

# CT3011: Inleiding watermanagement

## 4: Irrigatie

**College 4: Waterbeheer**  
**11 september 2008**

**Nick van de Giesen,**  
**Maurits Ertsen**



# CT3011: Inleiding watermanagement

## Colleges:

1. Water in de wereld
2. Water in de bodem
3. Polders
4. Irrigatie
5. Kunstwerken & operationeel
6. Reservoirs (+review)

# CT3011: Inleiding watermanagement

## Colleges:

1. Water in de wereld
2. Water in de bodem
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- 4. Irrigatie**
5. Kunstwerken & operationeel
6. Reservoirs (+review)

# CT3011: Inleiding watermanagement

## Colleges: Algemene logika

Eisen  $\Rightarrow$  Systeem  $\Rightarrow$  Elementen  $\Rightarrow$  Technieken

- Samenhang begrijpen
- Rekenen met technieken
- Afleidingen

# CT3011: Inleiding watermanagement

## Colleges: Algemene logika

### Five classics

- Darcy  $\Rightarrow$  Laplace  $\Rightarrow$  Boussinesq
- St. Venant  $\Rightarrow$  Manning (Strickler)
- **Penman**
- (Richards)
- Hurst

# CT3011: Inleiding watermanagement

## Irrigatie:

1. Irrigatie systeem
2. Proefje / waarom verdamping?
3. Penman
4. Waterbehoefte
5. Management

# Irrigatie systeem

## Types

- **Bron**
- **Transport**
- **Applicatie**



# Irrigatie systeem

## Bron

- **Grondwater**
- Rivier
- Reservoir

Qanats



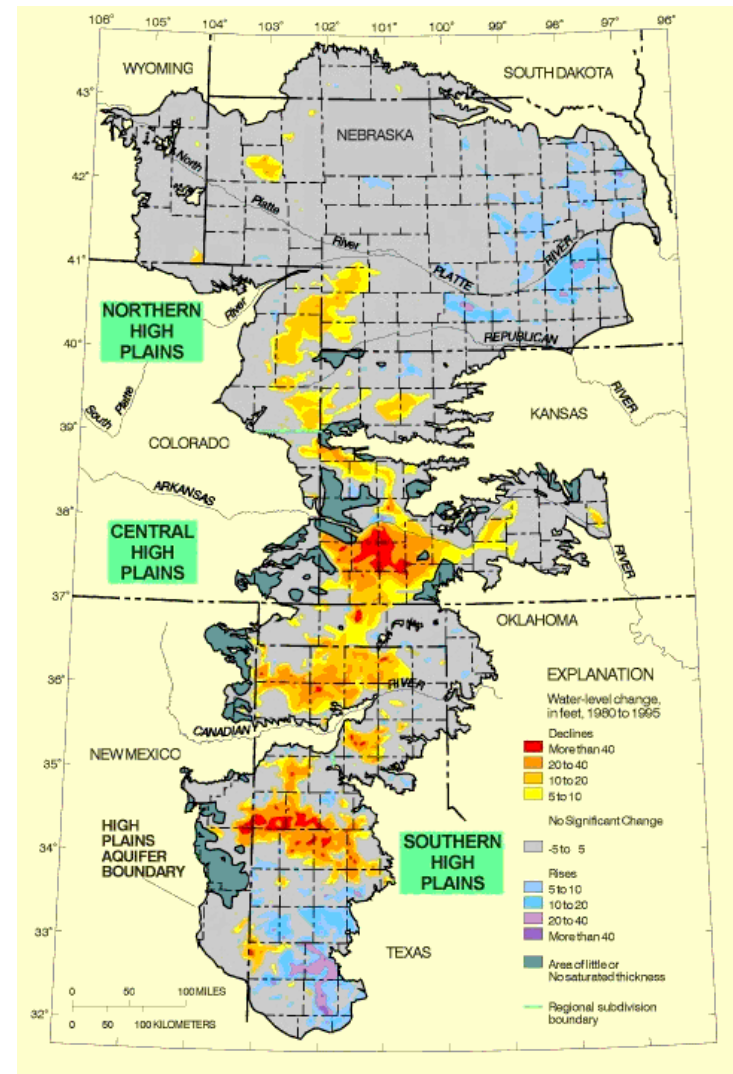


# Irrigatie systeem

## Bron

- **Grondwater**
- Rivier
- Reservoir

Ogallala



# Irrigatie systeem

## Bron

- **Grondwater**
- Rivier
- Reservoir



Betuwe

# Irrigatie systeem

## Bron

- Grondwater
- Rivier
- Reservoir



Betuwe

# Irrigatie systeem

## Bron

- Grondwater
- Rivier
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# Irrigatie systeem

## Bron

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# Irrigatie systeem

## Bron

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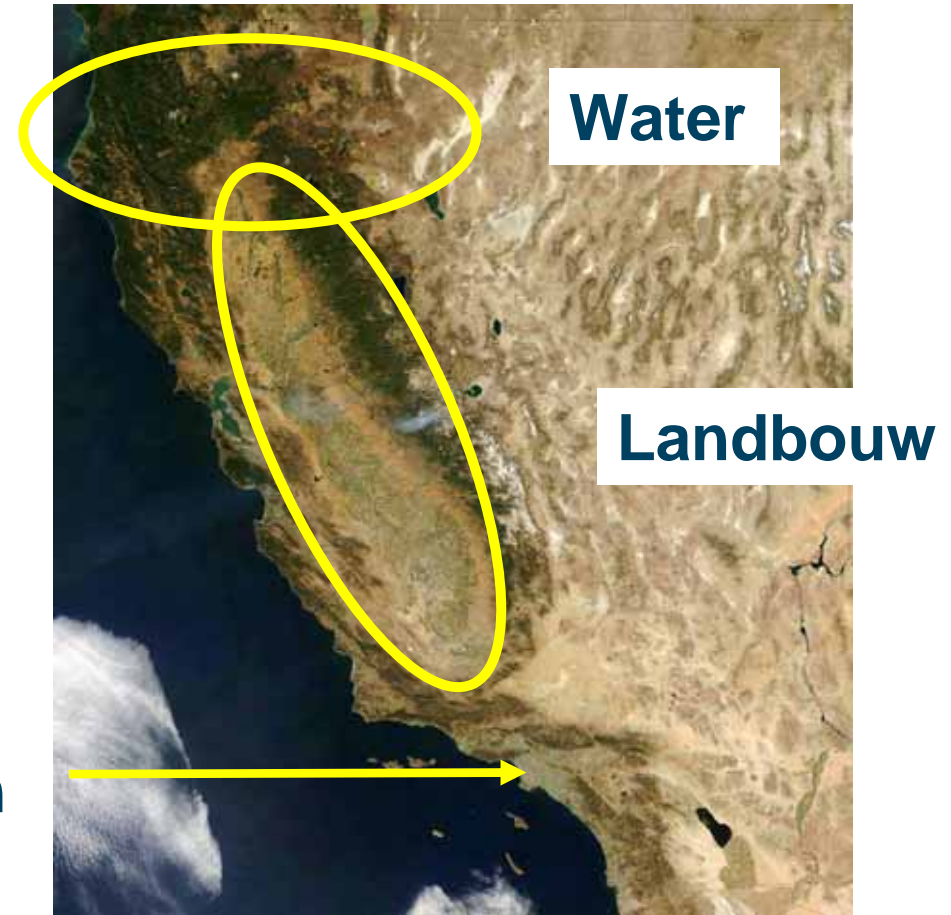


# Irrigatie systeem

## Bron

- Grondwater
- Rivier
- Reservoir

Mensen



California

# Irrigatie systeem

## Bron

- Grondwater
- Rivier
- Reservoir



# Irrigatie systeem

## Bron

- Grondwater
- Rivier
- Reservoir



# Irrigatie systeem

## Transport

- Kanalen
- Leidingen



# Irrigatie systeem

## Transport

- Kanalen
- Leidingen



# Irrigatie systeem

## Transport

- Kanalen
- Leidingen



# Irrigatie systeem

## Applicatie

- **Vloed**
- **Bassin**
- **Furrow (voren)**
- **Drip**
- **Sprinkler**
- **Central pivot**



# Irrigatie systeem

## Applicatie

- Vloed
- **Bassin**
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# Irrigatie systeem

