HYDRAULIC REDISTRIBUTION AND IT’S POTENTIAL FOR FOOD PRODUCTION

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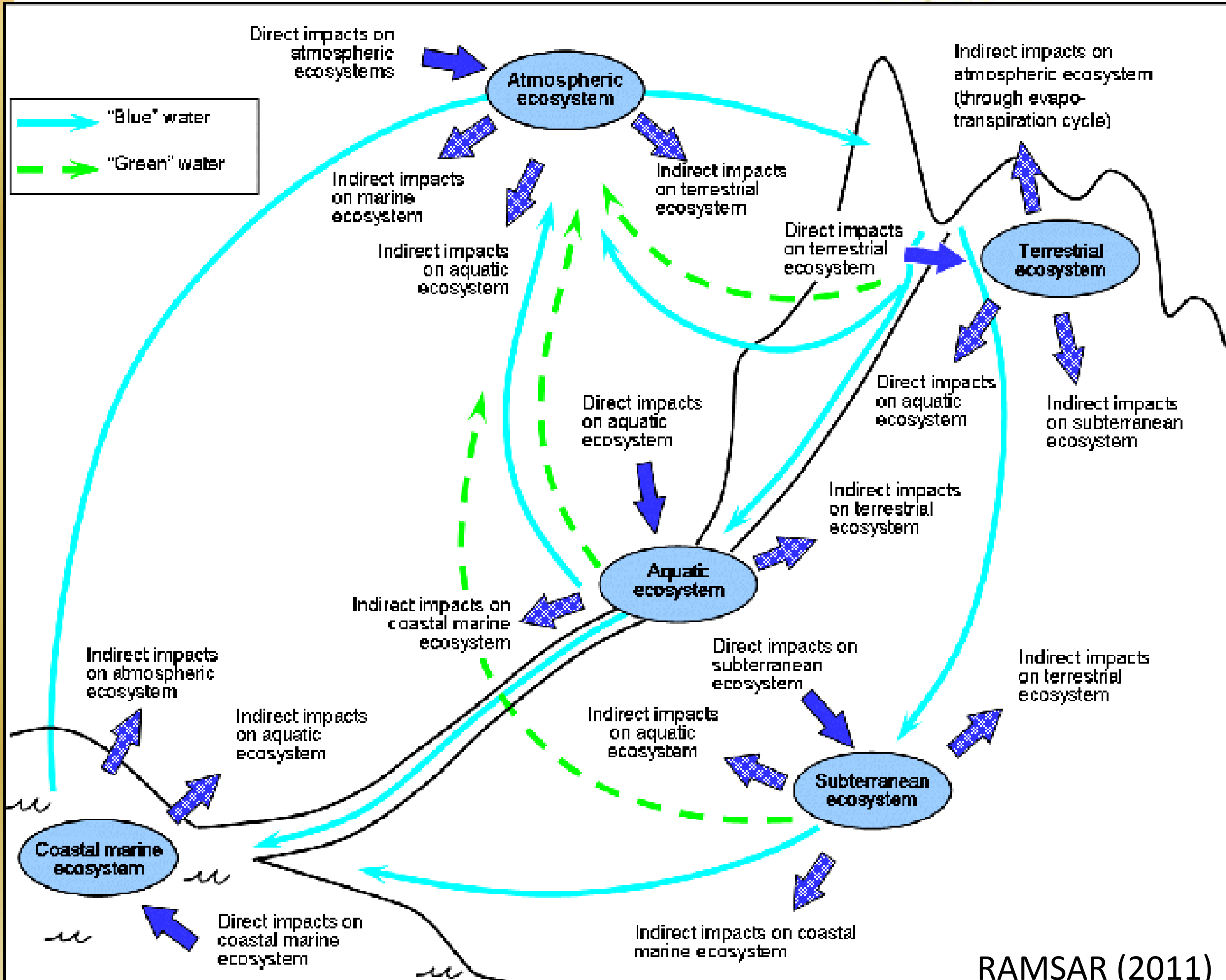
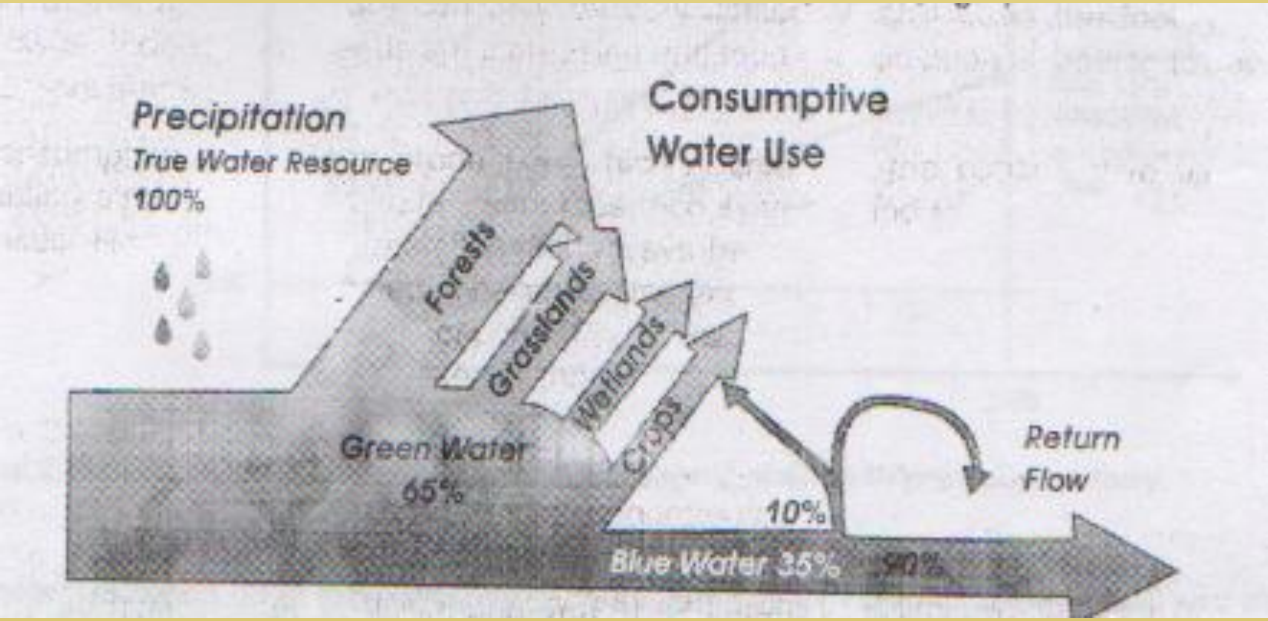
WATER CYCLE



"Blue" water
"Green" water
Direct impacts on atmospheric ecosystems
Atmospheric ecosystem
Indirect impacts on atmospheric ecosystem (through evapo-transpiration cycle)
Indirect impacts on marine ecosystem
Indirect impacts on terrestrial ecosystem
Indirect impacts on aquatic ecosystem
Direct impacts on terrestrial ecosystem
Terrestrial ecosystem
Direct impacts on aquatic ecosystem
Indirect impacts on subterranean ecosystem
Direct impacts on aquatic ecosystem
Indirect impacts on terrestrial ecosystem
Aquatic ecosystem
Indirect impacts on coastal marine ecosystem
Direct impacts on subterranean ecosystem
Indirect impacts on terrestrial ecosystem
Indirect impacts on atmospheric ecosystem
Indirect impacts on aquatic ecosystem
Indirect impacts on aquatic ecosystem
Subterranean ecosystem
Coastal marine ecosystem
Direct impacts on coastal marine ecosystem
Indirect impacts on coastal marine ecosystem
RAMSAR (2011)

BLUE WATER VS GREEN WATER



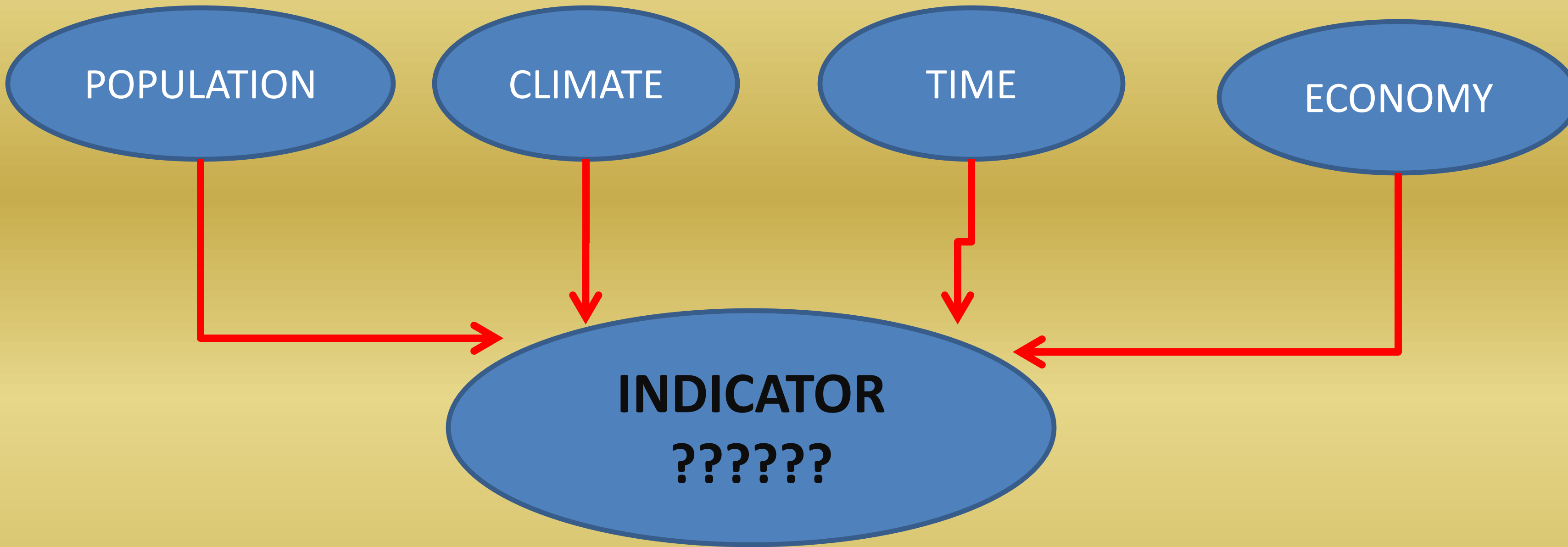
Hamdy (2008)

INVISIBLE WATER

BLUE WATER = SHARE OF WATER RESOURCES STORED IN RIVERS, LAKES AND GROUNDWATER THAT IS CONTROLLED BY PHYSICAL PROCESSES

GREEN WATER= WATER THAT IS INFLUENCED BY BIOLOGICAL PROCESSES SUCH AS EVAPO-TRANSPIRATION BY VEGETATION AND STORED AS SOIL MOISTURE

