Fapesp-Wilson Center Seminar

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The Carbon Cycle in the Amazon Basin

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To set the stage....

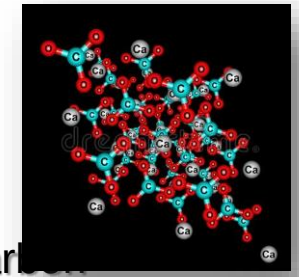
“The carbon cycle in Amazonia today is the result of evolutionary processes acting at different levels and at different times”:

- ✓ photosynthesis
- ✓ great oxidation event (GOE)
- ✓ the coupling of the oxygen and carbono cycles
- ✓ eukariotes – tissues - organisms
- ✓ plants – angiosperms - trees
- ✓ geotectonics events – biodiversity
- ✓ human action – land use change, global changes

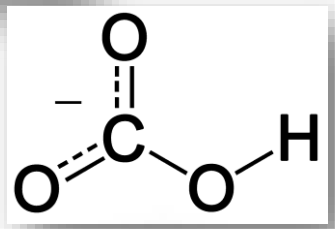
✓photosynthesis

carbon

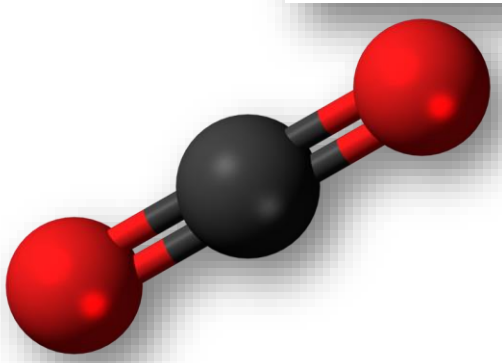
- Most of the carbon is bond with oxygen on Earth:
  - Rocks
    - $CaCO_3$ (calcite)
    - $FeCO_3$ (siderite)
    - $Ca(Mg)CO_3$ (dolomite)



  - Dissolved inorganic carbon



  - Atmospheric CO_2



✓photosynthesis

carbon fixation

- The life dream of every living being is to incorporate H atoms (reduce) in these C-O molecules.
- Carbon and hydrogen covalently bonded forms an organic molecules
- Organic molecules are used by living beings to build tissues or as an energy provider through the oxidation of these molecules.
- The process that transform inorganic carbon to organic carbon is called carbon fixation (carbon is not volatile anymore).
- One of the most successful carbon fixation process on Earth is photosynthesis

evolution of photosynthesis

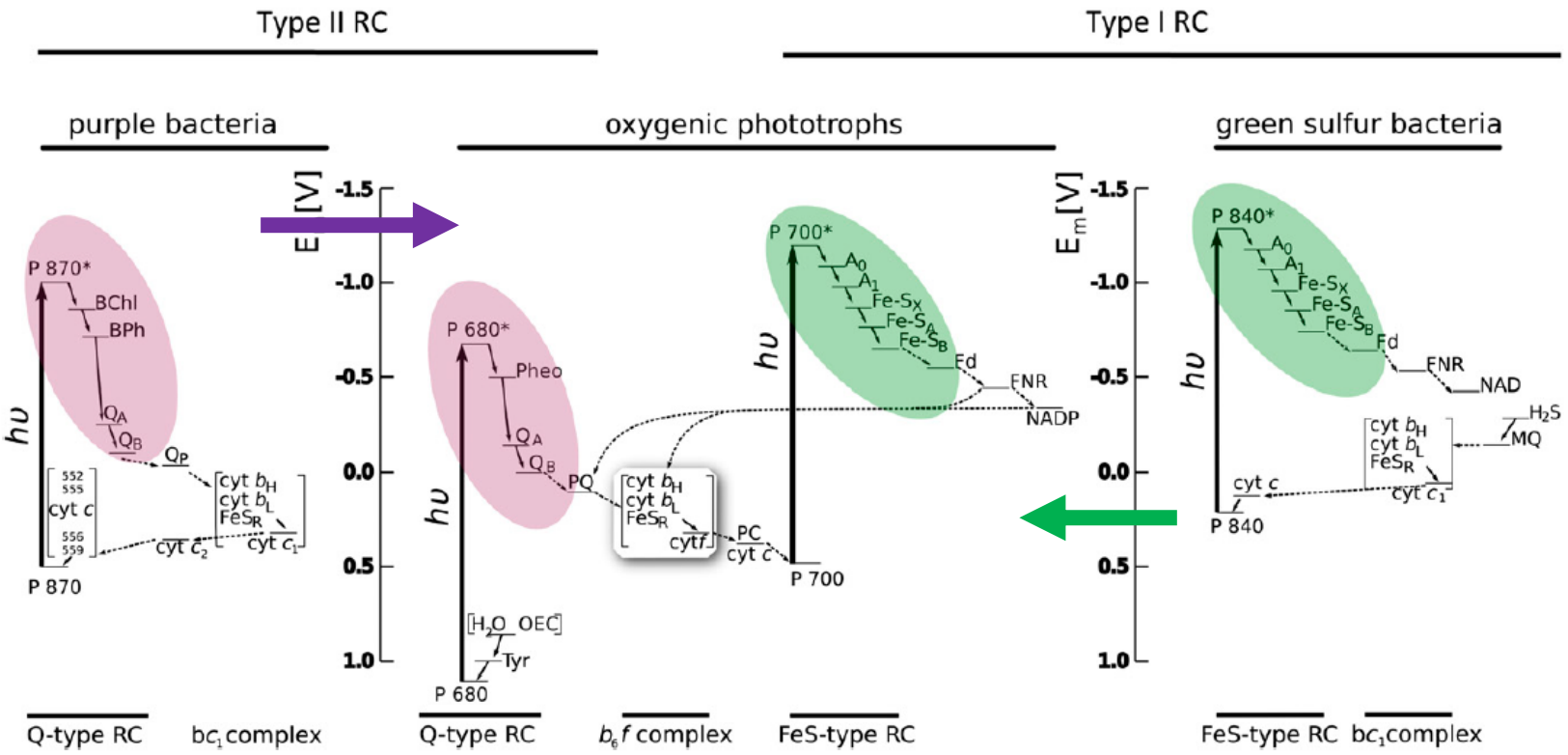
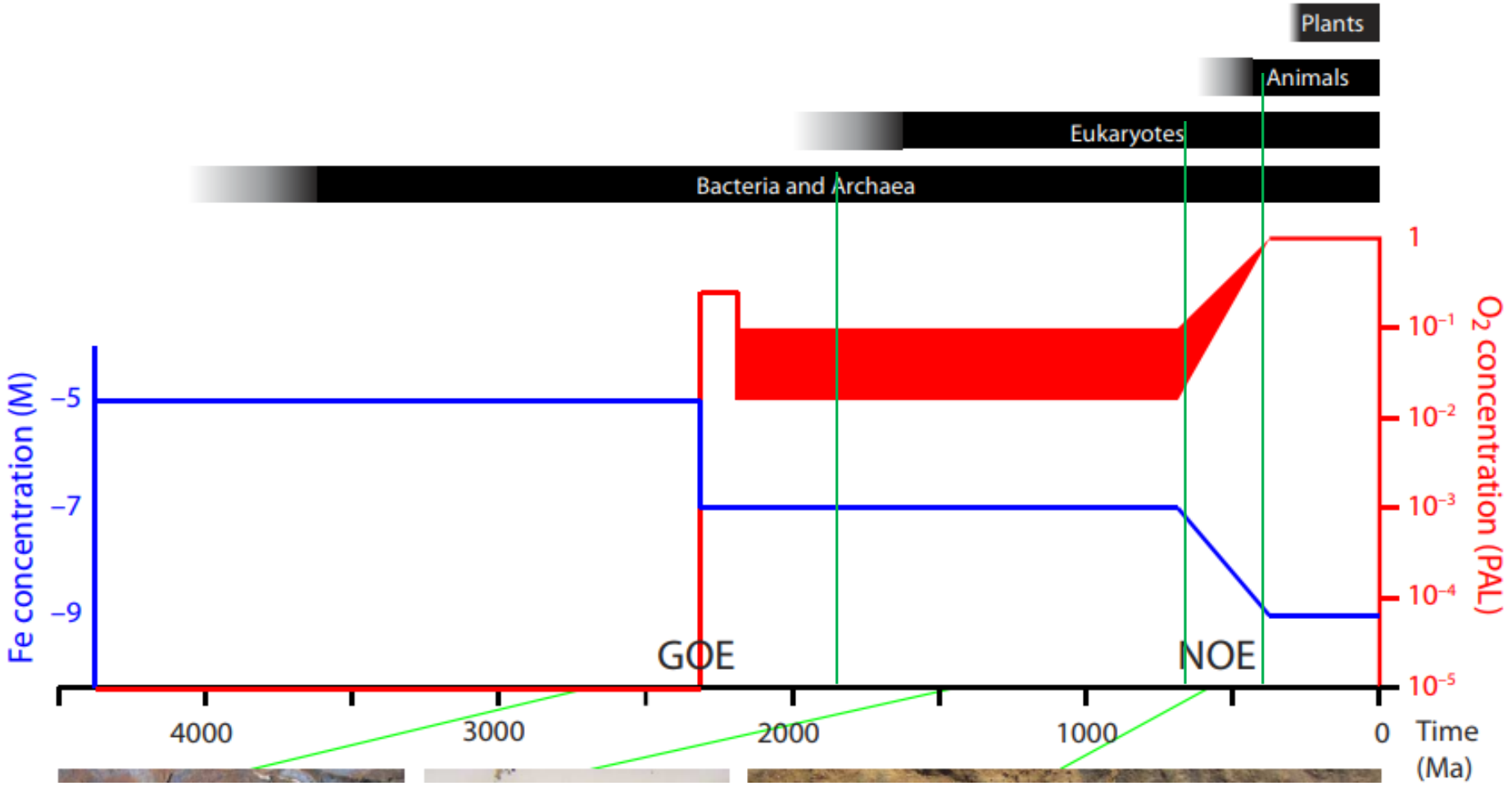


Figure 2. Electron transport diagram indicating the types or RCs and electron transport pathways found in different groups of photosynthetic organisms. The color coding is the same as for Figure 1 and highlights the electron acceptor portion of the RC. Figure courtesy of Martin Hohmann-Marriott.

