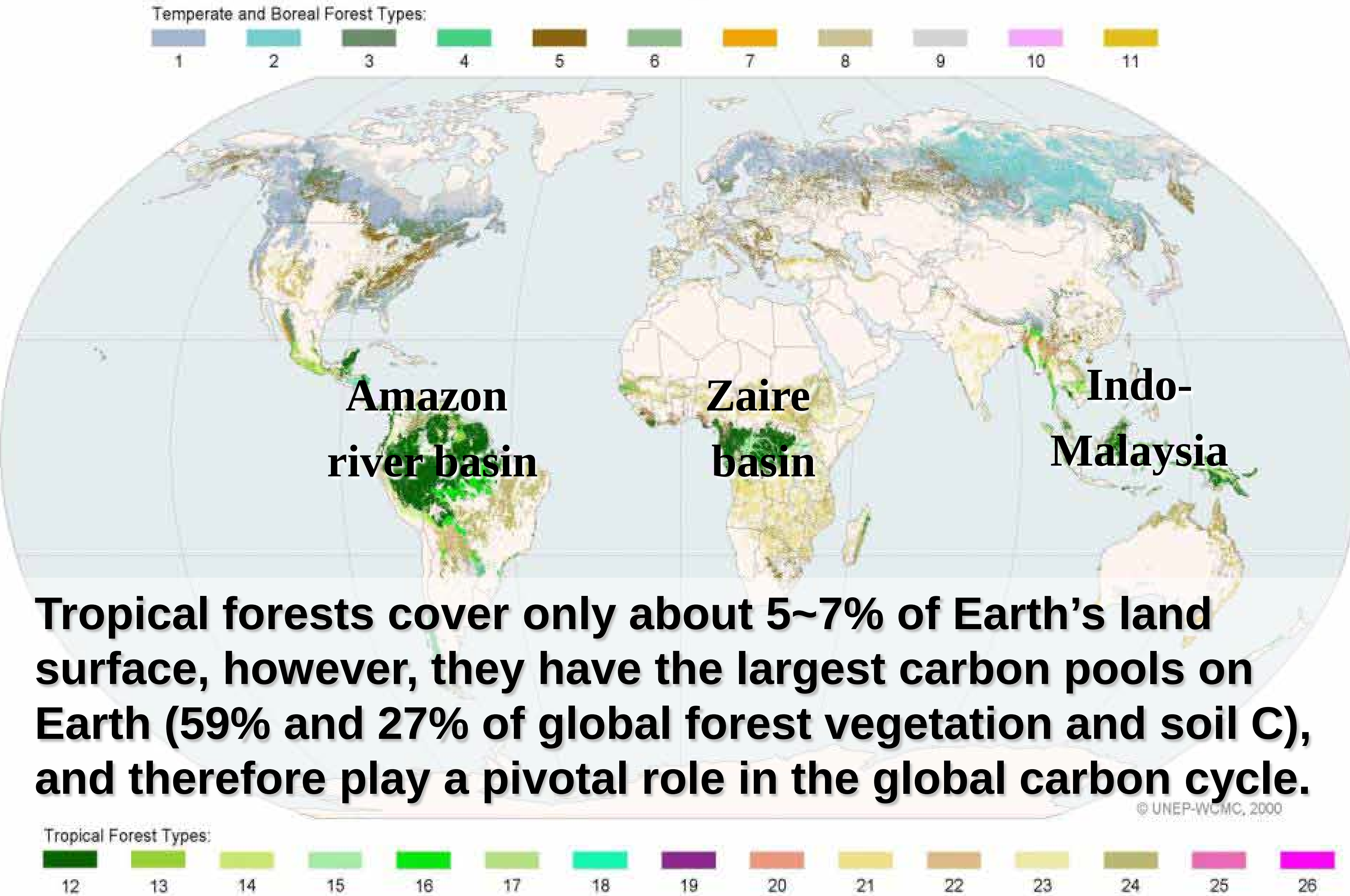
Soil Carbon Dynamic and REDD Credit of SE Asian Tropical Ecosystems

Naishen LIANG (CGER, National Institute for Environmental Studies, Japan)
T. Okuda (Hiroshima Univ)
S.C. Fletcher (FRIM)

Distribution of Tropical Forest Biome



Tropical forests cover only about 5~7% of Earth's land surface, however, they have the largest carbon pools on Earth (59% and 27% of global forest vegetation and soil C), and therefore play a pivotal role in the global carbon cycle.

Carbon Sinks & Sources in the World's Forests

Pan et al. 2011, Science

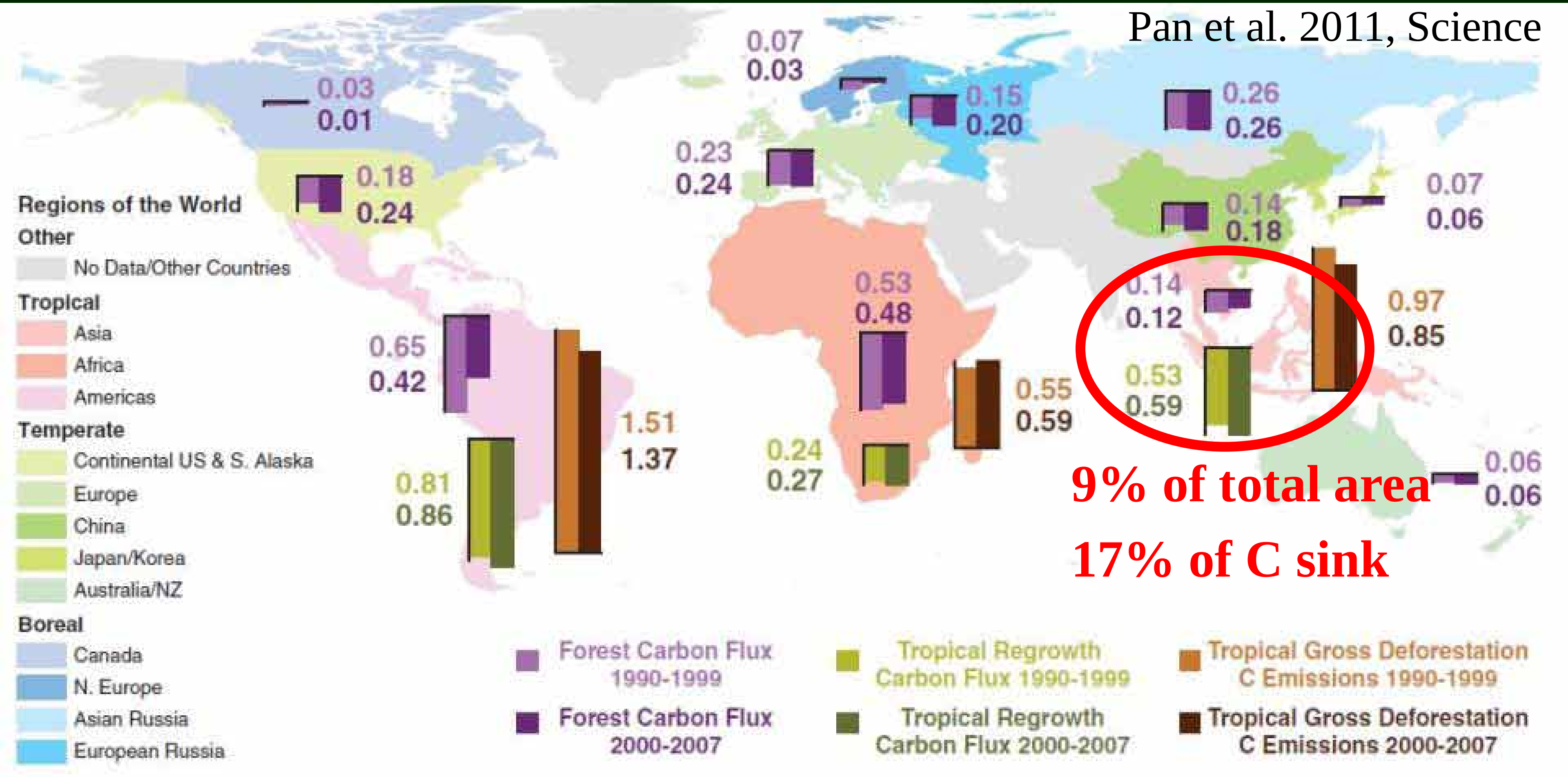


Fig. 1. Carbon sinks and sources (Pg C $year^{-1}$) in the world's forests. Colored bars in the down-facing direction represent C sinks, whereas bars in the upward-facing direction represent C sources. Light and dark purple, global established forests (boreal, temperate, and intact tropical forests); light and dark green, tropical regrowth forests after anthropogenic disturbances; and light and dark brown, tropical gross deforestation emissions.

1. A lack of soil C flux data in tropical forests caused uncertainty of 10-20% of the estimated total C sink.
2. They lack sufficient data in Southeast Asia to make robust estimates.

Climate Change vs. Tropical CO_2 Emissions

Drought and tropical soil emissions

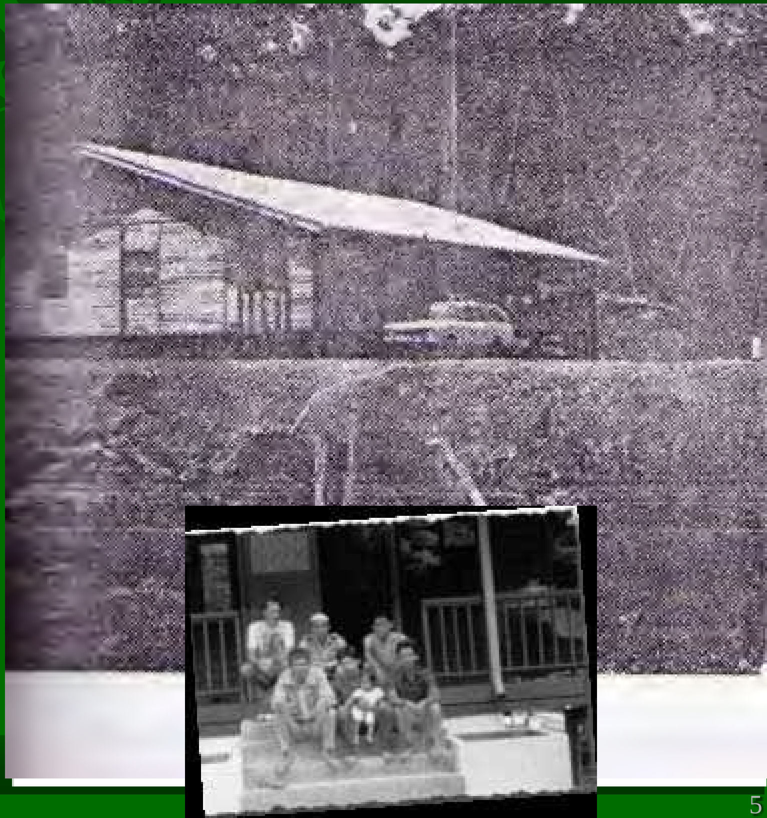
C.C. Cleveland & B.W. Sullivan, Nature, 489 (Sep 2012)

Past research implied that positive feedback might exist between climate change and greenhouse-gas emissions from soil. A study finds that drought-induced declines in such emissions from tropical forests could counter climate change.