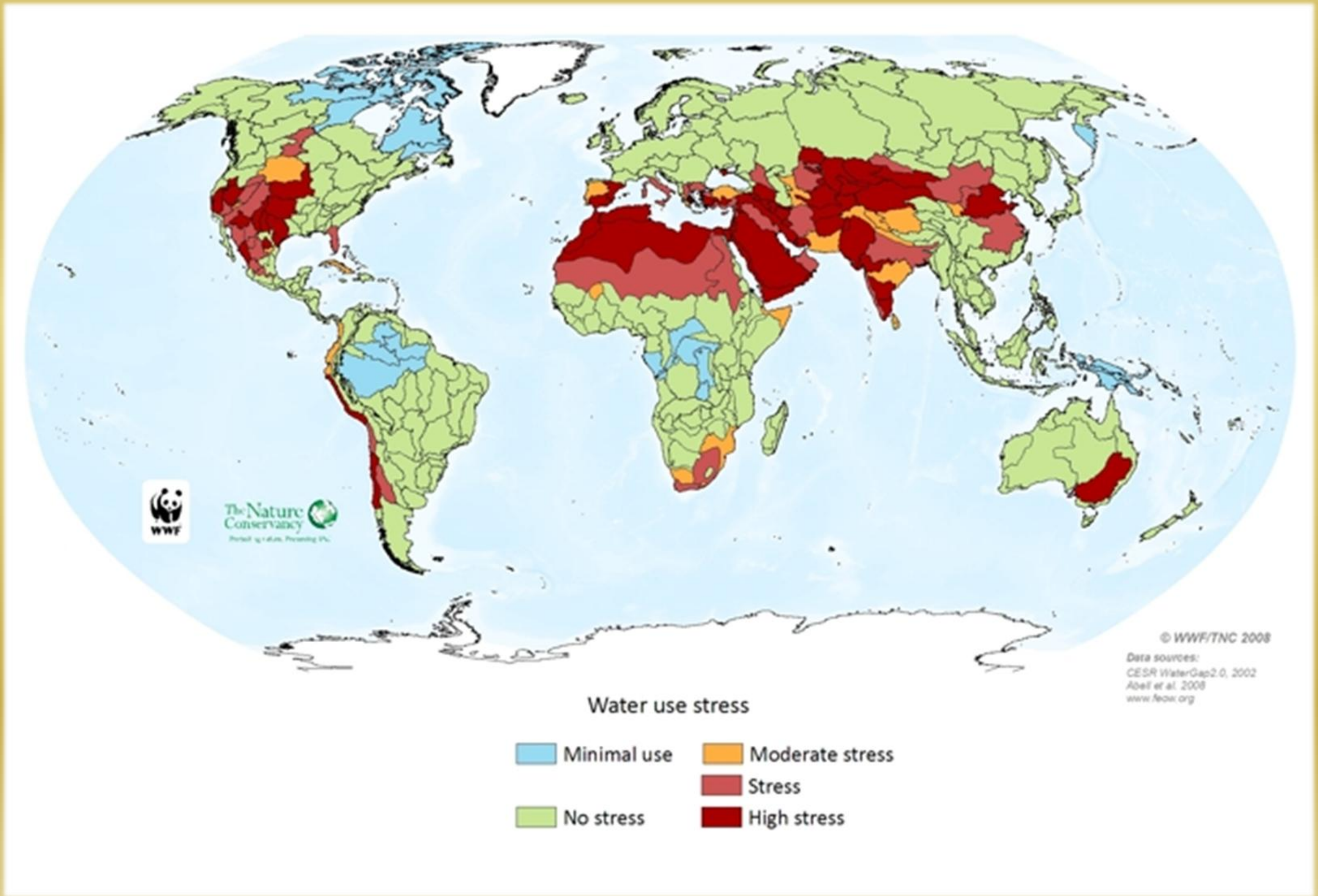
WATER USE



“WITHDRAWALS-TO-AVALABILITY RATIO”

LONG TERM EFFECTS

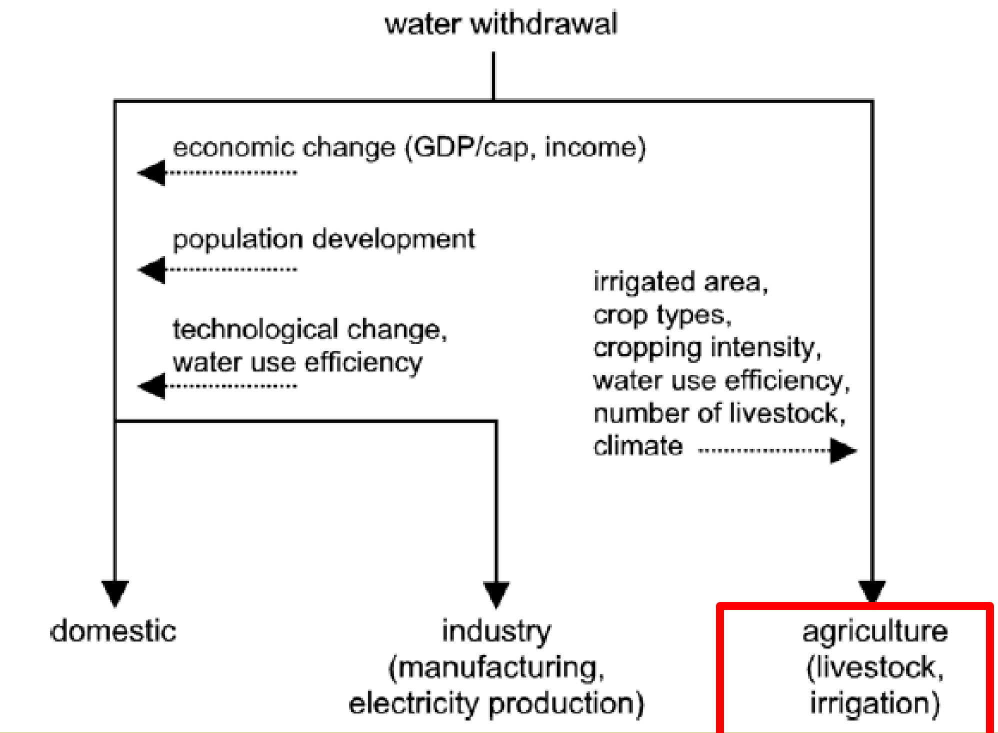
WATER AVAILABILITY



❖Fonte FEOW disponível em: http://www.feow.org

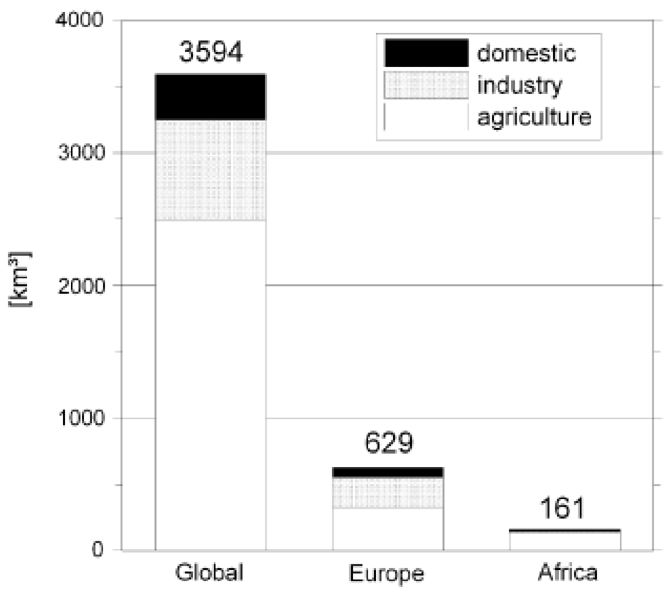
WATER USE

WATER USE SECTORS



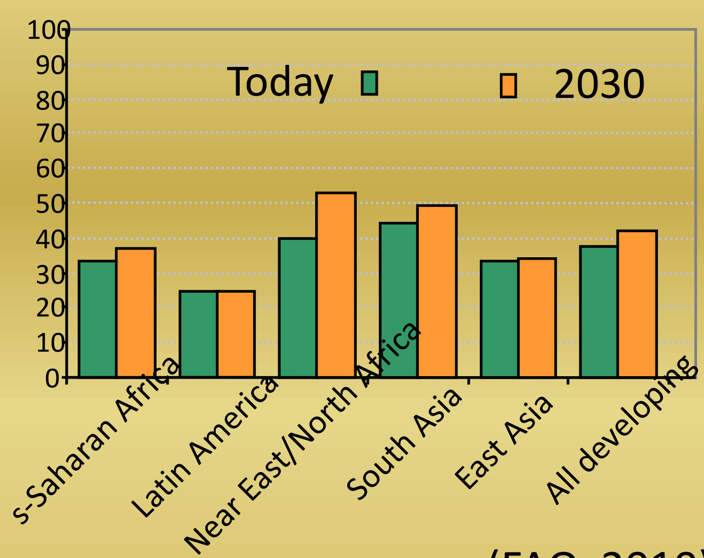
Menzel & Matovelle (2010)

ANNUAL WITHDRAWALS

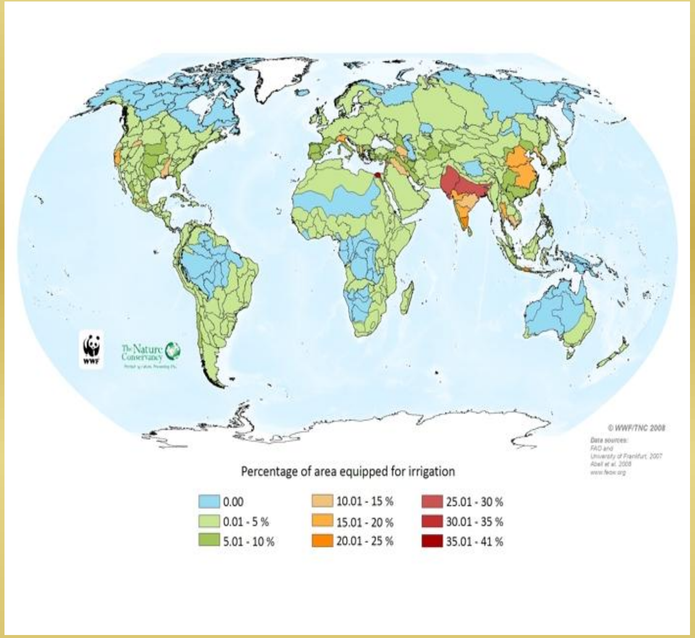


IRRIGATION

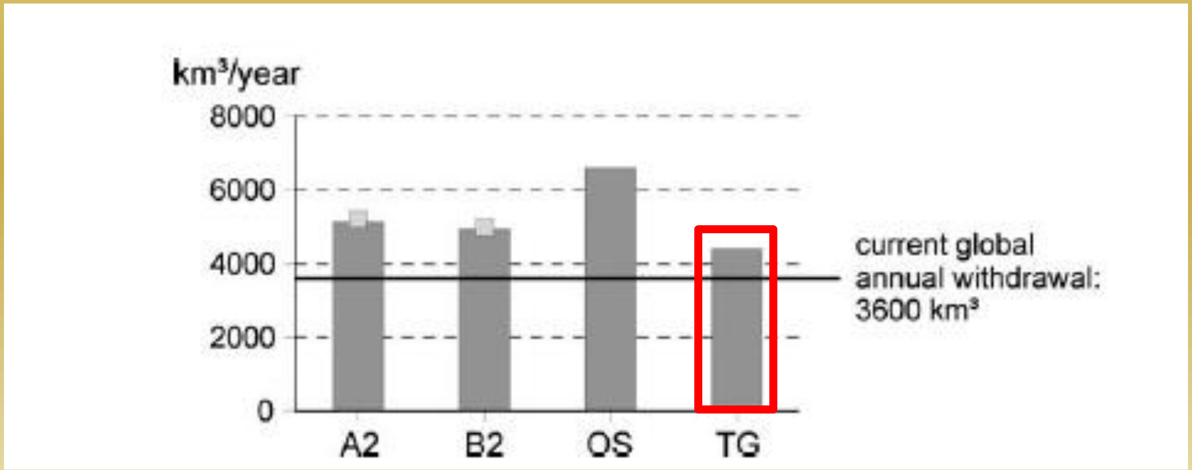
GREEN WATER USE EFFICIENCY



(FAO, 2010)



http://www.feow.org



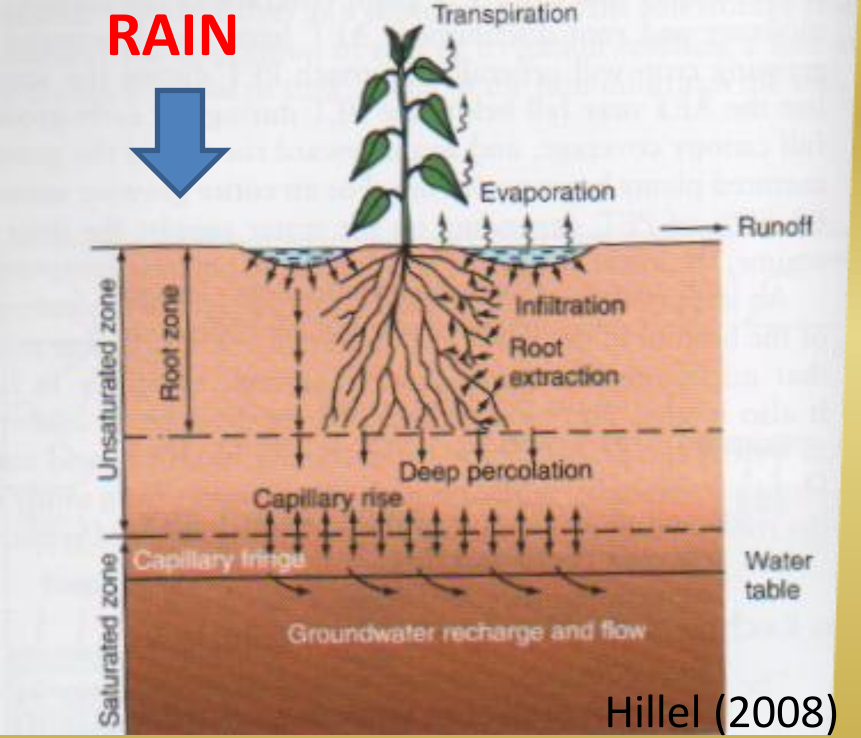
↑ EFFICIENCY

↓ WITHDRAWALS

IMPROVING WATER PRODUCTIVITY

WHERE DOES THE RAINWATER GO ?

