy, market prices and climatic scenarios)

EXAMPLES OF THE MANY APPLICATIONS

- Develop a seasonal irrigation schedule for a specific crop and field
- Determining the seasonal water requirements for various crops on a farm
- Evaluation and benchmarking of current irrigation practices
- Developing deficit and supplemental irrigation programs at the field scale
- Benchmarking yield gaps in rainfed and irrigated agriculture and assessment of long-term productivity
- Determining the optimal planting date based on probability analysis
- Developing water production functions with *AquaCrop* and using them in Decision Support Systems

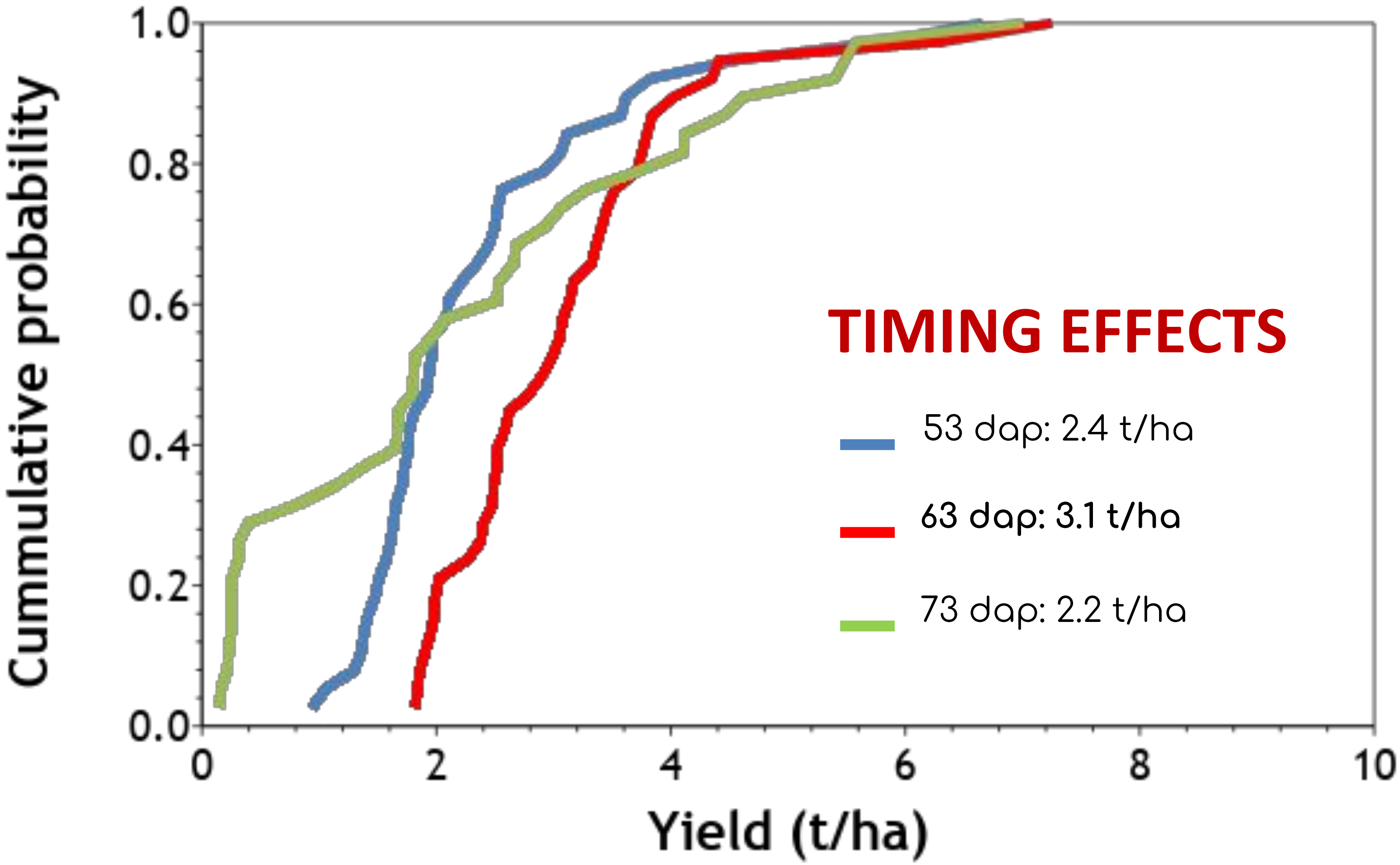
AN EXAMPLE OF AQUACROP APPLICATION SIMULATION OF SORGHUM PRODUCTION IN INDIA

TWO SOILS (BOTH AT FIELD CAPACITY AT PLANTING DATE

S1: SHALLOW (60CM) - PAW OF 84 MM
S2: DEEP (120) - PAW OF 120 MM

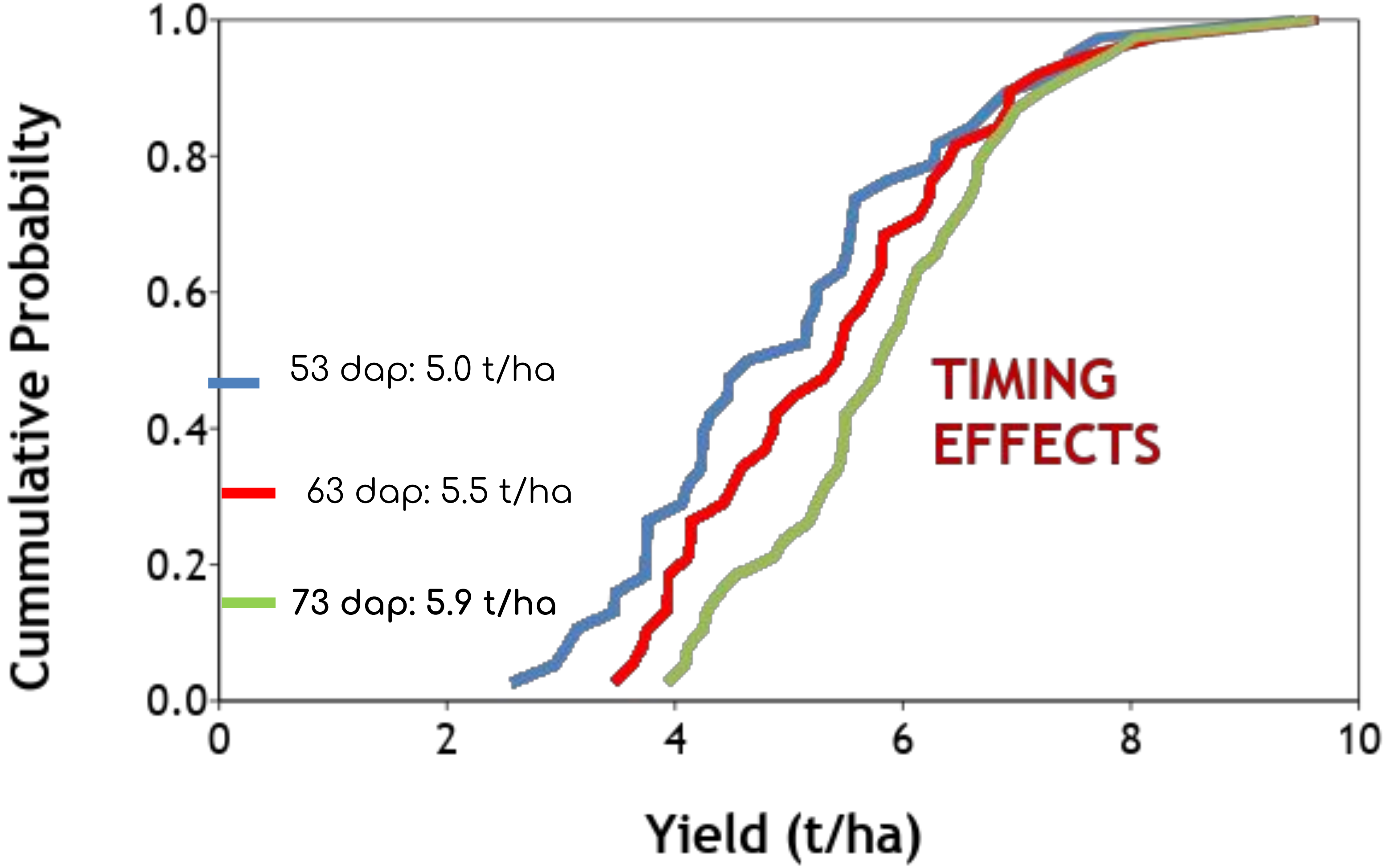
Supplemental Irrigation:
When to apply a single 70 mm application?

