Is the biosphere carbon limited?

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"Impacts of climate change", EXPO 2015 Milano, 23 June 2015

In Geneva 210 years ago:

'The primary plant food comes from air'

- Nicolas-Théodore de Saussure (1804)

  Recherches chimiques sur la Végétation. Paris.

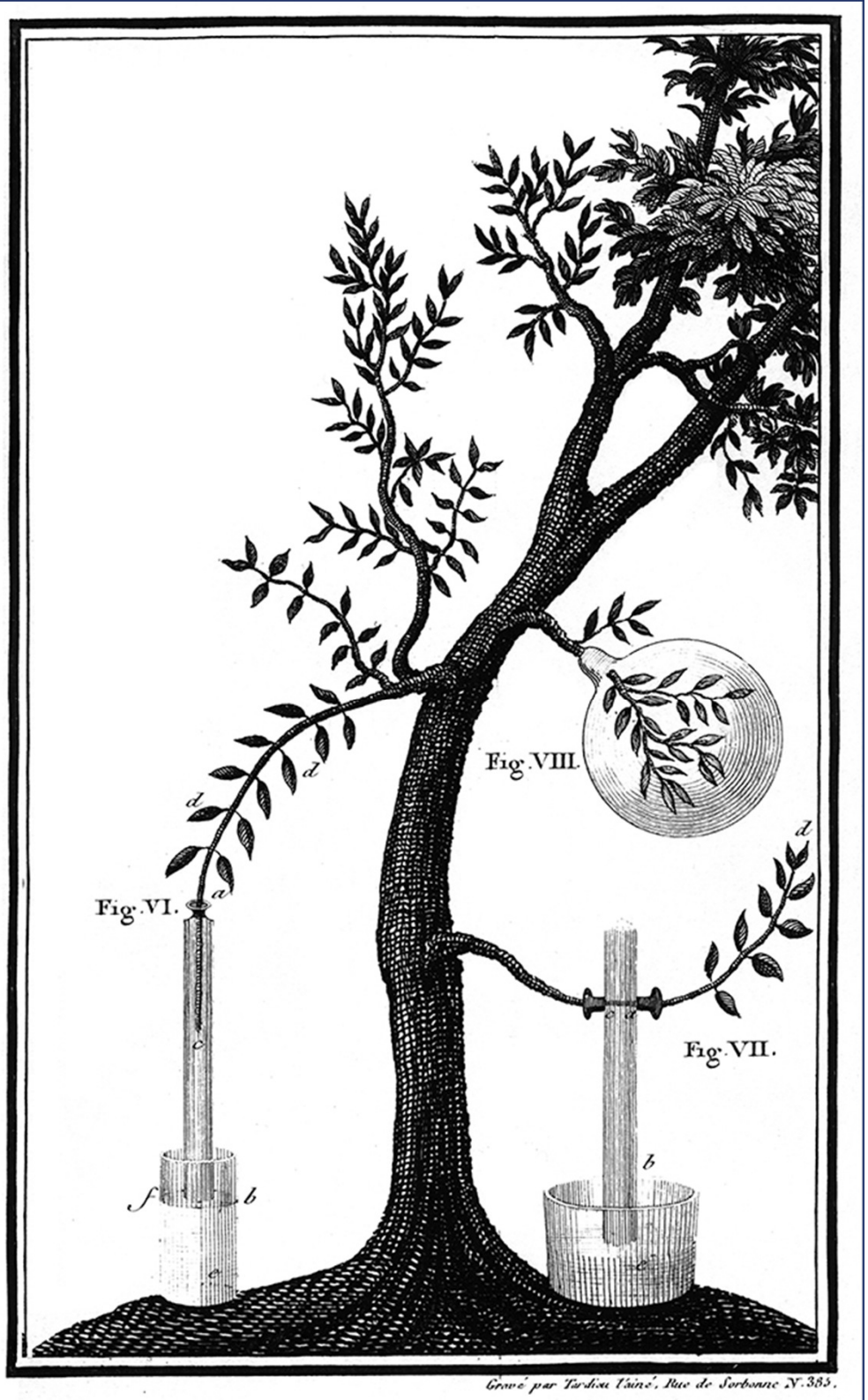
Paving the road:

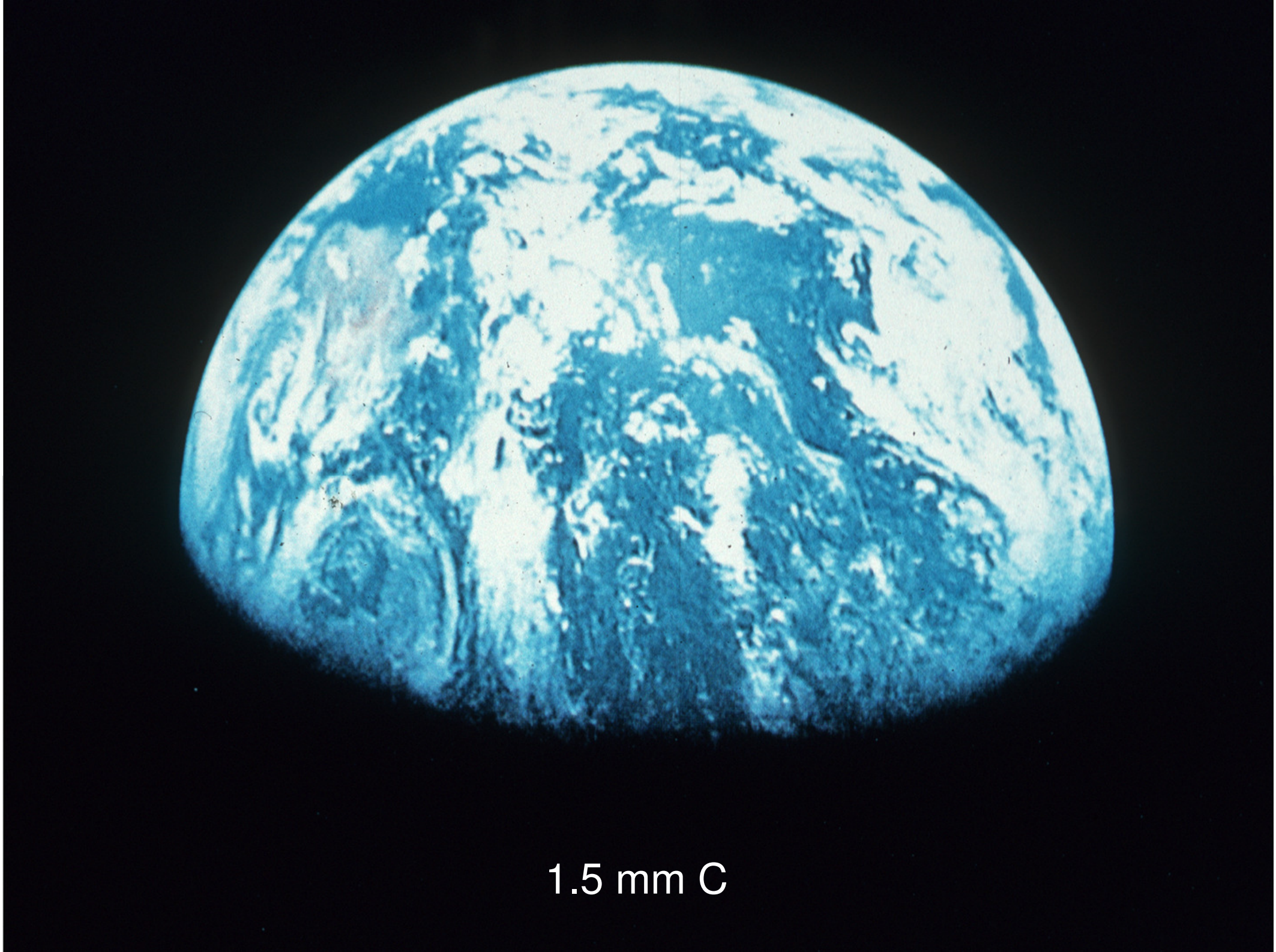
- Jan Ingenhousz (1779)

  Experiments upon vegetables, discovering their great power of purifying thecommon air in the sun-shine, and of injuring it in the shade and at night. P. Elmsly and H. Payne, London, UK.