## Applicatie

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## Applicatie

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# Irrigatie systeem

## Applicatie

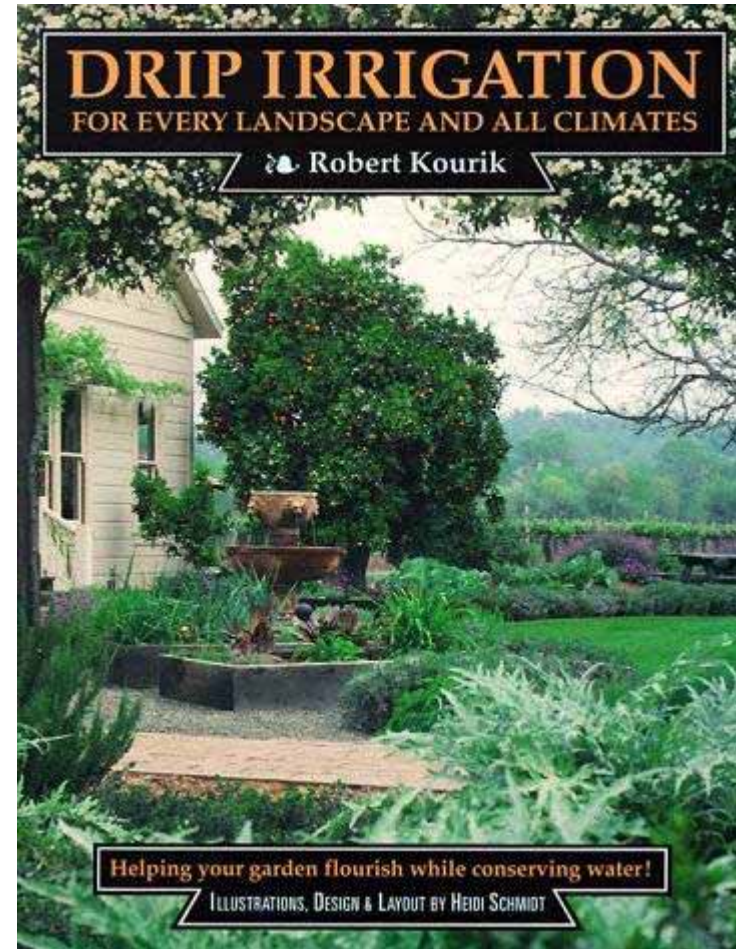
- Vloed
- Bassin
- Furrow (voren)
- Drip
- Sprinkler
- Central pivot



# Irrigatie systeem

## Applicatie

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# Irrigatie systeem

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# Irrigatie systeem

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# Irrigatie systeem

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# CT3011: Inleiding watermanagement

## Irrigatie:

1. Irrigatie systeem

**2. Proefje / waarom verdamping?**

3. Penman

4. Waterbehoefte

5. Management



# Waarom verdamping?

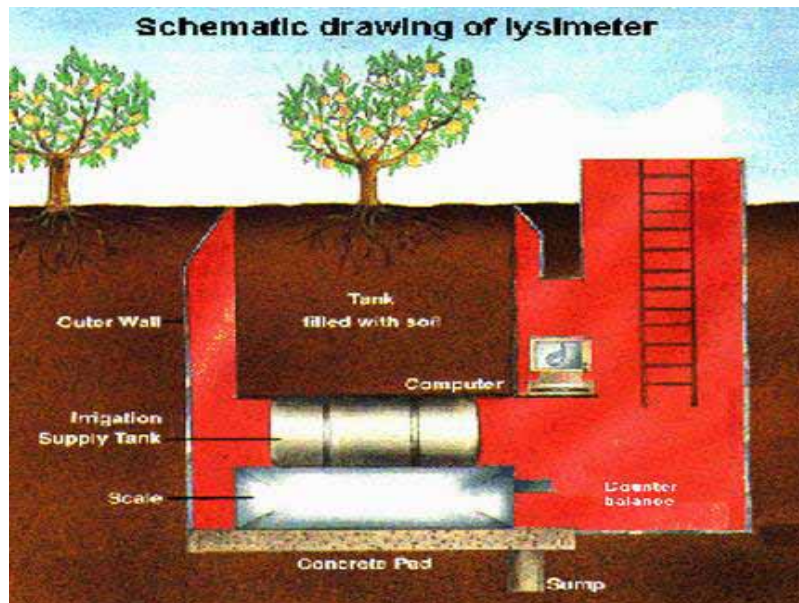
## Proefje



## Lysimeter

# Waarom verdamping?

## Proefje



## Lysimeter

# Waarom verdamping?

## Waterbehoefte produkt:

<b>1kg Watermeloen</b>	<b>300 liter</b>
<b>1kg Meeste gewassen</b>	<b>1000 liter</b>
<b>1kg Rijst</b>	<b>3000 liter</b>

**Physiologisch:**            **1:600 C3**  
   **1:300 C4**

# Waarom verdamping?

## Waterbehoefte

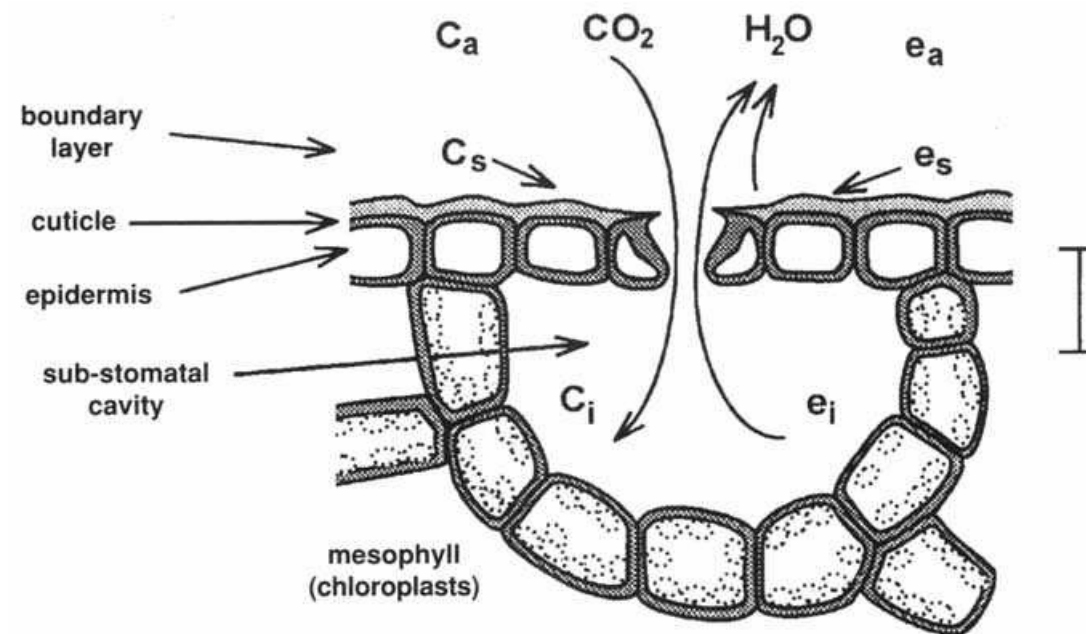
1700 m<sup>3</sup> pp / jaar (geen tekort)

- drinkwater 1
- koken etc. 5
- wassen etc. 10
- toilet 20
- industrie 200
- vegetarisch dieet 500
- vlees (extra) 500-1000

# Waarom verdamping?

Daarom verdamping

Plant heeft  $\text{CO}_2$  nodig...



# Waarom verdamping?

## Daarom verdamping

## Plant heeft CO<sub>2</sub> nodig...

Vol 448 | 30 August 2007 | doi:10.1038/nature06045

nature

LETTERS

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## Projected increase in continental runoff due to plant responses to increasing carbon dioxide

Richard A. Betts<sup>1</sup>, Olivier Boucher<sup>1</sup>, Matthew Collins<sup>1</sup>, Peter M. Cox<sup>1,2</sup>, Peter D. Falloon<sup>1</sup>, Nicola Gedney<sup>3</sup>, Deborah L. Hemming<sup>1</sup>, Chris Huntingford<sup>4</sup>, Chris D. Jones<sup>1</sup>, David M. H. Sexton<sup>1</sup> & Mark J. Webb<sup>1</sup>

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# Waarom verdamping?

Daarom verdamping

Huidmondje

Geen suiker/licht } Geen  
Geen water } osmotische  
druk





# Waarom verdamping?

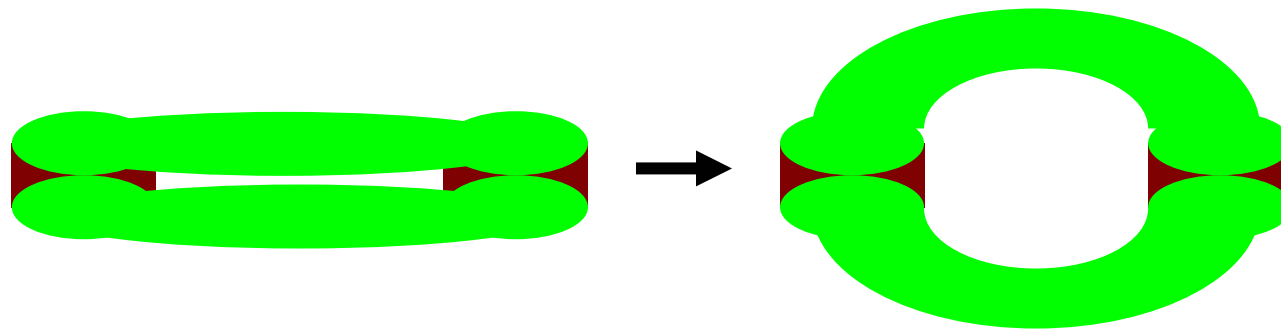
Daarom verdamping

Huidmondje

Veel suiker/licht

Veel water

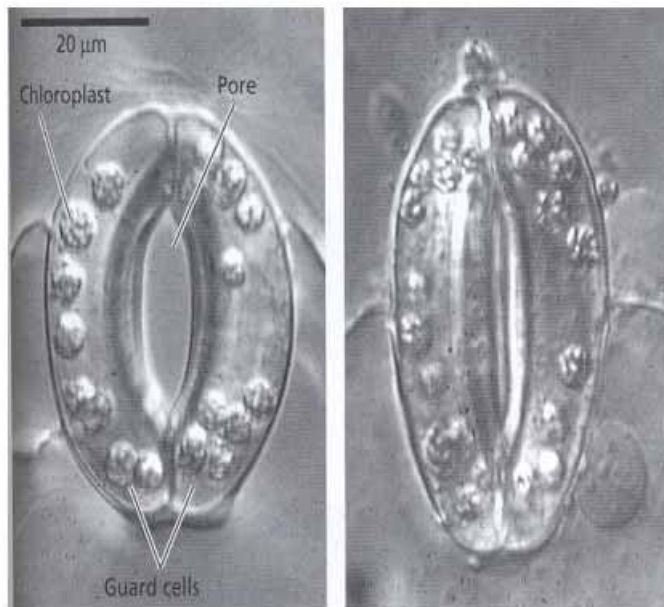
} Veel  
osmotische  
druk



# Waarom verdamping?

Daarom verdamping

Plant heeft CO<sub>2</sub> nodig...