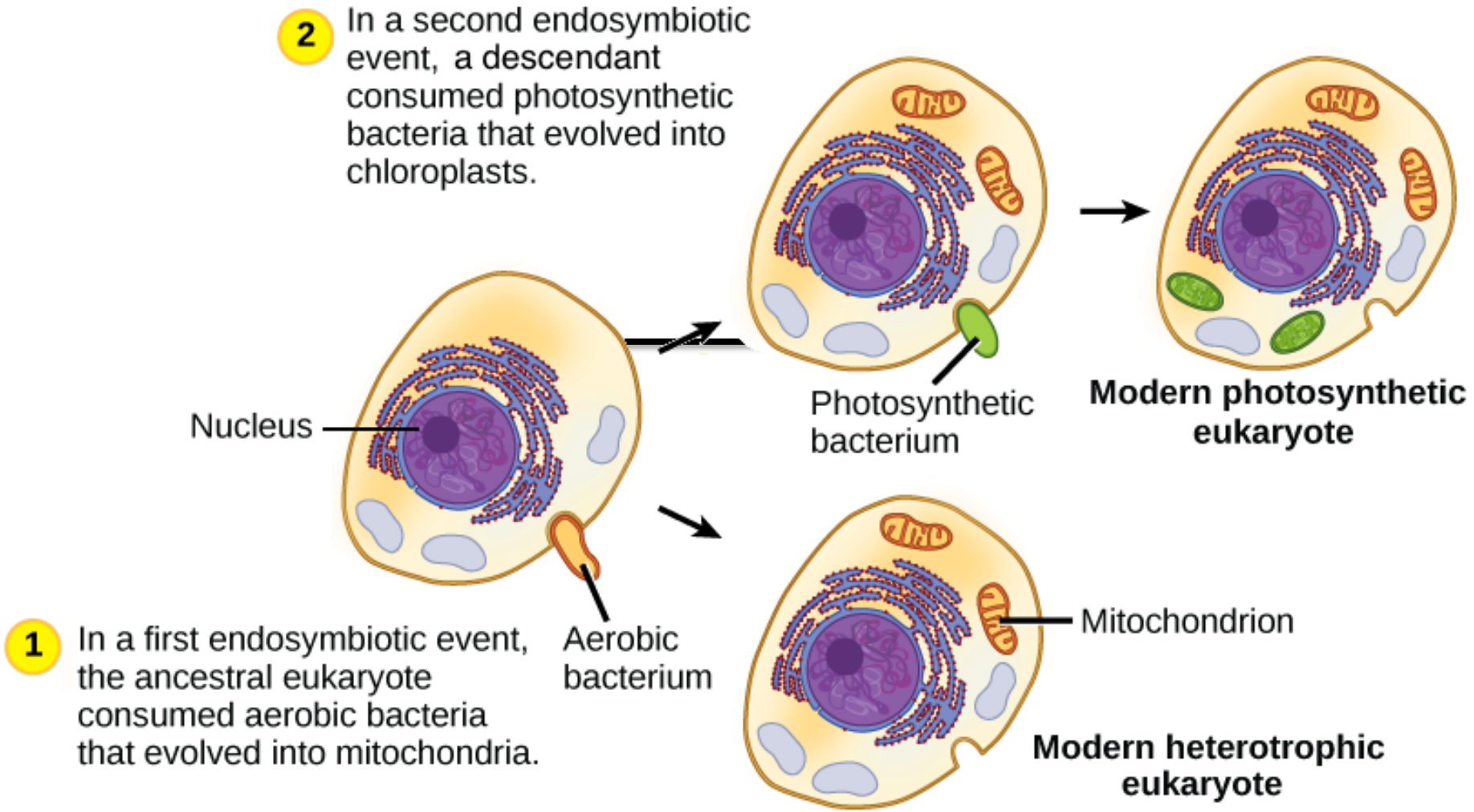
oxygen is in the air

✓great oxidation event (GOE)



Knoll and Novak (2017)

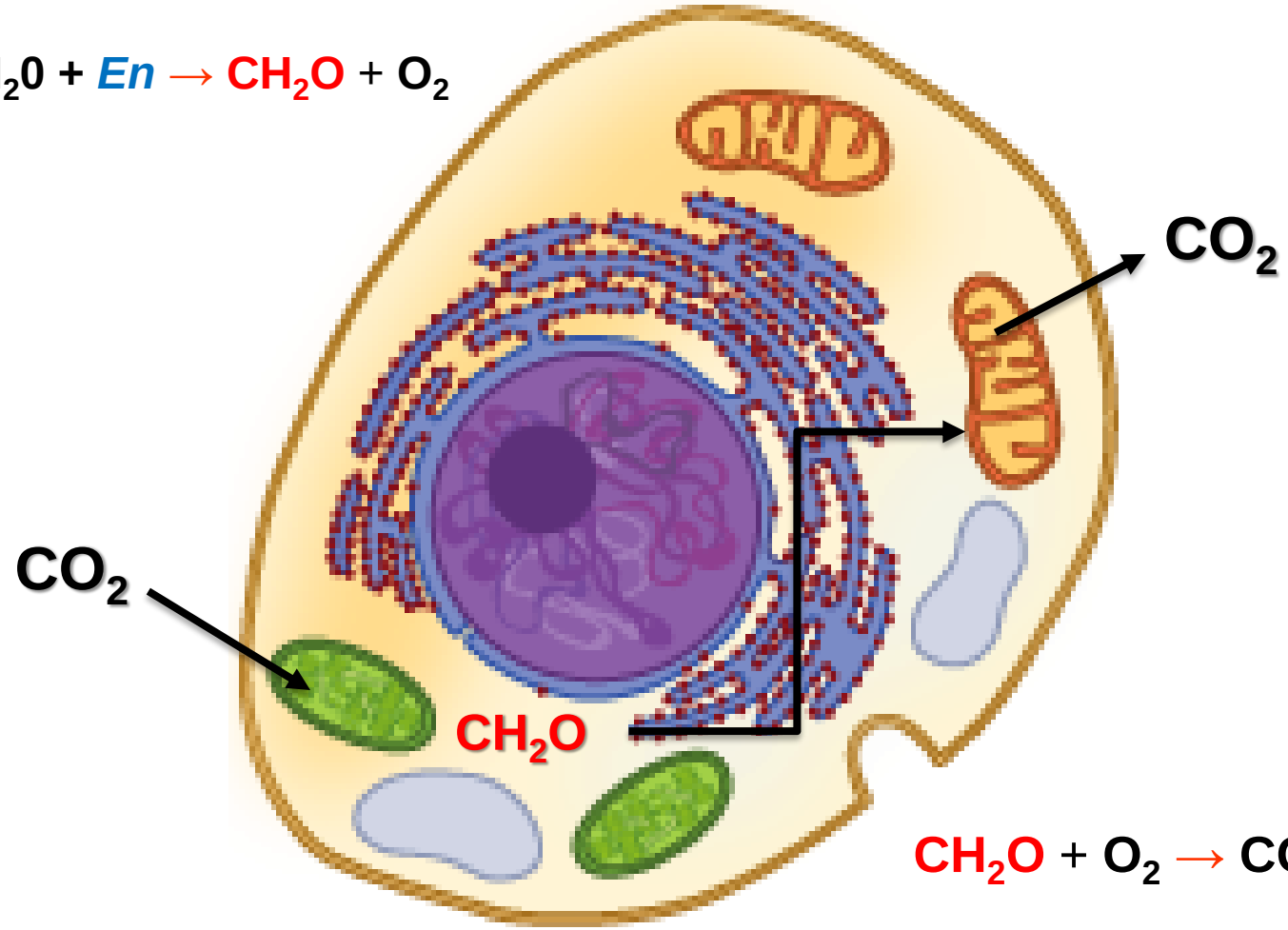
✓eukariotes – tissues - organisms



source: Khan Academy

✓the coupling of the oxygen and carbono cycles

$CO_2 + H_20 + En \rightarrow CH_2O + O_2$

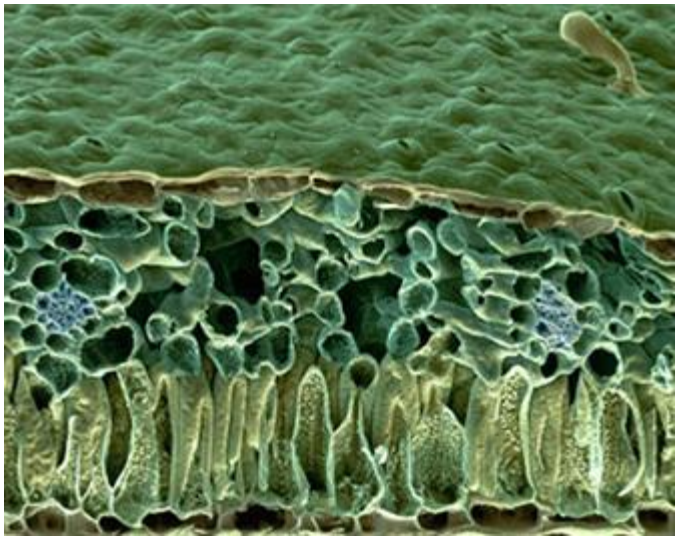


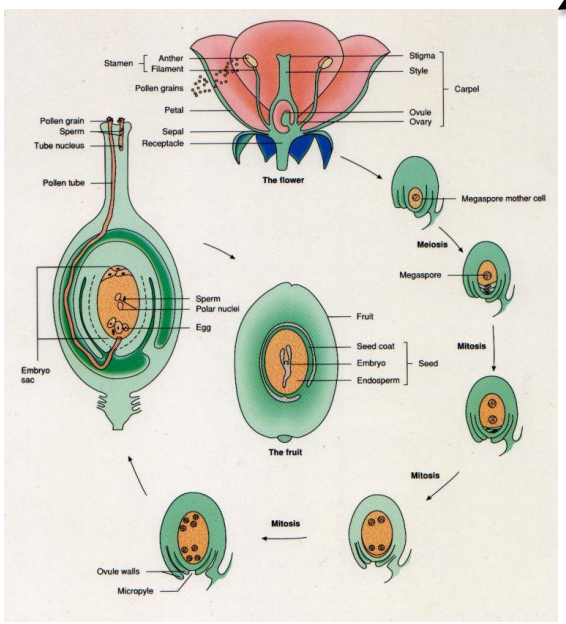
$CH_2O + O_2 \rightarrow CO_2 + H_2O + En$

