Stocks and flows of water, carbon and energy through ecosystems

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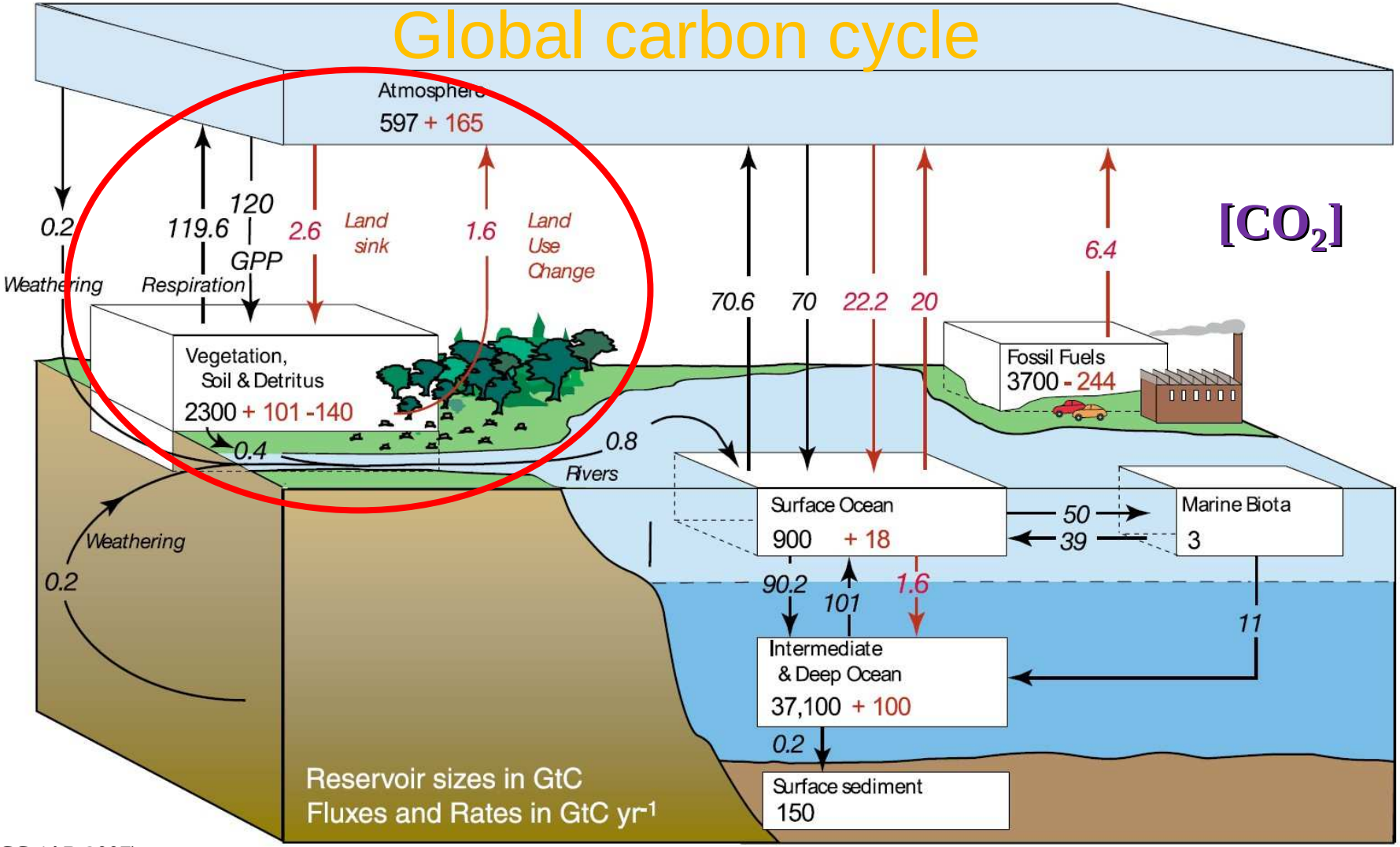
Talk Outline

- Terrestrial carbon cycle
- Stocks
- Fluxes and productivity
- Case study – tropical savanna