Important questions remain about the effect of climate change on GHG fluxes from soil, and hence to what extent the beneficial climate services provided by tropical forests will persist in the future.

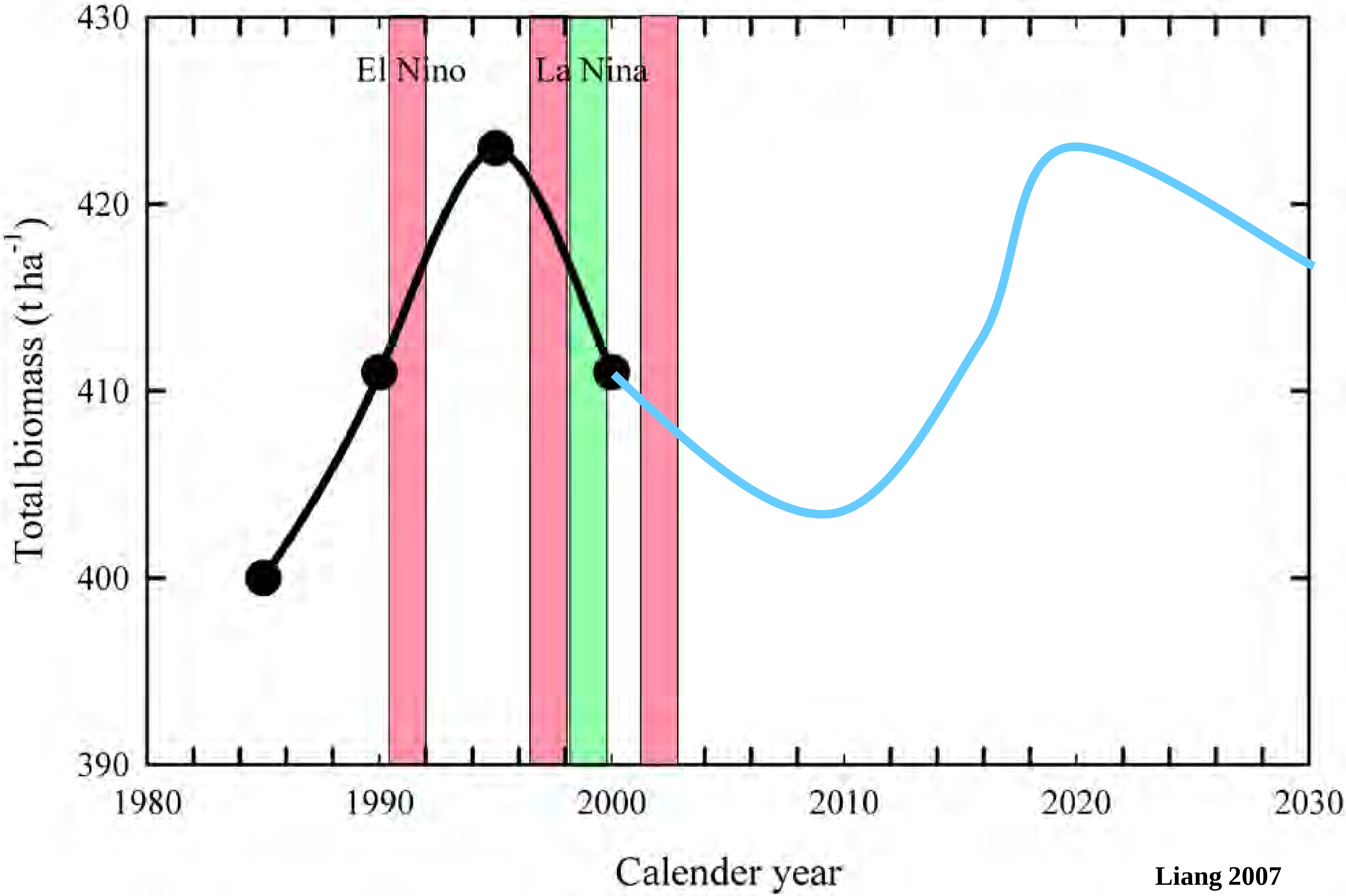
Pioneer Studies on Carbon Cycle of Southeast Asian Tropical Forests

1970~1978: **Intensive research on lowland rain forest ecology and dynamics under the International Biological Programme (IBP)**



Tree census

Biomass vs. Climate Change

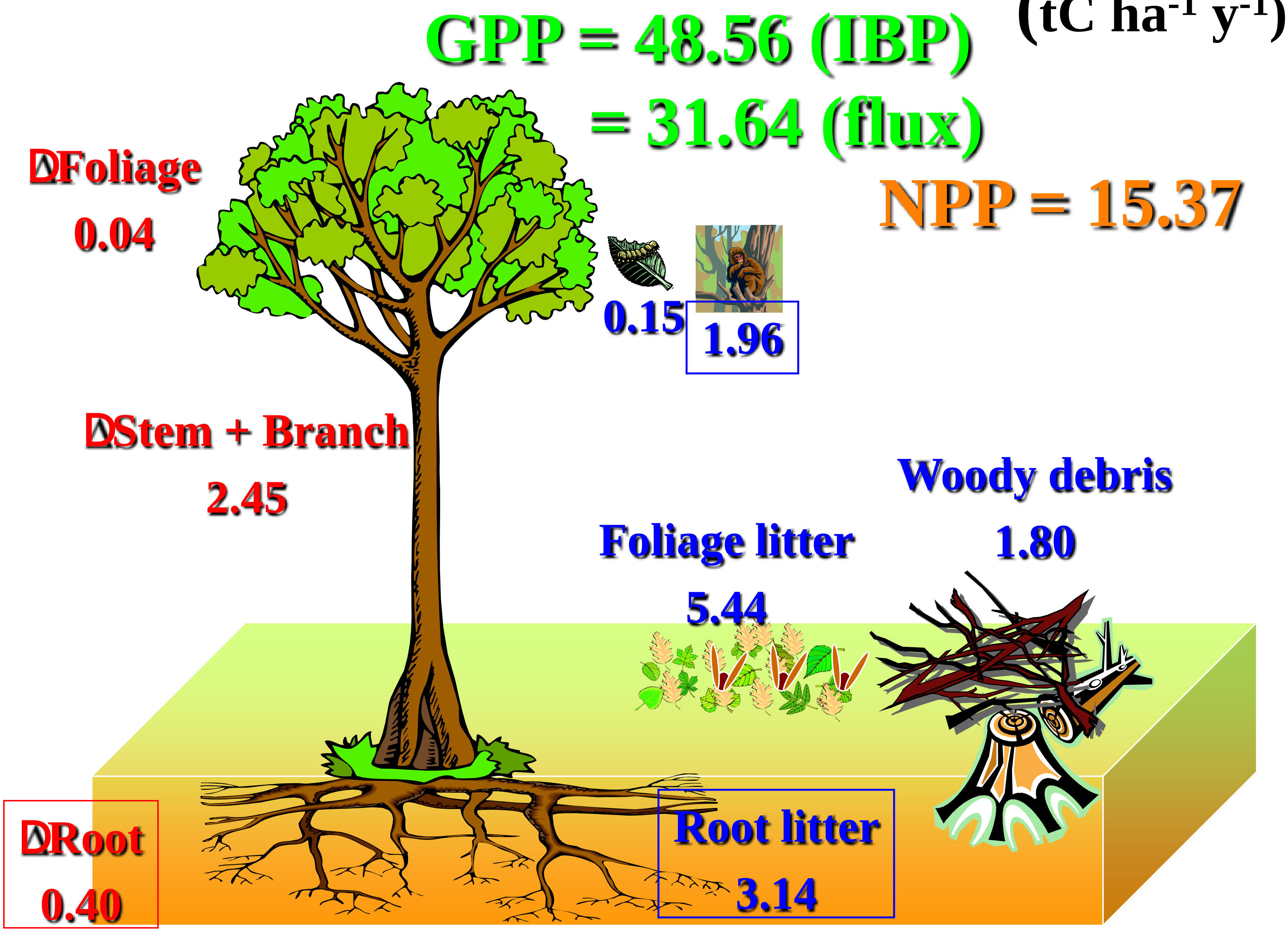


Liang 2007

Photosynthesis Tower (IBP Tower)

Carbon Balance of Pasoh Primary Forest

(tC ha^{-1} y^{-1})



High Carbon Stock of Southeast Asian Primary Forests

High Productivity of Sotheast Asian Forests

	Pasoh	Manaus
Location	2°59'N, 102°08'E	2°35'S, 60°06'W
Mean Temp (°C)	25.7	25.6
Precipitation	2050	2200
Aboveground biomass	430~475	300~350
LAI	6.25	5~6
Fine litter (t ha^{-1})	10.8	6.9~7.3
NPP (tC ha^{-1} y^{-1})	13.9 (Kira 1978) (Khao Chong: 15.5)	10.7 (Malhi et al. 2004)