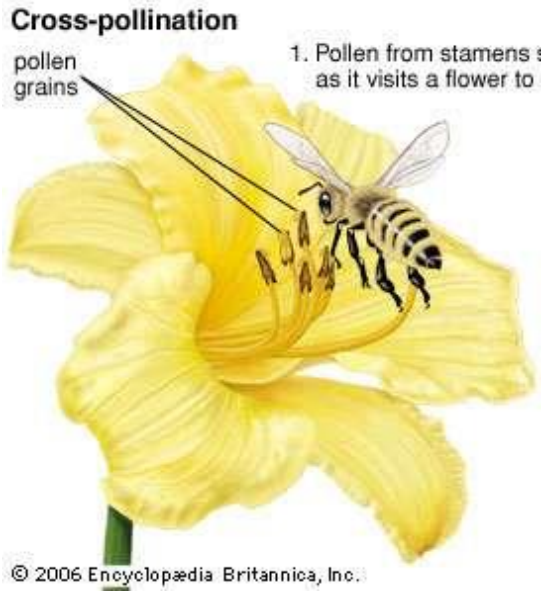
lern photosynthetic eukaryote

source: Khan Academy

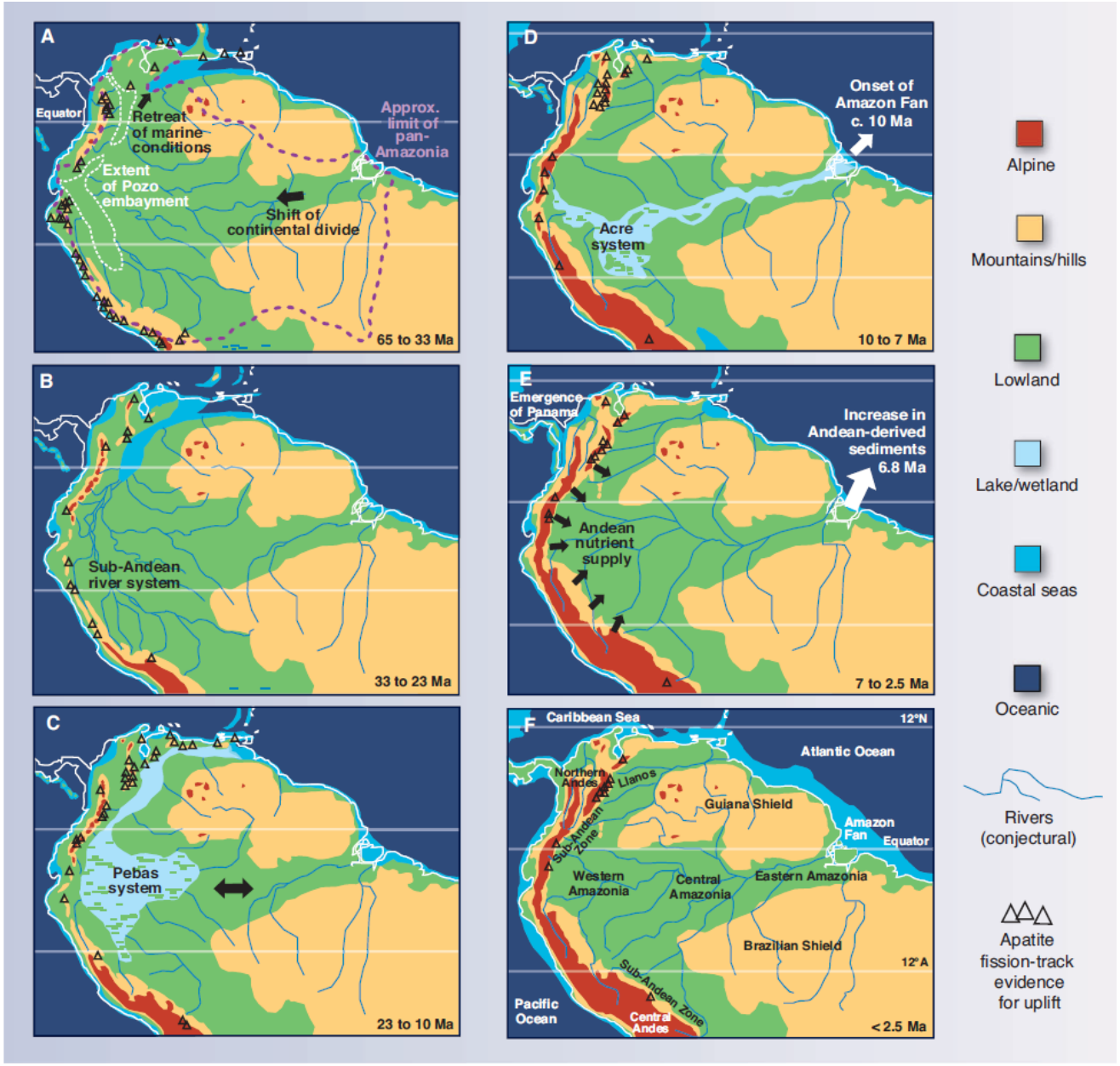
✓plants – angiosperms - trees



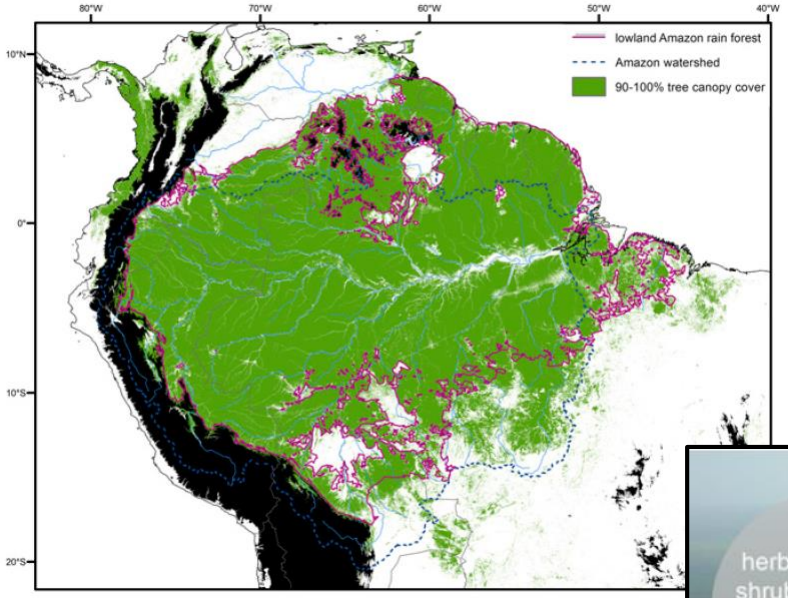


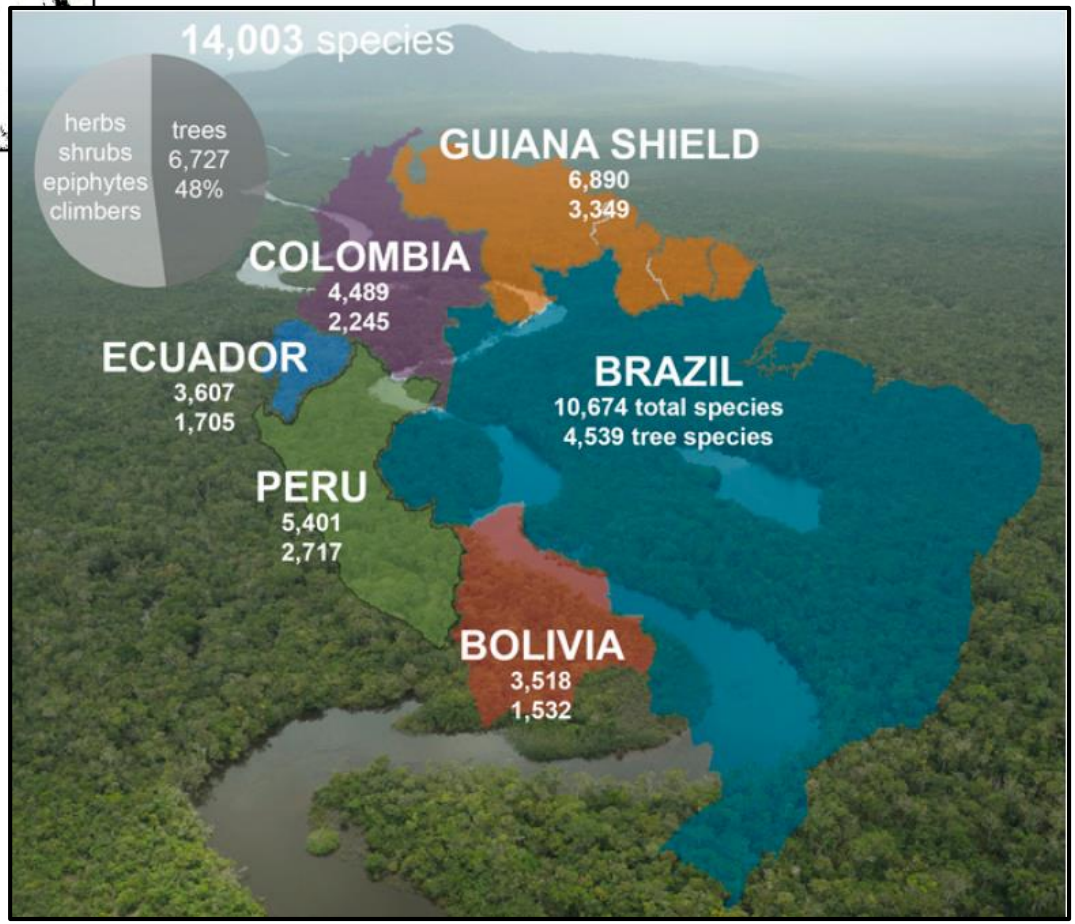


✓geotectonics events – biodiversity

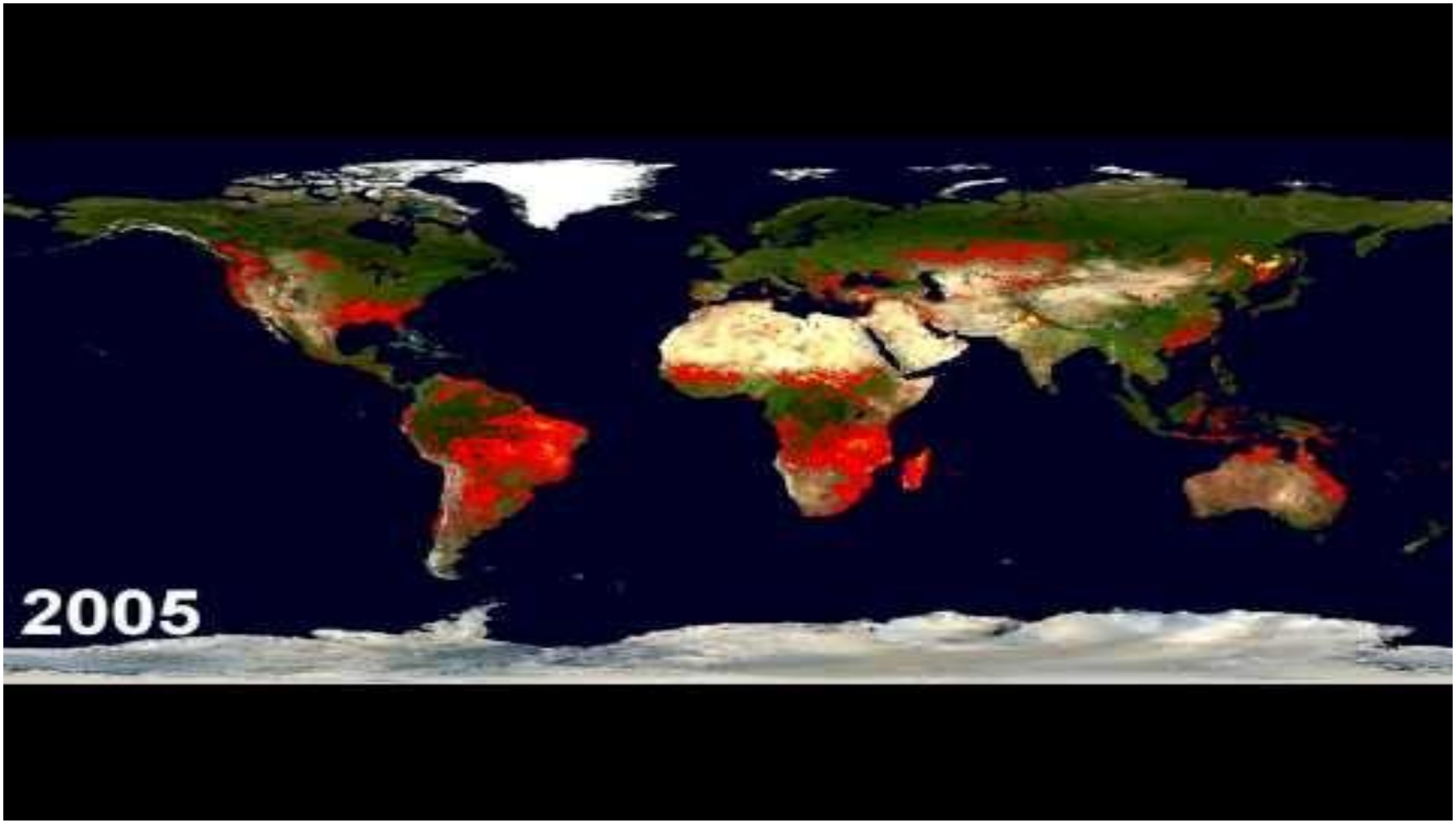


Hoorn et al. (2010)



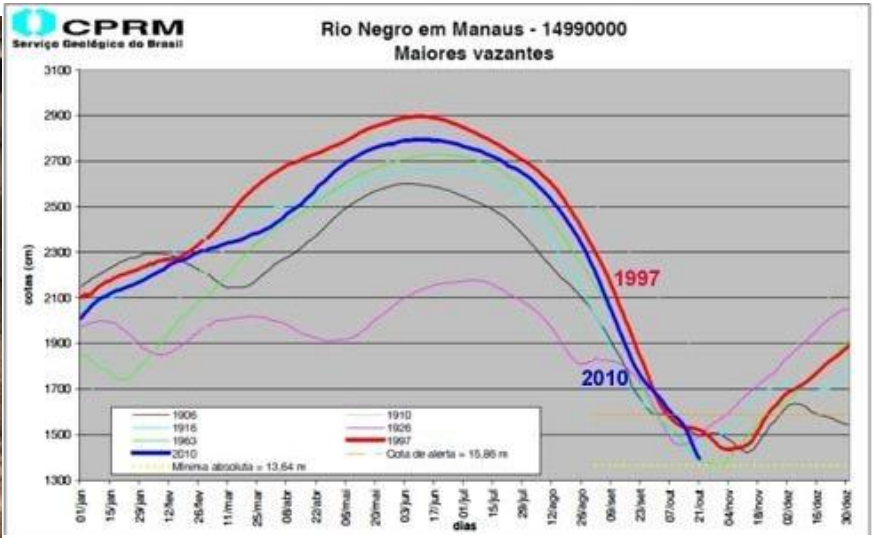


Cardoso et al. (2017)



source: MODIS Rapid Response System Global Fire Maps

