Strategie per l’adeguamento dei sistemi agricoli alla variabilità della risorsa idrica

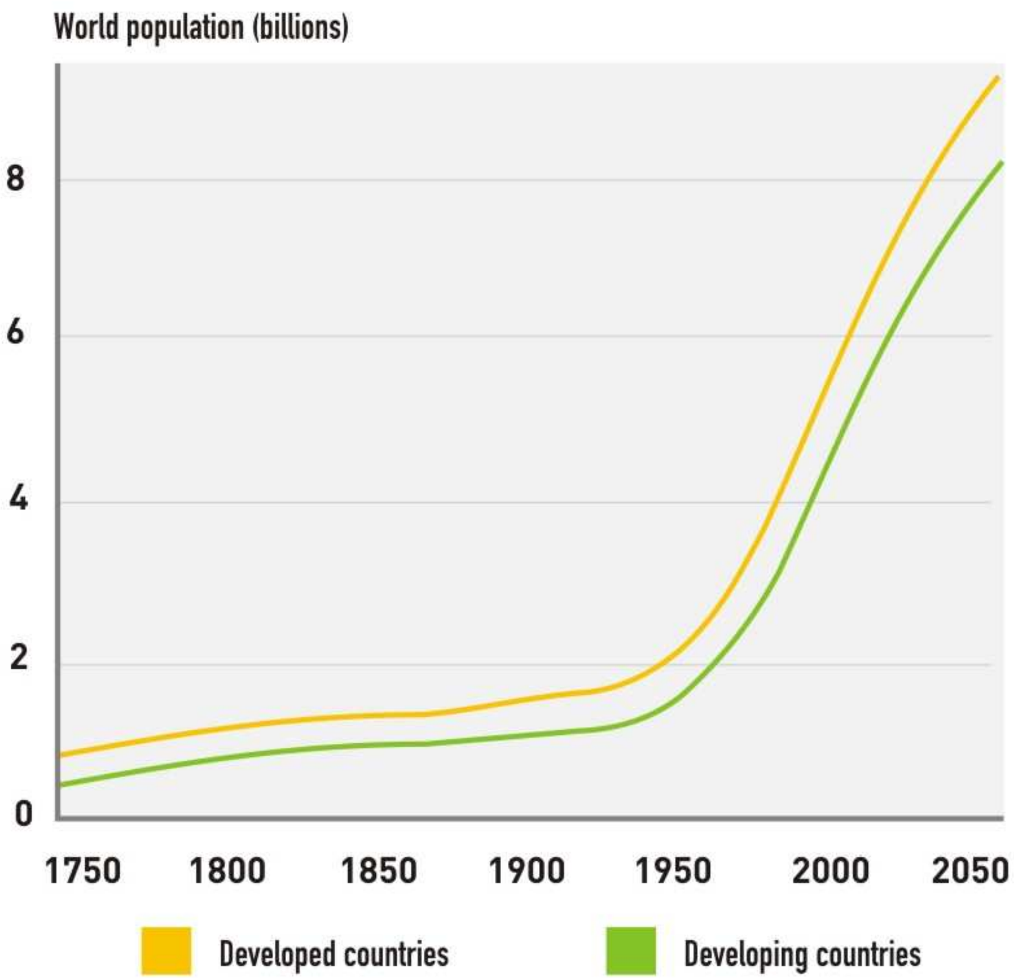
Paola Rossi Pisa

Università di Bologna

Problems focusing

- L'agricoltura e la produzione alimentare dipendono dalla disponibilità idrica. *(Jagtap and Jones, 1989; FAO, 2002)*
- L'aumento della popolazione mondiale richiede più cibo e quindi più acqua(FAO, 2003; OECD, 2008)
- Il cambiamento climatico può far variare la disponibilità idrica in molte aree del globo (Roderick and Farquhar, 2002; Smakthin et al., 2004)
- L'evapotraspirazione (ET) rappresenta la maggiore perdita di acqua. *(Burt et al., 2005; Ventura et al., 2006)*

World population and food production

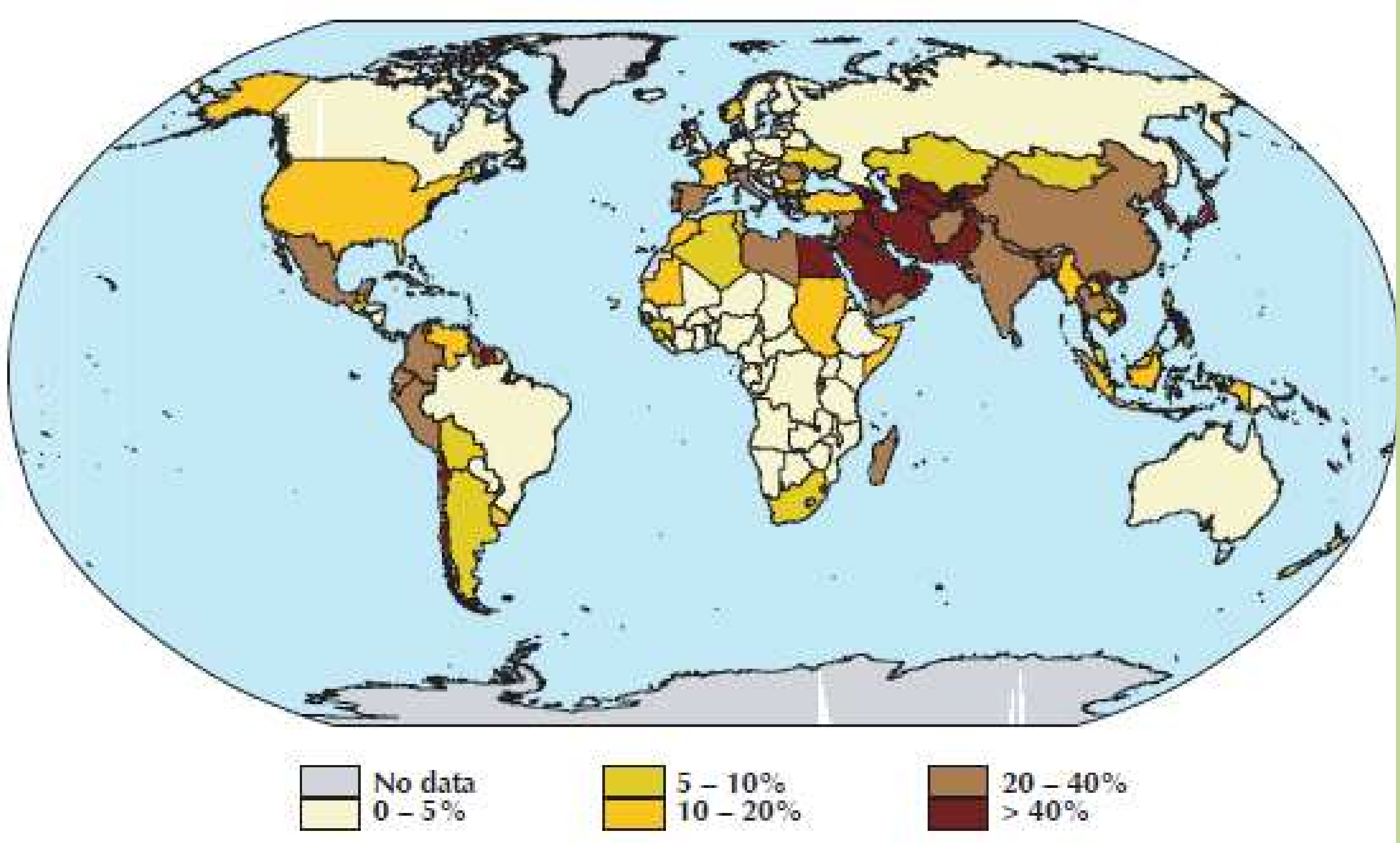


A population of 9 billion and beyond..
..will require a doubling of the food supply

Source, UN Population statistics, Aug 08;

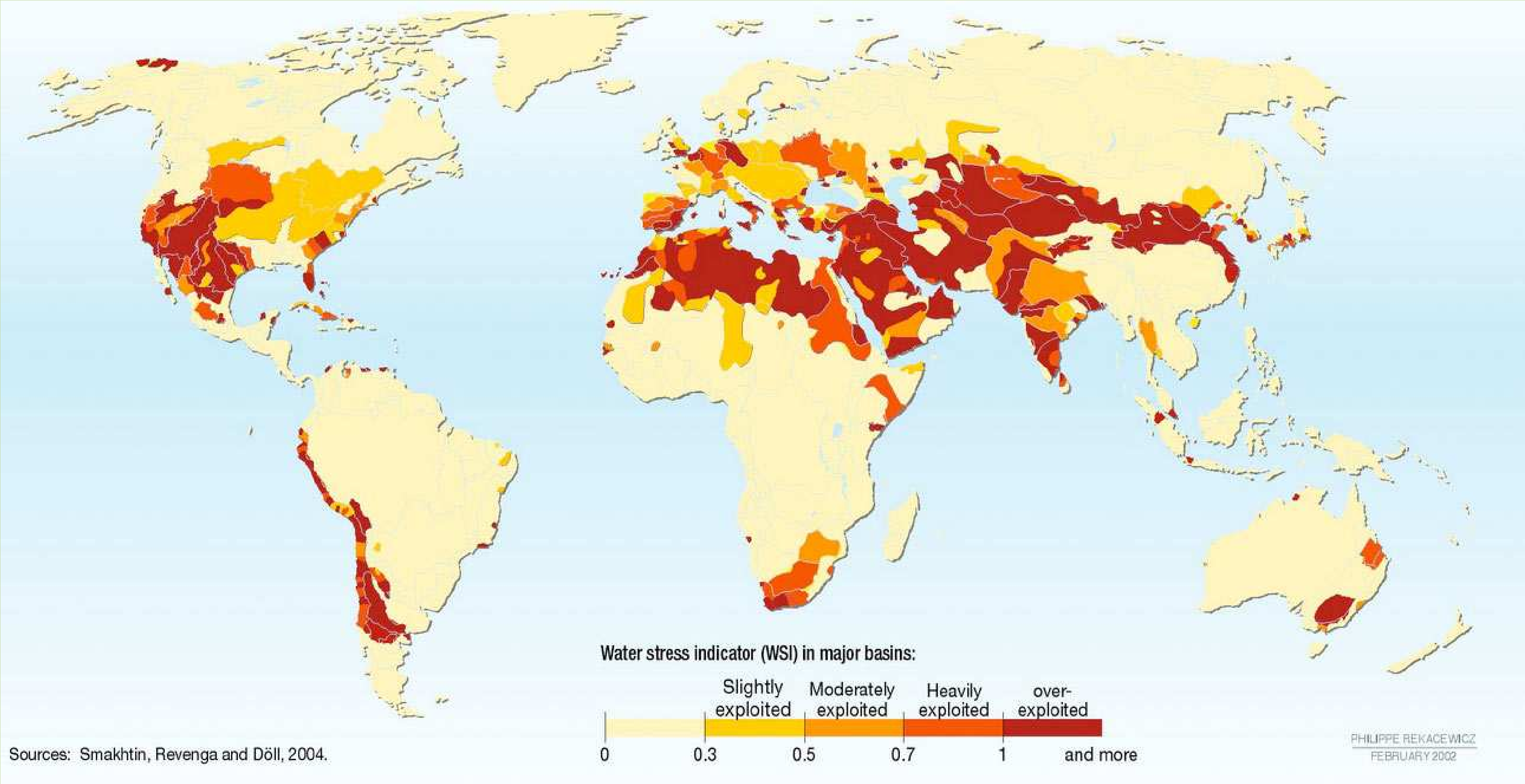
Source OECD (Organization for Economic Co-operation and Development)

Agricoltura e rifornimento idrico



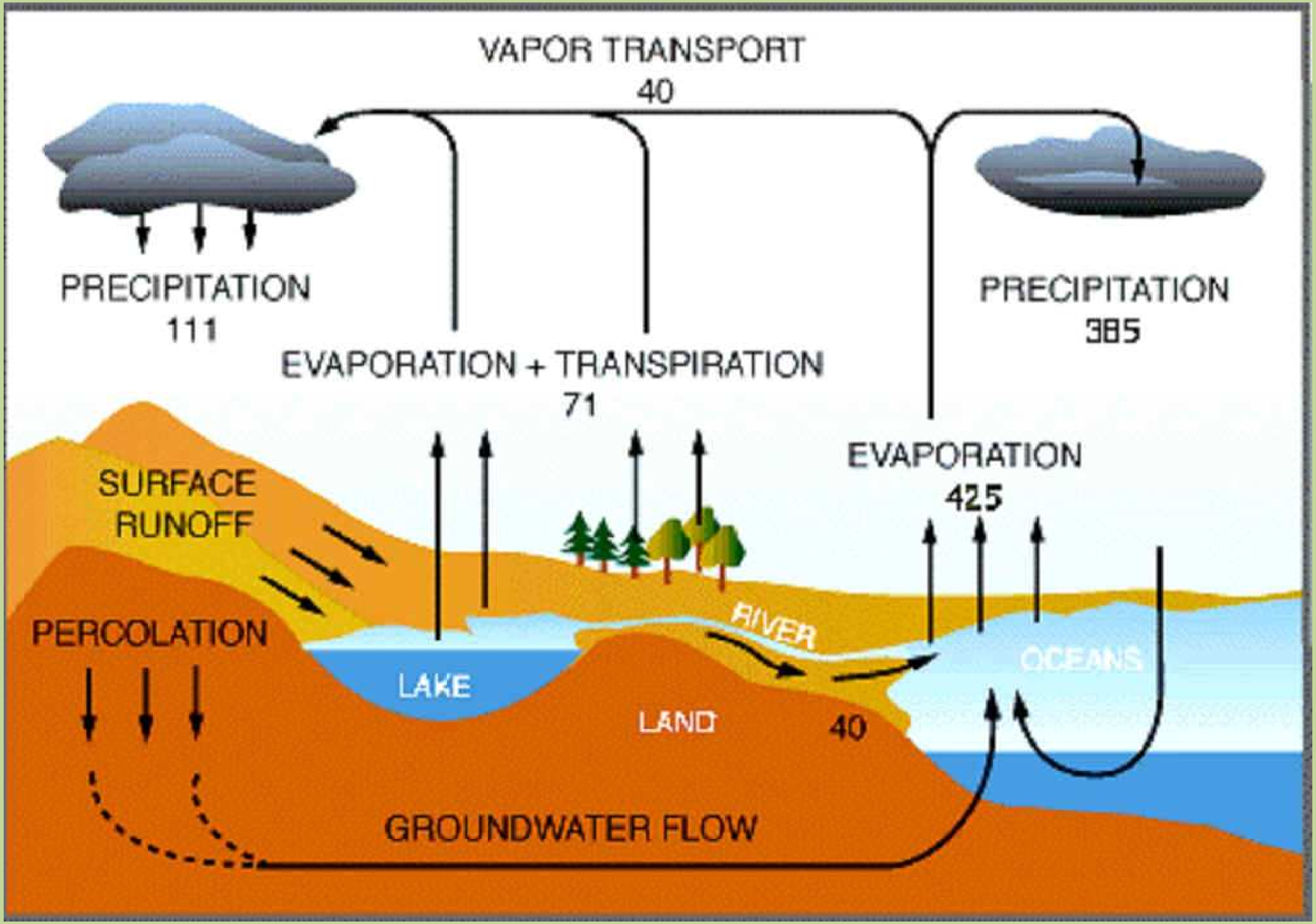
Area equipped for irrigation as percentage of cultivated land by country (1998) *(Source: FAOSTAT 2002)*

Scarsità dell’acqua a livello globale



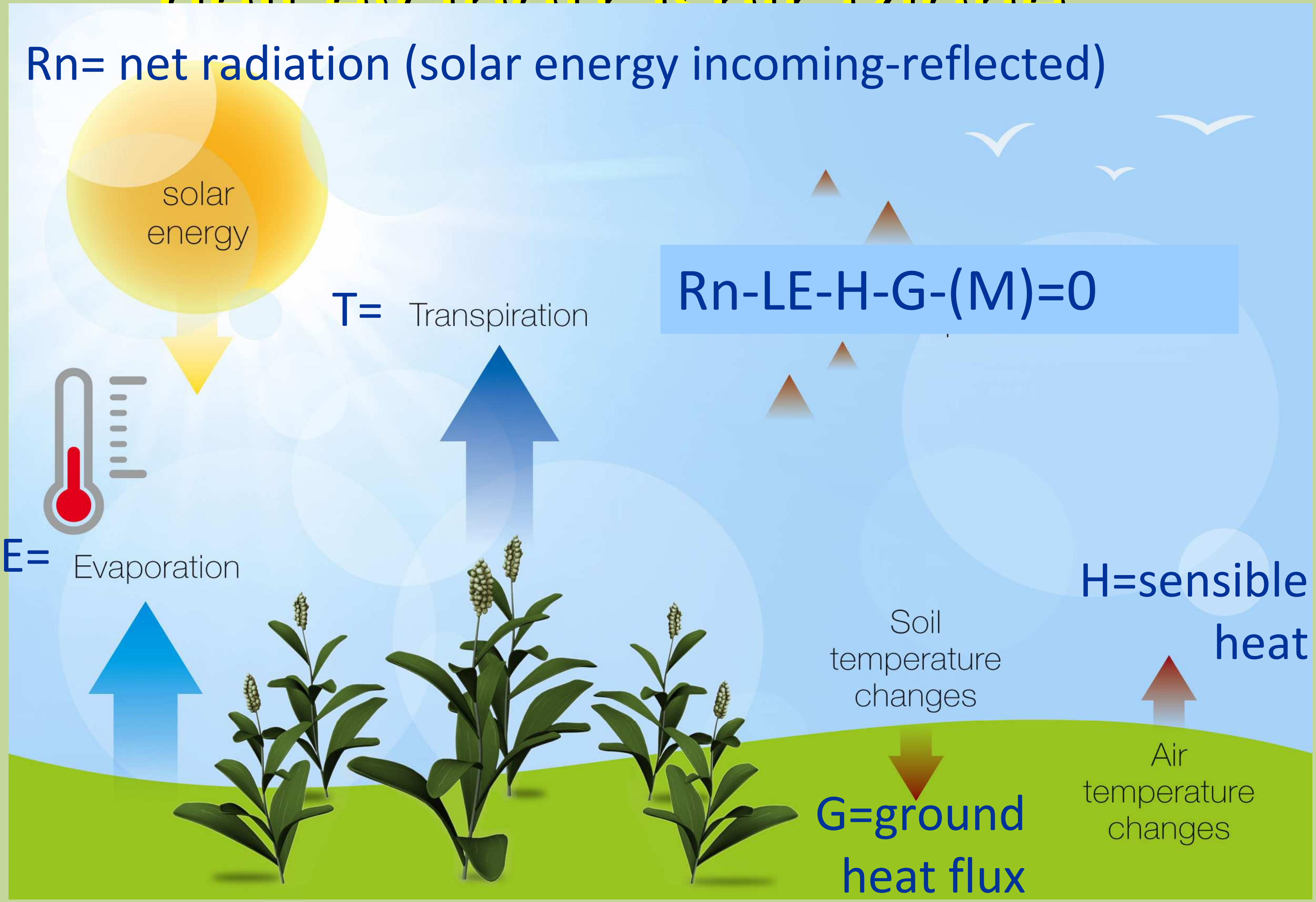
Global patterns of water exploitation, coloured according to water stress indicator (WSI). Illustration: United Nations Environment Programme

Climate and Agriculture: what is the relation?