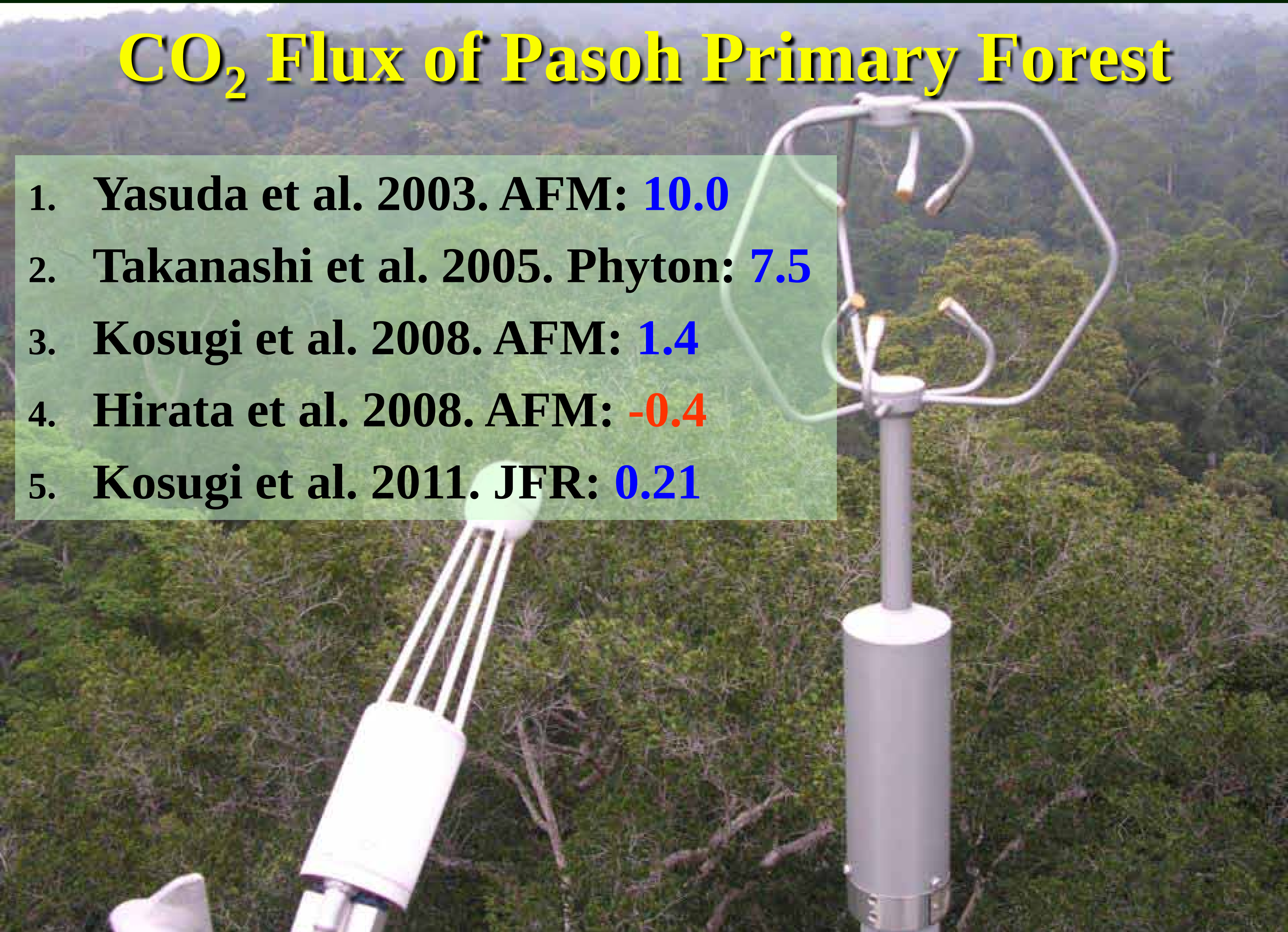
NEP = ?

Available heterotrophic respiration (R_h) data is in urgent need.

$$NEP = NPP - R_h$$

CO_2 Flux of Pasoh Primary Forest

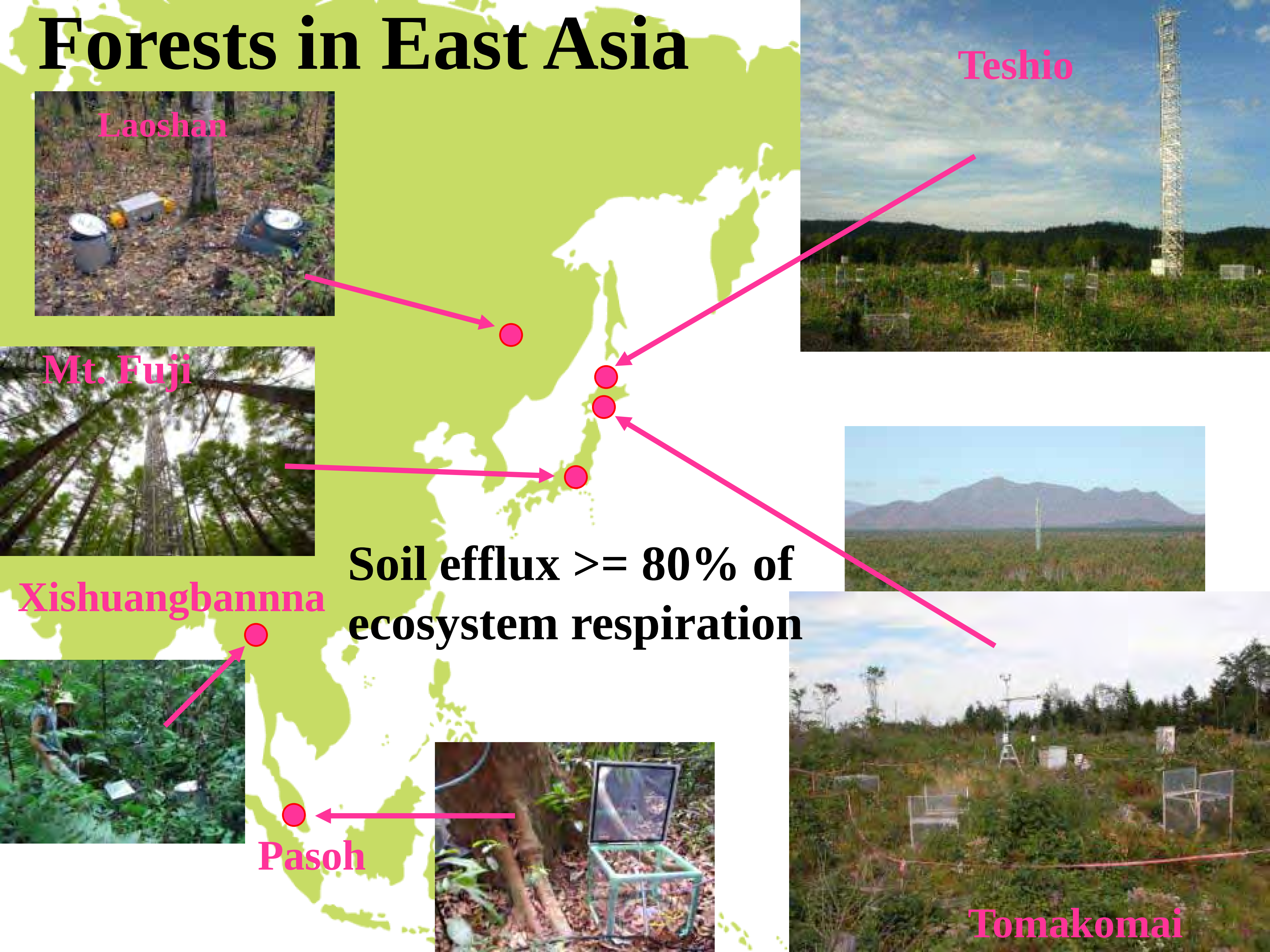
1. Yasuda et al. 2003. AFM: 10.0
2. Takanashi et al. 2005. Phyton: 7.5
3. Kosugi et al. 2008. AFM: 1.4
4. Hirata et al. 2008. AFM: -0.4
5. Kosugi et al. 2011. JFR: 0.21



Uncertainties of Micrometeorology

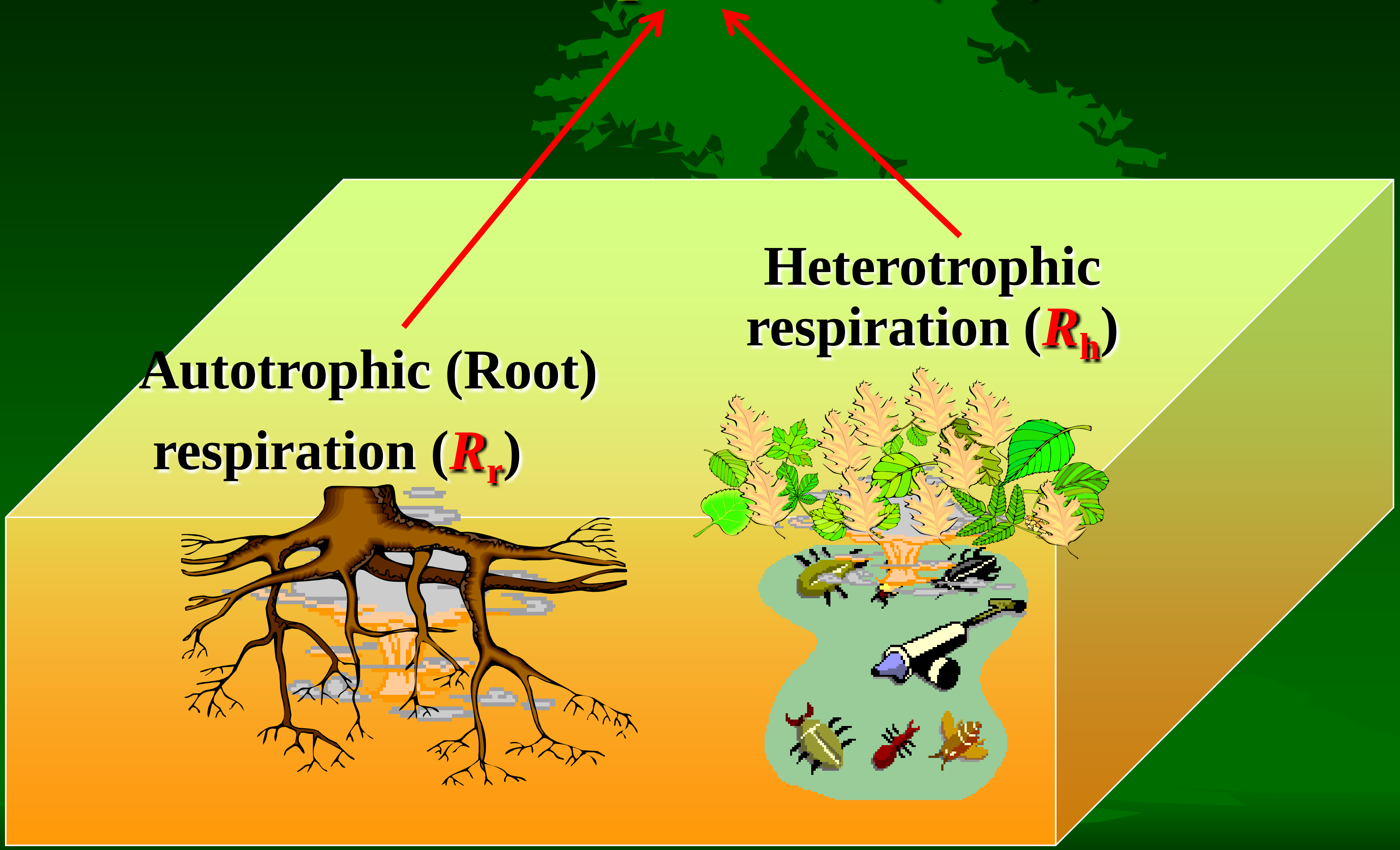
Missing measurement of nighttime ecosystem respiration