extreme events in the Amazon
2005-2010



Summary

The Amazon carbon cycle today is the ultimate result of several interconnect evolutionary processes.

Therefore, when a tree is burned in the Amazon all its evolutionary legacy is transformed in ashes....

net primary productivity (NPP)

$$NPP = GPP - R$$

where:
GPP is the gross primary productivity
R is respiration

$$GPP > R$$

$$NPP = (+)$$

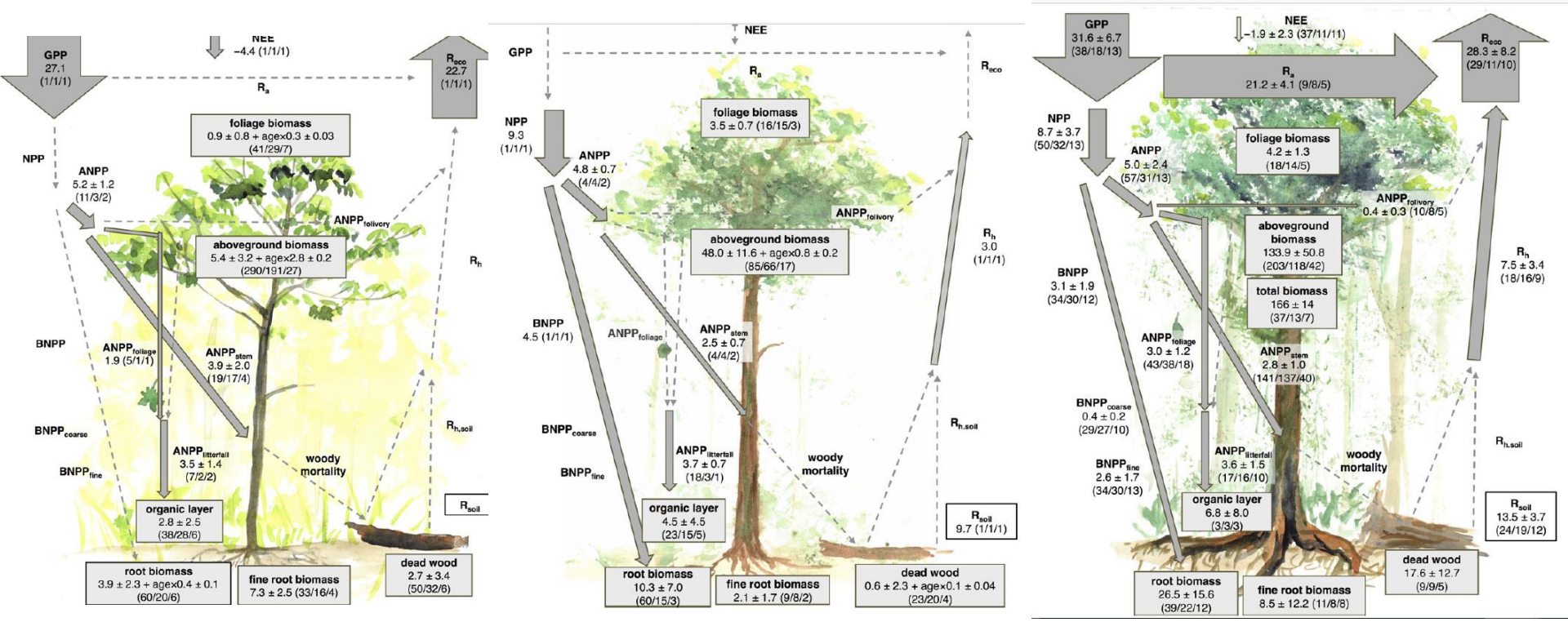
“carbon is increasing at species level”