The Global Water Cycle - Pathways and Fluxes. (Values in 103 km3/yr).

Ruolo dell'evapotraspirazione



Energy balance from irrigated land. Soil evaporation (E) and crop transpiration (T) are the main losses (ET=LE)

Come può essere resa più efficiente la produzione di cibo senza compromettere l'ambiente?

Come può essere migliorata l'efficienza irrigua?

Problemi

- *Criteri di irrigazione basati su ET_c*
- *Et_c dipende da K_c*
- K_c *sono dipendenti dal tempo locale*

Possible solution

Bisogna sviluppare un modello di simulazione di evapotraspirazione che tenga conto dei diversi climi.

1. **Adottare criterio irriguo**
2. **Coefficienti colturali e microclima**
3. **Precipitazioni**
4. **Misure di evapotraspirazione**
5. **Cambiamento climatico**

Esempi internazionali:
In California gli agricoltori che utilizzano il criterio di evapotraspirazione

1986 1.5%

2010 40%

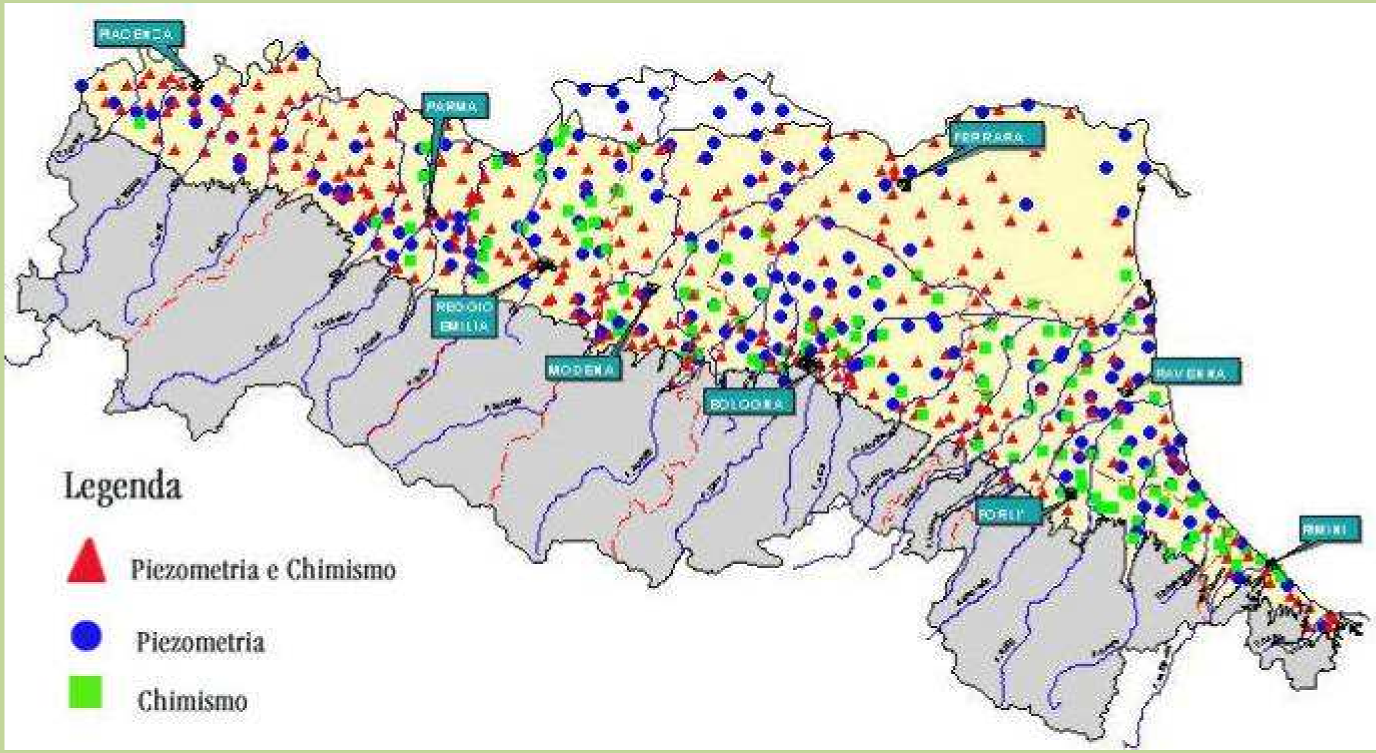
- Reti di misure meteorologiche automatiche

-Database di Et_o e dati meteo

- Migliorare l'efficienza dell'irrigazione

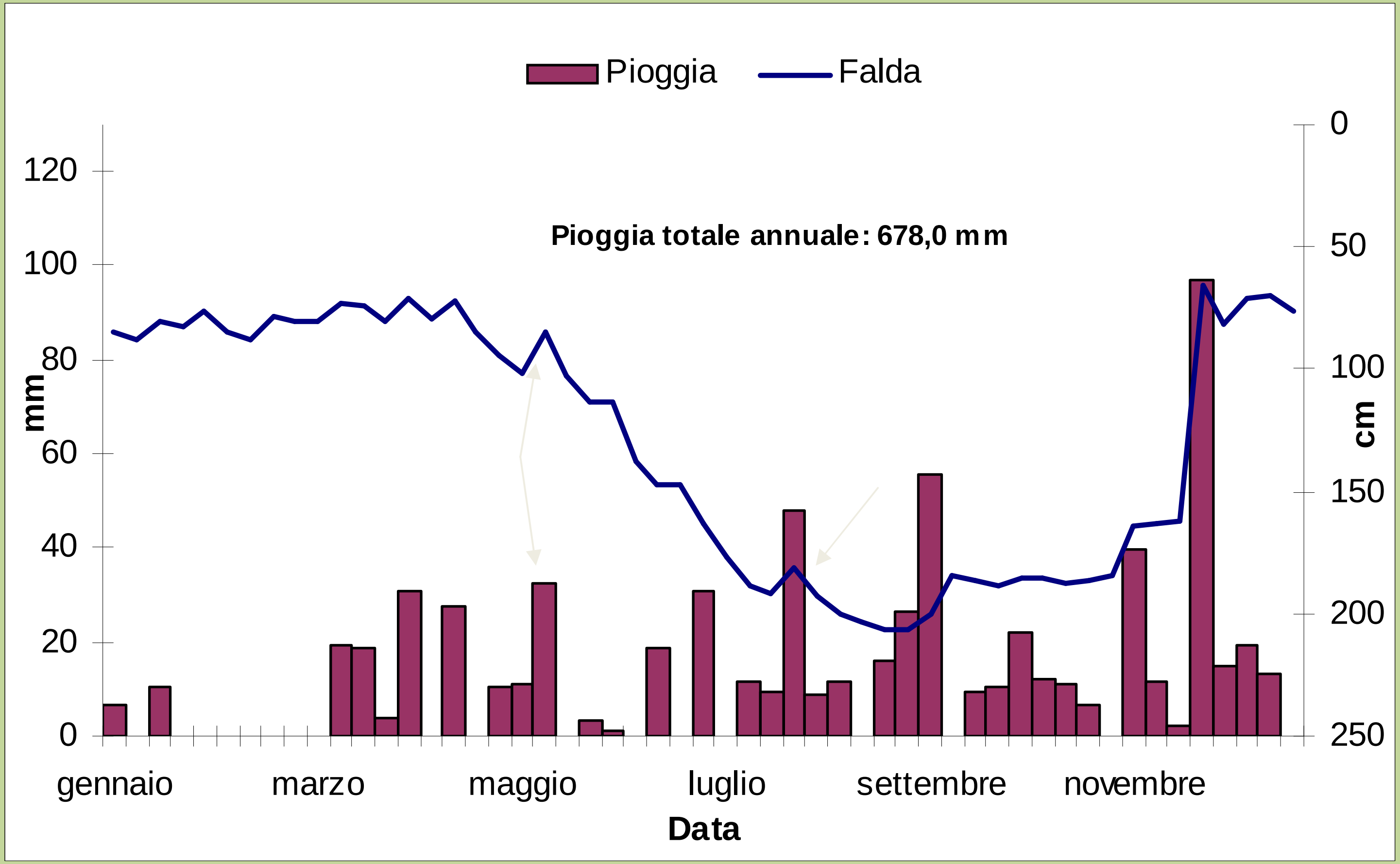
Bilancio Idrico per l’irrigazione

Rilievi di falda



Risultati di un anno

1982

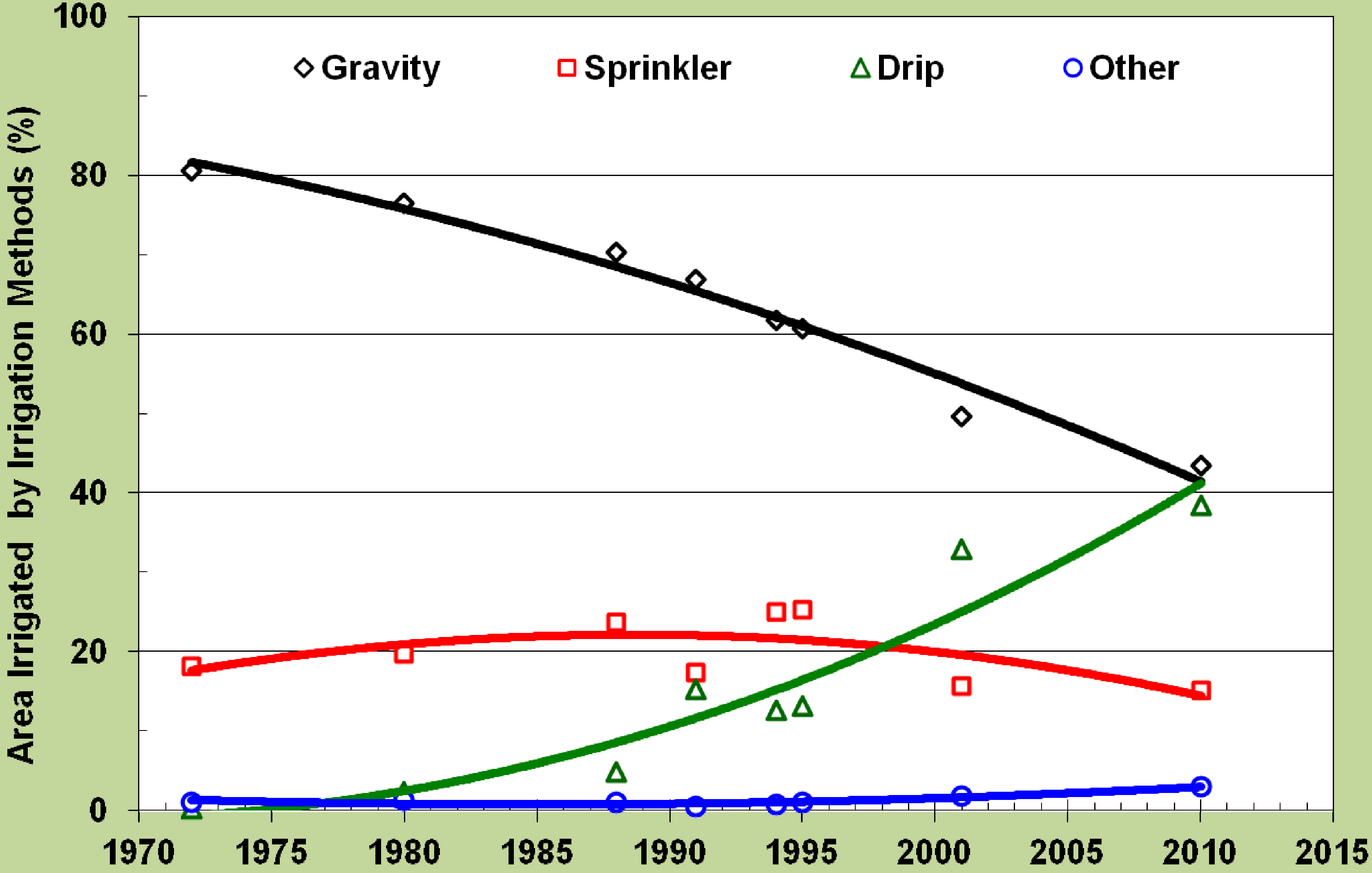


Fattori di impiego

1. Frutteti e vigneti
2. Sistemi irrigui in pressione
3. Problemi di irrigazione
4. Maggiore consapevolezza
5. Agricoltori parlano tra loro
6. Costo locale dell'acqua

Faber and Snyder (1990)

Metodi irrigui



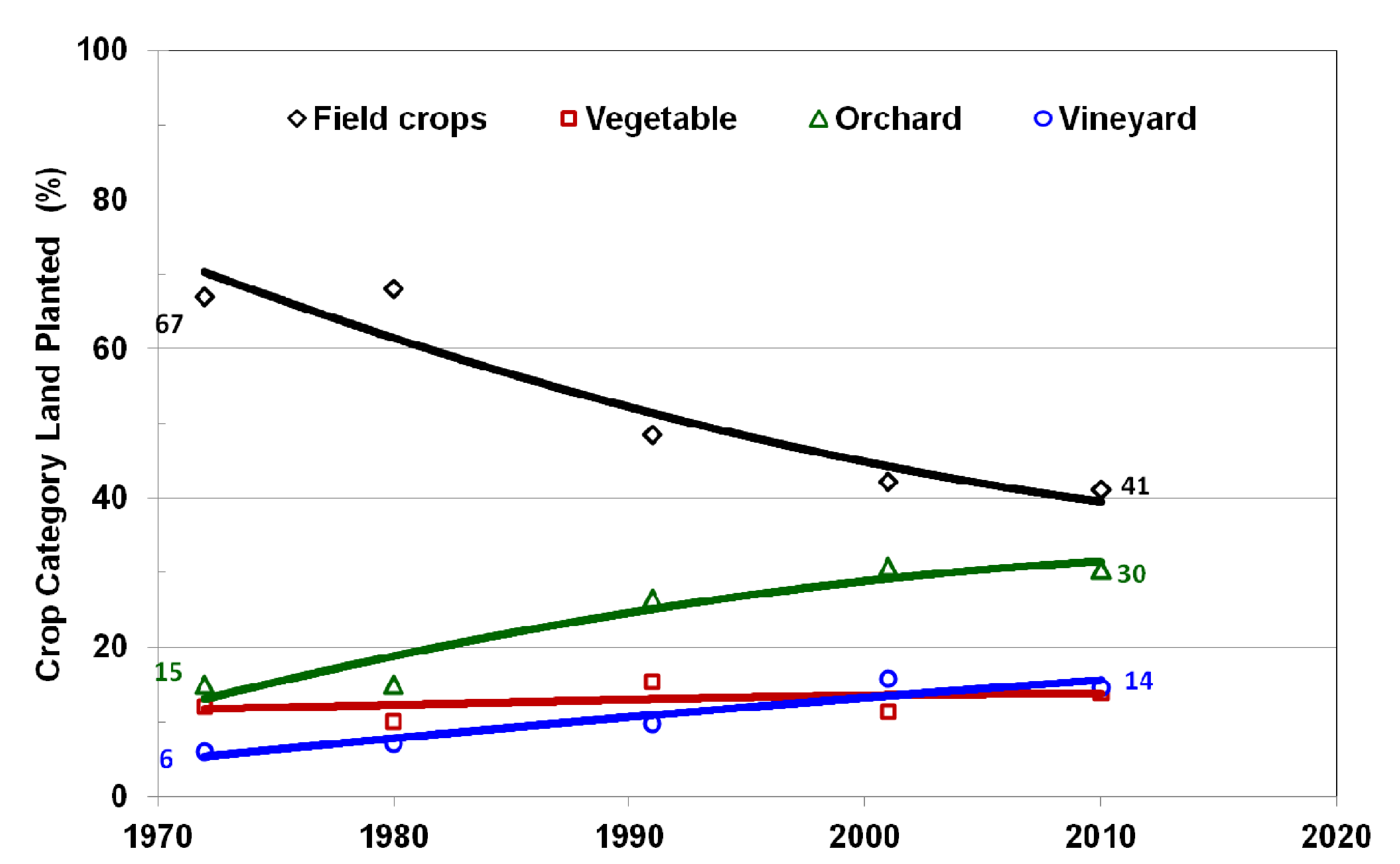
Irrigazione

$$ETE = P + F + I + \Delta\theta - Pr - R$$

Spesso è il risultato del bilancio

Una buona stima della irrigazione tramite bilancio idrico permettere di conservare le risorse e di limitare l'inquinamento per lisciviazione delle acque di falda

