Functional diversity in the first FACE experiment in a hyperdiverse Amazon forest

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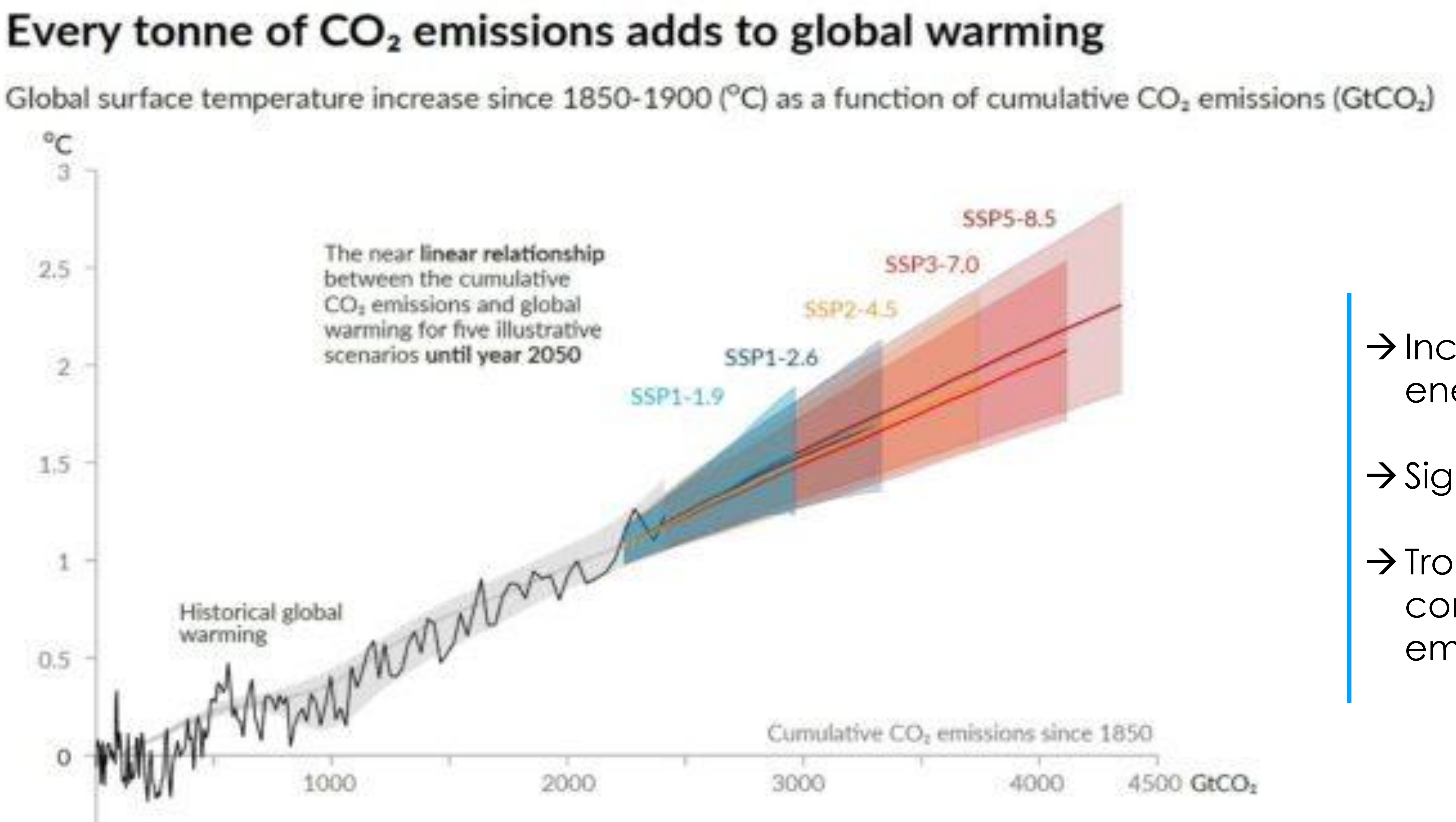


Source: adapted from SPM.10, IPCC (2021)

- → Increasing [CO_2] alter the global energy balance leading to warming
- → Significant uncertain in the models
- → Tropical forest plays a decisive role compensating a fraction of CO_2 emissions

ATBC OAXACA 2025

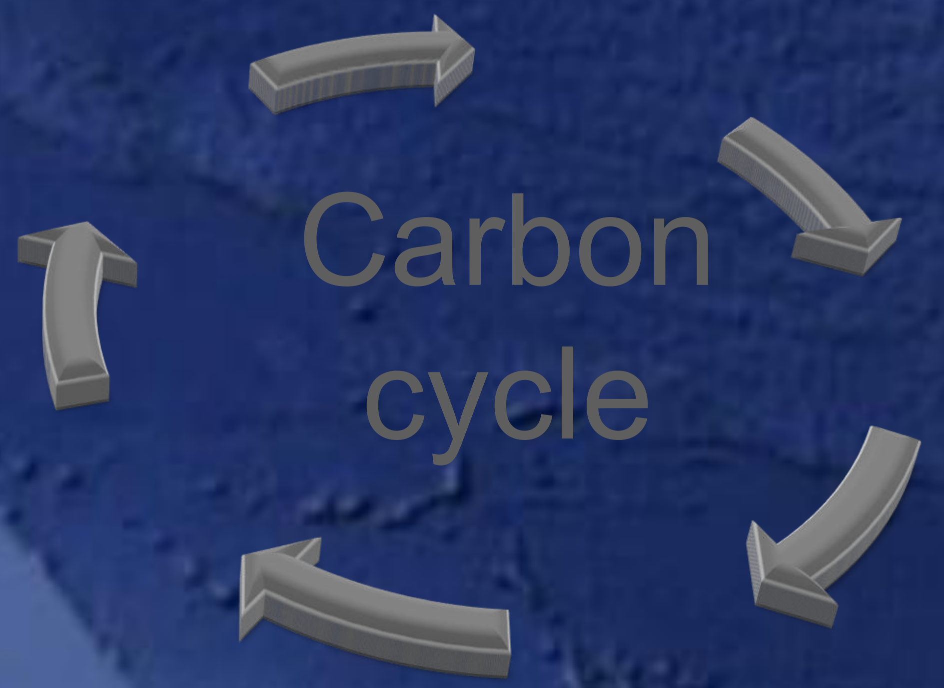
Amazon rainforest

- The world's largest tropical forest
- Land C reservoir: ~150 billions tons of C
- High biodiversity
- Global water cycle
- The Amazon rainforest plays an essential role in the global carbon cycles

