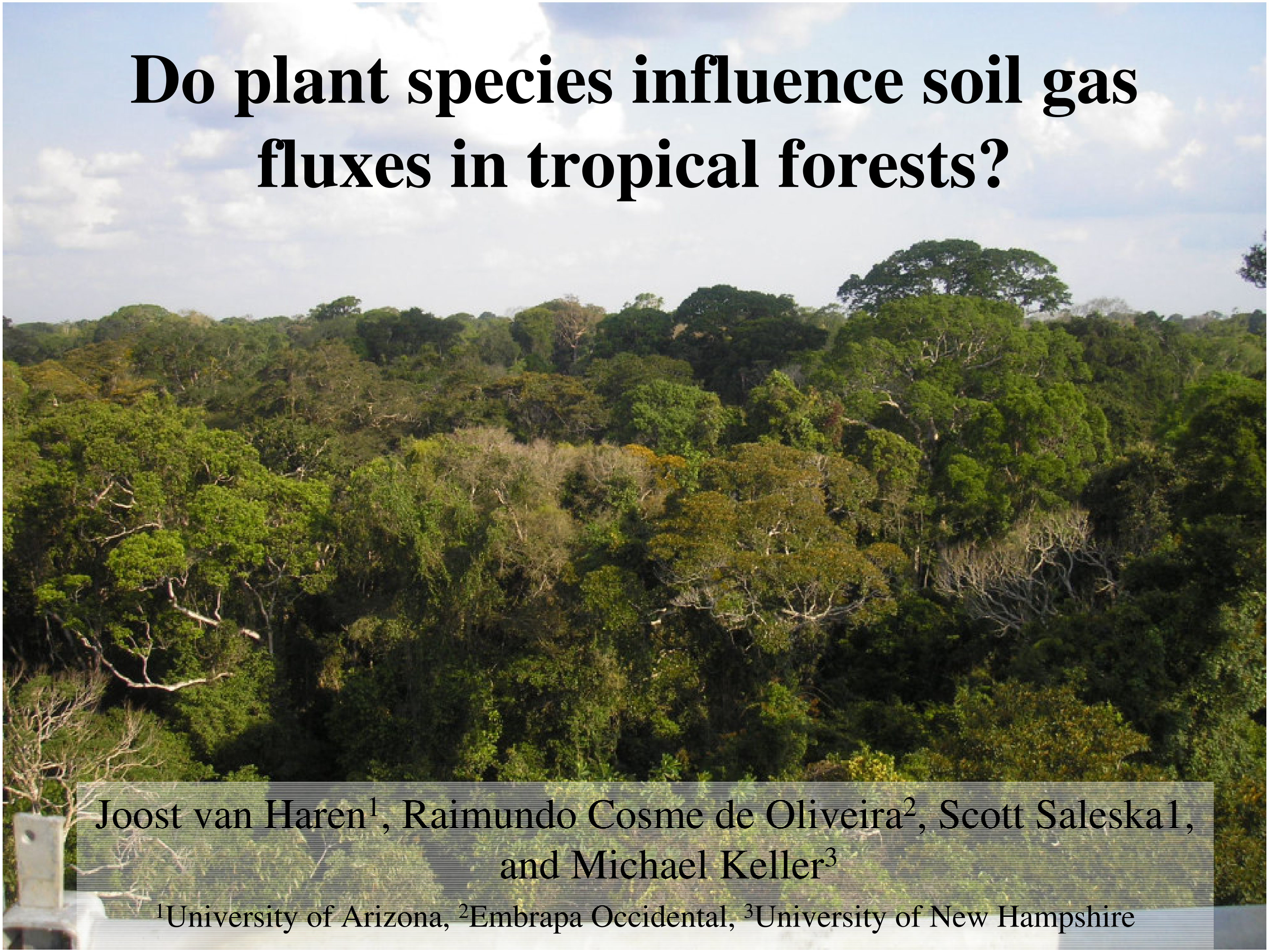
Do plant species influence soil gas fluxes in tropical forests?



Joost van Haren[1], Raimundo Cosme de Oliveira[2], Scott Saleska1, and Michael Keller[3]

[1]University of Arizona, [2]Embrapa Occidental, [3]University of New Hampshire

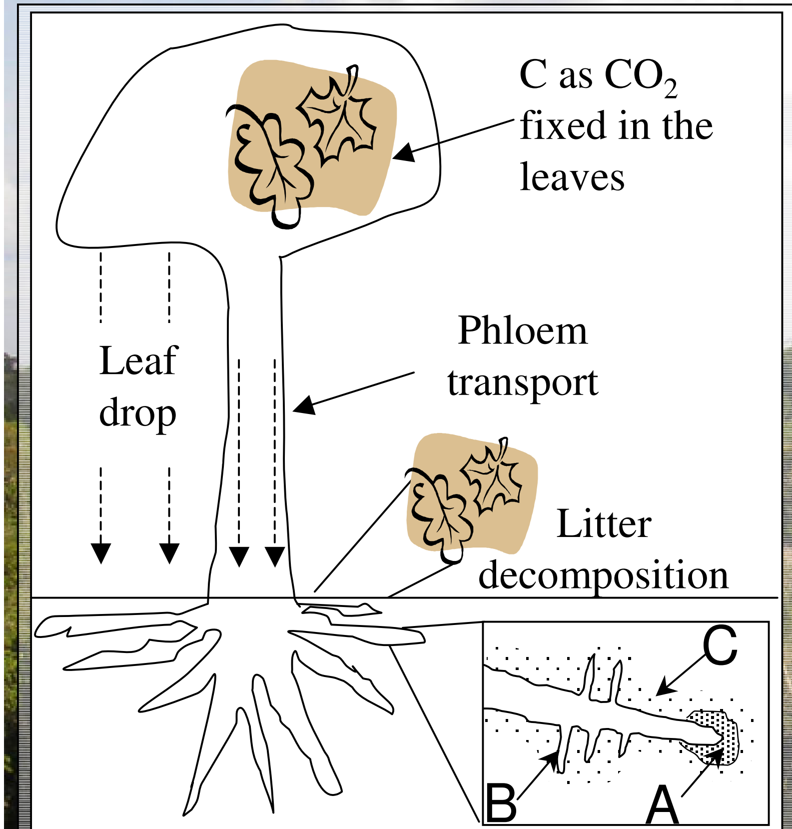
Potential implications

Species composition of forests is sensitive to changes in precipitation and nutrient inputs

Species associated fluxes could help assess spatial variability of soil gas fluxes

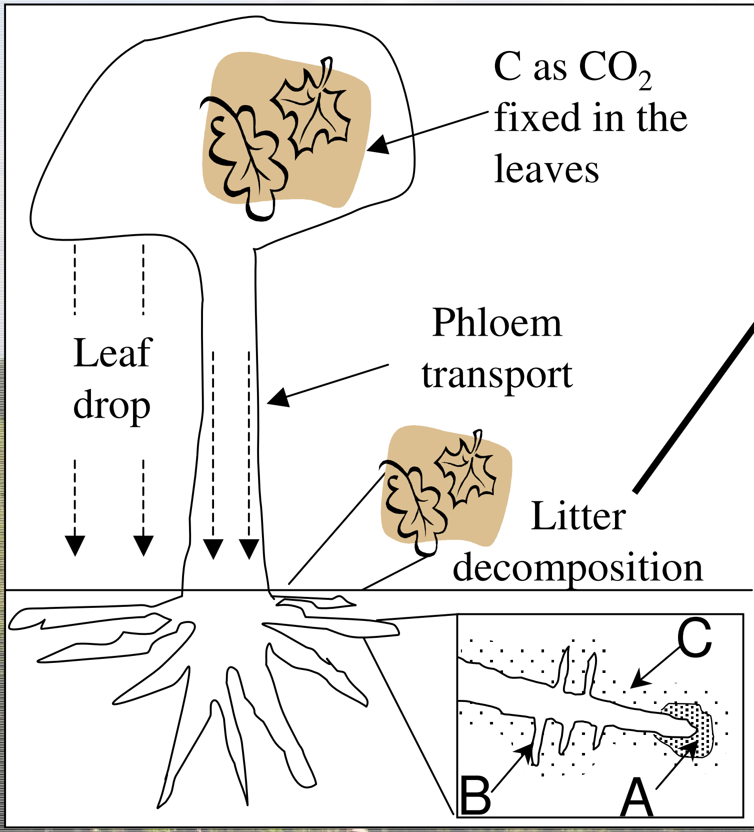
Species dependent effects on soil gas fluxes could lead to a better understanding of plant-soil interactions

Trees and soil CO_2 and N_2O production



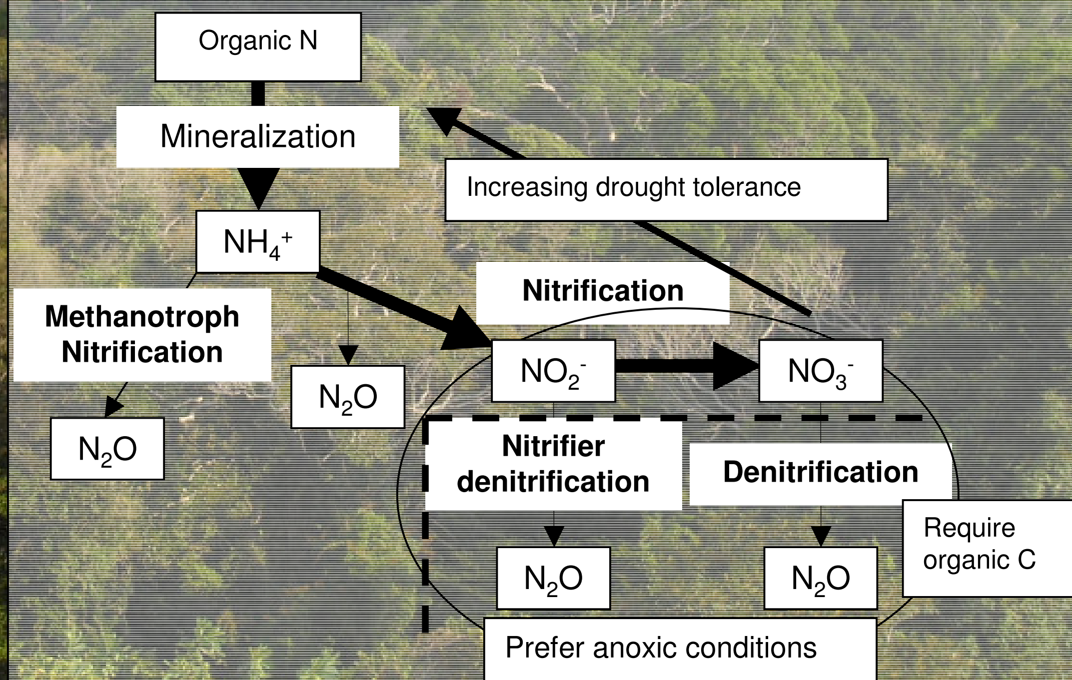
- CO_2 Production
  - Root respiration (B)
  - Microbial respiration
    - Border cell activity (A)
    - Rhizospheric (C)
    - Bulk soil
  - Fungal respiration

Soil CO_2 and N_2O production processes



- CO_2 Production
  - Root respiration (B)
  - Microbial respiration
    - Border cell activity (A)
    - Rhizospheric (C)
    - Bulk soil
  - Fungal respiration

- N_2O Production

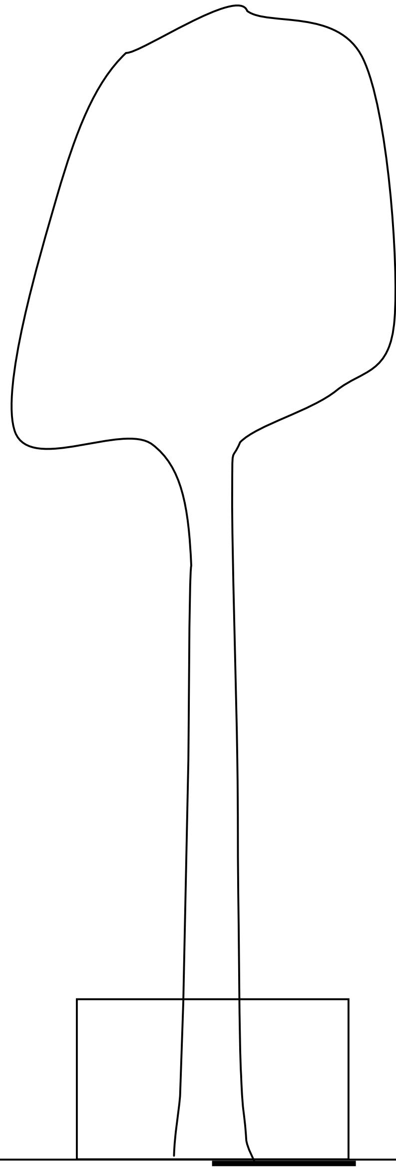


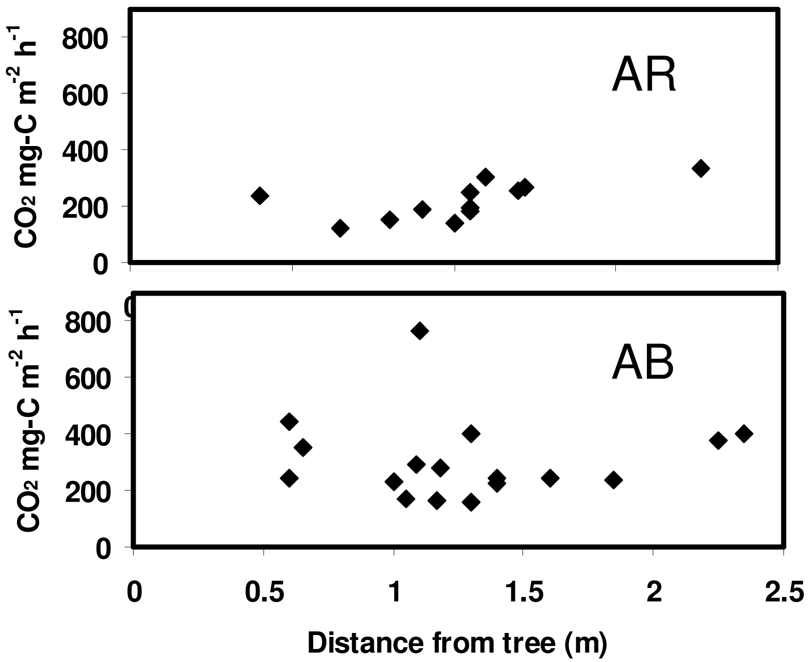
- N_2O Consumption
  - Denitrification N_2O to N_2