- Jean Senebier (1783)

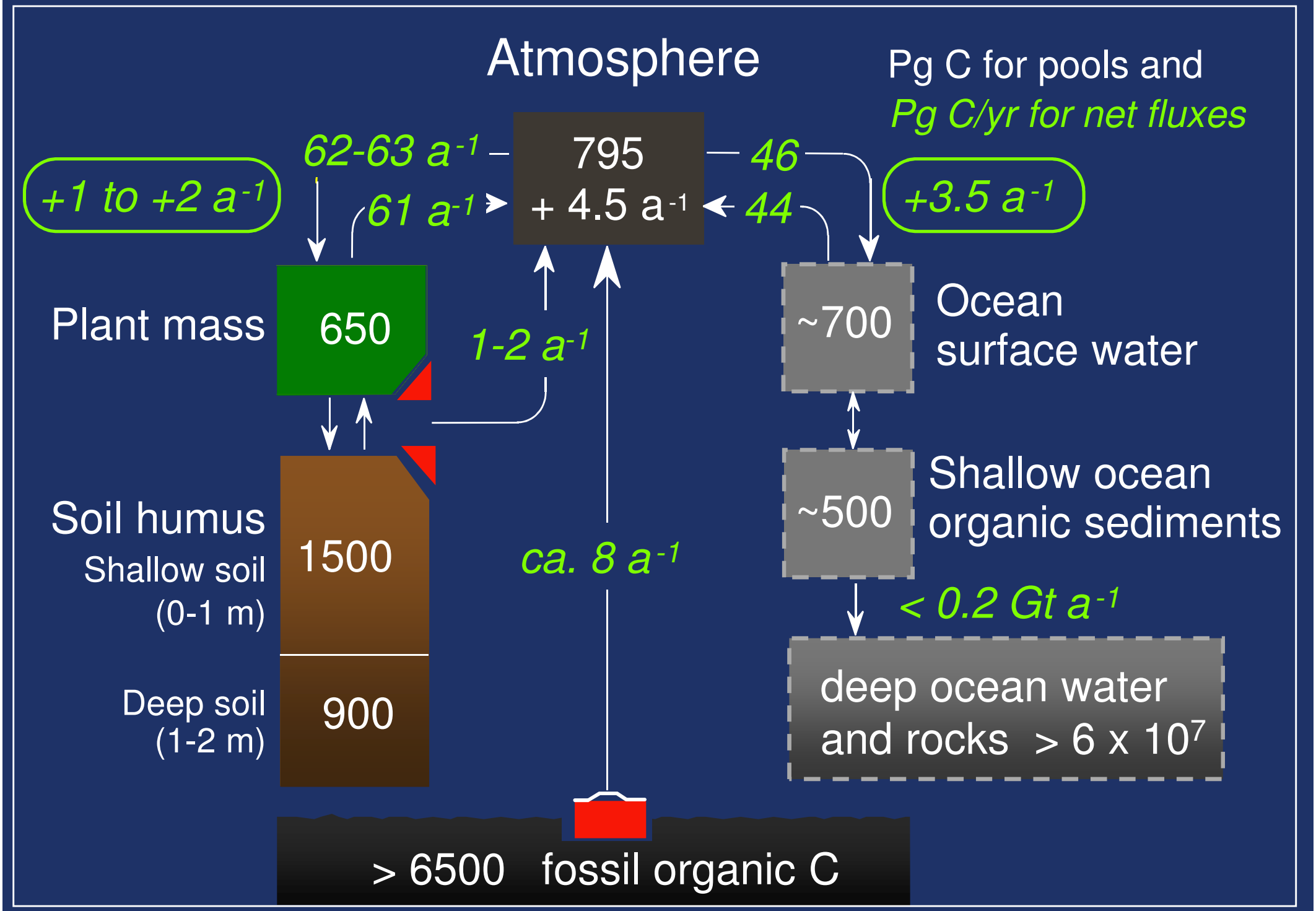
  Recherches sur l'nfluence de la lumière solaire pour métamorphoser l'air fixe en airpur par la vegetation. Barthelemi Chirol, Geneva, Switzerland.



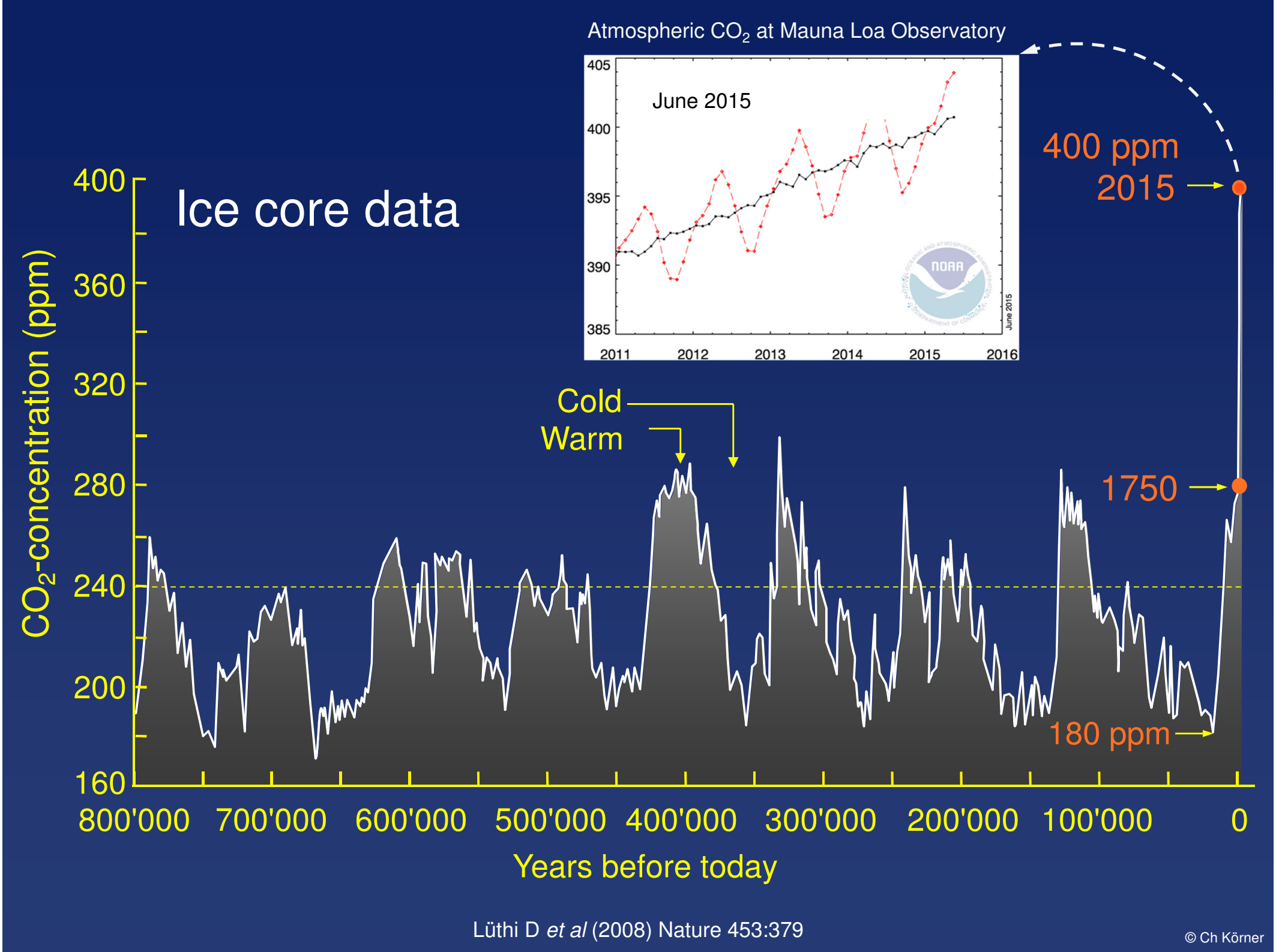

1.5 mm C


1-2 Gt C


7-8 Gt C
"We got the money."
Adjustable home loans.
lower than fixed.
SOLD
5:38
Seventh Street 1/4
Fourth Street 3/4
Main-Broadway Exit 1 1/4
© Ch Körner


