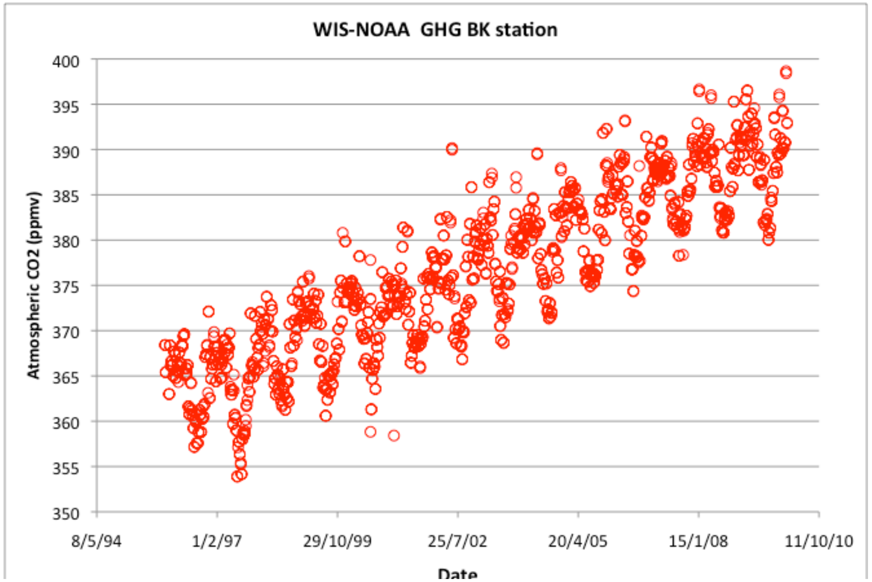
מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