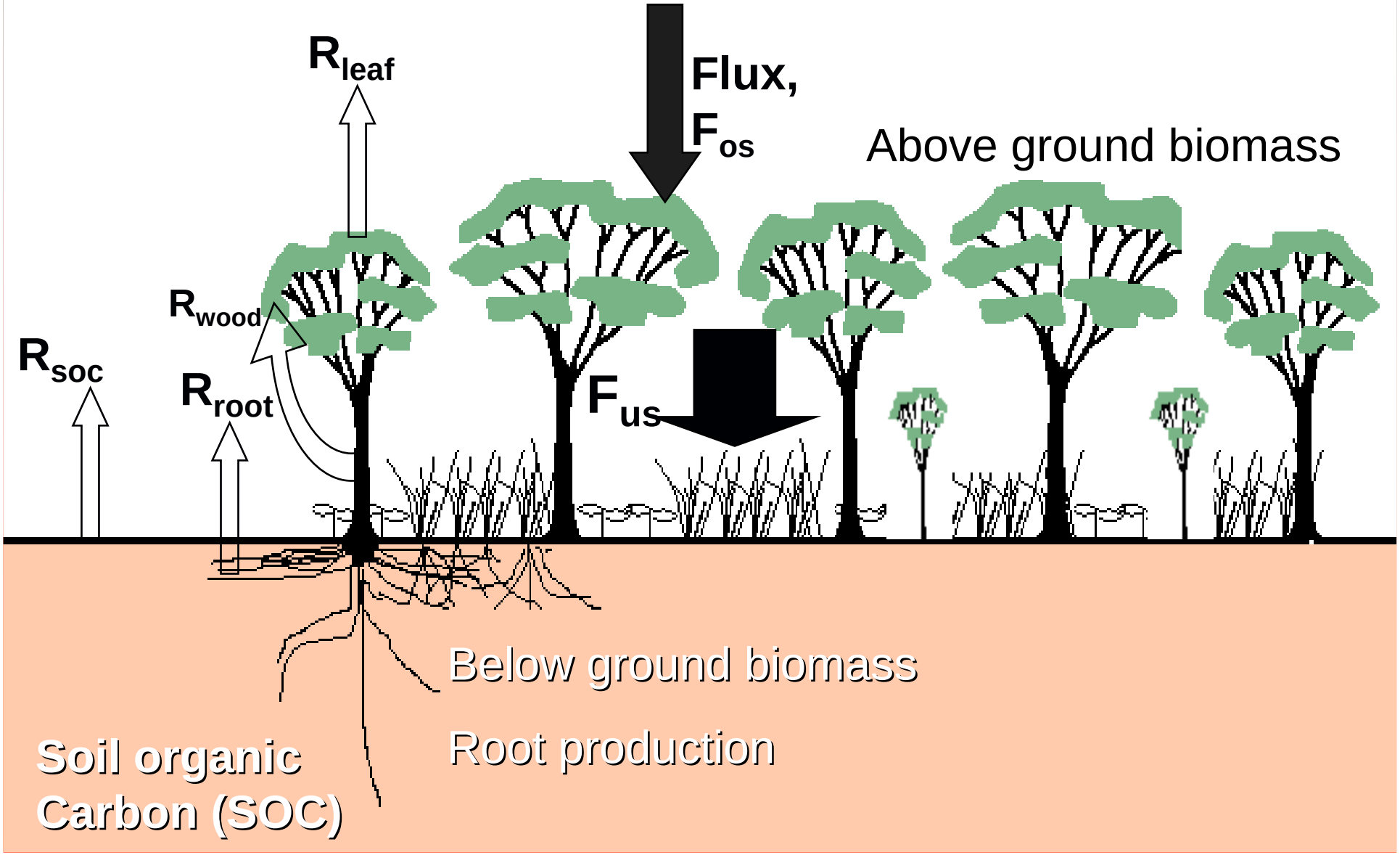
Global carbon cycle

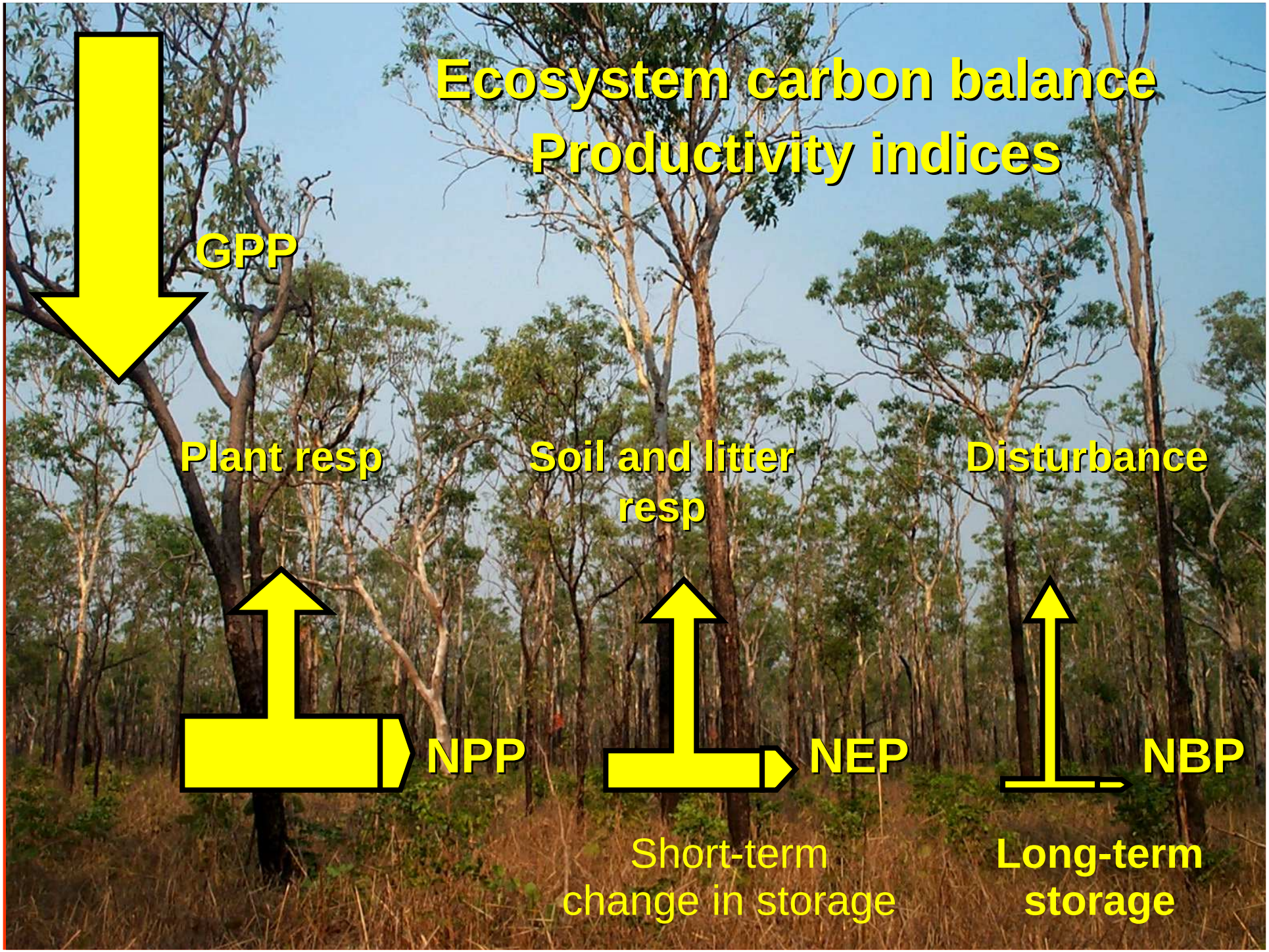


(IPCC 4AR 2007)

Figure 7.3. *The global carbon cycle for the 1990s, showing the main annual fluxes in GtC yr^{-1}: pre-industrial 'natural' fluxes in black and 'anthropogenic' fluxes in red (modified from Sarmiento and Gruber, 2006, with changes in pool sizes from Sabine et al., 2004a). The net terrestrial loss of –39 GtC is inferred from cumulative fossil fuel emissions minus atmospheric increase minus ocean storage. The loss of –140 GtC from the 'vegetation, soil and detritus' compartment represents the cumulative emissions from land use change (Houghton, 2003), and requires a terrestrial biosphere sink of 101 GtC (in Sabine et al., given only as ranges of –140 to –80 GtC and 61 to 141 GtC, respectively; other uncertainties given in their Table 1). Net anthropogenic exchanges with the atmosphere are from Column 5 'AR4' in Table 7.1. Gross fluxes generally have uncertainties of more than ±20% but fractional amounts have been retained to achieve overall balance when including estimates in fractions of GtC yr^{-1} for riverine transport, weathering, deep ocean burial, etc. 'GPP' is annual gross (terrestrial) primary production. Atmospheric carbon content and all cumulative fluxes since 1750 are as of end 1994.*

Carbon fluxes and pools




Ecosystem carbon balance
Productivity indices
GPP
Plant resp
Soil and litter resp
Disturbance
NPP
NEP
NBP
Short-term change in storage
Long-term storage

Production indices

- GPP = carbon input into ecosystem
- NPP = GPP - R_a

Measured by flux tower

- ***NEP*** = NPP – R_h or
- ***NEP*** = GPP – R_a – R_h ← sink strength
- NBP = ***NEP*** – D ← sink strength

Derived from flux measures

- GPP = ***NEP*** + $\boldsymbol{R_e}$, where R_e=R_a+R_h

Whole-plant photosynthesis

- Drivers
  - Radiation
  - Rainfall
  - VPD
  - PAM / PAN
  - LAI / phenology
  - Atmospheric CO_2 concentration