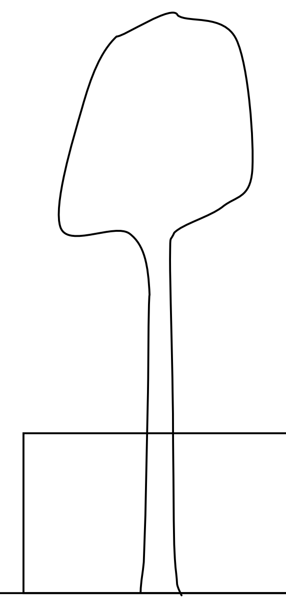
Field flux measurements

Measure fluxes close to (<3m)
and far (>10m) large trees

Wet season only





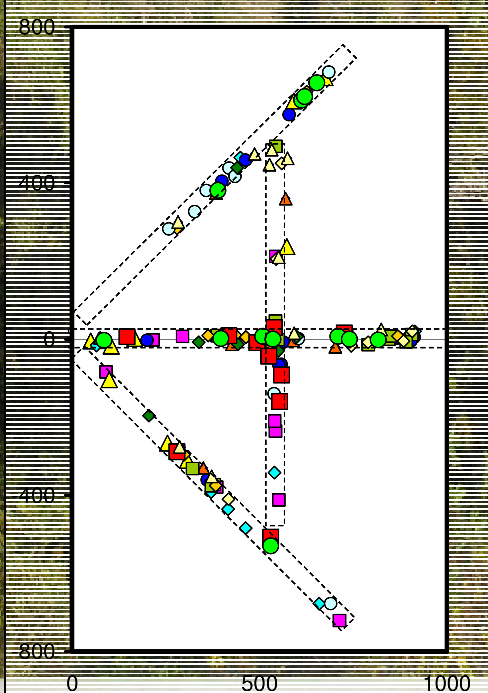


Field measurements

- Select large (>35cm DBH) individuals randomly or whole population

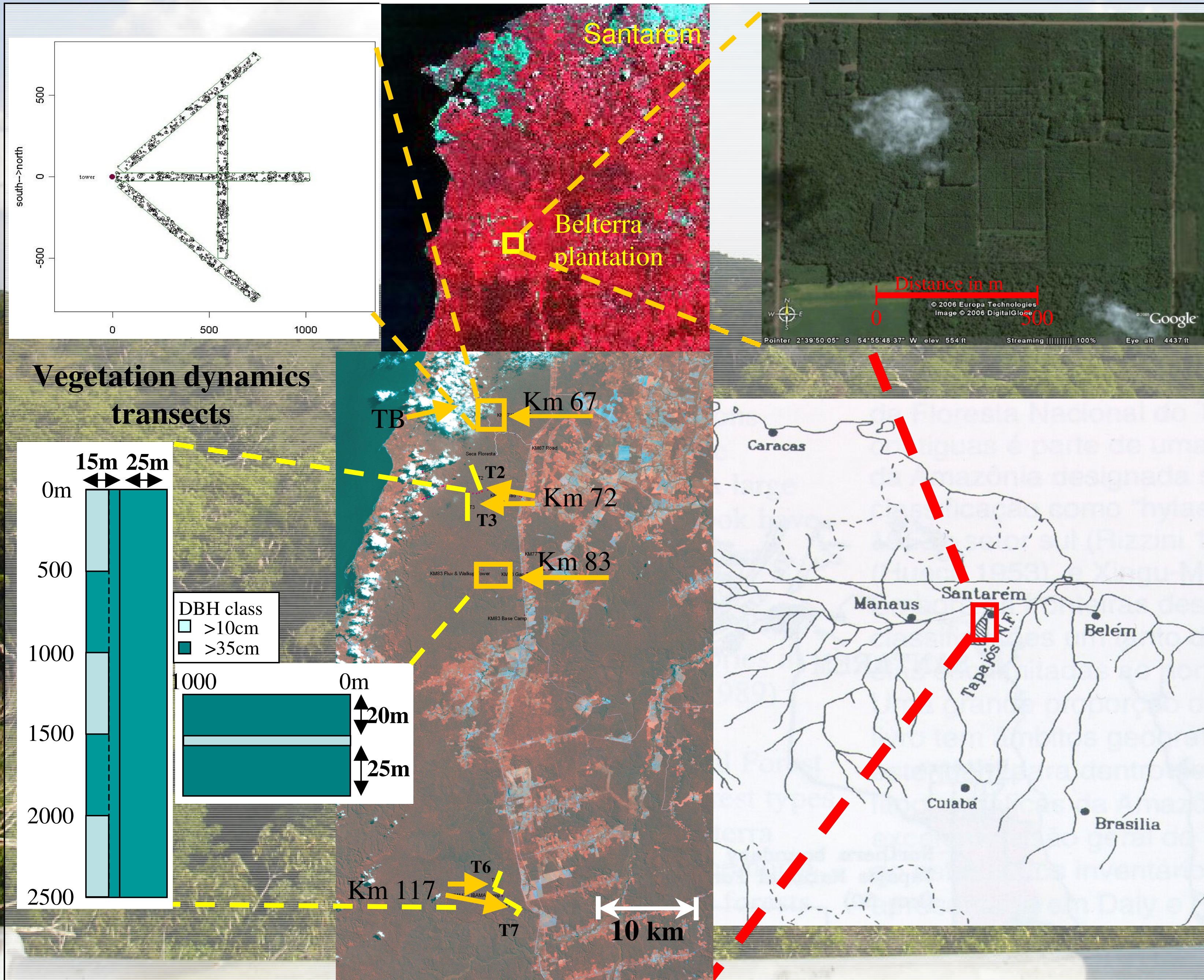
- Gas flux
- air T, soil T, and pH
- 0-3 cm BD and %WFPS
- DBH tree, DBH and species of all trees > 1 cm within a 3 m radius

KM 67 flux locations

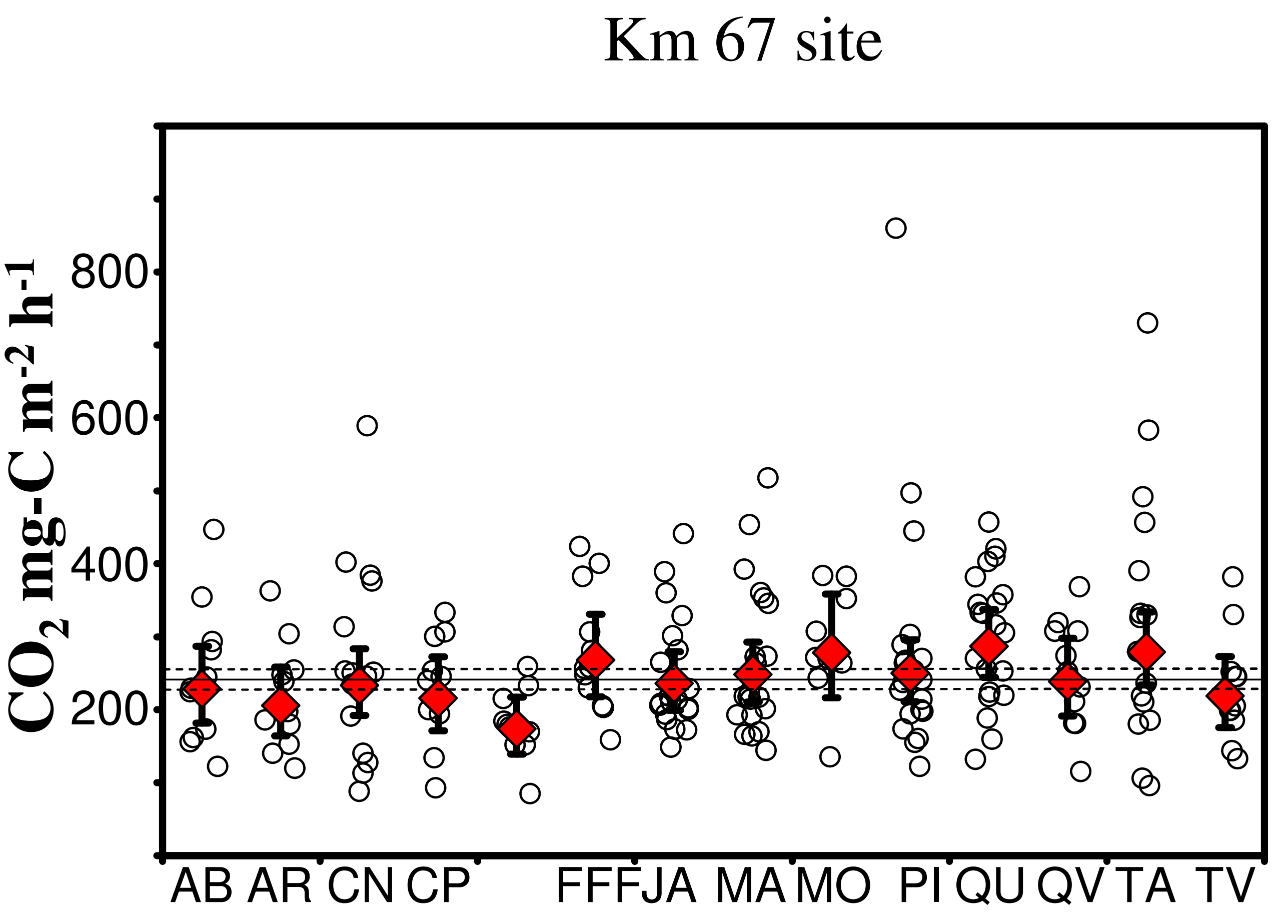


Tree species **(C = canopy, E = emergent, P = pioneer)**	
Caryocar villosum (Piquiá, E)	PI
Bertholletia excelsa (Castanha de para, E)	CP
Chamaecrista xinguensis (Coração de negro, C)	CN
Couratari stellata (Tauarí, E)	TA
Erisma uncinatum (Quarubarana, E)	QU
Lecythis lurida (Jarana, E)	JA
Manilkara huberi (Maçaranduba, E)	MA
Carapa guianensis (Andiroba, C)	AN
Pseudopiptadenia psilostachya (Fava folha fina, E)	FFF
Sclerolobium chrysophyllum (Tachi vermelho, C)	TV
Pouteria reticulata (Abiu, C)	AB
Vochysia maxima (Quaruba verdadeira, E)	QV
Astronium lecointei (Aroeira, C)	AR
Scheffleria morototoni (Morototo, P)	CO

Site Locations



Are CO_2 fluxes different by species?

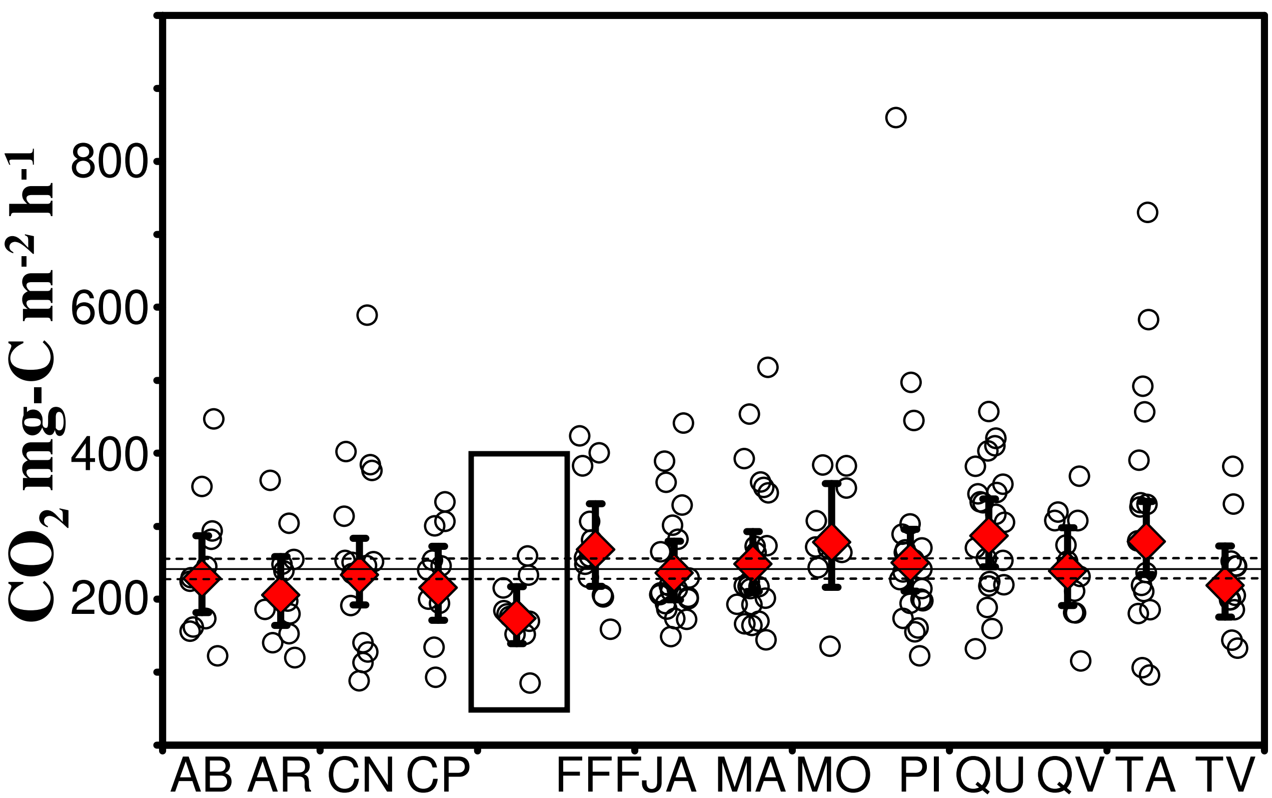


NO

Are CO_2 fluxes different by species?

Km 67 site

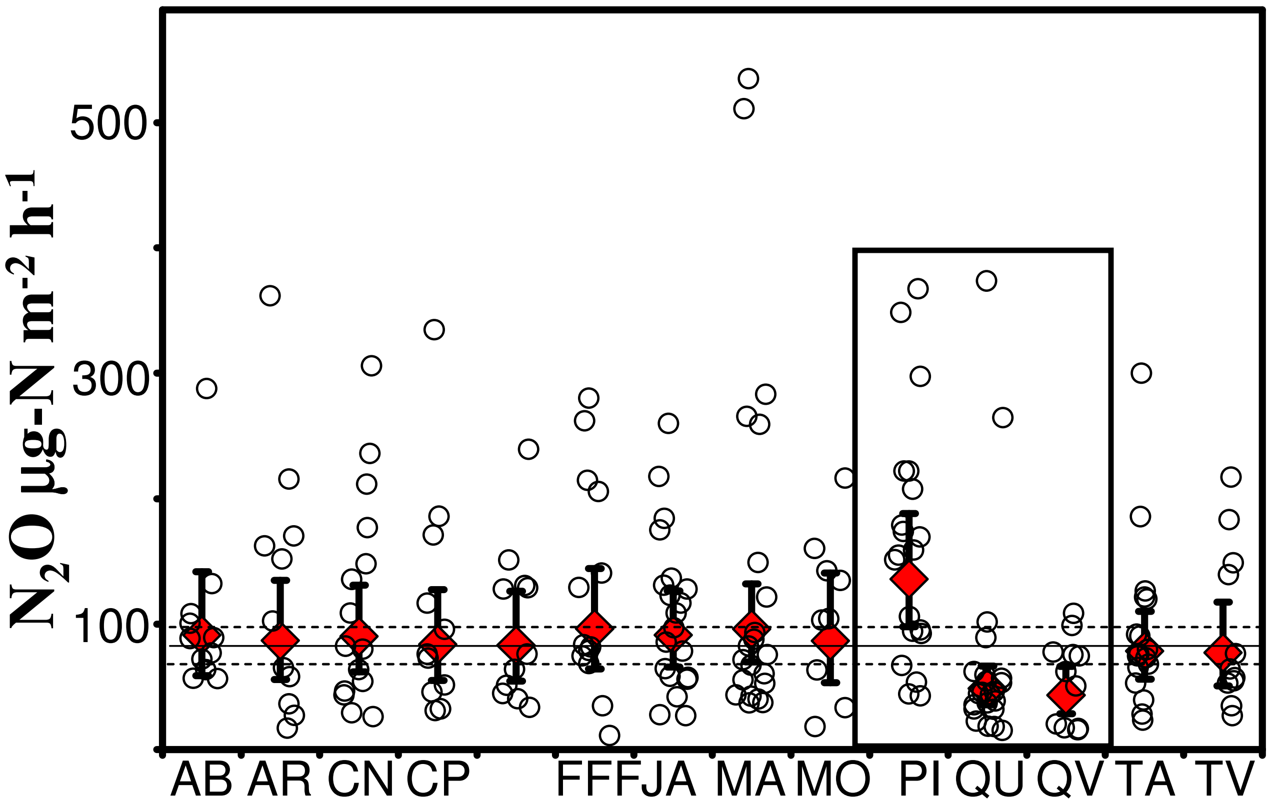
NO



Fluxes >10m from large trees 30% smaller than overall mean

Are N_2O fluxes different by species?