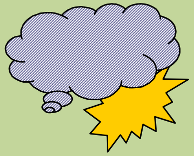
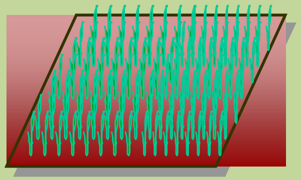
Cambio delle colture



Ragioni per una rete

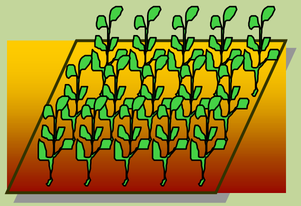
1. Evapotraspirazione
2. Adottare il criterio irriguo
3. Migliorare il sistema
4. Resa delle colture
5. Disponibilità idrica
6. Energia

Evapotraspirazione

 +  = ETo

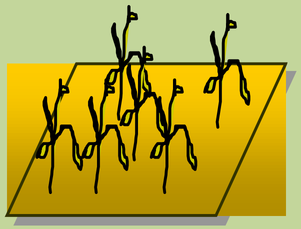
Et_o da dati meteo

K_c

ETo x  = ETc

$$ET_c = ET_o \times K_c$$

K_c x K_s

ETo x  = ETa

$$ET_a = ET_c \times K_s$$

Coefficienti colturali= f(clima)

$$K_c = \frac{ET_c}{ET_o}$$

ET_c - misurato **ET_o - stimato**

Esempio erba medica

Equazione di Penman Monteith

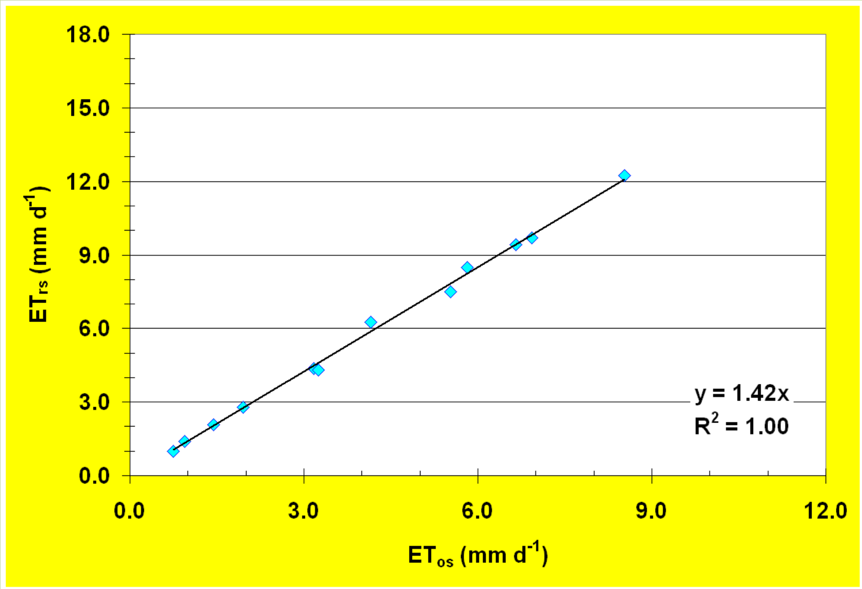
$$LE = \frac{\Delta\left(R_n - G\right) + \rho C_p\left(e_s - e_d\right) r_a^{-1}}{\Delta + \gamma\left(1 + \frac{r_c}{r_a}\right)}$$

Fattori che influenzano il Kc:

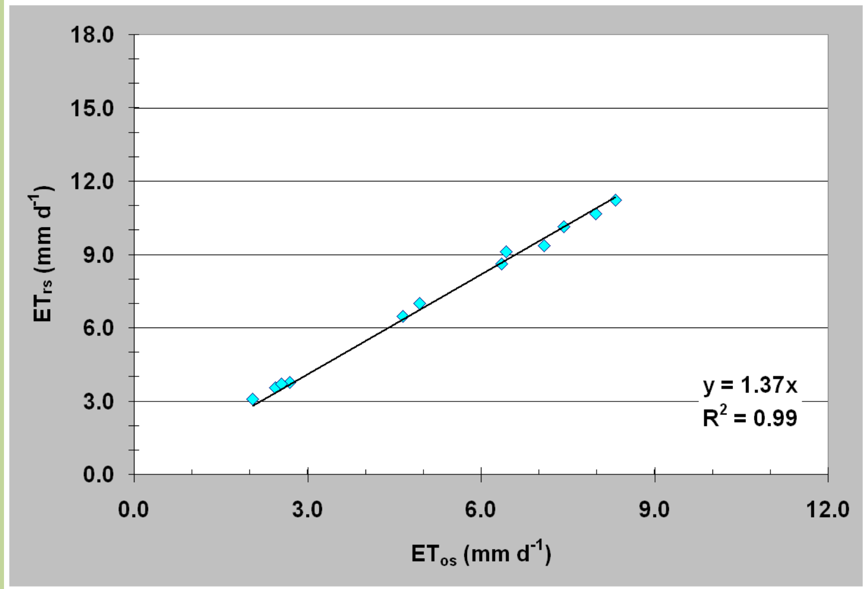
-Radiazione netta (R_n)

-Resistenza aerodinamica (r_a)

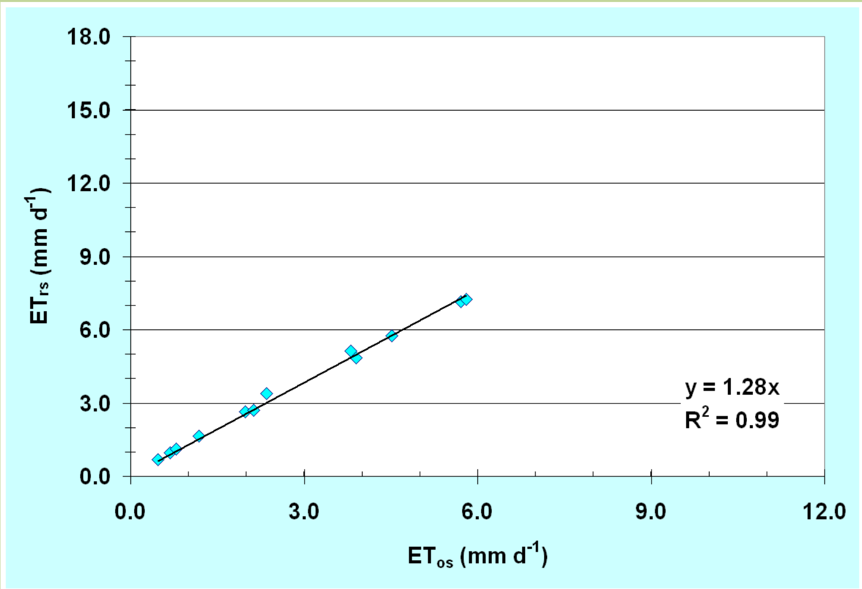
•Resistenza della canopia (r_c)



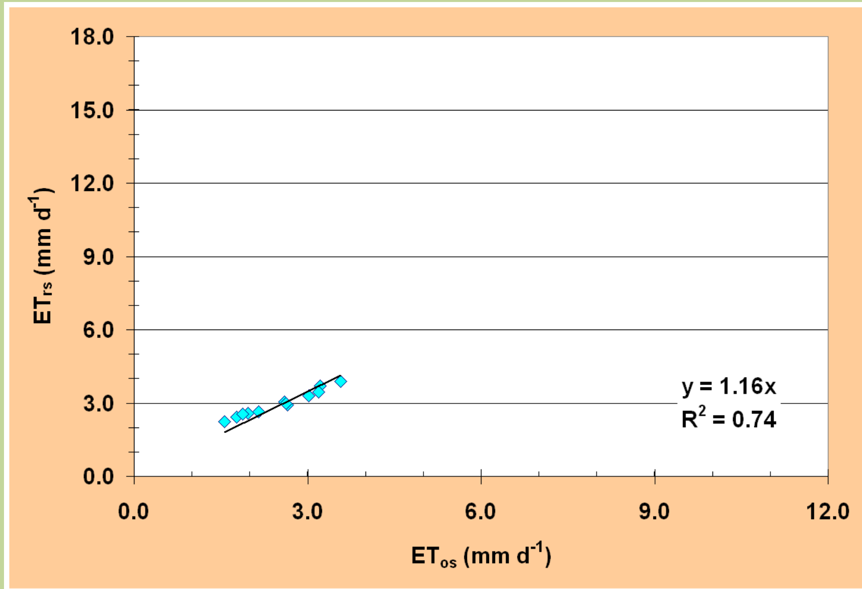
Twitchell Island



Meloland



Tulelake

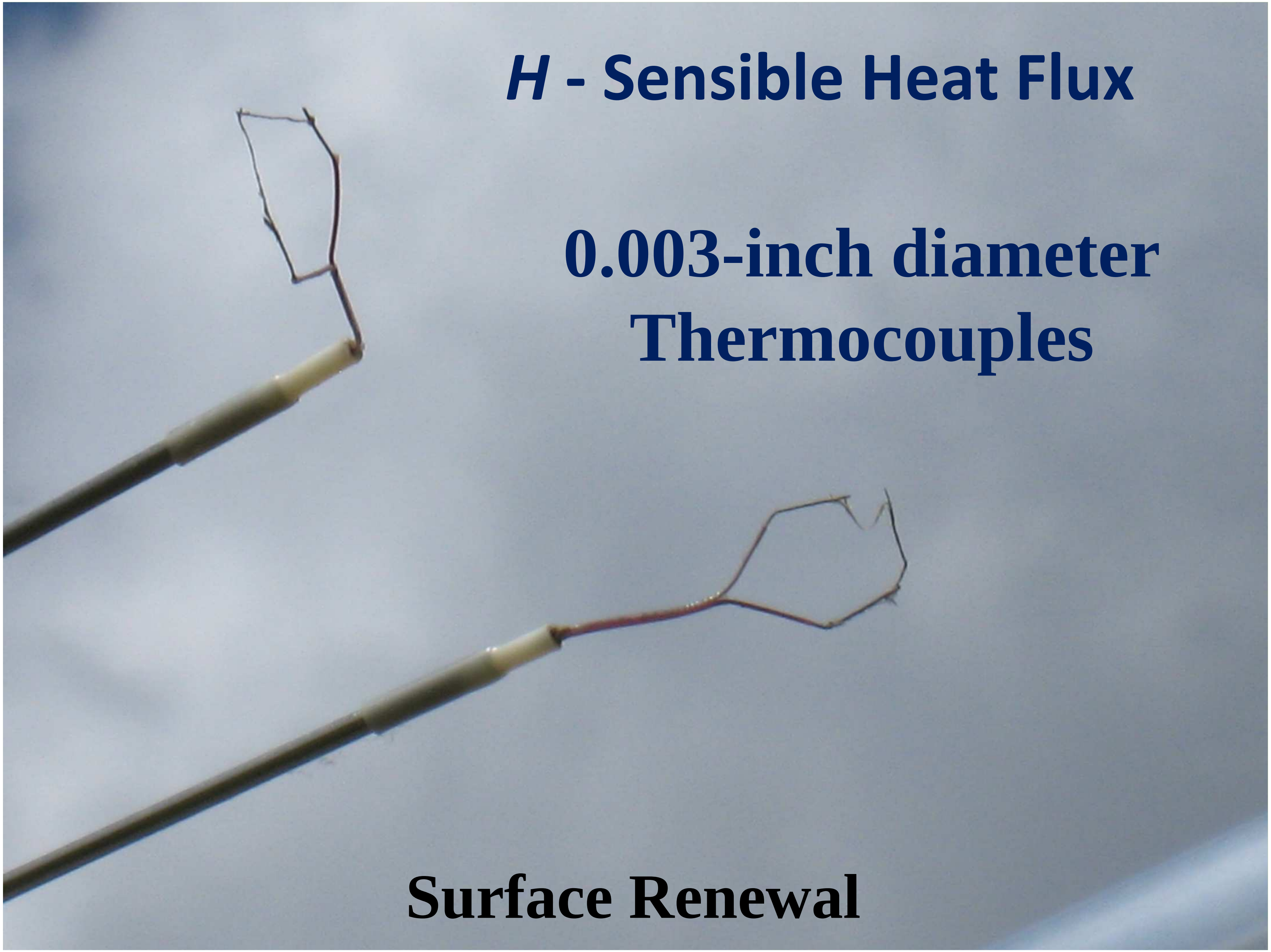


Torrey Pines

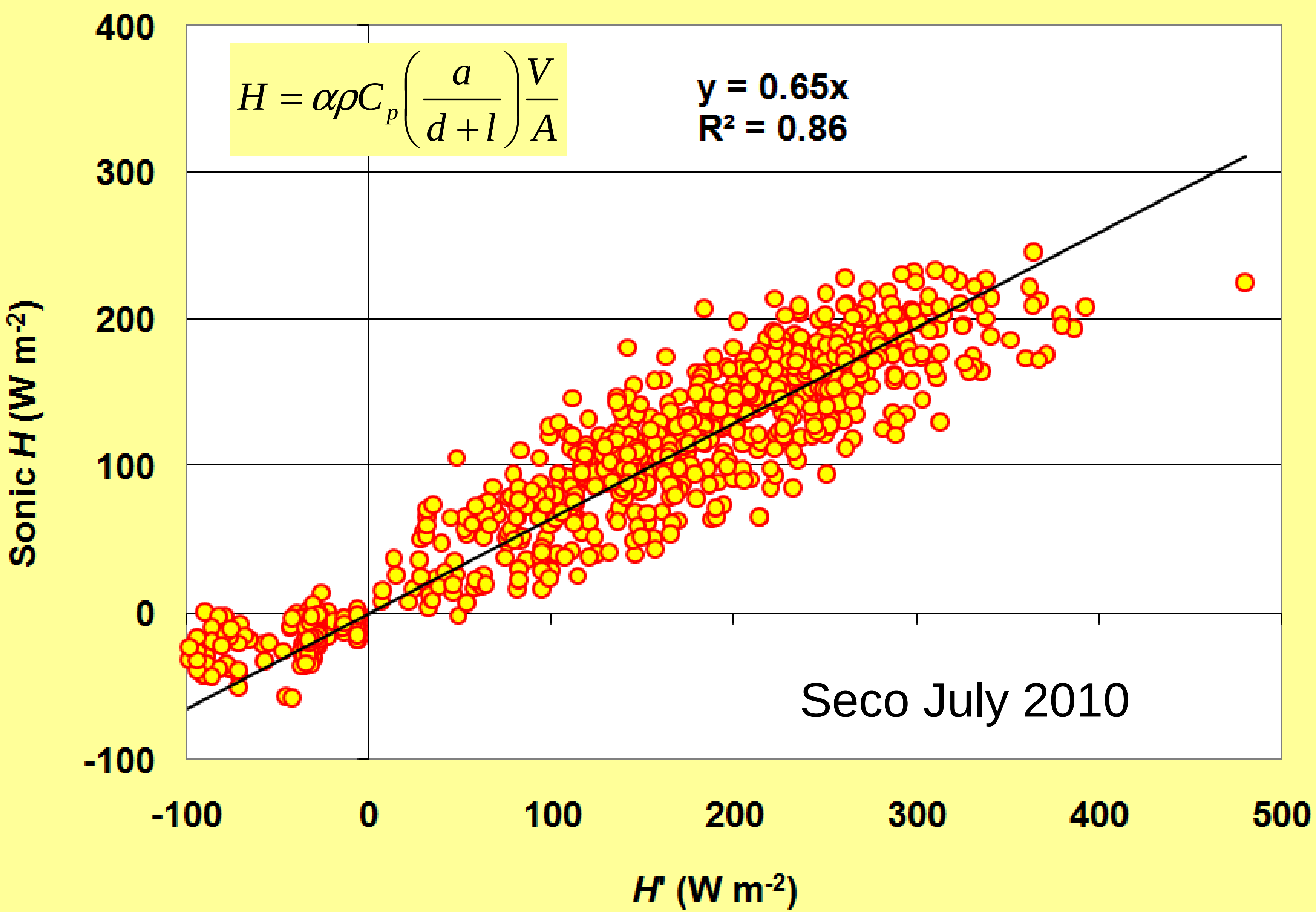

Come stimare il contributo
all’ evapotraspiazione di
nebbia, rugiada e pioggia
fine?