RAIN



Hillel (2008)

RAINFALL PARTIONING

RF – (E+T+R+D)

D= 10-30%

R= 10-25%

E= 30-50%

T= 15-30%

ROOT-ZONE WATER BALANCE

CHANGES IN STORAGE= GAINS – LOSSES

$(\Delta S + \Delta V) = (P+I+U) - (R+D+E+T)$

4-5 CROP YIELDS !!!!

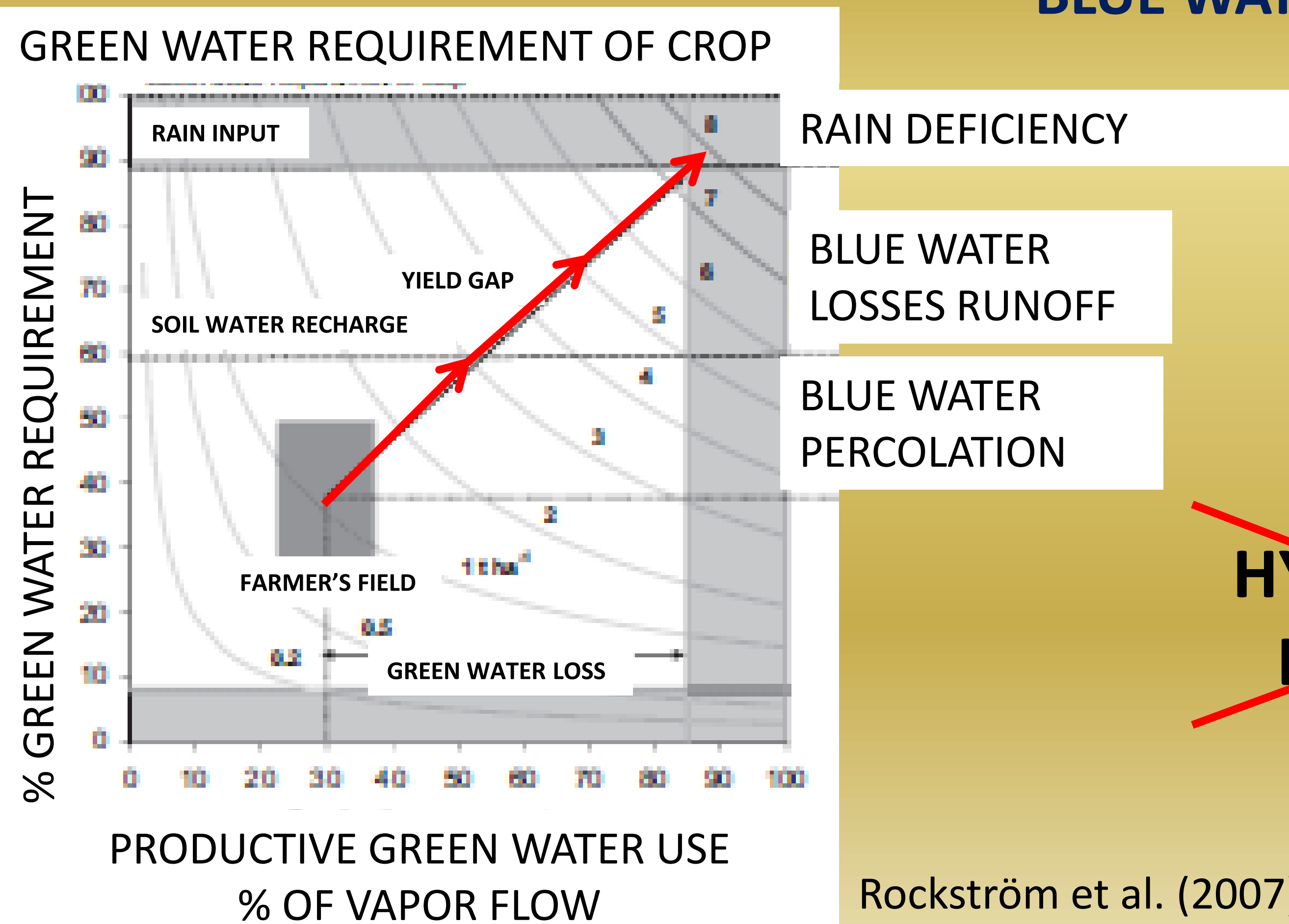
VAPOR FLOW

GREEN WATER FLOW

GREEN WATER RESOURCE

BLUE WATER RESOURCE

GREEN- BLUE WATER BALANCE

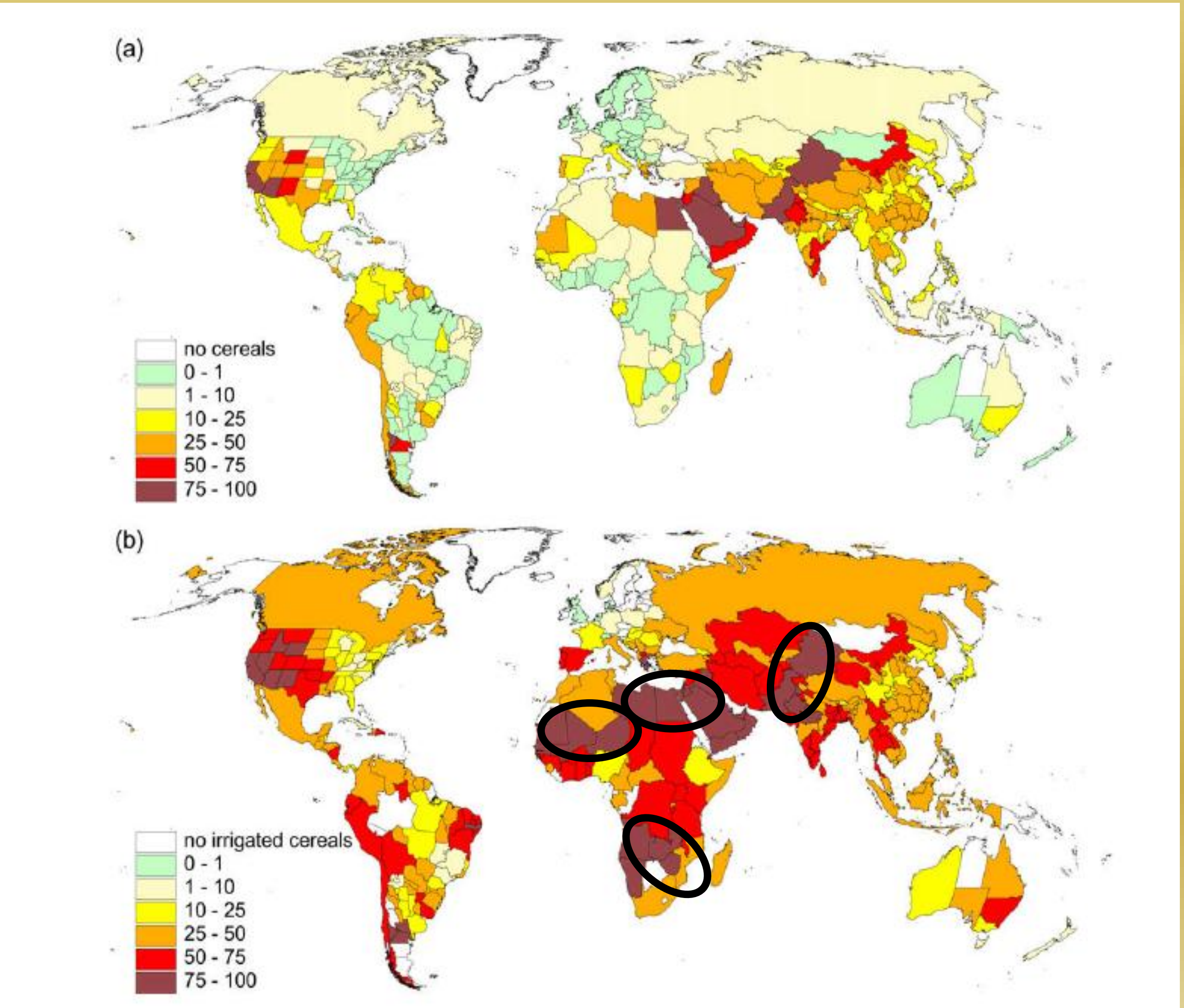


~~HYDROLOGICAL LIMITATIONS~~

Rockström et al. (2007)

GLOBAL PRODUCTION LOSSES

LOSSES TOTAL CEREAL VS IRRIGATED CEREALS



GREEN WATER USE EXCLSIVELY?!

WATER PRODUCTIVITY

Sieber & Döll (2010)

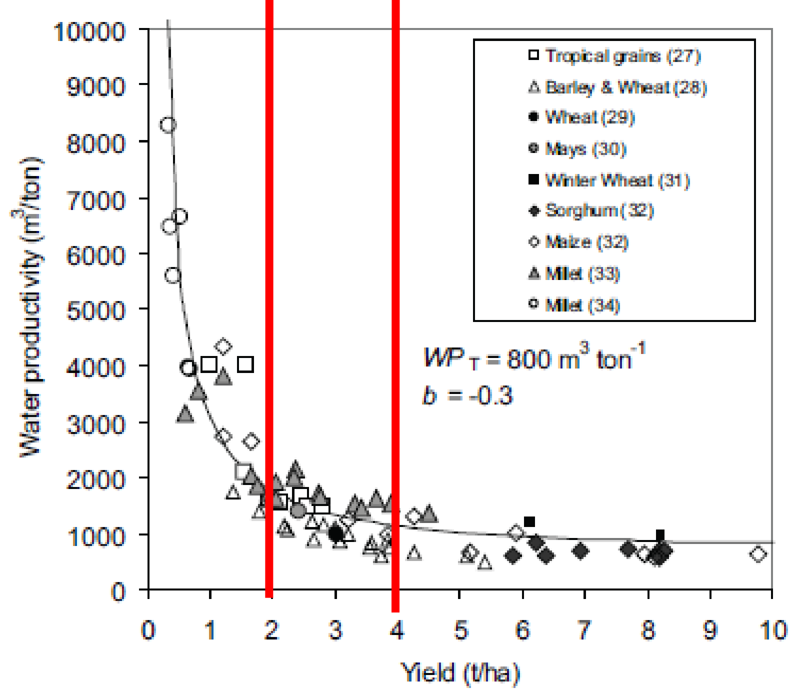
WATER PRODUCTIVITY

FOOD, FIBER PRODUCTION VS WATER CONSUMPTION

CULTURE TYPE	m^{-3} kg^{-1}	m^{-3} 1.000 k cal^{-1}
CEREALS	1,5	0,47
STARCHY ROOTS	0,7	0,78
SUGARCROPS	0,15	0,49
OILCROPS	2	0,73
VEGETABLE OILS	2	0,23
VEGETABLES	0,5	2,07
AVERAGE	1,14	0,5
EUCALYPTUS	0,6	
MEAT		4
DAIRY PRODUCTS		>6

600 m^3

WATER PRODUCTIVITY VS GRAIN YIELD



VAPOR SHIFT !!!!