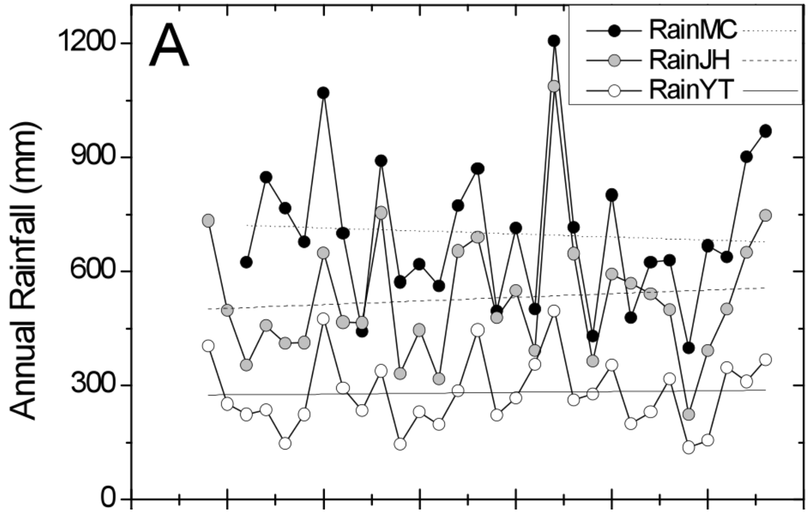
Tradeoffs in semi-arid pine forest

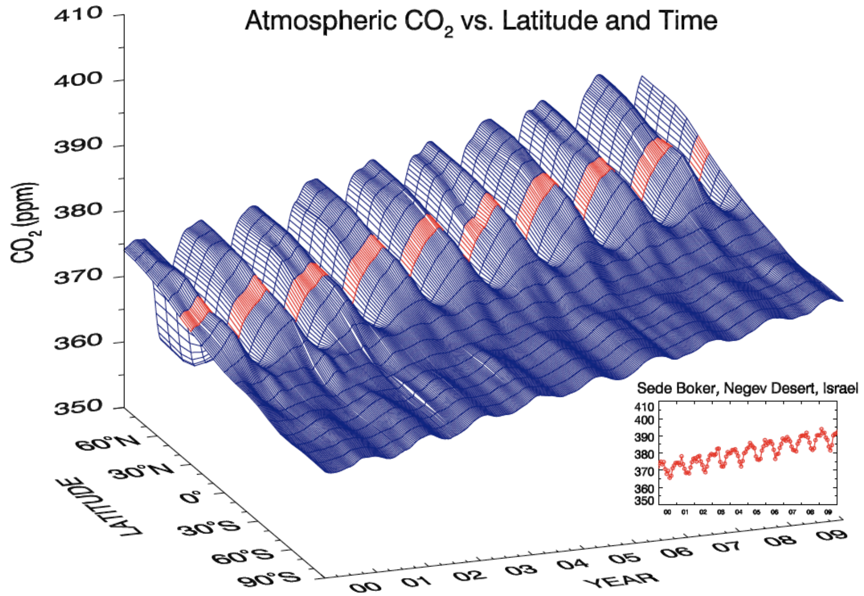
KKL; GLOW-JR; ISF

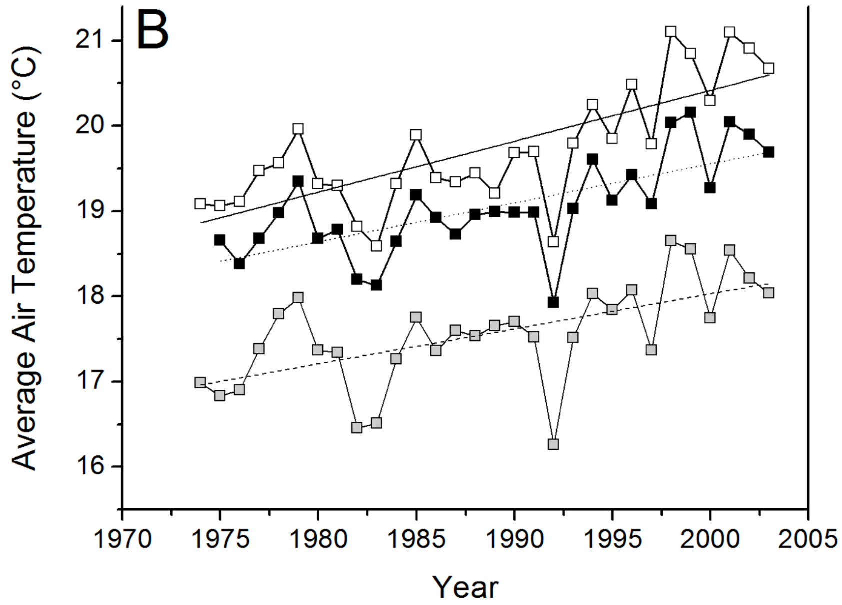
Dan Yakir & Eyal Rotenberg

ISEEQS, June 2010


WIS-NOAA GHG BK station
Atmospheric CO2 (ppmv)
400
395
390
385
380
375
370
365
360
355
350
8/5/94
1/2/97
29/10/99
25/7/02
20/4/05
15/1/08
11/10/10
Date


A
RainMC
RainJH
RainYT
Annual Rainfall (mm)
1200
900
600
300
0


Atmospheric CO_2 vs. Latitude and Time
CO_2 (ppm)
410
400
390
380
370
360
350
LATITUDE
60°N
30°N
0°
30°S
60°S
90°S
YEAR
00
01
02
03
04
05
06
07
08
09
Sede Boker, Negev Desert, Israel

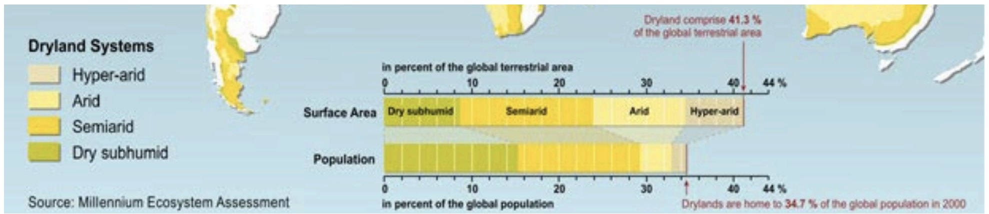

B
Average Air Temperature (°C)
21
20
19
18
17
16
1970
1975
1980
1985
1990
1995
2000
2005
Year