Forests in East Asia

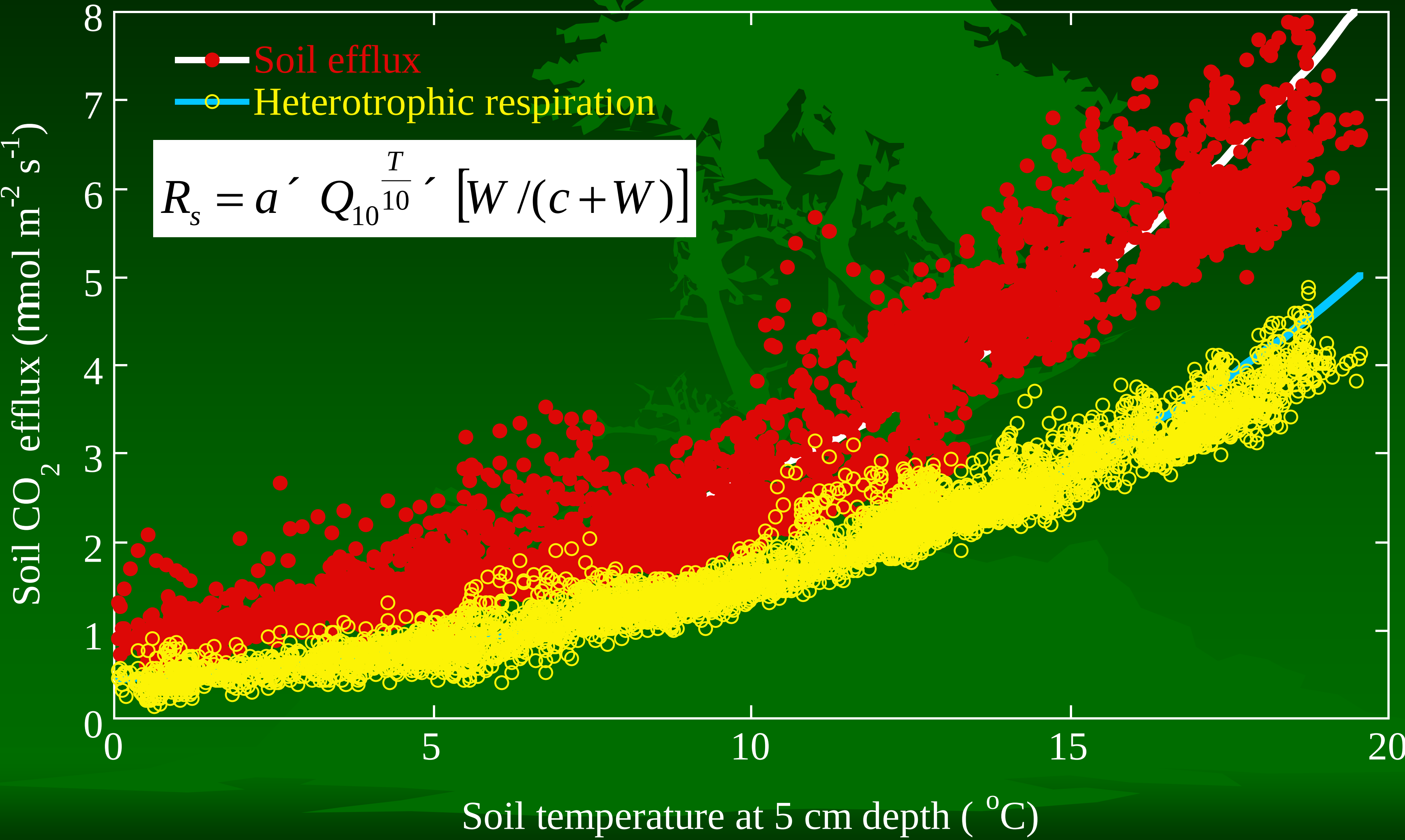


Soil efflux >= 80% of ecosystem respiration

Soil Respiration (Rs)



Soil Temperature Drives Soil Efflux



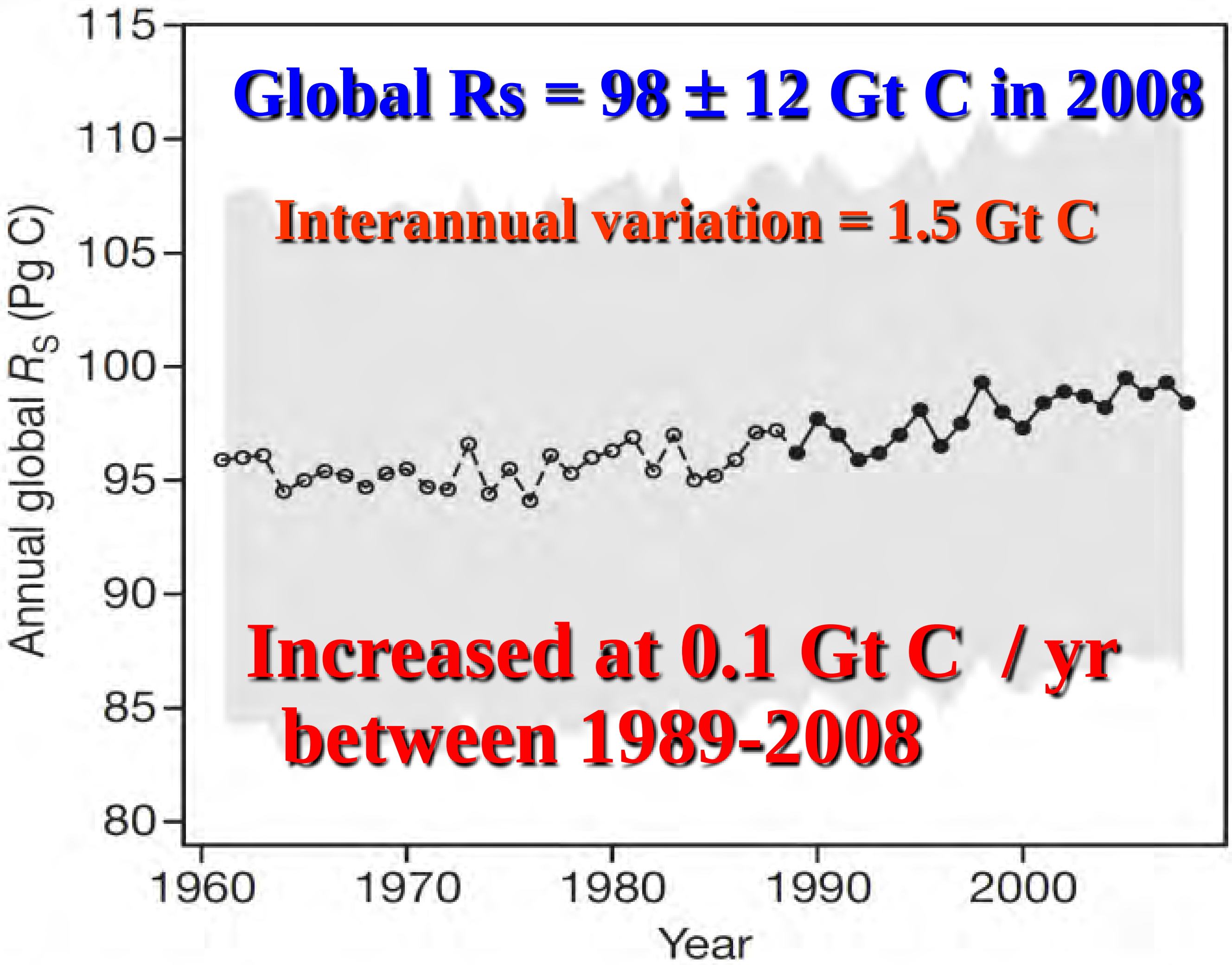


Figure 2 | Estimated annual global R_S. The dashed line indicates results outside the time period covered by main data set, S1 (1989–2008), but within the period covered by the entire R_S database, S0 (1961–2008), and should be considered speculative. The grey region shows the standard deviation of the Monte Carlo simulations ($N = 1,000$). Bond-Lamberty & Thomson 2010 (Nature)

Global Heterotrophic Respiration (Rh)