$$GPP < R$$

$$NPP = (-)$$

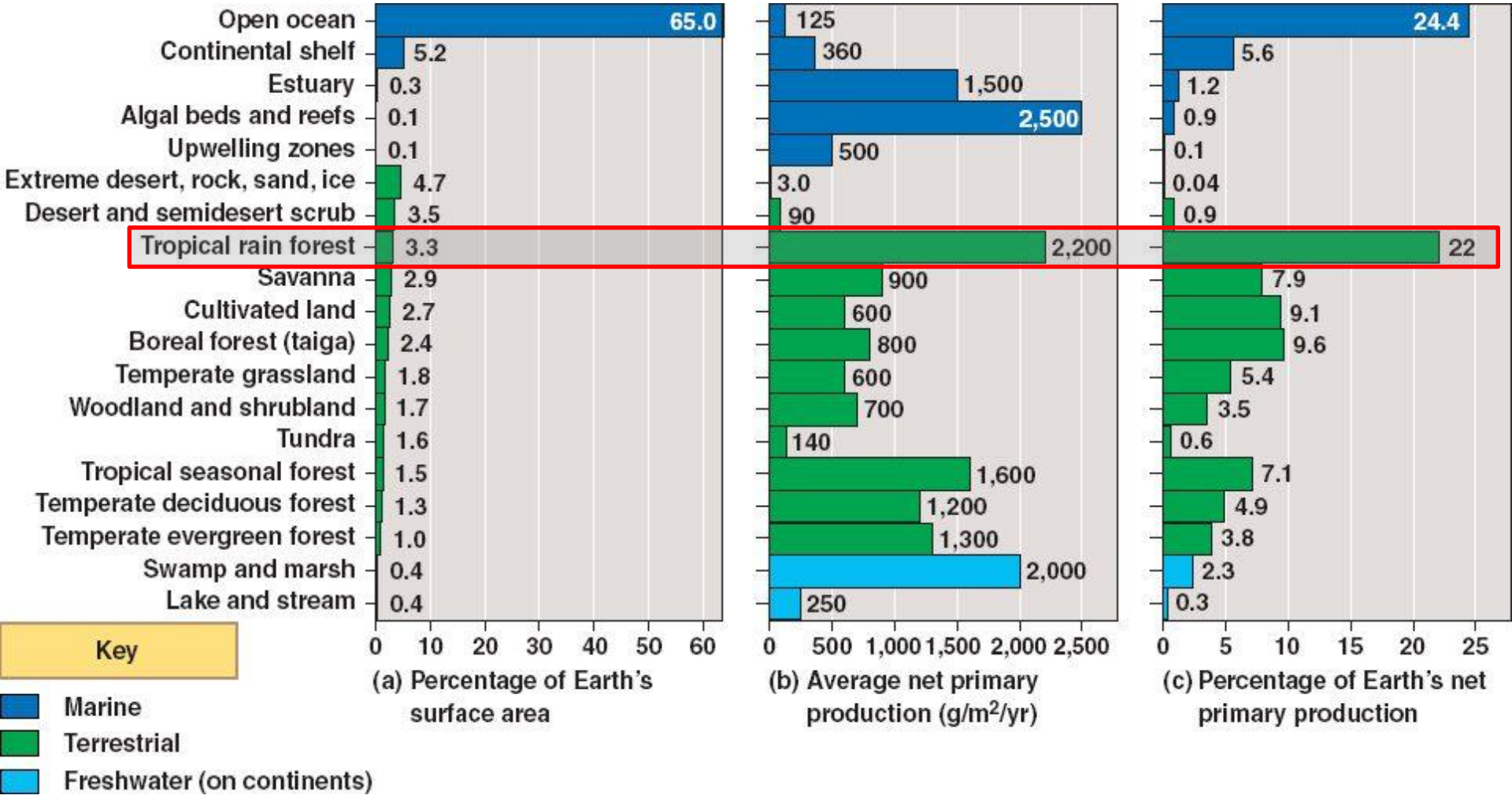
“carbon is decreasing at species level”

forest succesional stages



Anderson-Teixeira et al. (2016)

NPP by biomes



net ecosystem exchange (NEE)

$$NEE = \sum GPP - \sum R_p - \sum R_s$$

where:

GPP is the gross primary productivity

R_p is the plants respiration

R_s is the soil respiration

$$GPP > (R_p + R_s)$$

$$NEE = (+)$$

"carbon is increasing at ecosystem level"

$$GPP < (R_p + R_s)$$

$$NEE = (-)$$

"carbon is decreasing at ecosystem level"

paradigm of tropical forests: clímax Odum?

$$GPP = (R_p + R_s)$$

$$NEE = 0$$

“carbon is neutral at ecosystem level”

why we need to measure the carbon balance in the Amazon?

Because.....

✓ We are in a world that we can't afford a forest like the Amazon leaking carbon

✓ We have to know how land use changes are affecting the Amazon carbon balance

✓ We have to know how global changes such as warming and extreme events are interfering in the Amazon carbon balance

✓ Carbon dynamics in Amazonia affects the Earth, not only the region

why we need to measure the carbon balance in the Amazon?

By the way.....

- ✓ The Amazon region is warming
- ✓ Extreme events in climate and hydrology have been frequent

in the last decades

how to make carbon accountability in the Amazon?

In theory it is easy, we need only to measure carbon input by photosynthesis and losses by respiration at ecosystem level

But, it is a nigthmare....

- ✓ we need to make forest inventories: changes in biomass
- ✓ we need to make inventories over time (years)
- ✓ we need to make inventories all over the Amazon
- ✓ we need to know how global changes interfere in growth, mortality and recruitment.

historical perspective of carbon accountability

First phase: experimental plots to measure above-ground biomass for comercial purposes

Second phase: experimental plots to measure above-ground biomass for scientific purposes

Third phase: measurements over time to establish full forestry inventories (Niro Higuchi legacy)

Fourth phase: measurements of NEE using eddy covariance flux towers

Fifth phase: expansion of experimental plots over large areas

Last phase: remoting sensing & modelling....thanks God!

Third phase: measurements over time to establish full forestry inventories

long-term forestry inventory: the legacy of Niro Higuchi (INPA)

Third phase: measurements over time to establish full forestry inventories

long-term forestry inventory: the legacy of Niro Higuchi (INPA)