Data SIO, NOAA, U.S. Navy, NGA, GEBCO Landsat / Copernicus IBCAO PGC/NASA

- Highly-weathered soils limited by P in at least 60% of the basin area

- Climate uncertain



Quesada, et al. 2012

Data SIO, NOAA, U.S. Navy, NGA, GEBCO Landsat / Copernicus IBCAO PGC/NASA

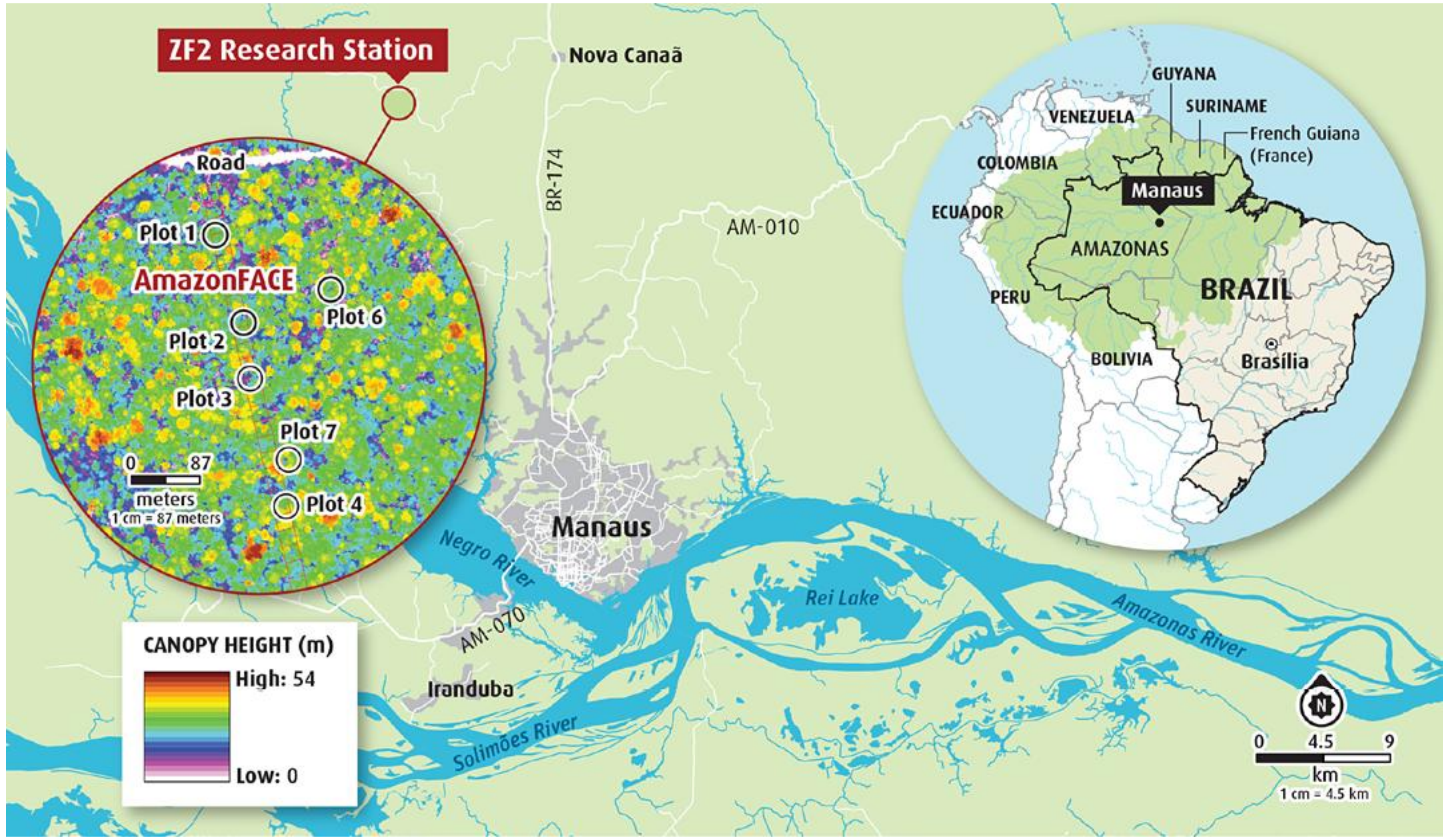
Main Goal:

To reduce key uncertainties about how tropical forests respond to rising atmospheric CO_2 and climate

Research Question:

How will rising CO_2 affect the resilience, biodiversity, and ecosystem services of the Amazon forest?

- Understand how the forest responds functionally, rather than on a species-by-species basis
- Functional groups reflect strategies, which is more informative for predicting ecosystem responses to elevated CO_2
- Focusing on ecological processes allows for generalizations and favors models integration



AMAZONFACE

6 plots – 30 m diameter each (706.8m²)

3 Treatment plots – 200 ppm above control
3 Control plots – ambient CO_2 (~420 ppm)

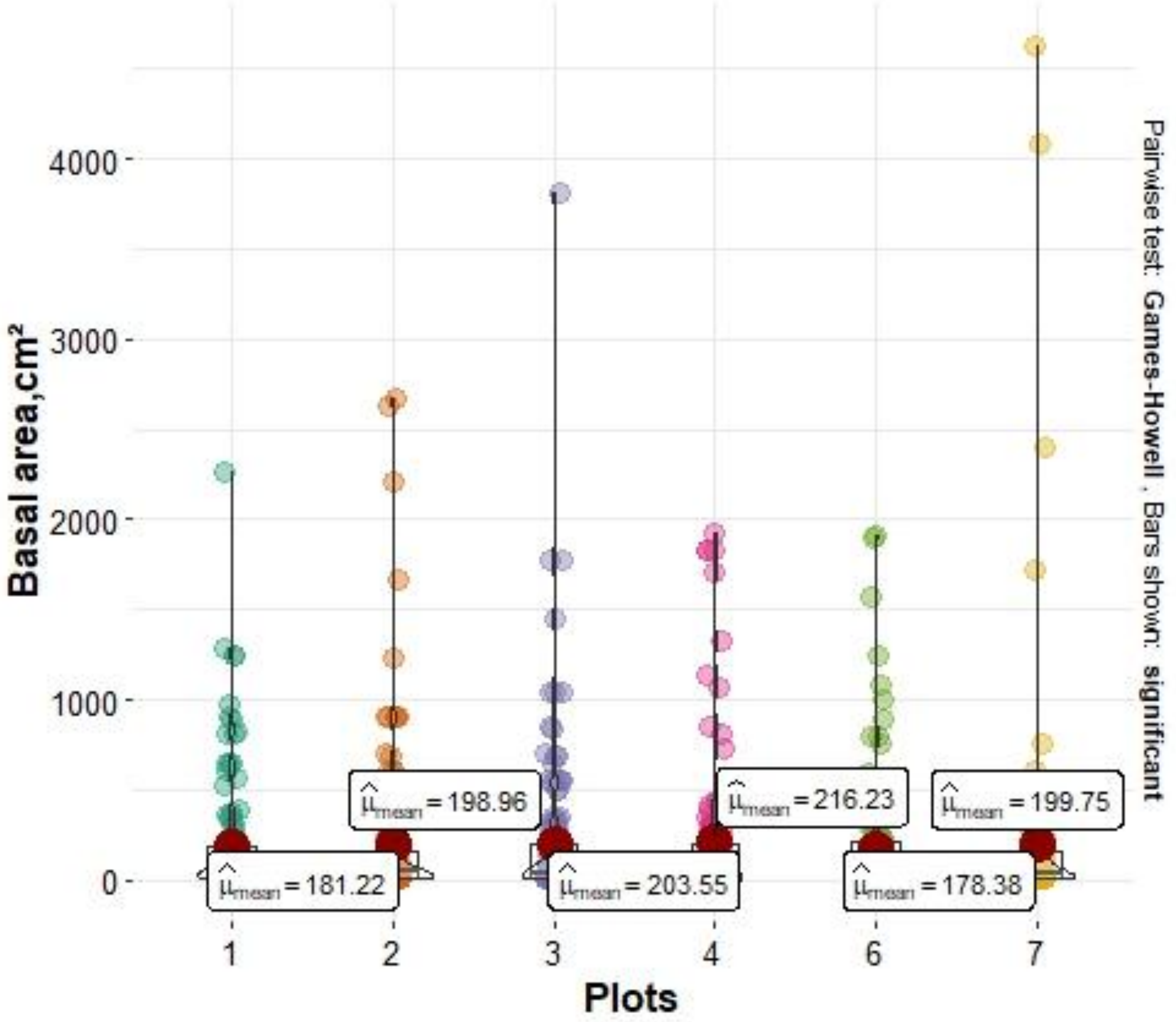
Total area = 0.42 ha

Basal area occupied by stems = 33.4 m²/ha

1305 plants identified (2< DBH <71cm)