Potter & Klooster 1998 (*GBC*); Bond-Lamberty & Thomson 2010 (*Nature*)

by CASA model

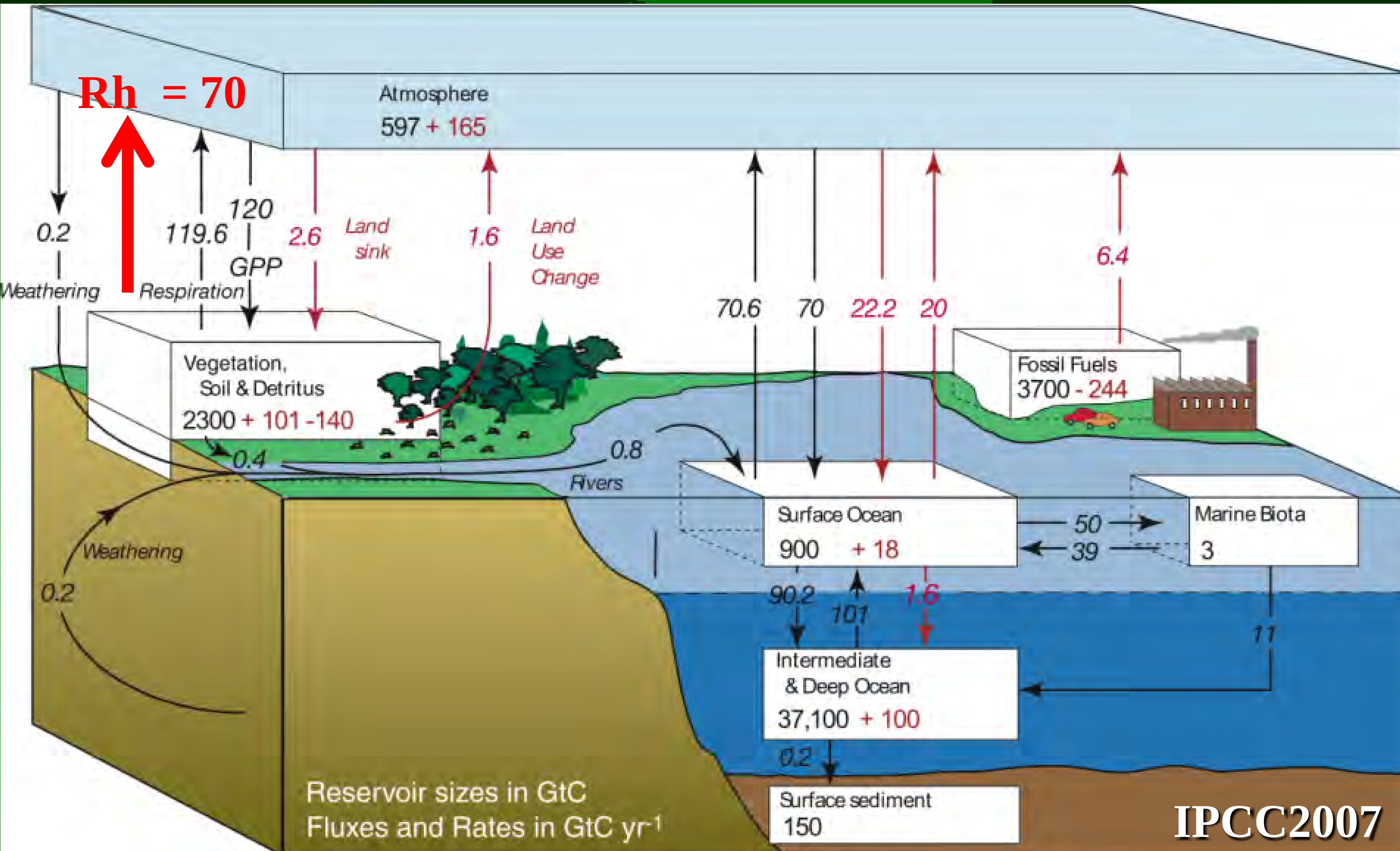
Global Rh = 71% of Rs (69.6 Gt C y^{-1})

10 times of fossil fuel emission (7.2 GtC y^{-1})

70 times of land C sink (1.0 GtC y^{-1})

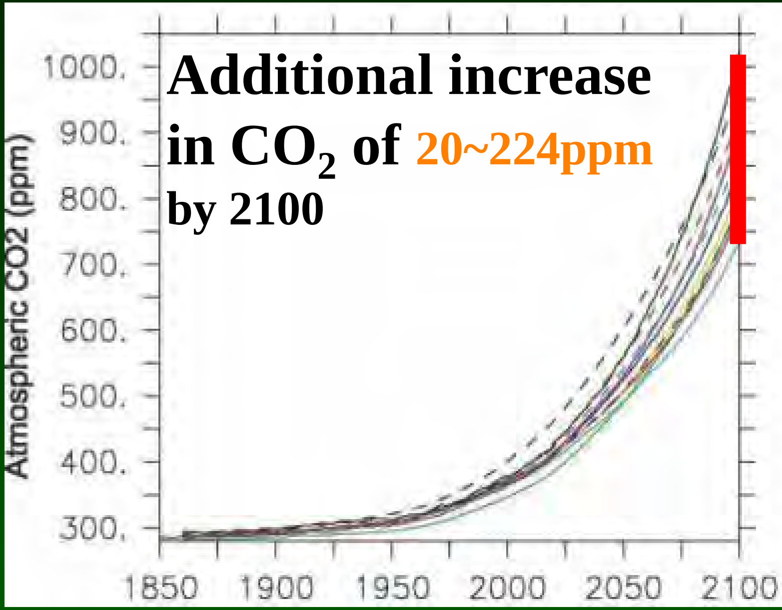
- **Plays a key role in global carbon cycle**

Global Carbon Balance



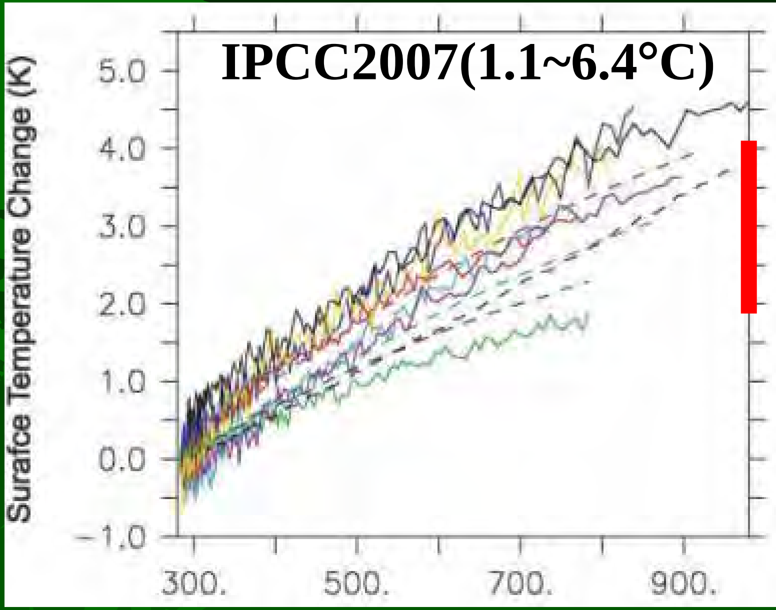
Feedback of Heterotrophic Respiration to Global Warming

(Friedlingstein et al. 2006; IPCC 2007)