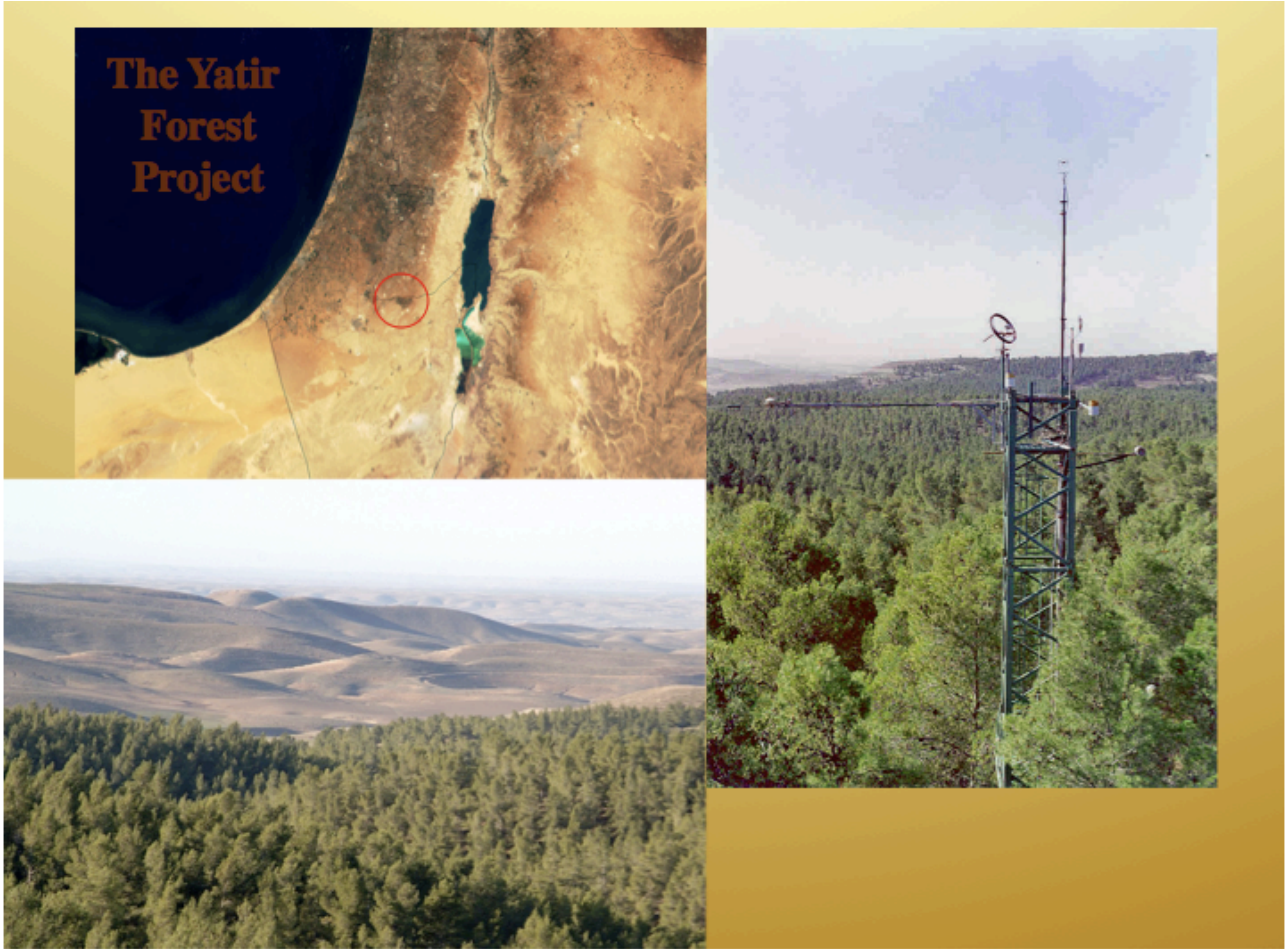
The global FluxNet

Extent of Drylands

Region	Arid	%	Semi Arid	%	Dry Sub-Humid	%	All Drylands	%	Population
Asia (Incl. Russia)	6,164	13	7,649	16	4,588	9	18,401	39	1,444,906
Africa	5,204	17	5,073	17	2,808	9	12,933	43	267,563
Oceania	3,488	39	3,532	39	996	11	8,016	89	140,586
North America	379	2	3,436	16	2,081	10	5,896	28	86,990
South America	401	2	2,980	17	2,233	13	5,614	32	59,323
C. America & Caribbean	421	18	696	30	242	10	1,359	58	31,719
Europe	5	0	373	7	961	17	1,339	24	6,960
	15,910	**12**	**23,739**	**18**	**13,909**	**10**	**53,558**	**41**	**2,038,047**

Land area: millions of square kilometers. Population: thousands. From White and Nackoney (2003)




The Yatir
Forest
Project

Indicators of high carbon use efficiency

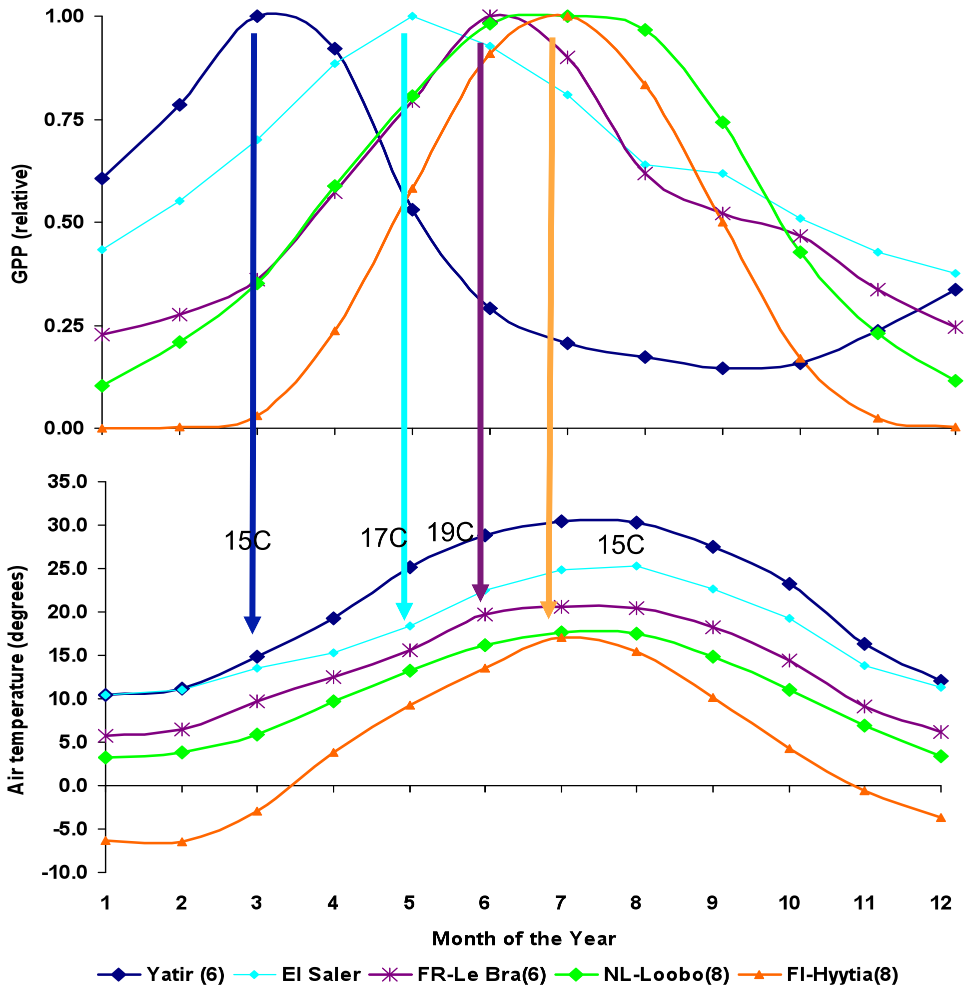
Pine forest	GPP	Re	NEE	NEE/GPP
European (Carboeurope)	1142	944	200	0.17
Global (FluxNet)	1540	1280	260	0.17
Semi-arid (Yatir)	820	600	220	0.27