Atalaia e Benjamin


PICADAS
INVENTÁRIO FLORESTAL
ANTROPOLOGIA SOCIAL
BOTÂNICA
SOLOS

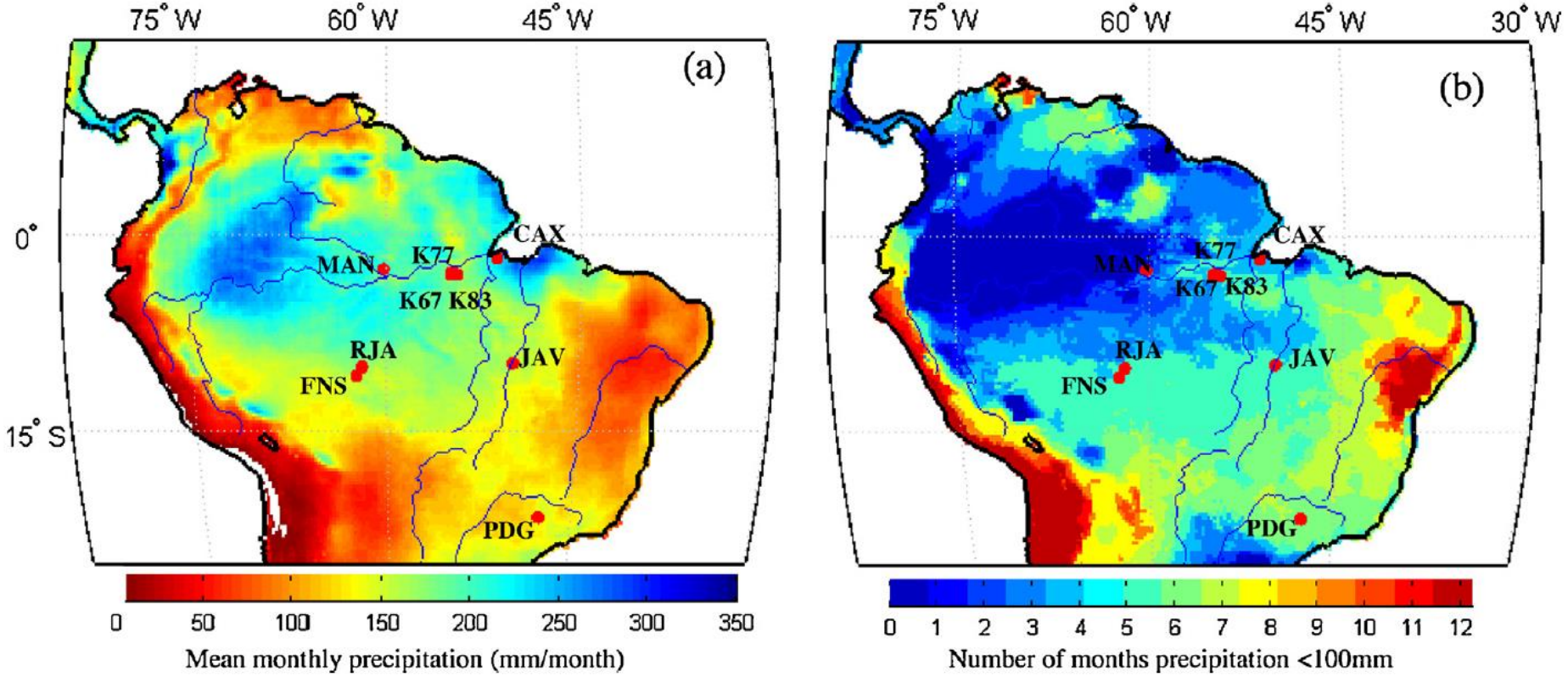

Resex Capanã Grande - Manicoré

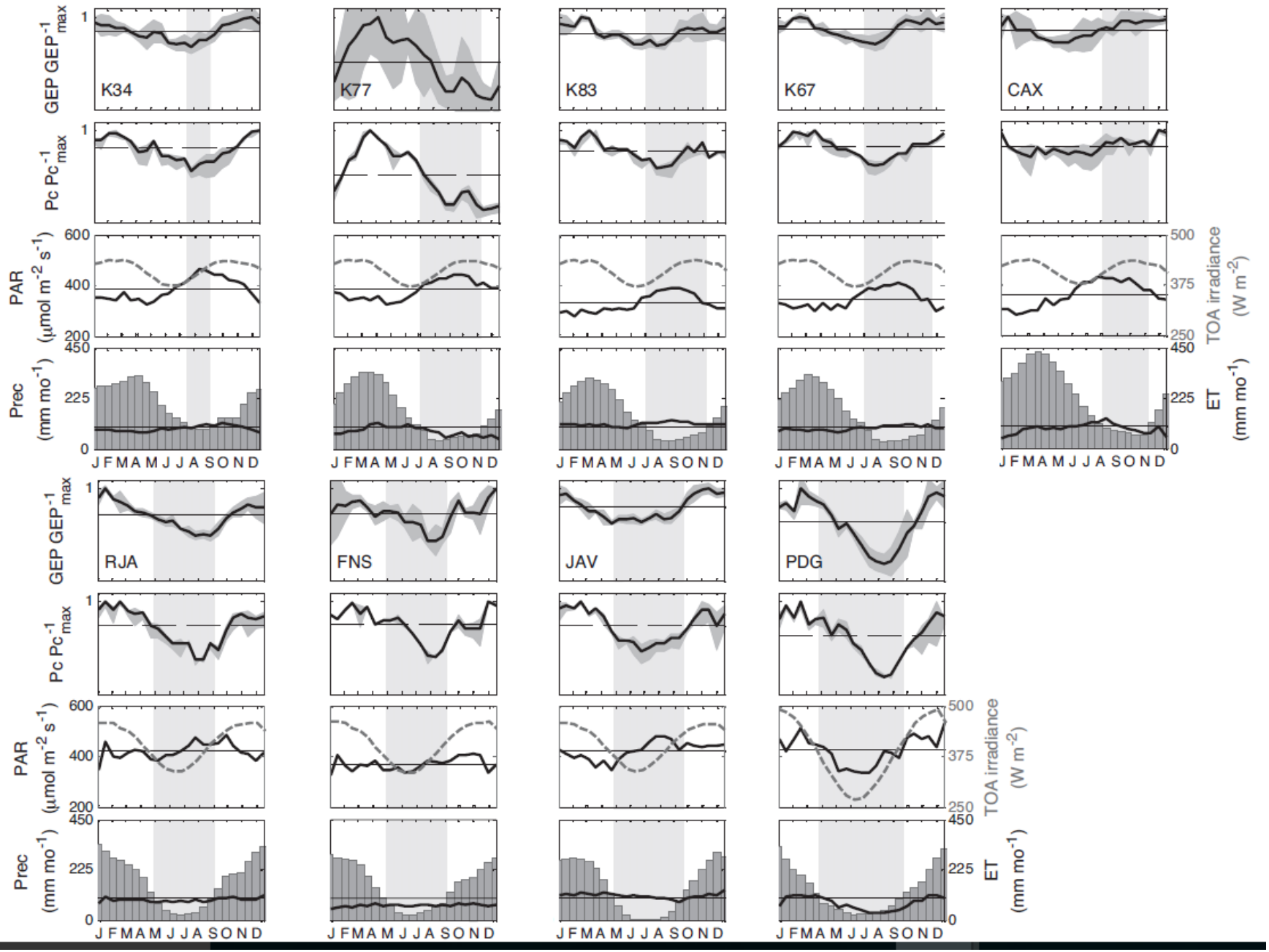
Fourth phase: measurements of NEE using eddy covariance flux towers

eddy covariance towers...FLUXNET

location of Amazon flux towers

N. Restrepo-Coupe et al. / Agricultural and Forest Meteorology 182–183 (2013) 128–144



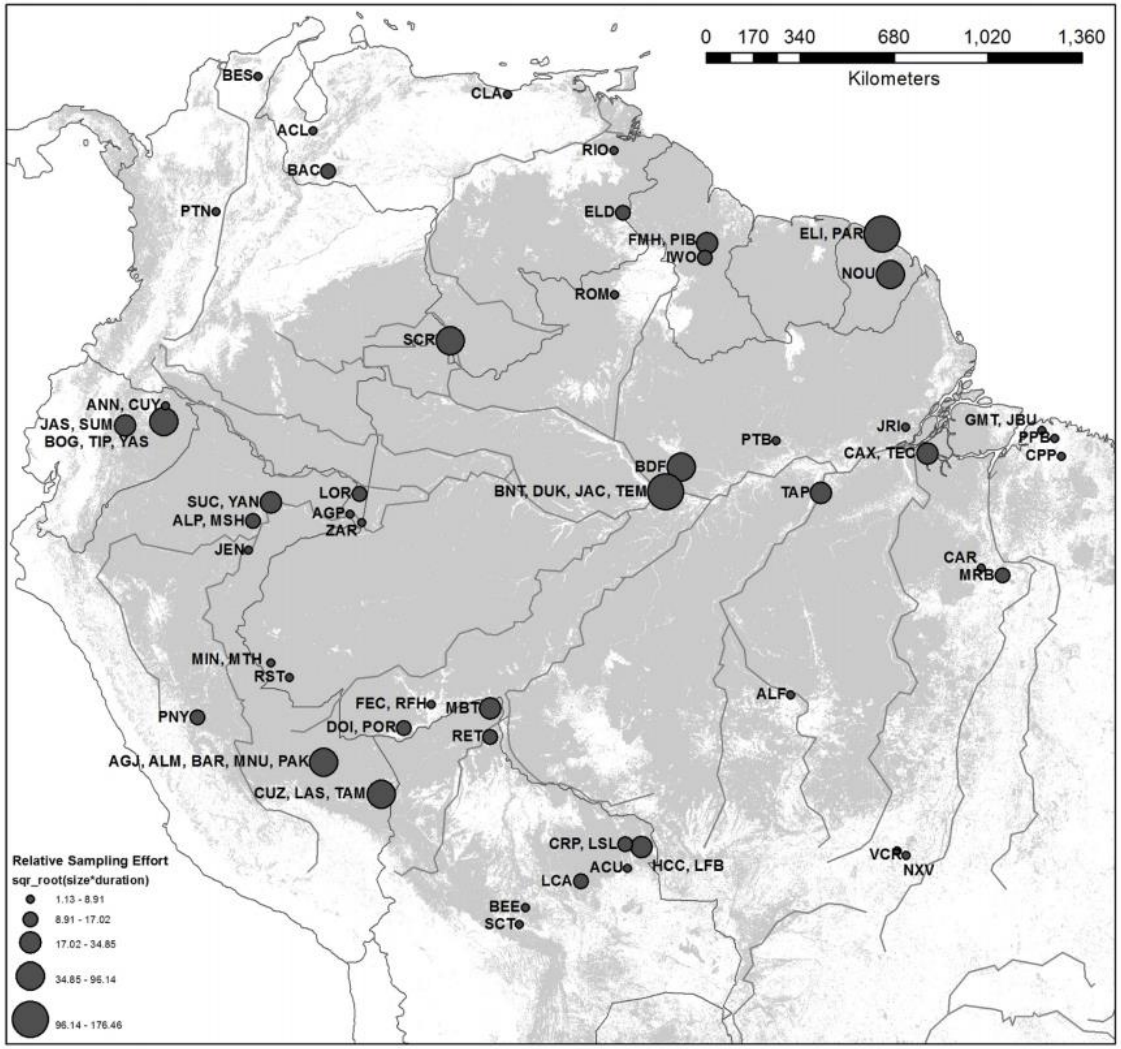


Restrepo-Coupe et al. (2013)

Fifth phase: expansion of experimental plots over large areas

expanding the plots...RAINFOR

(Loyd, Mahli and Phillips...Quesada, Aragão....)