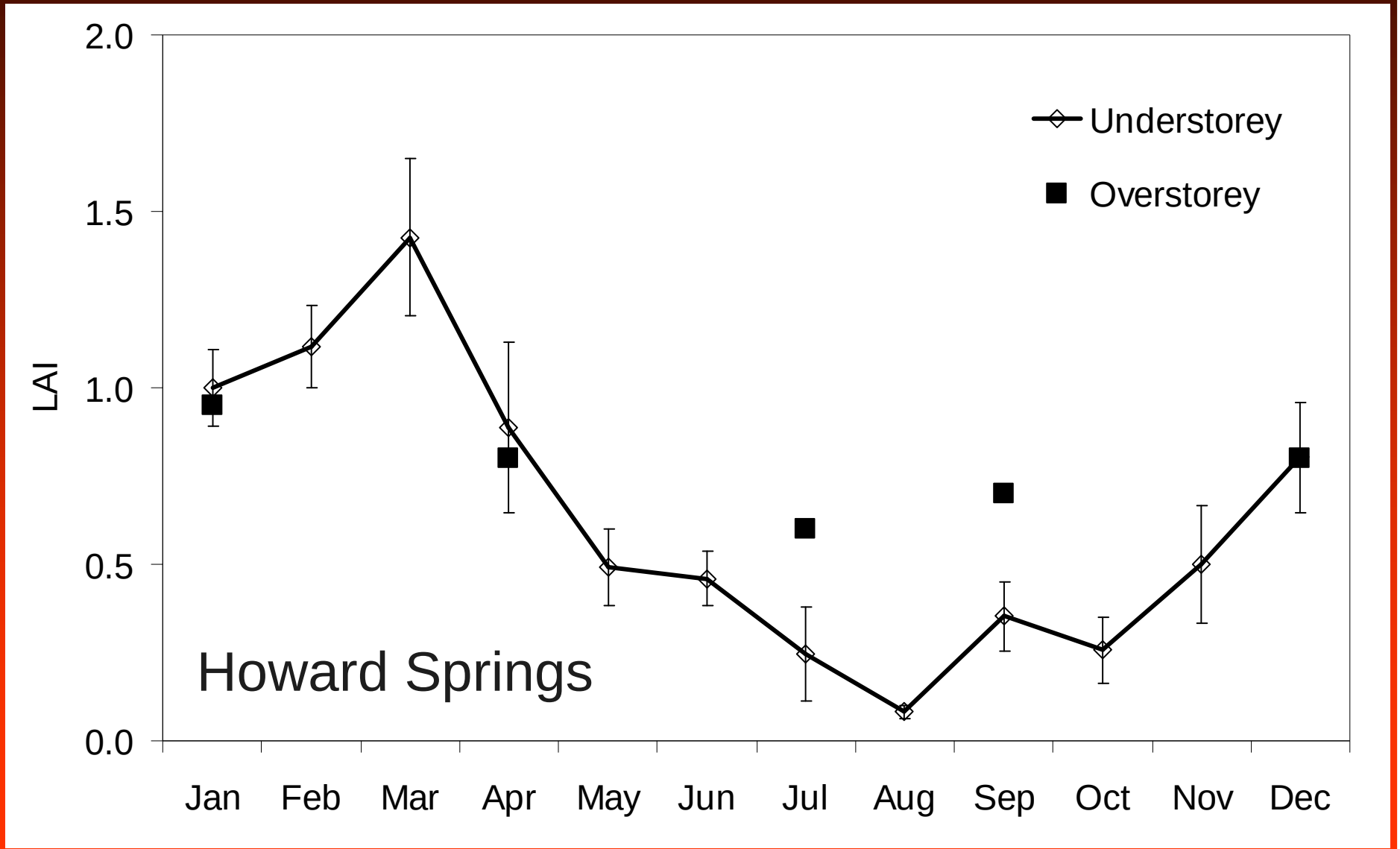
Whole-plant respiration

- All tissues respire - *internal* carbon balance
- 30-60% of daily carbon gain by photosynthesis (gross photosynthesis) lost via respiration
- Respiration
  - maintenance respiration
  - growth respiration (growth ‘costs’)
  - temperature dependence
- Tends to increase with age as increased biomass of non-photosynthetic material
- Tropical regions - respiration significant, high nocturnal temperature