Evapotranspiration and Crop Coefficients
“Surface Renewal”


Sonic
anemometer
for
Sensible
heat flux
density (H)

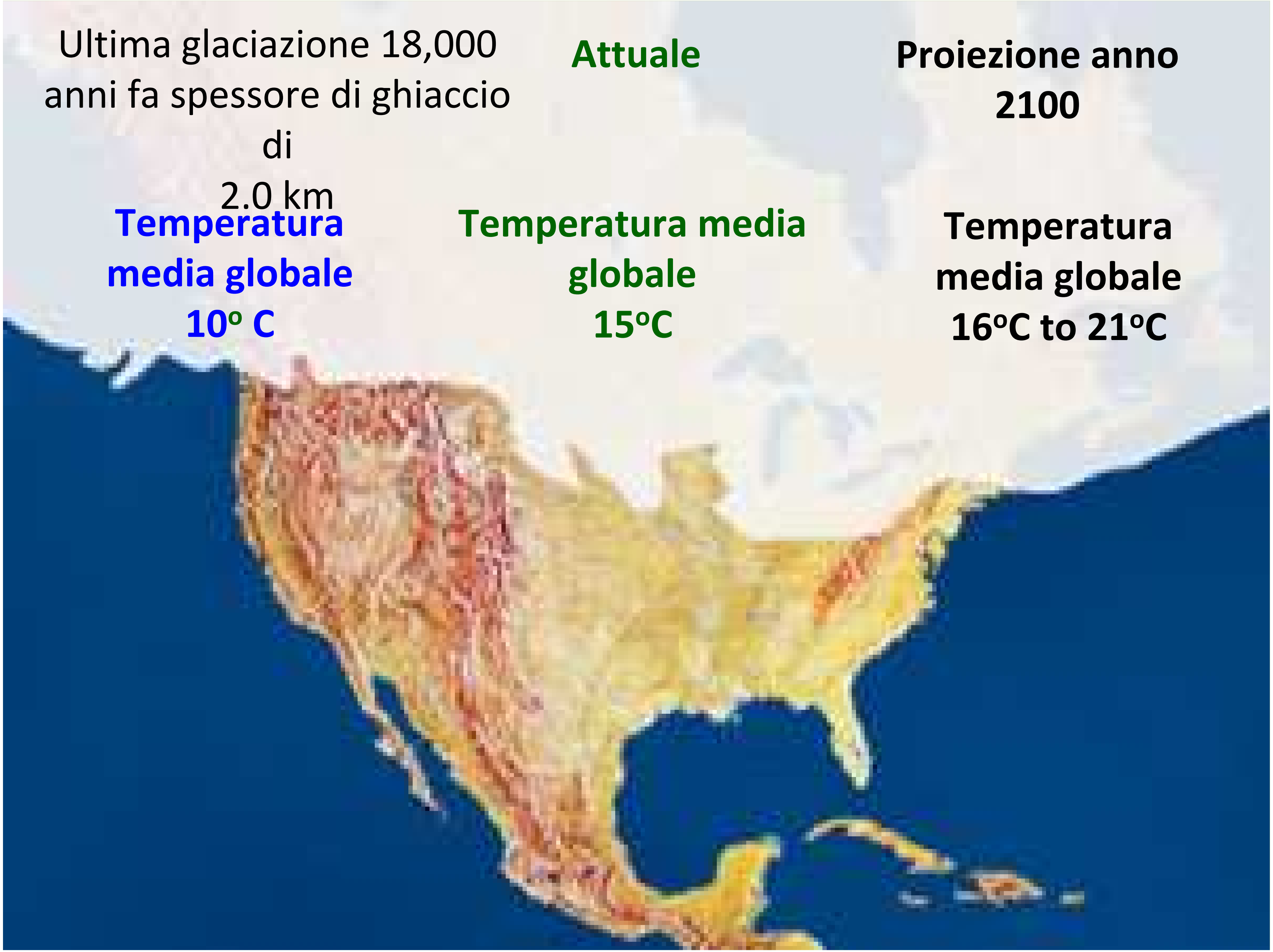

H - Sensible Heat Flux
0.003-inch diameter Thermocouples
Surface Renewal

Surface Renewal Calibration

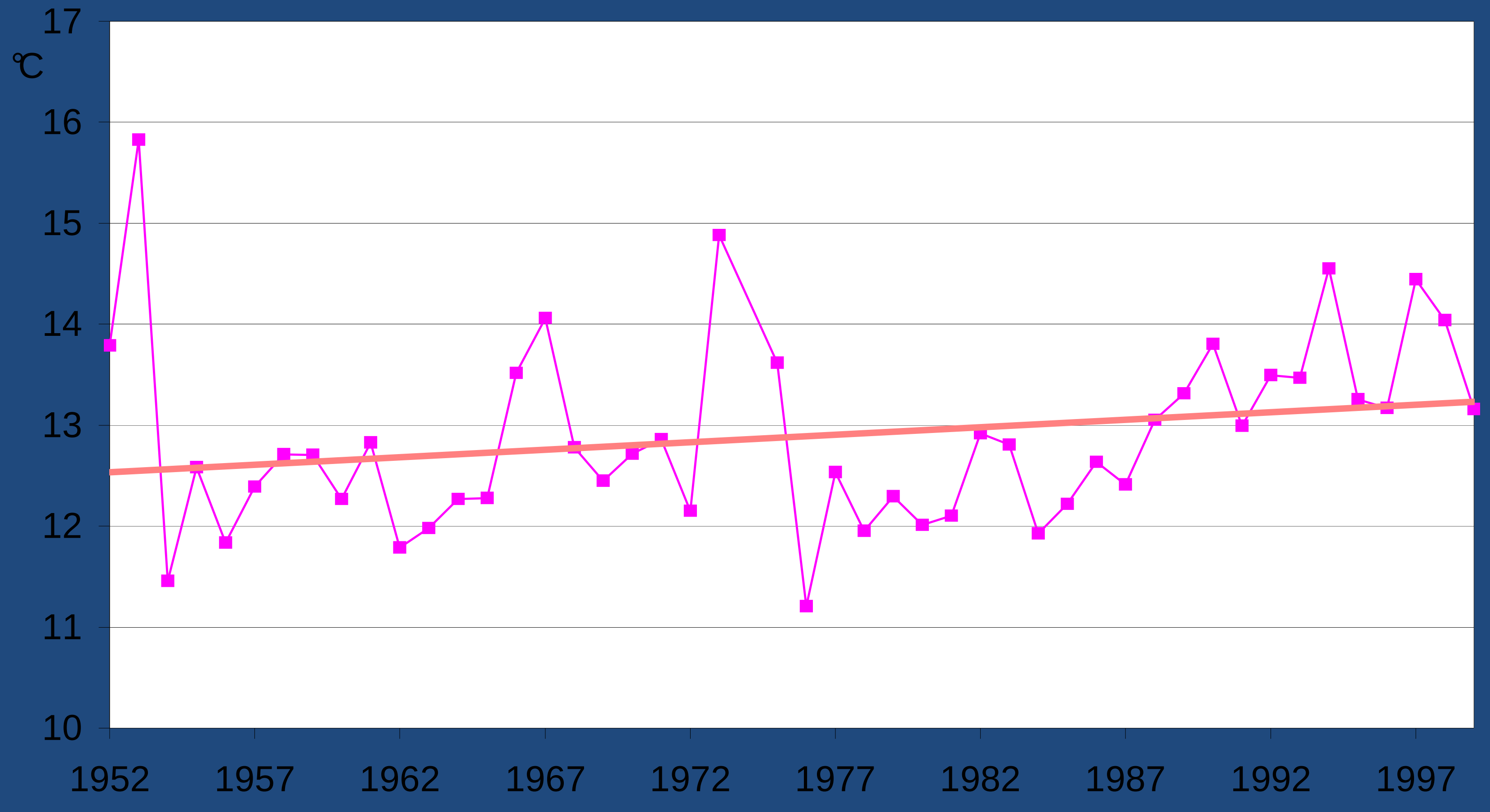


CAMBIAMENTO CLIMATICO

Inserire testo

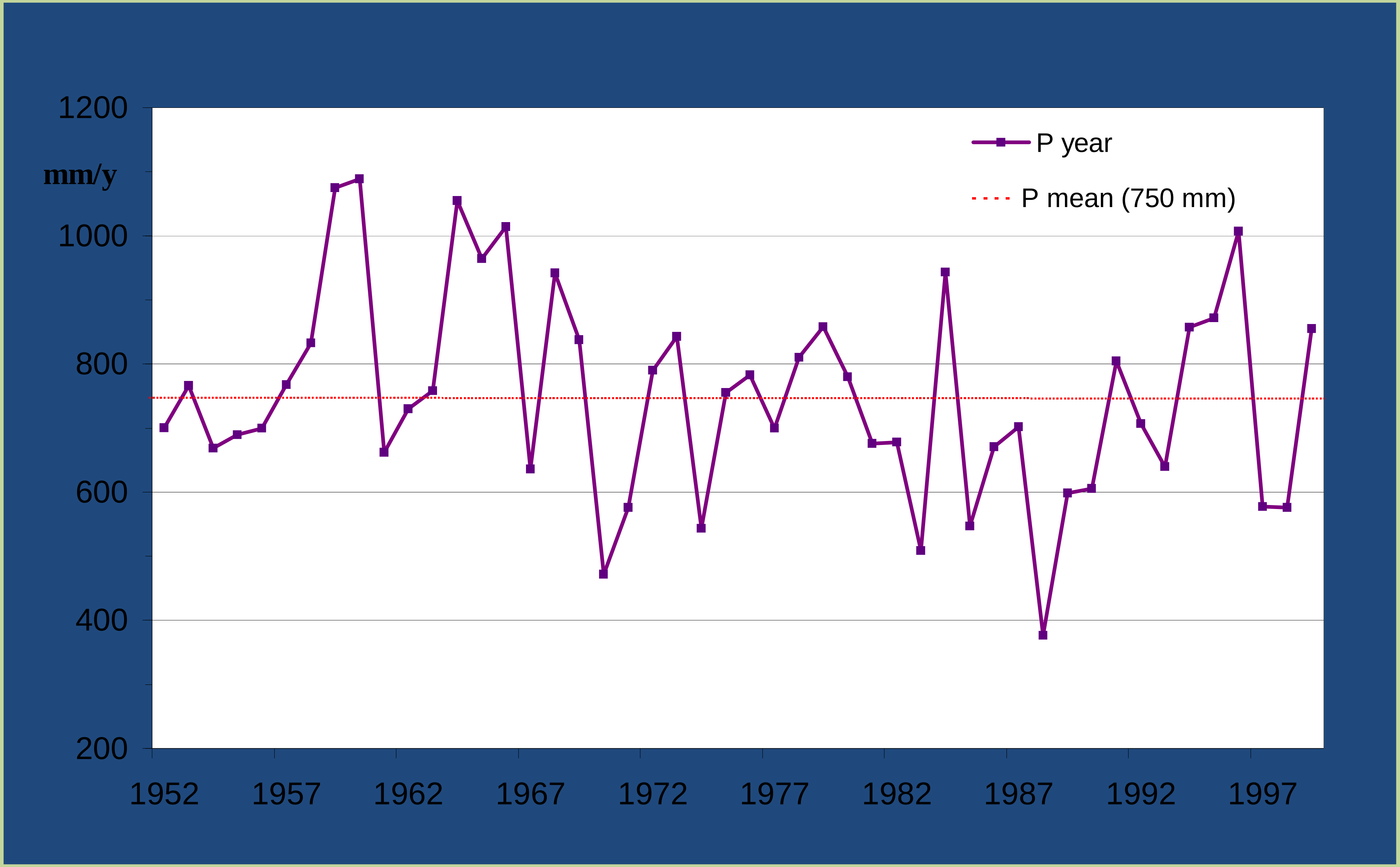

Ultima glaciazione 18,000 anni fa spessore di ghiaccio di
2.0 km
Temperatura media globale
10º C
Attuale
Temperatura media globale
15ºC
Proiezione anno 2100
Temperatura media globale
16ºC to 21ºC