*gr C m^{-2}

Maseyk et al., 2007a,b; Grunzweig et a., 2009

Large-scale “homeostasis” response

$$DOY_{GPP} = -0.71(R_G) + 263.1;\ R^2=0.87)$$

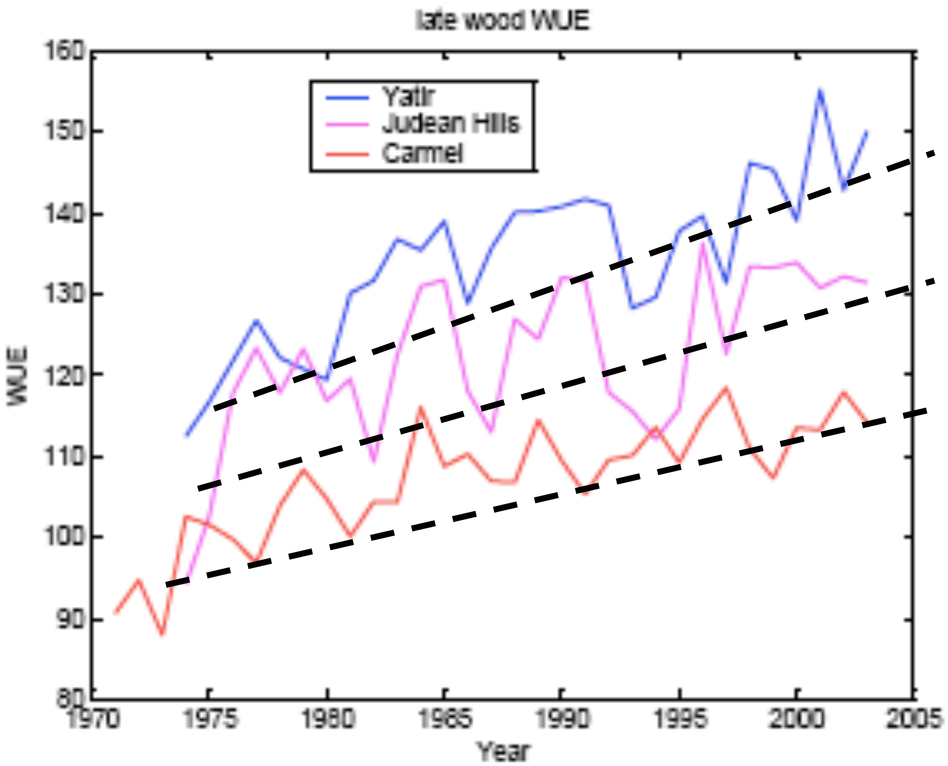


Rotenberg & Yakir, Science 2010

Annual pattern of a.. the monthly relative gross primary productions (defined as ((monthly sum of GPP)/(sum of highest productive GPP month)), and b.