414 species

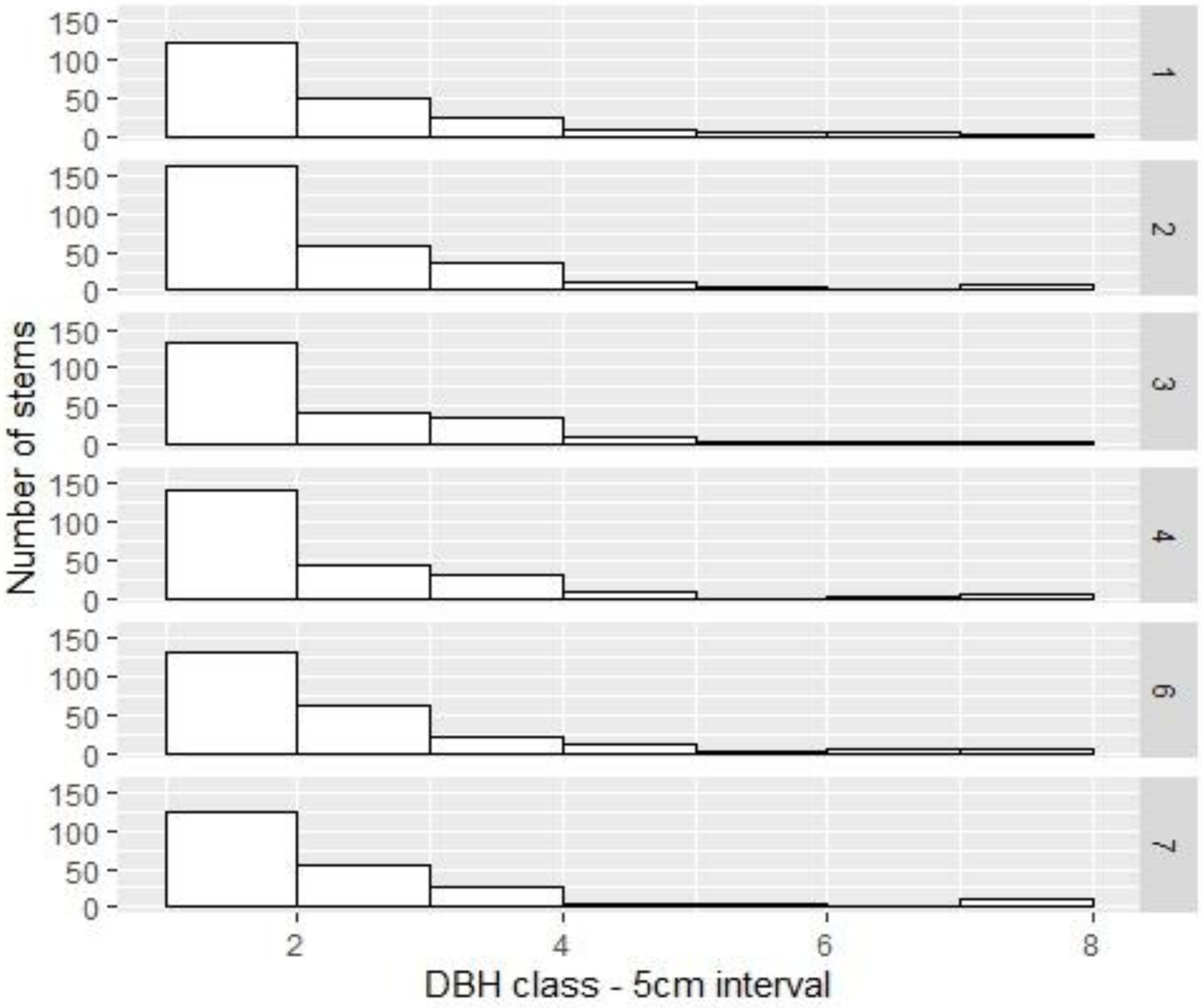
55 families

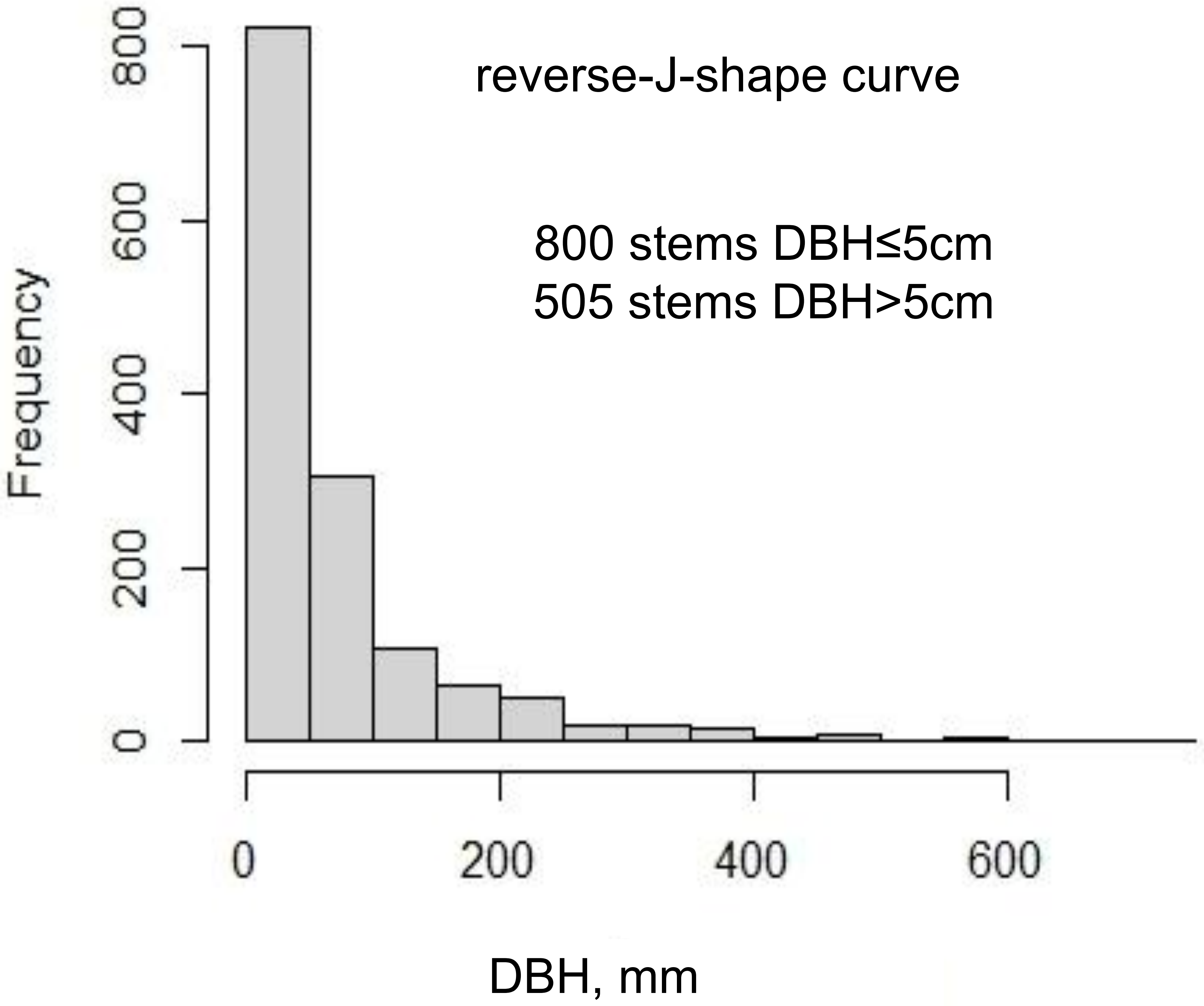


Tree basal area

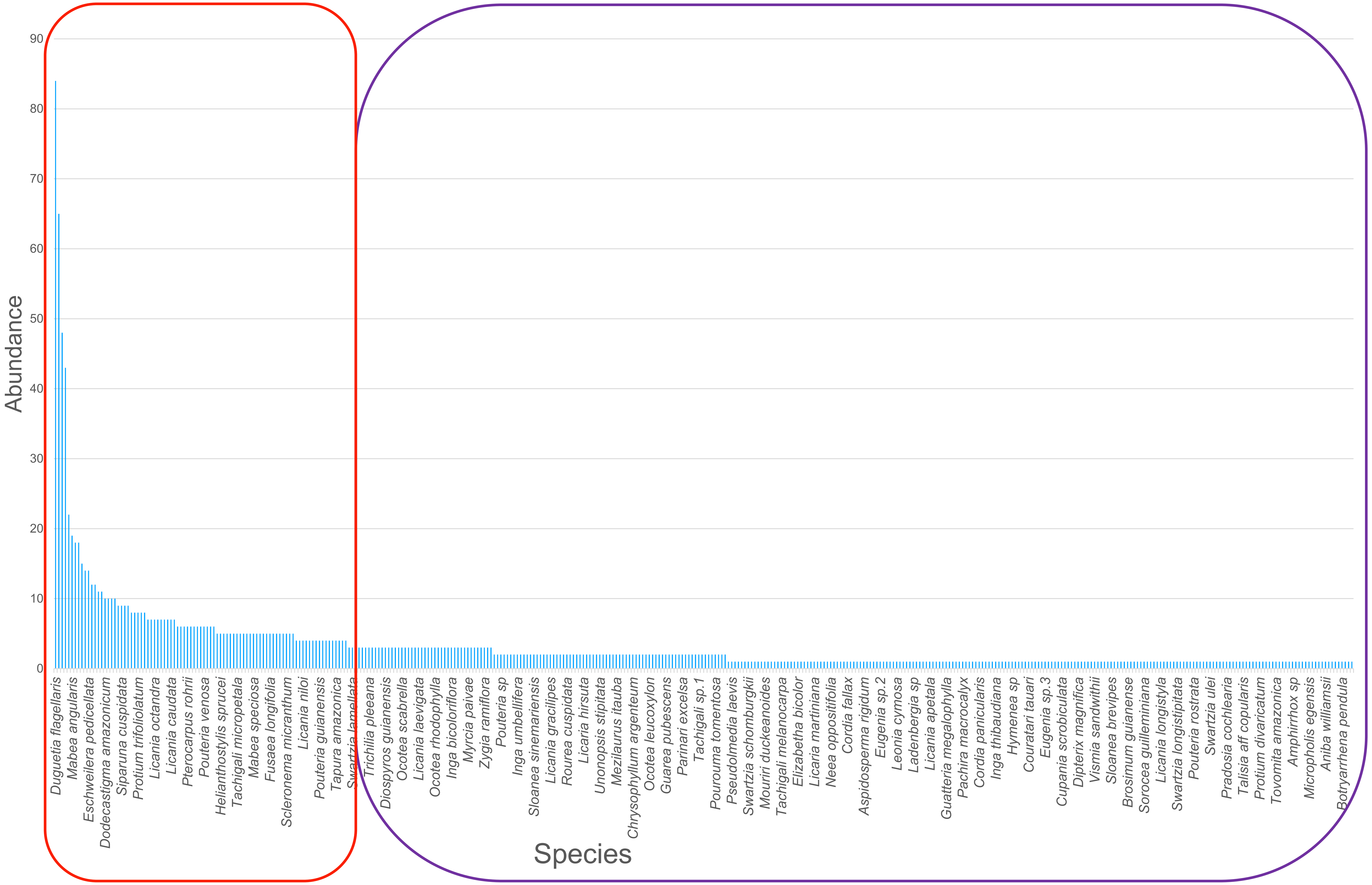
Plot	n_ind	n_sp	BA,m²
1	183	118	1.96
2	239	136	2.58
3	215	129	2.25
4	231	107	2.17
6	221	136	2.22
7	216	124	2.99
Total	**1305**	**414**	**14.17**
Mean	**217**	**125**	**2.36**