Vicious cycle

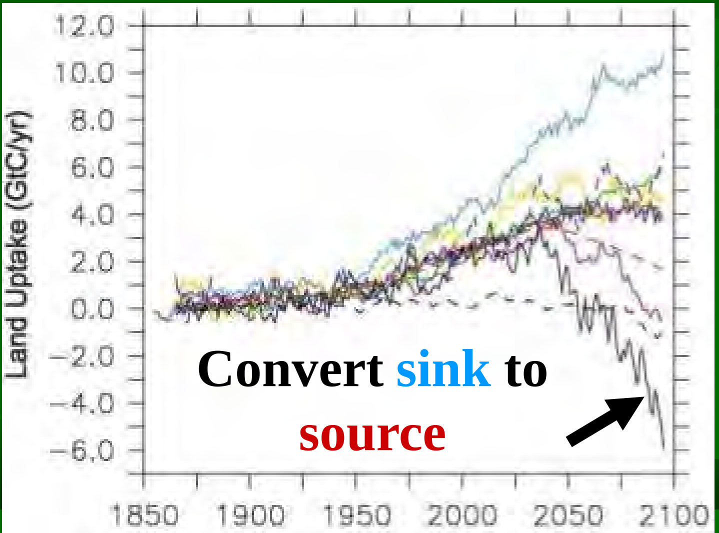
0.1~1.5°C



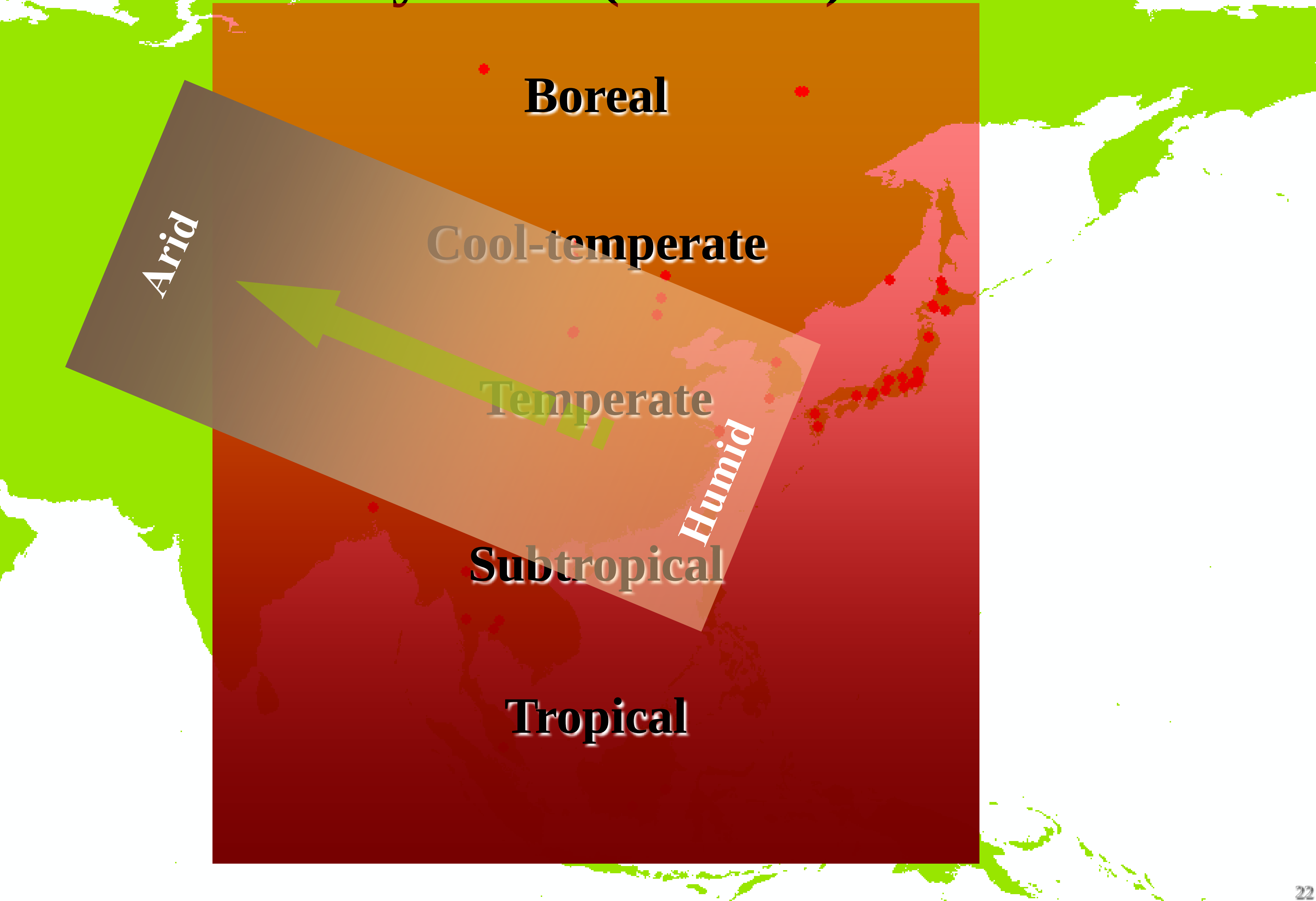
Heterotrophic respiration

Q_{10}=1.1~2.2

Positive feedback

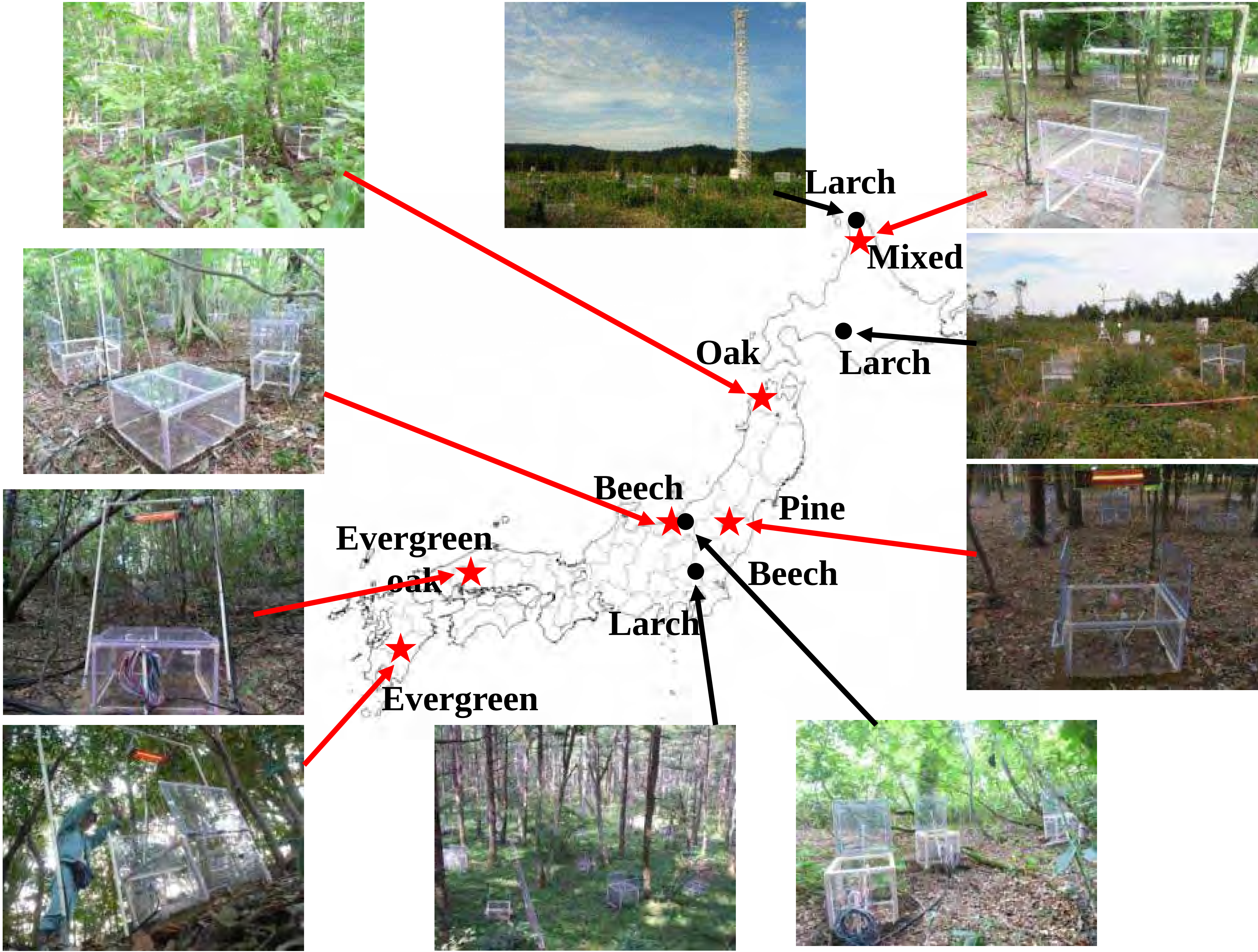


Ecosystems (Biomes) in Asia



Open Questions

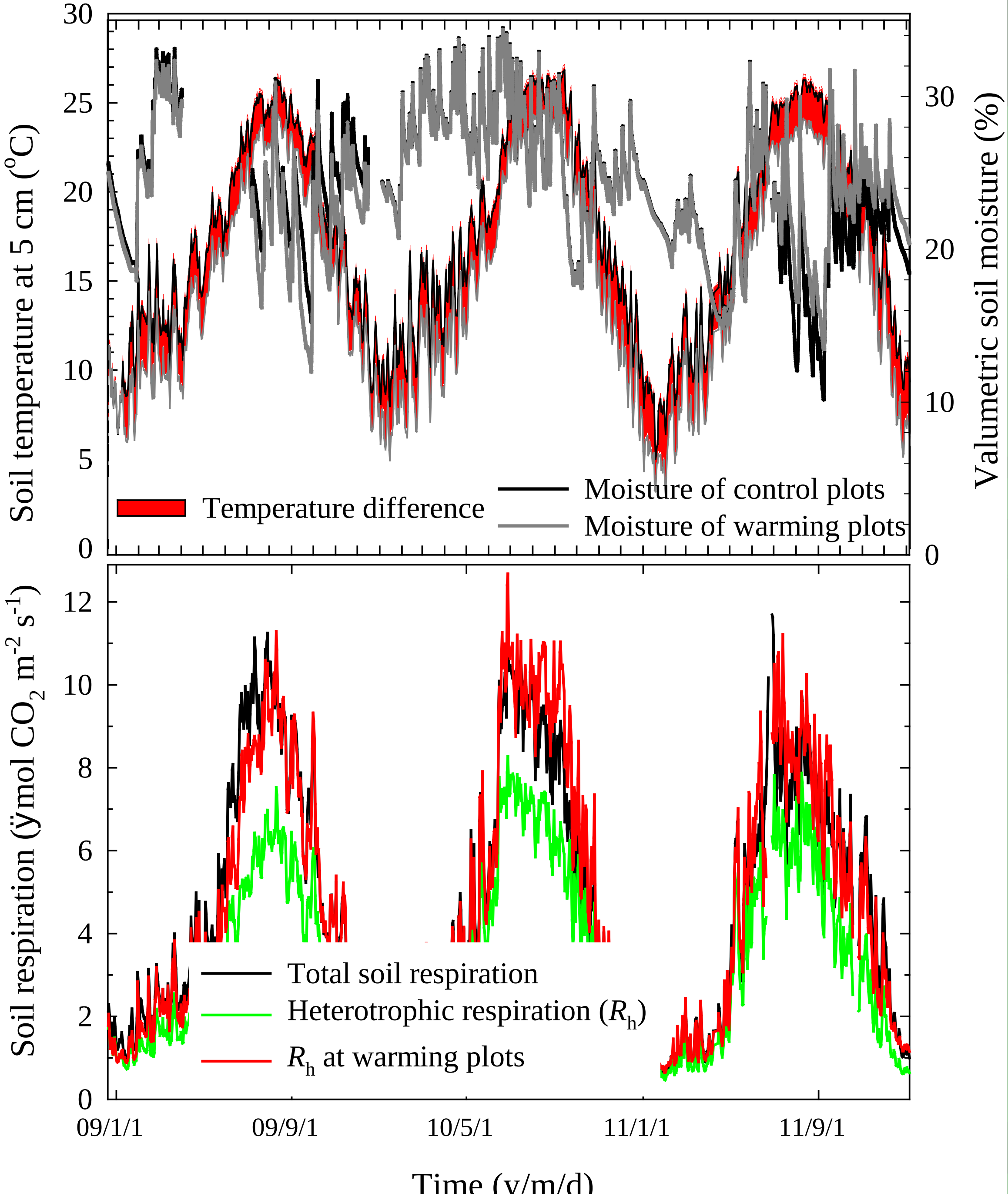
- **With global warming, will Asian terrestrial ecosystems continuous be carbon sink?**
- **or potentially convert to carbon source?**



Larch
Mixed
Oak
Larch
Beech
Pine
Evergreen oak
Beech
Larch
Evergreen


Soil WarmingExperiment Designing
15~24 chambers (90´×90 ´×50 cm)
5 heterotrophic plots
10 trench plots
5 warming plots