WATER PRODUCTIVITY

$$WP = \frac{WP_t}{(1 - e^{bY})}$$

WP= green WP m^{-3} t^{-1} (ET flow)

WP_t = productive green WP m^{-3} t^{-1} (T flow)

b= constant (rate of decline in E)

Y= grain yield (t ha^{-1})

$$ET_0\_PT = \alpha \frac{\Delta}{\Delta + \gamma}(R_n - G)$$

Shuttleworth (1993)

ET_o = reference evapotranspiration (mm day^{-1})

Δ= slope of vapor pressure curve (kPa $^0C^{-1}$)

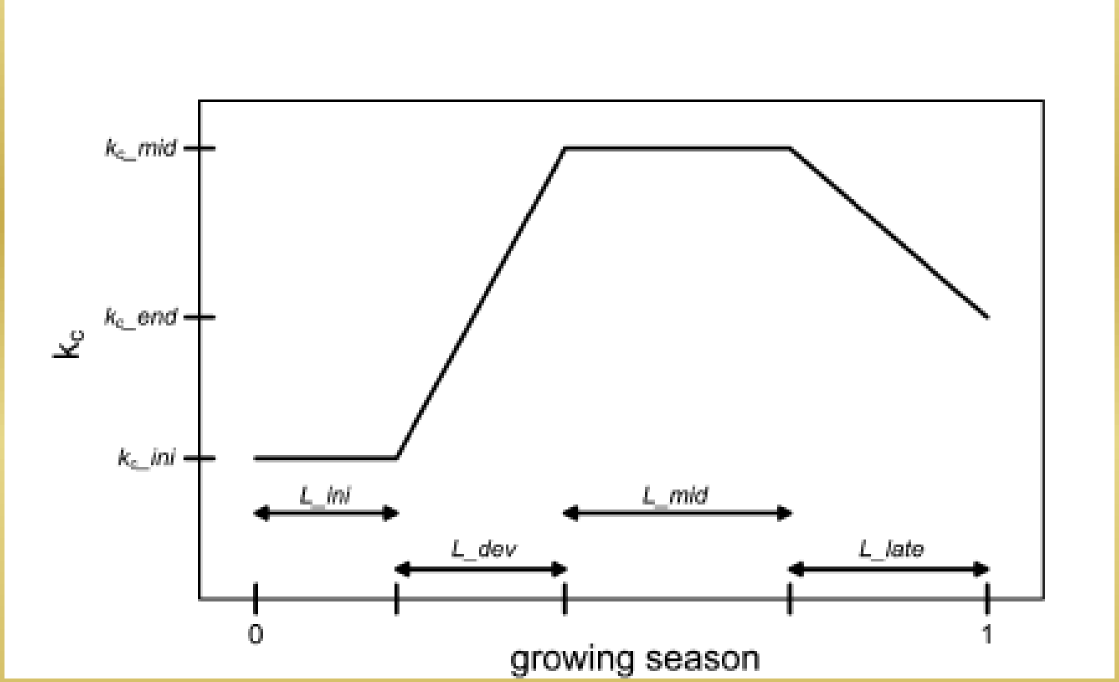
ϒ= psychrometric constant (kPa $^0C^{-1}$)

R_n= net radiation at crop surface (mm day^{-1})

G= soil heat flux (mm day^{-1})

SOIL – PLANT - ATMOSPHERE

$$PETc = k_c ET_0$$

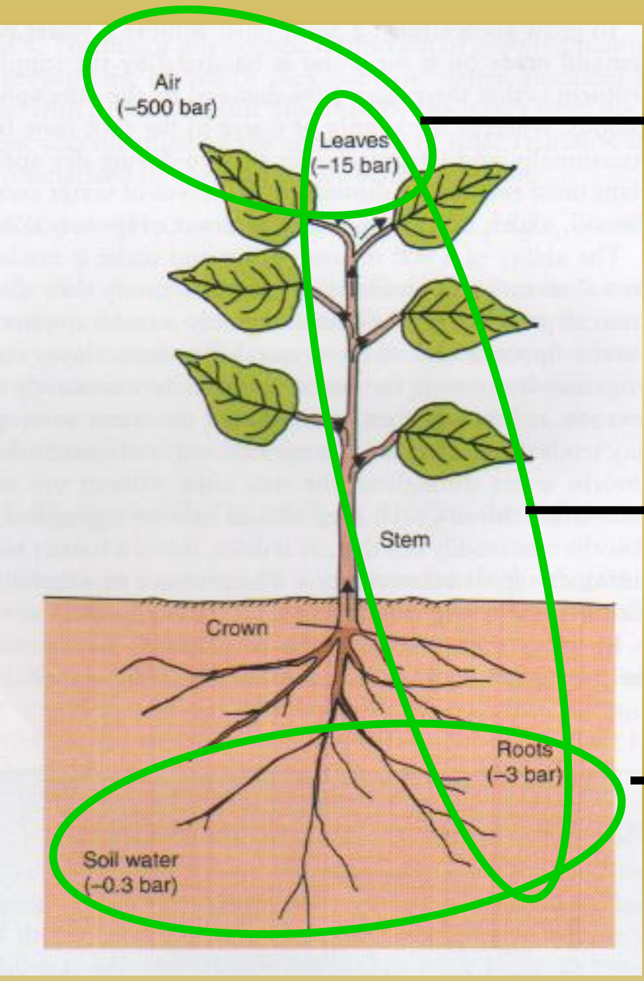


$$AETc = k_s PETc$$

$$k_s = \begin{cases} \frac{S}{(1-p)S_{max}} & \text{if } S < (1-p)S_{max} \\ 1 & \text{otherwise} \end{cases}$$

$$p = p_{std} + 0.04(5 - PETc)$$

DELTA FLOWS



Δ_1

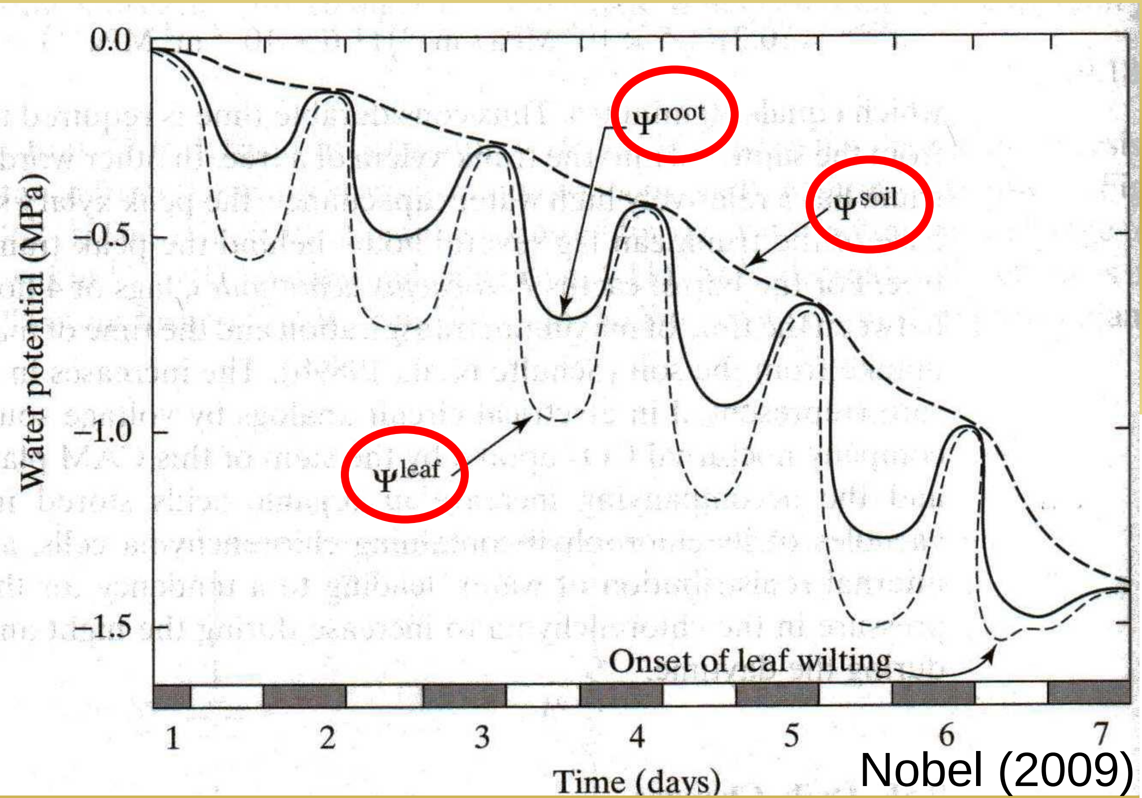
Δ_2

Δ_3

Δ

DELTA FLOWS

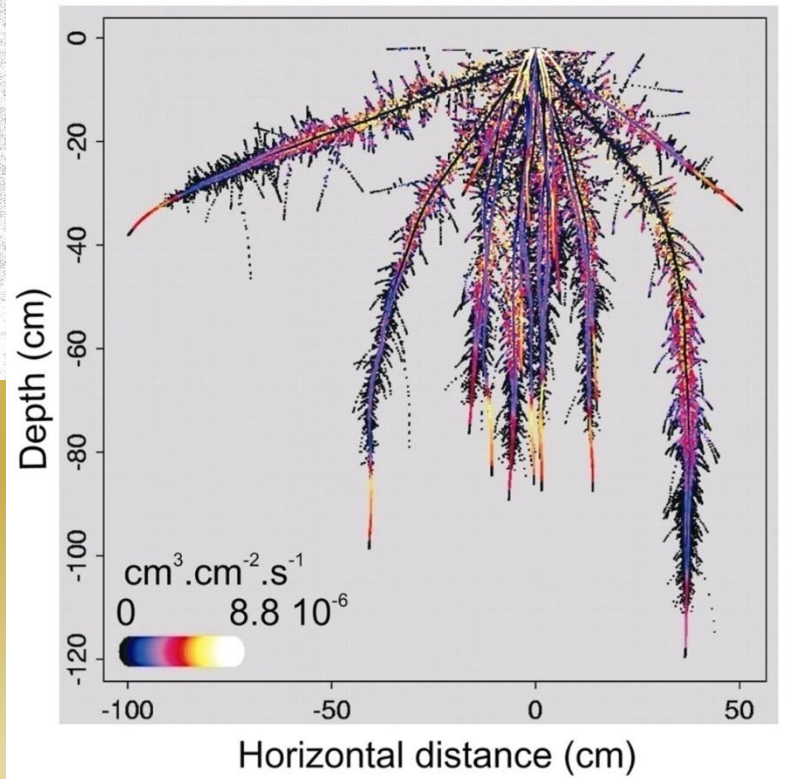
DAILY CHANGES



Nobel (2009)