^{13}C derived WUE along precipitation gradient

~25% increase in WUE, in dry sites: CO_2 response…



CO_2 up (330 to 380 ppm)
T up ~1.5C, no IA correlation
P no change, strong IA correlation

Episodic events vs. long-term climate change…

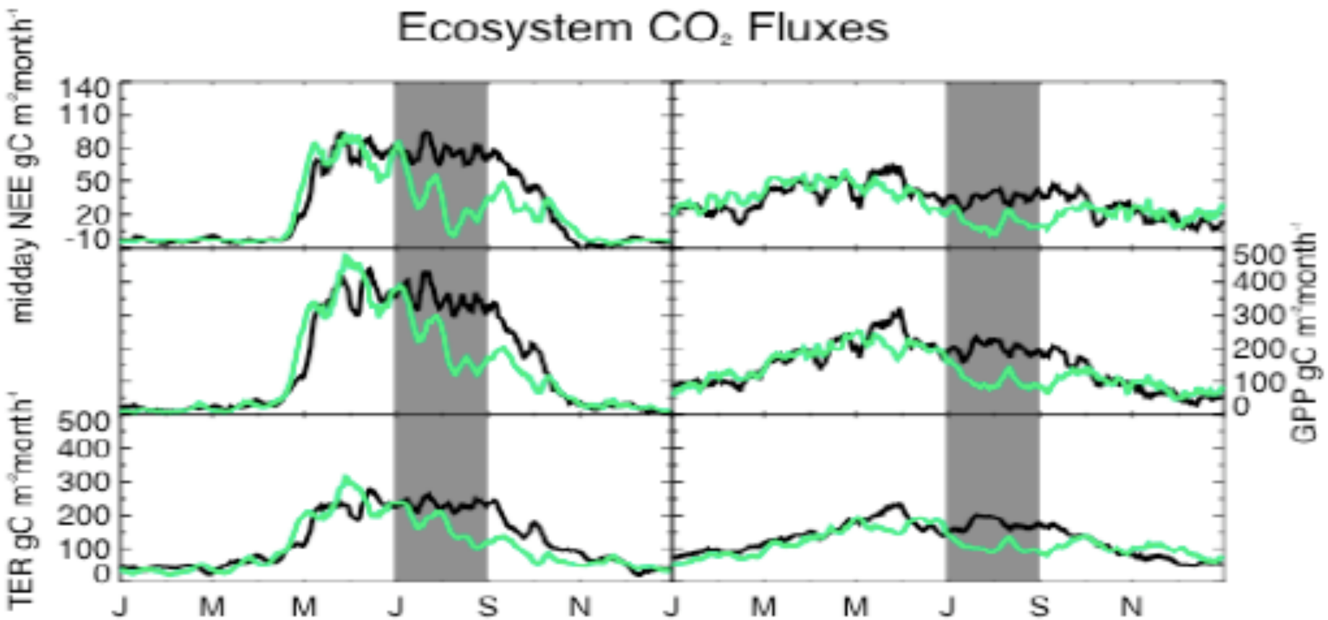
Vol 437|22 September 2005|doi:10.1038/nature03972