Atmosphere
Pg C for pools and
Pg C/yr for net fluxes
795
+ 4.5 a-1
62-63 a-1
61 a-1
46
44
+1 to +2 a-1
+3.5 a-1
Plant mass
650
1-2 a-1
~700
Ocean
surface water
Soil humus
Shallow soil
(0-1 m)
1500
~500
Shallow ocean
organic sediments
ca. 8 a-1
< 0.2 Gt a-1
Deep soil
(1-2 m)
900
deep ocean water
and rocks > 6 x 10^7
> 6500 fossil organic C

Sequestration = Storage



Lüthi D *et al* (2008) Nature 453:379

180 → 280 → 380 → → 580 ppm CO_2

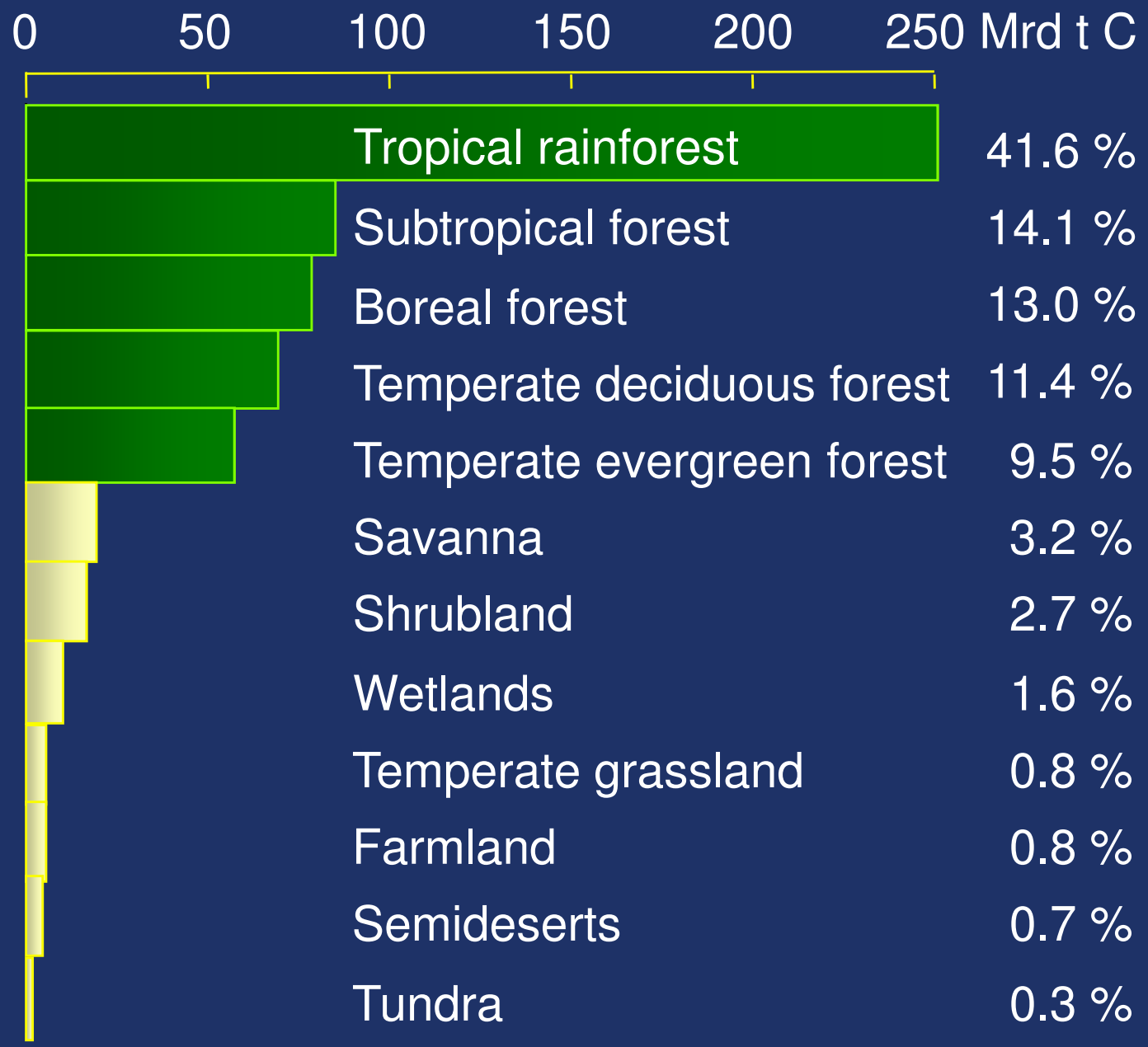
Atmospheric CO_2

Climate effects

Direct biological effects

Indirect effects


50 % of plants = C
© Ch Körner

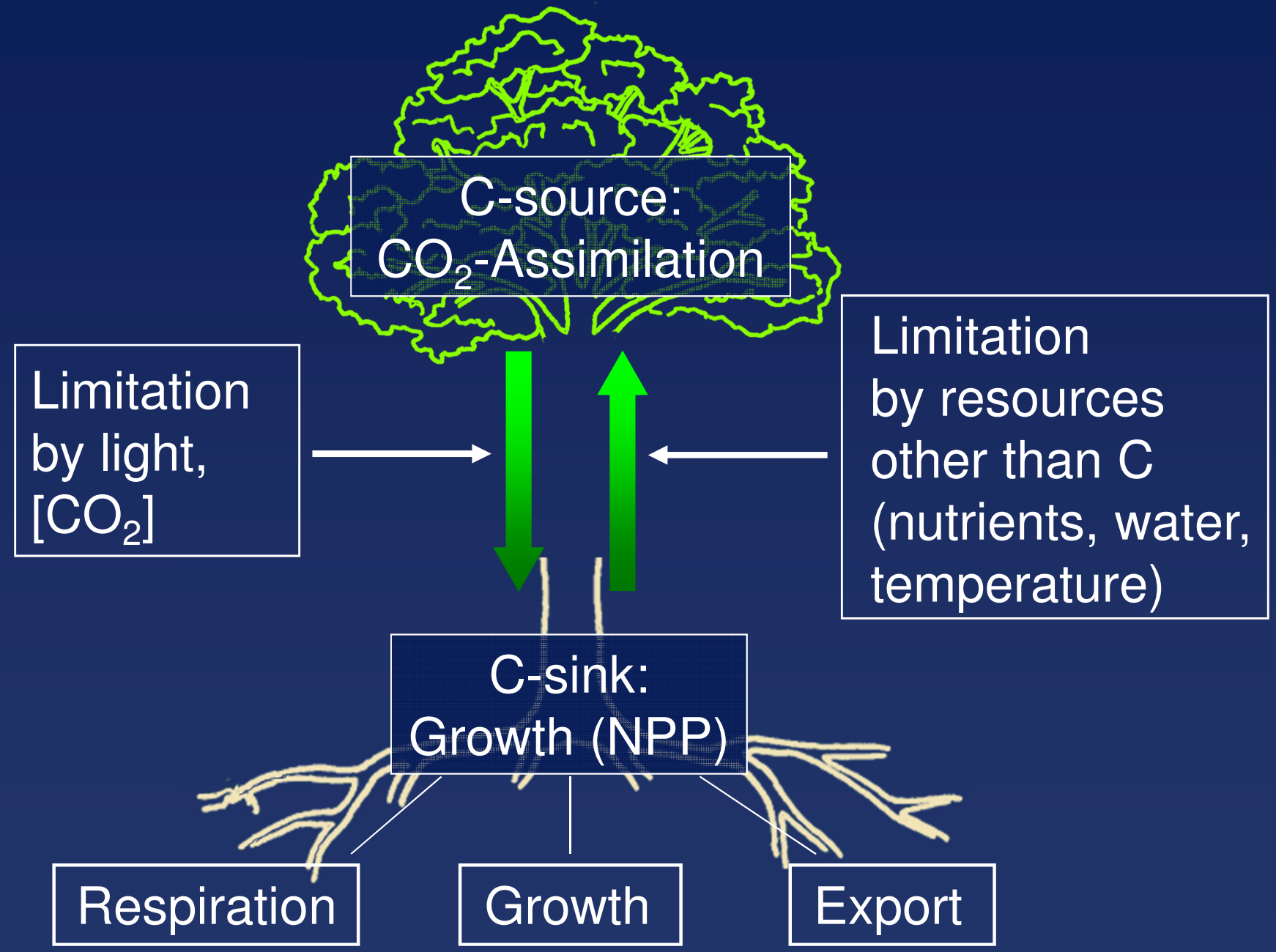


For C-storage in biomass only trees matter (>86 %)

100 % = 652 Mrd t C

Hierarchy of controls

Carbon uptake and carbon use by plants



C source activity rarely controls sink activity