Trend della temperatura a Bologna



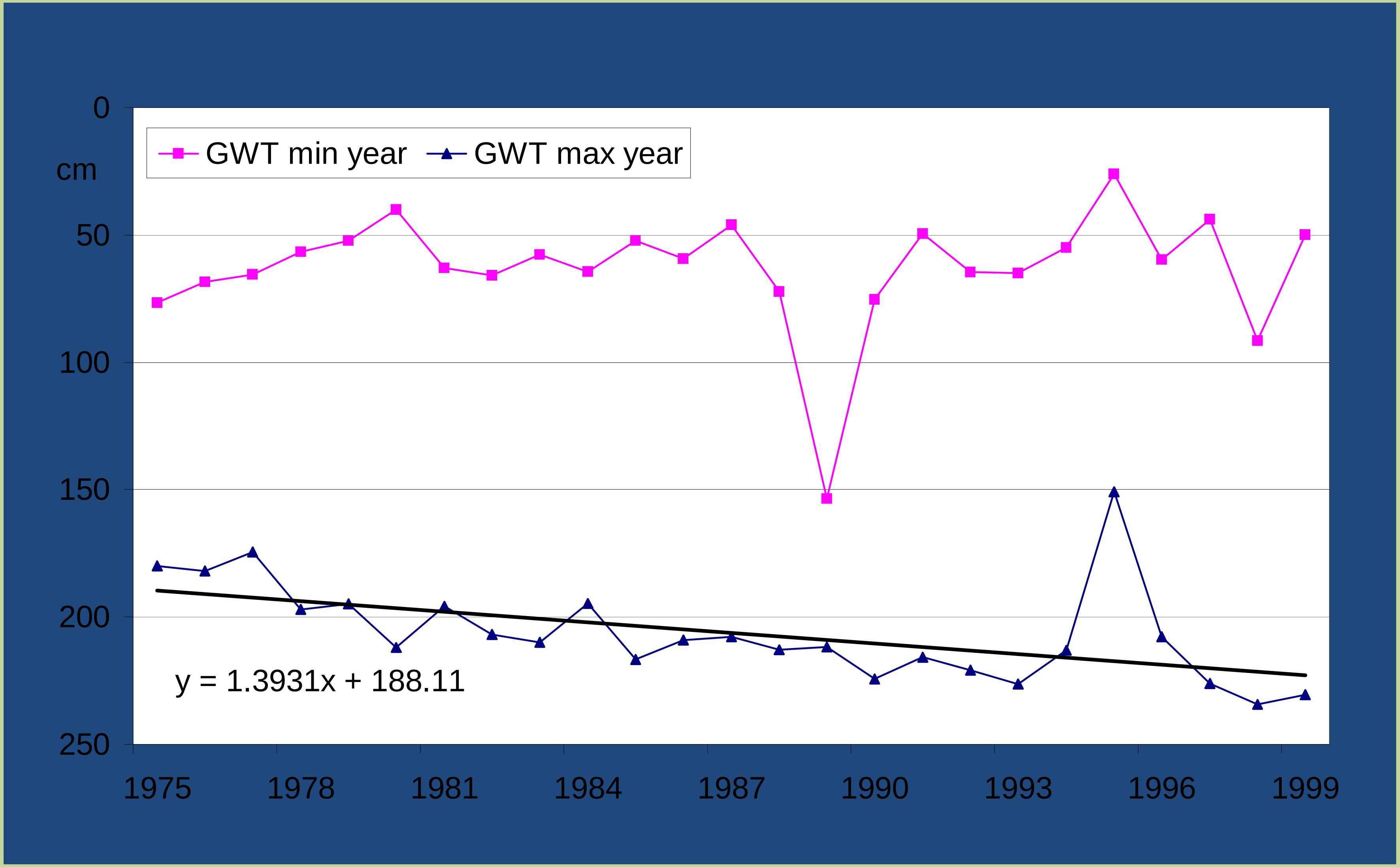
Trend della pioggia a Bologna

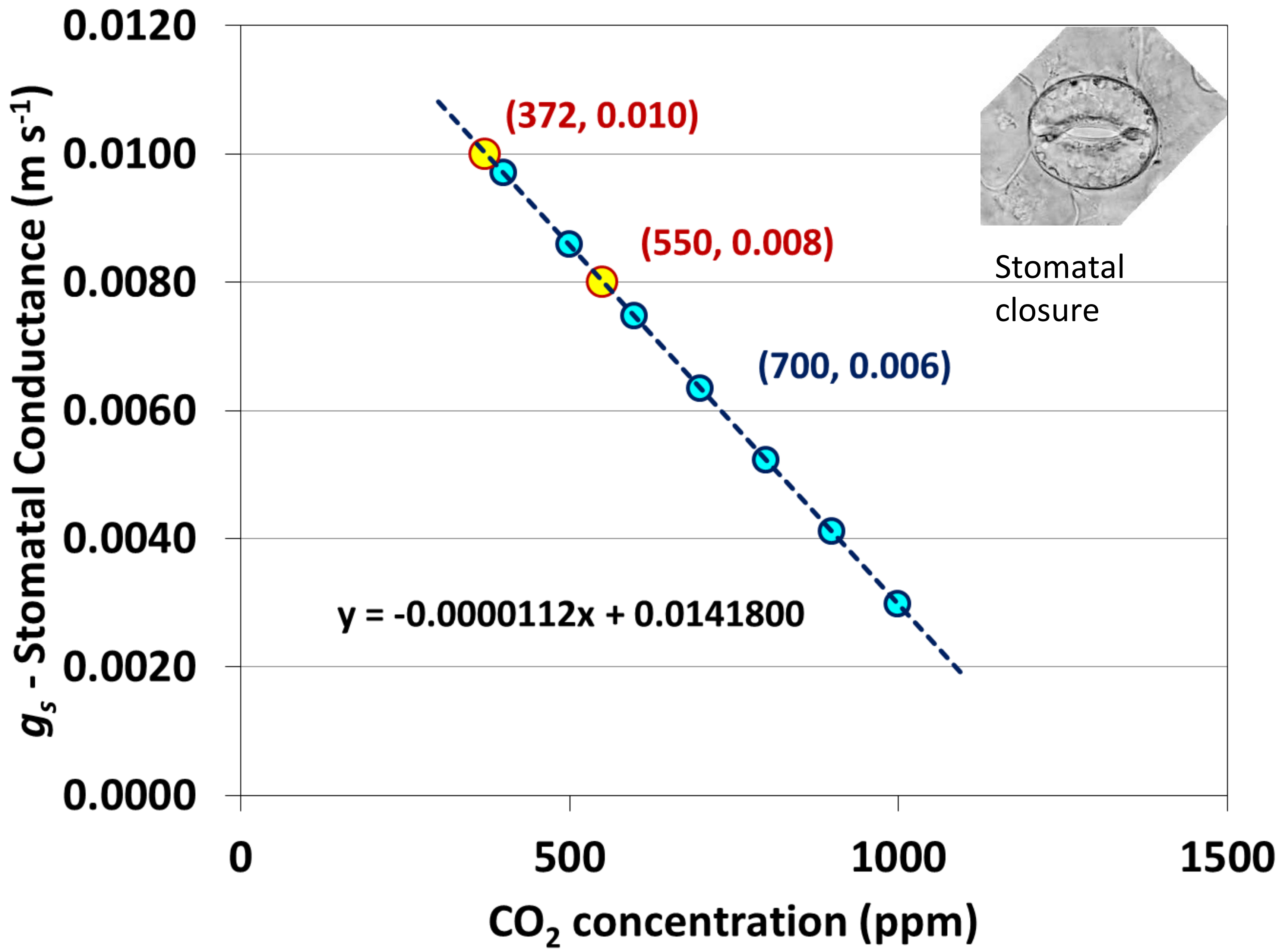
dal 1952 al 2004



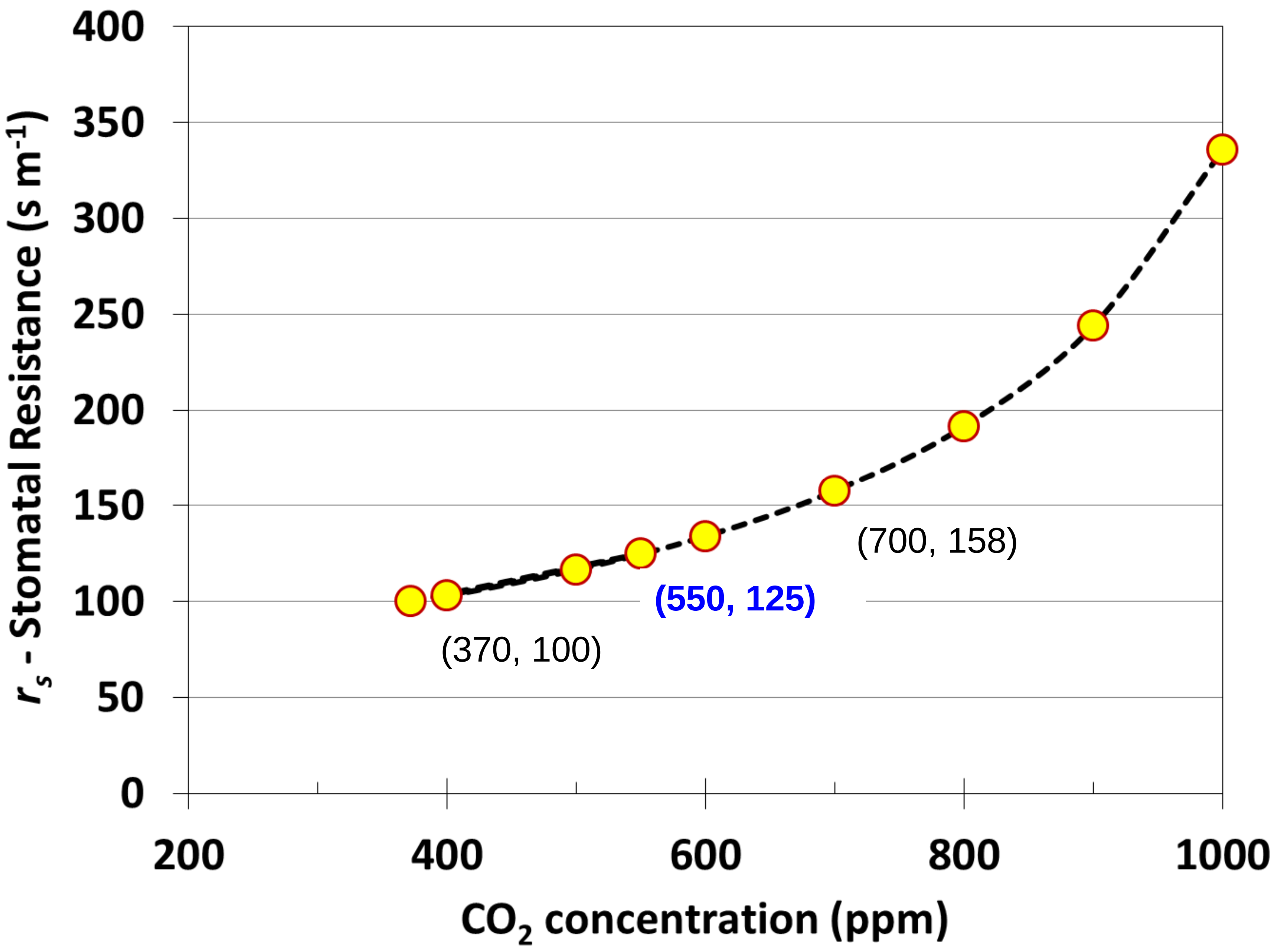
Trend della profondità di falda

a Bologna dal 1952 al 2004

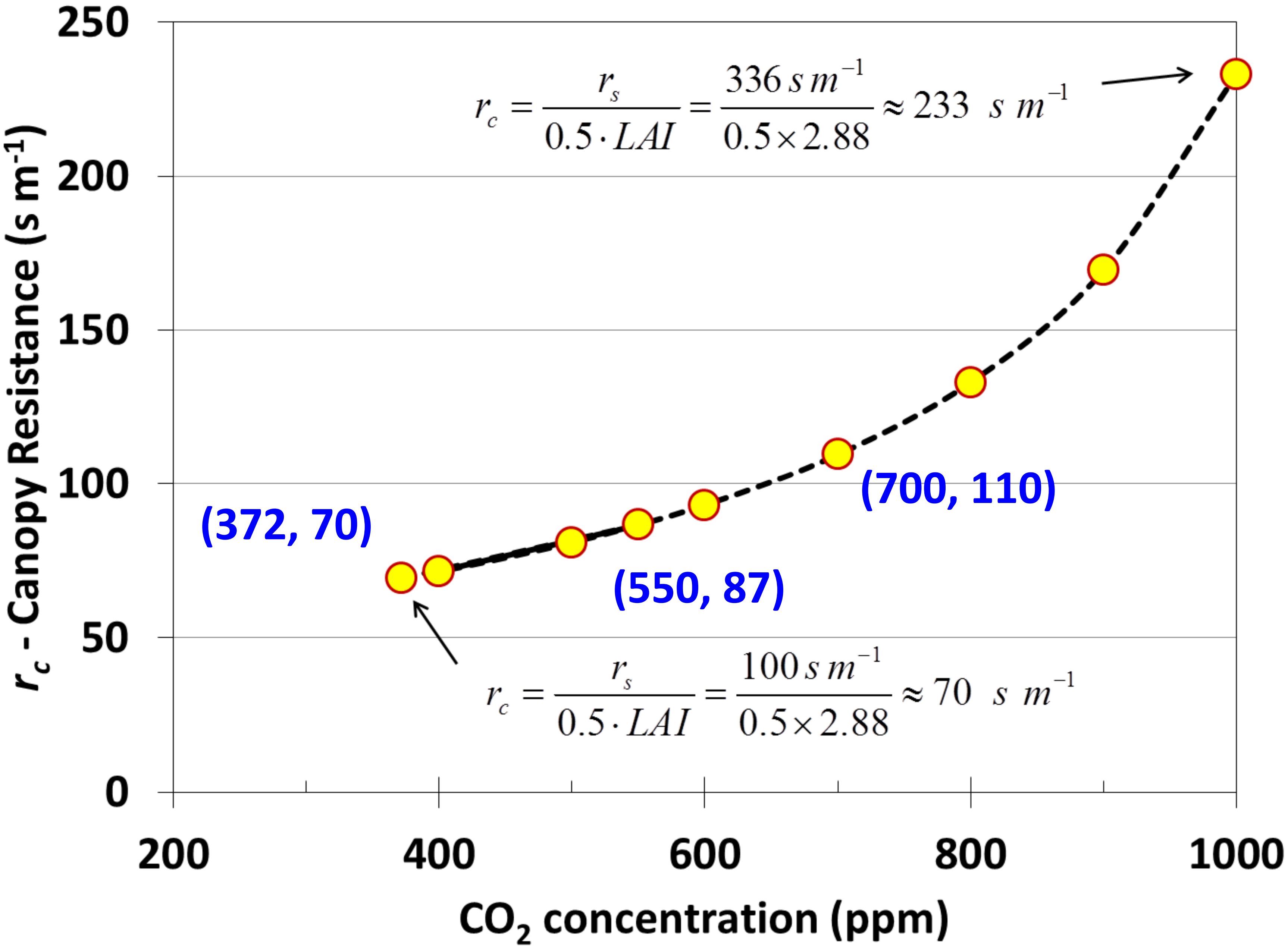




Long et al. (2004)

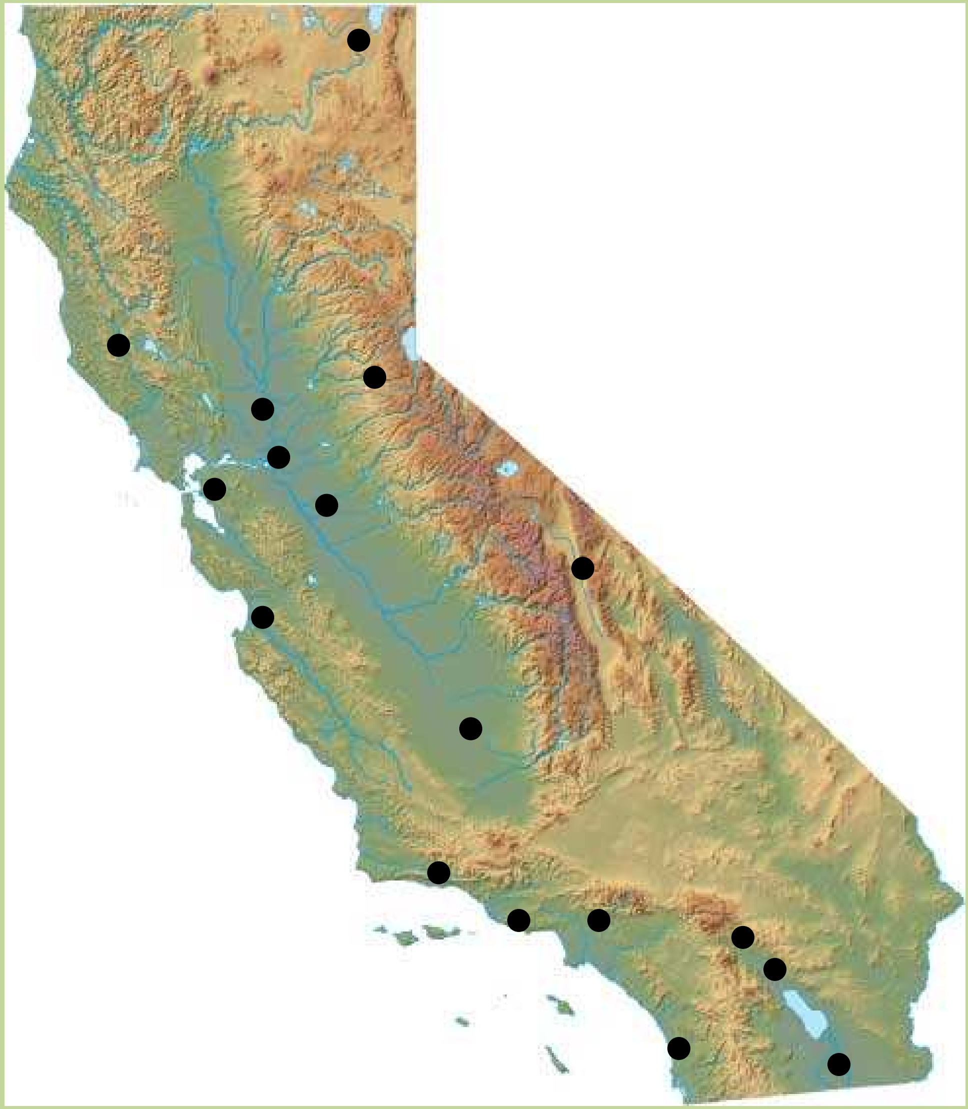


400
350
300
250
200
150
100
50
0
r_s - Stomatal Resistance (s m^{-1})
(370, 100)
(550, 125)
(700, 158)
200
400
600
800
1000
CO_2 concentration (ppm)



250
200
150
100
50
0
r_c - Canopy Resistance (s m^{-1})
200
400
600
800
1000
CO_2 concentration (ppm)
$r_c = \frac{r_s}{0.5 \cdot LAI} = \frac{336\, s\, m^{-1}}{0.5 \times 2.88} \approx 233\ \ s\ m^{-1}$
(372, 70)
(700, 110)
(550, 87)
$r_c = \frac{r_s}{0.5 \cdot LAI} = \frac{100\, s\, m^{-1}}{0.5 \times 2.88} \approx 70\ \ s\ m^{-1}$