Vegetation structure - DBH distribution





Species composition



‘Dominant’ species (>5 ind/specie)
50.3% of all plants
49 species (n=657)

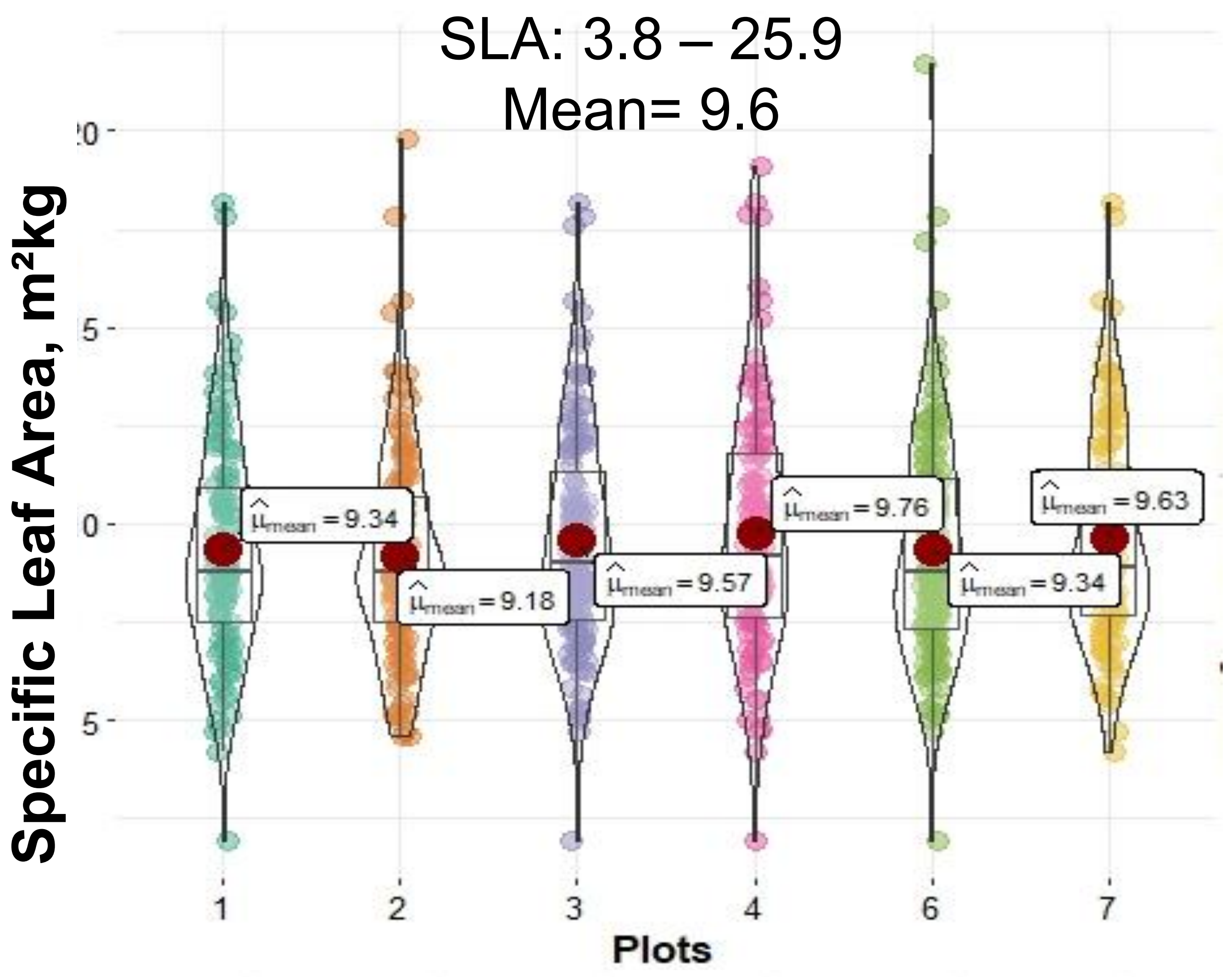
Basal area = 10.9 m²/ha

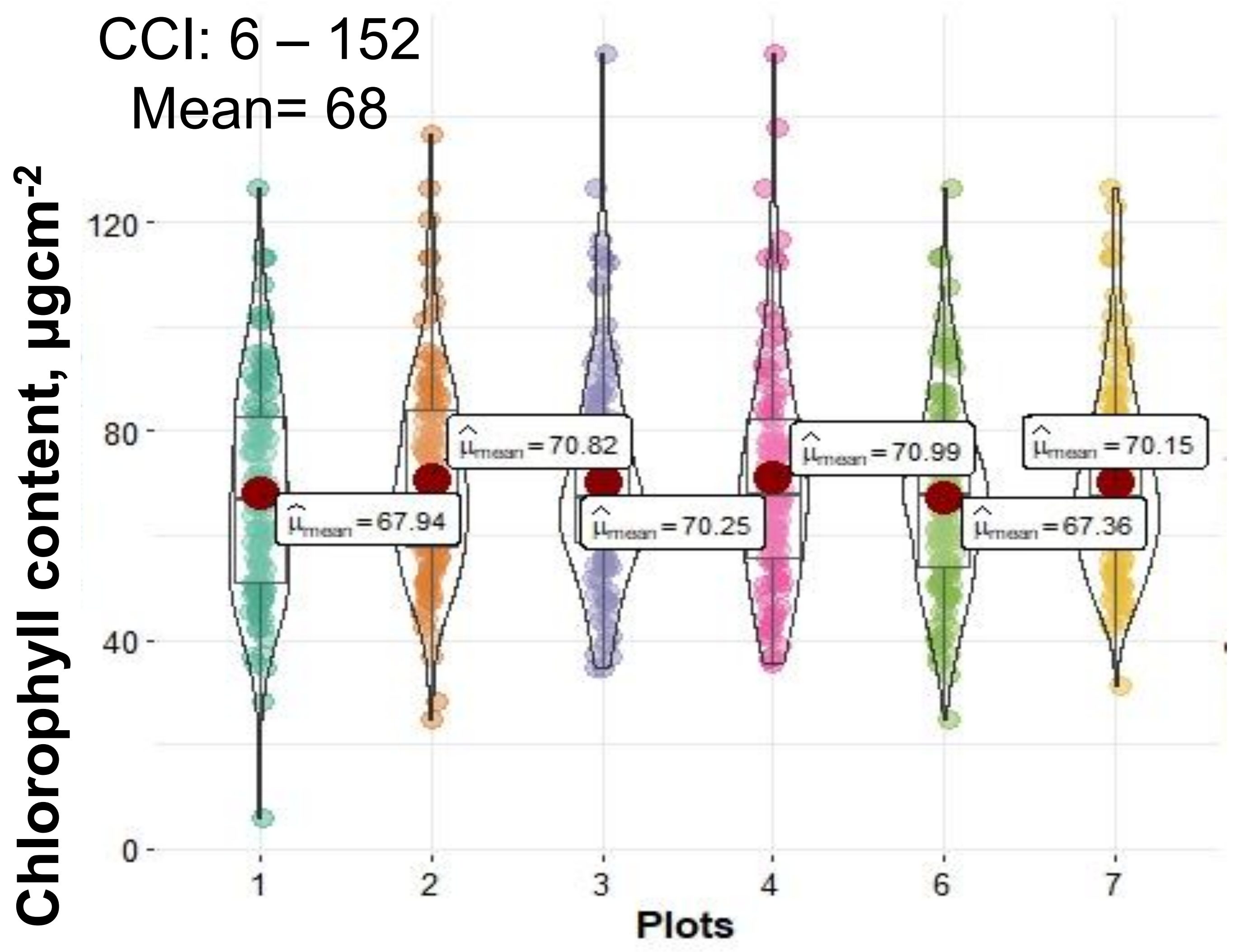
‘Rare’ species (≤5 ind/specie)
49.7% of all plants
345 species (n=648)