**Diffusie, Fick's law**

$$J_x = -D \cdot \frac{\partial c}{\partial x}$$

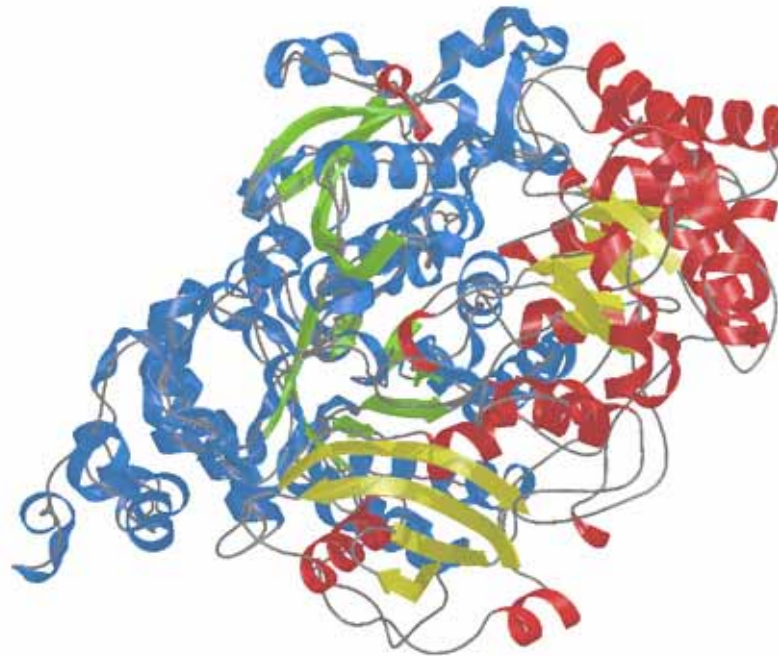
**Faktor 10**

# Waarom verdamping?

Daarom verdamping

**Ribulose 1,5 Bis Phosphate Carboxylase**

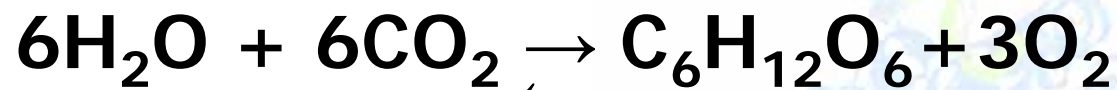
**Rubisco**



# Waarom verdamping?

Daarom verdamping

**Rubisco**

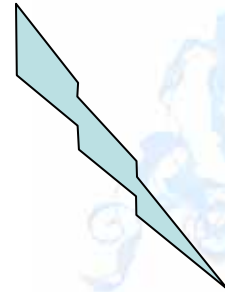
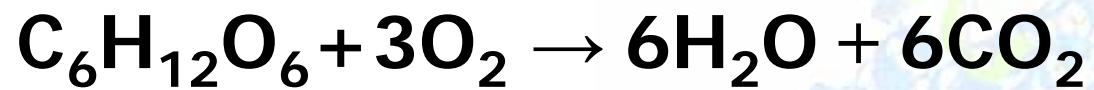
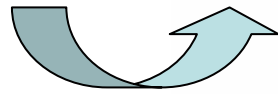


**Licht**

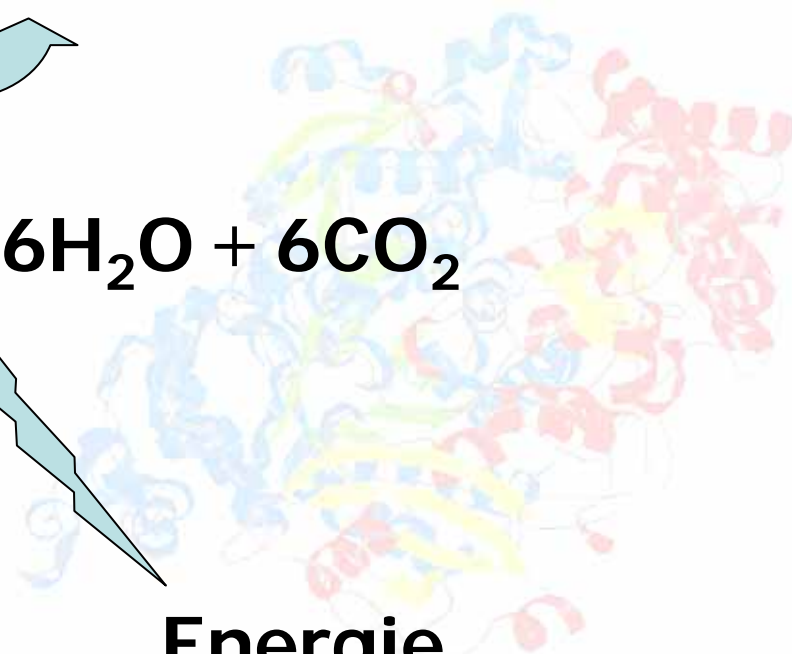
# Waarom verdamping?

Daarom verdamping

**Rubisco**



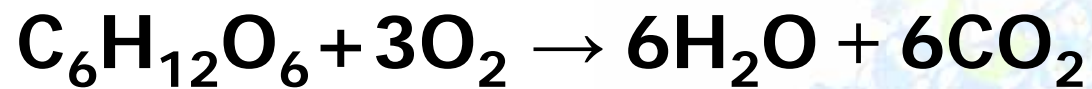
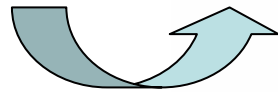
**Energie**



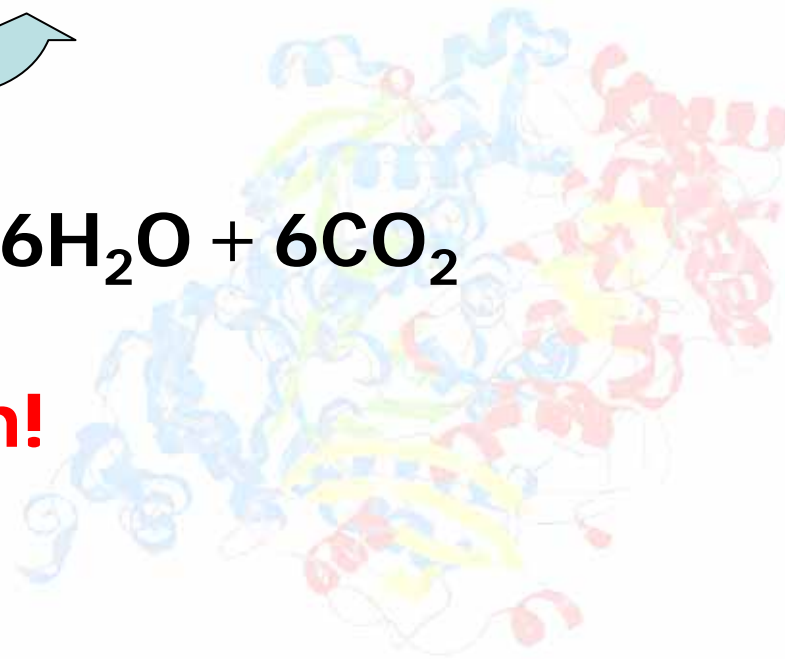
# Waarom verdamping?

Daarom verdamping

**Rubisco**



**Wagenwijd open!**



# Waarom verdamping?

Daarom verdamping

**C3 planten**

**Stomata wijd open!**

**Koeler, natter klimaat**

**Tarwe, aardappelen, rijst**



# Waarom verdamping?

Daarom verdamping

C4 planten vangen CO<sub>2</sub>

Kost extra energie,  
spaart water

Savanna planten (Mais, sorgum, millet)