Km 67 site



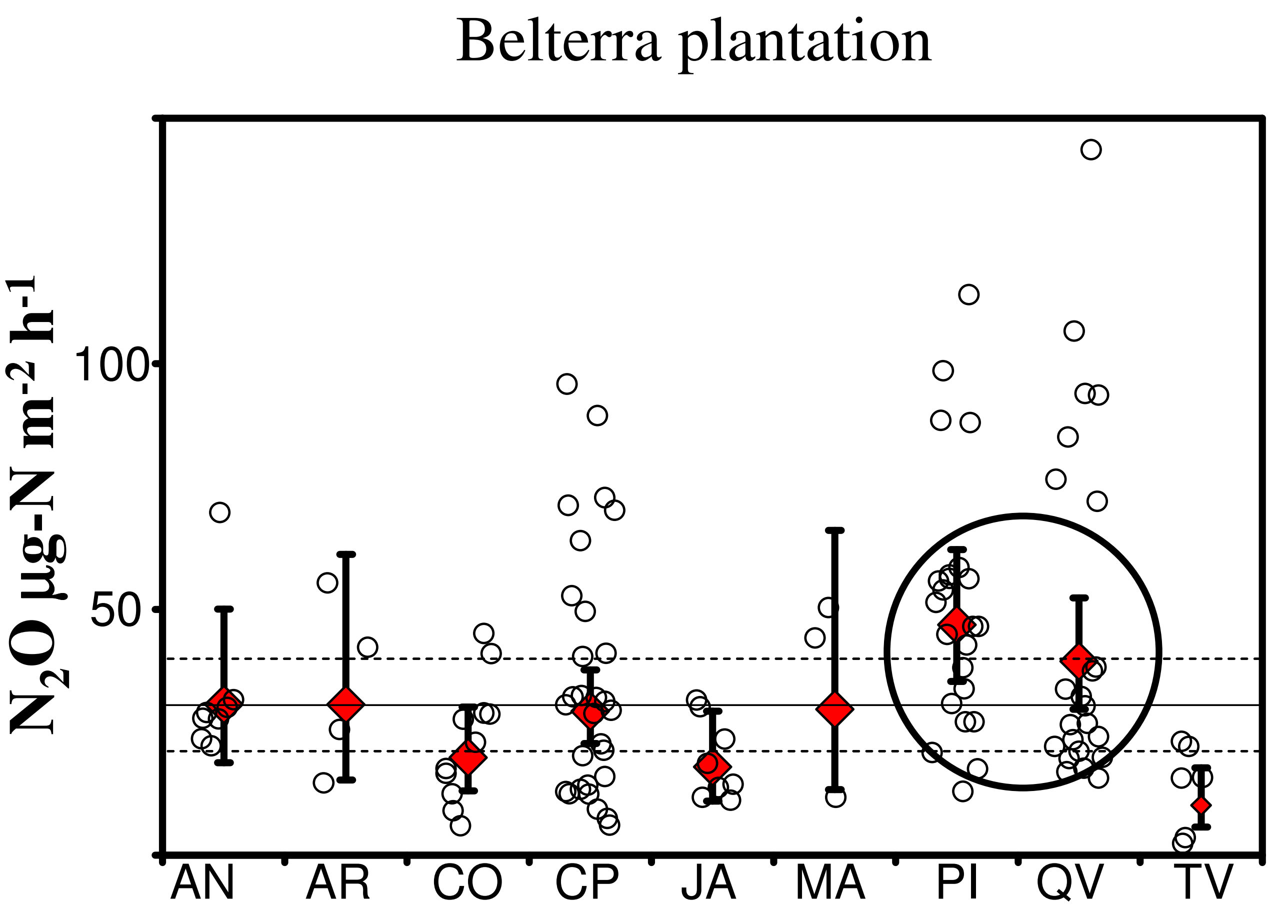
YES

N_2O flux close to PI

- ~ 2x overall mean
- ~4x QU and QV

Pattern consistent for 2006 and 2007

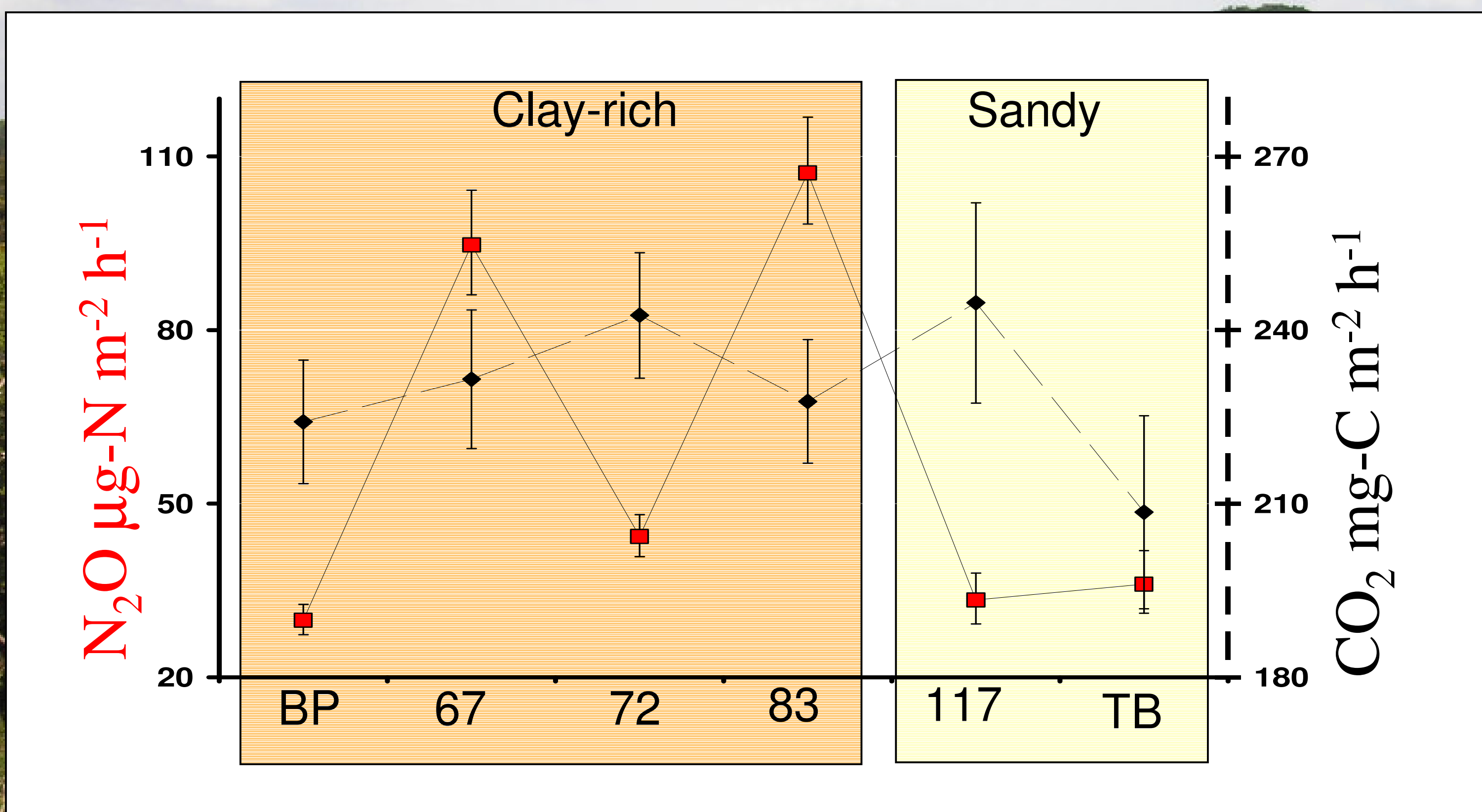
Species differences on plantation



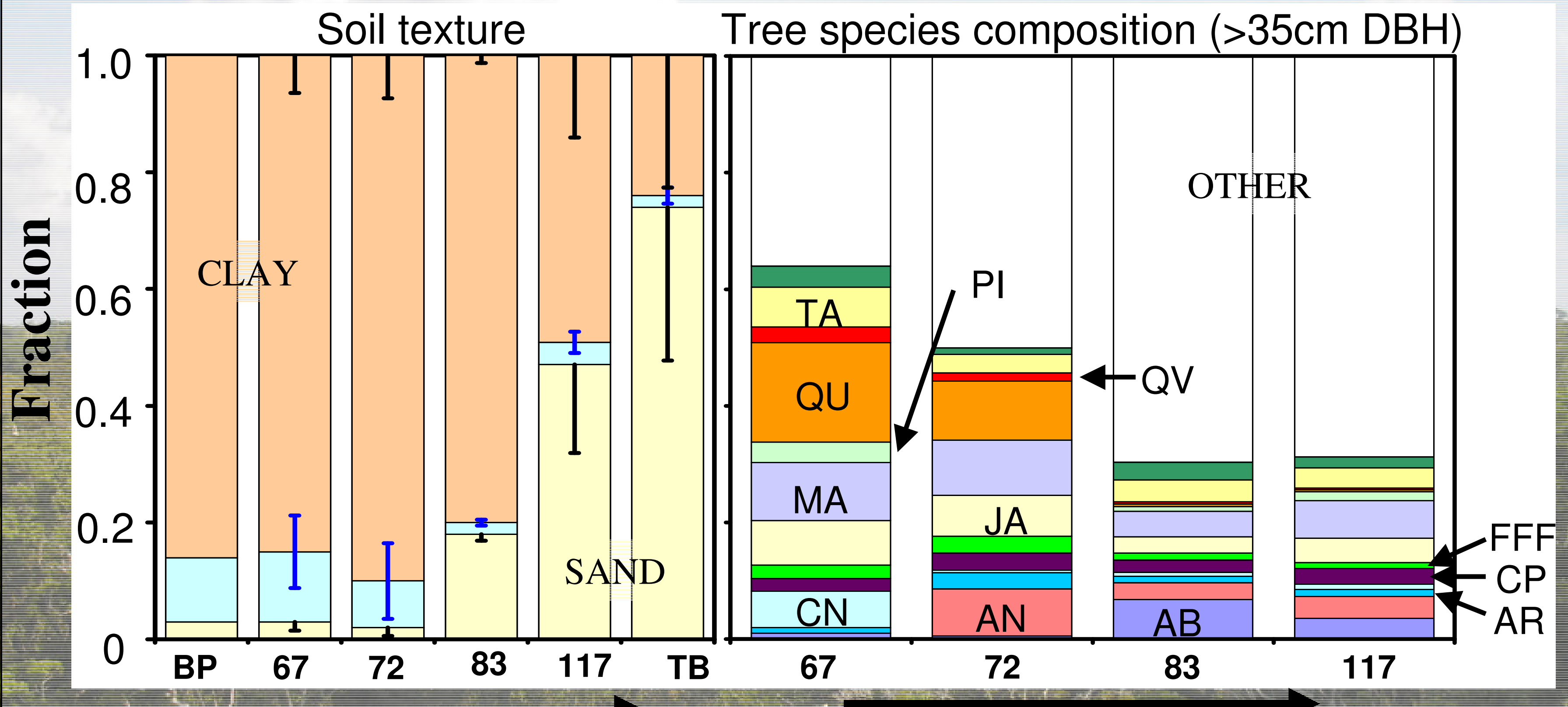
YES

Not consistent with forest data

Site to site variability



Site characteristics

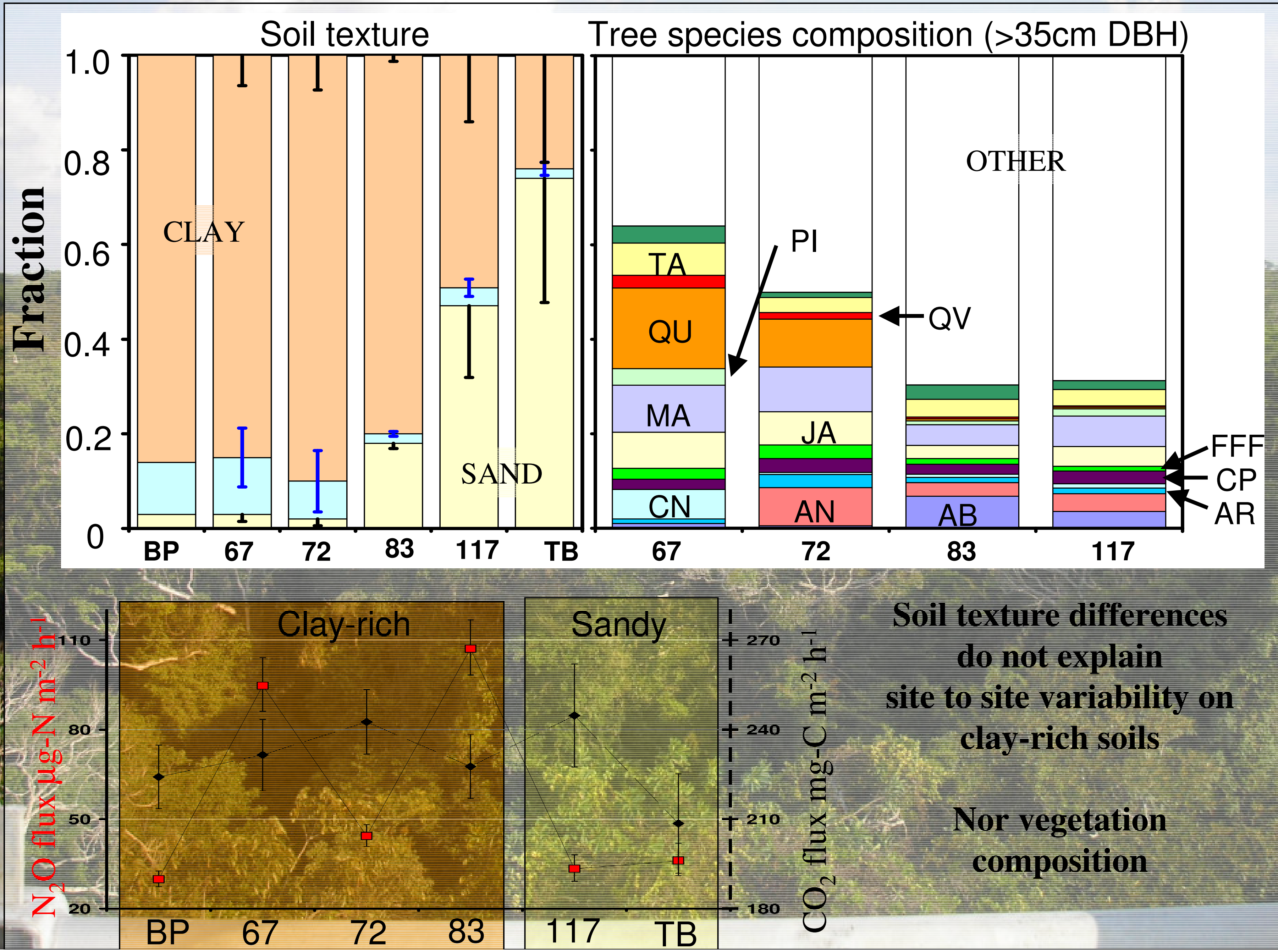


Increasing sand fraction

Increasing vegetation diversity

Data from:
km 72 and 117: de Camargo & Hutyra
BP: da Silva et al. 2001
km 83: Silver et al. 2000
km 67 and TB: Williams et al. 2002

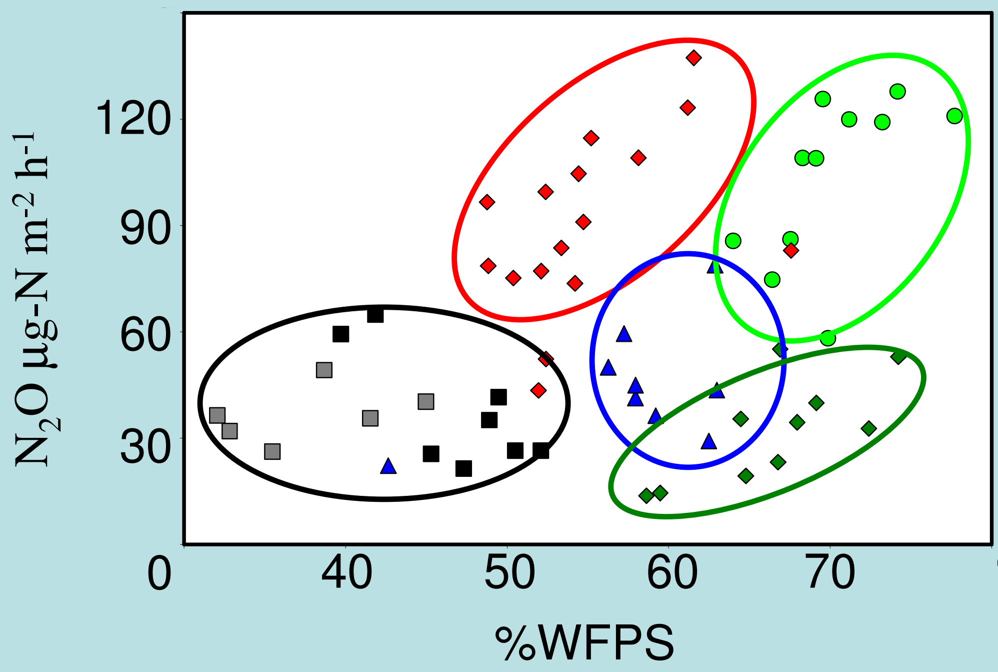
Site characteristics



Soil texture differences do not explain site to site variability on clay-rich soils

Nor vegetation composition

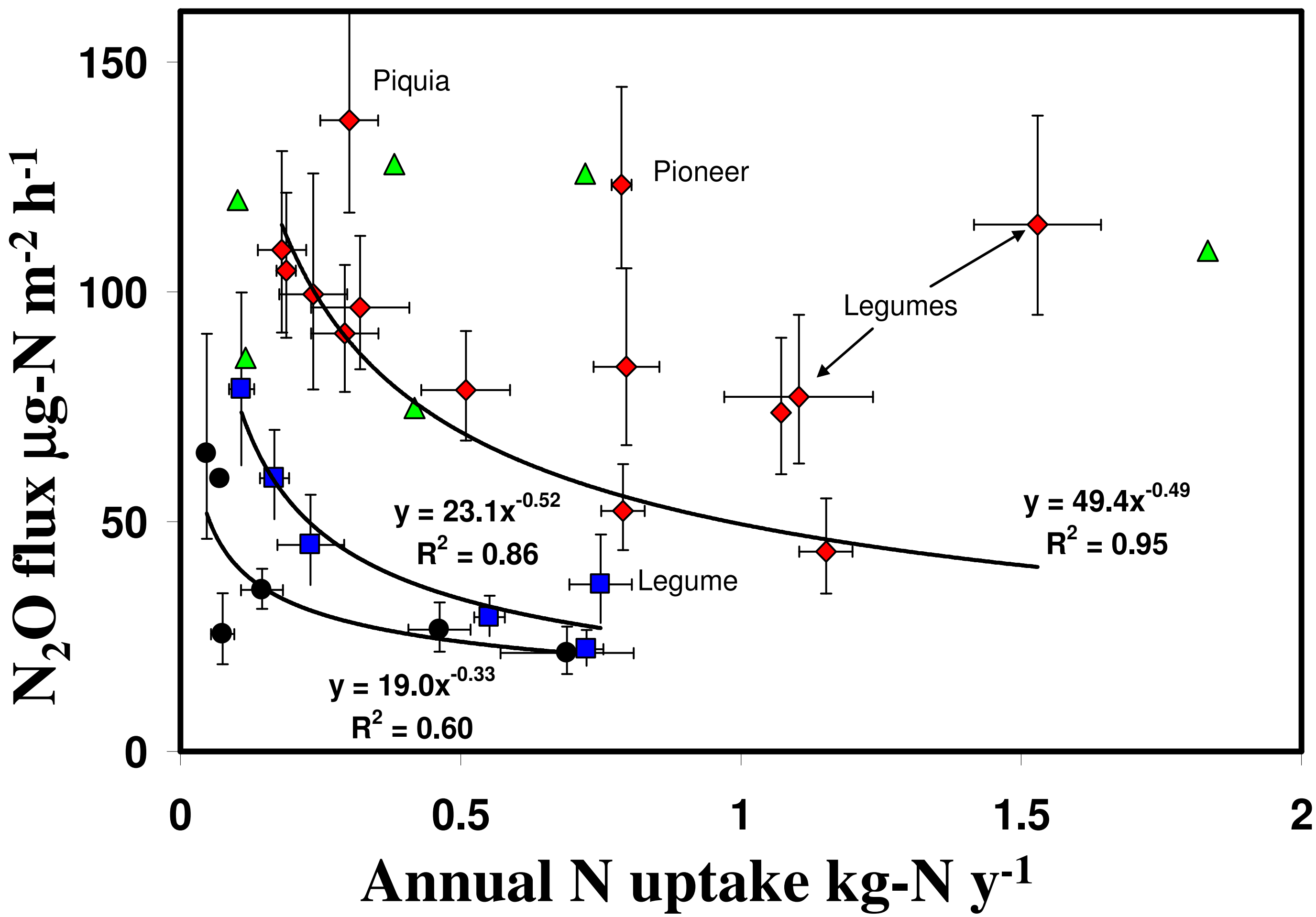
Can water content explain the difference?