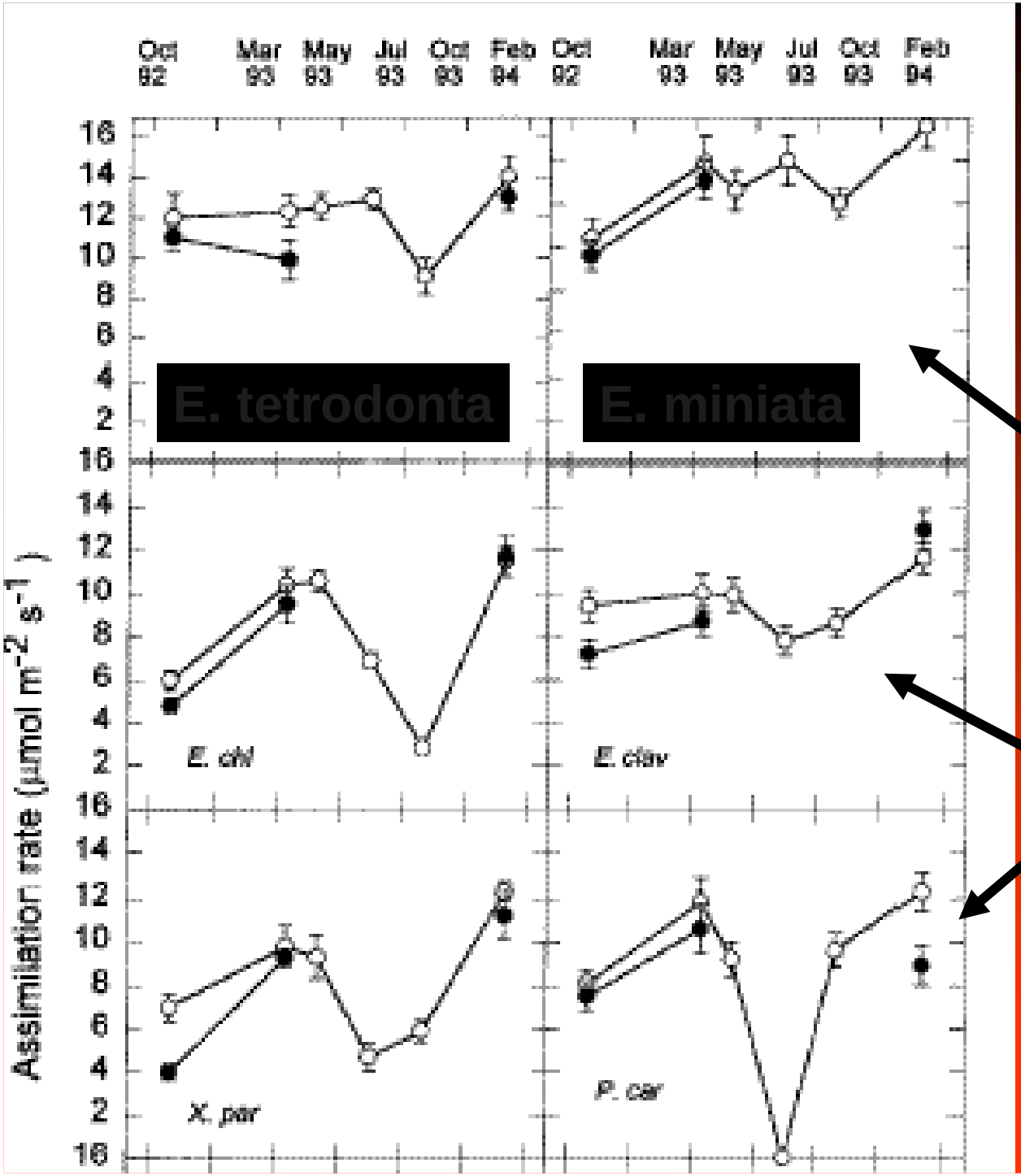
Savanna carbon balance

Seasonal patterns of production

Seasonality – Leaf Area Index



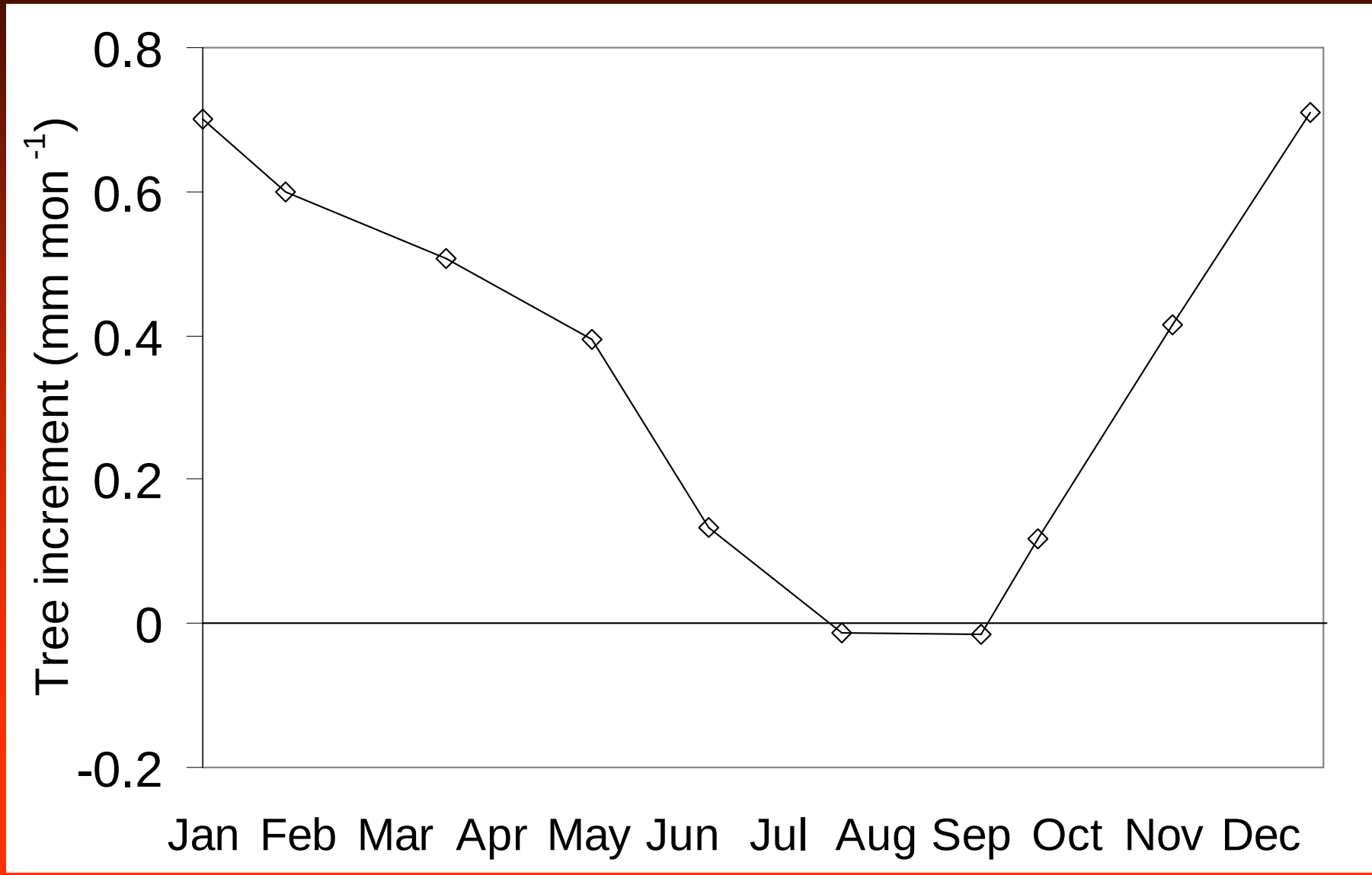
Seasonality - leaf photosynthesis