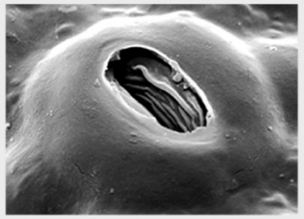
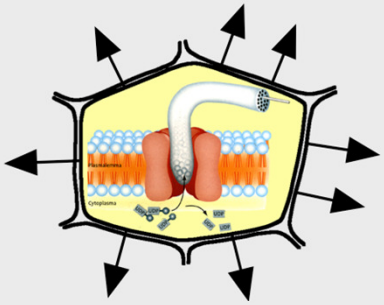
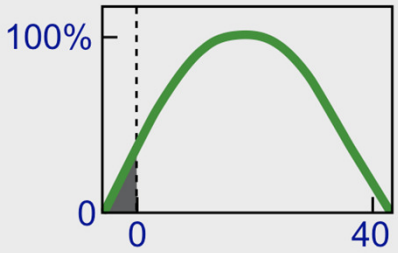
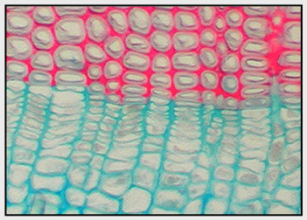
Source (photosynthesis)

Transport of building material

Sink (growth)

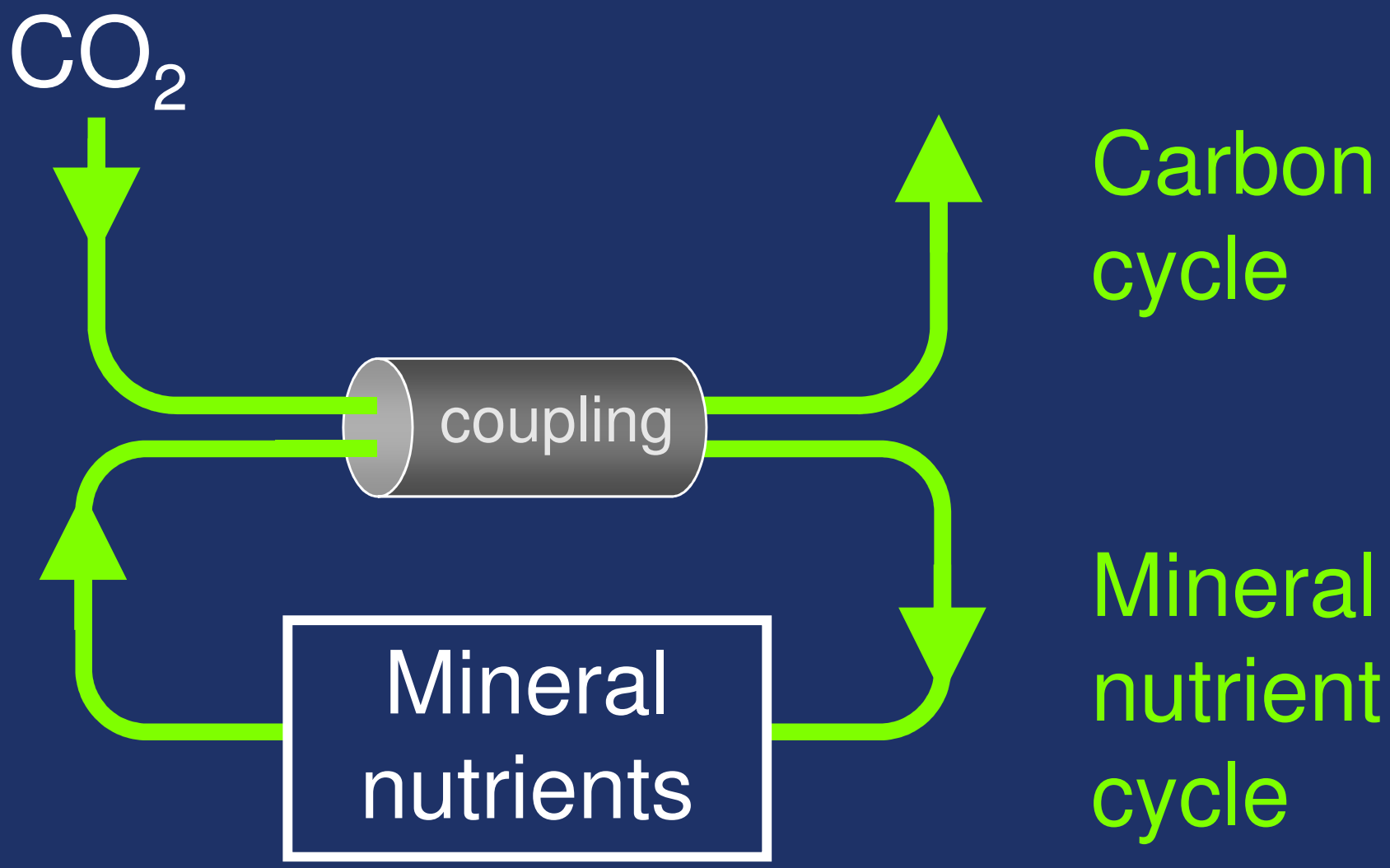
Körner C (2012) Biologie in unserer Zeit 4:238
Körner C (2013) Nova Acta Leopoldina NF 114, 391:273

Source ⟷ Sink balance

OLD	NEW	
Stomatal closure and inhibition of photosynthesis  -1.2 to -2.0 MPa critical	Inhibition of cell growth and tissue formation  -0.5 to -1.0 MPa critical	Drought
Net photosynthesis  30-40 % at 0 °C 50-70 % at +5 °C	Meristems  No cell production and differentiation < +5 °C	Low temperature
More photosynthates permit capturing more elements other than C 	Element stoichiometry controls the amount of C incorporated 	Nutrient limitation