Subtropical forest in Kyusyu



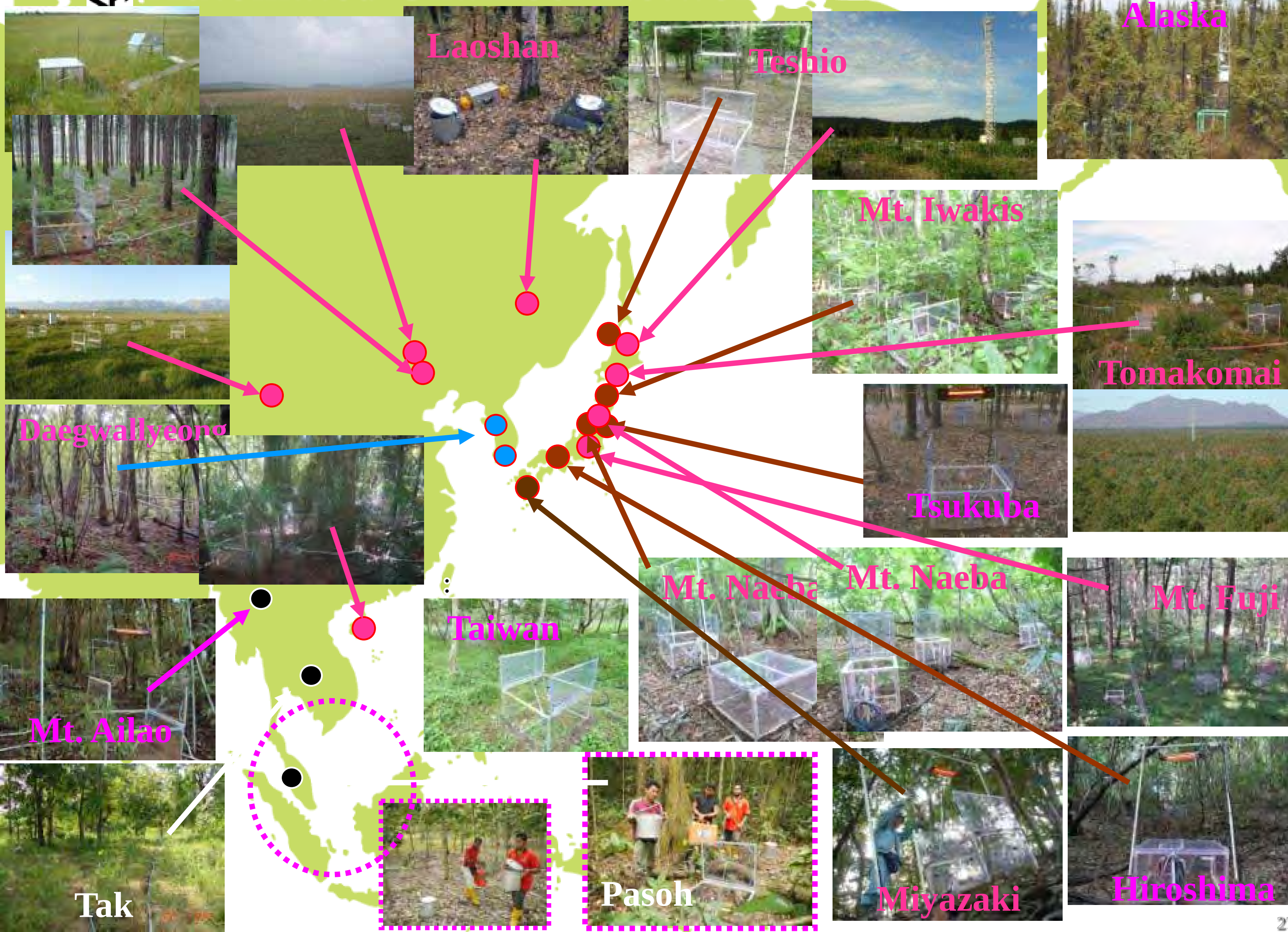
Warming:

⬆ 2.5°C Tsoil at 5-cm

Effect:

Rh⬆ 11% per °C

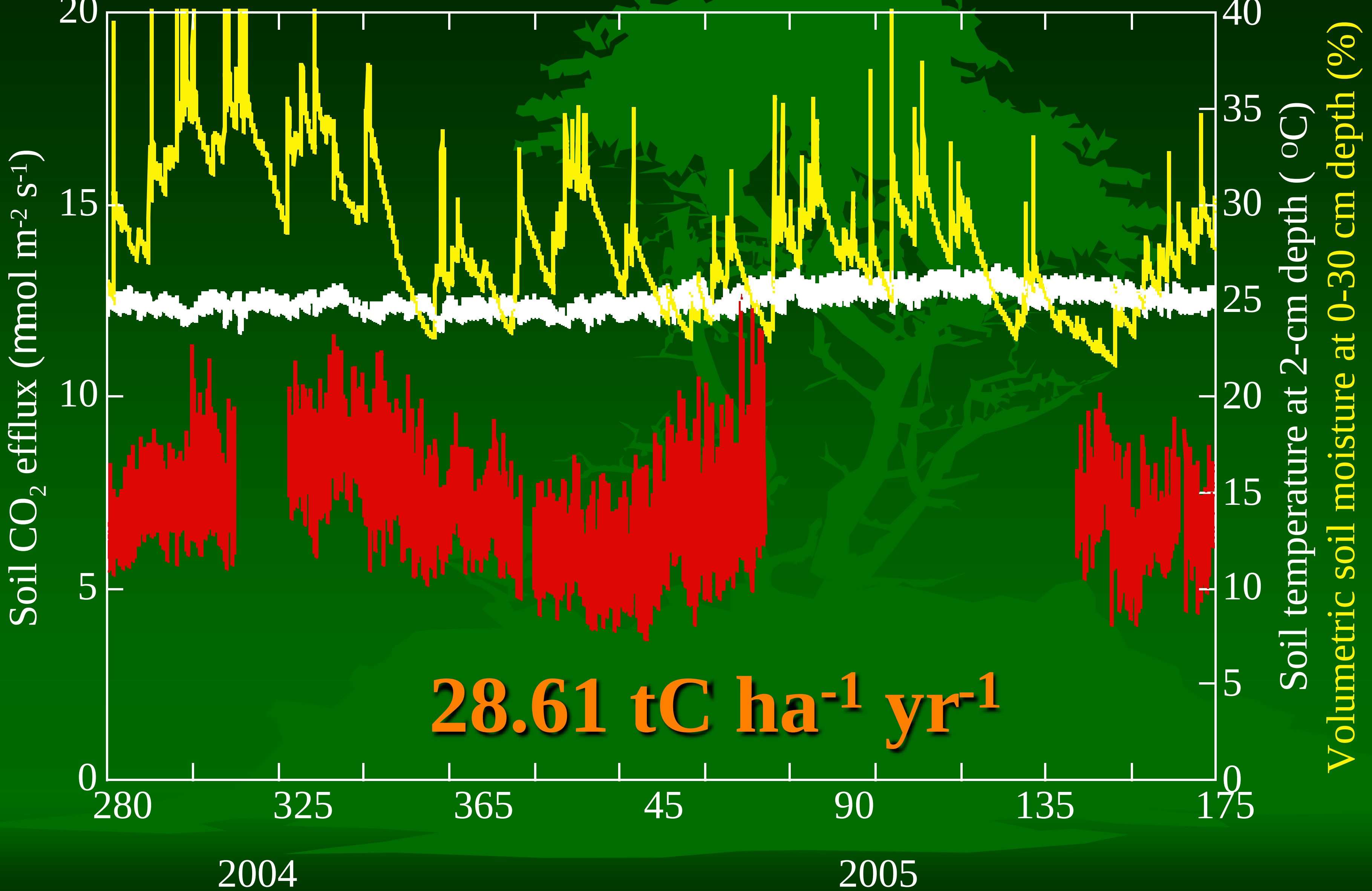
Automated Chamber Networks



Continuous Measurement Rs at Malaysian Tropical Rainforests

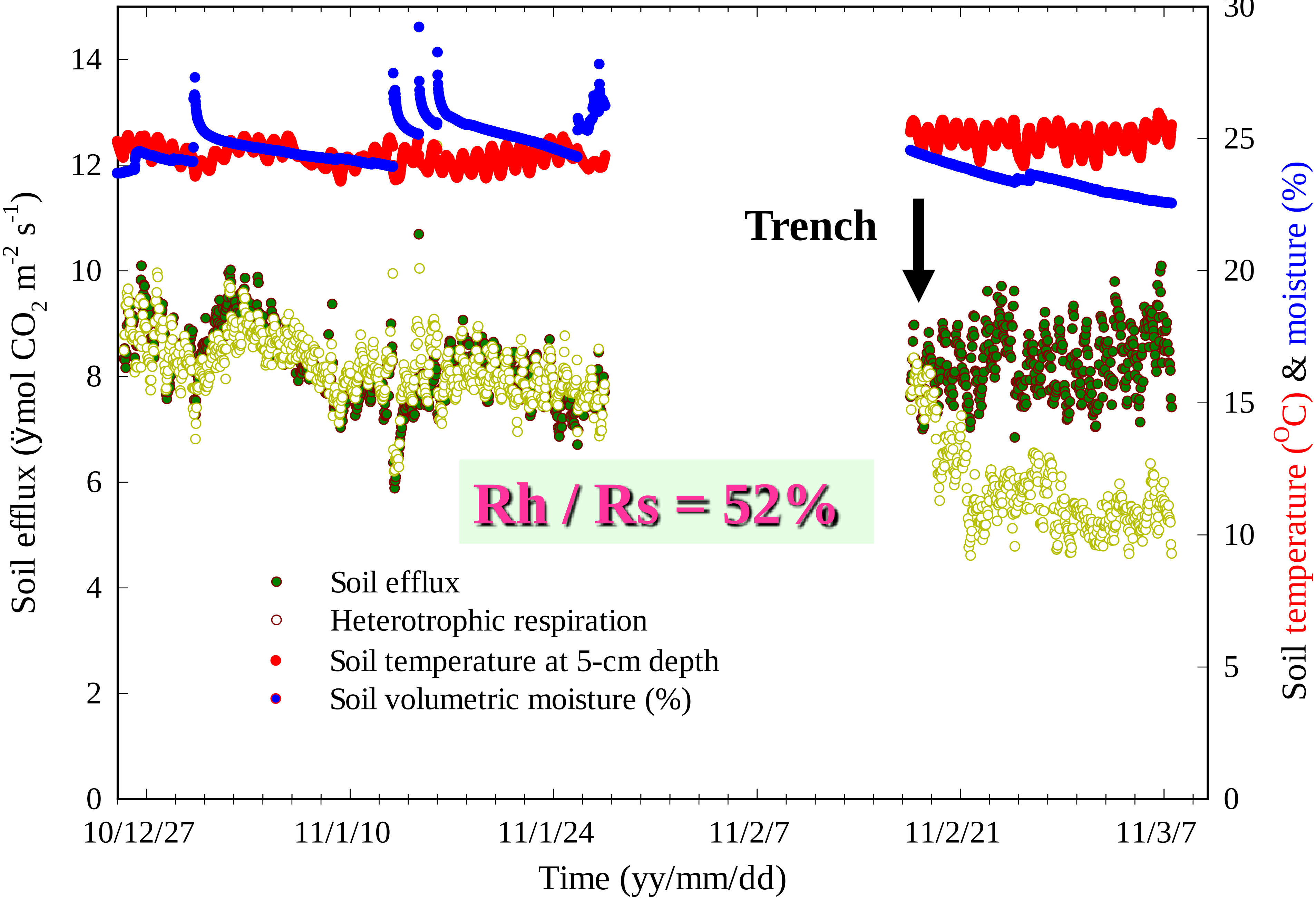
http://www.nies.go.jp/biology/pasoh/English/index.html