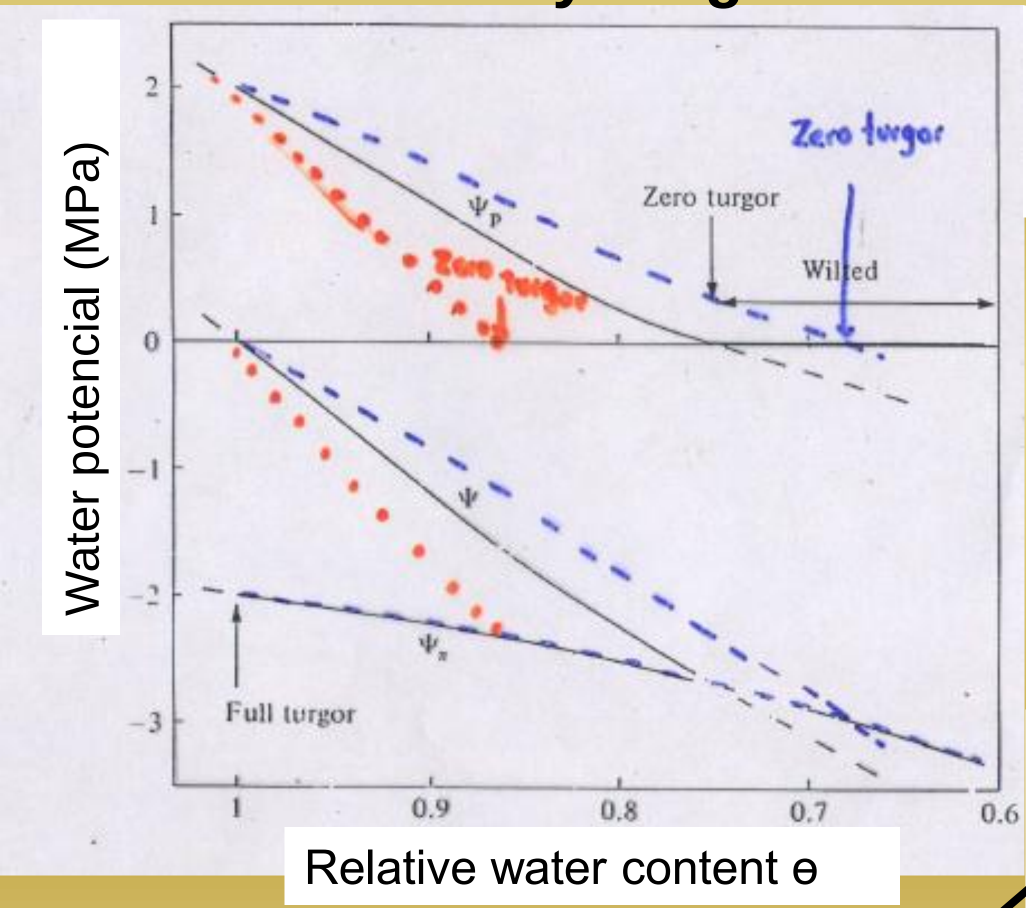
DRYING

ROOT AGING



DELTA FLOWS

Höfler-Thoday Diagram



$$J_v = L_p * \Delta\psi_w$$

Transport speed

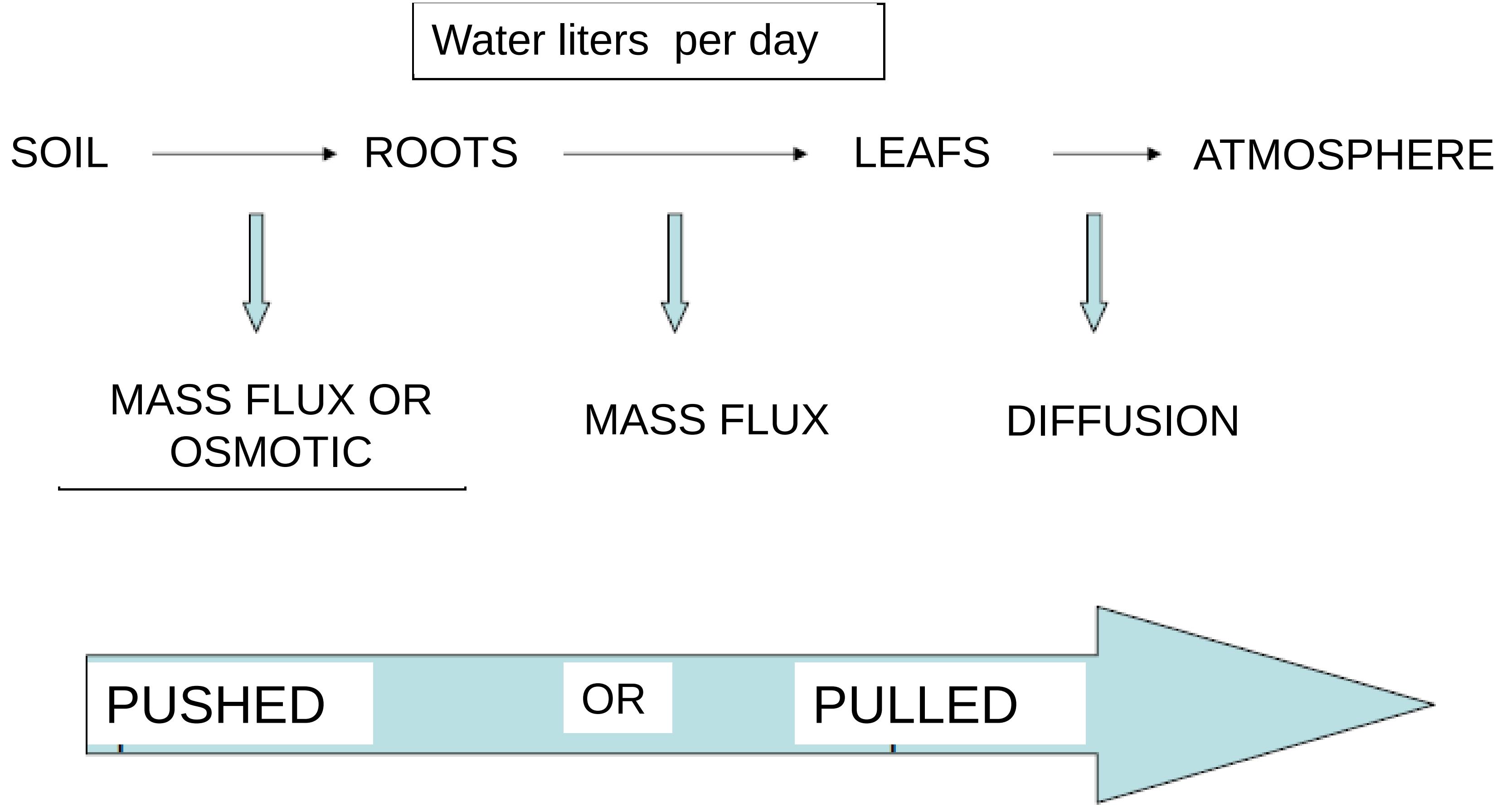
Membrane hydraulic conductivity

Water potencial gradient

$$t_{1/2} = \left(\frac{0{,}693}{A\,L_p} \right) \left(\frac{V}{\varepsilon - \psi_\pi} \right)$$

Half-time (seconds)

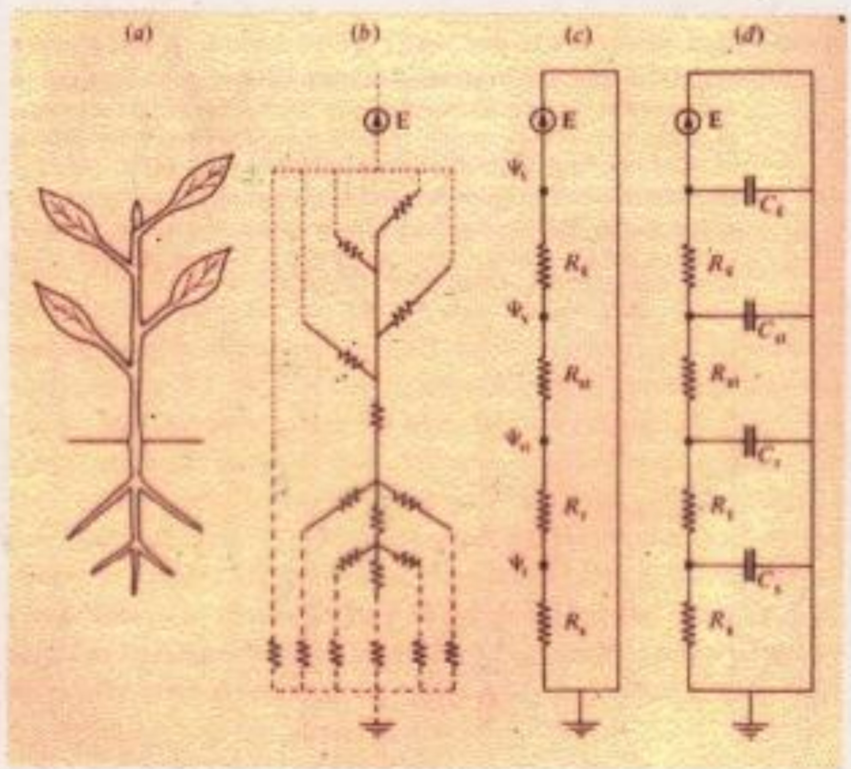
DELTA FLOWS

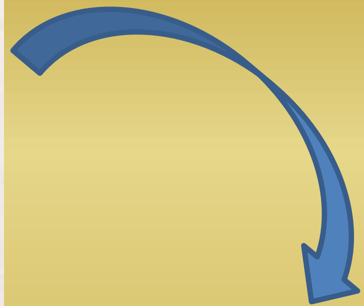


TAIZ & ZEIGER (2009)

DELTA FLOWS

ANALOGY TO OHM'S LAW

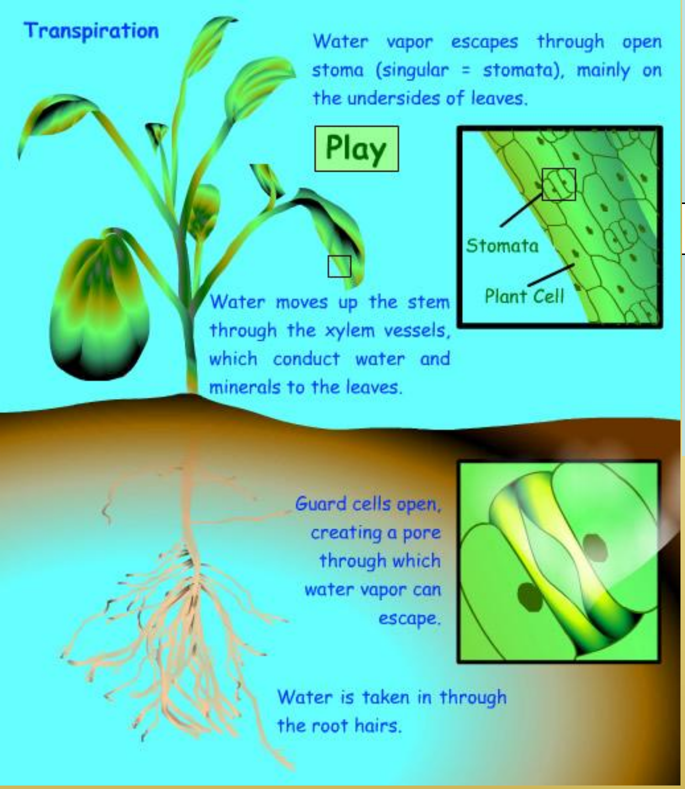




FLUX = DIFFERENCE BETWEEN ELECTRIC AL POTENCTAL / RESISTANCES

FLUX = VOLTAGE / RESISTANCES

DELTA FLOWS



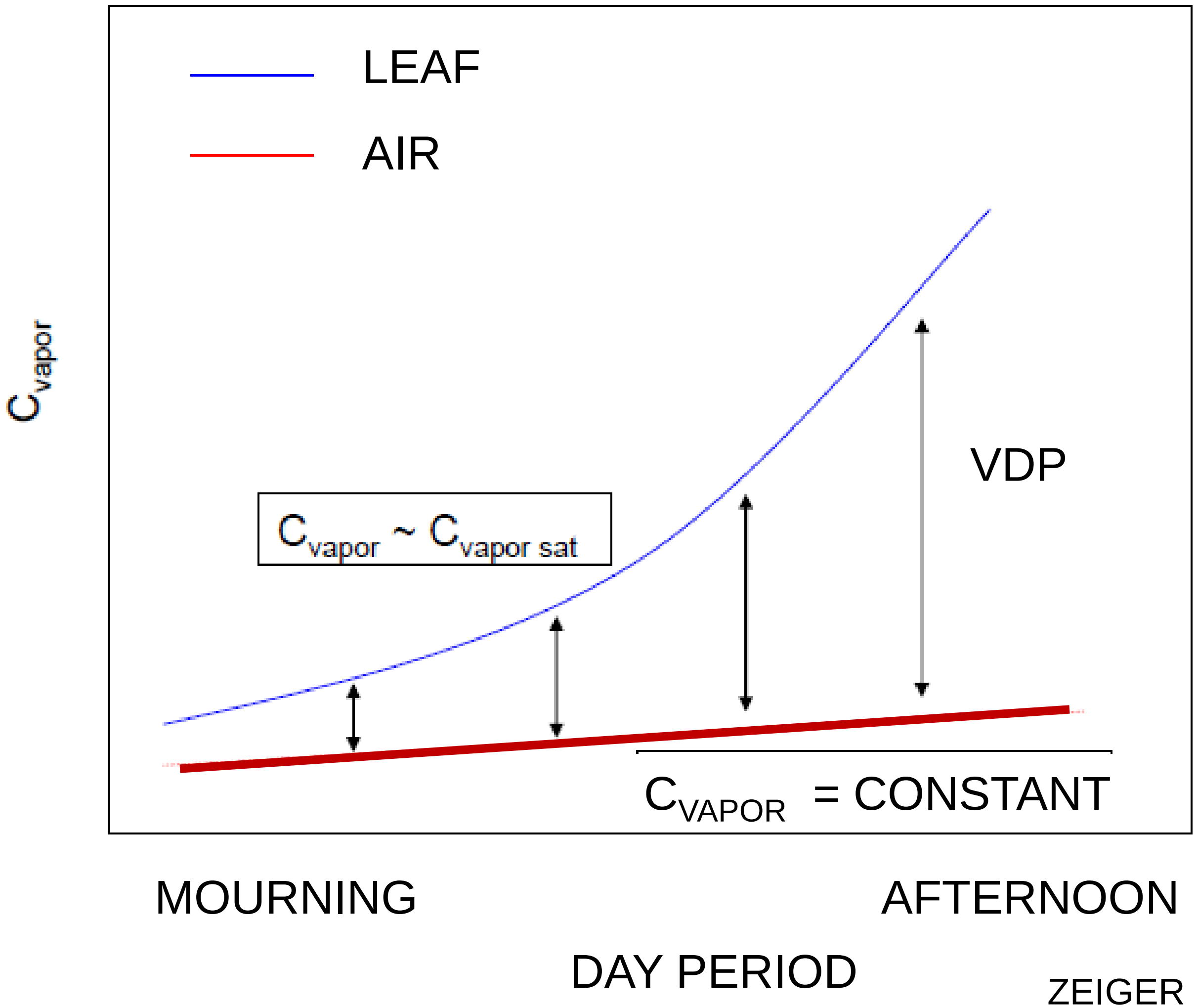
$$\text{TRANSPIRATION} \quad \frac{[\text{LEAF VAPOR}] - [\text{ATMOSPHERE VAPOR}]}{\text{LEAF + AIR RESISTANCE}}$$

$$\text{TRANSPIRATION} \quad \frac{\text{VPD}_{\text{LEAF-AIR}}}{\text{LEAF + AIR RESISTANCE}}$$