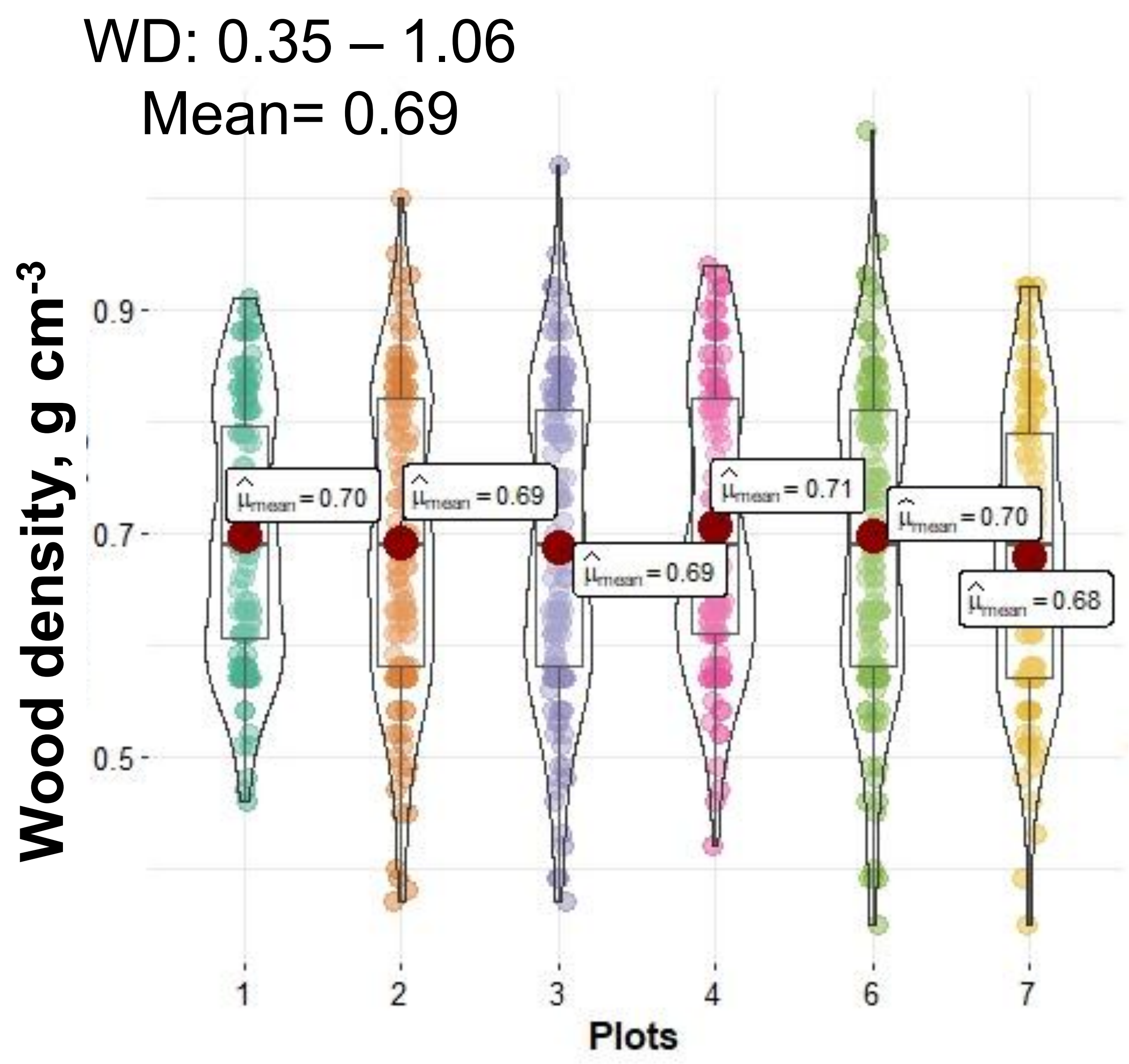
Basal area = 22.6 m²/ha

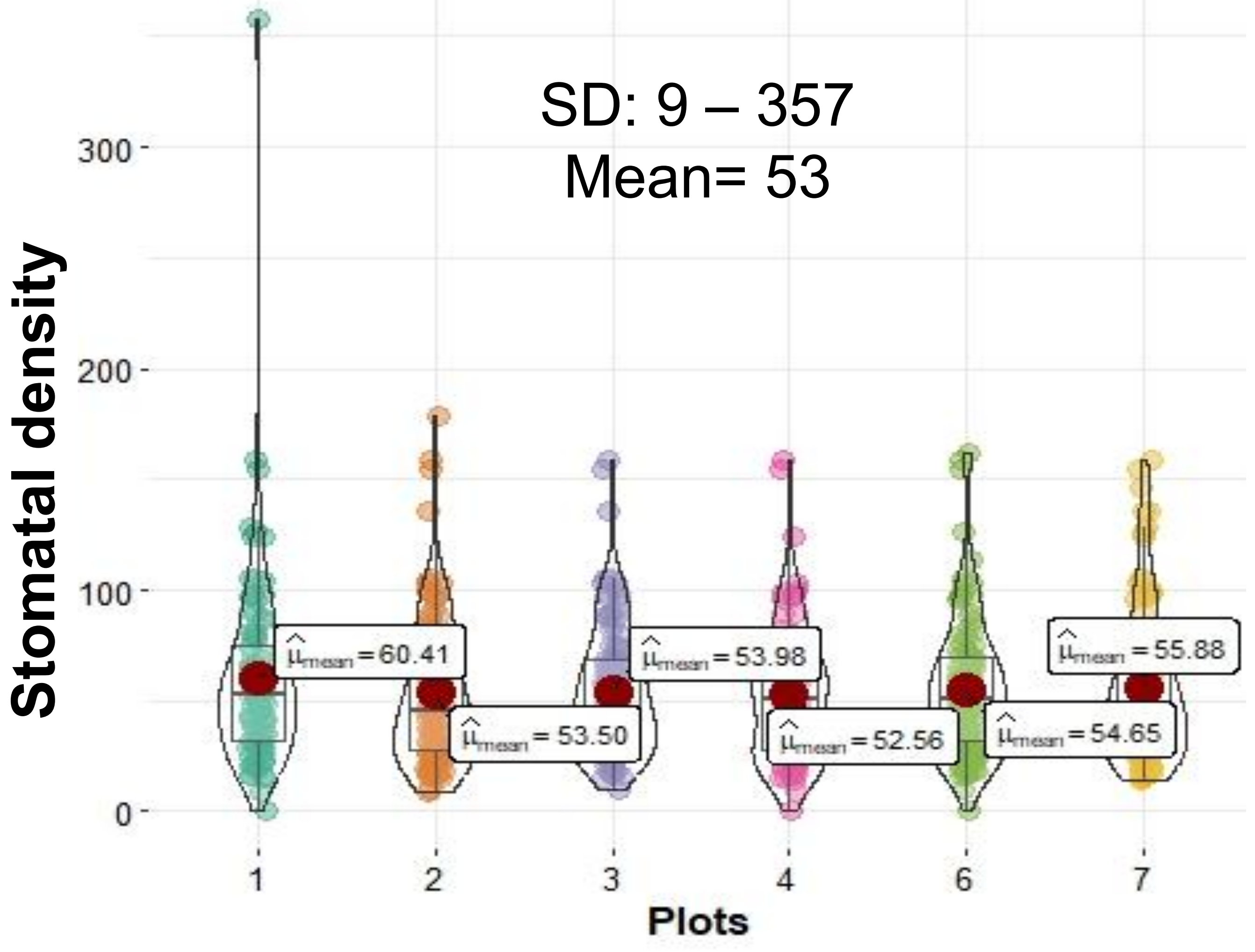
→ 190 species are represented by just one tree