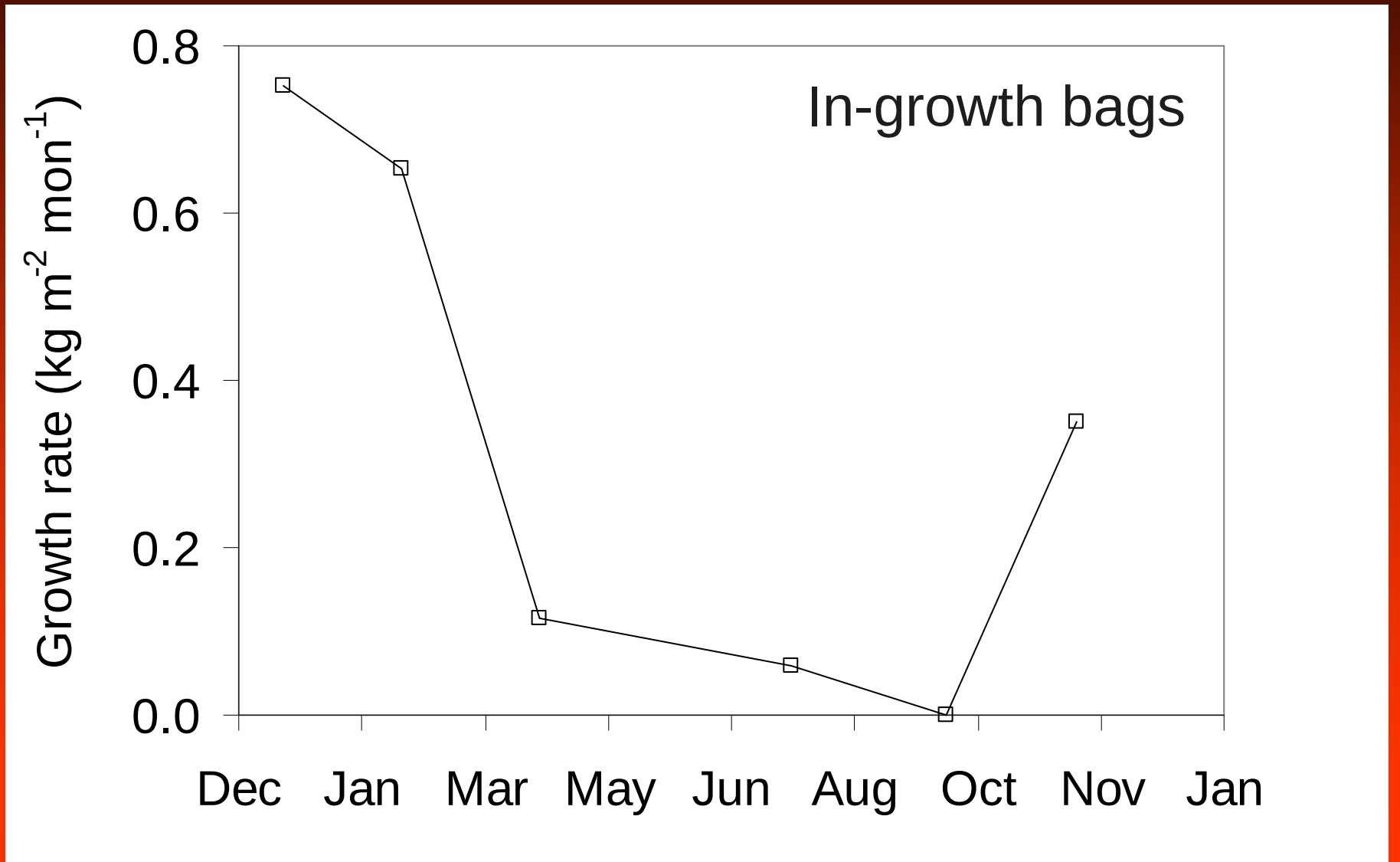
Evergreen trees

Semi-deciduous

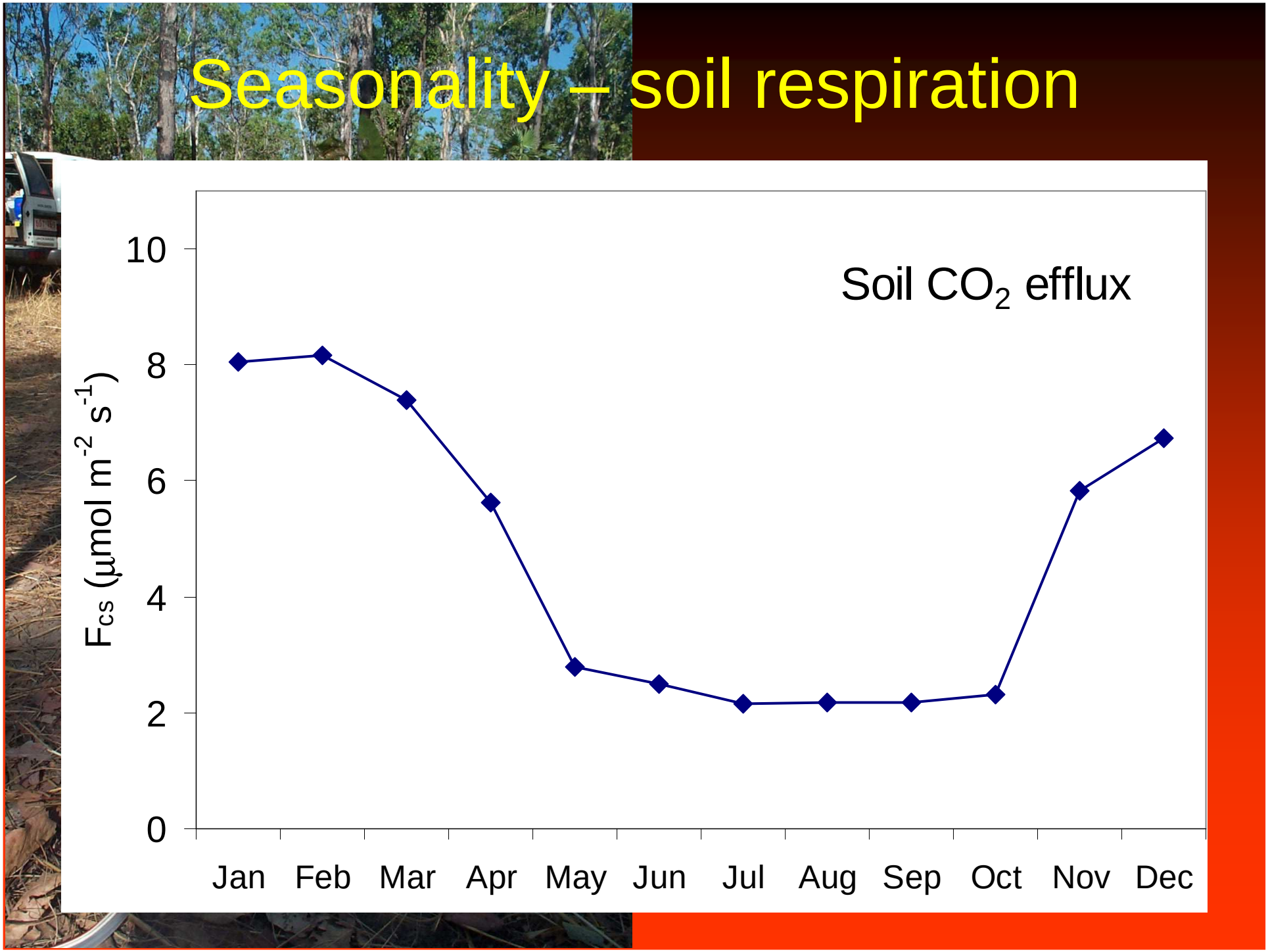
Seasonality - tree increment

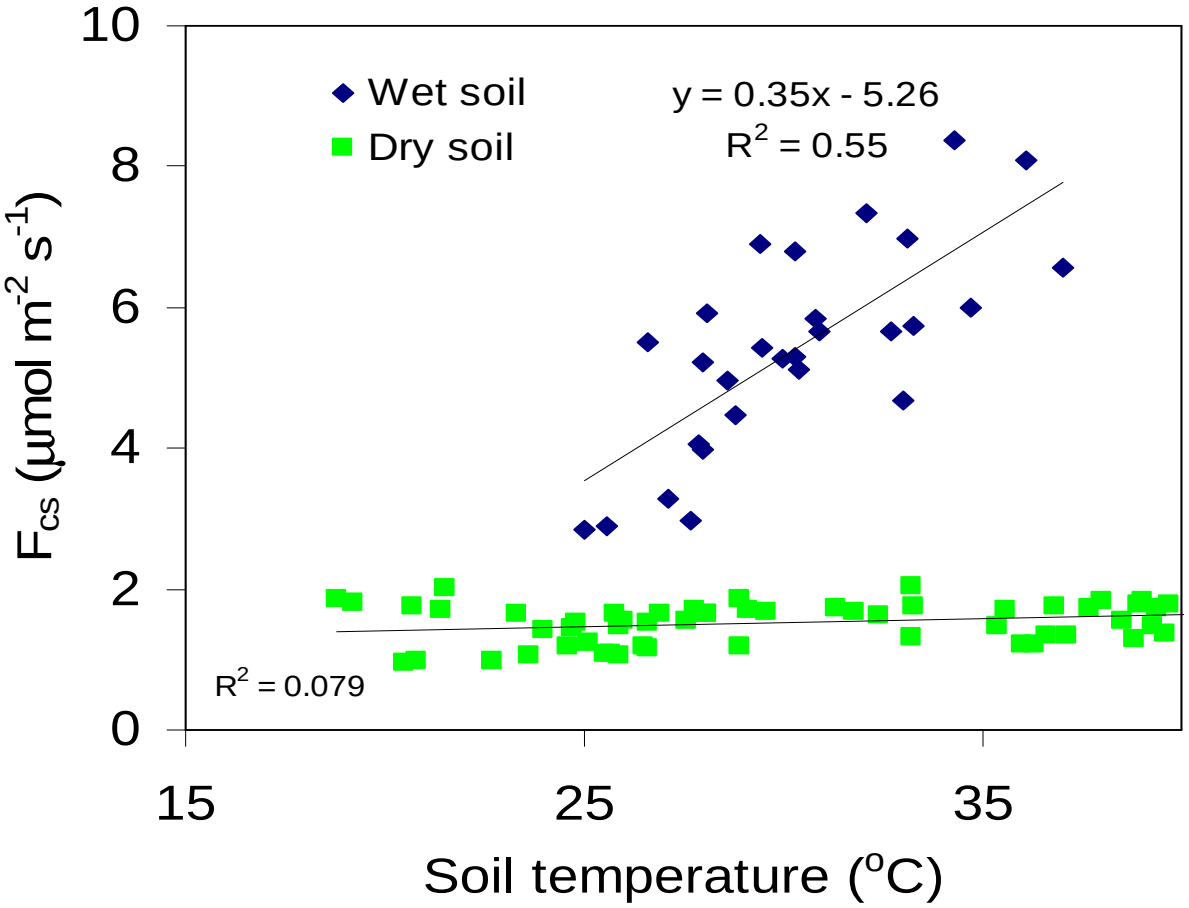


Seasonality – fine root turnover



Seasonality – soil respiration





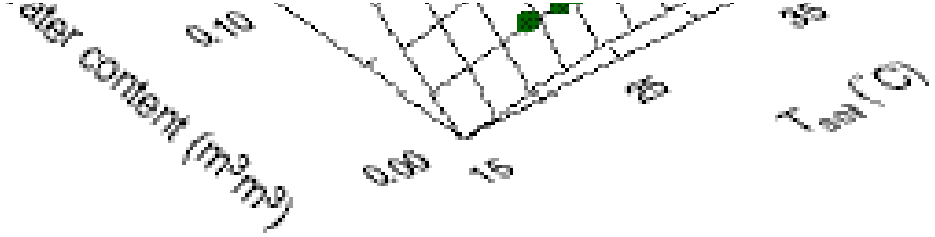


Fig. 5. Surface plot (smoothed quadratic) describing the efflux of CO_2 from the soil (F_{cs}) as a function of soil temperature and soil water content.