Körner C (2015) Curr Opin Plant Biol 25:107
Fatichi S *et al* (2014) New Phytol 201:1086

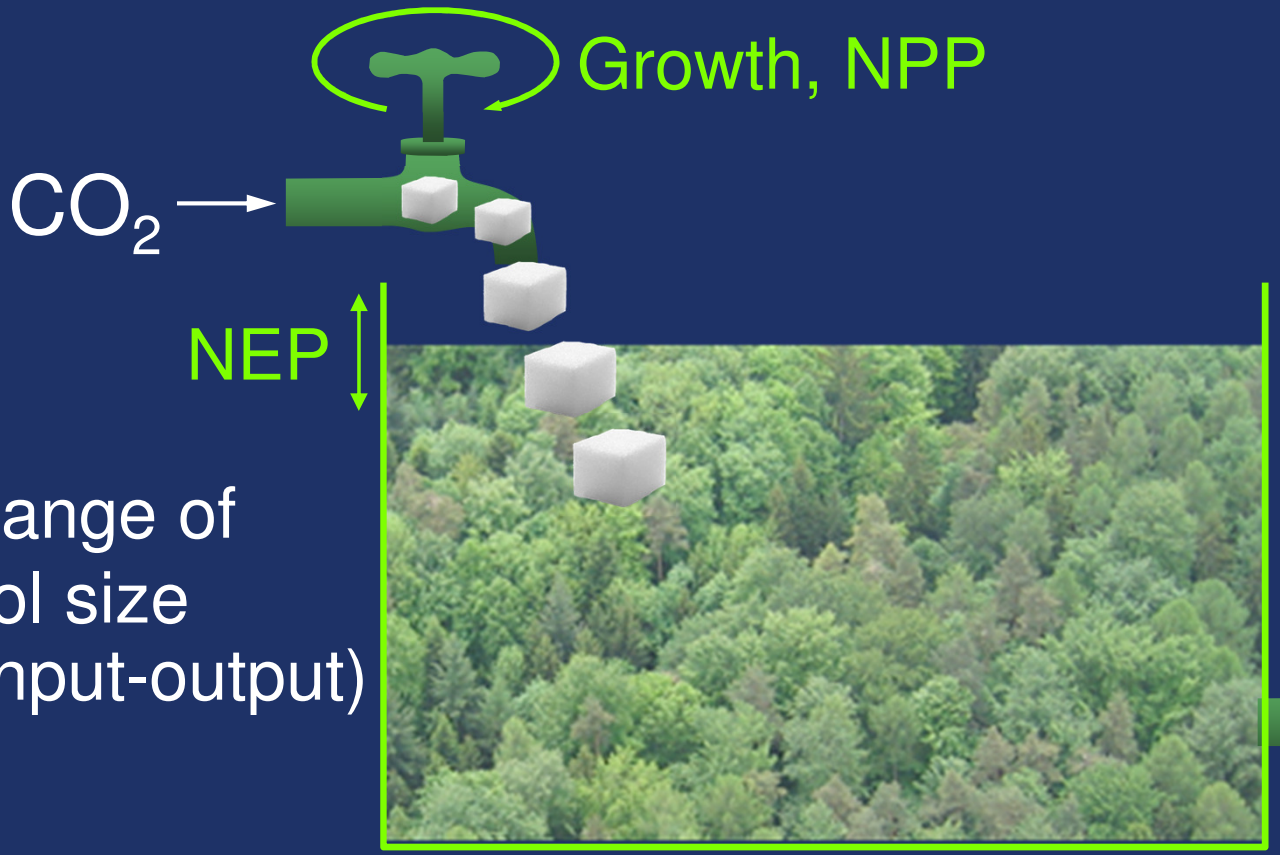
The ecosystem carbon cycle is driven by the nutrient cycle and other growth ‘facilitators‘




Horticular systems are decoupled
from the natural nutrient cycle
© Ch Körner


Growth rate should never be confused with C-storage
... the more older trees the more carbon
© Ch Körner

The C-capital (storage) is controlled by tree demography (residence time of C)



Fluxes do not scale to pools !

Change of pool size f (input-output)

Finite storage capacity f (soil, climate, taxa, vigor)

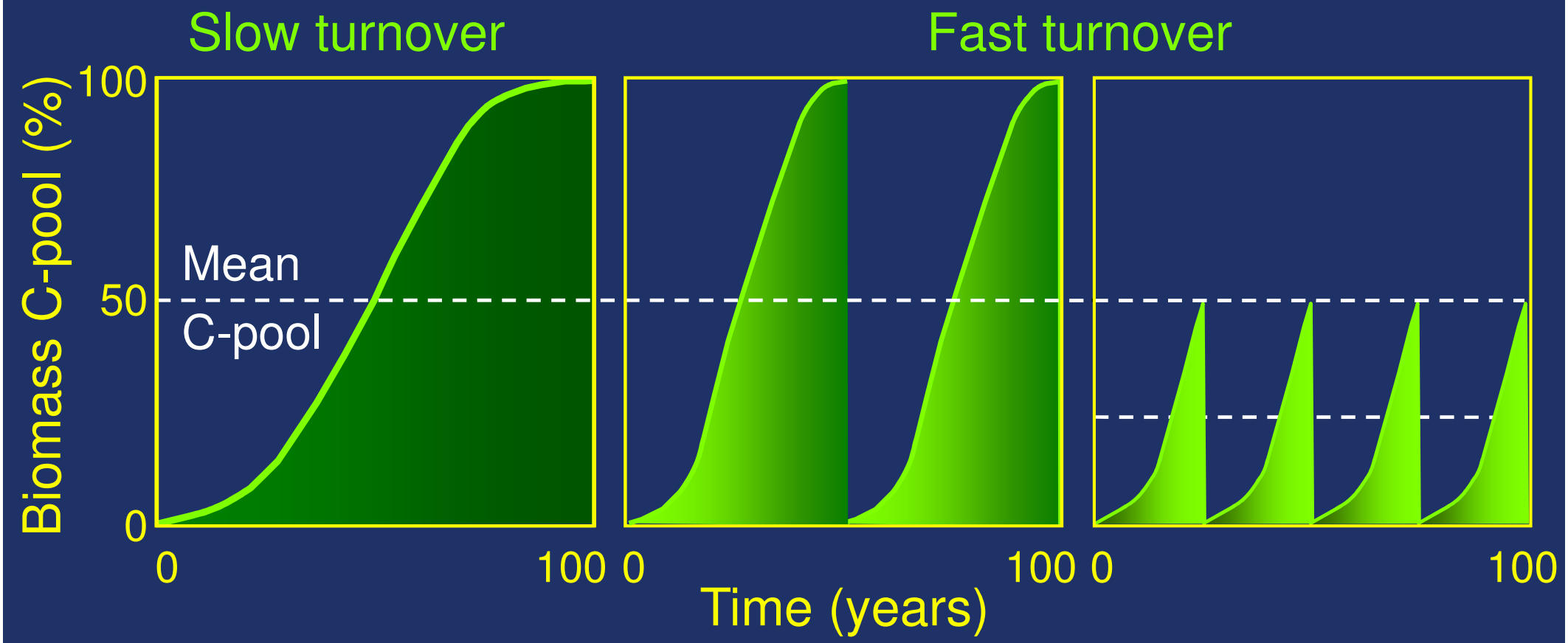
Harvest
Mortality
Recycling

CO_2

Körner C (2006) New Phytol 172:393
Bugmann H, Bigler C (2011) Oecologia 165:533

→ Rates (productivity, growth) *versus* [cash flow]

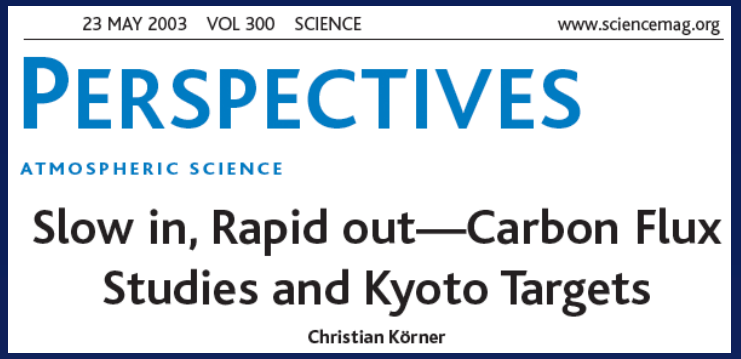
→ Pools (biomass, C-storage) [capital]



A growth stimulation (experiments) should never be confused with landscape-wide carbon sequestration

→ C-sequestration in biomass is a demography issue.