# CT3011: Inleiding watermanagement

## Irrigatie:

1. Irrigatie systeem
2. Proefje / waarom verdamping?
- 3. Penman**
4. Waterbehoefte
5. Management



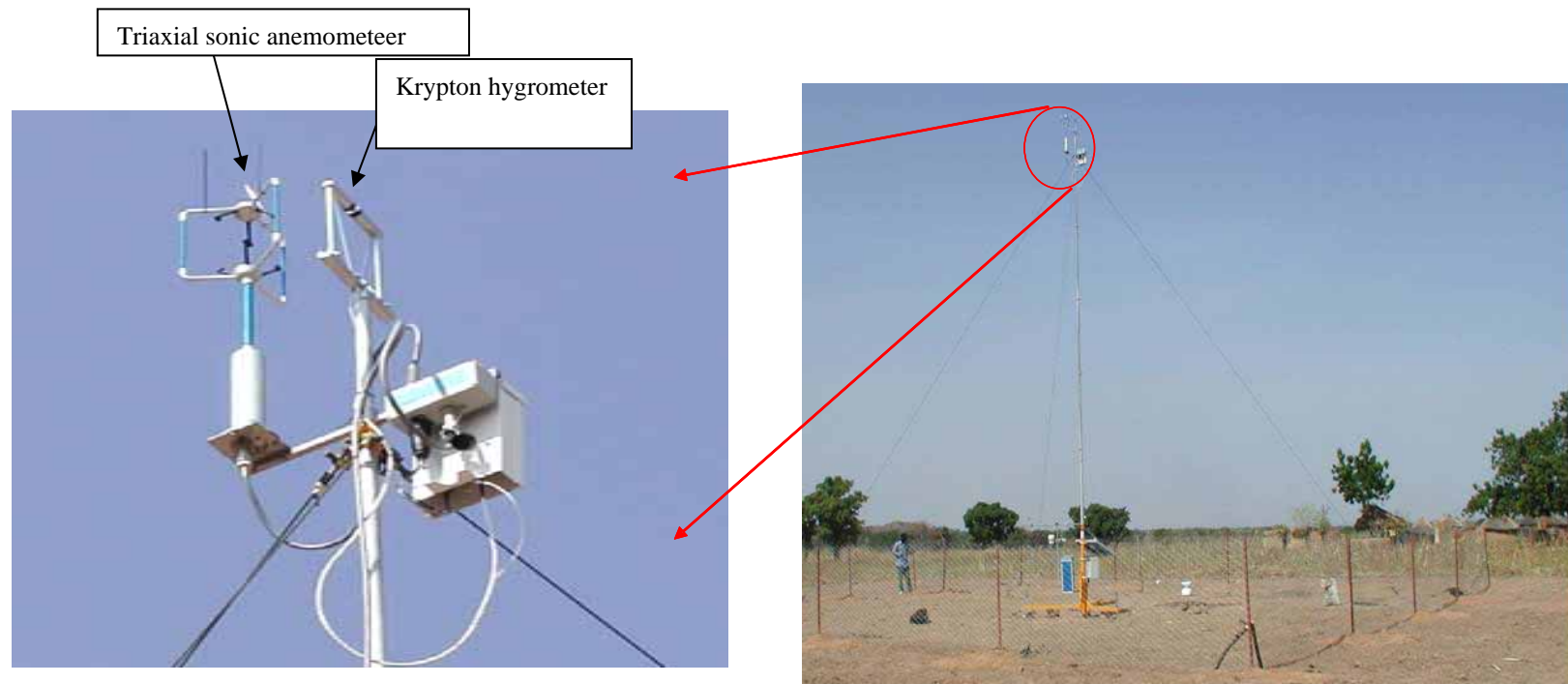
# Penman

## Verdampingsmetingen

- **Lysimeter**
- **Eddy correlation**

# Penman

## Eddy covariantie



Eddy correlation, Kompienga, Burkina Faso

# Penman

Eddy covariantie

Reynoldse splitsing

$$u_z = \bar{u}_z + u'_z$$

$$E(u'_z) = \langle u'_z \rangle = 0$$



# Penman

## Eddy covariantie

## Reynoldse splitsing

$$u_z = \bar{u}_z + u'_z$$

$$q = \bar{q} + q'$$

$$\langle u_z \cdot q \rangle = \langle u'_z \cdot q' \rangle$$

Covariantie

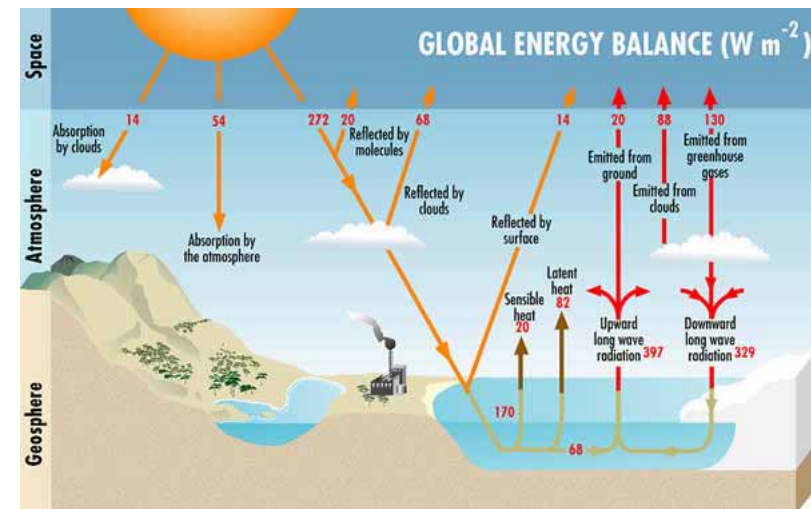


# Penman

## Referentie verdamping

$$R_n = H + \lambda E + G \quad \text{W/m}^2$$

## Energie balans



# Penman

## Referentie verdamping

$$R_n = H + \lambda E + G \quad \text{W/m}^2$$

### Energie balans

$$1 \text{ W/m}^2 = 0.036 \text{ mm/d}$$

$$1 \text{ mm/d} = 28 \text{ W/m}^2$$

$$(\lambda = 2445 \text{ kJ/kg})$$

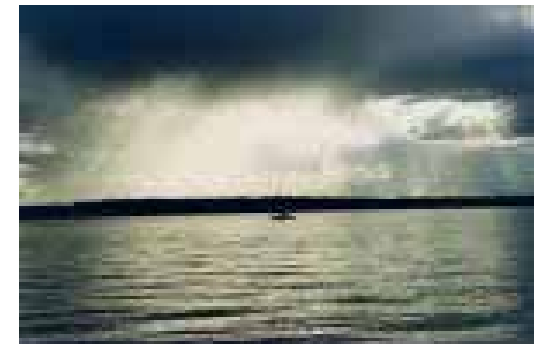
# Penman

## Referentie verdamping

$$R_n = R_S^\downarrow + R_S^\uparrow + R_L^\uparrow + R_L^\downarrow$$

$$R_n = R_S^\downarrow (1 - \alpha) + \varepsilon_m (R_L^\downarrow - \sigma T^4)$$

## Netto straling





# Penman

## Referentie verdamping

$$R_n = R_S^\downarrow + R_S^\uparrow + R_L^\downarrow + R_L^\uparrow$$

$$R_n = R_S^\downarrow (1 - \alpha) + \varepsilon_m (R_L^\downarrow - \sigma T^4)$$

## Netto straling

W/m<sup>2</sup>



# Penman

## Referentie verdamping

$$R_n = R_S^\downarrow + R_S^\uparrow + R_L^\downarrow + R_L^\uparrow$$

$$R_n = R_S^\downarrow (1 - \alpha) + \varepsilon_m (R_L^\downarrow - \sigma T^4)$$

## Netto straling



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# Penman

## Warmte en vocht transport

$$H = c_1 (T_0 - T_A) \cdot \varphi(u)$$

$$E = c_2 (e_0^* - e_A) \cdot \varphi'(u)$$

Neem aan:

$$\varphi'(u) = \varphi(u)$$

$$\beta \equiv H / E$$



Credit: Kidzone Fun Facts

# Penman

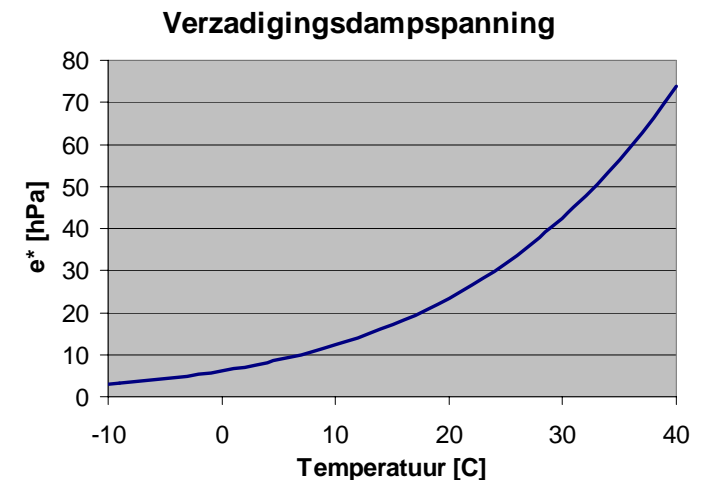
## Warmte en vocht transport

$$\frac{H}{E} = \frac{c_1 (T_0 - T_A)}{c_2 (e_0^* - e_A)} \cdot \frac{\cancel{\varphi(u)}}{\cancel{\varphi'(u)}}$$

verder:

$$c_1 / c_2 = \gamma = 0.67 \quad \text{mbar} / K$$

## psychrometer

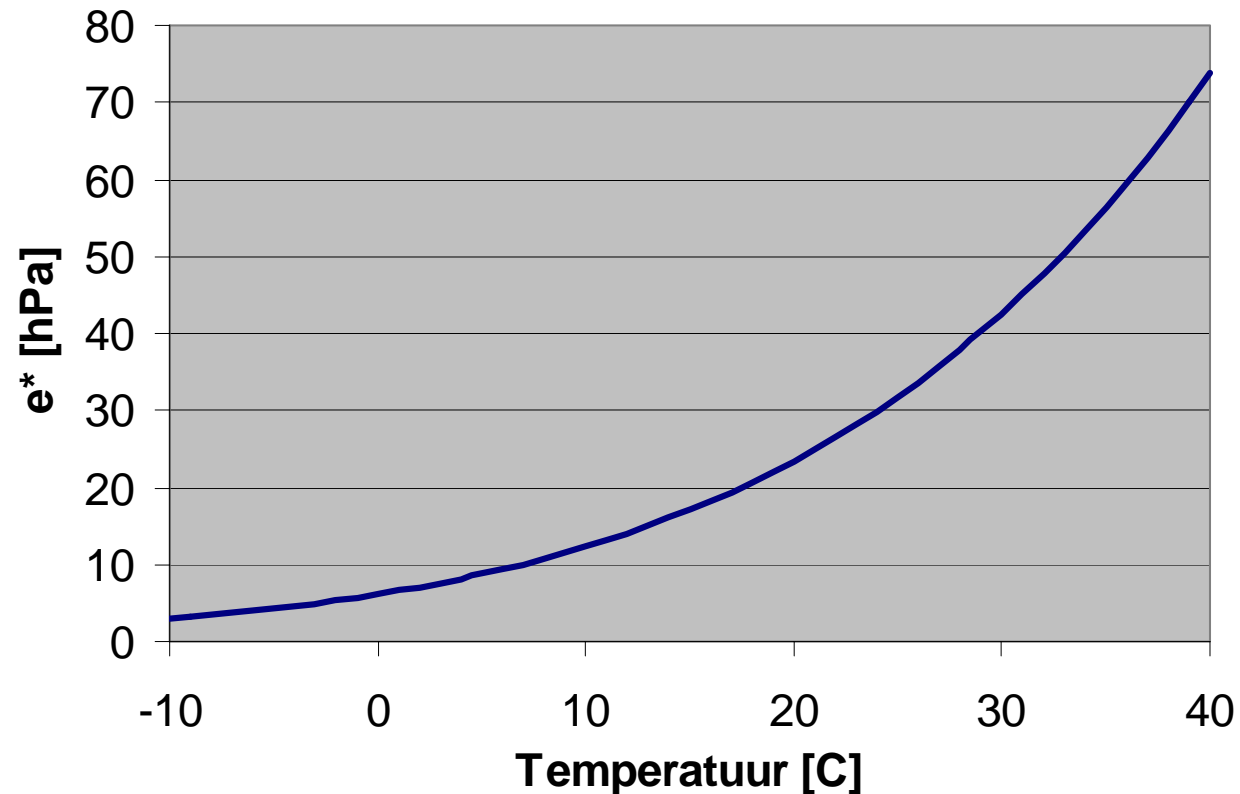


# Penman

$$c_1 / c_2 = \gamma = 0.67 \quad \text{mbar} / K$$

## Psychrometer

### Verzadigingsdampspanning



**B**

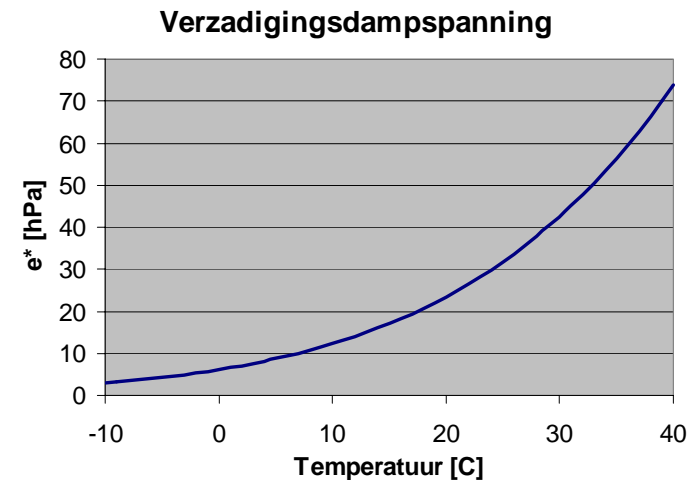
# Penman

## Warmte en vocht transport

$$\frac{H}{E} = \gamma \frac{(T_0 - T_A)}{(e_0^* - e_A)}$$

verder:

$$\Delta \equiv \left. \frac{de^*}{dT} \right|_{T=T_A} \approx \frac{e_0^* - e_A^*}{T_0 - T_A}$$

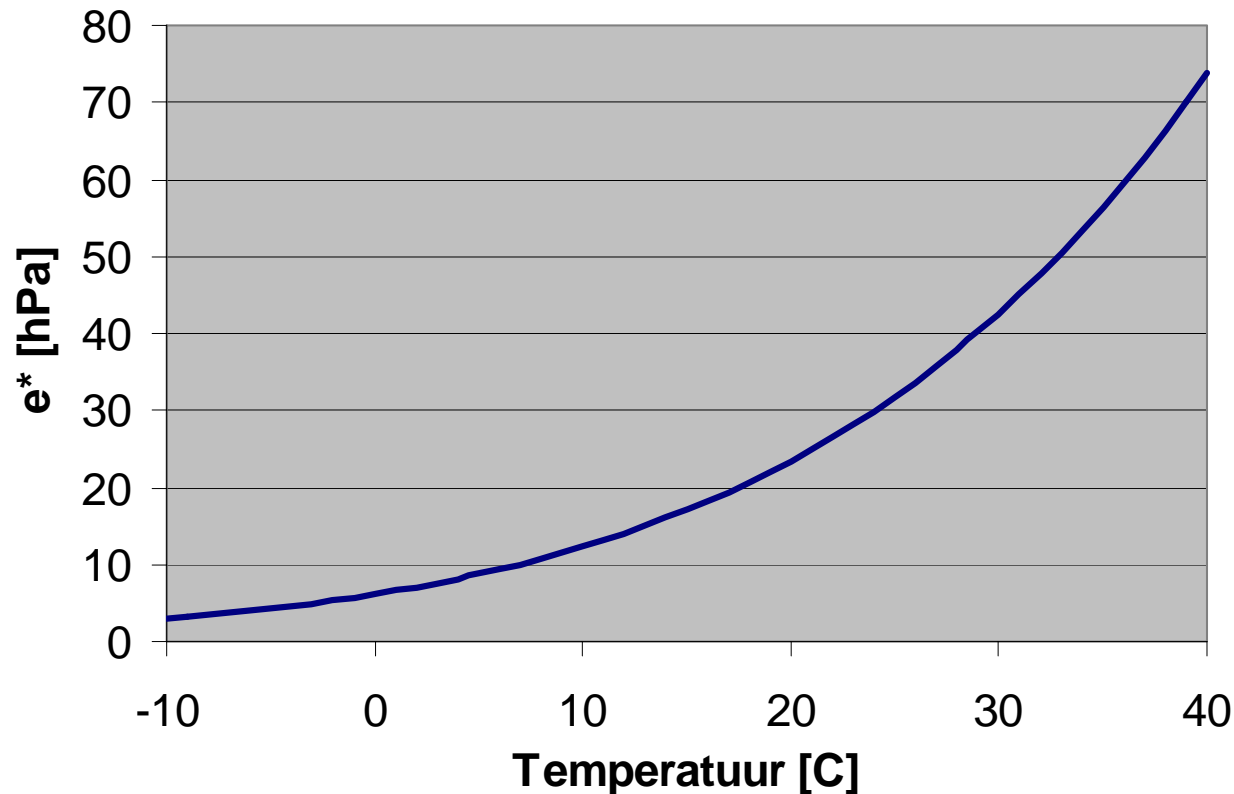


# Penman

$$\Delta \equiv \left. \frac{de^*}{dT} \right|_{T=T_A} \approx \frac{e_0^* - e_A^*}{T_0 - T_A}$$