Savanna soils

R_{soil}

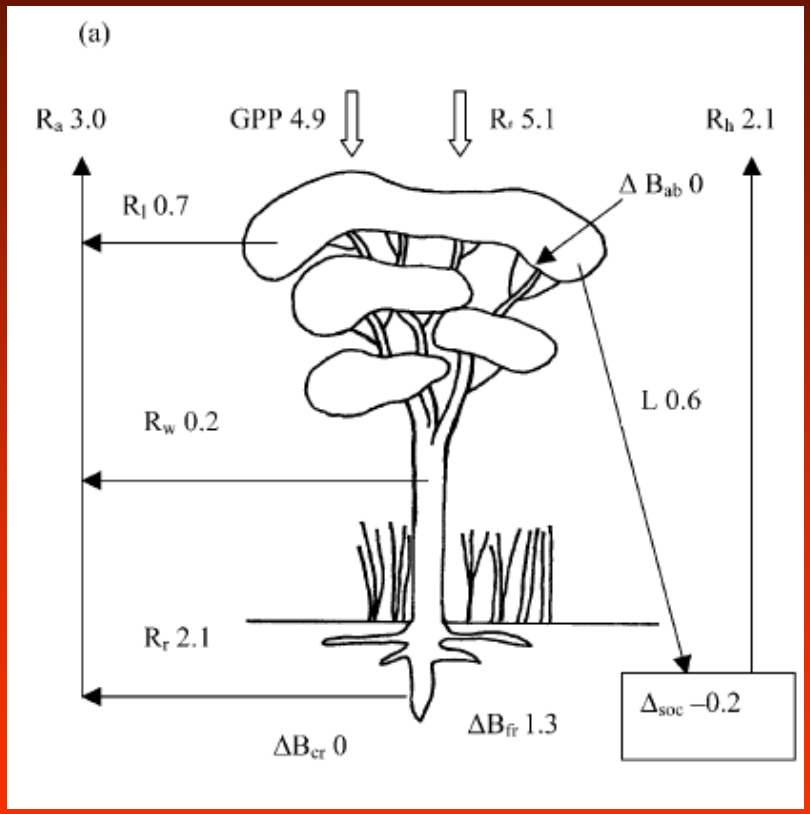
Soil respiration

R_a (roots) + R_h

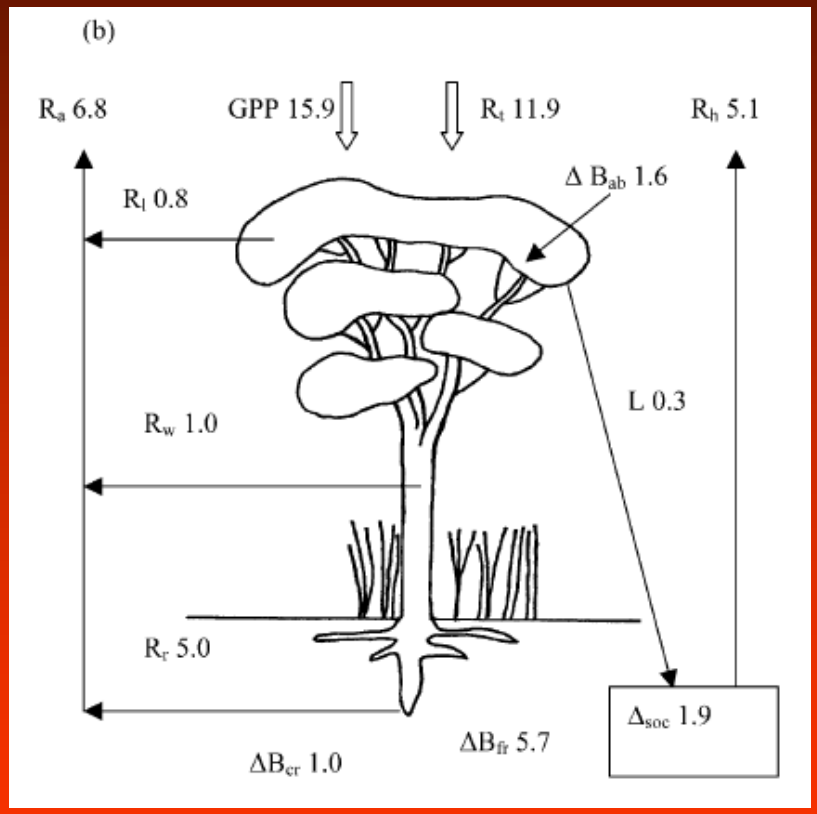
For savanna,

R_{soil}= f(water, T_{soil})

Carbon fluxes – inventory approach
Tropical savanna



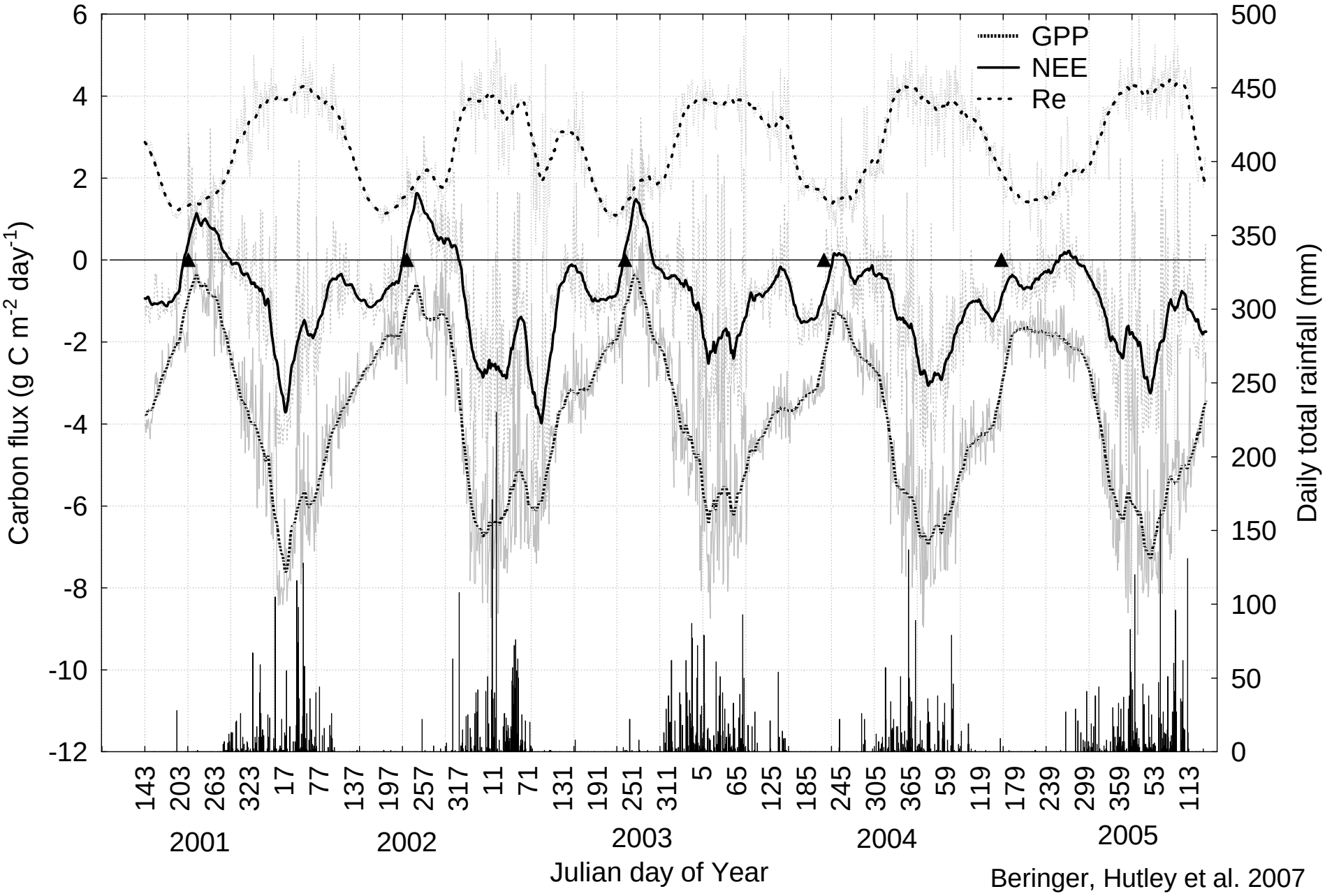
Dry season



Wet season

Chen et al. (2003)