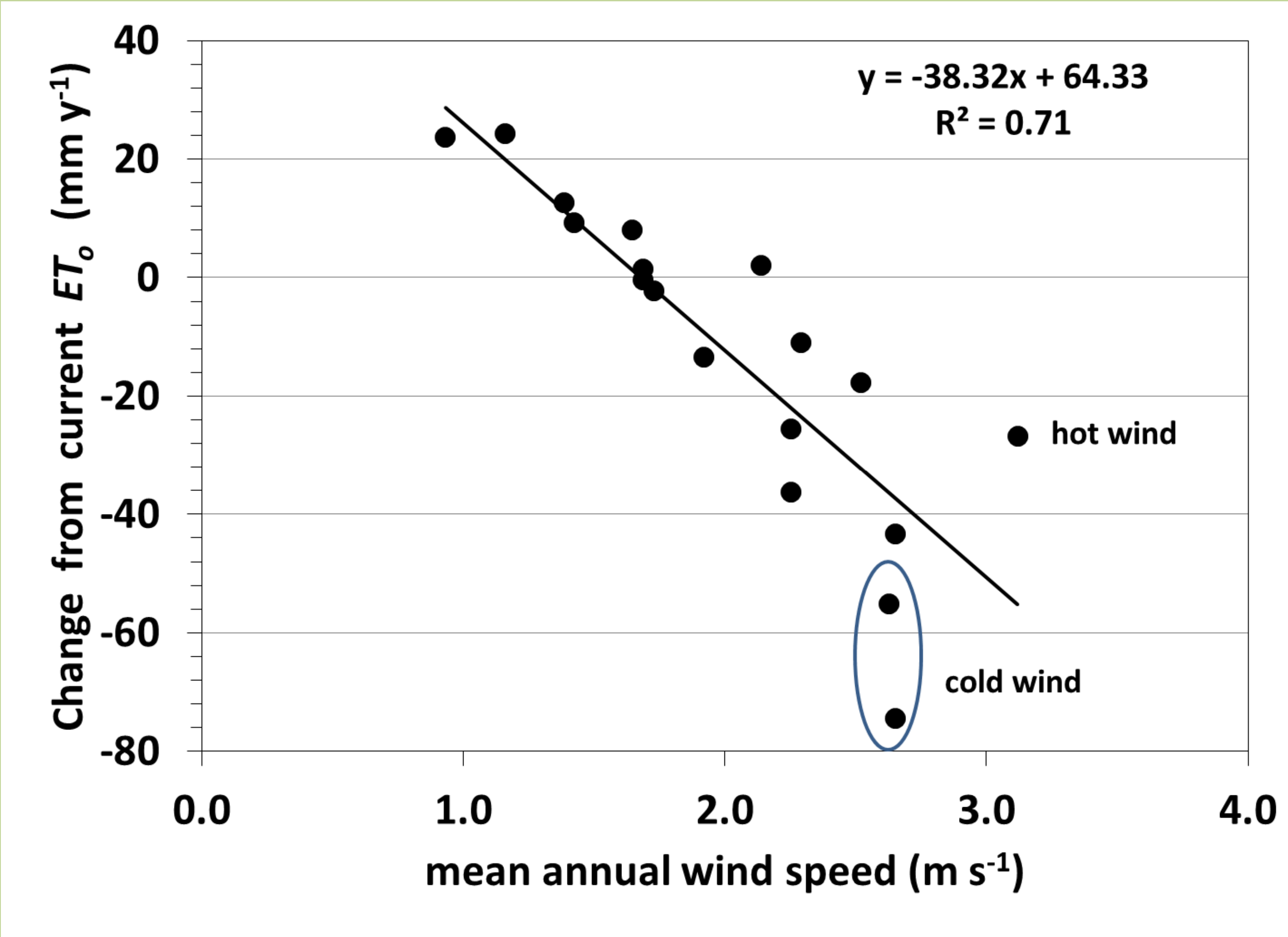
Locations



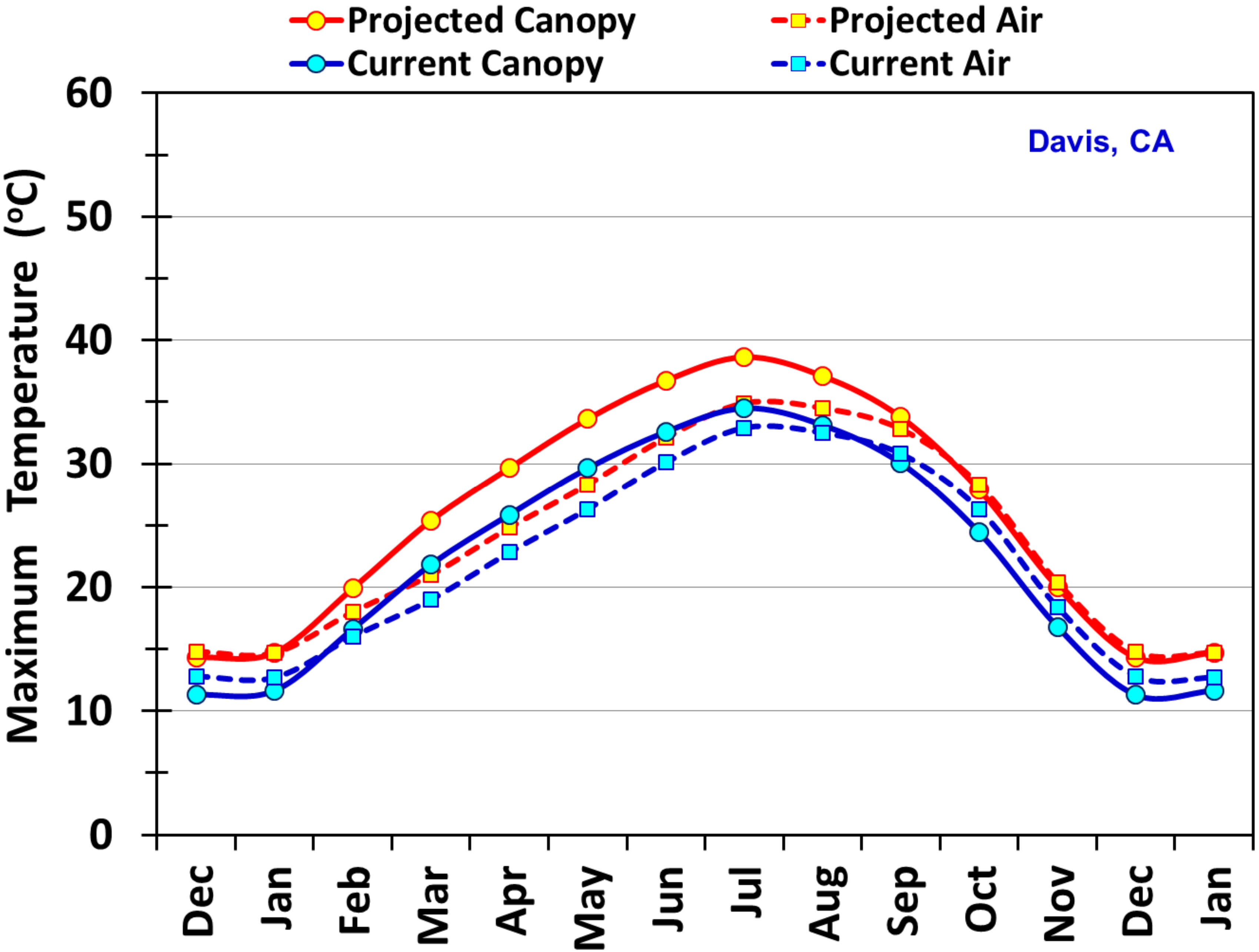
Projected 2100

Var	Curr	Proj	unit
CO_2	372	550	ppm
Solar	100	100	%
T_{max}	0.0	+2.0	^oC
T_{min}	0.0	+4.0	^oC
T_{dew}	0.0	+4.0	^oC

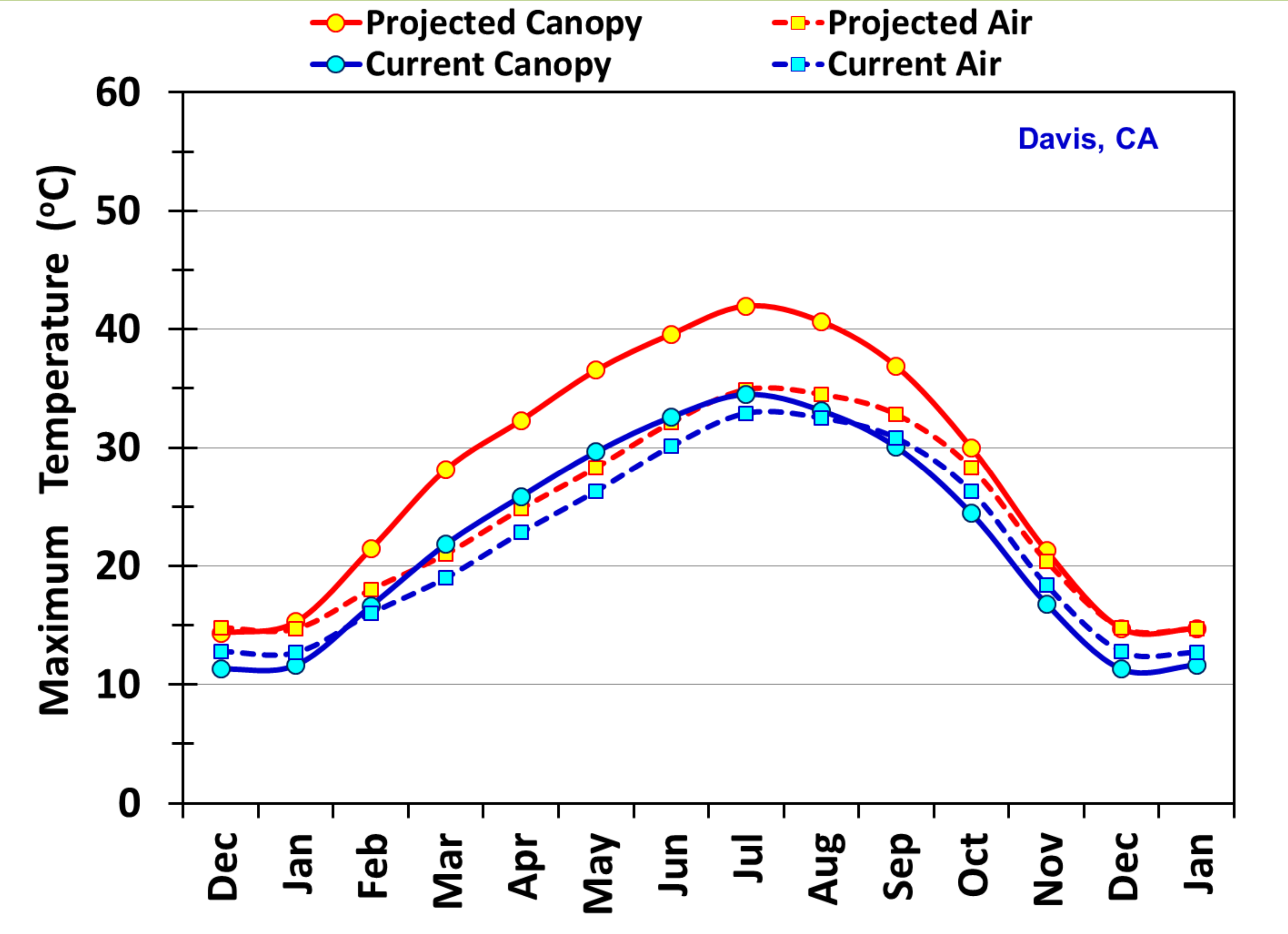
Change from Current Mean Annual ET_o



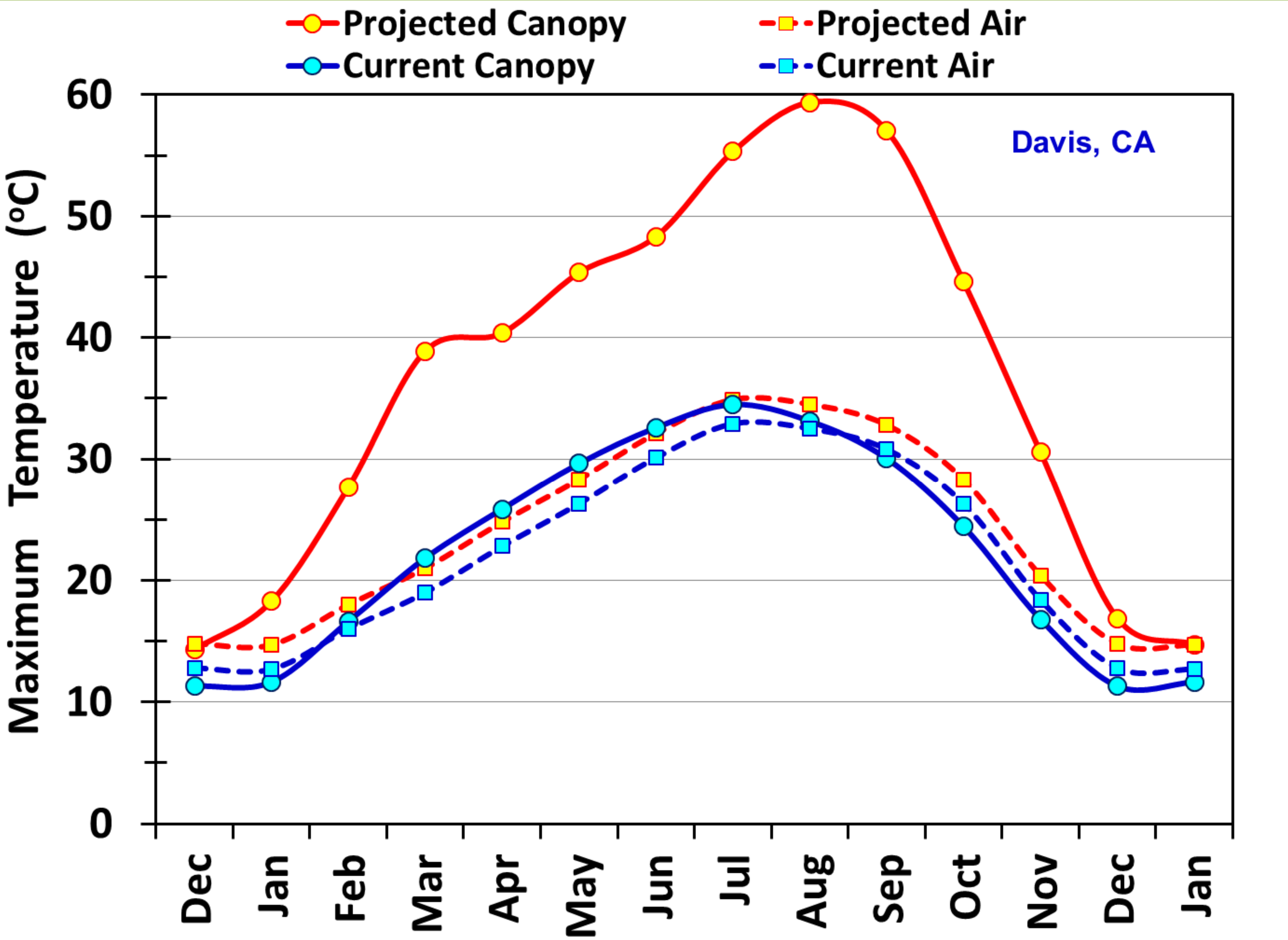
CO_2 = 700 ppm r_c = 110 s m^{-1} Δu_2 =0 m s^{-1}



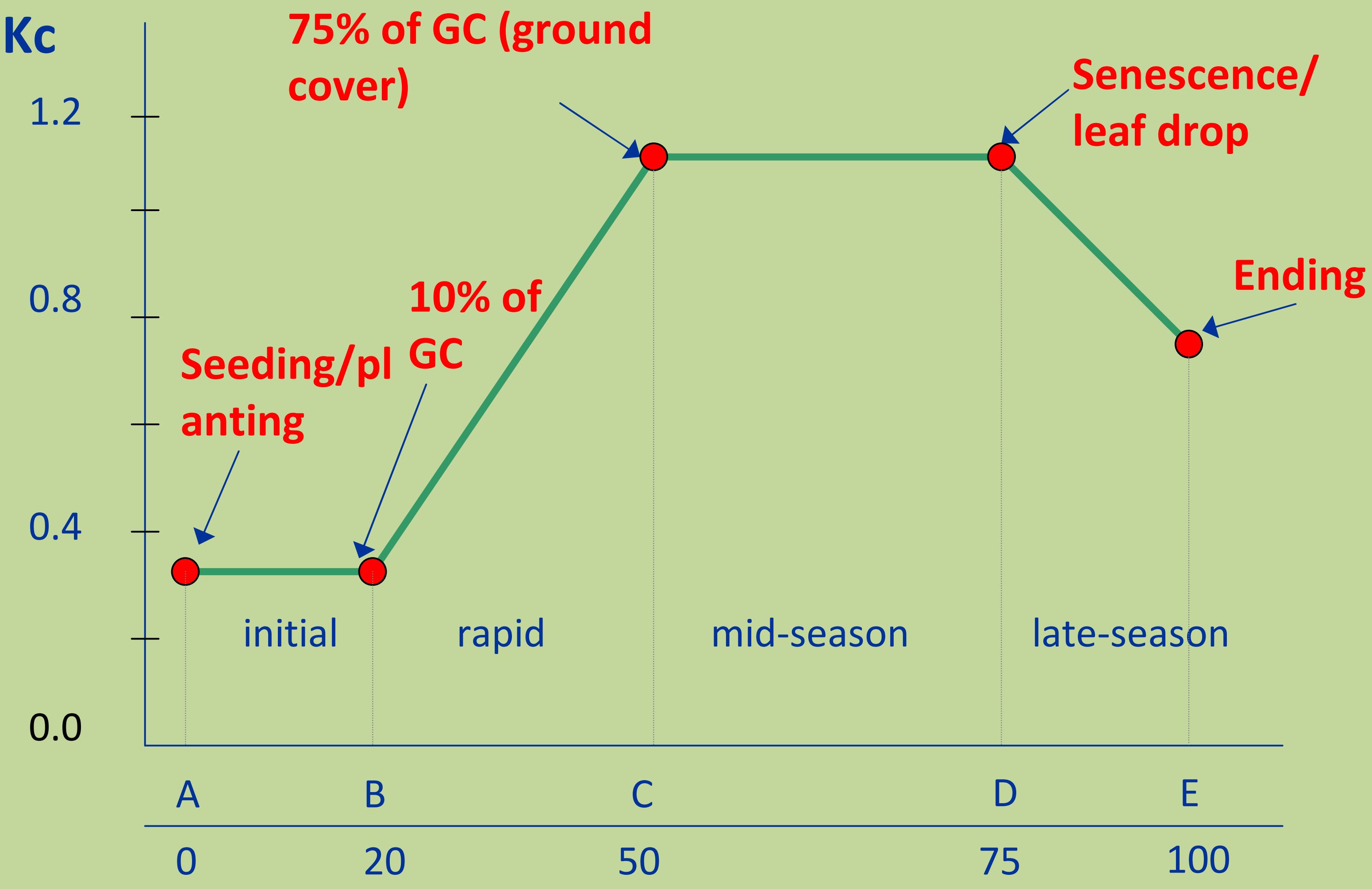
CO_2 = 700 ppm r_c = 110 s m^{-1} Δu_2 =-1 m s^{-1}