nature

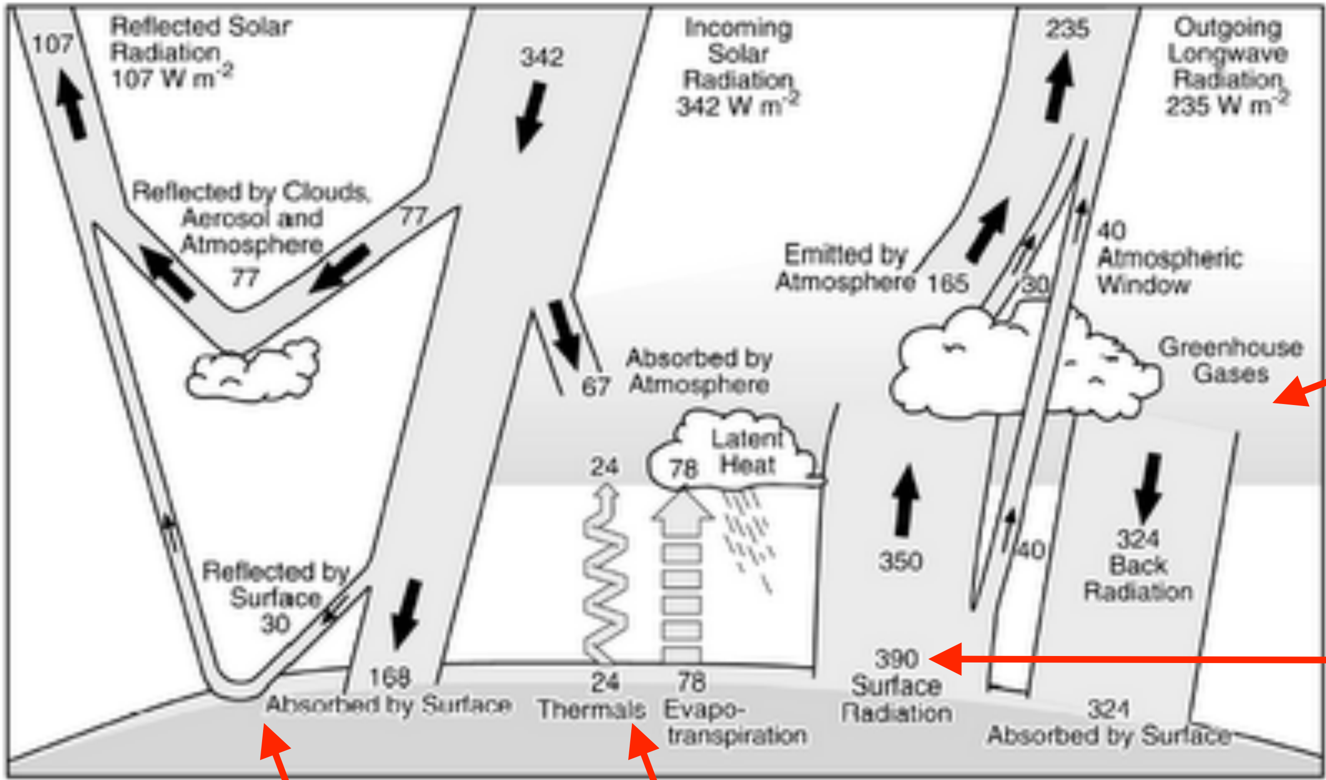
LETTERS

Europe-wide reduction in primary productivity caused by the heat and drought in 2003

Ph. Ciais[1], M. Reichstein[2,3], N. Viovy[1], A. Granier[4], J. Ogée[5], V. Allard[6], M. Aubinet[7], N. Buchmann[8], Chr. Bernhofer[9], A. Carrara[10], F. Chevallier[1], N. De Noblet[1], A. D. Friend[1], P. Friedlingstein[1], T. Grünwald[9], B. Heinesch[7], P. Keronen[11], A. Knohl[12,13], G. Krinner[14], D. Loustau[5], G. Manca[2]†, G. Matteucci[15]†, F. Miglietta[16], J. M. Ourcival[17], D. Papale[2], K. Pilegaard[18], S. Rambal[17], G. Seufert[15], J. F. Soussana[6], M. J. Sanz[10], E. D. Schulze[12], T. Vesala[11] & R. Valentini[2]



The Earth energy Balance



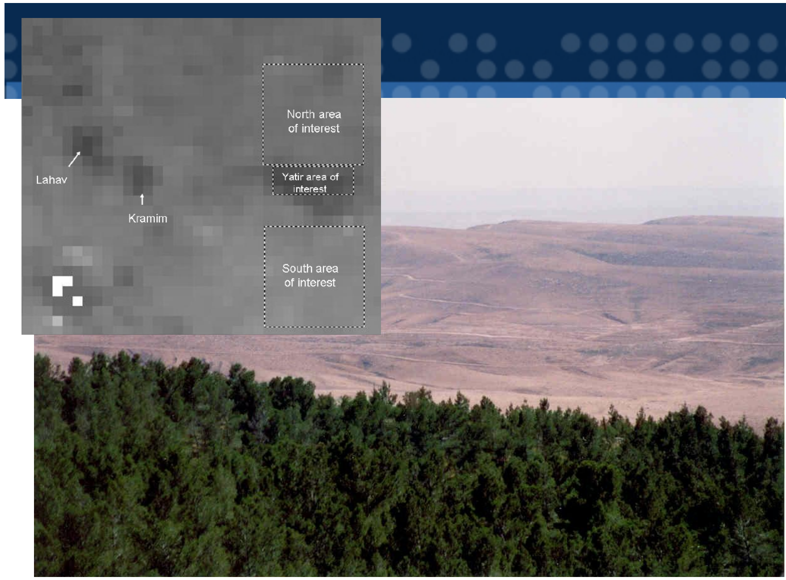
CO_2 uptake lowers downward thermal radiation=Cooling

Thermal radiations temperature-dependent

Vegetation reduces albedo

ET cools surface

Bowen ratio (H/LE) <3 for vegetation



Albedo effect: High radiation,
low cloud, reflective background…

Water-cooled canopy…

Air-cooled canopy…
(‘convector effect’; low r_a)

*Cooling relative to non-forest area:
~5C annual mean
Up to ~30C in summer mid-day

Forest/non-forest characteristics

Variable	Forest	Shrubland	
Global radiation (Eg, Wm^{-2})	238	238	
Albedo (unit-less)	0.11	0.21	d=+23.8 Wm^{-2}
Net solar radiation (Sn, Wm^{-2})	212	188	
Net longwave radiation (Ln, Wm^{-2})	-96	-121	d=+25 Wm^{-2}
Net radiation (Rn=Sn+Ln, Wm^{-2})	115	67	d=+48 Wm^{-2}
Skin temperature [°C]	19	24*	

Rotenberg & Yakir, Science 2010

Radiative forcing (RF) as a metric for the tradeoffs*:

1) **Cooling effect: ~2.2 t ha^{-1} a^{-1} since 1965=>~27 w m^{-2}**

3) **Warming effect: Increased surface radiation load (24 S + 25 L) ~49 w m^{-2}**

$$RF_{S+L}(y) = A(y)(\delta\alpha \cdot Eg + \delta L) / ES$$

3) **Balance: requires ~30 more years... (Worst case scenario!)**

$$y = \left(\frac{RF_{\mathrm{surface}} \cdot \kappa \cdot C_0}{A_E \cdot NEE \cdot \eta \cdot \zeta} \right)$$

*Radiative forcing is not climate or temperature

A=area; α=albedo; Eg=global irradiance; L=LWR; η=CO2 RF efficiency; C=CO2 emitted/absorbed; κ=convert KgC to ppmv; ζ=airborne fraction

Bottom line:

*Ecosystem adjustments help maintain high productivity in the face of warming/drying (phenology, CUE, WUE, NUE).