Soil 1: 84 mm PAW



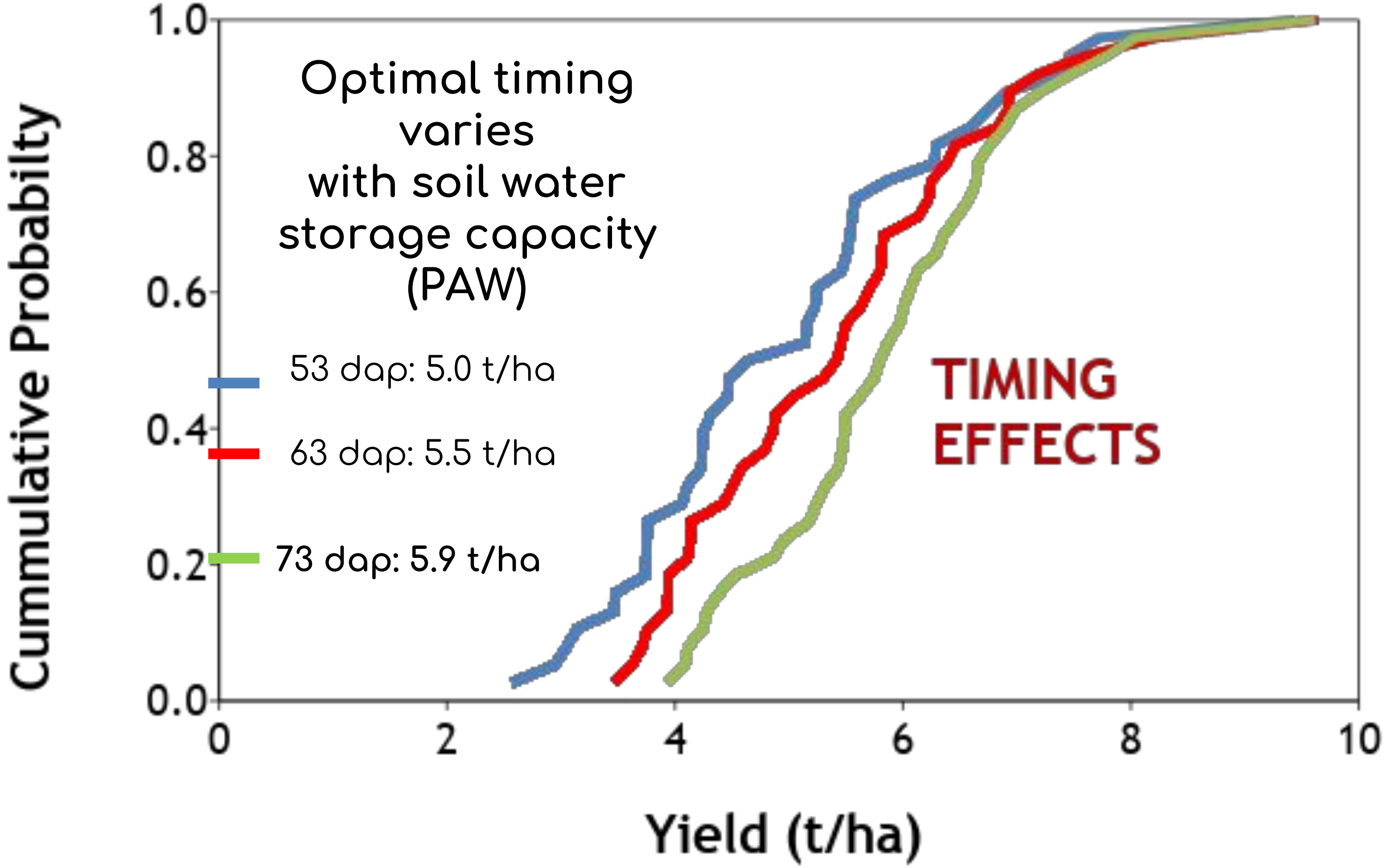
Irrigation supply: a single, 70 mm application