# Psychrometer

## Verzadigingsdampspanning



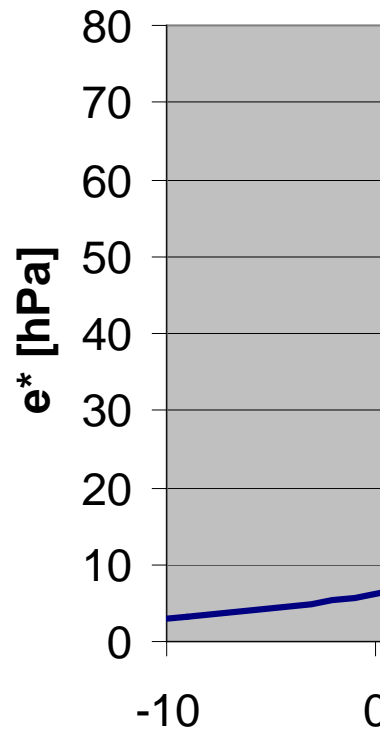
**B**

# Penman

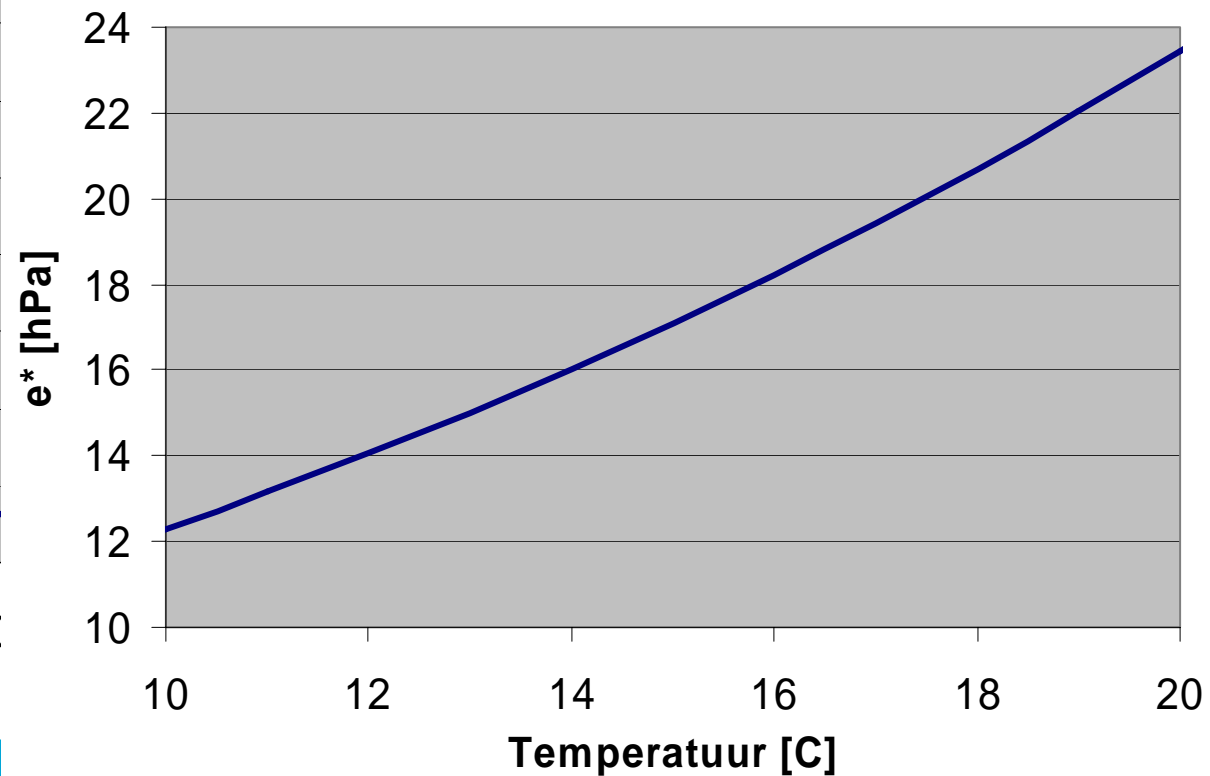
$$\Delta \equiv \left. \frac{de^*}{dT} \right|_{T=T_A} \approx \frac{e_0^* - e_A^*}{T_0 - T_A}$$

# Psychrometer

## Verzadigingsdampspanning



## Verzadigingsdampspanning





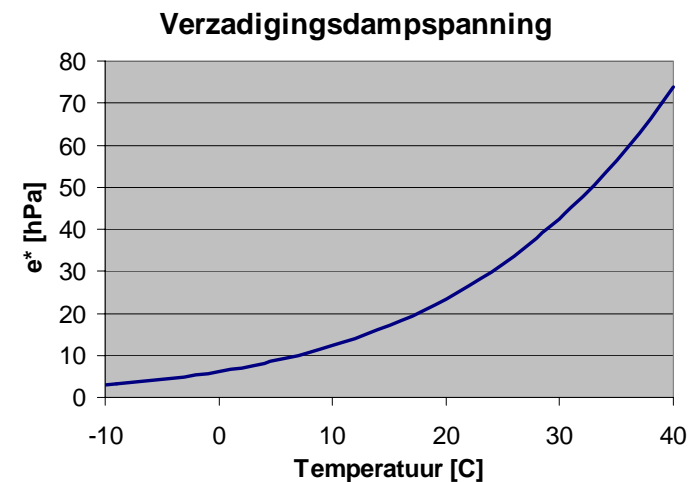
# Penman

## Warmte en vocht transport

$$\frac{H}{E} = \frac{\gamma}{\Delta} \cdot \frac{(e_0^* - e_A^*)}{(T_0 - T_A)} \cdot \frac{(T_0 - T_A)}{(e_0^* - e_A^*)} = \frac{\gamma}{\Delta} \frac{(e_0^* - e_A^*)}{(e_0^* - e_A^*)}$$

$$\frac{H}{E} = \frac{\gamma}{\Delta} \left\{ 1 - \frac{(e_A^* - e_A)}{(e_0^* - e_A)} \right\}$$

**B**



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# Penman

## Warmte en vocht transport

$$\frac{E_I}{E} = \frac{c_2 \cdot (e_A^* - e_A) \cdot \varphi'(u)}{c_2 \cdot (e_0^* - e_A) \cdot \varphi'(u)}$$

of:

$$\frac{H}{E} = \frac{\gamma}{\Delta} \left\{ 1 - \frac{e_A^* - e_A}{e_0^* - e_A} \right\} = \frac{\gamma}{\Delta} \left( 1 - \frac{E_I}{E} \right)$$

# Penman

## Warmte en vocht transport

$$E = \frac{\Delta R_N + \gamma E_I}{\Delta + \gamma}$$

$$E_I = f(u) \cdot (e_A^* - e_A)$$

Penman



Credit: Kidzone Fun Facts

# Penman

## Windfuncties

$$E = \frac{\Delta R_N + \gamma \cdot f(u) \cdot (e_A^* - e_A)}{\Delta + \gamma}$$

$$f(u) = \begin{cases} 0.26(1 + 0.54 \cdot u_{2m}) \\ 0.182 \cdot u_{2m} \\ 53.7 * 10^6 \cdot \frac{\rho K}{P} \cdot \frac{u_z}{(\ln(z / z_0))^2} \\ \dots \end{cases}$$

Penman

Rijtema

Thornthwaite-  
Holzman



# Penman

## Windfuncties

$$E = \frac{\Delta R_N + \gamma \cdot f(u) \cdot (e_A^* - e_A)}{\Delta + \gamma}$$

$$f(u) = \begin{cases} 0.35(0.50 + 0.54 \cdot u_{2m}) & \text{Penman} \\ 0.182 \cdot u_{zm} & \text{Rijtema} \\ 53.7 * 10^6 \cdot \frac{\rho K}{P} \cdot \frac{u_z}{(\ln(z/z_0))^2} & \text{Thornthwaite-} \\ \dots & \text{Holzman} \end{cases}$$



# Penman

## Overzicht afleiding

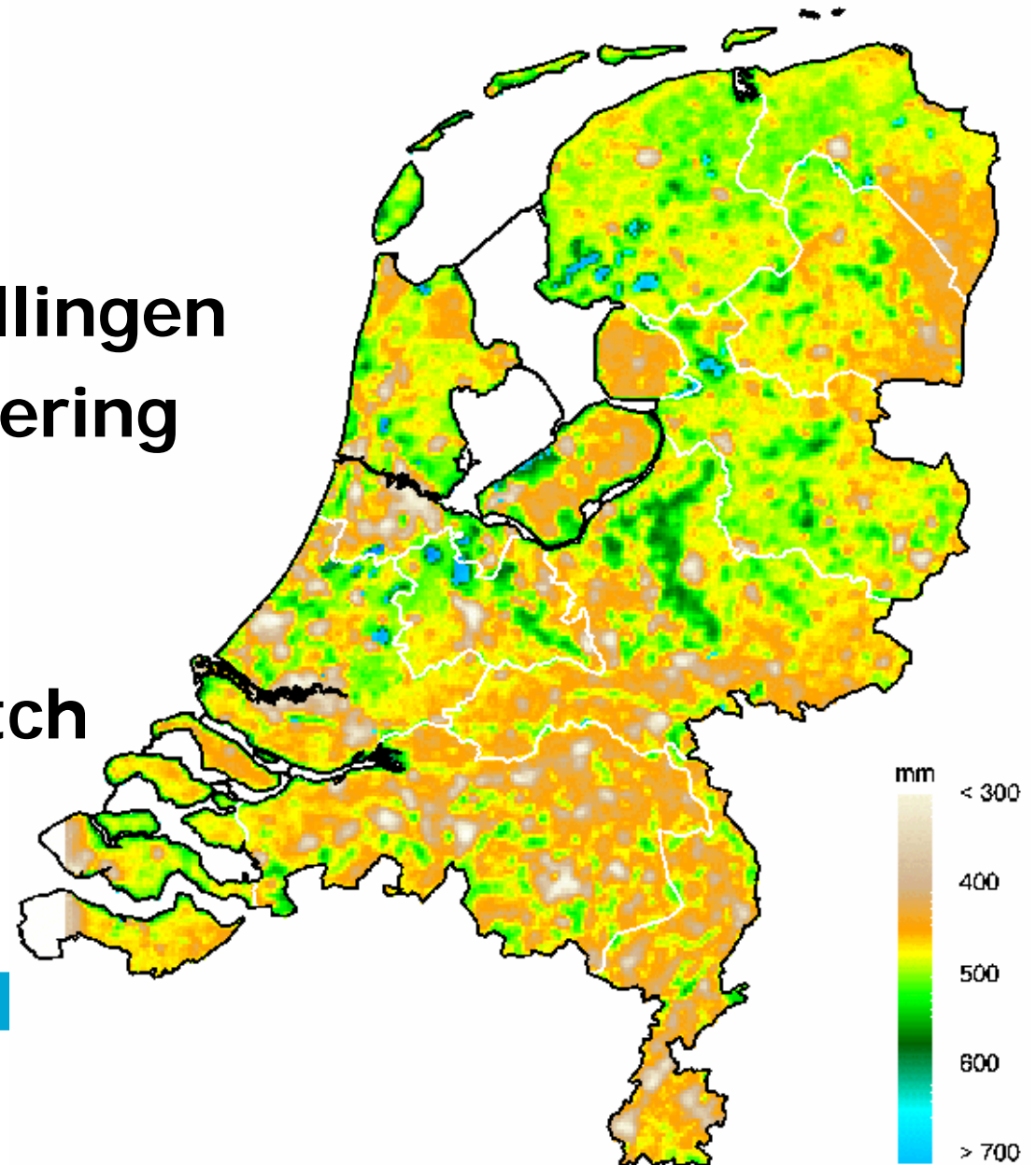
1.  $H/E$       $(\varphi' = \varphi)$
2.  $\gamma$
3.  $\Delta$
4.  $E_I = f(u)(e_a^* - e_a)$
5. Algebra  $\Rightarrow E = \Delta R_n + \gamma E_I / (\Delta + \gamma)$