Regional above-ground biomass dynamics

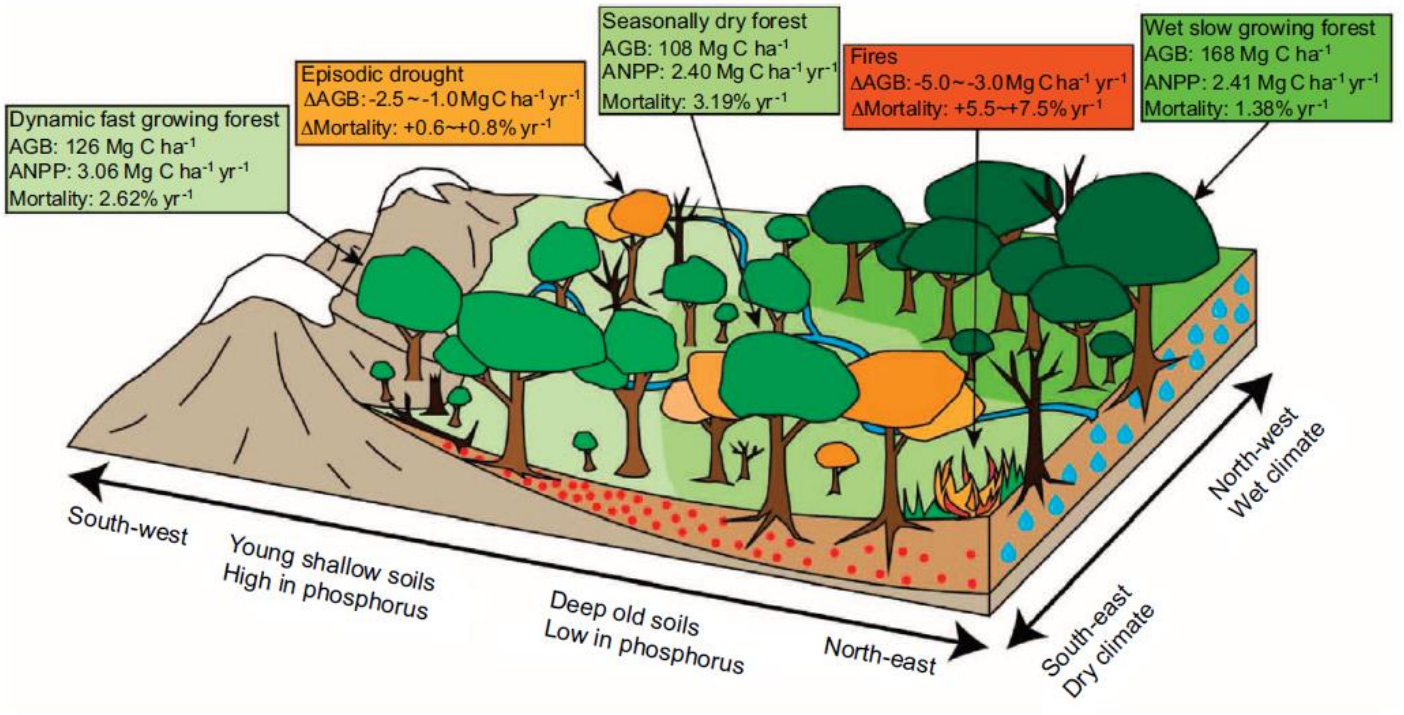


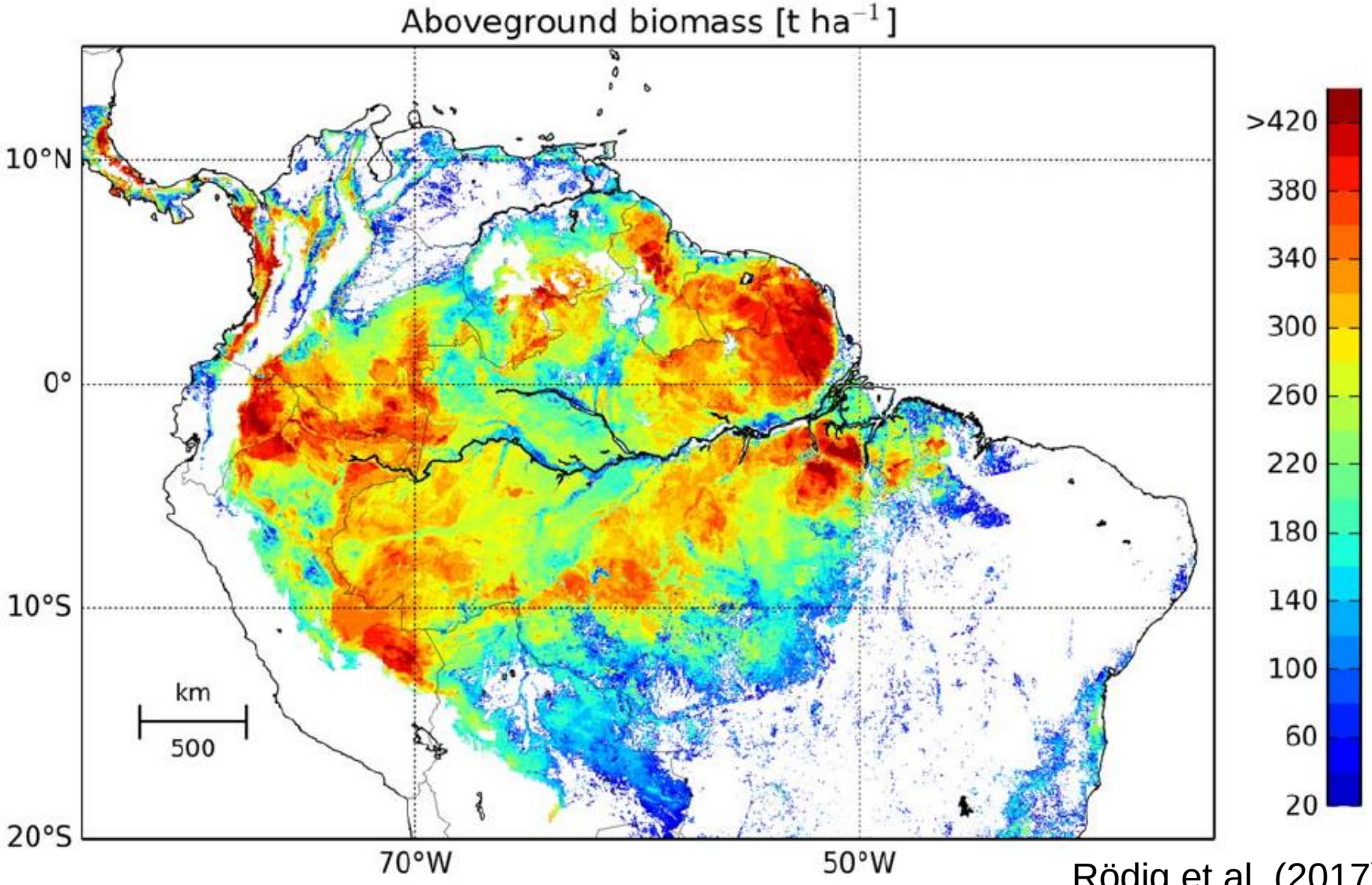
Figure 1. Two perpendicular environmental gradients in the Amazon basin drive the spatial variations in above-ground biomass, forest productivity and tree mortality. Above-ground biomass (AGB, Mg C ha^{-1}), above-ground net primary productivity (ANPP, Mg C ha^{-1} yr^{-1}) and tree mortality (% yr^{-1}) are retrieved from Johnson *et al* (2016). Change in AGB (ΔAGB, Mg C ha^{-1} yr^{-1}) and tree mortality (Δ Mortality, percentage point, % yr^{-1}) for episodic droughts from Feldpausch *et al* (2016), Williamson *et al* (2000) and Phillips *et al* (2009) and for fires from Brando *et al* (2014). Dynamic and highly productive forests are found on fertile and shallow soils in the west of the basin. Seasonally dry forests are found on the Brazilian shield in the south-east of the basin where seasonal drought and recurrent fires limit forest growth and enhance tree mortality resulting in relatively low AGB. In the wet east-central part of the basin, soils are deep and low in phosphorus resulting in relatively low productivity and mortality and high AGB.

Dolman and Janssen (2018)

Last phase: remoting sensing & modelling....thanks God!

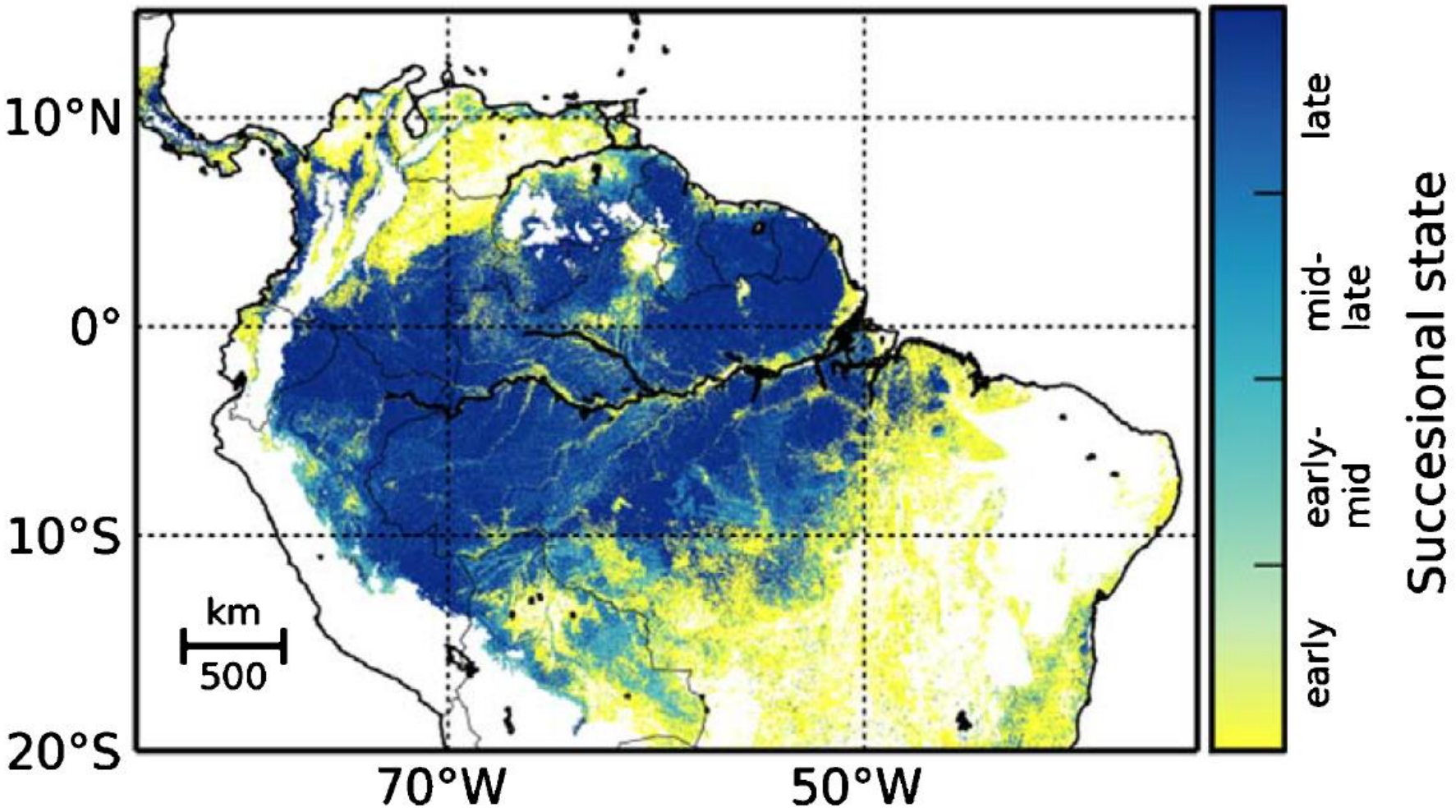
Remote sensing and modelling

(INPE, INPA, NASA, Chambers, Greg Asner...many others)