Soil 2: 120 mm PAW



Irrigation supply: a single, 70 mm application

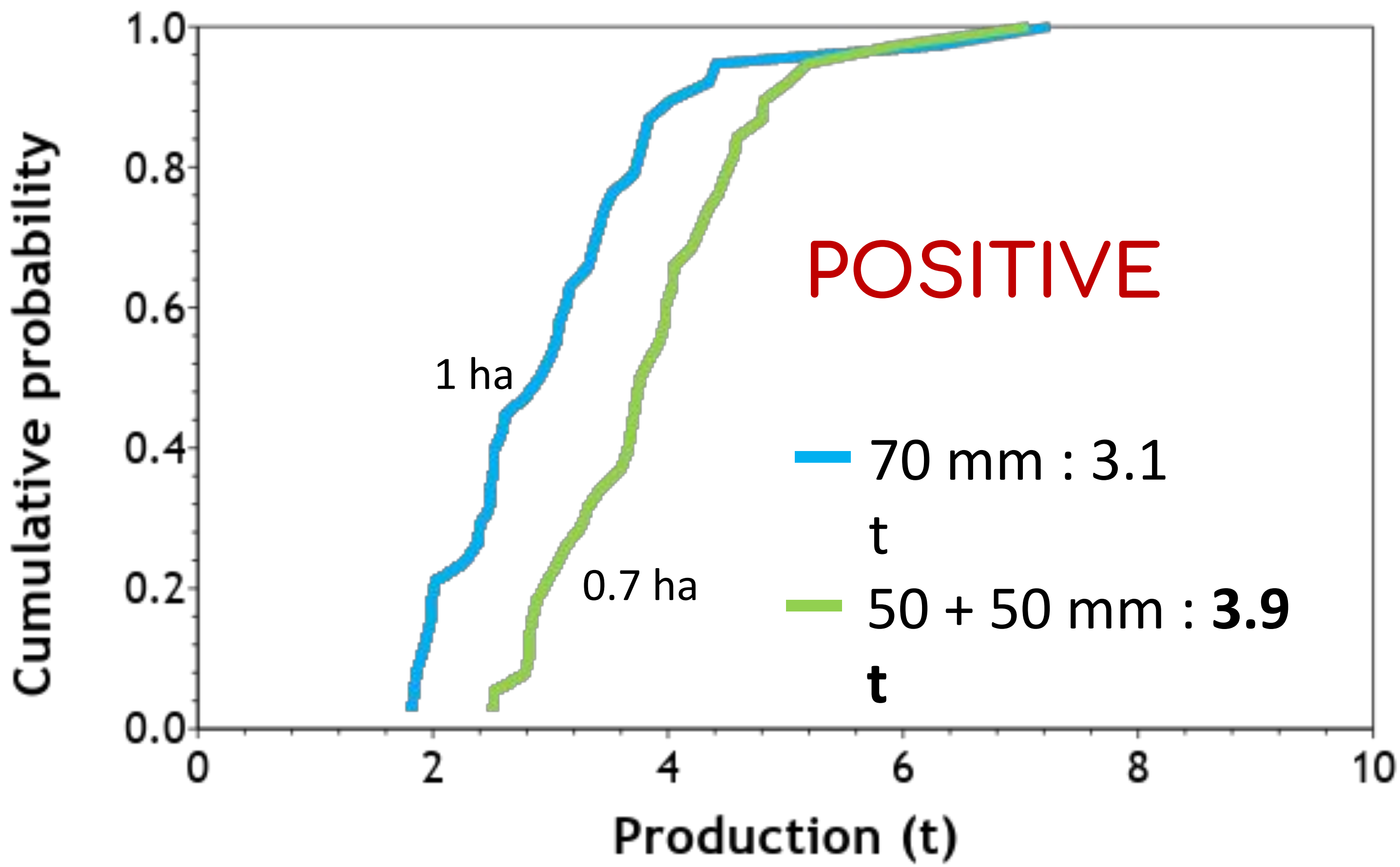
Soil 2: 120 mm PAW



SHOULD WE CONCENTRATE THE LIMITED IRRIGATION WATER ON A SMALLER AREA (one irrigation of 70 mm in 1 ha or two irrigations of 50 mm in 0.7 ha)?

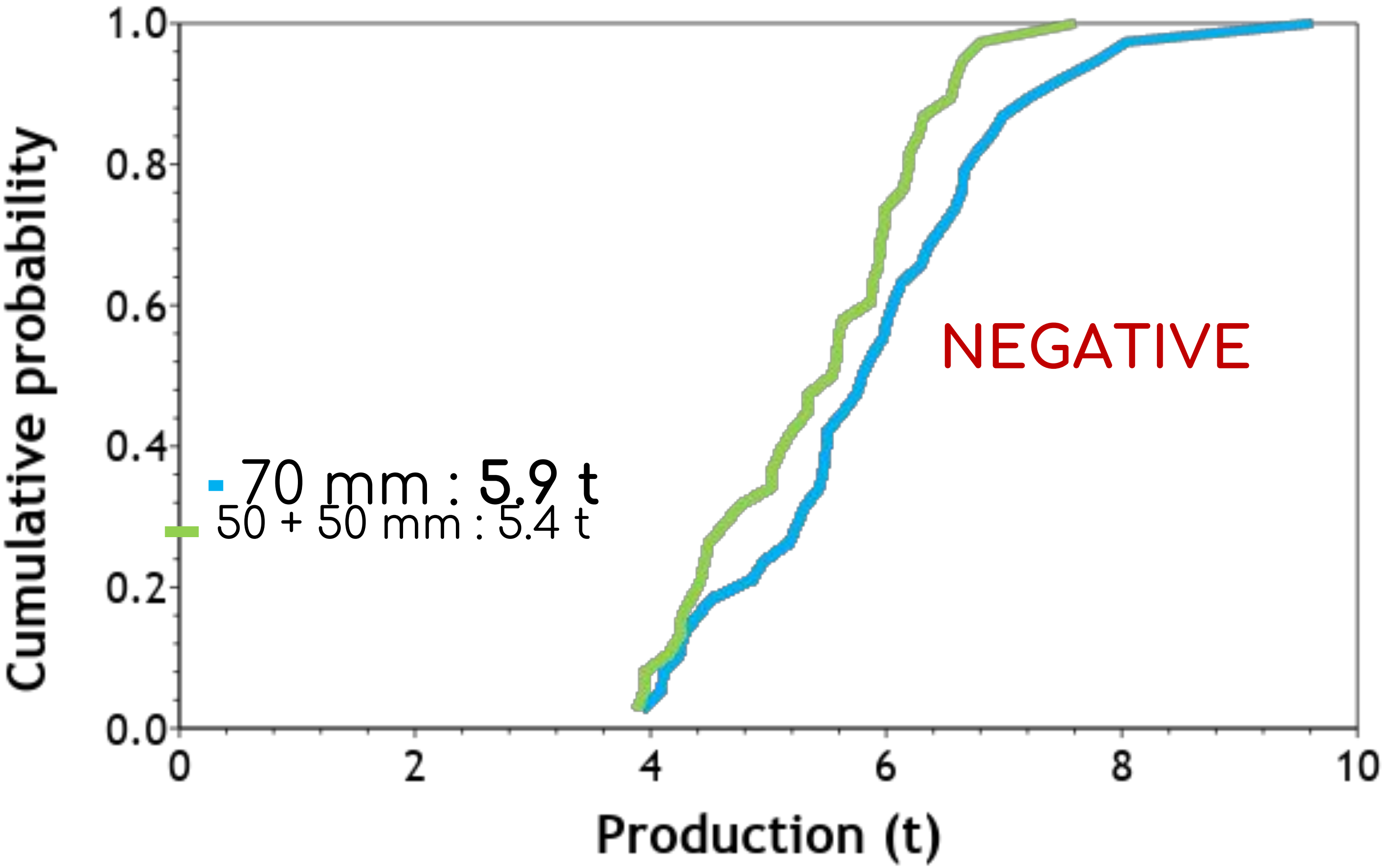
SHOULD WE CONCENTRATE THE LIMITED IRRIGATION WATER ON A SMALLER AREA (one irrigation of 70 mm in 1 ha or two irrigations of 50 mm in 0.7 ha)?