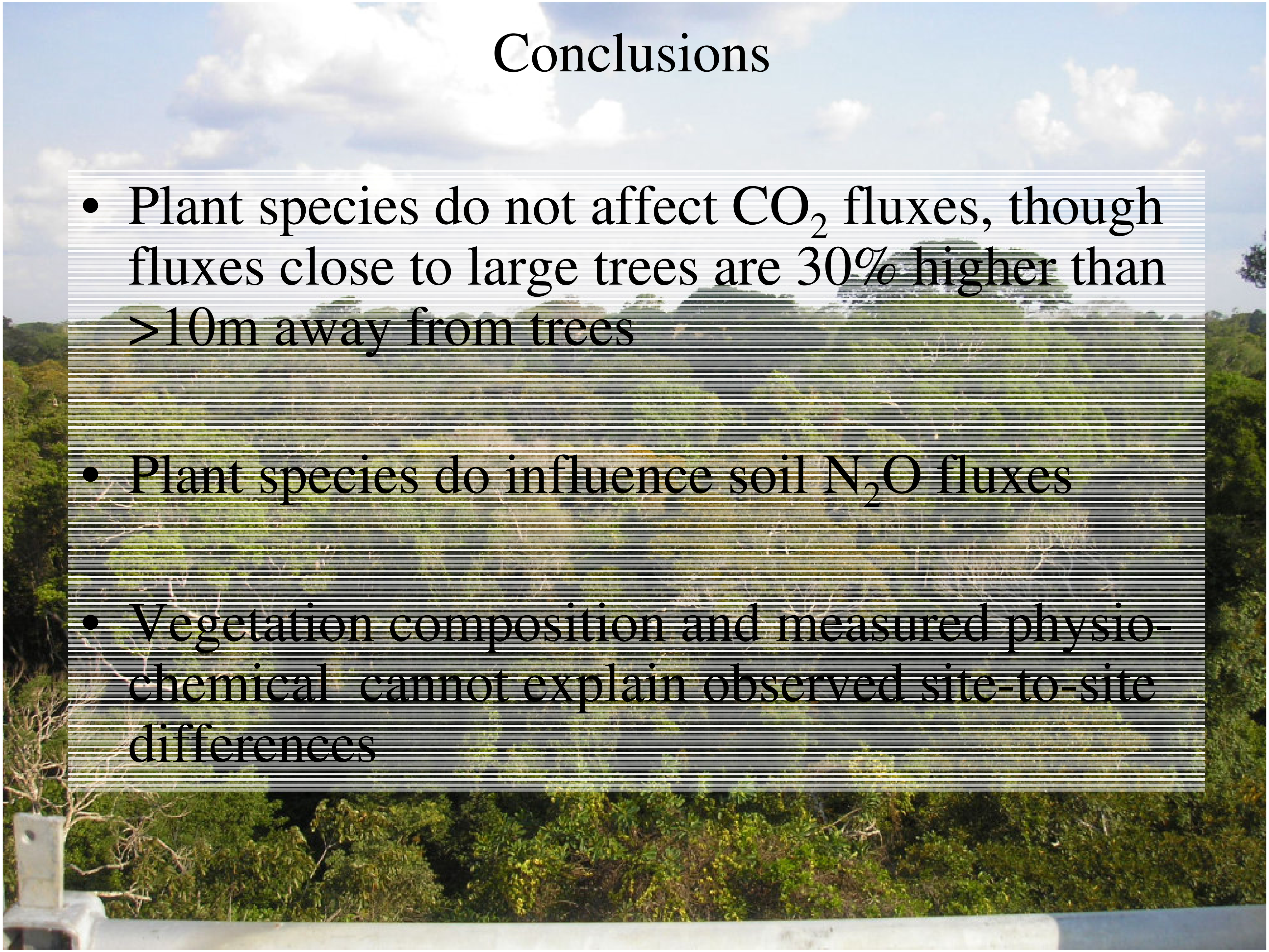
%WFPS cannot explain the difference between km 67 and 72.

Red: km 67
Blue: km 72
Light green: km 83
Dark green: BP
Black: km 117
Grey: TB

N_2O flux related to annual tree N uptake* at km 67, 72, 83, and 117.



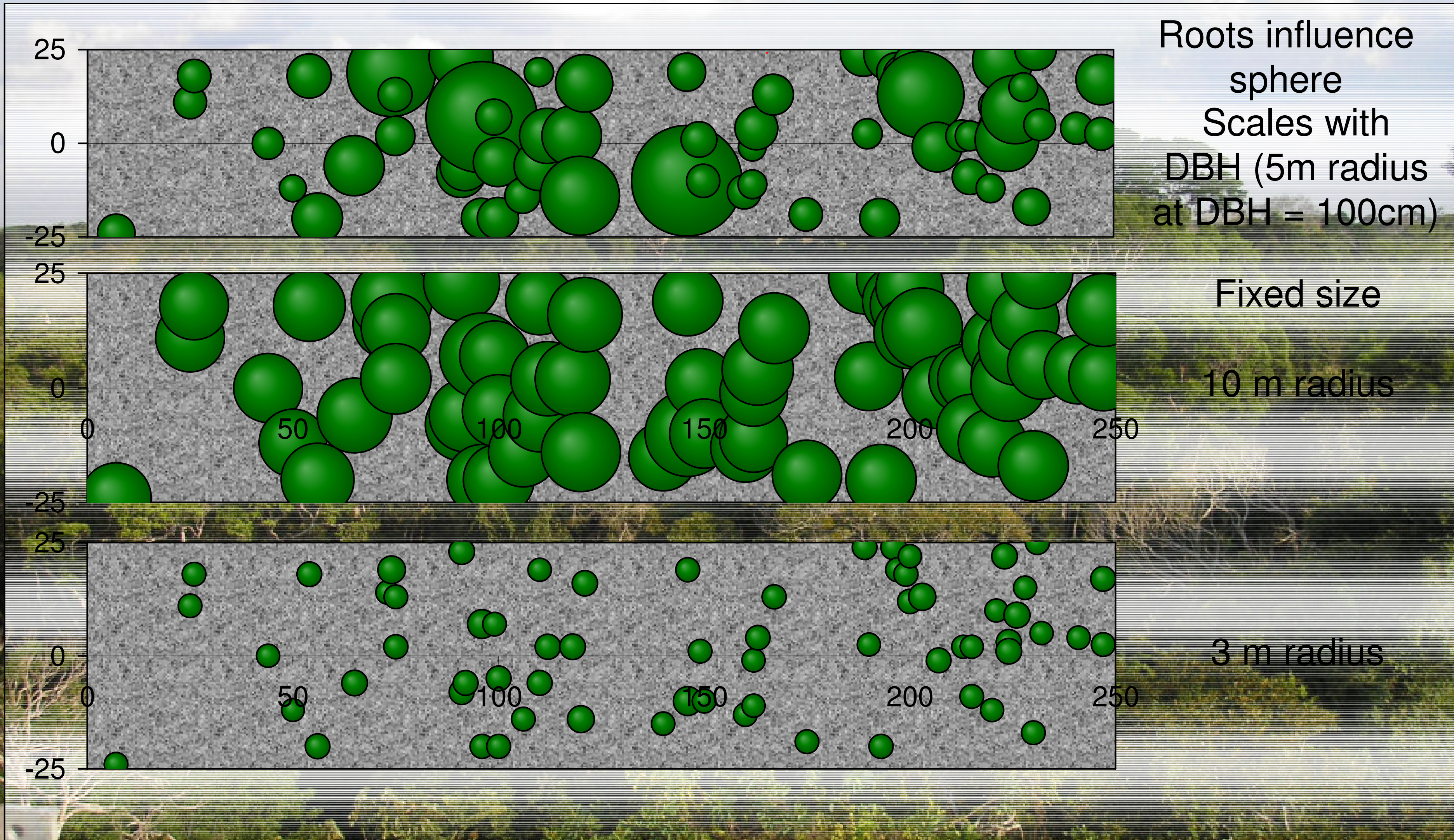
* Calculated from mean growth rate (repeated DBH measurements and, at km 67, dendrometry bands), Amazon tree allometry (Chambers et al. 2001) and foliar N content (Ehleringer et al. Bejaflor database).



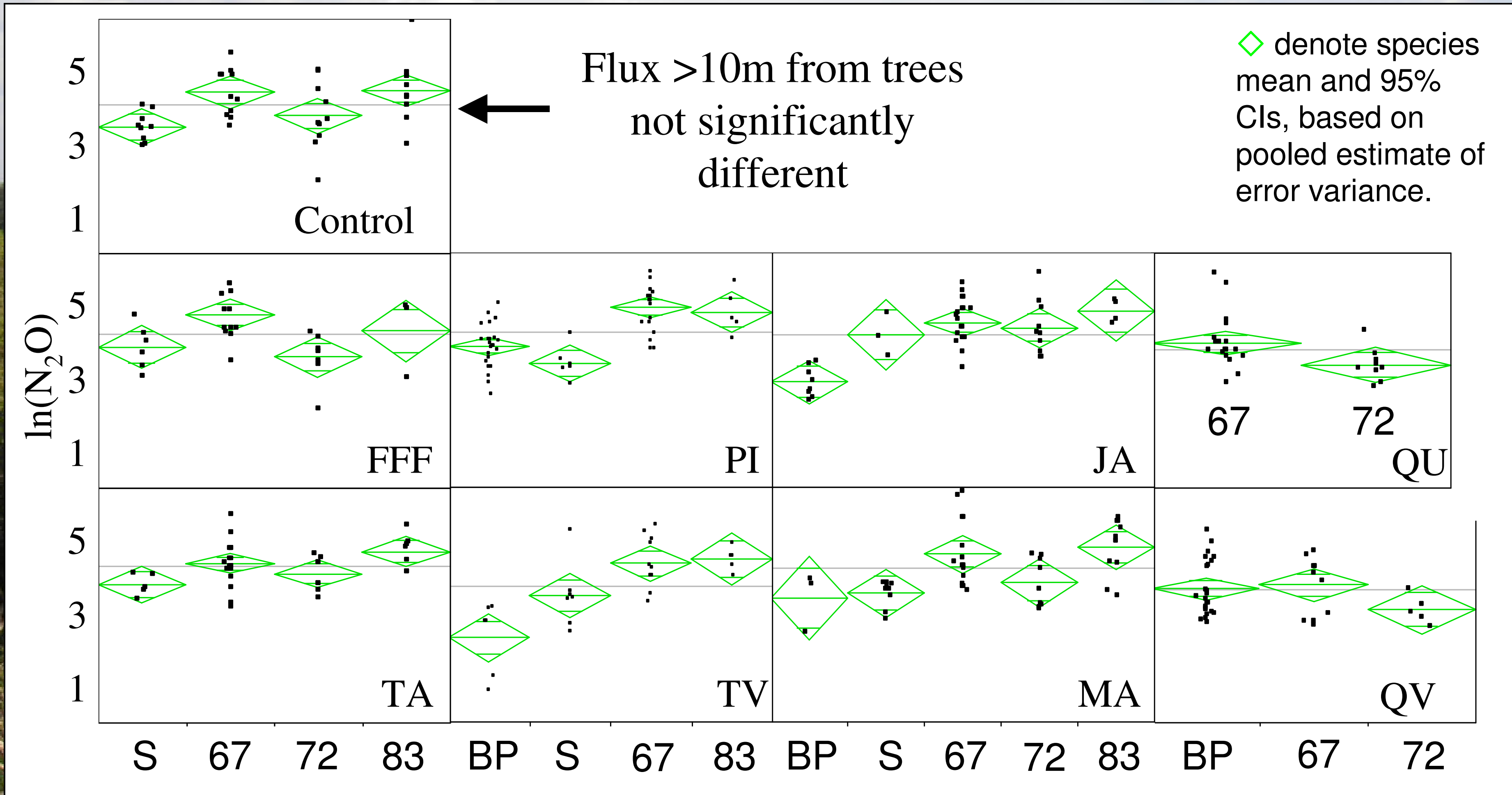
Conclusions

- Plant species do not affect CO_2 fluxes, though fluxes close to large trees are 30% higher than >10m away from trees
- Plant species do influence soil N_2O fluxes
- Vegetation composition and measured physio-chemical cannot explain observed site-to-site differences

From tree fluxes to forest flux

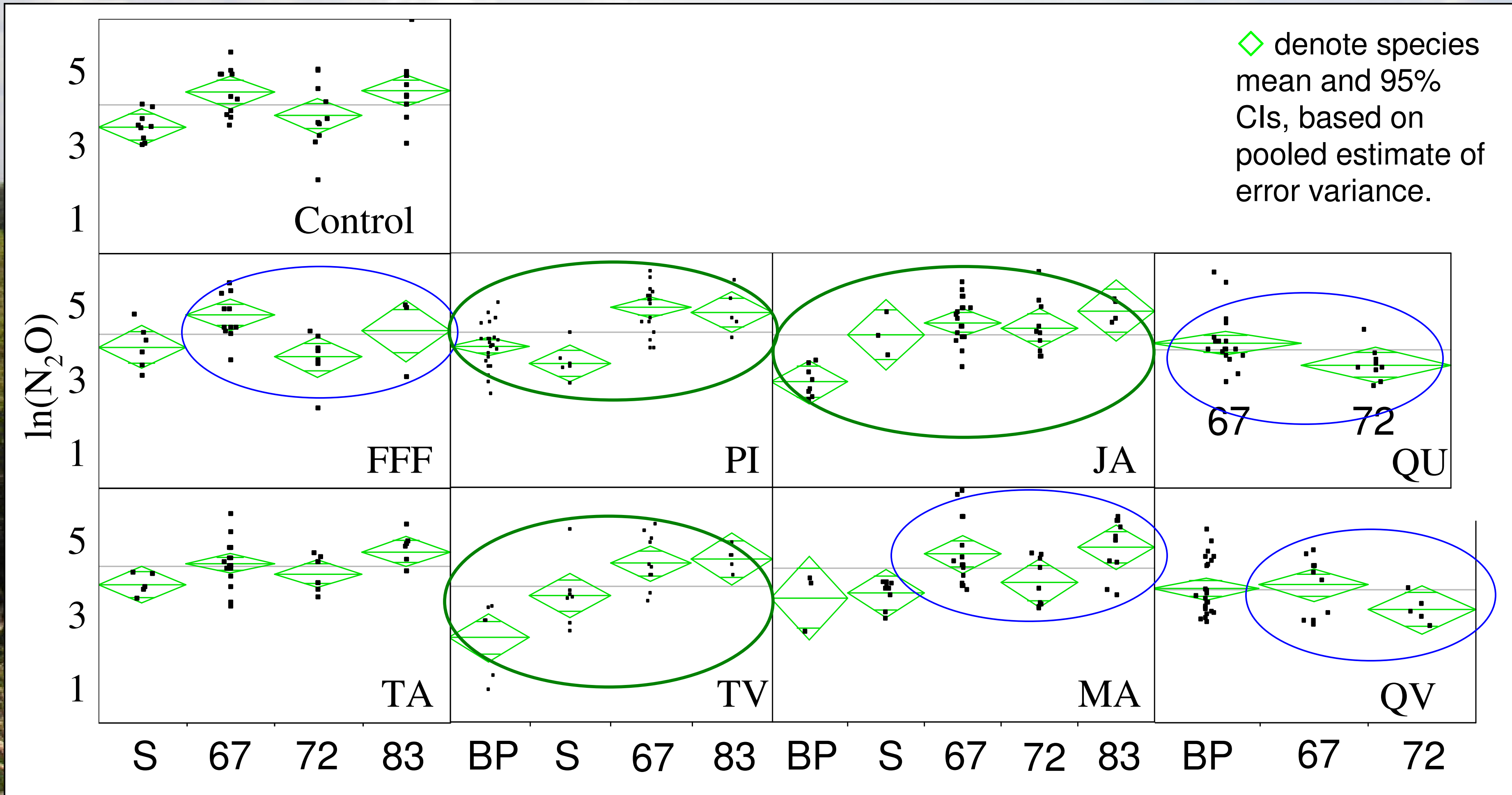


Do species fluxes vary by site?