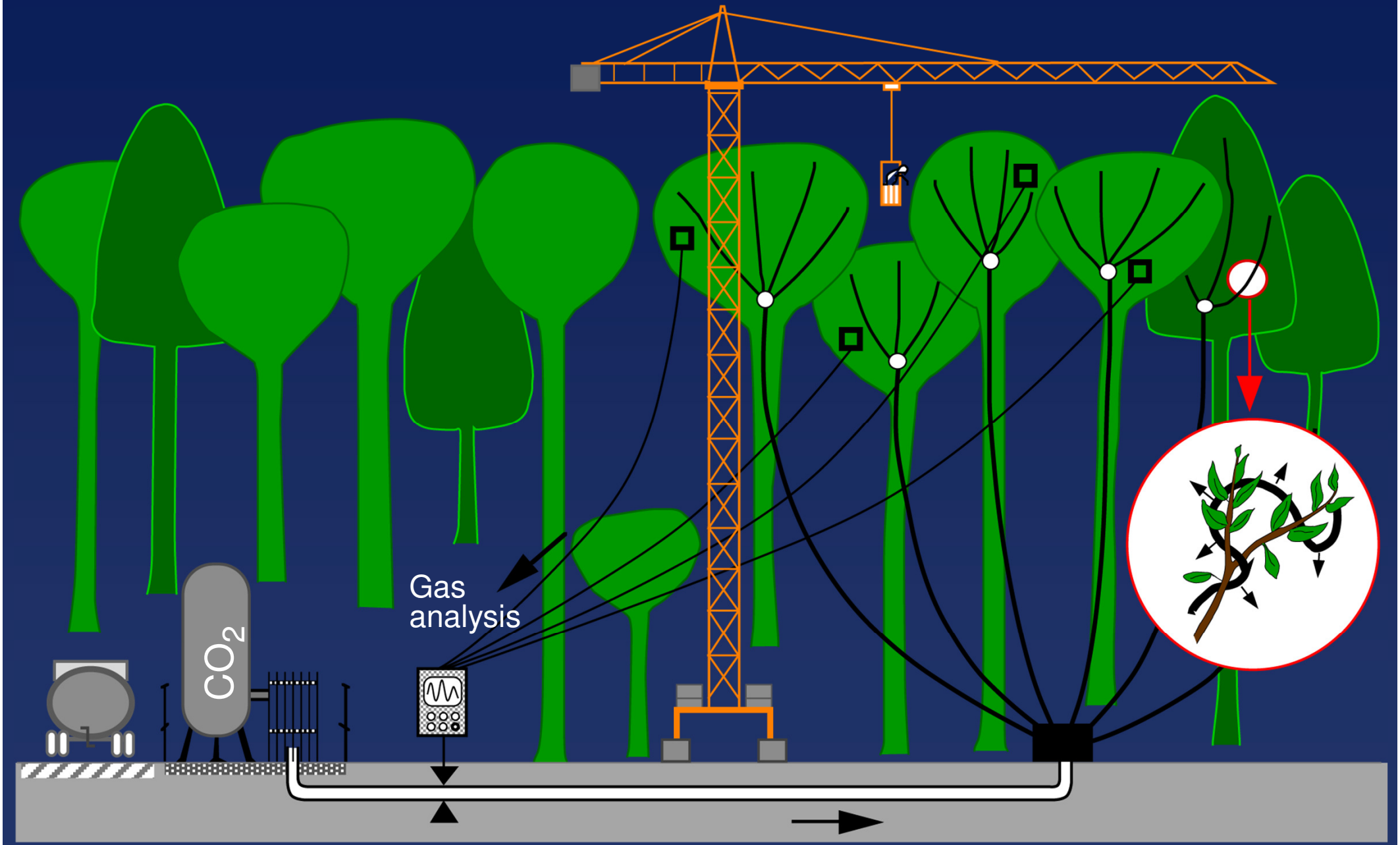
Körner C (2006) New Phytol 172:393



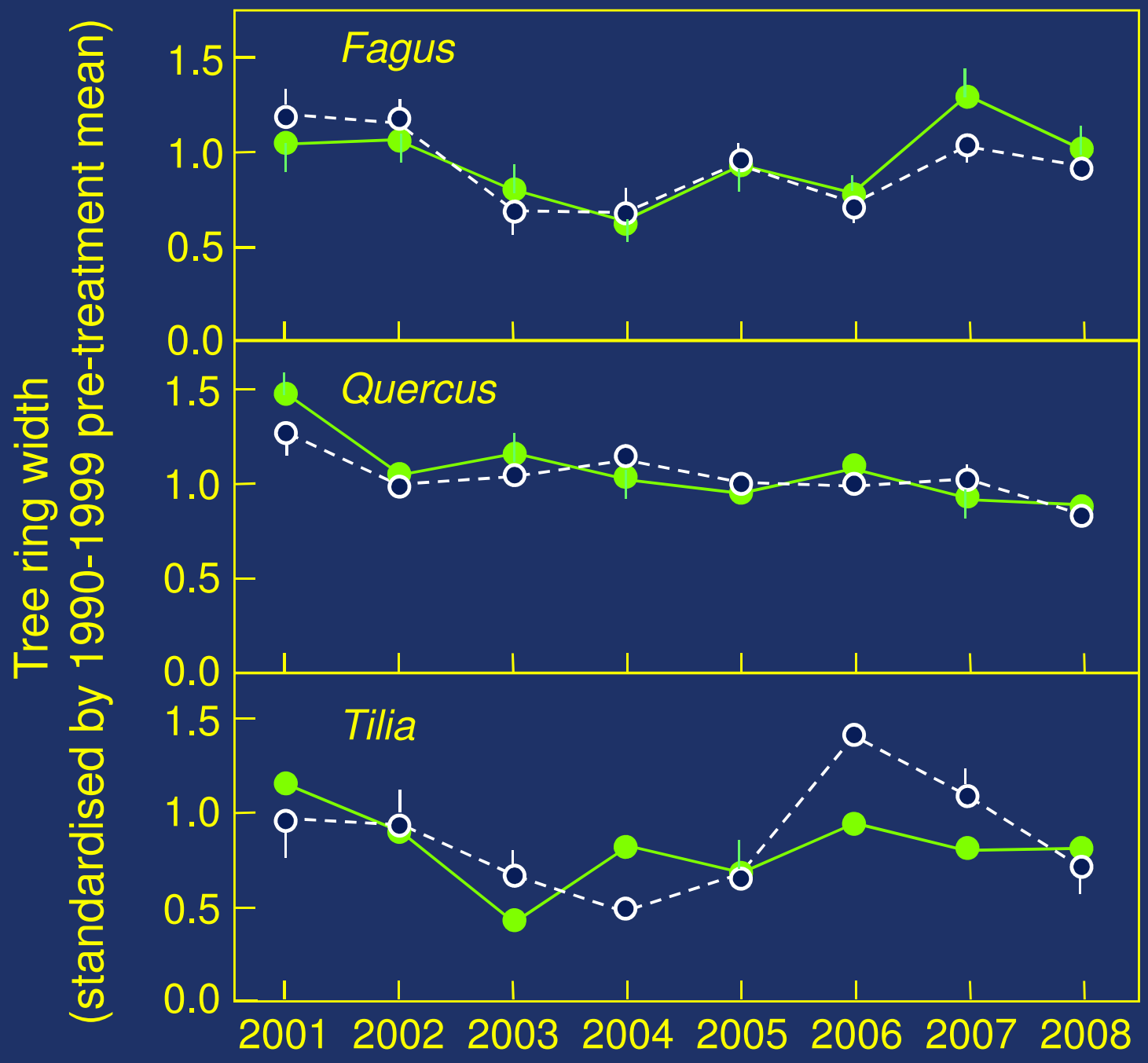
- All trees grow until trees die.
  → We do not need science to prove this.
  → That is why we have foresters!
- A growing tree does not sequester C unless the mortality or harvest of another tree is prevented.