Rödig et al. (2017)

successional state of forests

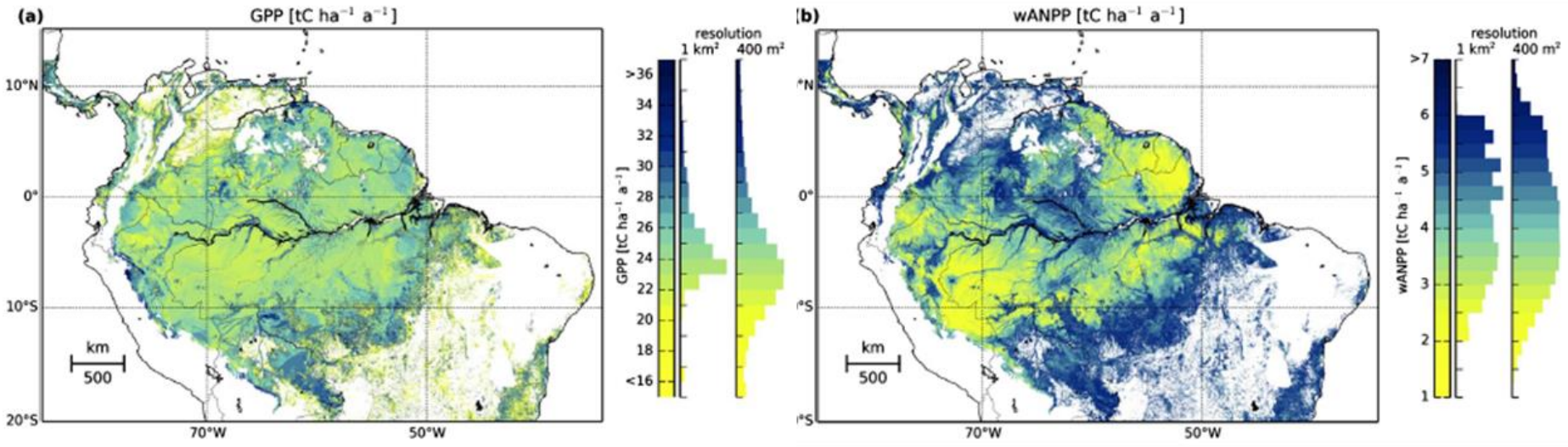


Rödig et al. (2018)

GPP & NPP

GPP

NPP

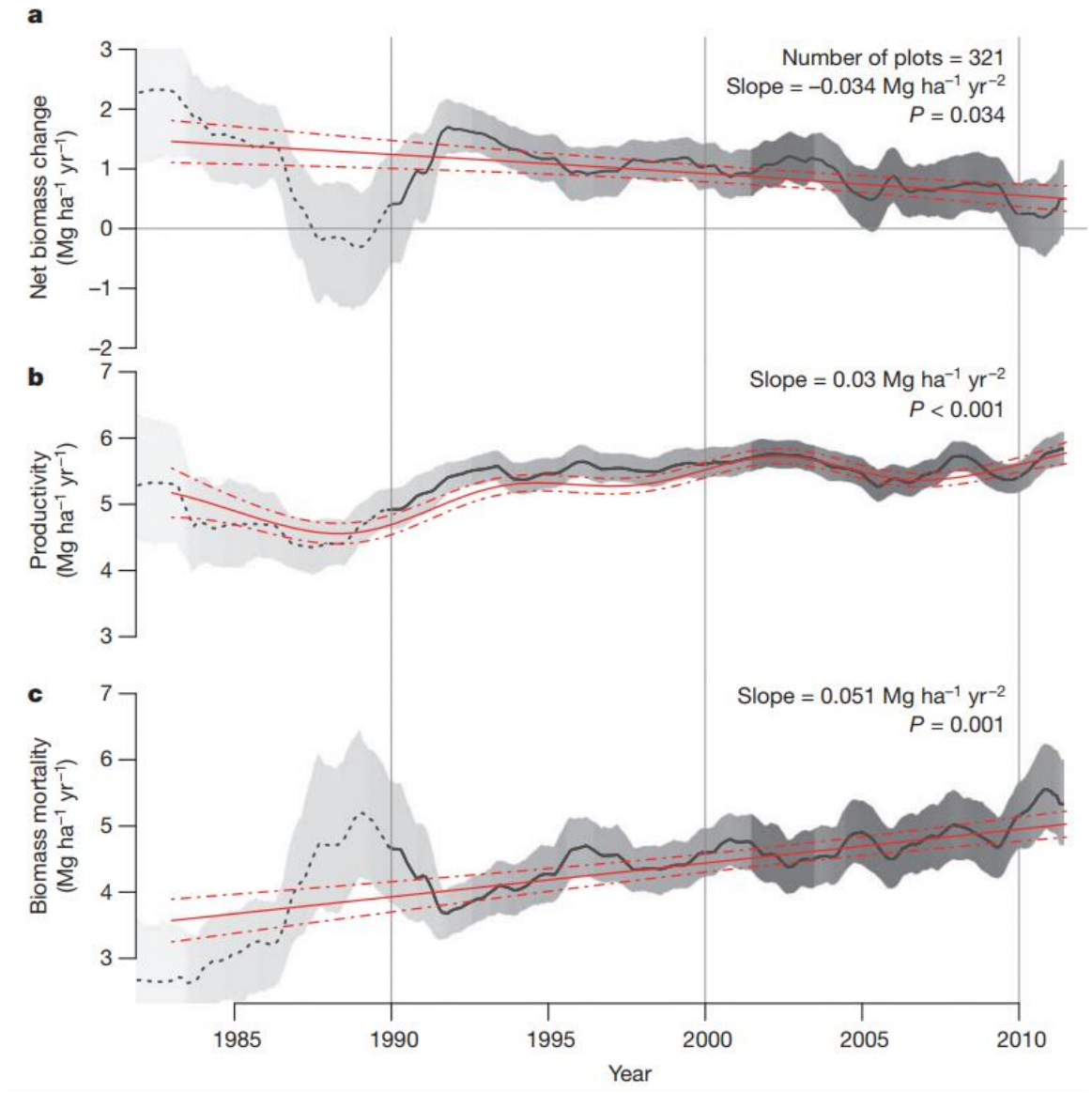


Rödig et al. (2018)

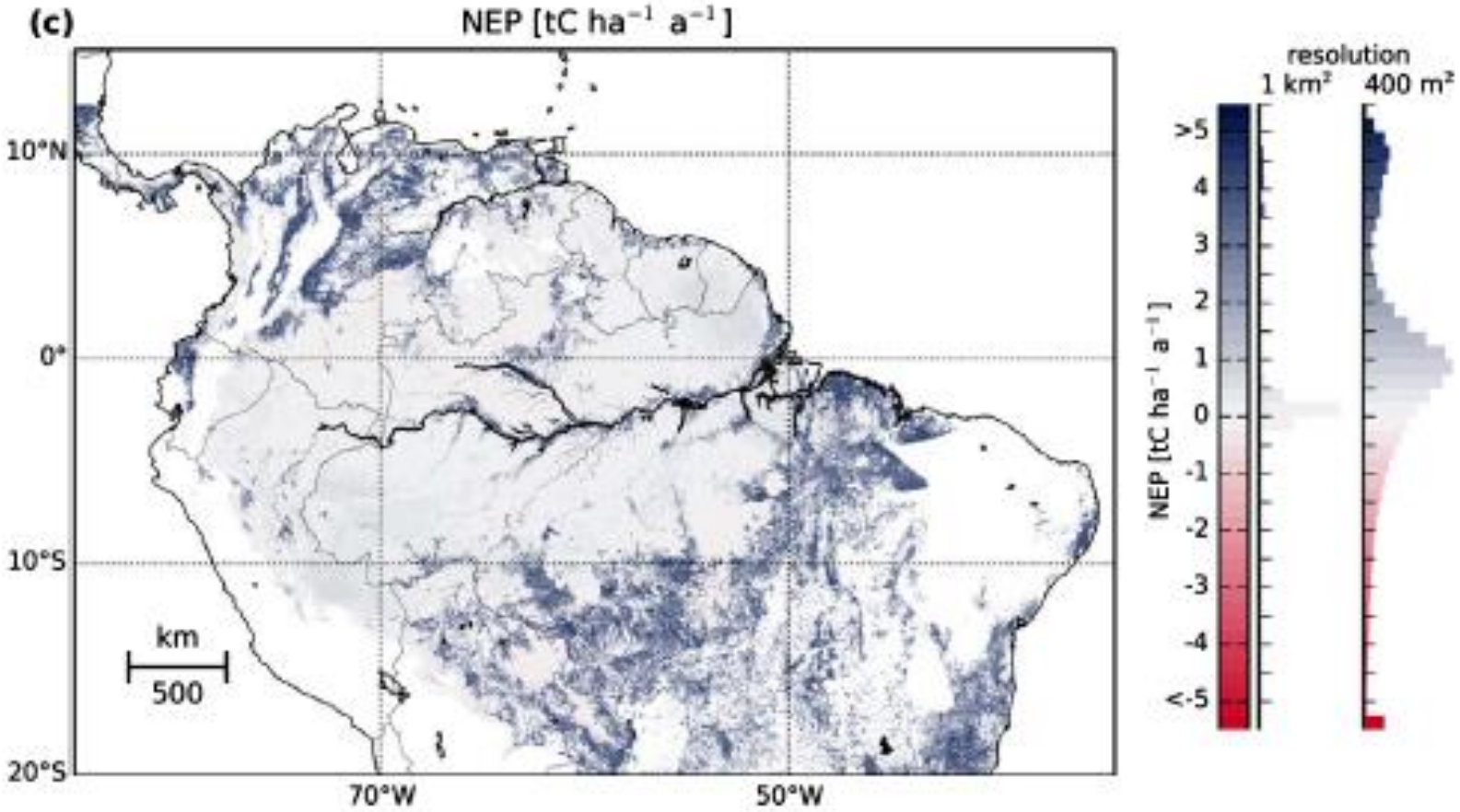
Amazon: sink or source of carbon?

What we know so far?

net biomass change



Brienen et al. (2018)



Rödig et al. (2018)

If the Amazon forest is a small sink of carbon, climax seems not to be the case in the Amazon...

Maybe, a vexing question is why?

Why the Amazon forest is accumulating carbon?

Perhaps, the forest is not so pristine as was considered before. Therefore, the forest is " recovering" from past disturbances

Perhaps, the forest is responding to the so called "CO_2 fertilization"

Perhaps, the forest is responding to the "N fertilization"

Conclusions

- The Amazon carbon cycle is the ultimate result of several interconnect evolutionary processes.

- Biodiversity plays a very important role in the carbon balance of the Amazon

- The forest dynamics (mortality vs. recruitment) is a key component of the carbon cycle

- There are short-term and long-term effects that regulates the regional carbon balance

- For now, it is fair to conclude that there is the Amazon is a small net sink of carbon, BUT this sink is decreasing

- Global changes may accentuate this trend and the Amazon forest could become a source of carbon to the atmosphere in the future