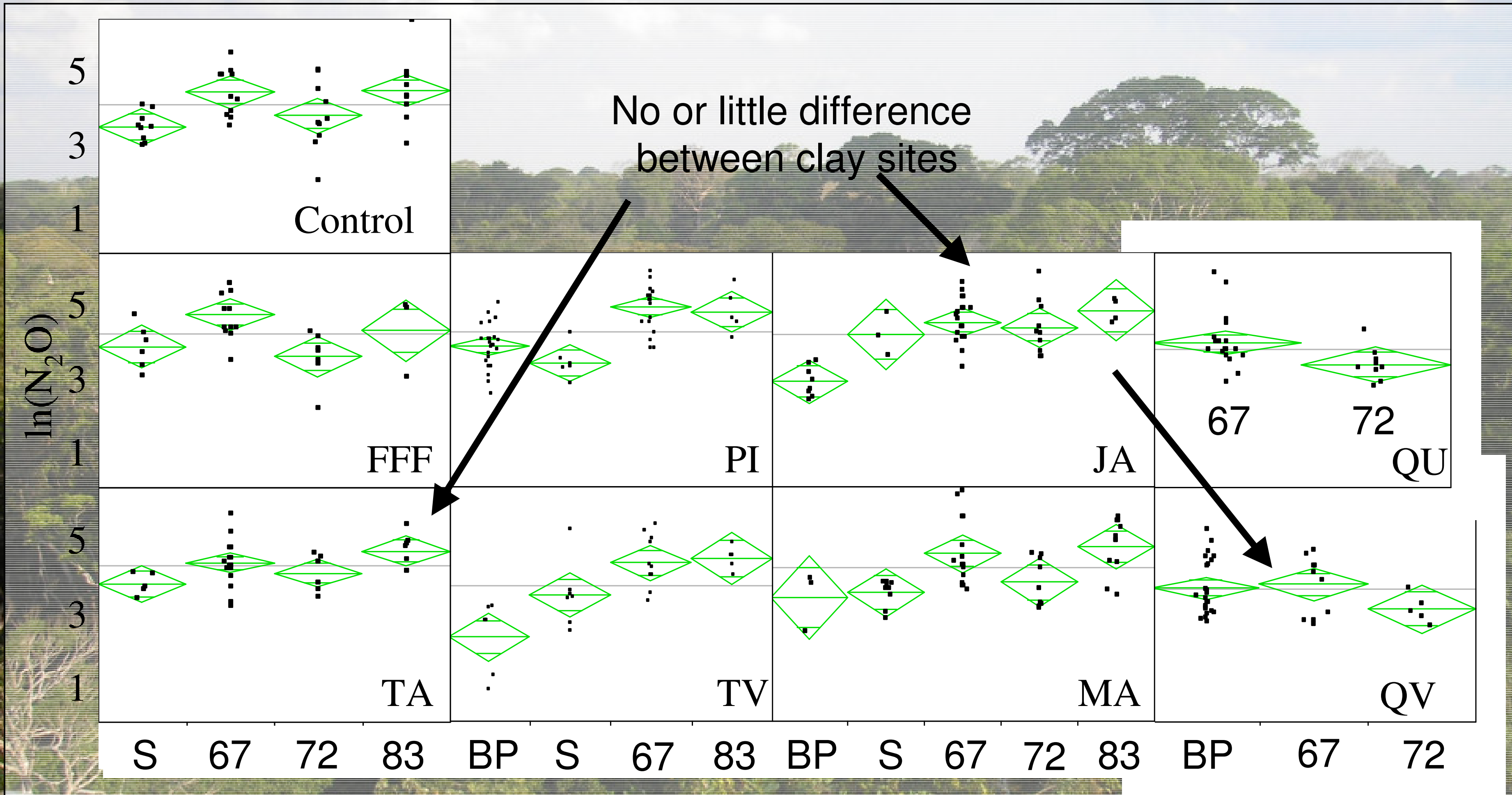
FFF,

Do species fluxes vary by site?



FFF,

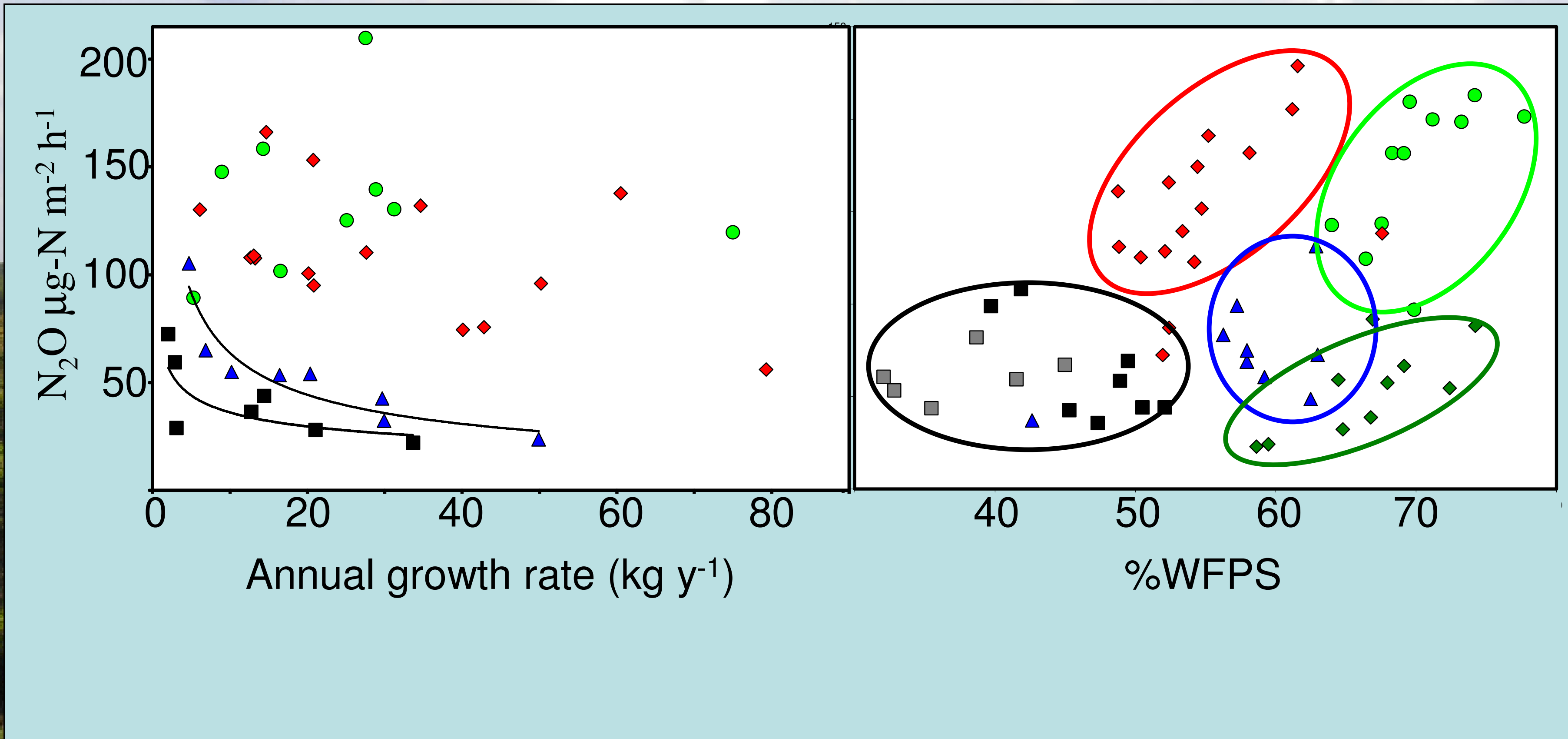
Species by site

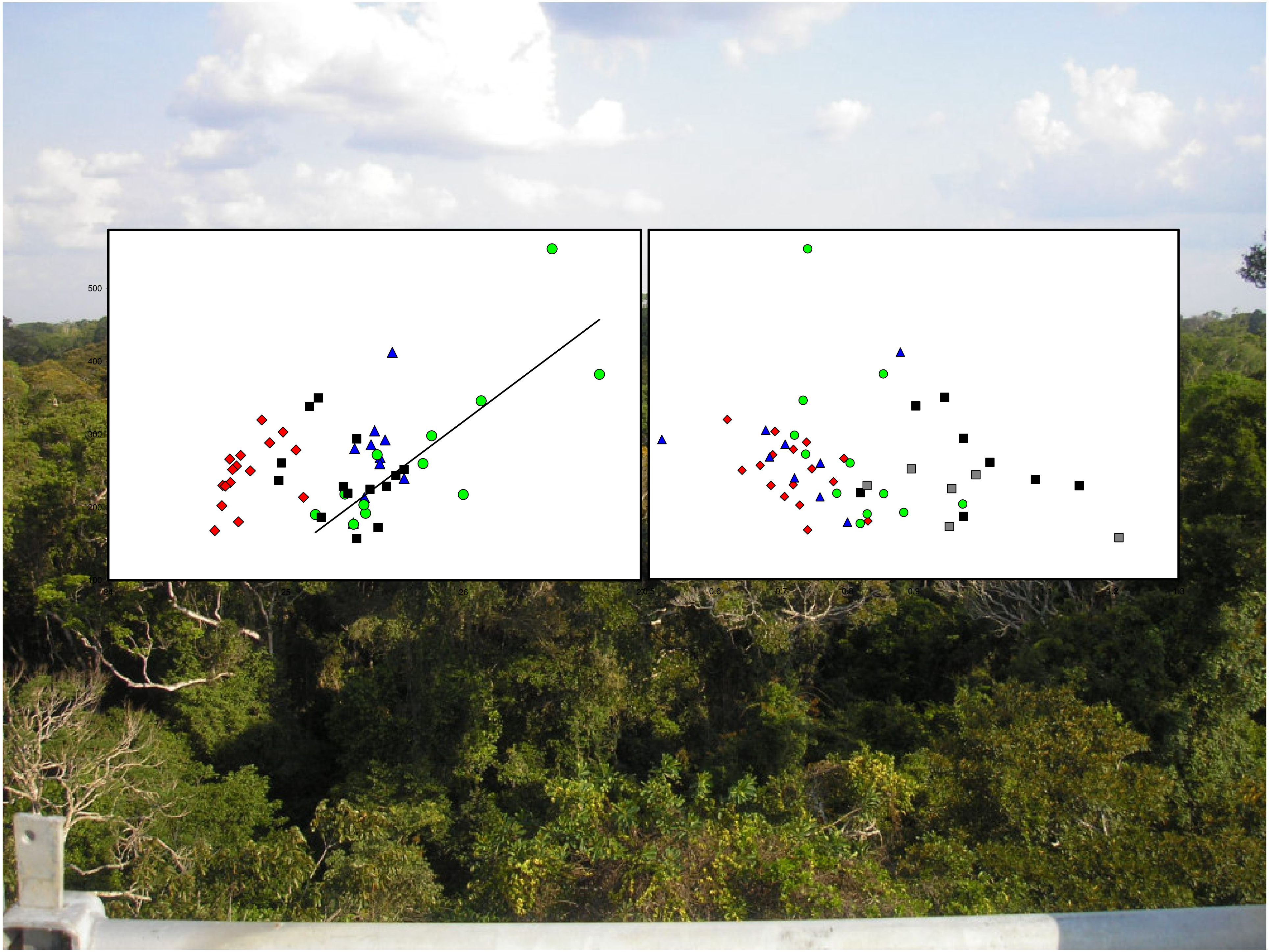


Future directions

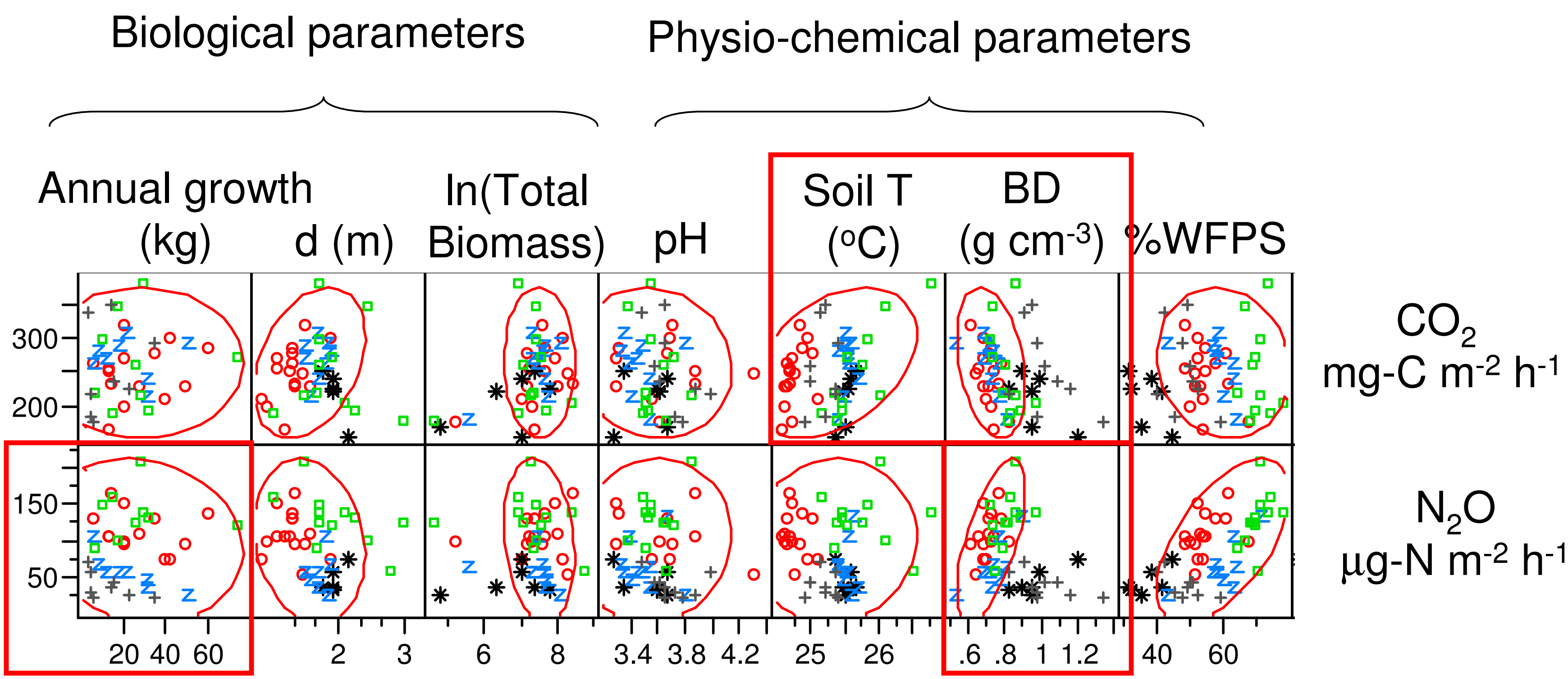
- Use the fluxes and species composition to calculate overall forest fluxes