Is carbon a limiting resource?

web-FACE at the Swiss Canopy Crane site



No change in growth of 100 year old decidous trees in elevated CO_2, Swiss web-FACE



Ambient CO_2

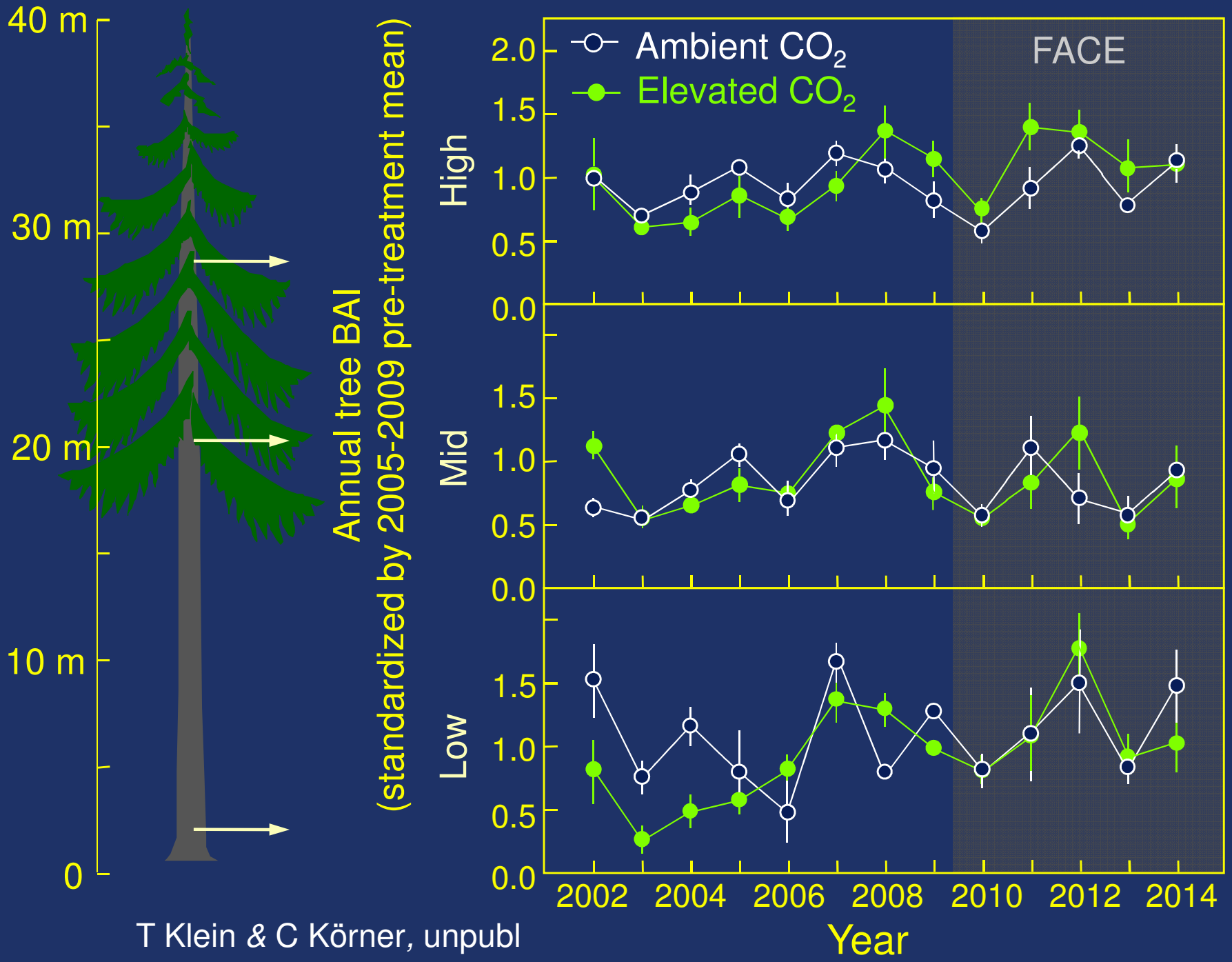
Elevated CO_2

Bader MKF *et al* (2013)
J Ecol 101:1509

and similar results by

Sigurdsson BD *et al* (2013)
Tree Physiol 33:1192

No growth effect of elevated CO_2 on *Picea abies*



T Klein & C Körner, unpubl

Conclusions for CO_2 effects on plants

- Carbon sinks control C sources (mostly).
- Forest productivity is not C limited.
- C sequestration in forests requires a longer residence time of C (tree demography matters).

Priority in theory and modeling of plant growth or NPP

Old model
(sources control sinks)

C-uptake

↓

Other drivers

CO_2 acquisition has priority over any other growth control

New model
(sinks control sources)

Other drivers

↓

C-uptake

Meristem activity determines C-demand, and thus, C uptake

Körner C (2015) Curr Opin Plant Biol 25:107
Fatichi S *et al* (2014) New Phytol 201:1086

The enhanced greenhouse effect can be mitigated

1) by reduced carbon release

2) by carbon capture and storage
   - → technologically
   - → biologically

3) by substitution of fossil carbon by renewable energy sources
   - → technologically
   - → biologically

Pretentious claims for mitigation by C storage

- Afforestation takes 100-200 years to pay the debth of cutting
  → don‘t cut in the first place
- Enhanced storage by stocking (more C by unit land area)
  → limited, can be done only once, risk of windthrow
- Expand forest area at the cost of other land area
  → competion with agriculture