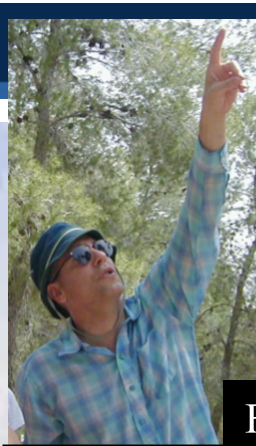
*But, surface energy aspects complicate pictures and must also be considered…

*Similarly, desertification also involves “complicating” factors of surface energy vs. carbon…

Rotenberg & Yakir, Science 2010


Back in the lab


Tree rings


Energy budget


From NEE to GPP


Ecophysiology


Physiology


Below ground…

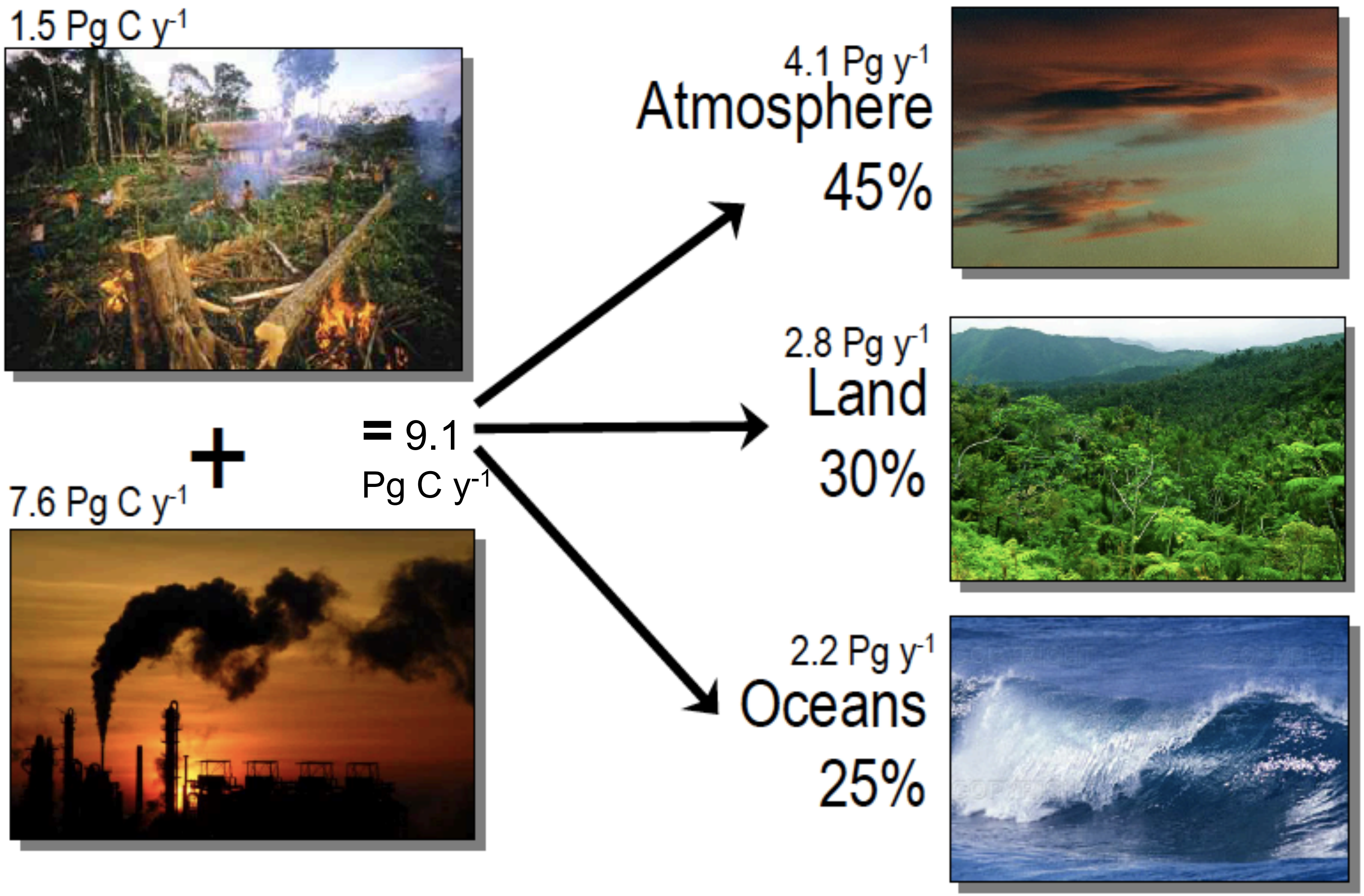

Stable isotopes


Data processing


Where is the water


Peace of mind

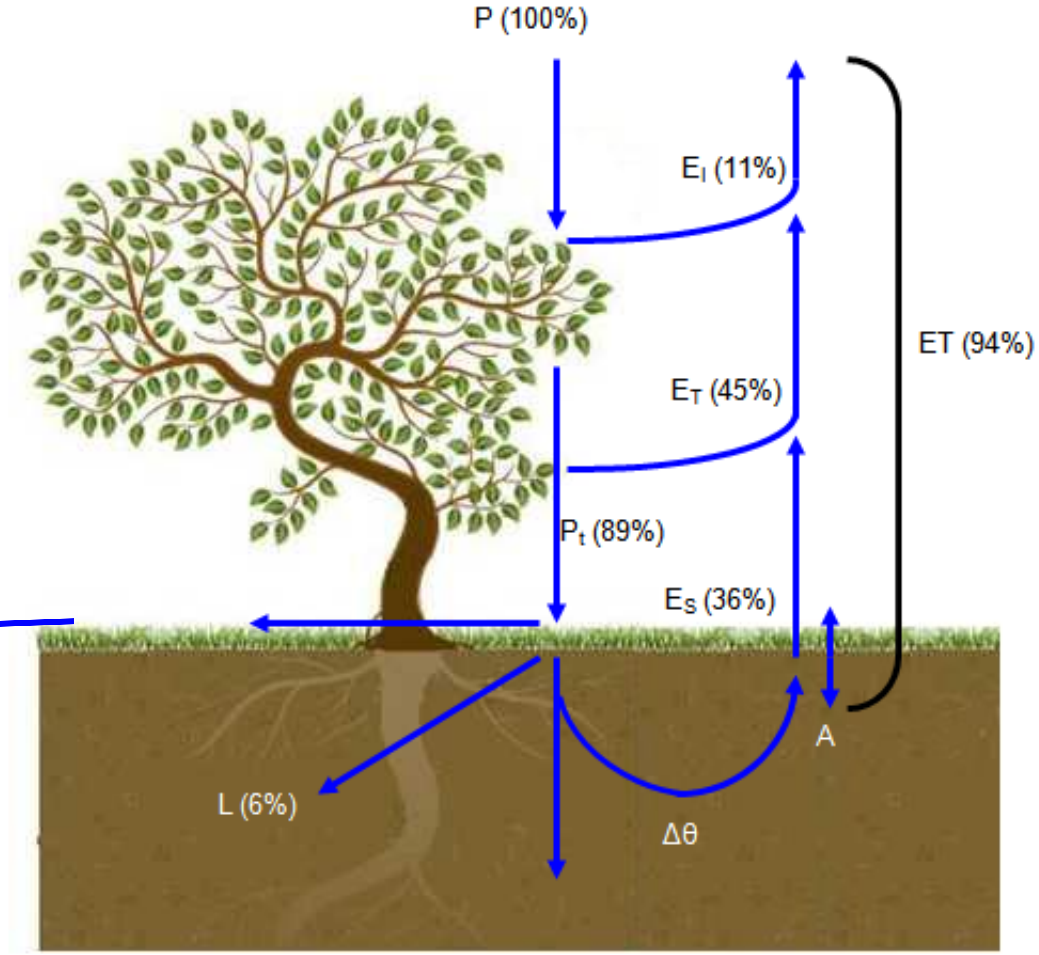

N cycle


1.5 Pg C y-1
+
7.6 Pg C y-1
= 9.1
Pg C y-1
4.1 Pg y-1
Atmosphere
45%
2.8 Pg y-1
Land
30%
2.2 Pg y-1
Oceans
25%

Yatir's Ecohydrology

T/E=f(density)

No runoff



Raz-Yaseef et al., 2009, 2010

The desertification perspective

1) 35 years desertification ~5.8 Mha y^{-1}

2) Albedo + LWR suppression => RF ~0.145 W m^{-2}(cooling)

$$RF_{S+L}(y) = A(y)(\delta\alpha \cdot Eg + \delta L) / ES$$

1) C release, 2.2 kg m^{-2} => RF ~0.006 W m^{-2} (warming)

$$RF_{CO2}(y) = \eta \cdot Ln\left(1 + \frac{C(y)}{C_O}\right); C(y) = A(y)C\kappa / \zeta$$

2) 44 ppm CO2 same period => ~0.62 W m^{-2} (warming).

3) (0.145-0.06)/0.62=~20% moderation, same period.
(similar to 'airborne fraction' moderation)

Estimates based on: Lal 2004, Betts 2000, Myhre et al. 1998, this work

A=area; α=albedo; Eg=global irradiance; L=LWR; η=CO2 RF efficiency; C=CO2 emitted/absorbed;
κ=convert KgC to ppmv; ζ=airborne fraction

Unique radiation budget of semi-arid forest