Mean Species N_2O fluxes

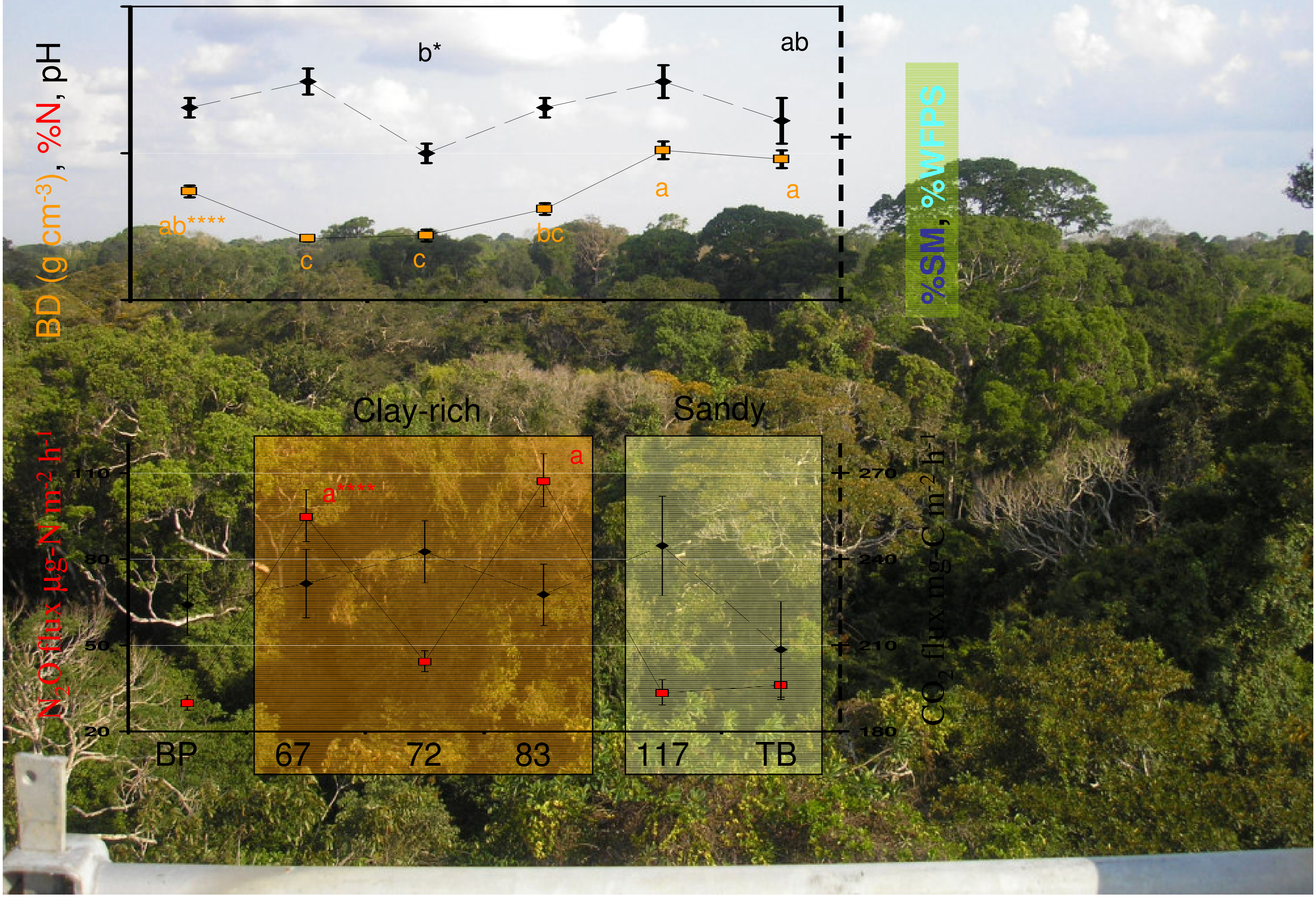



500
400
300
200
100
24
25
26
0.6
0.7
0.8
0.9
1.1
1.2
1.3

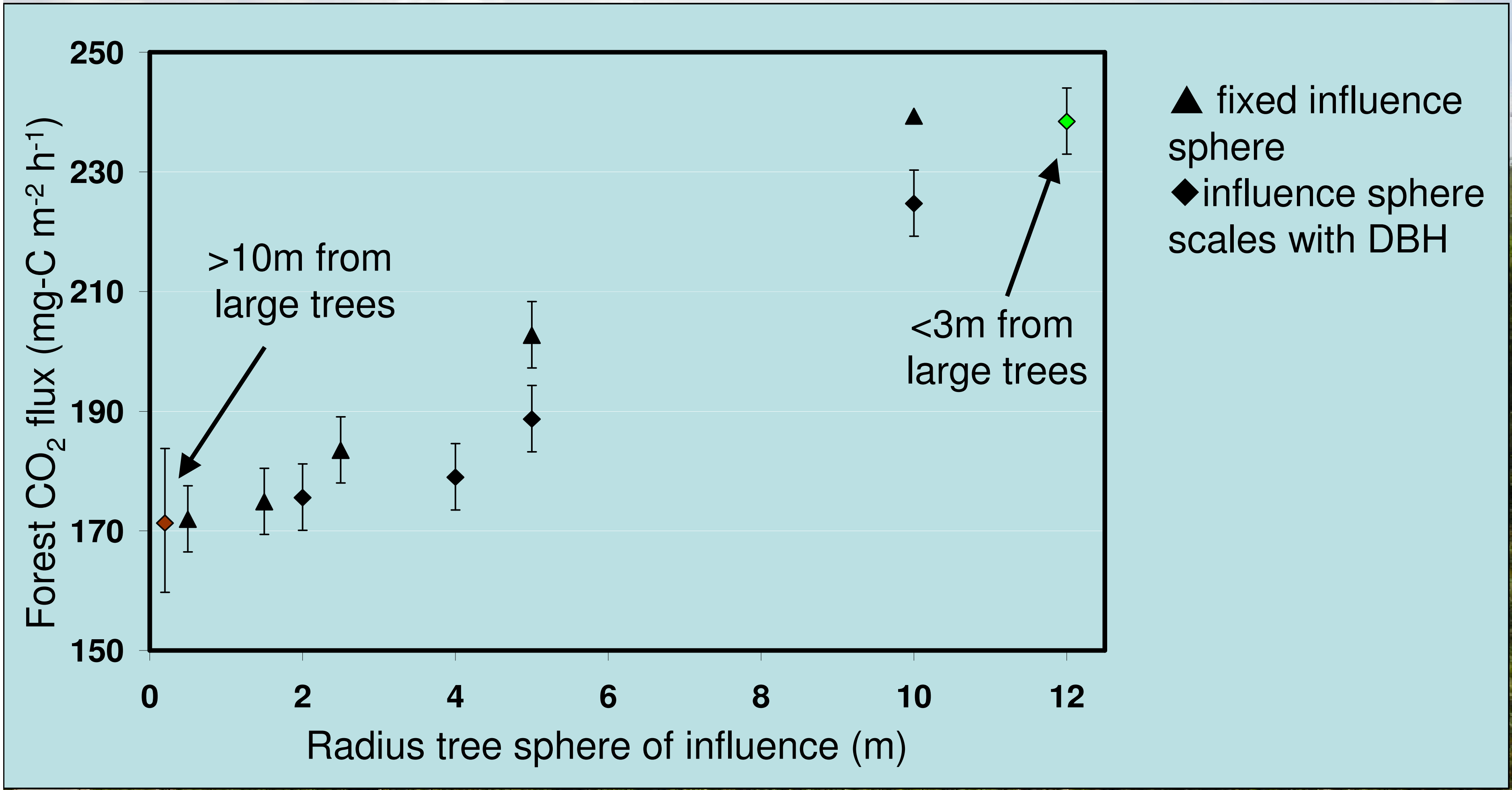
Potential factors influencing soil CO_2 and N_2O fluxes



Site to site variability

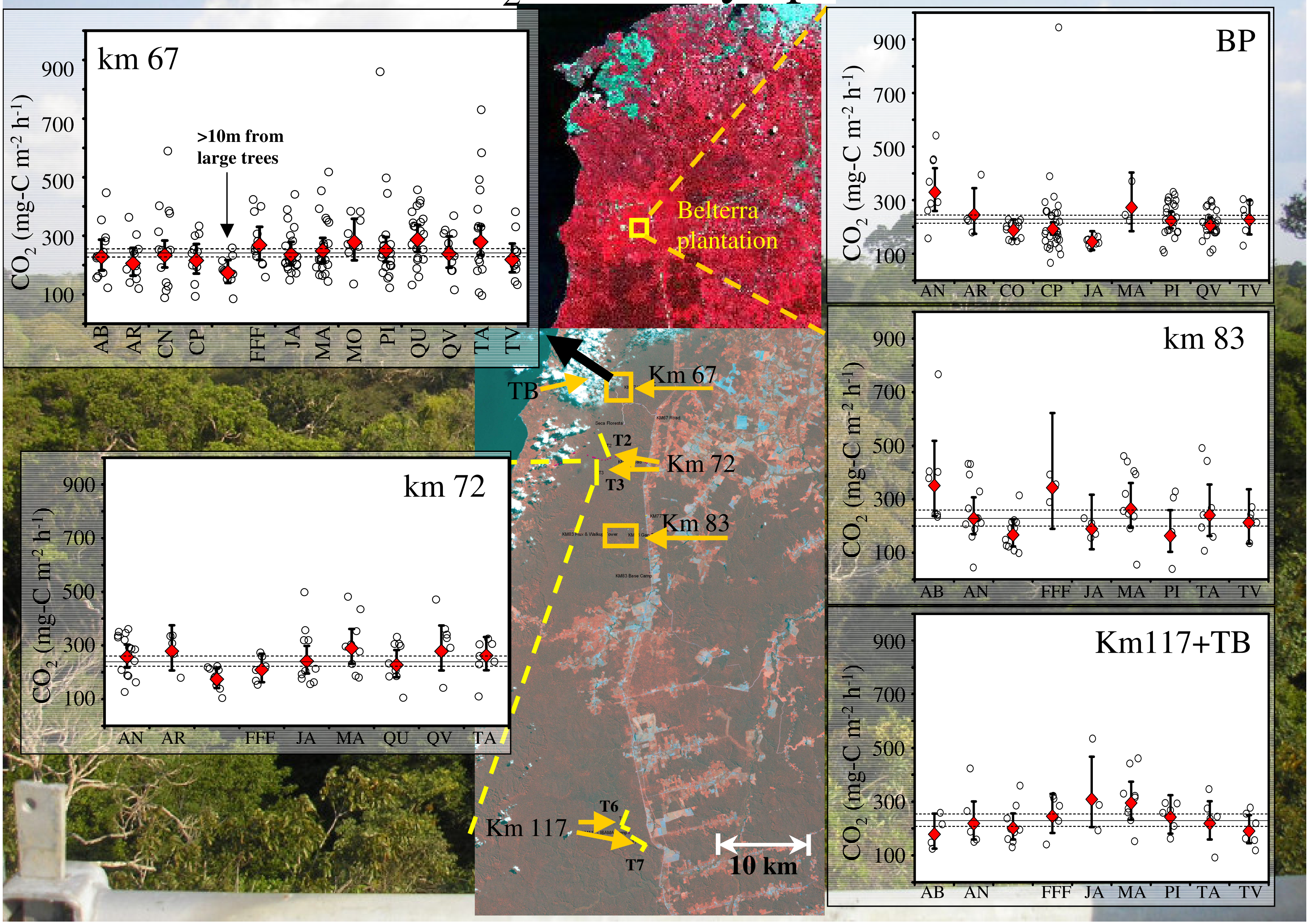


Tree influence sphere and forest flux

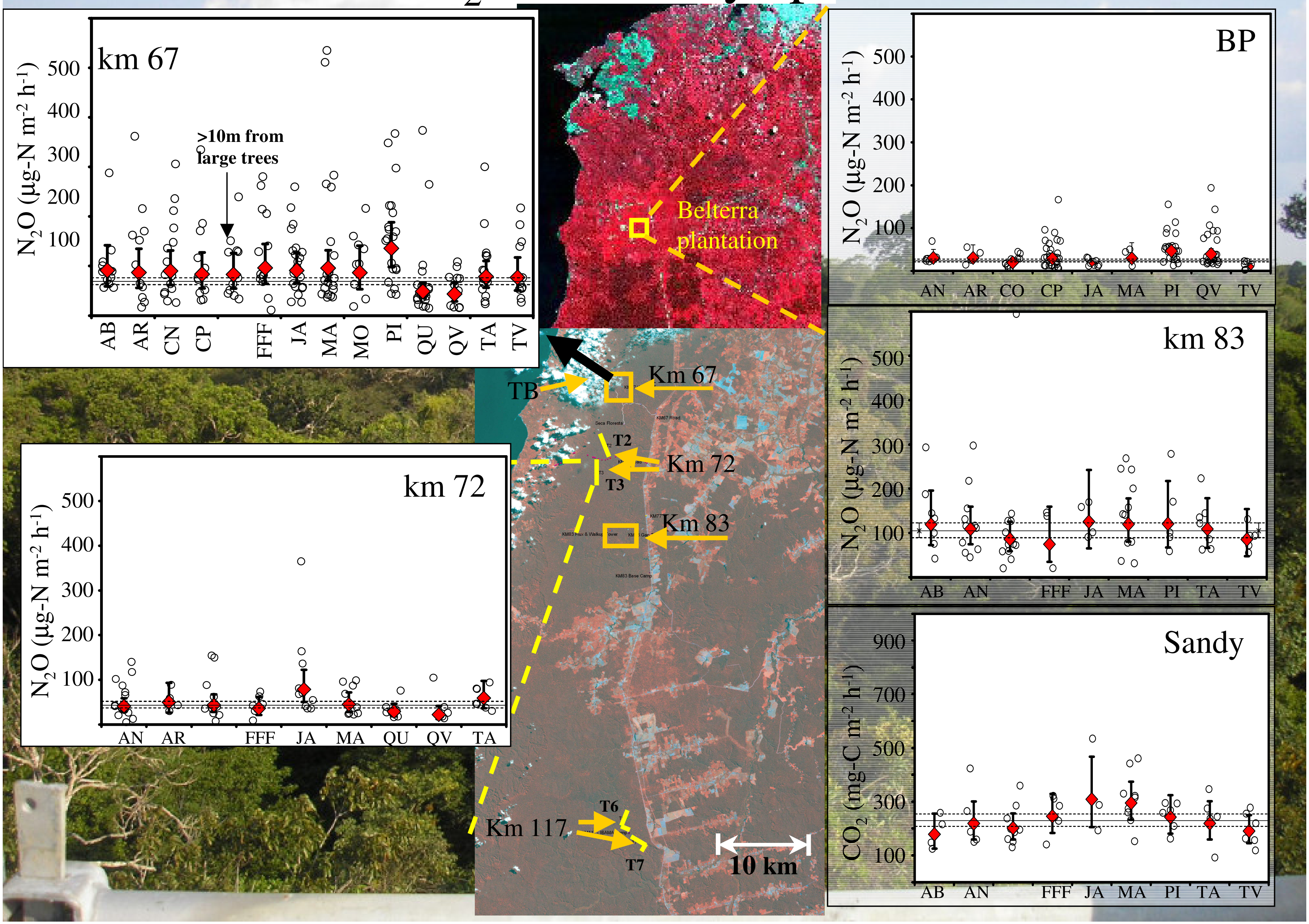


Each point is calculated based on total influence sphere area by species and mean flux. Area of species not measured were pooled and multiplied by the overall mean species flux.

Site CO_2 fluxes by species



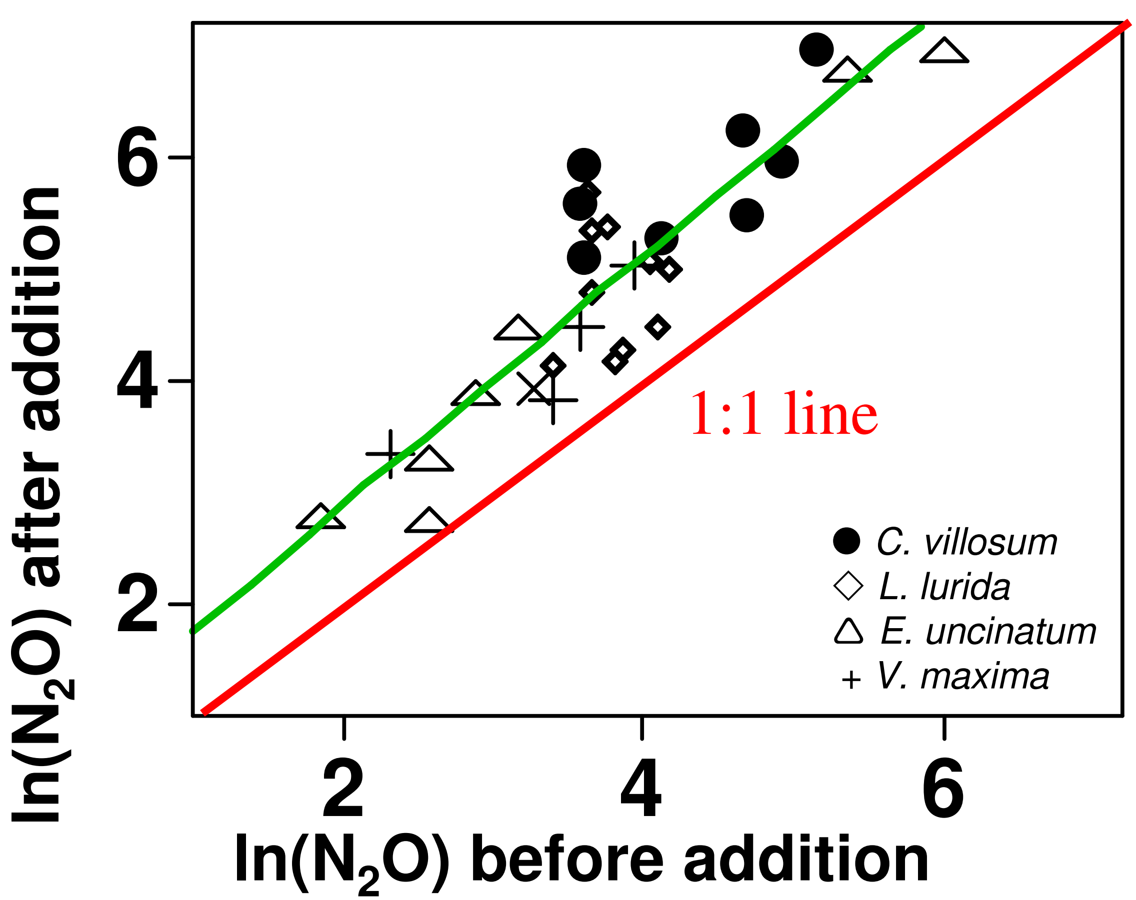
Site N_2O fluxes by species



Species differences

- N_2O fluxes higher close to Caryocar villosum (Caryocaraceae) than Erisma uncinatum and Vochysia maxima (Vochysiaceae)
- Possible mechanisms:
  - Root derived carbon is greater under C. villosum
    - Test with sugar additions to soil
  - Nutrient cycling between these plants is different
    - C. villosum lacks the dense root mats that are found under many tropical tree species (including Vochysiaceae)
  - Soil texture or moisture differences close to these tree species