Carbon fluxes – micrometeorology approach



Beringer, Hutley et al. 2007

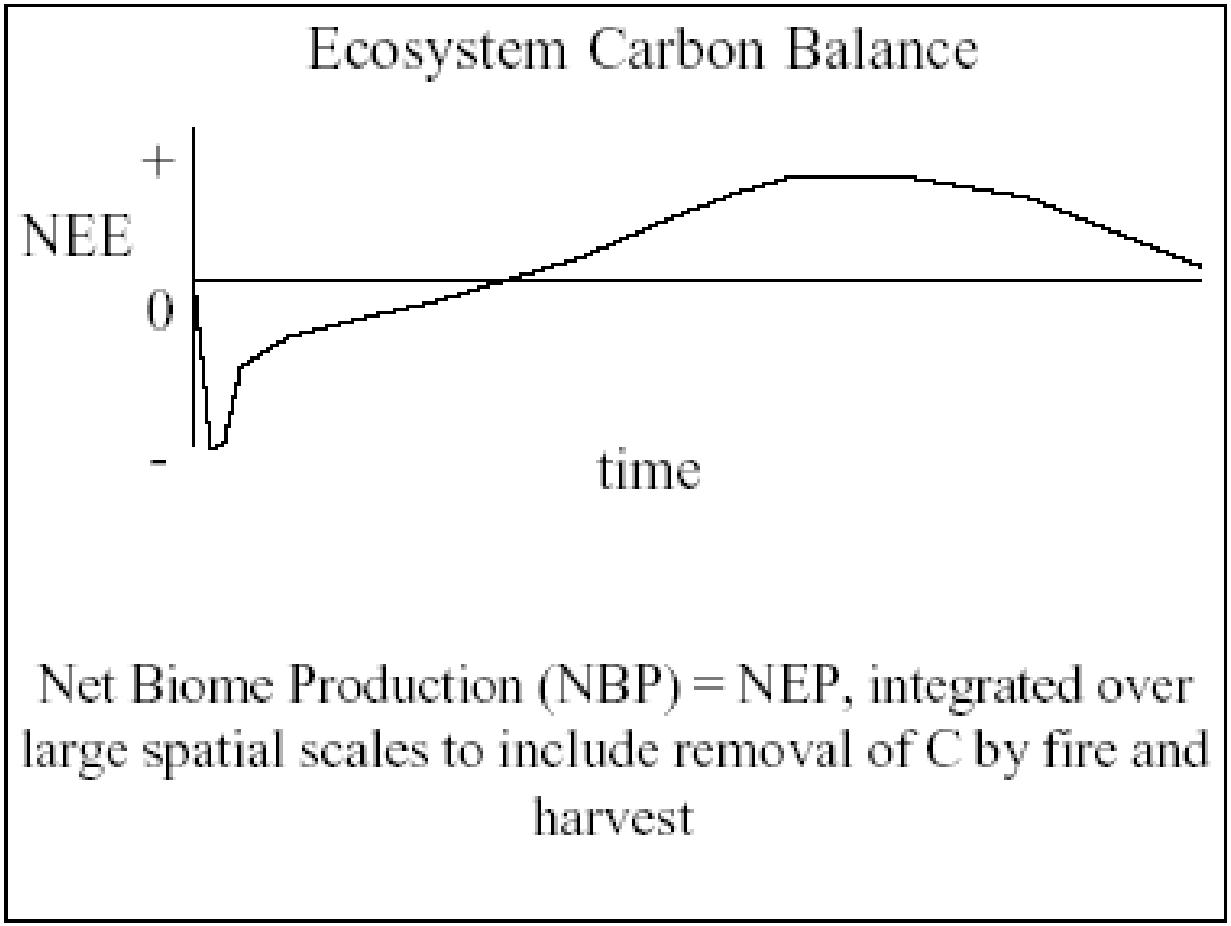
Stocks and fluxes

	Habitat			
	Boreal[1]	Temperate[1]	Wet Tropical[1]	Wet-dry Tropical[2]
	Evergreen coniferous forest	*Deciduous Broadleaf forest*	*Rainforest*	*Tall-grass savanna*
Carbon stocks (t C ha^{-1})				
Above-ground biomass	49.2	79	217	34
Below-ground biomass	18.2	50	105	17
Total Biomass	67.4	129	322	51
Soil carbon	390.4	56	162	150
Ecosystem total	458	185	484	201
Productivity (t C ha^{-1} y^{-1})				
GPP	9.6	17.3	30.4	20
NPP	5.2	9.4	15.6	10.1
Respiration	9.0	11.4	24.6	17.2
NEP	0.7	5.8	5.8	2.8
NPP/GPP	54%	55%	51%	51%

Effects of burning ?

- Not specifically examined in previous measures
- Impact on C cycle ?
- NBP estimate

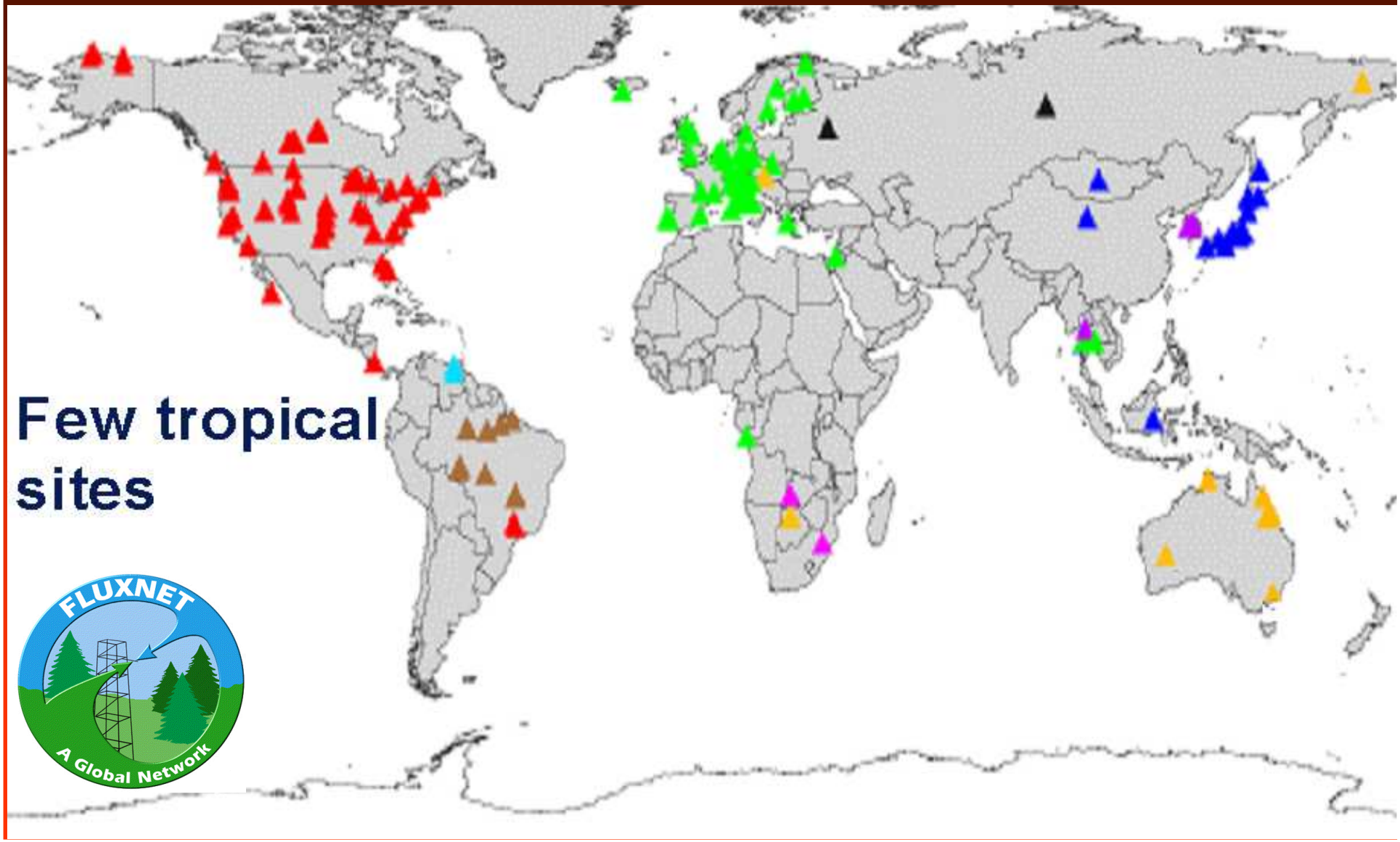
Terrestrial ecosystems carbon sink dynamics



Net Biome Production (NBP) = NEP, integrated over large spatial scales to include removal of C by fire and harvest

- What is the global distribution of NEP?
- Climate change may alter balance between R_e and GPP

Eddy covariance sites – Fluxnet
Global measurement of GPP, NEP, R_e



Ozflux – Australian flux stations