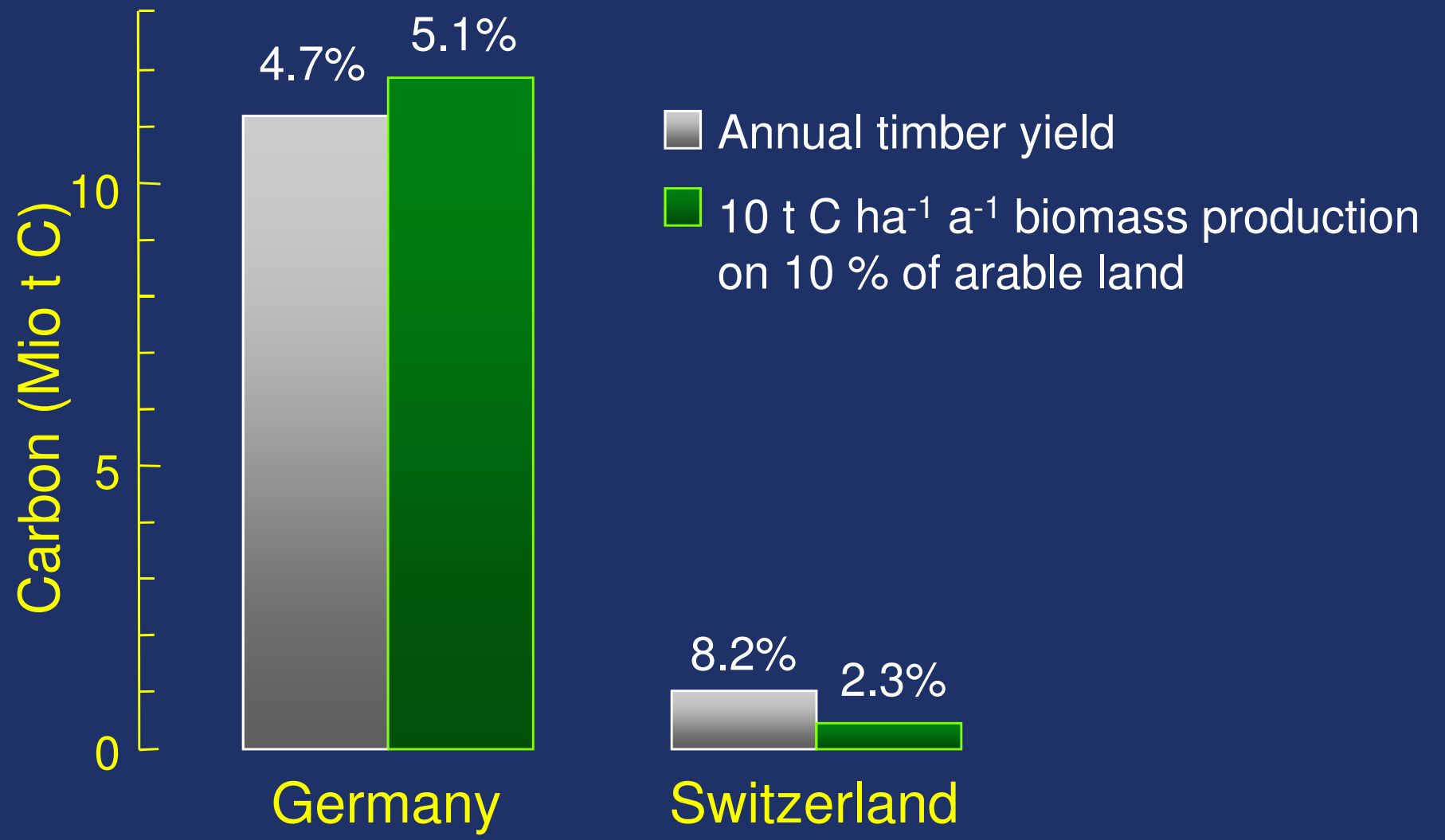
‘Replacing fossil by renewable C?
‘Fuel crops‘?

→ The total fossil C-savings are close to zero, when the total environmental footprint is accounted for.

1l fossil oil for
1l rape oil

Zah R *et al* (2007) EMPA, BFE Bern

Substitution potential in % of fossil C emission (100%)



3-5 % of bio-fuel-carbon (substitution) corresponds to driving with 6.1 (D) or 6.3 (CH) instead of 6.6 litres gasoline per 100 km.

Körner C (2004) Nova Acta Leopoldina NF 91, 339:287-303


Energy crops should be forbidden!
• They allocate food production elsewhere
• They rise food prices
• They are commonly not produced sustainably
• They lead to N_2O emission and groundwater pollution if productive
• They commonly require pesticide application
© Ch Körner

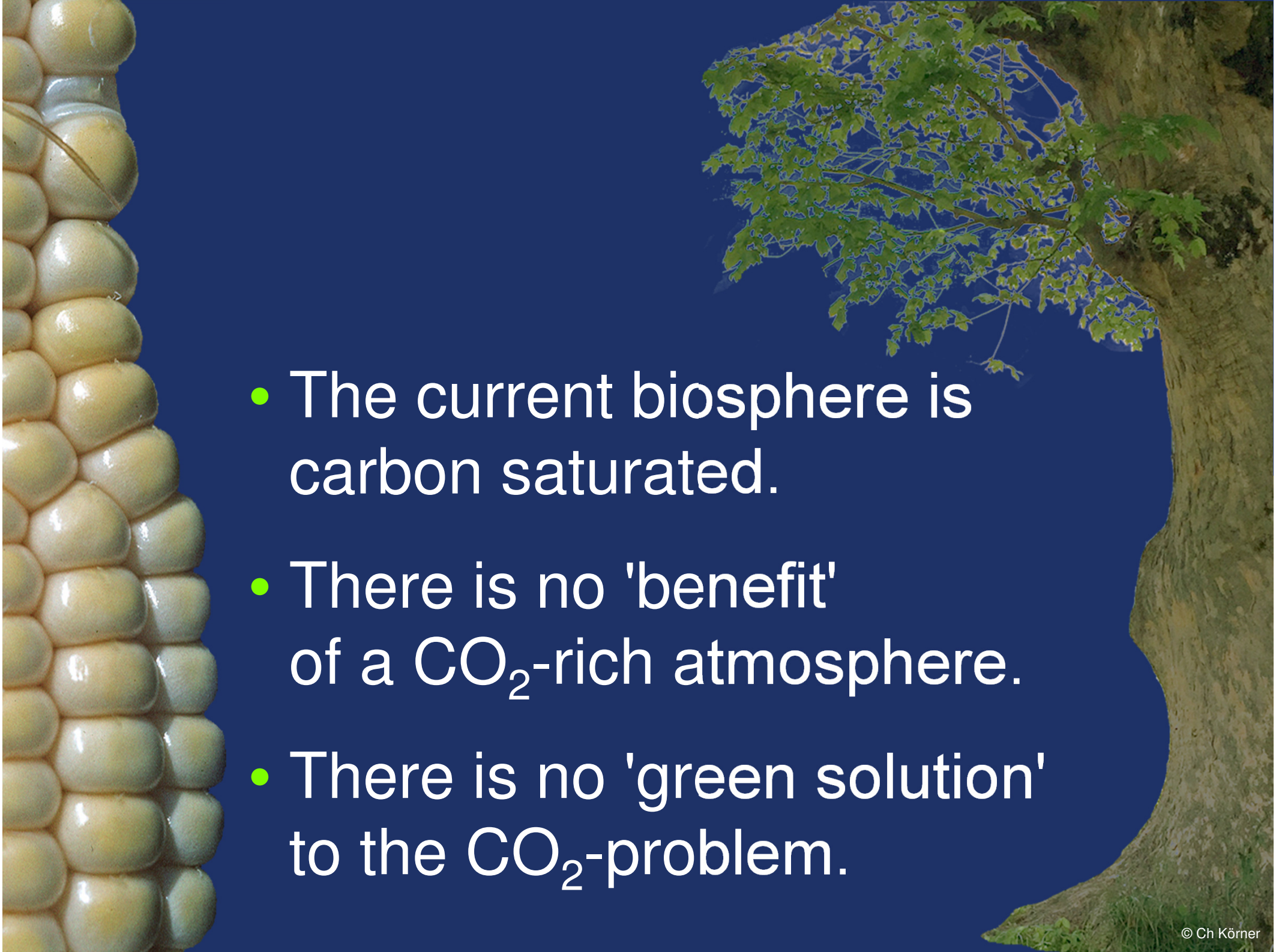
Pretentious claims in the context of green options to mitigate the climate change

The net saving of the fossil energy is very small:

- Afforestation: better don't clearcut in the first place
- Fuel crops: not efficient, compete with food
- Bioenergy: effects are tiny (mainly waste combustion)

... fully accounting for all costs and benefits there is little potential for substituting fossil energy with bioenergy by more than 3-5 % of current total consumption.

The future is solar ...



- The current biosphere is carbon saturated.
- There is no 'benefit' of a CO_2-rich atmosphere.
- There is no 'green solution' to the CO_2-problem.