CO_2 = 700 ppm r_c = 110 s m^{-1} Δu_2 =-2 m s^{-1}

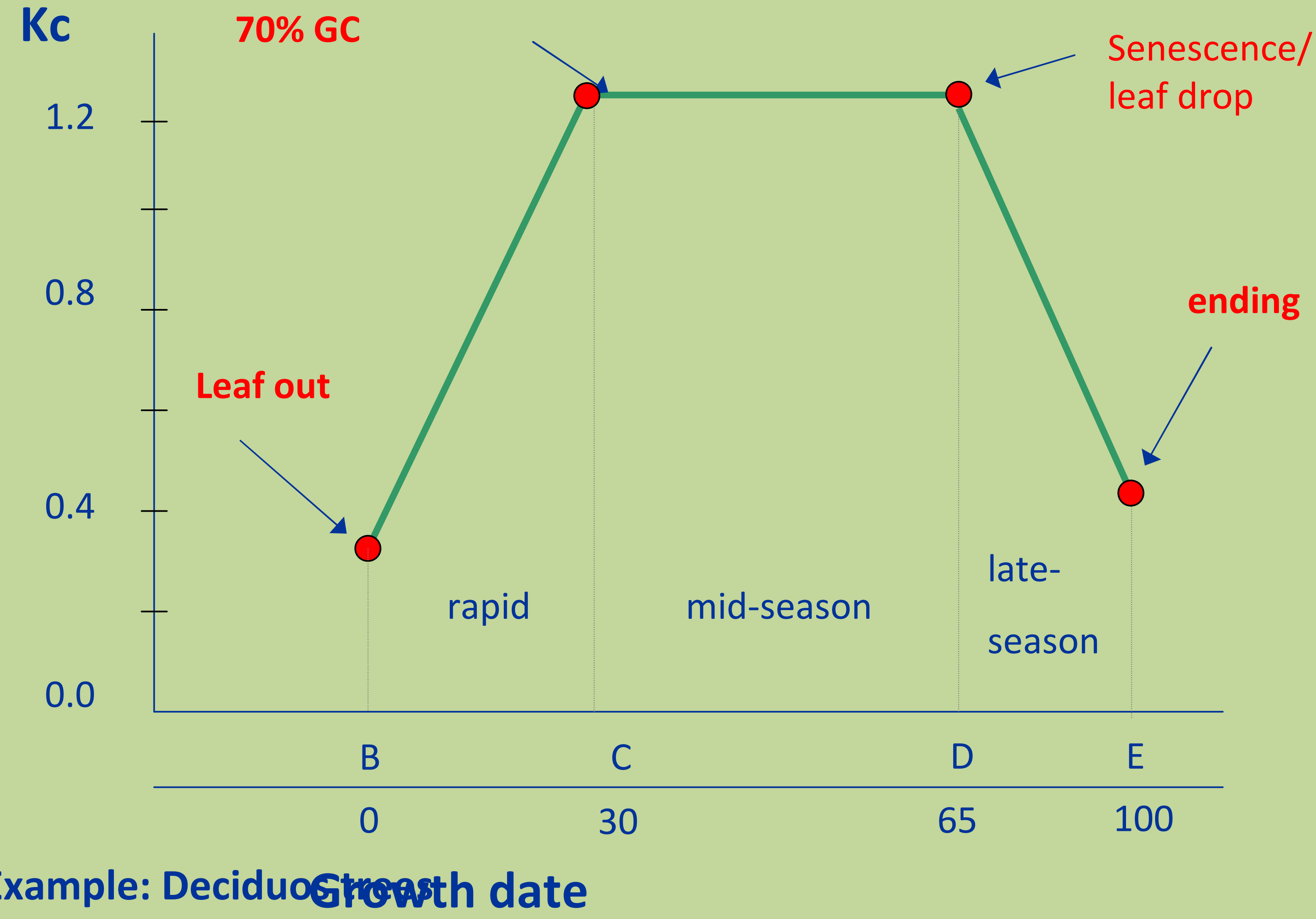


Crop Coefficient curves



Example: Seasonal crops

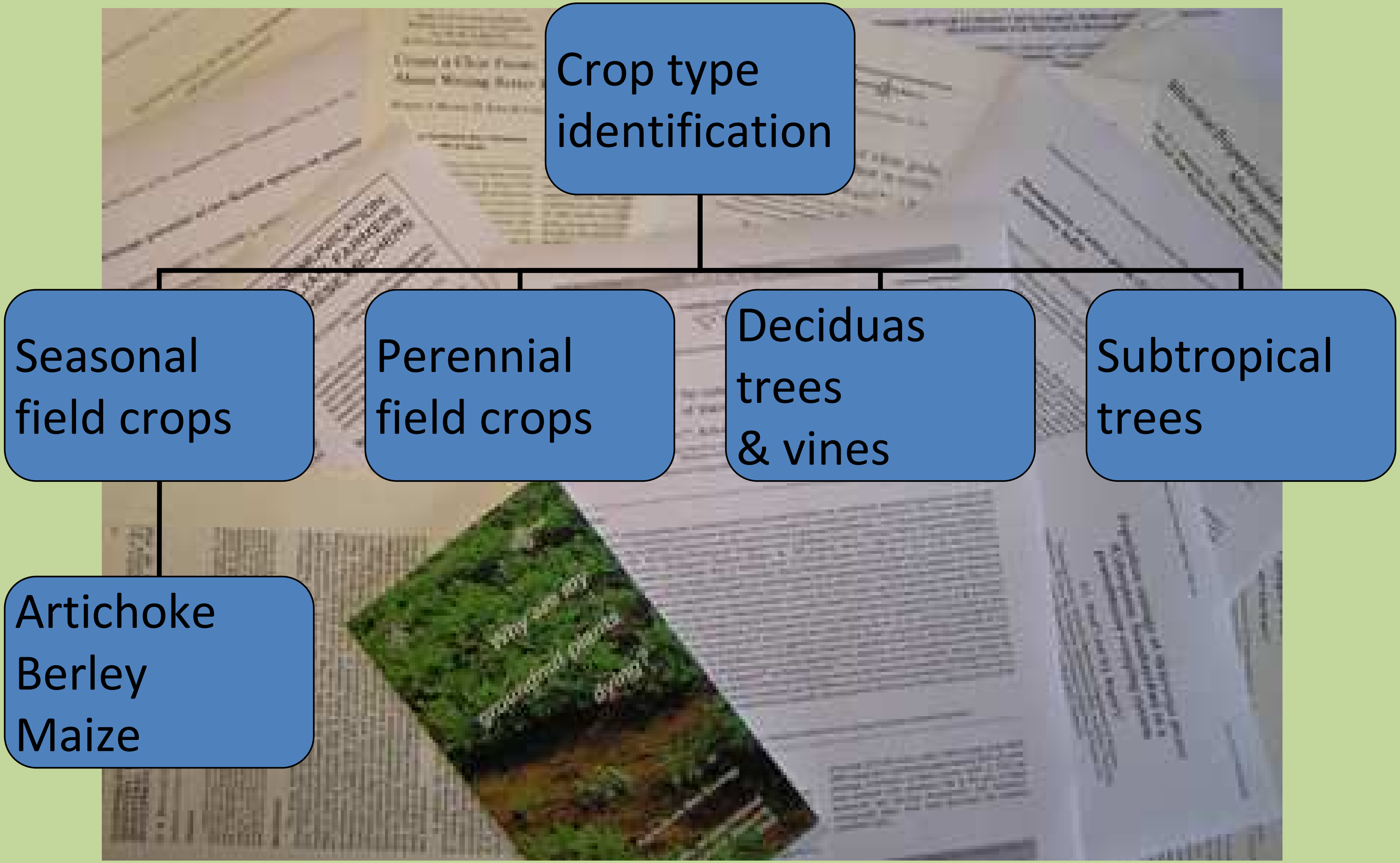
Crop coefficients curves



Example: Deciduous trees

CREAZIONE DI UN MODELLO PER I KC LOCALI

Creare un database di Kc



Indice della descrizione del modello

INPUT

- Scelta della coltura
- Dati meteo
- Irrigazione
- Proprietà del terreno
- Profondità delle radici

OUTPUT

- Evaporazione del terreno nudo (Ke)
- Kc
- Etc
- Irrigazione cumulata
- Valori giornalieri, settimanali e mensili

Indagine sui Kc

CATEGORIE DI COLTUTURE:

1. Erbacee da pieno campo

2. Colture perenni

3. Frutteti e vigneti

4.Agrumi e olivi

Esempio di scheda di Kc

59. **MEAN CROP CONSUMPTIVE USE AND FREE-WATER EVAPORATION FOR TEXAS**

1. INTRODUCTION

The manual provides information on the amounts of water consumptively used by vegetation and evaporation from free-water surfaces. The main purpose of this manual is to provide estimates of mean-annual consuptive use rates for crops in the State of Texas, using crop coefficients, determined from lysimeter studies.

2. MATERIALS AND METHODS

The Kcb values used here were adapted from SCS (1993). Note that the Kcb values found in Doorenbos and Pruit (1977) were used as Kcb values in SCS (1993).

Period of the Experiment

The growing seasons for the major crops grown in Texas and the planting dates were assumed to be the time between when 50% of the crop was planted and 50% of the crop was harvested (except cotton). The planting date was assumed to be the date when 50% of crops within a crop reporting district were planted.

Place of the Experiment

Texas, USA.

Calculation

Kcb values were adjusted for minimum relative humidity and strength of wind speed.

To determine the average Kcb values for each month, the first step is to plot the Kcb (adjusted) for the growing season and to divide the curve into the calendar months. The last step was to calculate the average Kcb for each calendar month.

The growing season is divided into 4 stages: initial, canopy development, mid season and maturation. There are 3 main points of the Kcb curve:

1. Kcb value for the initial stage= 0.25 (set by SCS, 1993; it does not change);
2. Kcp value for the start of the mid-season stage;
3. Kcm value for the end of the maturation stage.

The wet soil evaporation factor (Kw) used only when the Kcb < 1, it was define by Wright (1981) as:

Kw=(1-Kcb)[1-(t/td)^0.5](Fw)

Where t= elapsed time since wetting days, td= time required for the soil surface to dry, days

Fw= relative prtion of the soil surface originally wetted.

For a significative precipitation event, the 0.1 inch threshold appeared toprovide a balance between over and under estimation of wet soilevaporation.

3. RESULTS AND DISCUSSION

Green beans	Moderate wind		Strong wind	
	Kcp	Kcm	Kcp	Kcm
Arid	1.00	0.90	1.05	0.90
Humid	0.95	0.85	0.95	0.85
Dry beans	Moderate wind		Strong wind	
	Kcp	Kcm	Kcp	Kcm
Arid	1.15	0.25	1.20	0.25
Humid	1.05	0.30	1.10	0.30

Conclusion

The Kcb values used in this manual are for grass reference crop evapotranspiration, ETo. The coefficients were published in SCS (1993) and Jensen manuals on consumptive use of crops.

In general, FAO 24 Penman procedure (Doorenbos and Pruitt, 1977) estimated a greater ETo than does the SCS (1993) Penman-Monteith procedure.

- A box was set up for each paper reviewed.
- each box has got a number of identification
- each number is reported in the Kc data base.

Creare un database di Kc

Maize Example of Kc values investigated:

Paper n	Country	Kc ini	Kc mid	Kc end
7	California, USA	0.2	1.2	0.5
20	Kenya, Africa	0.5	1.0	0.8
8	Karnal, India	0.6	1.1	0.6
29	Wokingham, UK	-	0.8	-
40	Taiwan	0.4	0.8	0.7
45	Nebraska, USA	0.3	1.2	0.3
55-57	Shaanxi, China	0.2	1.1	0.6
50	Khon Kae, Tailand	1.0	1.2	1.1
59	Texas, USA	0.3	1.1	1.0
81	Idaho, USA	0.2	0.9	0.7

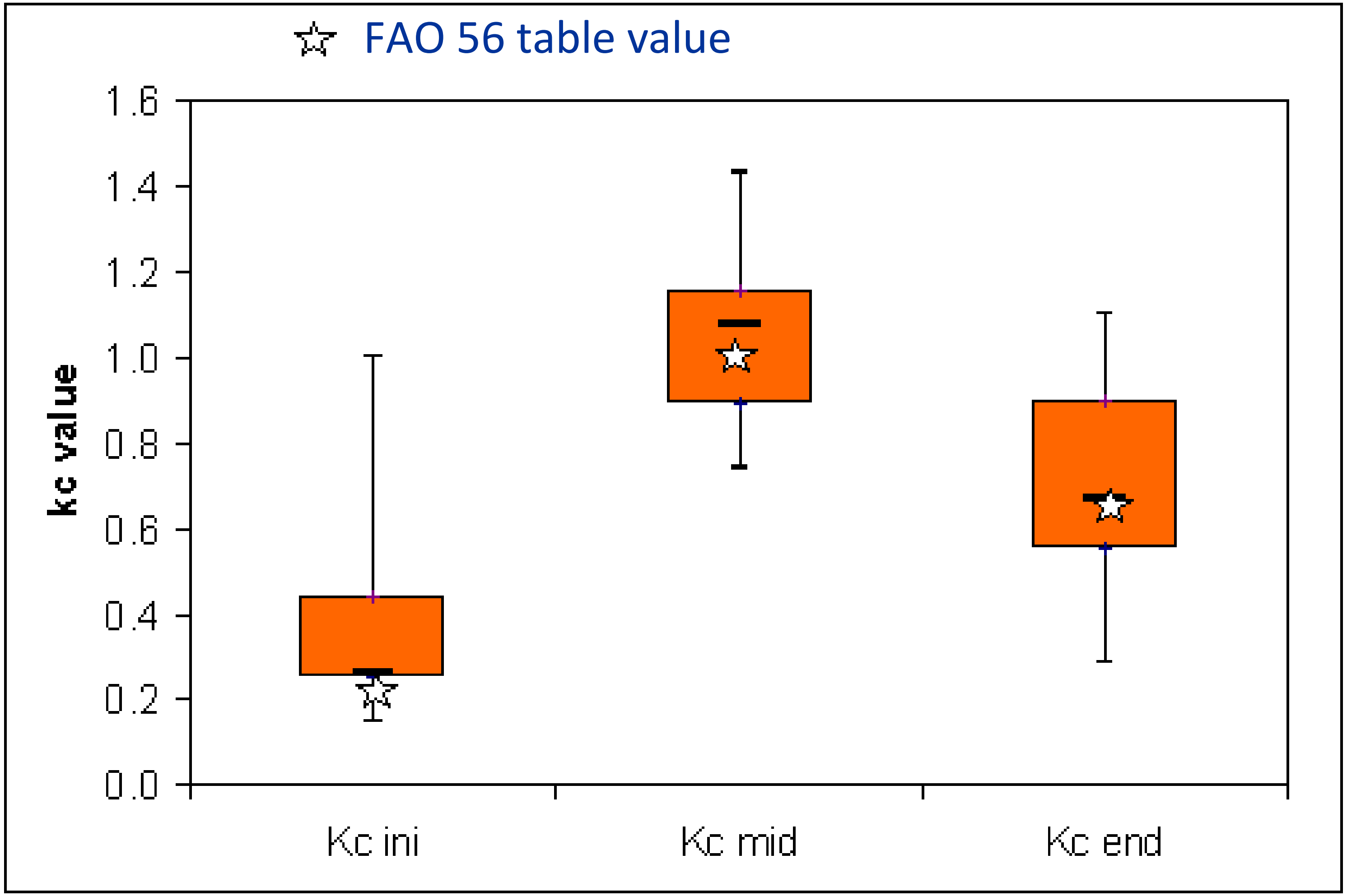
- high variability due to different cultivar and different climates.

Sample Kc data base

CROP			PLACE	Kc VALUES			REFERENCE
Type	N#	Name		ini	mid	end	
1		sunflower	Texas, US	0.25	1.15	1.00	Mean Crop Consumptive Use and Free-Water Evaporation for Texas
1	44	tomato	California, US	0.21	1.25	0.60	Water used by crops as affected by climate and plant factors
1	44	tomato	Jordan	0.65	0.82	0.53	Developing crop coefficients for field-grown tomato (Lycopersicon esculentu
1	44	tomato	California, US	0.00	0.05	0.95	Estimating evapotranspiration in processing tomatoes
1	44	tomato	California, US	0.01	0.70	1.15	New crop coefficients developed for high-yield processing tomatoes
1	44	tomato	Texas, US	0.25	1.05	0.85	Mean Crop Consumptive Use and Free-Water Evaporation for Texas
1	44	tomato	Texas, US	0.25	1.20	0.90	Mean Crop Consumptive Use and Free-Water Evaporation for Texas
1	45	wheat	Shaanxi, China	0.20	0.04	0.04	Peak crop coefficient values for Shaanxi, North-west China
1	45	wheat	Bengal, India	0.33	1.08	0.64	Actual evapotraspiration and crop coefficients of wheat (Triticum Aestivum)
1	45	wheat	Shaanxi, China	0.20	1.70	0.70	Crop coefficient and ratio of transpiration to evapotranspiration of winter wh
1	45	wheat, winter	Texas, US	0.25	1.05	0.25	Mean Crop Consumptive Use and Free-Water Evaporation for Texas
1	45	wheat, winter	Texas, US	0.25	1.15	0.20	Mean Crop Consumptive Use and Free-Water Evaporation for Texas
1	45	wheat, winter	Idaho, US	0.15	1.00	0.20	New evapotrasnpiration crop coefficients
1	45	wheat, winter	Idaho, US	0.10	1.00	0.20	Using weighing lysimeters to develop evapotranspiration crop coefficients
1	45	wheat, spring	Texas, US	0.25	1.05	0.55	Mean Crop Consumptive Use and Free-Water Evaporation for Texas

Esempio di confronto tra i valori di Kc

Maize Kc values comparison between all papers reviewed.