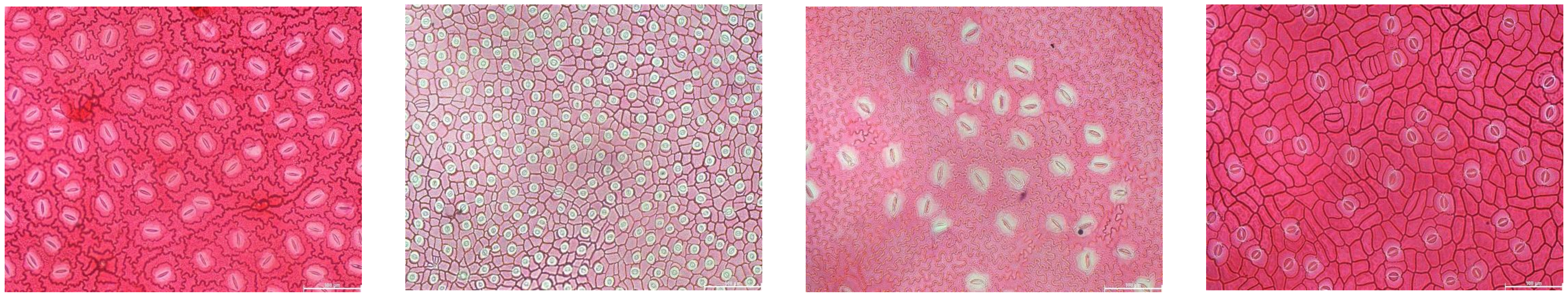
Highly diverse and heterogeneous forest



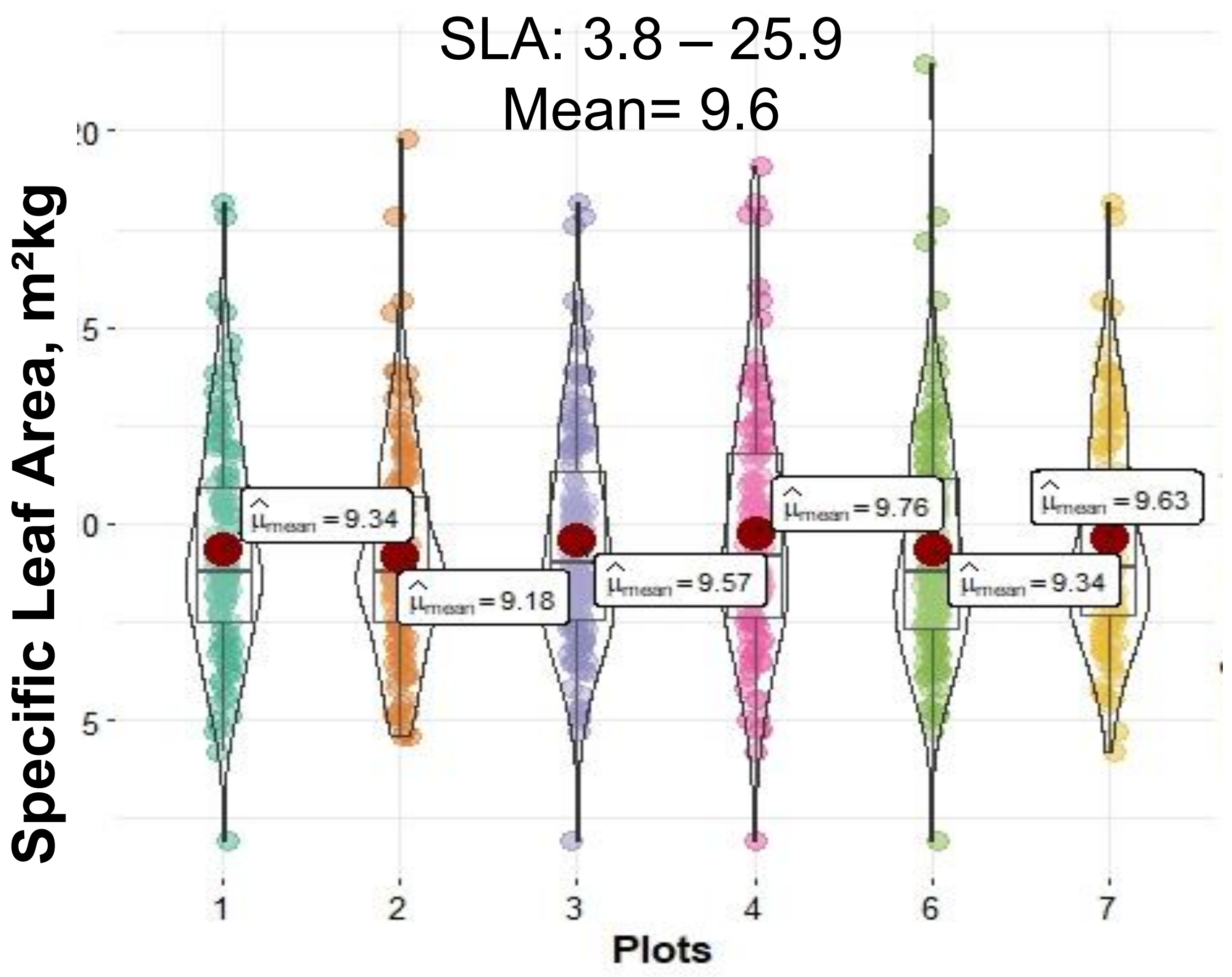


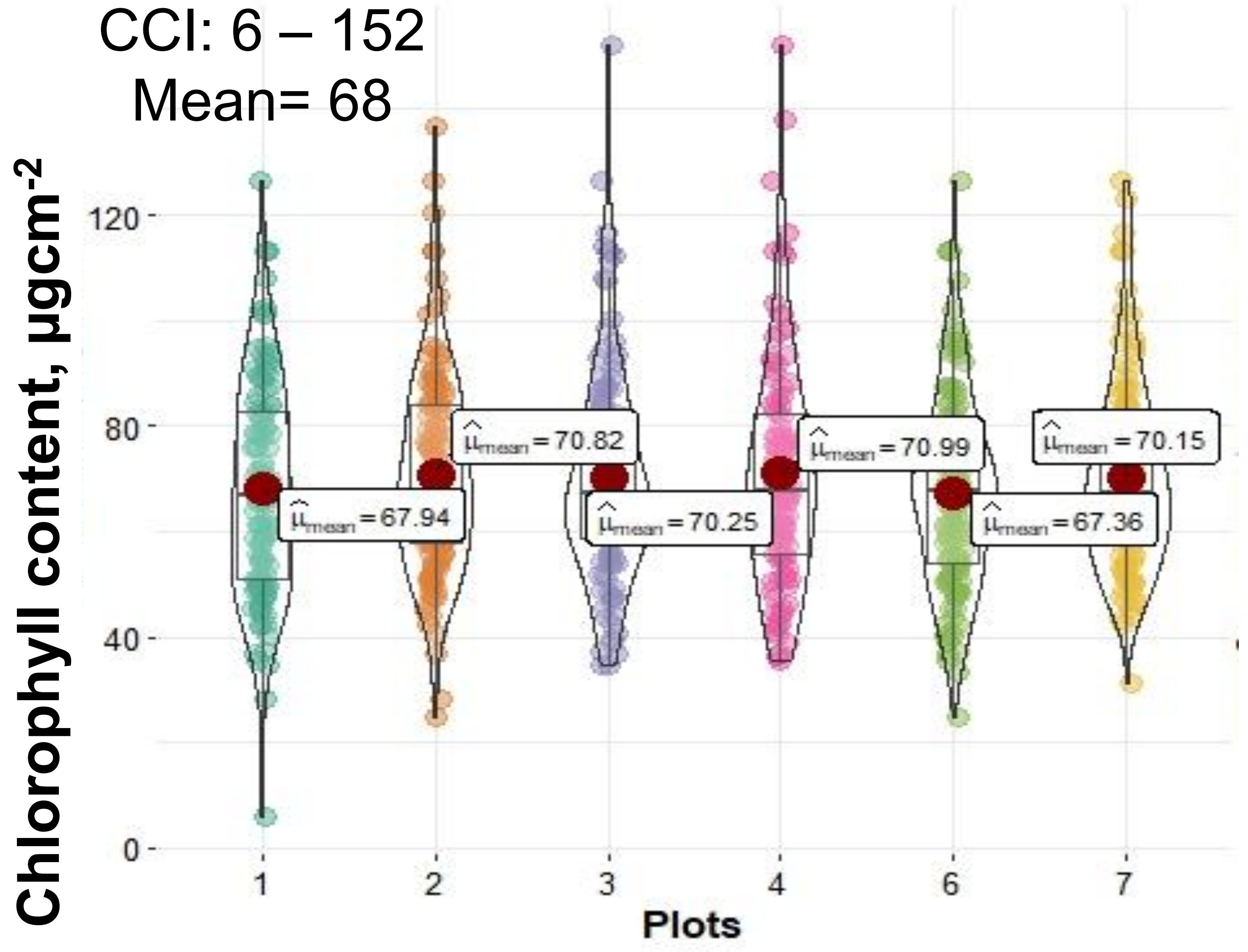


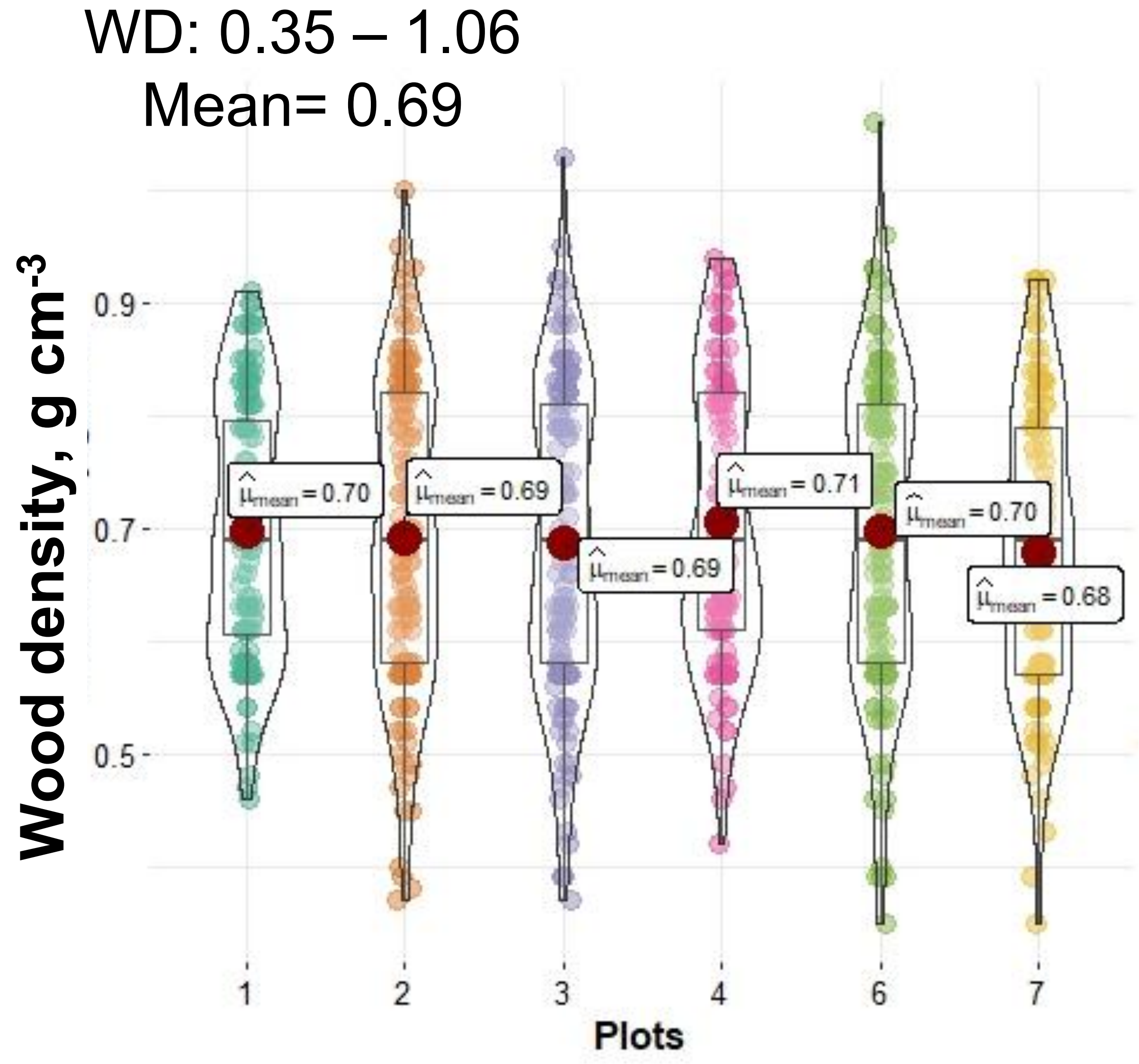


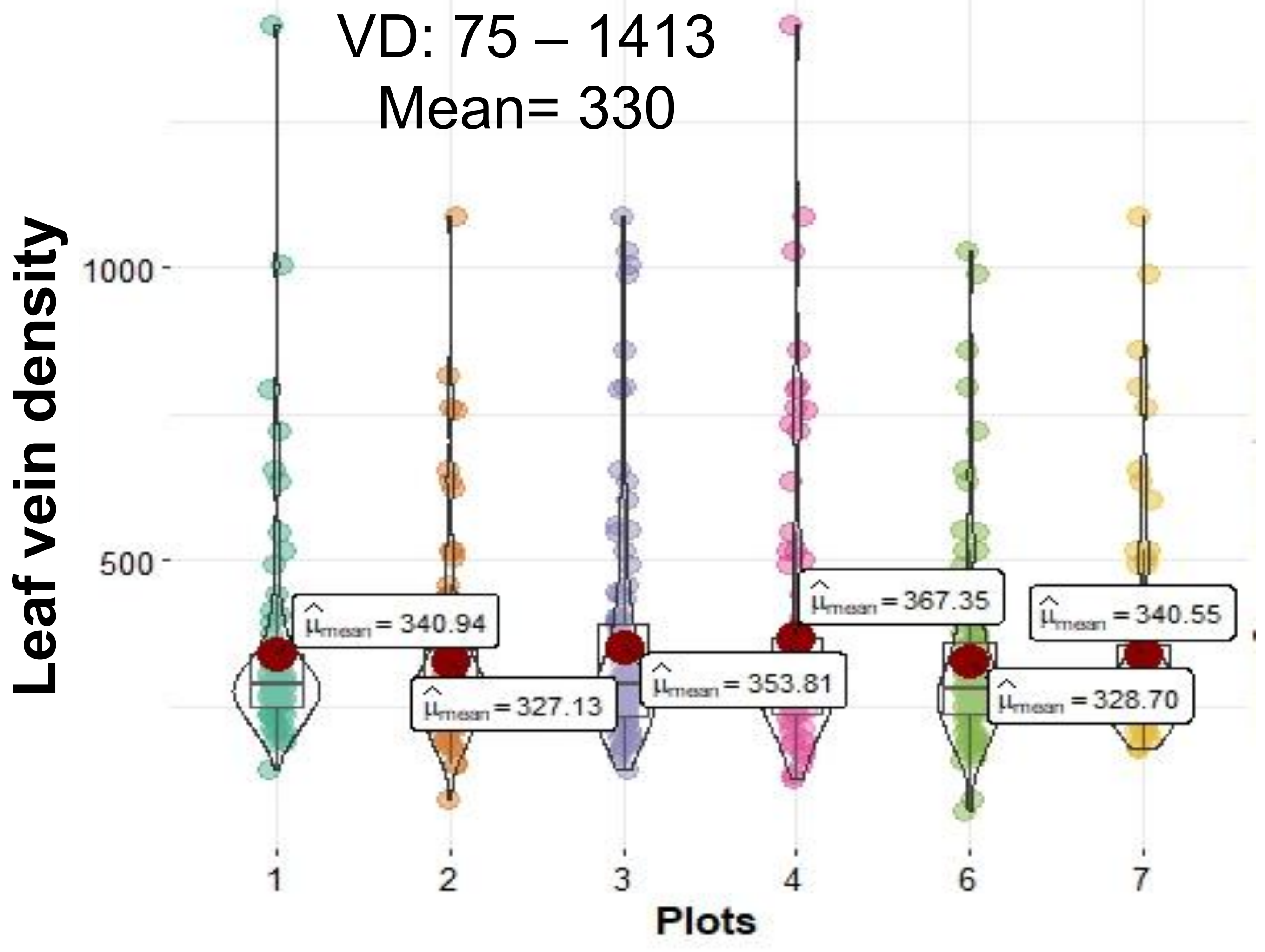