VPD
HIGHEST GRADIENT
SOIL-PLANT-ATMOSPHERE

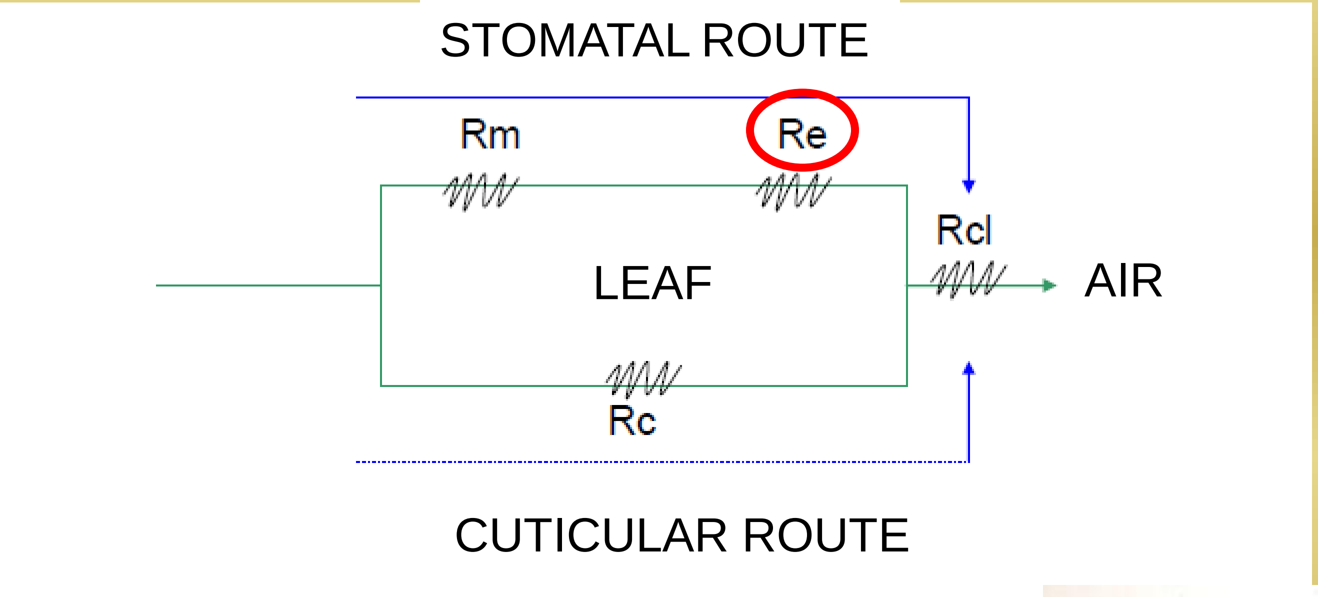
DELTA FLOWS

DIEL $VDP_{LEAF\text{-}AIR}$ FLUCTUATIONS



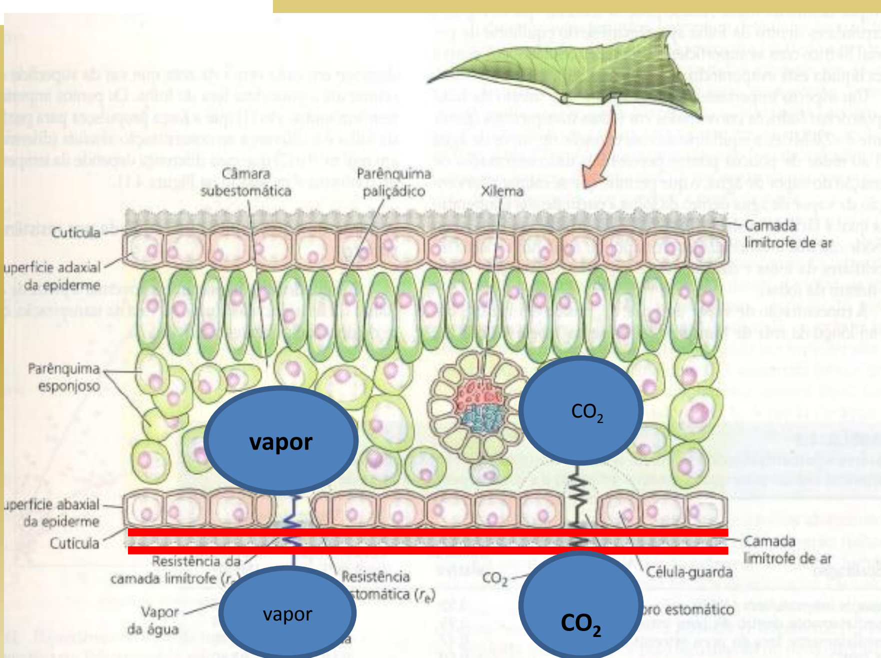
ZEIGER (2009)

DELTA FLOWS

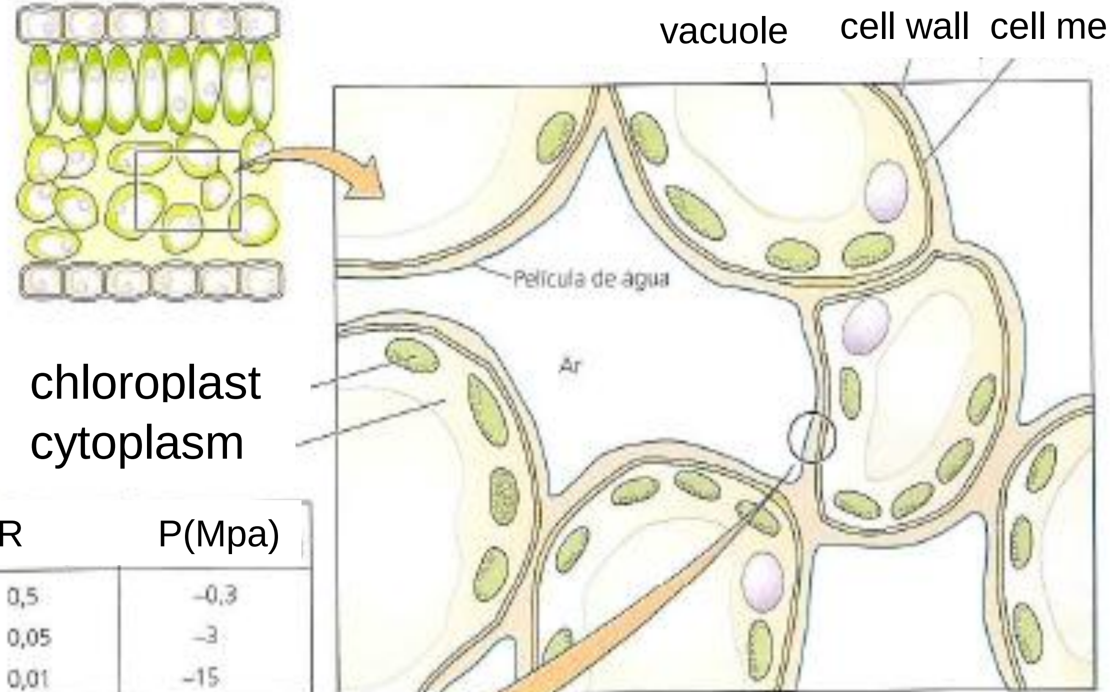


SHORT TERM REGULATION

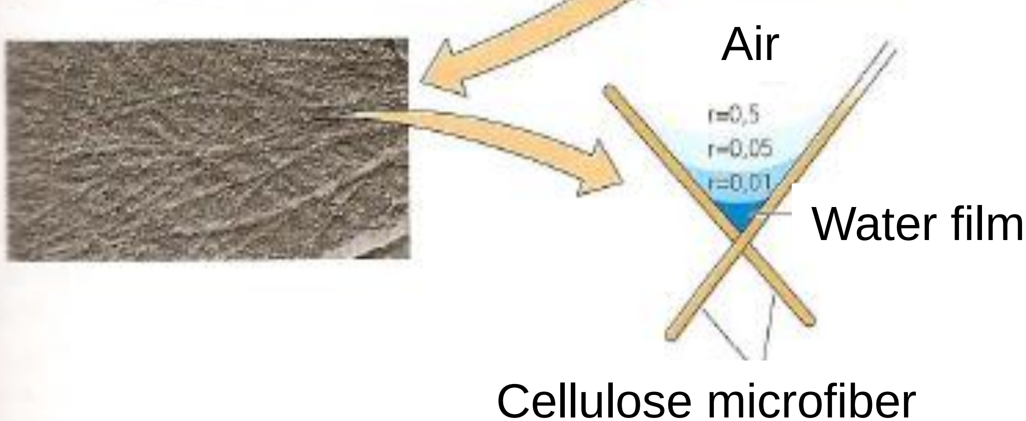
$$R_{folha} = \frac{(Rm + Re)(Rc)}{Rm+Re+Rc}$$



WATER DRIVING FORCE



	CR	P(Mpa)
(A)	0,5	–0,3
(B)	0,05	–3
(C)	0,01	–15



$\Psi p = -2T/r$

T= Water surface tension

r = Air-water interface curvature radius (CR)

DELTA FLOWS

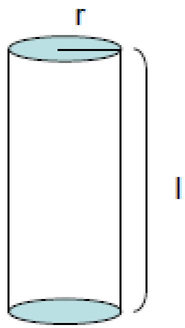
ROOT XYLEM ⇨ LEAF XYLEM

LONGEST ROUTE

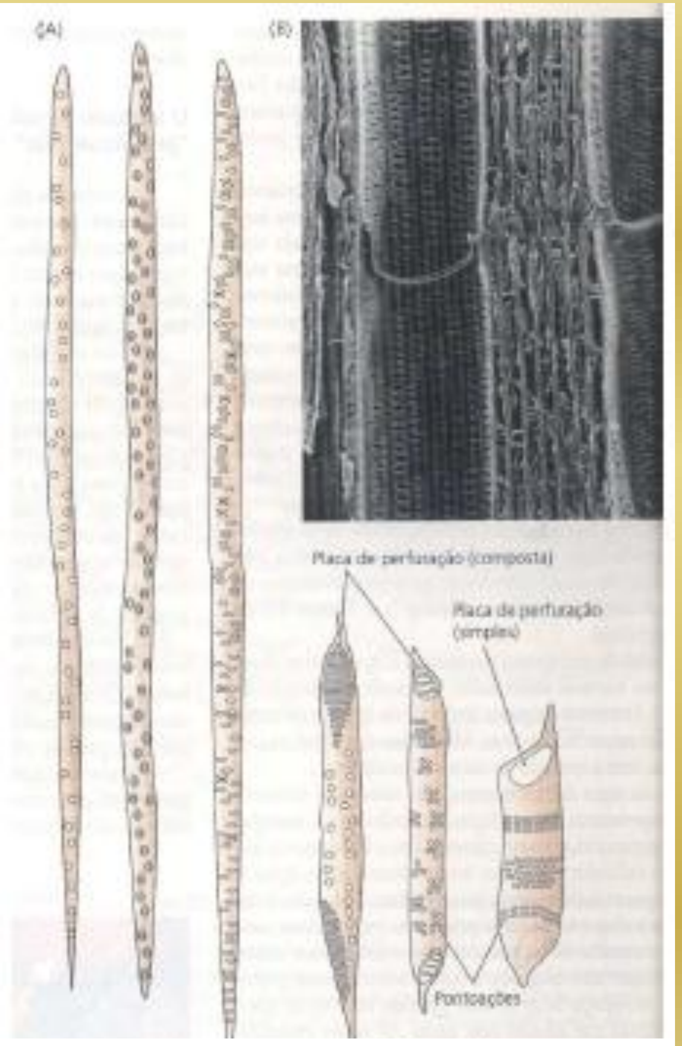
Poiseuille-Haggen:

– MASS FLUX IN CILINDERS

$$F_{(VOLUME/TIME)} \quad \frac{\pi r^2 \, r^2 \, \Delta P}{8 \, n \, l}$$



DELTA FLOWS

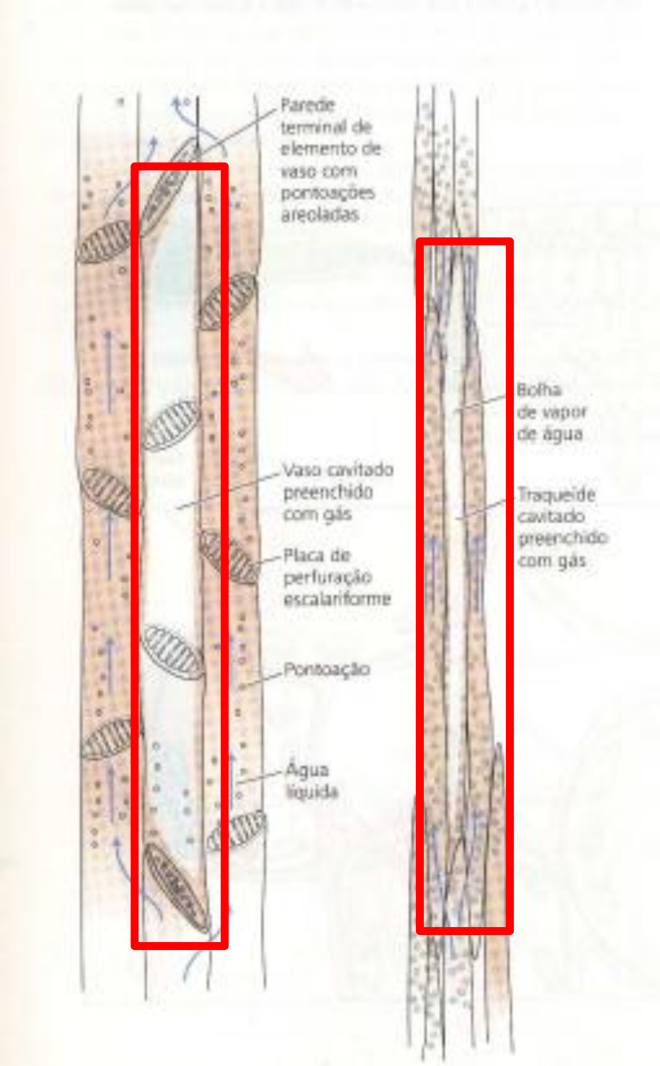


TRACHEIDS VESSEL MEMBERS

EFFICIENCY

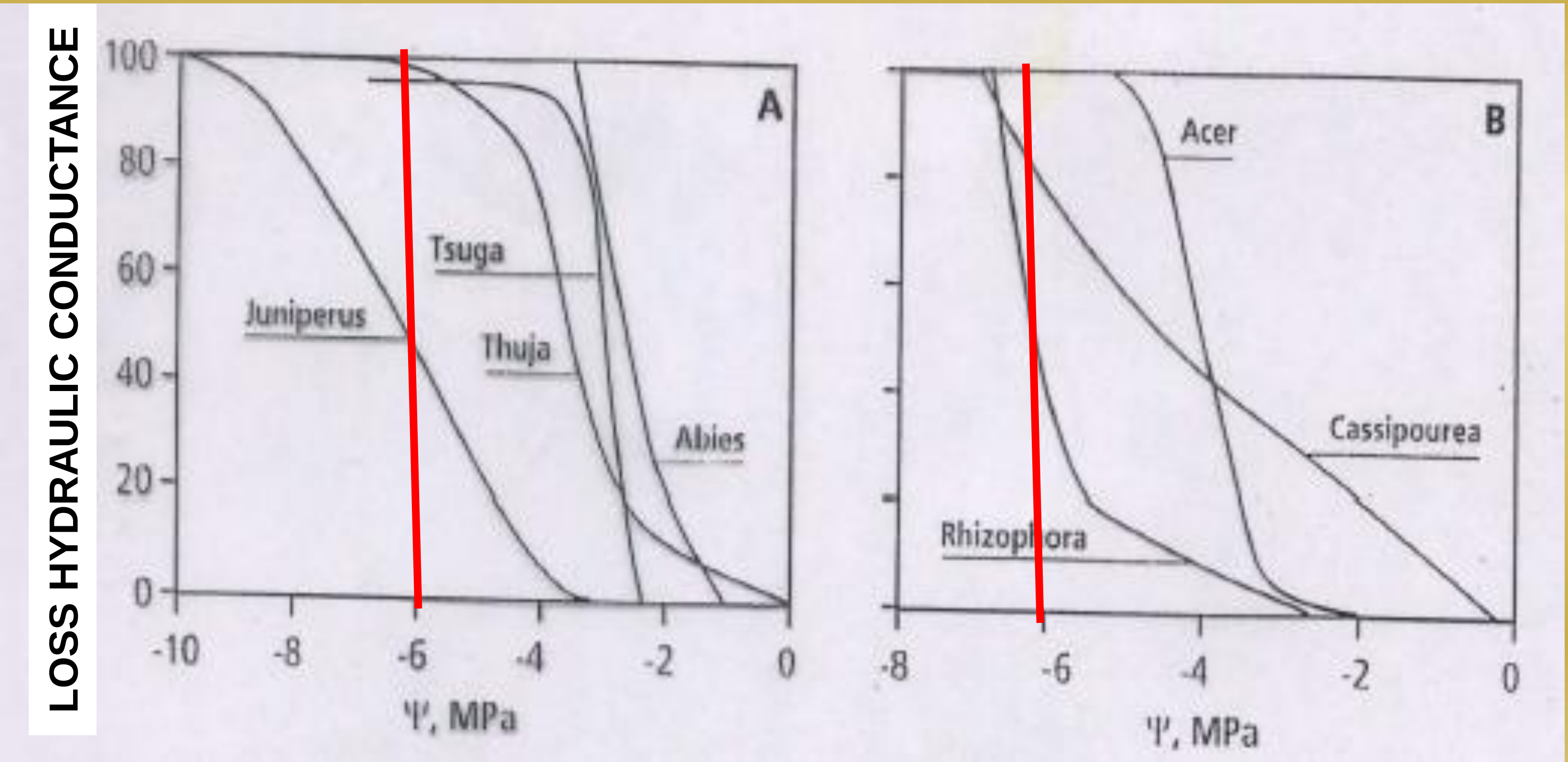
HOWEVER!!!!!

" AIR SEEDING"