Descrizione del modello Kc

1. Scegliere la coltura
2. Inserire i dati meteorologici (pioggia e ET_0)
3. Criteri di irrigazione (massima diminuzione di acqua nel terreno consentita)
4. Valutare l’eta degli alberi, delle colture, il tipo di irrigazione.
5. Tabella del Kc adeguata al clima locale

Model description

1. Choose a crop number ("Kc info" and "Crop list" worksheets)

Crop Number 2006	CROP Name	CROP Type	Enter the % of the season from date A to the growth			Kc factors corresponding to the indicated growth date			
			B	C	D	B	C	D	E
1	Almonds	3	0	50	90	0.55	1.15	1.15	0.65
2	Apple	3	0	50	75	0.55	1.05	1.05	0.80
3	Artichokes	1	6	19	90	0.65	0.65	0.65	0.65
4	Asparagus	1	12	25	95	0.25	1.00	1.00	0.25
5	Avocado	3	0	33	67	0.70	0.70	0.70	0.70
6	Barley	1	20	45	75	0.70	1.10	1.10	0.15
7	Beans (dry)	1	24	40	91	0.20	1.00	1.00	0.10
8	Beans (green)	1	22	56	89	0.80	1.00	1.00	0.85
9	Beans (pinto)	1	24	40	91	0.20	0.90	0.90	0.10
10	Beets (table)	1	25	60	90	0.30	0.90	0.90	0.90
11	Broccoli	1	20	50	83	0.30	1.00	1.00	0.80
12	Cabbage	1	25	63	88	0.30	1.00	1.00	0.85
13	Carrots	1	20	50	83	0.85	0.95	0.95	0.80
14	Celery	1	15	40	90	0.80	0.95	0.95	0.95
15	Citrus	4	25	50	75	1.00	1.00	1.00	1.00

Model description

2. Input weather data (“Climate” and “Weather” worksheets)

Date	DOY	Historical mm/day ETo	Current mm/day ETo	Analysis mm/day ETo	Historical mm Pcp	Current mm Pcp	Analysis mm Pcp	Historical °C Tmax	Current °C Tmax	Analysis °C Tmax	Historical °C Tmin	Current °C Tmin	Analysis °C Tmin
1-Jan	40179		0.23	0.23		1.0		5.8	0.2	0.2	-1.7	-6.9	-6.9
2-Jan	40180		0.15	0.15		0.0		5.6	0	0.0	-1.9	-7.4	-7.4
3-Jan	40181		0.13	0.13		0.0		5.4	4.8	4.8	-2.1	-5.8	-5.8
4-Jan	40182		0.08	0.08		0.4		5.3	3.6	3.6	-2.3	-7.7	-7.7
5-Jan	40183		0.25	0.25		0.0		5.1	3.1	3.1	-2.5	-2.5	-2.5
6-Jan	40184		0.16	0.16		0.0		4.9	6.1	6.1	-2.7	-4	-4.0
7-Jan	40185		0.22	0.22		0.0		4.8	3.9	3.9	-2.9	-4.5	-4.5
8-Jan	40186		0.19	0.19		0.2		4.7	5.9	5.9	-3.0	-2.5	-2.5
9-Jan	40187		0.17	0.17		0.0		4.6	6.4	6.4	-3.1	-3.4	-3.4
10-Jan	40188		0.20	0.20		0.0		4.5	4.3	4.3	-3.3	-6.3	-6.3
11-Jan	40189		0.43	0.43		0.4		4.4	6.1	6.1	-3.4	-5.2	-5.2
12-Jan	40190		0.30	0.30		0.2		4.3	6	6.0	-3.5	-5.2	-5.2
13-Jan	40191		0.27	0.27		0.0		4.2	5.8	5.8	-3.6	-5.6	-5.6

Reference Evapotranspiration (ET_0) and rainfall (Pcp)

Model description

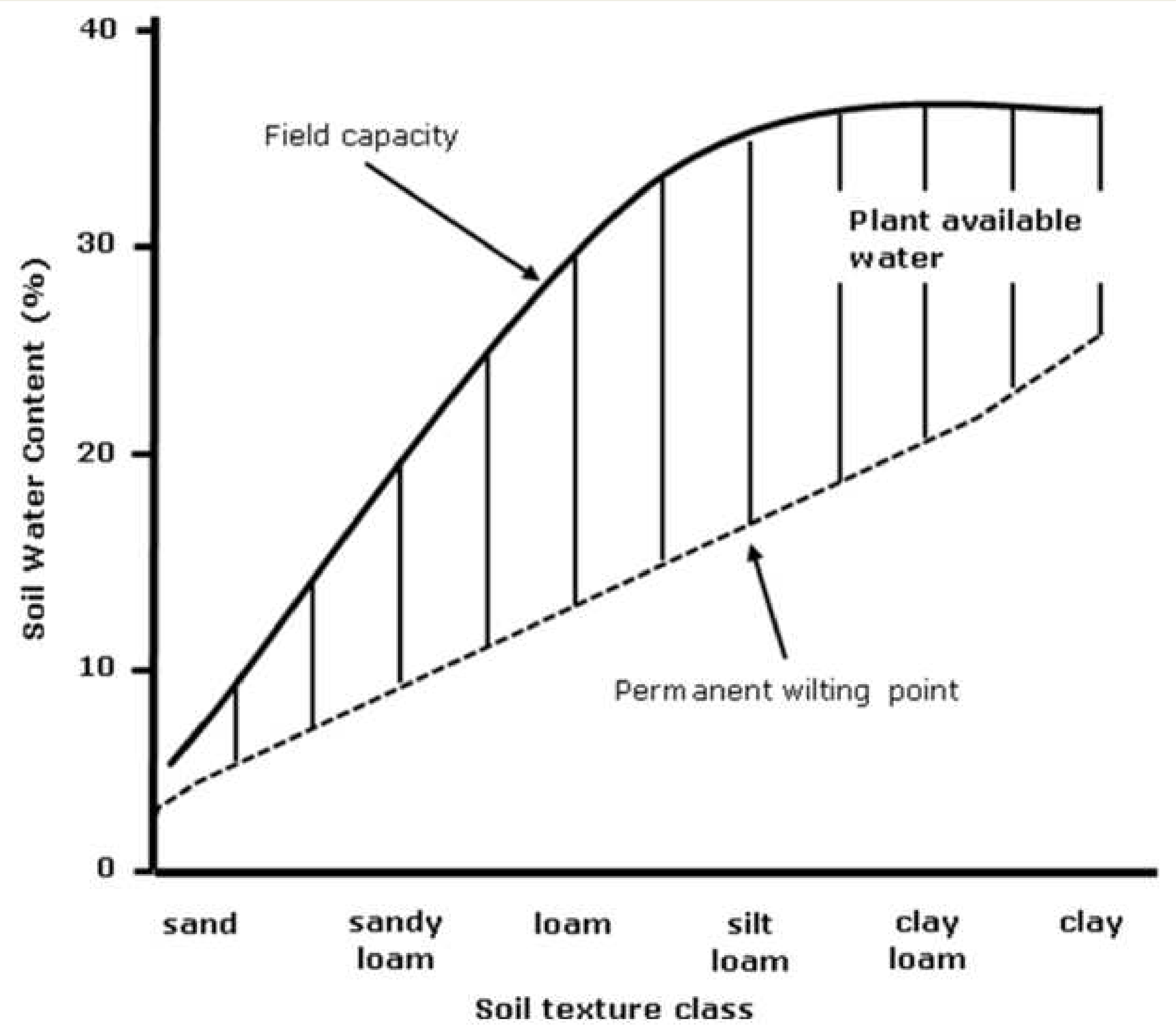
3. Irrigation scheduling: roots depth, soil water holding capacity, plant available water and yield threshold depletion

Date	Growth Date	Rooting Depth	Total Water Holding Capacity	Available Water Holding Capacity	Cum Field Capacity CFC	Plant Available Water PAW	Allowable Depletion	Yield Threshold Depletion YTD	wetted volume	adjusted YTD
		m	m/m	m/m	mm	mm	%	mm	%	mm
30-mag-06	A	1.5	0.36	0.18	540	270	50	135	100	135
24-giu-06	B	1.5	0.36	0.18	540	270	50	135	100	135
20-lug-06	C	1.5	0.36	0.18	540	270	50	135	100	135
14-set-06	D	1.5	0.36	0.18	540	270	50	135	100	135
10-ott-06	E	1.5	0.36	0.18	540	270	50	135	100	135

Date	CFC	PWP	YTD	YT
30-mag-06	540.00	270.00	135.00	405.00
31-mag-06	540.00	270.00	135.00	405.00
01-giu-06	540.00	270.00	135.00	405.00
02-giu-06	540.00	270.00	135.00	405.00
03-giu-06	540.00	270.00	135.00	405.00
04-giu-06	540.00	270.00	135.00	405.00
05-giu-06	540.00	270.00	135.00	405.00

Yield threshold depletion (“YTD” worksheet)

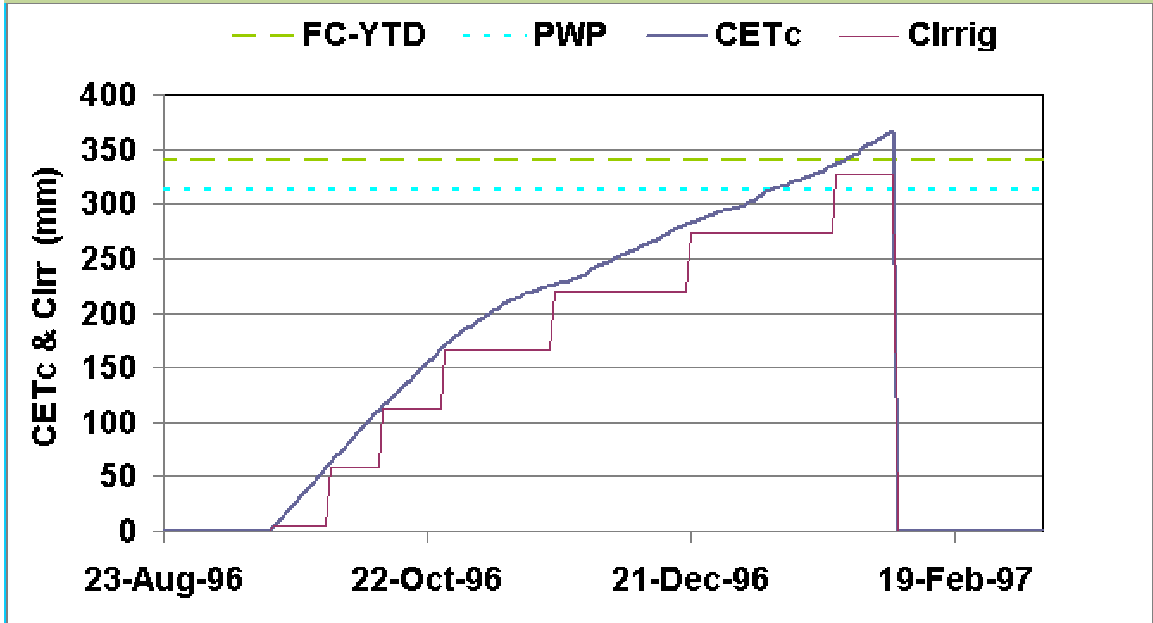
Caratteristiche del suolo



FC=Capacità idrica di campo

PWP= Punto di appassimento permanente

Descrizione del modello



Enter the soil and crop root information in the YTD worksheet. The Max YTD and Max PAW will automatically appear below. Use YTD the to find the last irrigation.

Using the maximum YTD, compare with the Depl. values and enter an irrigation equal to the Max PAW when the Depl. exceeds the Max PAW

The last irrigation should occur when the CIrr falls between FC-YTD and PWP

ETc mm d^{-1}	Pcp mm	CETc (mm)	DOY	Date	Depl. (mm)	Irrig (mm)	CIrrig (mm)	
1.4	0.1	335	388	22-Jan-97	52		274	0.00
2.0	0.0	337	389	23-Jan-97	0	54	328	0.00
2.0	0.3	339	390	24-Jan-97	2		328	0.00

Maximum YTD	27	1-Jan-96	340	313
Maximum PAW	54	30-Jul-97	340	313

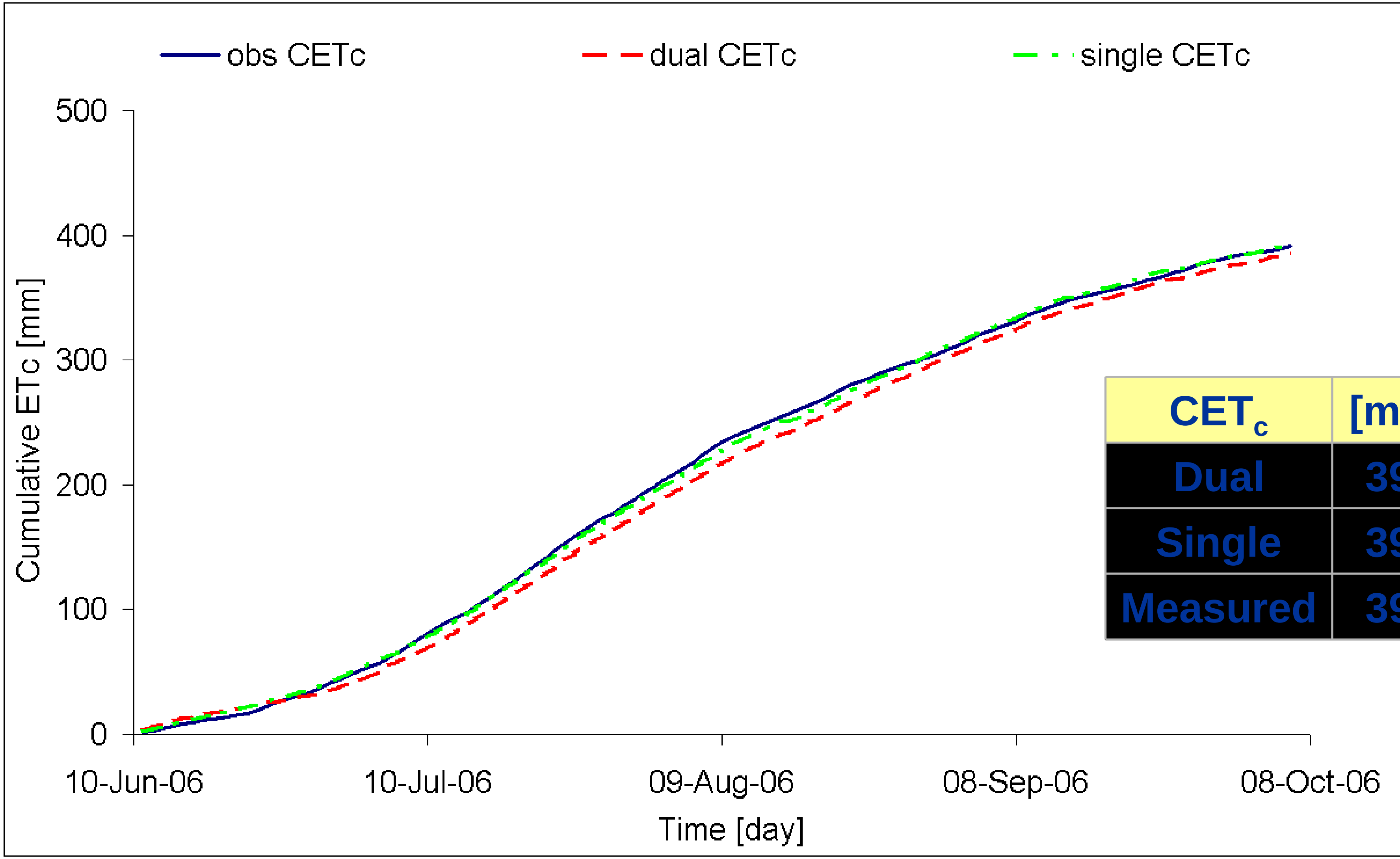
Simulated cumulative irrigation curve (example: lettuce)

Descrizione del modello

4. Alberi giovani e inerbimento

Cover Crop Contribution:		0.35
Start Gnd Cover #1 Date:		
End Gnd Cover #1 Date:		
Start Gnd Cover #2 Date:		
End Gnd Cover #2 Date:		
Irrigation Surface Area Wetted (%):	100	TKc
Ground shading on date A (%):		0.55
Ground shading on date B (%):	45	0.55
Ground shading on date C (%):	55	1.20
Ground shading on date D (%):		1.20
Ground shading on date E (%):		0.65
Percent of the season from date A to the growth date	B	40
	C	50
	D	30

Model Validation



CET_c	[mm]
Dual	392
Single	398
Measured	391

Conclusioni

- Et_c è il fattore chiave per migliorare l'efficienza dell'uso dell' acqua
- Dalla bibliografia si deduce che i valori di Kc sono dipendenti dal clima locale
- Un modello è stato sviluppato per valutare l Etc delle diverse colture
- Il modello è pronto all'utilizzo da parte di tecnici pubblici o privati

Previsioni

- Etc è connesso con la temperatura e la resistenza degli stomi (r_c)

- Si può predire l’ Etc usando i dati del tempo simulato nel modello del Kc e che tenga conto delle concentrazioni di CO_2

Grazie per l'attenzione