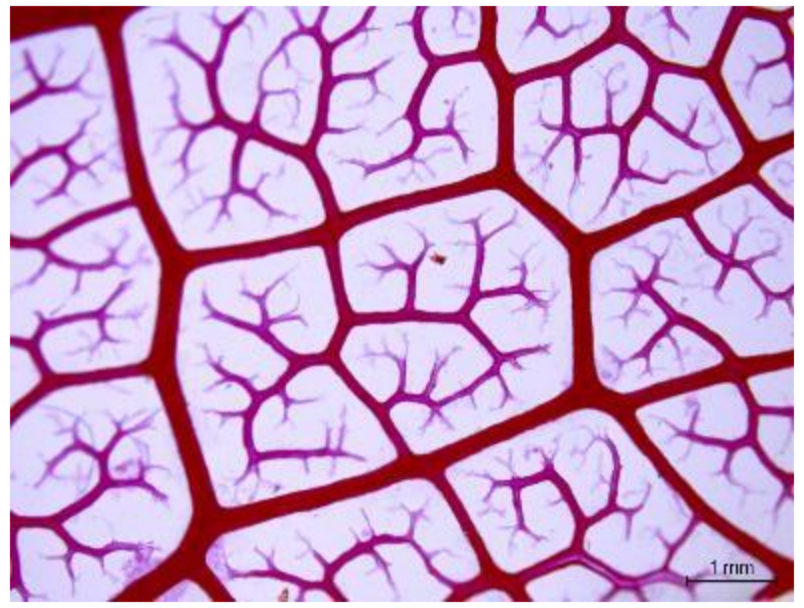
Example of stomatal image. (a) ID 3019 - *Inga rhynchocalyx* (Fabaceae) (b) ID 4001 – *Licania irwinii* (Chrysobalanaceae) (c) ID 7016 - *Inga gracilifolia* (Fabaceae) and (d) ID 4046 - *Swartzia reticulata* (Fabaceae)