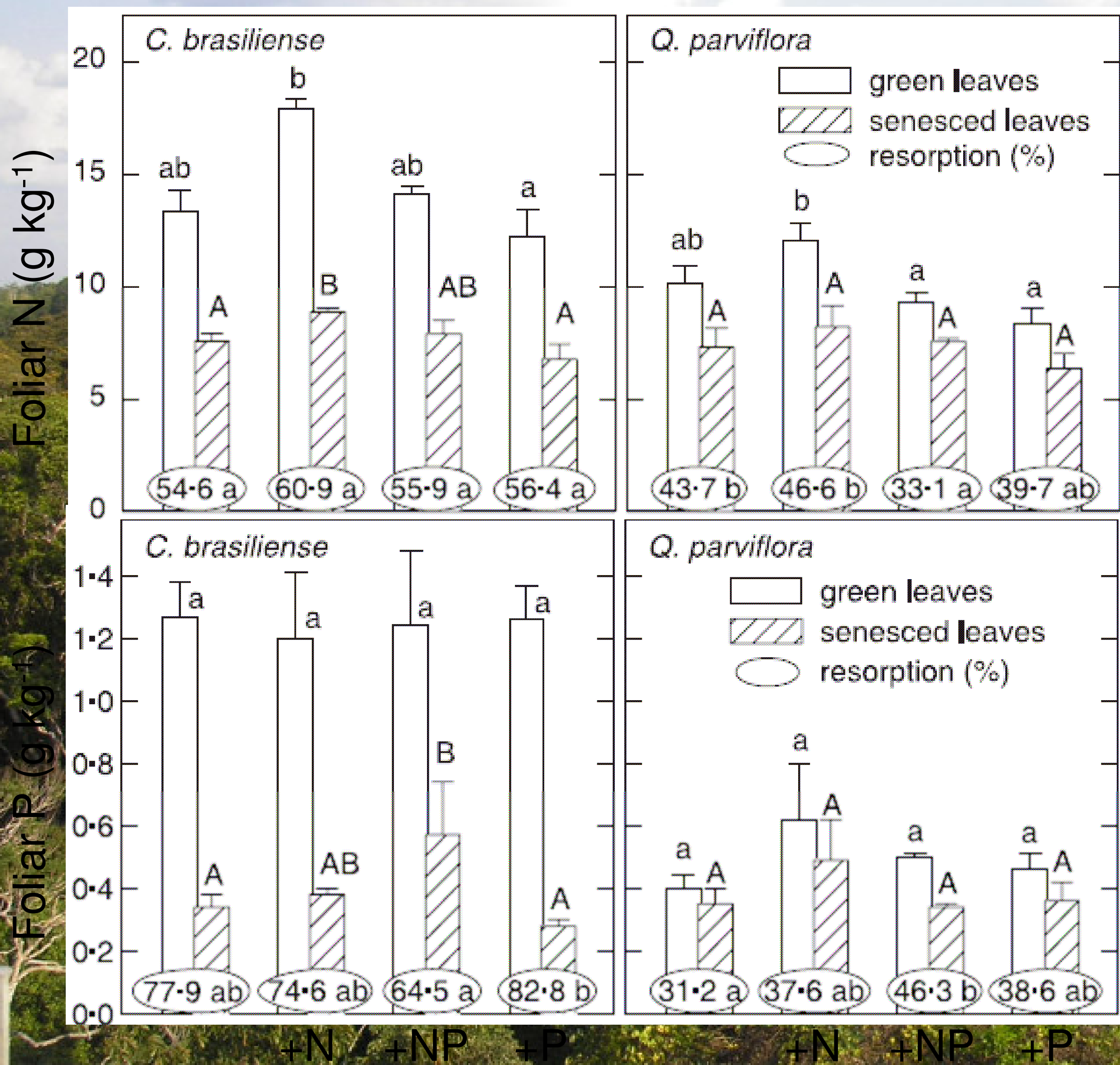
Soil response to sugar additions



Peak N_2O fluxes after addition were strongly correlated with N_2O flux before addition

Suggests that microbial response to common C (sugar) is community and not plant species dependent

NUE of Caryocaraceae and Vochysiaceae



Foliar N and P content in Cerrado species

Resorption of N and P greater in Caryocaraceae species than in Vochysiaceae species

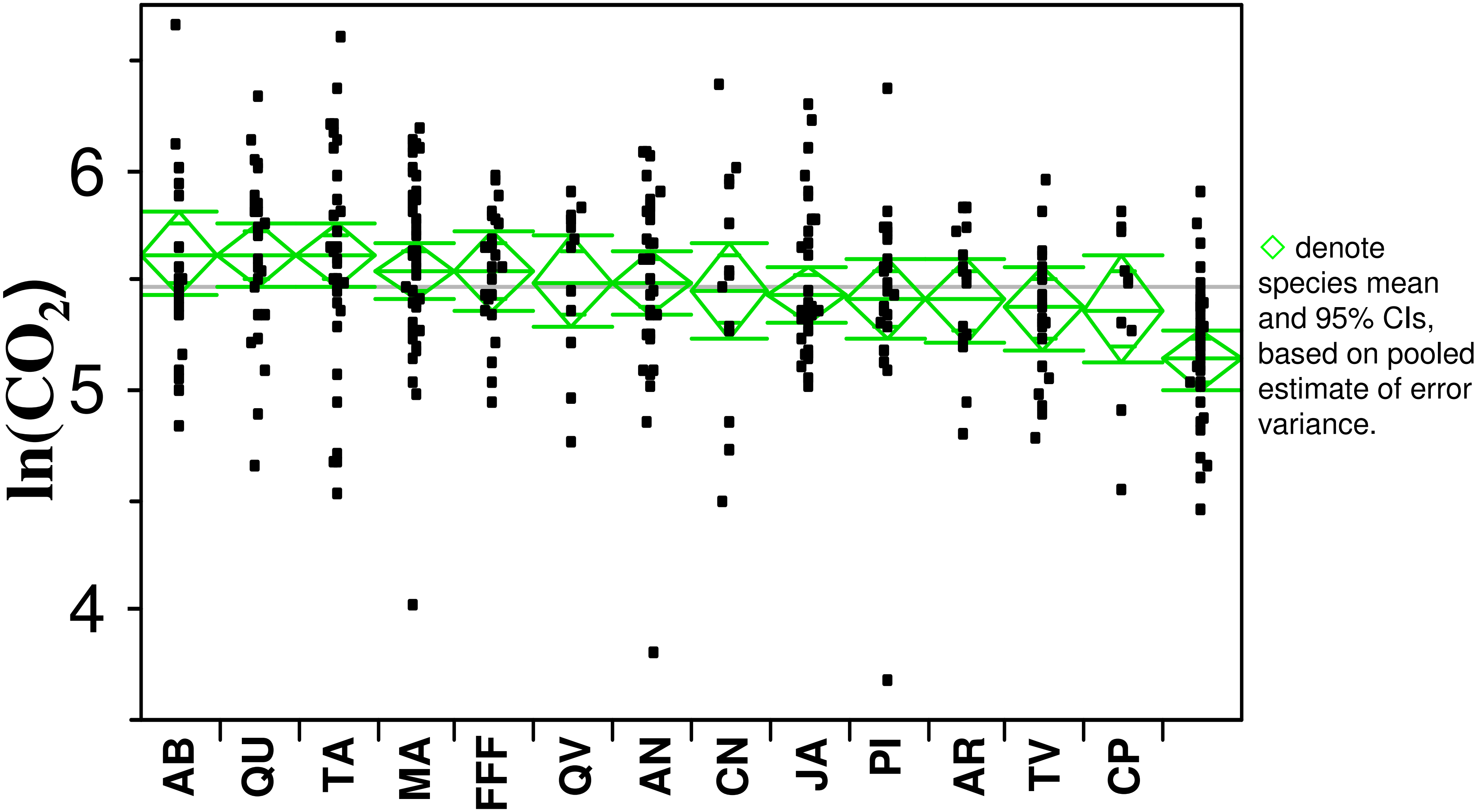
Kozovits et al. 2007

Conclusions

Plant species and Biogeochem cycling

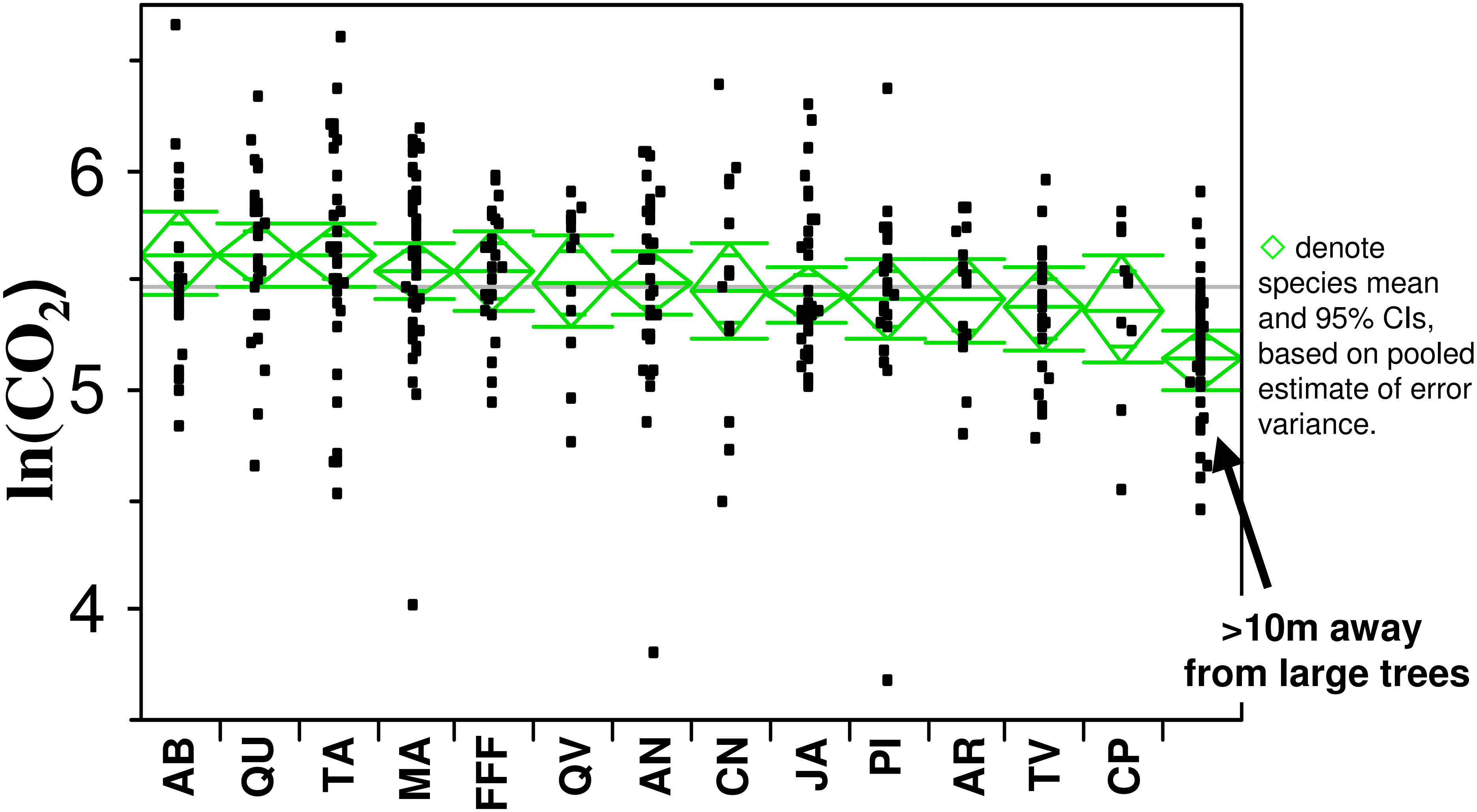
- Trees are limited in growth by light and nutrient supply
  - Growth severely hampered by light in understory, but in general trees >35 cm DBH are less affected
  - Nutrient supply comes from soil and for N also from air, which makes N not a good indicator for tree soil use!
- Trees are main carbon source for micro-organisms
  - Species are known to have different growth and photosynthetic efficiencies, NUE's, and ability to fix N
  - Litter quality and quantity differs between species, though litter mixing and roaming animals (termites) would probably reduce these differences in diverse forests over plantation settings.
- If there are differences then are these differences significant enough to influence the overall forest flux (Model based on different assumptions of sphere of influence of each tree based on size).

Tapajos clay-rich sites (km 67, 72 and 83)



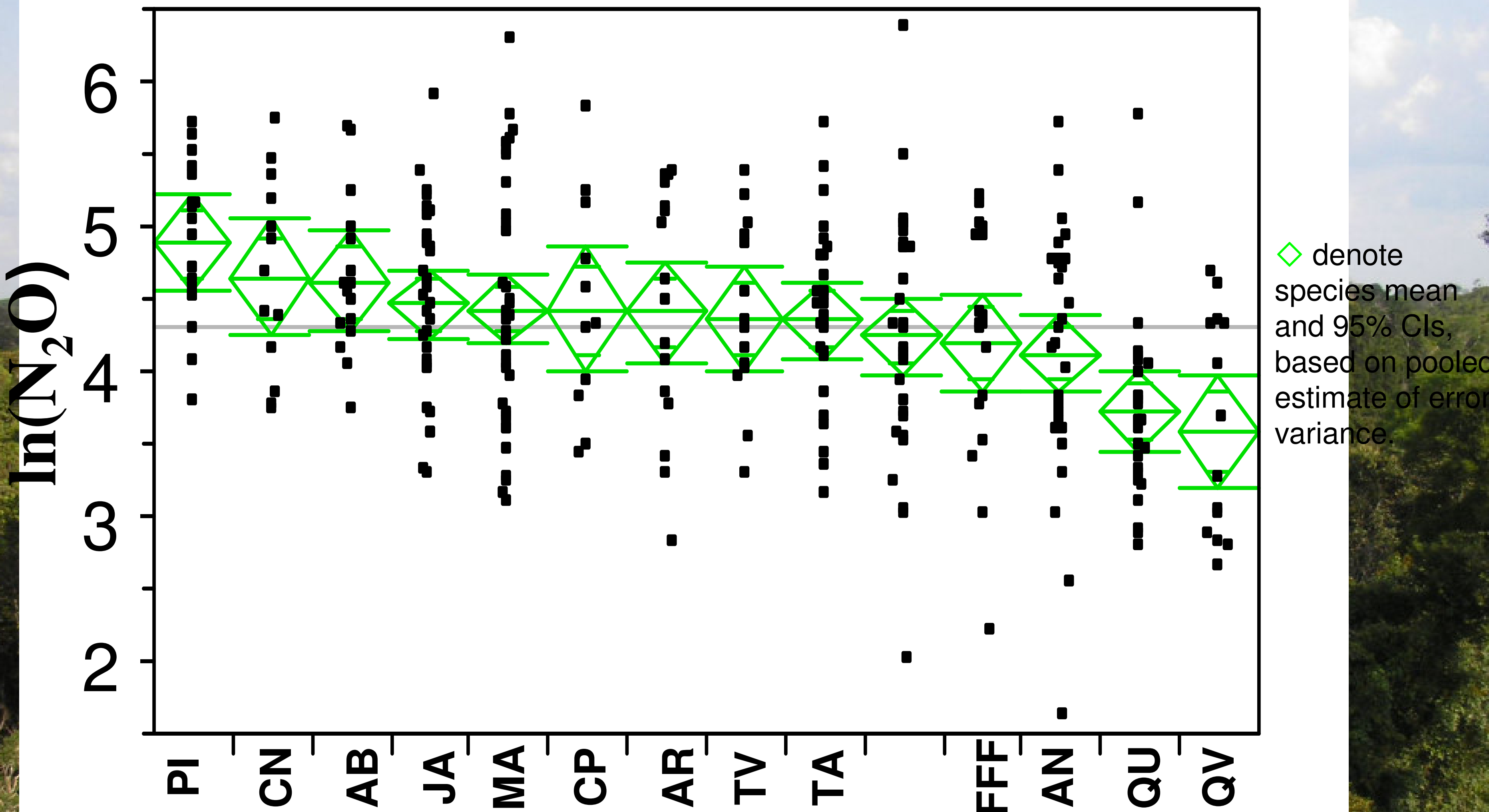
Controls (171_{12}^{12} mg-C m^{-2} h^{-1}, geometric mean$_{-SE}^{+SE}$) 30% smaller than overall mean (238_{5}^{6} mg-C m^{-2} h^{-1}, ANOVA: $F_{13,324}$=2.85, P=0.0007) and smaller at α=0.05 (AB=277_{25}^{28}, QU=276_{20}^{21}, TA=274_{19}^{21}, MA=258_{16}^{17}, FFF=257_{23}^{25}, and AN=244_{18}^{19}, Tukey-Kramer).

Tapajos clay-rich sites (km67, km72, & km83)



Controls (171_{12}^{12} mg-C m^{-2} h^{-1}, geometric mean$_{-SE}^{+SE}$) 30% smaller than overall mean (238_{5}^{6} mg-C m^{-2} h^{-1}, ANOVA: $F_{13,324}=2.85$, $P=0.0007$) and smaller at $\alpha=0.05$ (AB=277_{25}^{28}, QU=276_{20}^{21}, TA=274_{19}^{21}, MA=258_{16}^{17}, FFF=257_{23}^{25}, and AN=244_{18}^{19}, Tukey-Kramer).