S1: 84 mm PAW



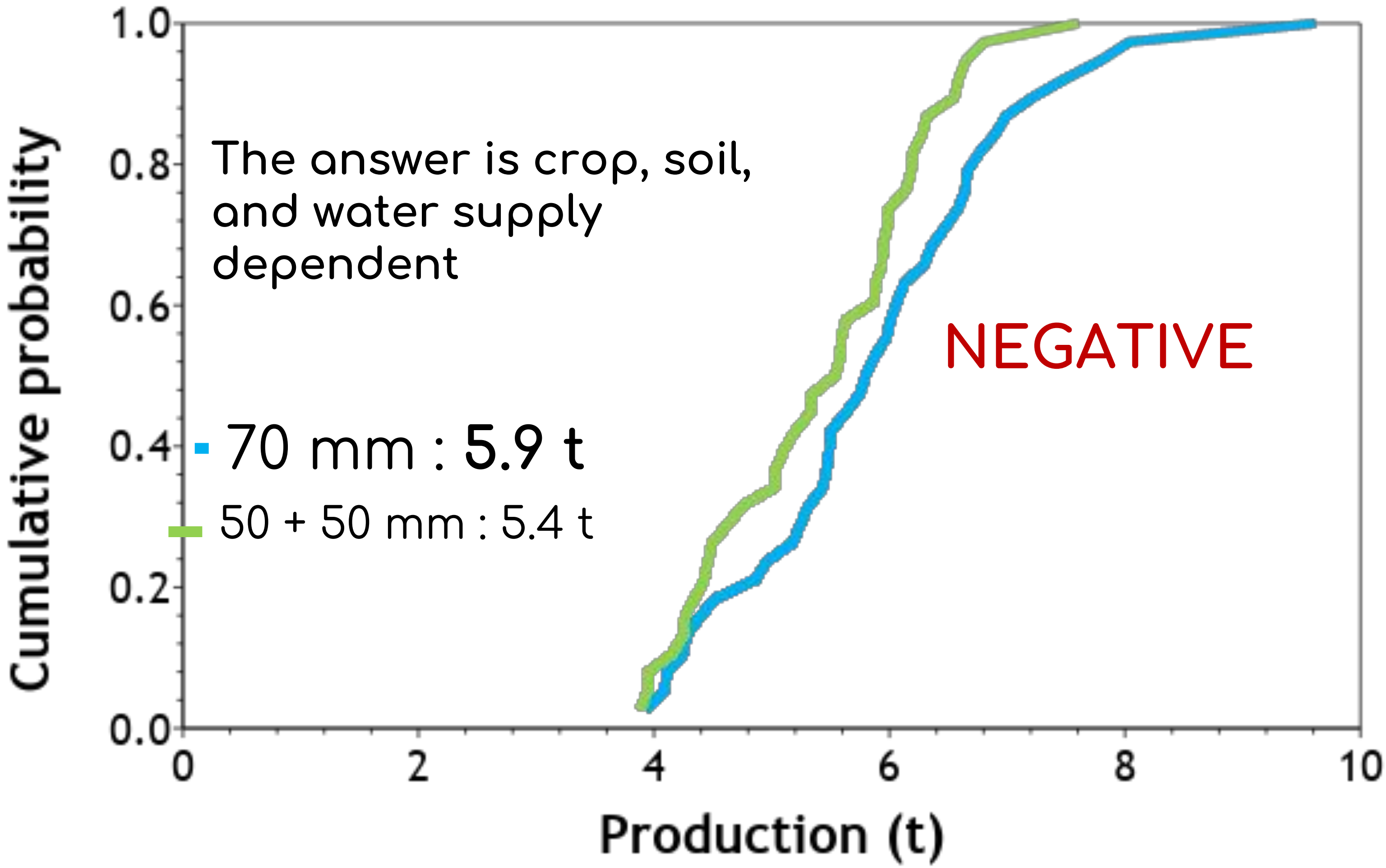
EFFECTS OF CONCENTRATING THE IRRIGATION WATER IN A SMALLER AREA

Soil 2: 120 mm PAW



EFFECTS OF CONCENTRATING THE IRRIGATION WATER IN A SMALLER AREA

Soil 2: 120 mm PAW



LET'S DESIGN IMPROVED GENOTYPES AND COMPARE THEM AGAINST THE STANDARD IN THE SAME LIMITED IRRIGATION SCENARIO

**TWO NEW IDEOTYPES:
A CONSERVATIVE AND AN 'EXPENDER'