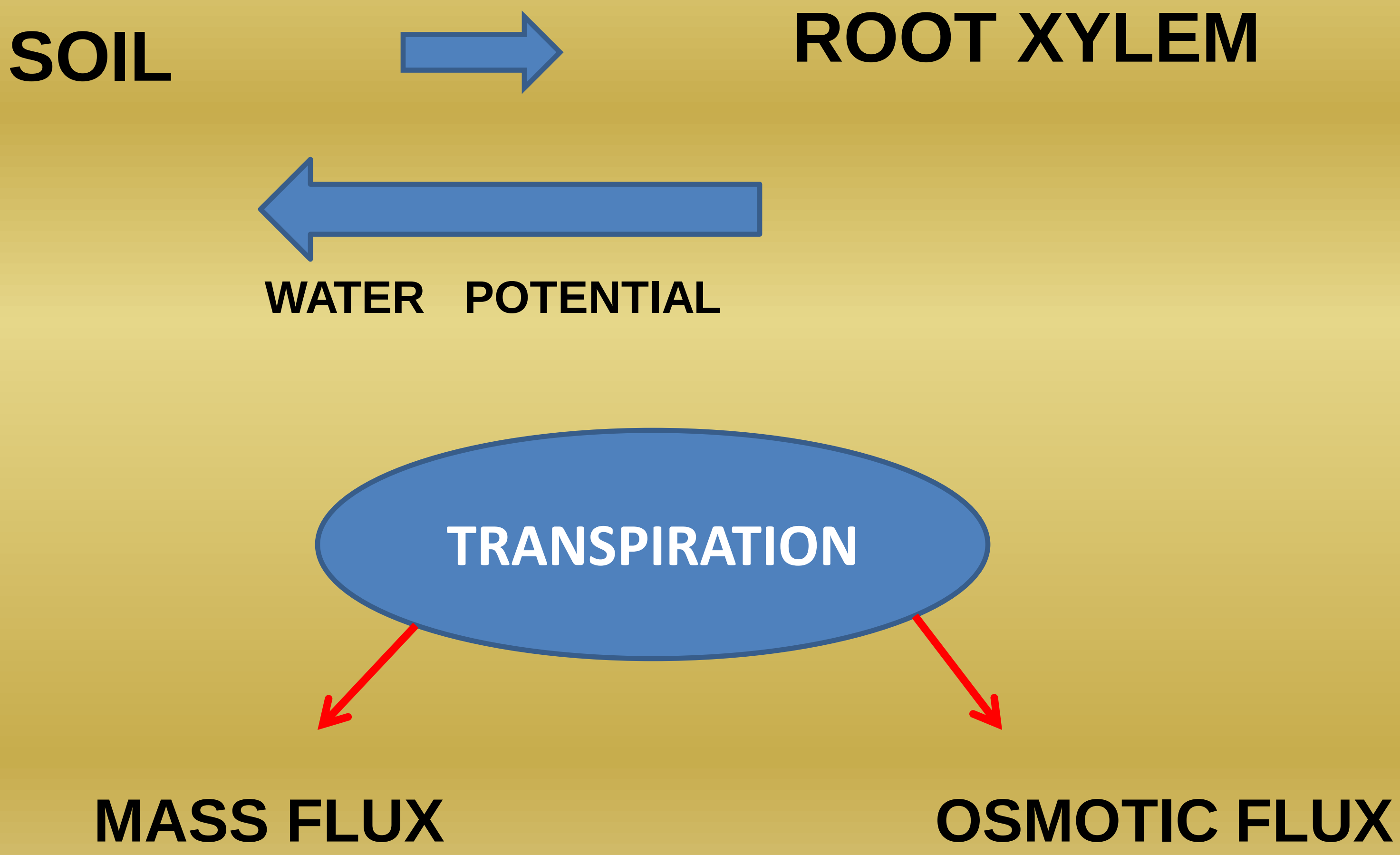
WATER MOVEMENT THROUGH PLANTS

VULNERABILITY TO EMBOLISM



XYLEM WATER POTENCIAL

SOIL- ROOT INTERFACE



SOIL- ROOT INTERFACE

- $$F_{(volume/\ Time)} = \frac{A\,K\,\Delta\Psi_P}{d}$$

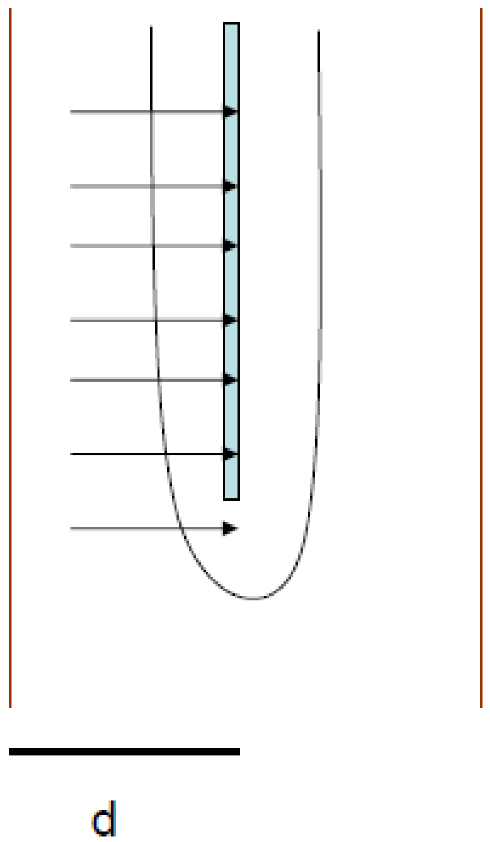
$A =$ Root superficial area

$\Delta\Psi_P =$ Soil - root delta pressure

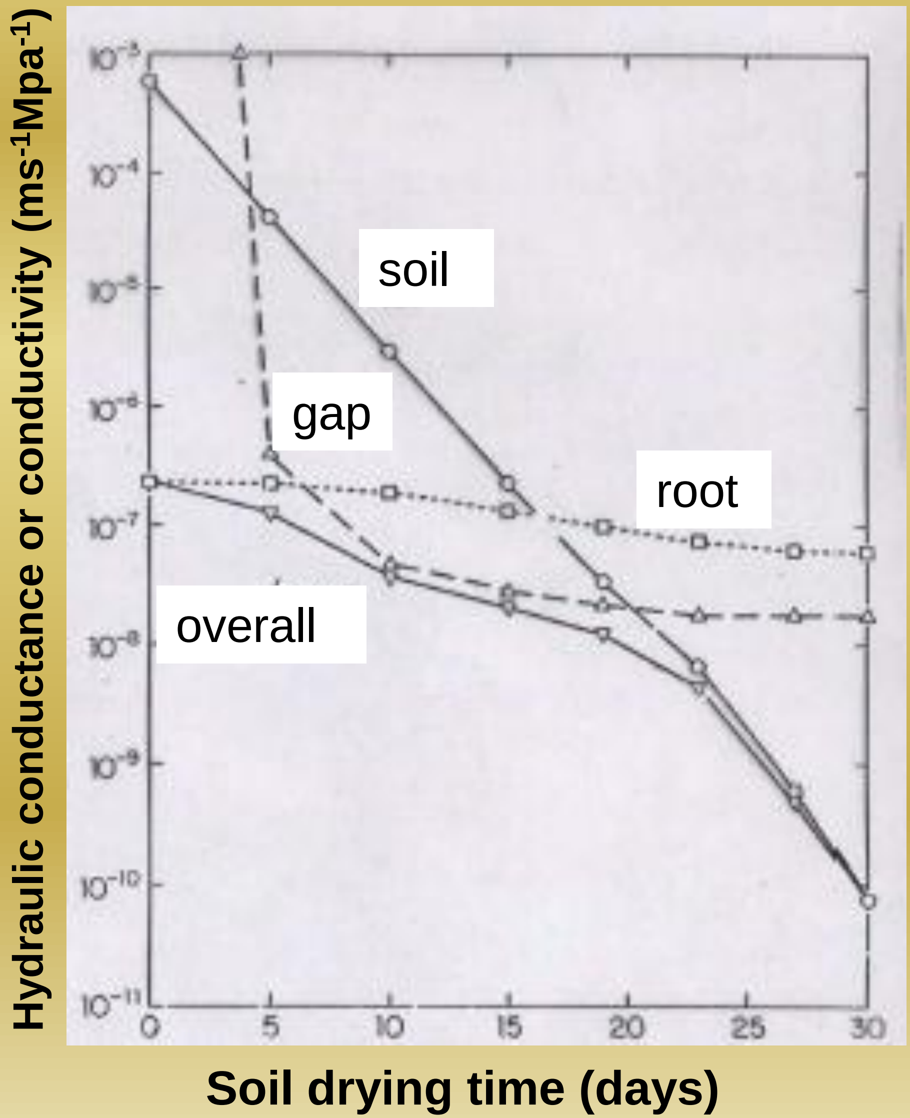
$d =$ Soil-root cylinder radius

$K =$ Hydraulic conductivity Σ effects

$K_s =$ soil
$K_i =$ interface
$K_r =$ root



SOIL- ROOT INTERFACE



COMPACTION?!

HYDRIC STRESS

SITUATIONS LEADING TO LOW WATER AVAILABILITY

HIGH VDP

HIGH EVAPOTRANSPIRATION
SALINITY
FREEZING

GROWTH $G = m\,(\Psi_P - Y)$ (Eq. 1)

$G = A\,Lp\,(\Delta\Psi_w)$

G= CELULAR EXPANSION RATE $(m^3\,s^{-1})$

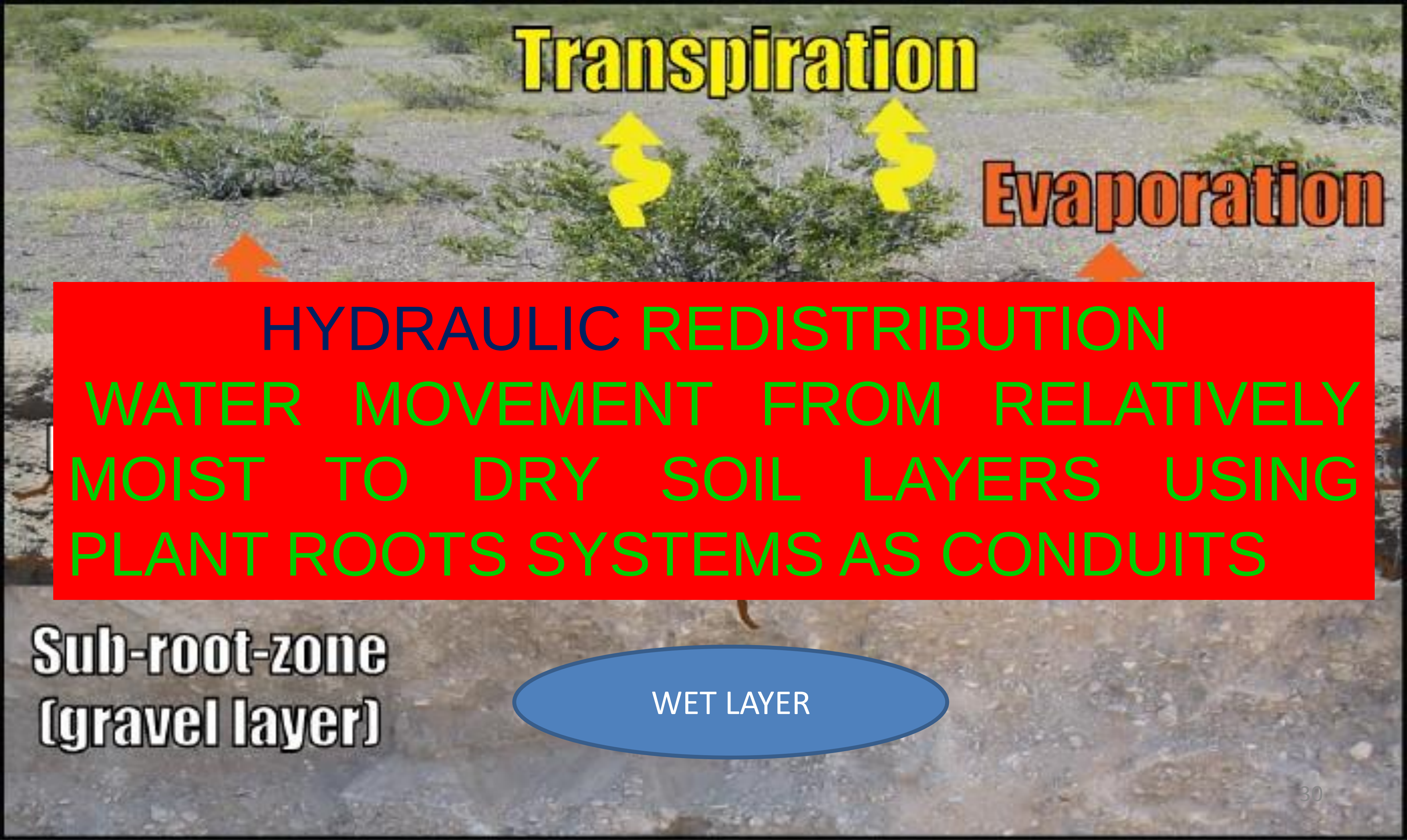
m = CELL WALL EXTENSIBILITY $(m^3\,MPa^{-1}\,s^{-1})$

Ψ_P = HYDRAULIC PRESSURE (MPa)

Y = CELL WALL THRESHOLD (MPa)

CELULAR EXPANSION RATE

HYDRAULIIC REDISTRIBUTION



HYDRAULIC REDISTRIBUTION

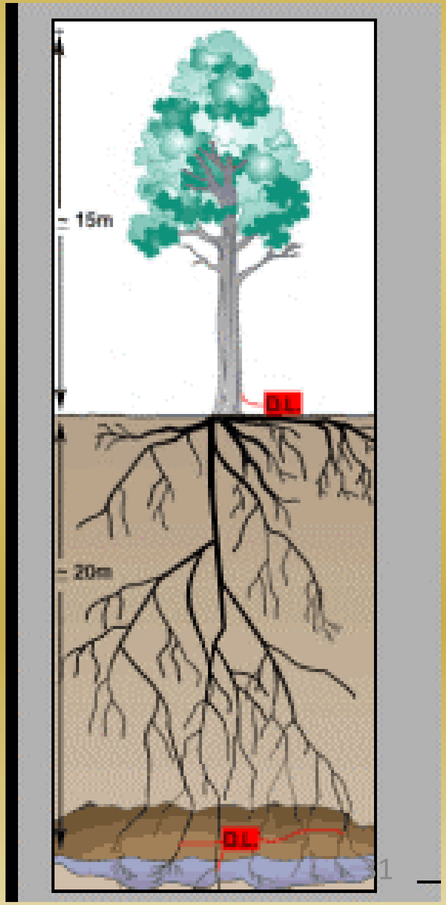
WATER MOVEMENT FROM RELATIVELY MOIST TO DRY SOIL LAYERS USING PLANT ROOTS SYSTEMS AS CONDUITS

WET LAYER

HYDRAULIC REDISTRIBUTION

- LABORATORY TRIALS – ROOTS EXPELLING WATER IN DRIER LAYERS
- REDISTRIBUTIO OCCURS IN ALL DIRECTIONS- **GRADIENT**

1987 (RICHARD & CALDWELL)



PROCESS EFFICIENCY

14 – 33% DAILY EVAPOTRANSPIRATION

⇩

50% - 100 days year^{-1}

ROOT ARQUITECTURE

+

ROOT LENGTH DENSITY

Acacia tortilis

GRAIN PRODUCTION

Table 1 Crop yield increases through engineered water irrigation in the field

Crop	Climate	Yield increase	Reference
Chickpea	Cool-temperate, sub-humid	74–124% (grain)	Rajin Anwar et al. 2003
Wheat	Semi-arid	73.4% (grain)	Li et al. 2007
Corn	Temperate, continental	179.2% (grain)	Scheierling et al. 1997
Beans	Temperate, continental	145.6% (grain)	Scheierling et al. 1997
Cashew	Tropical	77% (nut yield)	Oliveira et al. 2006
Potatoes	Temperate, maritime/continental	20–>30%	Dörter 1986
Corn	Temperate, maritime/continental	43% (fresh shoot)	Dörter 1986

RAZÃO DE TRANSPIRAÇÃO = ÁGUA TRANSPIRADA/CO_2 ASSIMILADO

ESPÉCIES	RAZÃO DE TRANSPIRAÇÃO
C 3	500
C 4	250
CAM	50

INTEGRATED SYSTEMS

BIOIRRIGATION

RESISTANCE TO DRY SPELLS

“IS IT PROBLEMATIC, FROM A WATER RESOURCES PERSPECTIVE, IF PEOPLE USE CROPS PRODUCED WITH ALMOST EXCLUSIVELY GREEN WATER? MAYBE, IT IS NOT, UNLESS CROP PRODUCTION LEADS TO WATER POLLUTION”

Siebert (2010)







THANK YOU !