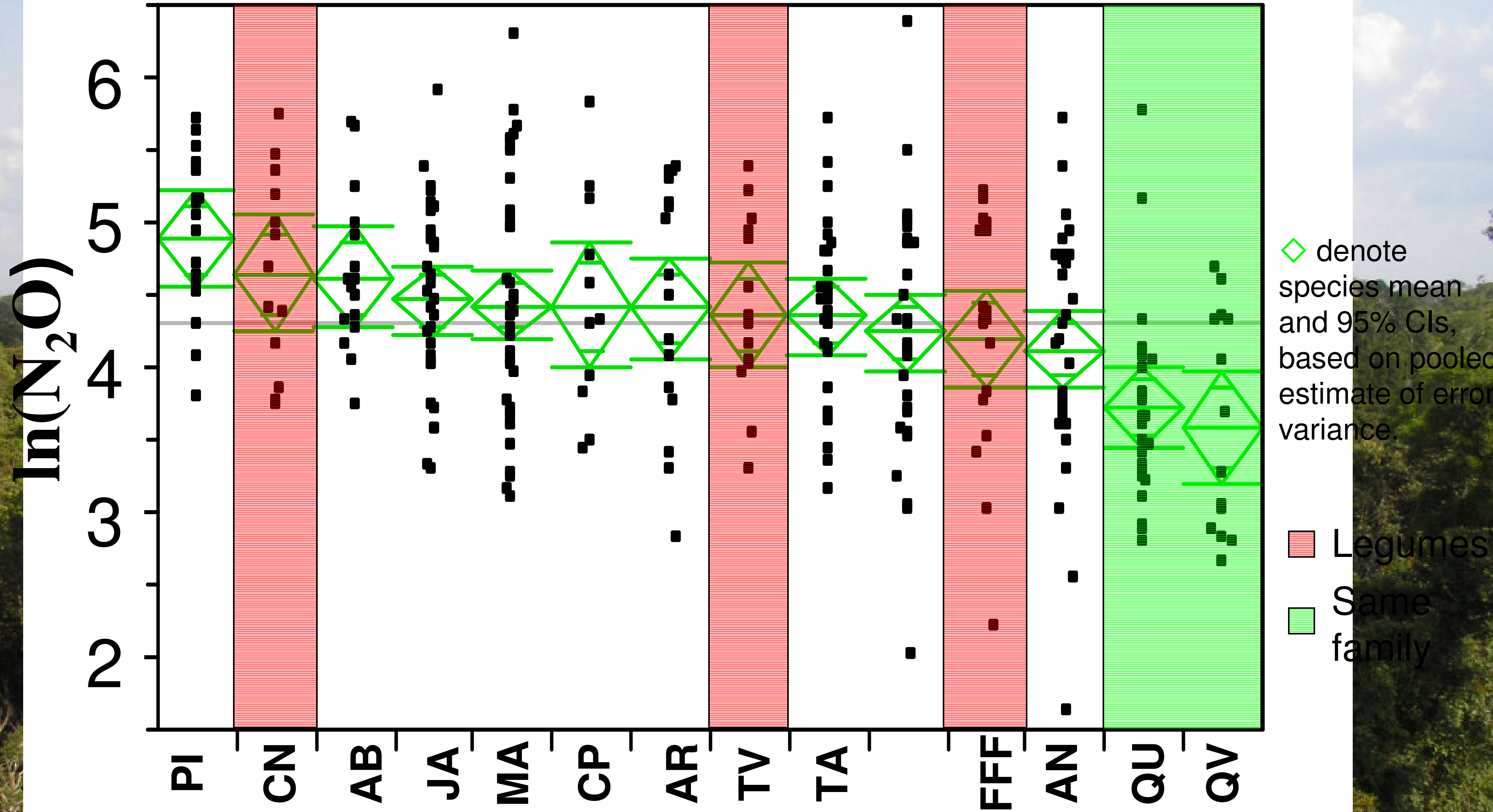
Tapajos clay-rich sites (km67, km72, & km83)



N_2O fluxes close to PI* (133_{21}^{25} µg-N m^{-2} h^{-1}, geometric mean$_{-SE}^{+SE}$), QU (42_5^6 µg-N m^{-2} h^{-1}) and QV (37_6^8 µg-N m^{-2} h^{-1}) were respectively 1.8 times greater, 1.8 and 2.1 times smaller than the overall mean (75_3^3 µg-N m^{-2} h^{-1}, ANOVA: $F_{13,324}$,=4.46, P<0.0001).

* different from QU and QV at Tukey-Kramer α=0.0001.

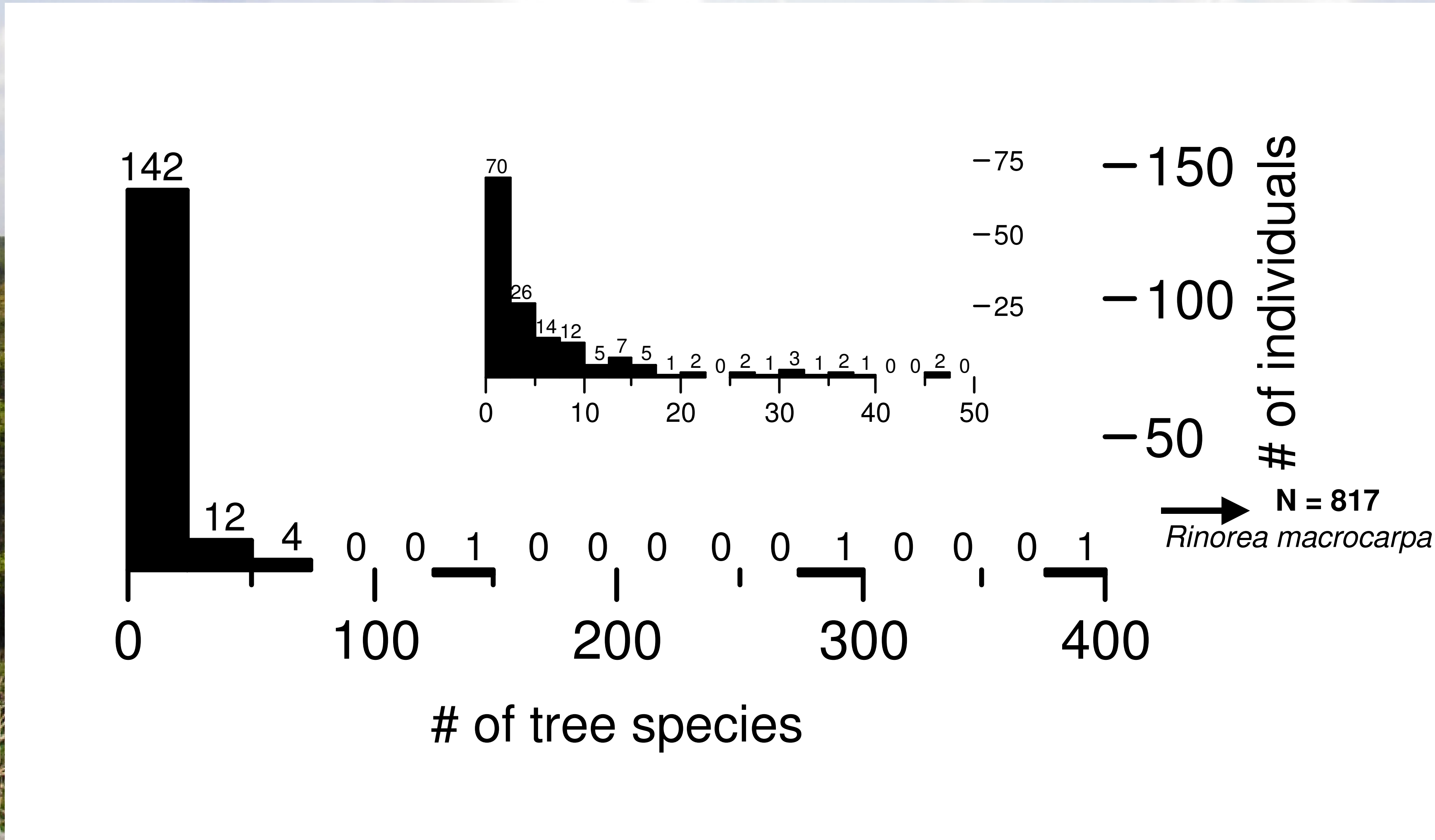
Tapajos clay-rich sites (km67, km72, & km83)



N_2O fluxes close to PI* (133_{21}^{25} µg-N m^{-2} h^{-1}, geometric mean$_{-SE}^{+SE}$), QU (42_5^6 µg-N m^{-2} h^{-1}) and QV (37_6^8 µg-N m^{-2} h^{-1}) were respectively 1.8 times greater, 1.8 and 2.1 times smaller than the overall mean (75_3^3 µg-N m^{-2} h^{-1}, ANOVA: $F_{13,324}$,=4.46, P<0.0001).

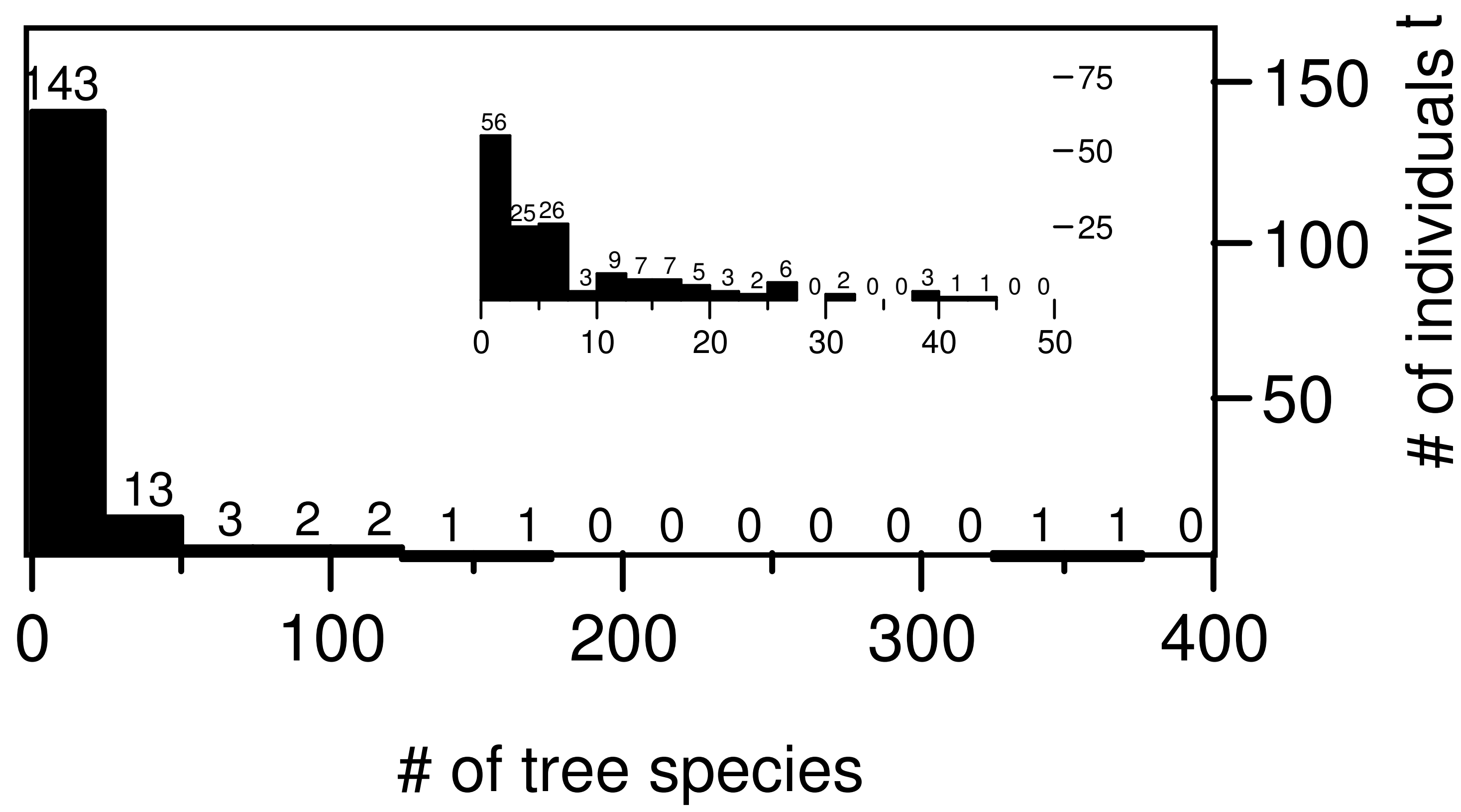
* different from QU and QV at Tukey-Kramer α=0.0001.

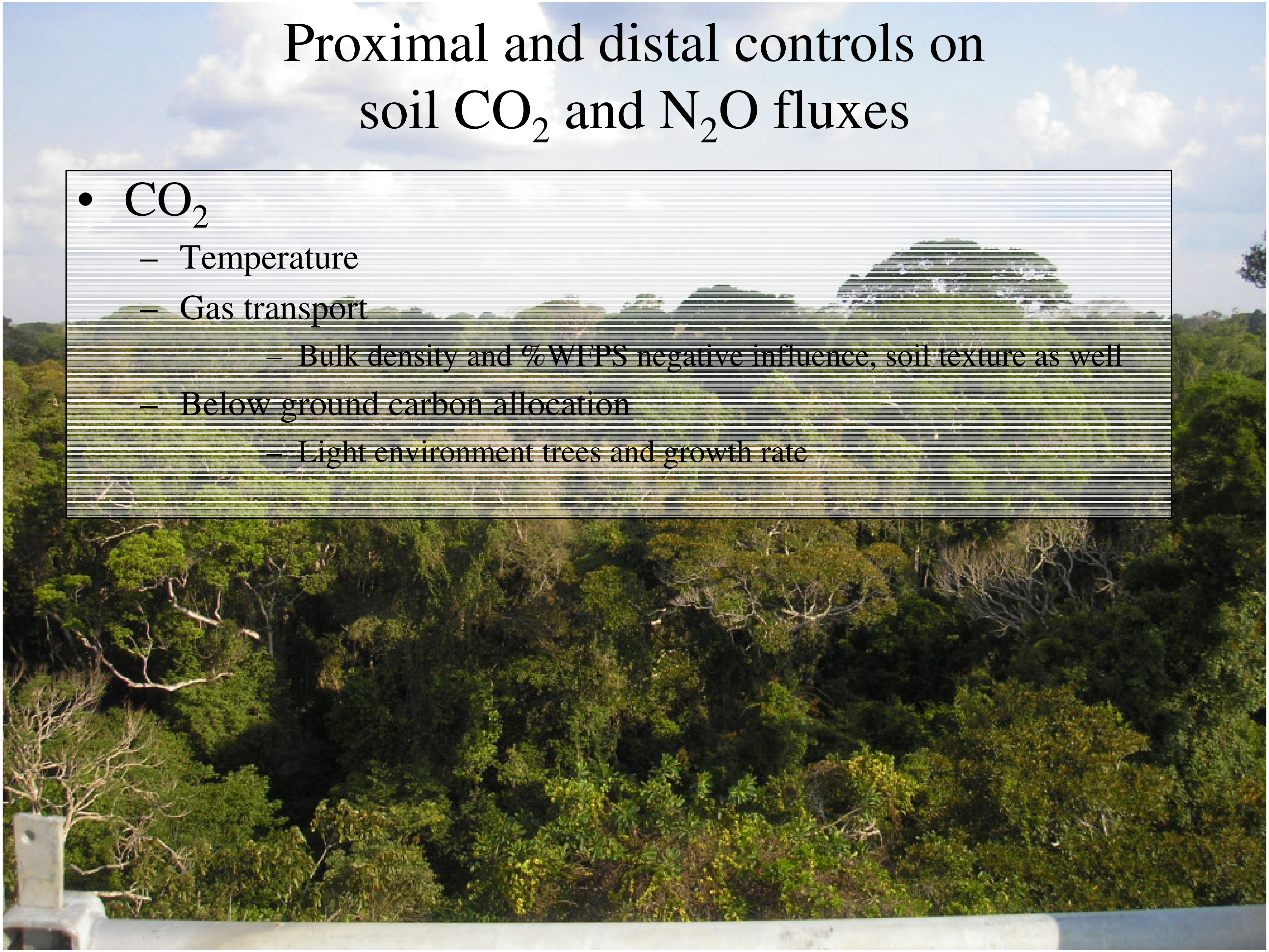
2005+2006 Km67



Add # of locations

2007 km67+km72+km83+TB





Proximal and distal controls on soil CO_2 and N_2O fluxes

- CO_2
  - Temperature
  - Gas transport
    - Bulk density and %WFPS negative influence, soil texture as well
  - Below ground carbon allocation
    - Light environment trees and growth rate

Proximal and distal controls on soil CO_2 and N_2O fluxes

- CO_2
  - Temperature
  - Gas transport
    - Bulk density and %WFPS negative influence, soil texture as well
  - Below ground carbon allocation
    - Light environment trees and growth rate
- N_2O
  - Temperature
  - Texture: influences %WFPS and O_2 transport
  - %WFPS: barrier for O_2 transport
  - Precipitation: disturbance causing microbial lysing
  - Labile carbon as food for denitrifiers, biomass allocation
  - pH, which controls enzymatic processes and can suppress N_2O reductase at low pH
  - Competition with plants for N-forms