RELATIVE TO THE STANDARD**

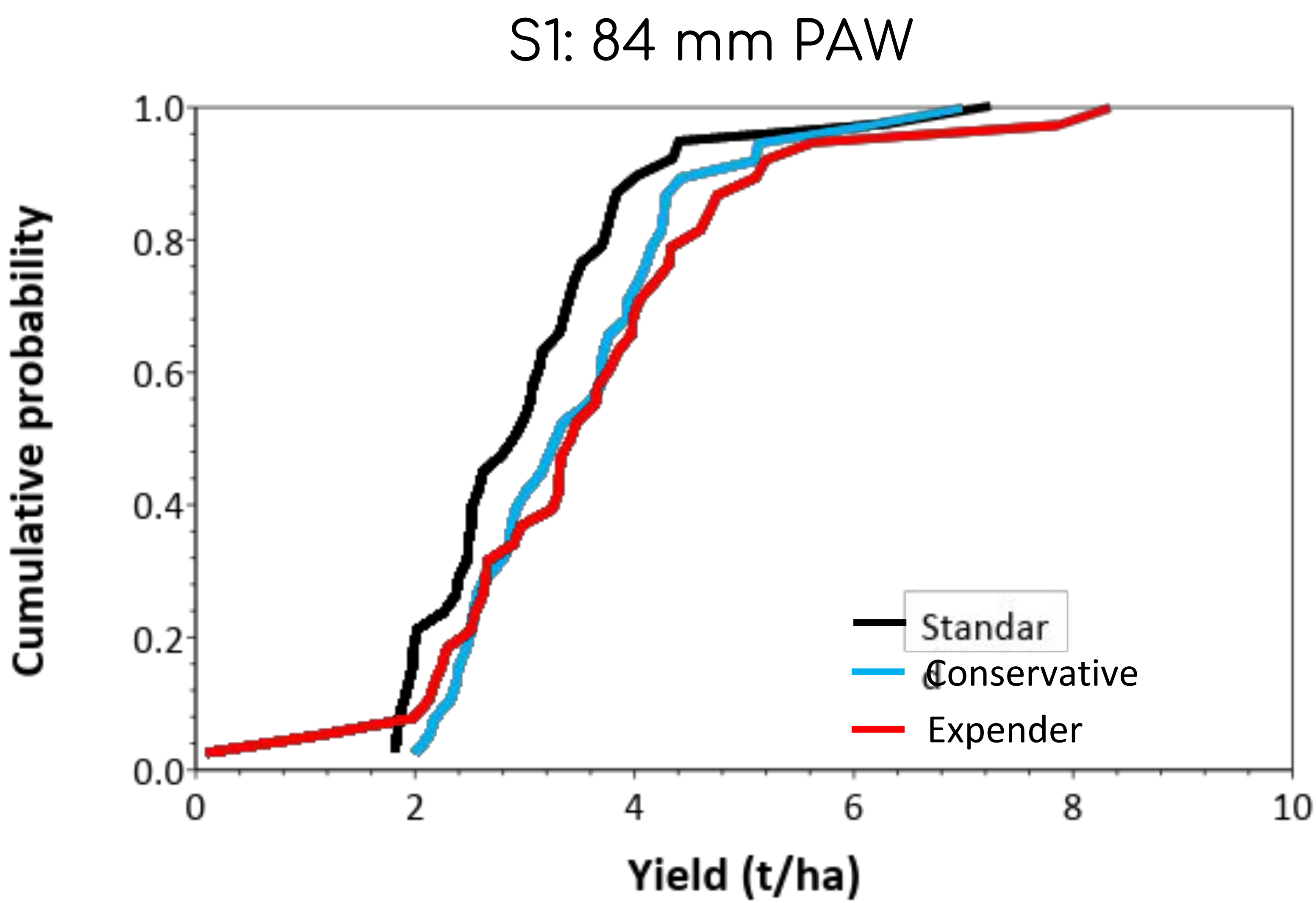
CONSERVATIVE:

- SLOWER CANOPY DEVELOPMENT (10% less) AND MORE SENSITIVE TO WATER DEFICITS (threshold from 0.2 to 0.15)
- SLOWER ROOT SYSTEM EXPANSION (10% less)
- EARLIER STOMATAL CLOSURE AND SHARPER RESPONSE (threshold from 0.7 to 0.5 of PAW)
- HIGHER RATE OF DM ACCUMULATION IN THE GRAIN (7% higher)