Seasonality of Soil CO_2 Efflux

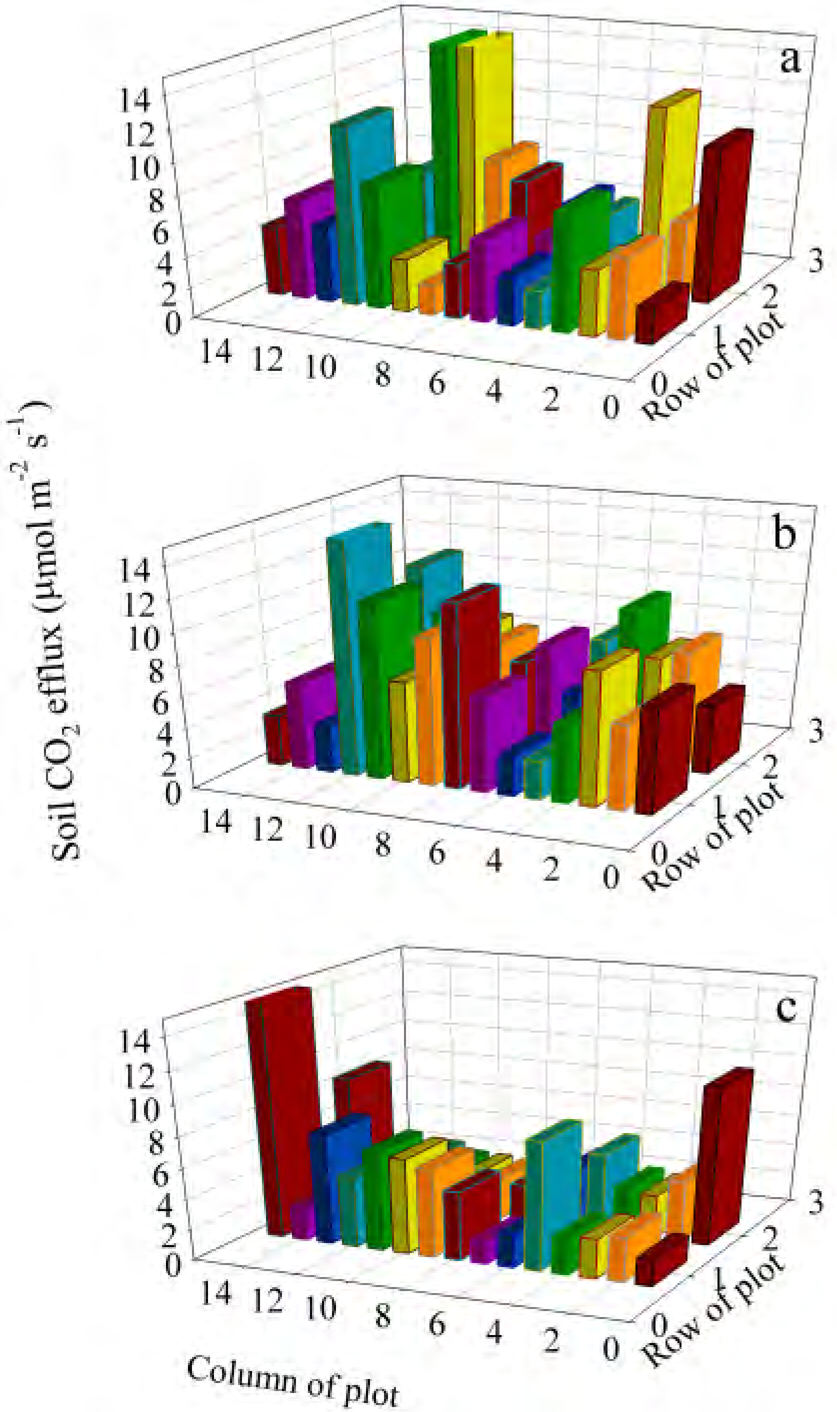


Partitioning Soil Respiration

Temperal viration of soil CO_2 efflux at Pasoh primary forest



Logging site & Secondary forests



Contribution of Harvest Residue

With the Sustainable Management System (SMS: 50~65% of logging intensity), soil CO_2 efflux:

Primary forest

6.65 μmol m^{-2} s^{-1}

5 years after SMS

6.60 μmol m^{-2} s^{-1}

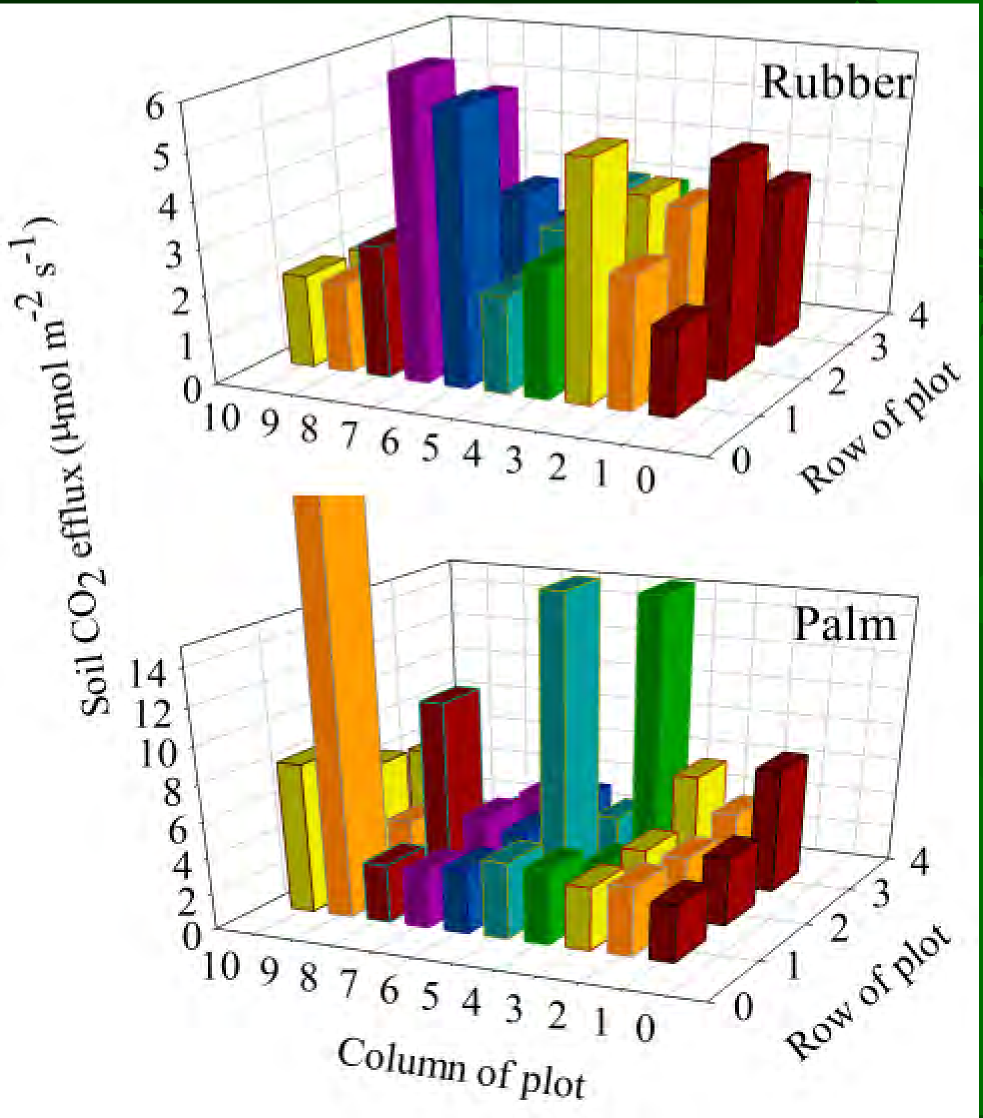
5 years after low-impact logging

5.58 μmol m^{-2} s^{-1}

R_h increased about 40~45%

Young Plantations

Soil CO2 Efflux at Rubber & Oil Palm Plantations



Rubber plantation

3.17 μmol m^{-2} s^{-1}

Oil palm plantation

4.81 μmol m^{-2} s^{-1}

***R_h* decreased about 28% (oil palm) ~ 52% (rubber)**

Carbon Lost Following Harvest Events

$$\sum \$ = [1.5 \times (e^{0.0705 \times T_1} - e^{0.0705 \times 23.5}) \times 3.78432 + (C \times d)] \times \$$$

With normal (50% of harvest intensive) harvest system

- **T_1 = 23.5ºC + 3ºC (soil temperature increase)**
- **C = 63 tC/ha (harvest residue: AG=35, BG=28)**
- **d = 15% (decomposition ratio of CWD)**
- **\$ = 15 US\$/tC**

Total carbon lost at the first year after the logging:

$$\sum \$ = (7.01 + 9.45) \times 15 = 247 US\$ / ha$$

here, 7.01 tC is SOC lost from the degradation;

9.45 tC is decomposition of the harvest residue

Soil CO_2 Efflux vs. REDD Credit

With 30% of logging intensive (low-impact logging):

T_2 = 23.5ºC + 1.5ºC (soil temperature increase)

C = 38 tC/ha (harvest residue: AG=21, BG=17)

d = 13% (decomposition ratio of CWD)

\$ = 15 US\$/tC

Total carbon lost at the first year after the logging:

$$\sum \$ = (3.32 + 5.70) \times 15 = 135 US\$ / ha$$

REDD credit = 247 - 135 = 112 US$ / ha

Conclusions

- Tropical forests have large biomass C pool, but with large uncertainties of C sink/source that estimated by using different approaches.

- Effects of deforestation and LULUC:
  - **Tropical forest soil degradation, and**
  - **Its long-term feedback on forest carbon stock**

  should be unable to disregard.

Thanks!