# Penman

## Klassiek

- Irrigatie
- Weersvoorspellingen
- Klimaatmodellering
- Satellieten

SEBAL, WaterWatch



# CT3011: Inleiding watermanagement

## Irrigatie:

1. Irrigatie systeem
2. Proefje / waarom verdamping?
3. Penman
- 4. Waterbehoefte**
5. Management

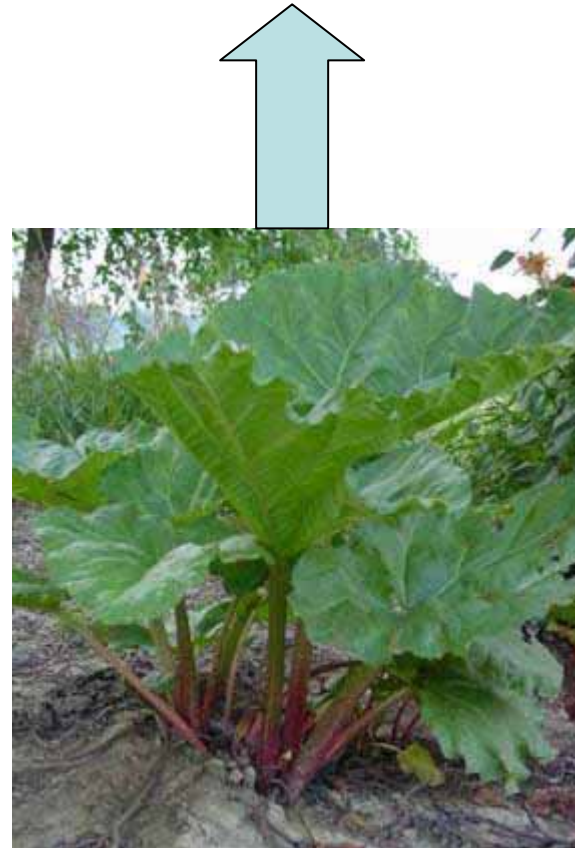




# Waterbehoefte

## Actuele verdamping

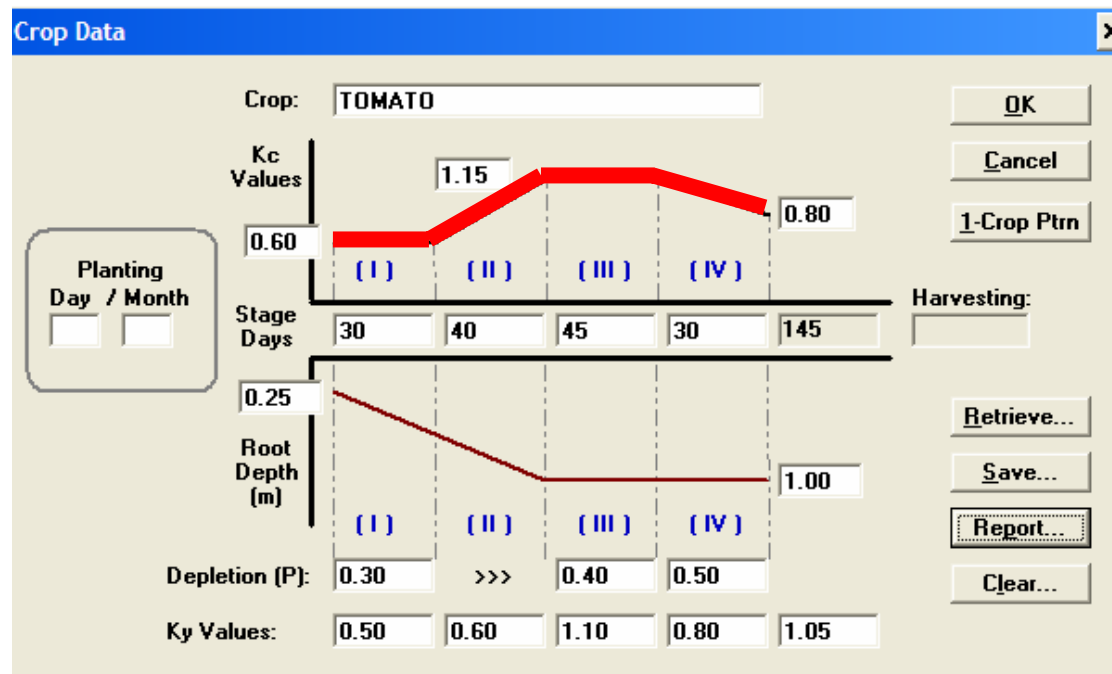
- Gewasfactoren
- Bodemfactoren



# Waterbehoefes

## Actuele verdamping

- Gewasfactoren



# Waterbehoefte

## Actuele verdamping

Bodemfactoren

1. Wortelzone diepte
2. Field capacity
3. Readily available soil moisture
4. Wilting point

# Waterbehoefte

## Actuele verdamping

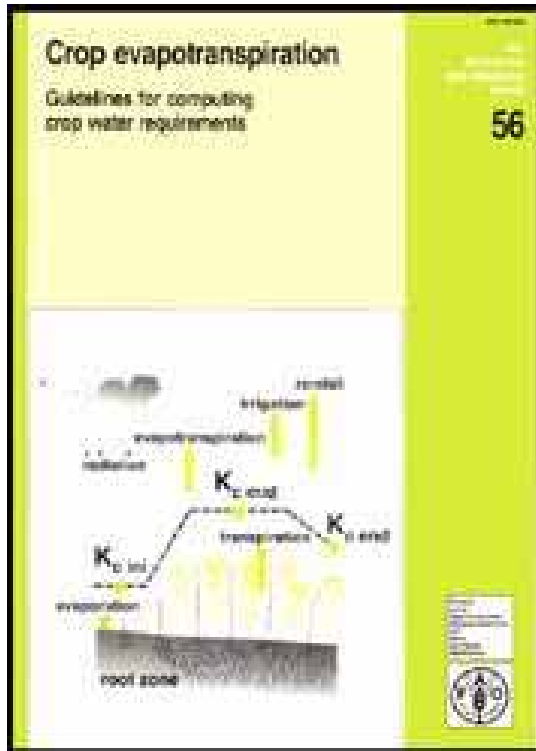
Bodemfactoren

$$S = 1 \quad \left( \Theta_{FC} < \Theta < \Theta_{RAM} \right)$$

$$S = 1 - \frac{\Theta_{RAM} - \Theta}{\Theta_{RAM} - \Theta_{WP}} \quad \left( \Theta < \Theta_{RAM} \right)$$

# Waterbehoefte

## Actuele verdamping

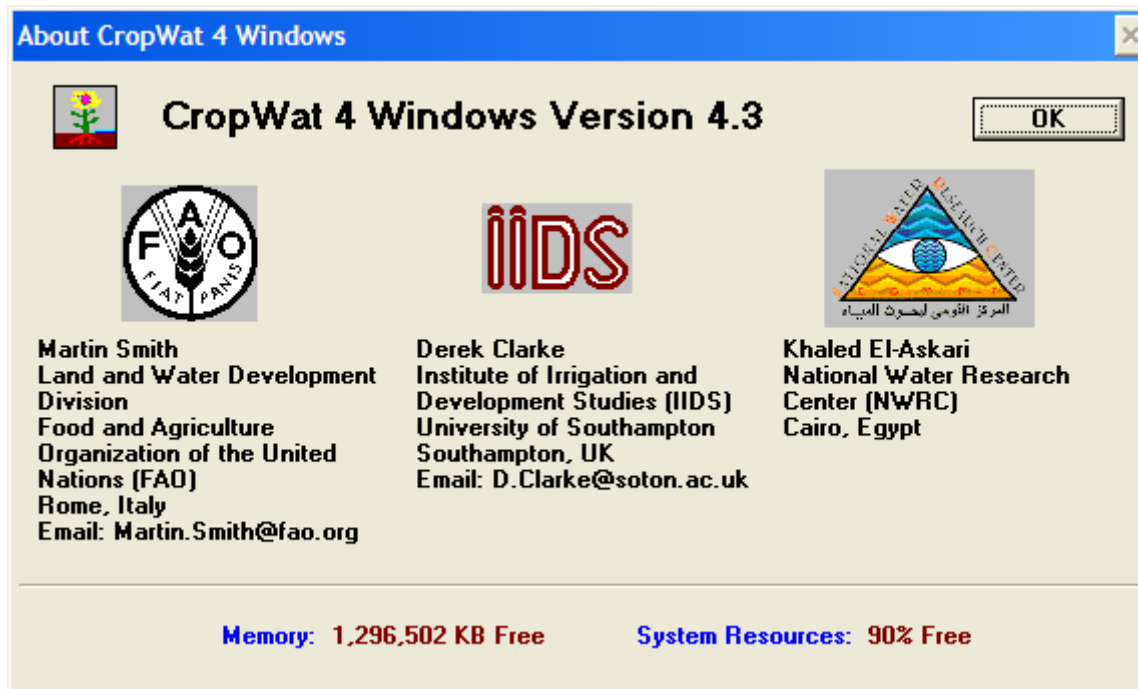


**FAO 56**

# Waterbehoefte

## Actuele verdamping

$$E_a = \frac{\Theta - \Theta_{wp}}{\Theta_{fc} - \Theta_{wp}} \cdot K_C \cdot E_0$$