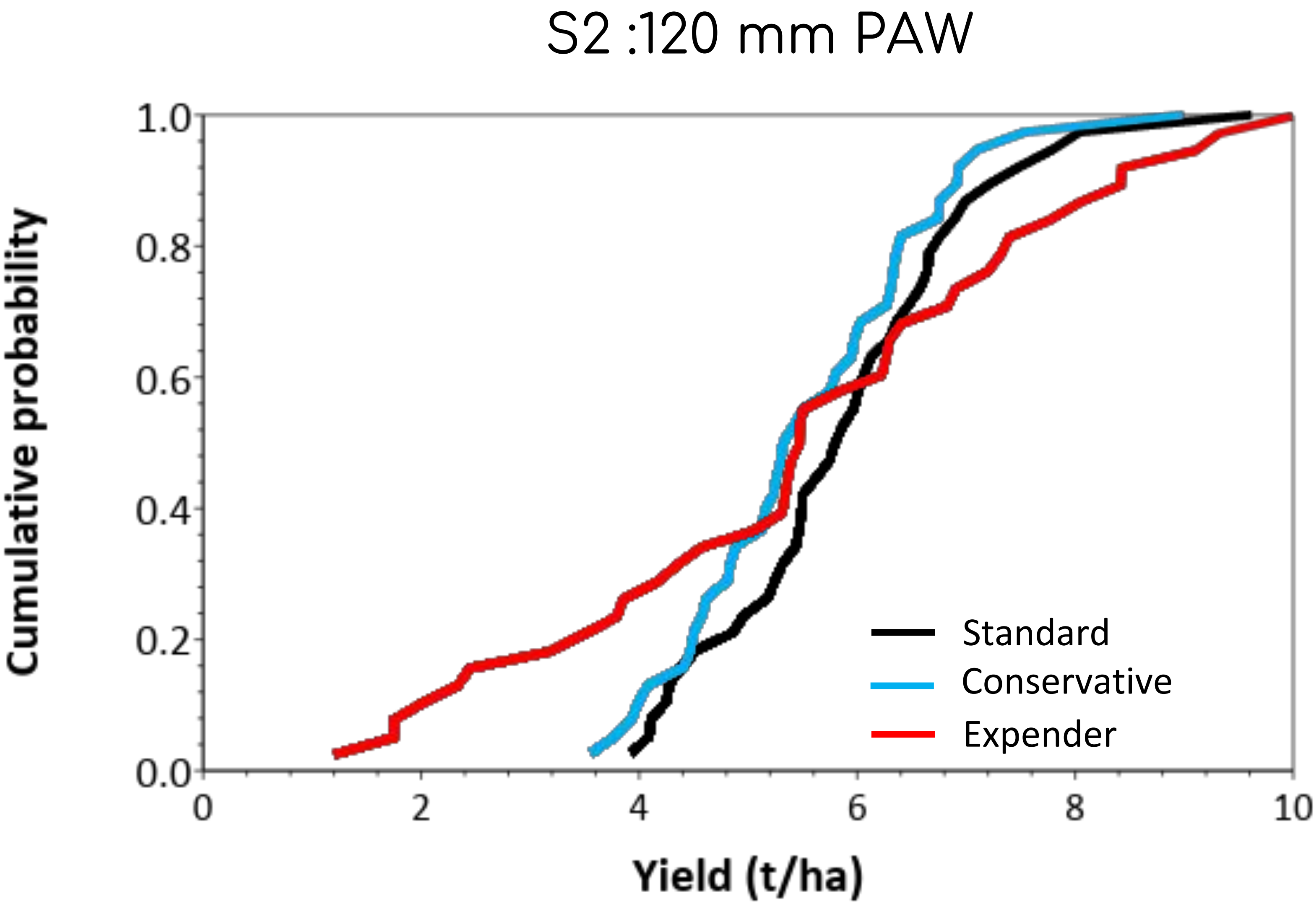
'EXPENDER':

- FASTER CANOPY DEVELOPMENT (15% more)
- FASTER ROOT SYSTEM EXPANSION (15 % more)
- HIGHER RATE OF DM ACCUMULATION IN THE GRAIN (14 % higher)
- HARVEST INDEX LESS SENSITIVE TO WATER DEFICITS
- STAY GREEN UNDER WATER DEFICITS (threshold for leaf senescence from 0.75 to 0.8)

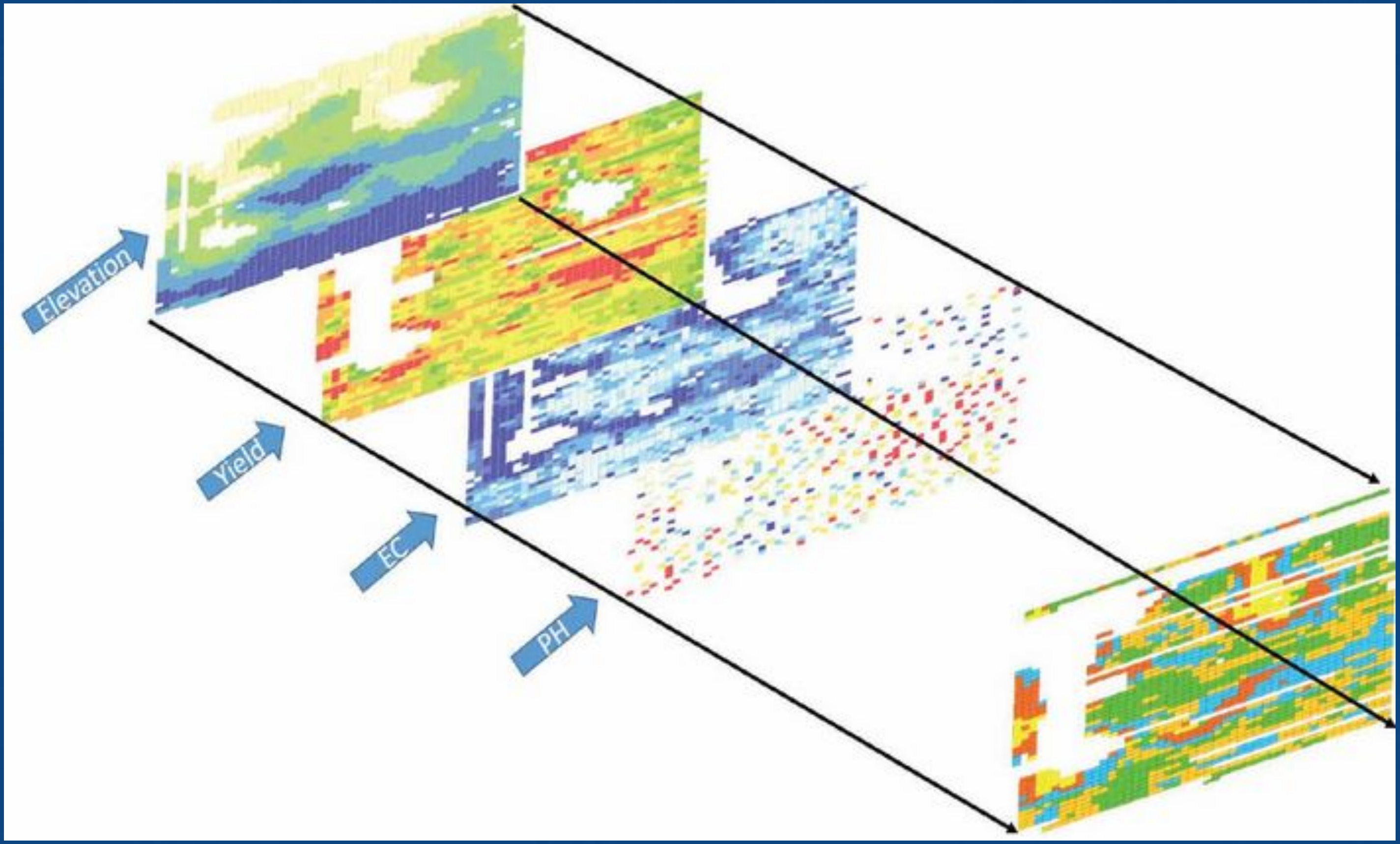
NEW, IMPROVED IDEOTYPES UNDER LIMITED IRRIGATION (70 mm)