# CT3011: Inleiding watermanagement

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# Management

## Waarom belangrijk...



**Joshua Faulkner**  
**Ghana**



# Management

## Waarom belangrijk...

Joshua Faulkner  
Ilja van Kinderen



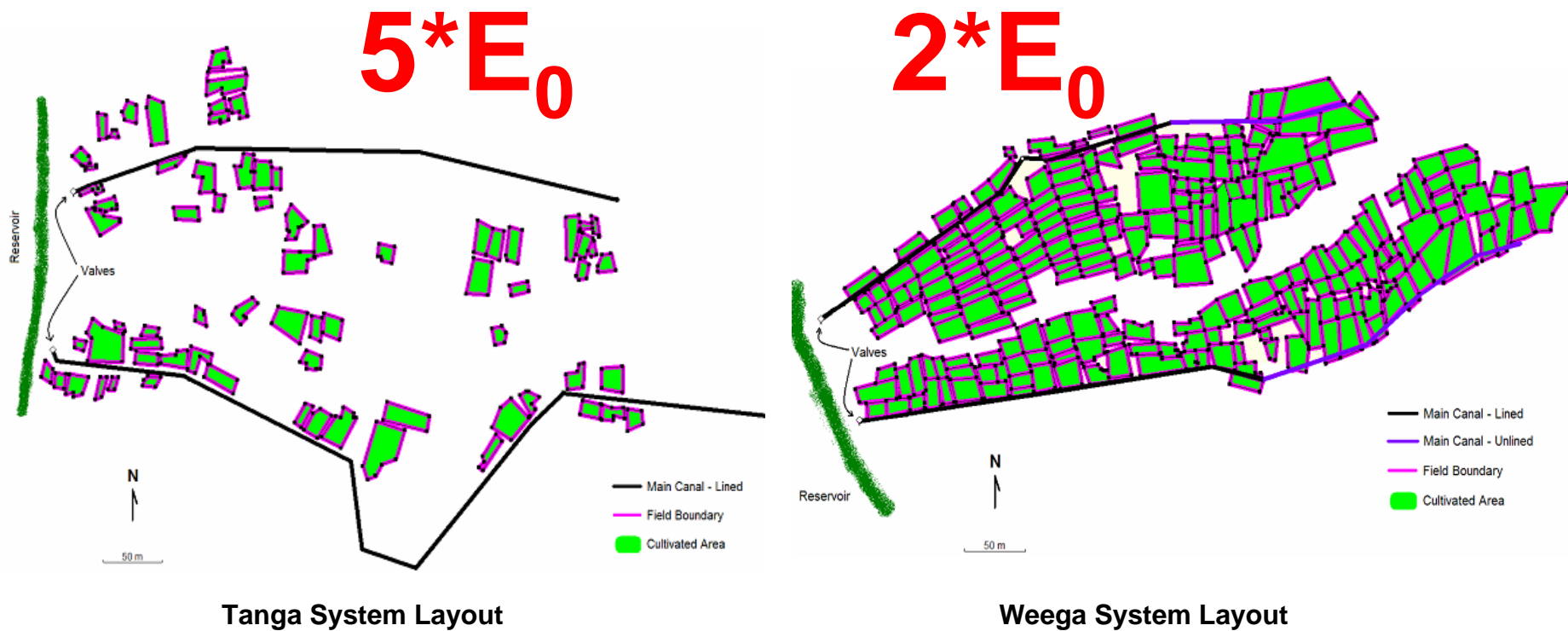
Tanga System Layout



Weega System Layout

# Management

Waarom belangrijk...



# Management

## Scheduling

**Efficientie  
Productie**    ⇔    **Management  
kosten**

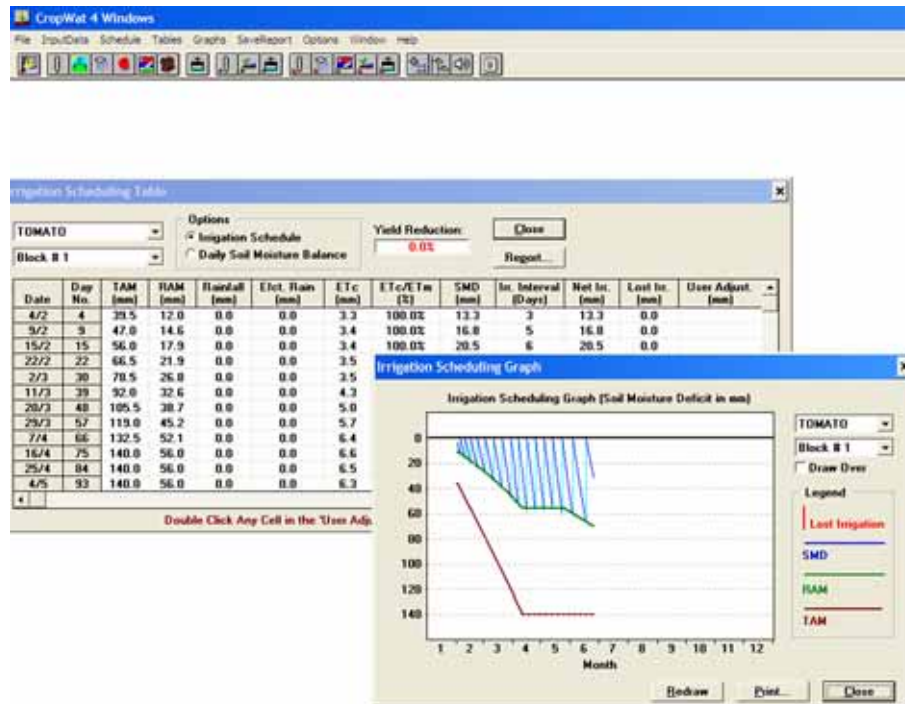


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# Management

## Scheduling

CropWat



# Management

## Scheduling

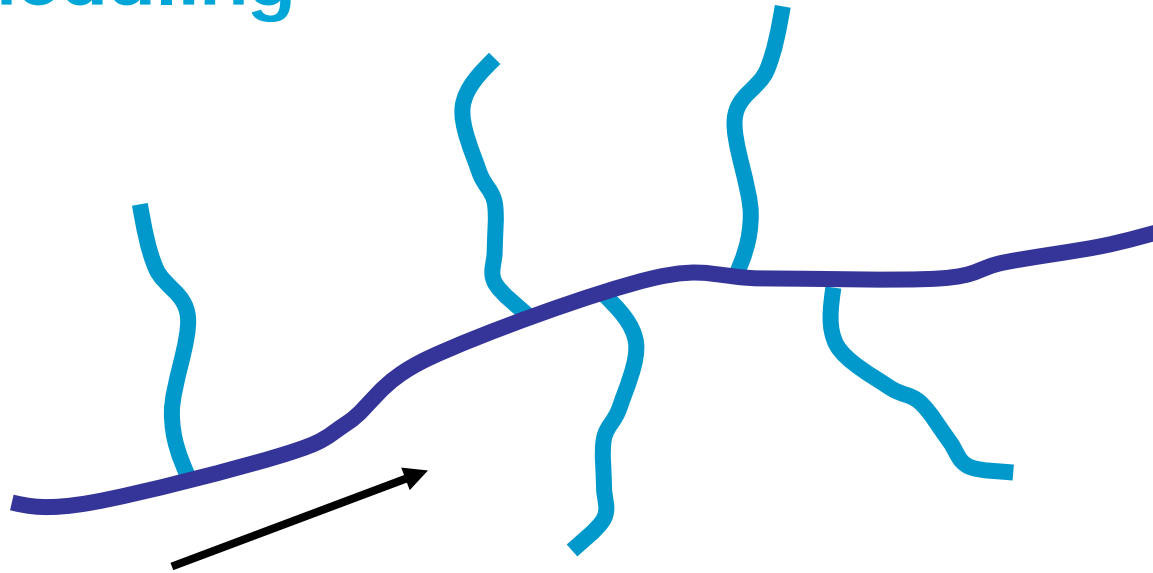


LTRIS – UPRIIS – Luzon - Filippijnen

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# Management

## Scheduling



LTRIS – UPRIIS – Luzon - Filippijnen

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# Management

## Scheduling



LTRIS – UPRIIS – Luzon - Filippijnen

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# Management

## Scheduling



LTRIS – UPRIIS – Luzon - Filippijnen

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# Management

## Scheduling



LTRIS – UPRIIS – Luzon - Filippijnen

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CT3011 4: Irrigatie

# Management

## Scheduling



LTRIS – UPRIIS – Luzon - Filippijnen

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# Management

## Scheduling



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# Management

## Scheduling



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# Proefje

## Resultaten

### Lysimeter

# Proefje

## Resultaten

## Penman