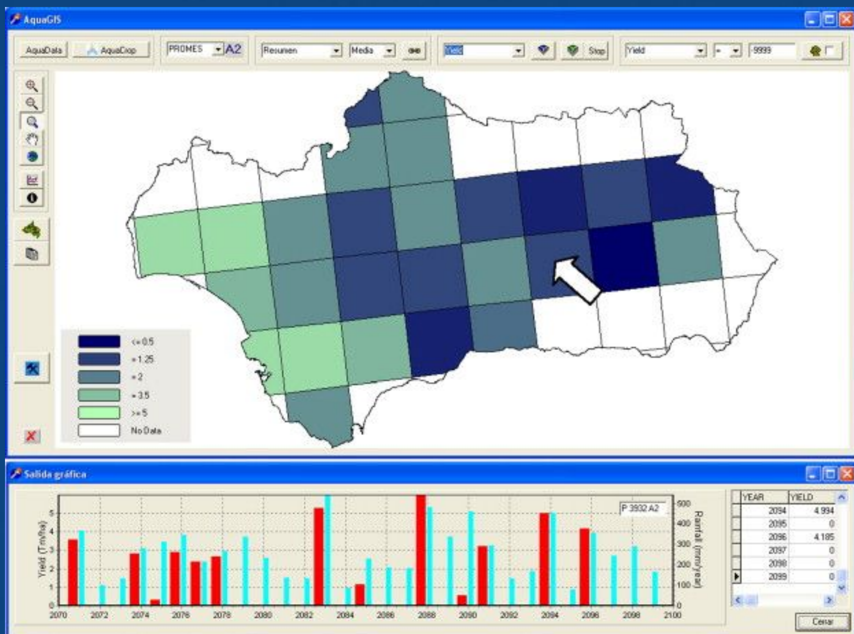


NEW, IMPROVED IDEOTYPES UNDER LIMITED IRRIGATION (70 mm)



… future perspectives



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AquaCrop

Resumen | Software | Noticias | Aplicaciones | Seminarios | Recursos

Programa estándar AquaCrop para Windows

Programa de plug-in AquaCrop

AquaCrop-GIS

AquaCrop-GIS

AquaCrop-GIS facilitates the use of AquaCrop when a high number of simulations is needed, simplifying the task of generating inputs and project files and the management of output files. AquaCrop-GIS prepares the required inputs and executes AquaCrop, and it presents the results in a geographic information system. Users of AquaCrop-GIS should be familiar with AquaCrop. Aquacrop-GIS will only work with the 32-bit version of Aquacrop Plug-in Version 4.0, which can also be downloaded below.

Descargue Aquacrop-GIS

Descargue el programa de plug-in Aquacrop Versión 4.0

Documentos clave

AquaCrop training handbooks. Book I: Understanding AquaCrop

AquaCrop training handbooks. Book II: Running AquaCrop

http://www.fao.org/aquacrop/software/aquacrop-gis/en/

SHui

Managing water scarcity in European and Chinese cropping systems

Overview Work Plan Partners Dissemination Training Links News

Project Overview

https://www.shui-eu.org/

Thank you

roquettetenreiro@gmail.com
troquette@ias.csic.es

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Consejo Superior de Investigaciones Científicas

Universidad de Córdoba

European Commission

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