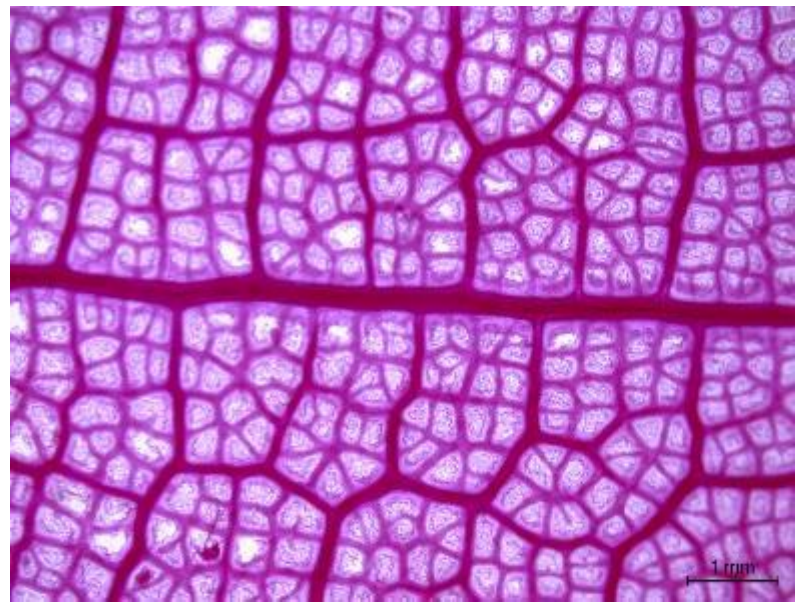

SLA: 3.8 – 25.9
Mean= 9.6
Specific Leaf Area, m²kg
μmean = 9.34
μmean = 9.18
μmean = 9.57
μmean = 9.76
μmean = 9.34
μmean = 9.63
1 2 3 4 6 7
Plots

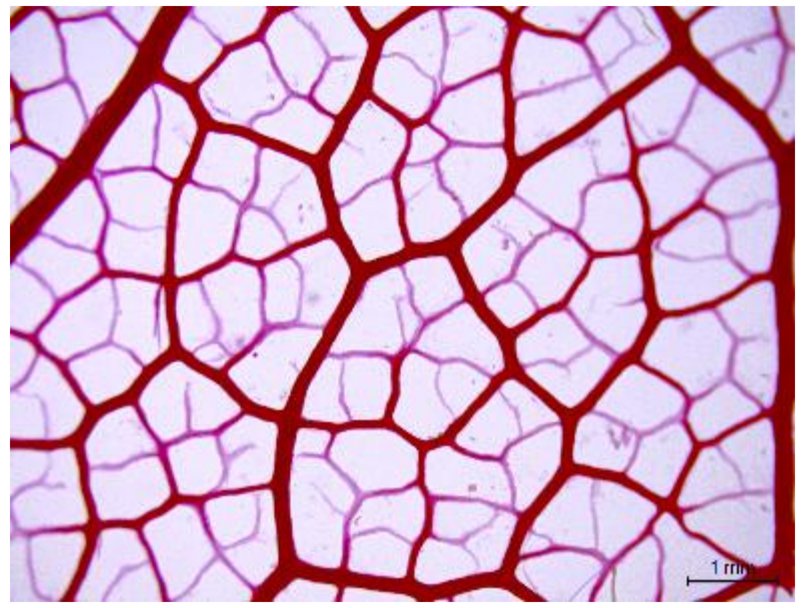

CCI: 6 – 152
Mean= 68
Chlorophyll content, μgcm-2
120
80
40
0
μmean = 67.94
μmean = 70.82
μmean = 70.25
μmean = 70.99
μmean = 67.36
μmean = 70.15
1 2 3 4 6 7
Plots

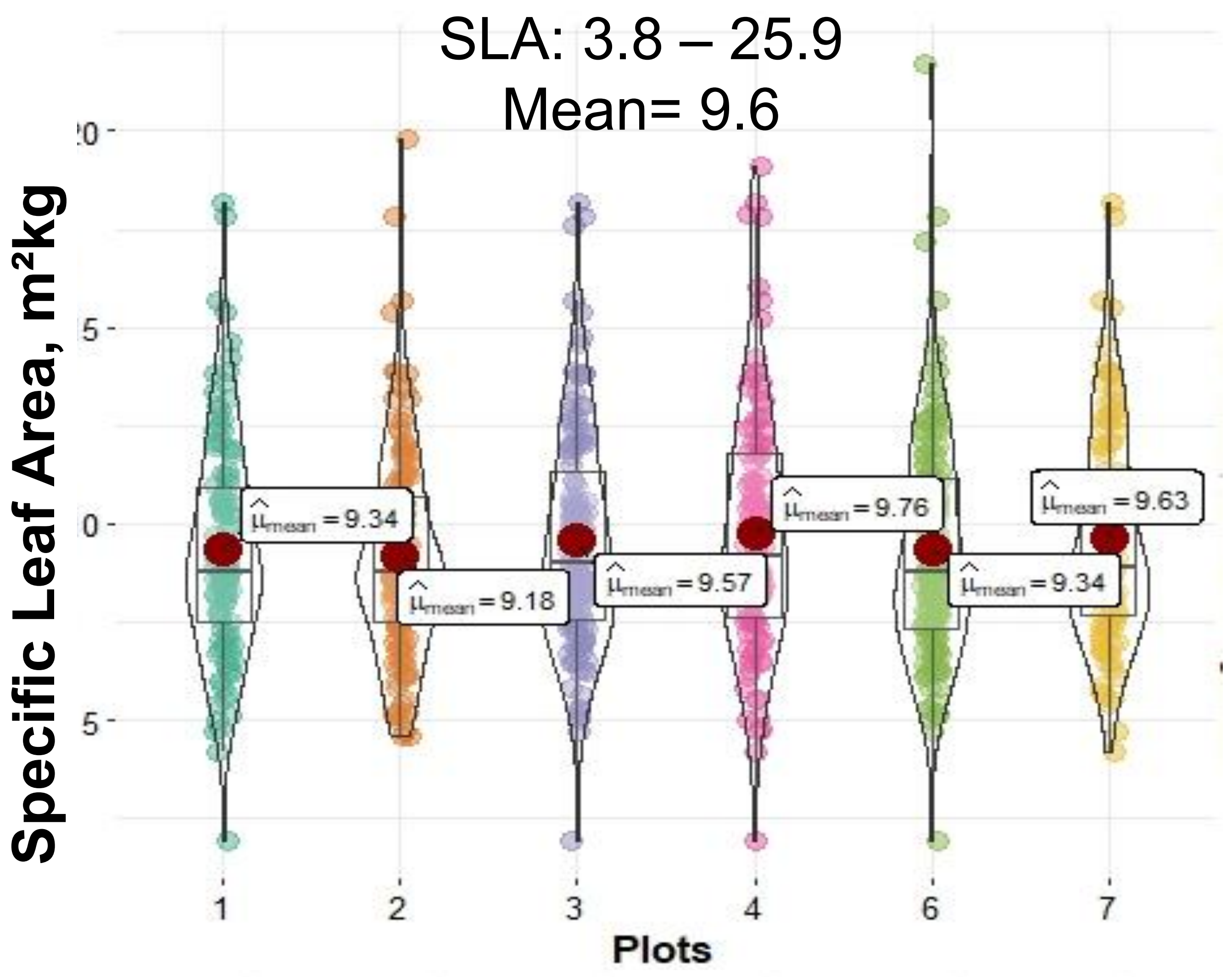

WD: 0.35 – 1.06
Mean= 0.69
Wood density, g cm-3
0.9
0.7
0.5
μmean = 0.70
μmean = 0.69
μmean = 0.69
μmean = 0.71
μmean = 0.70
μmean = 0.68
1 2 3 4 6 7
Plots

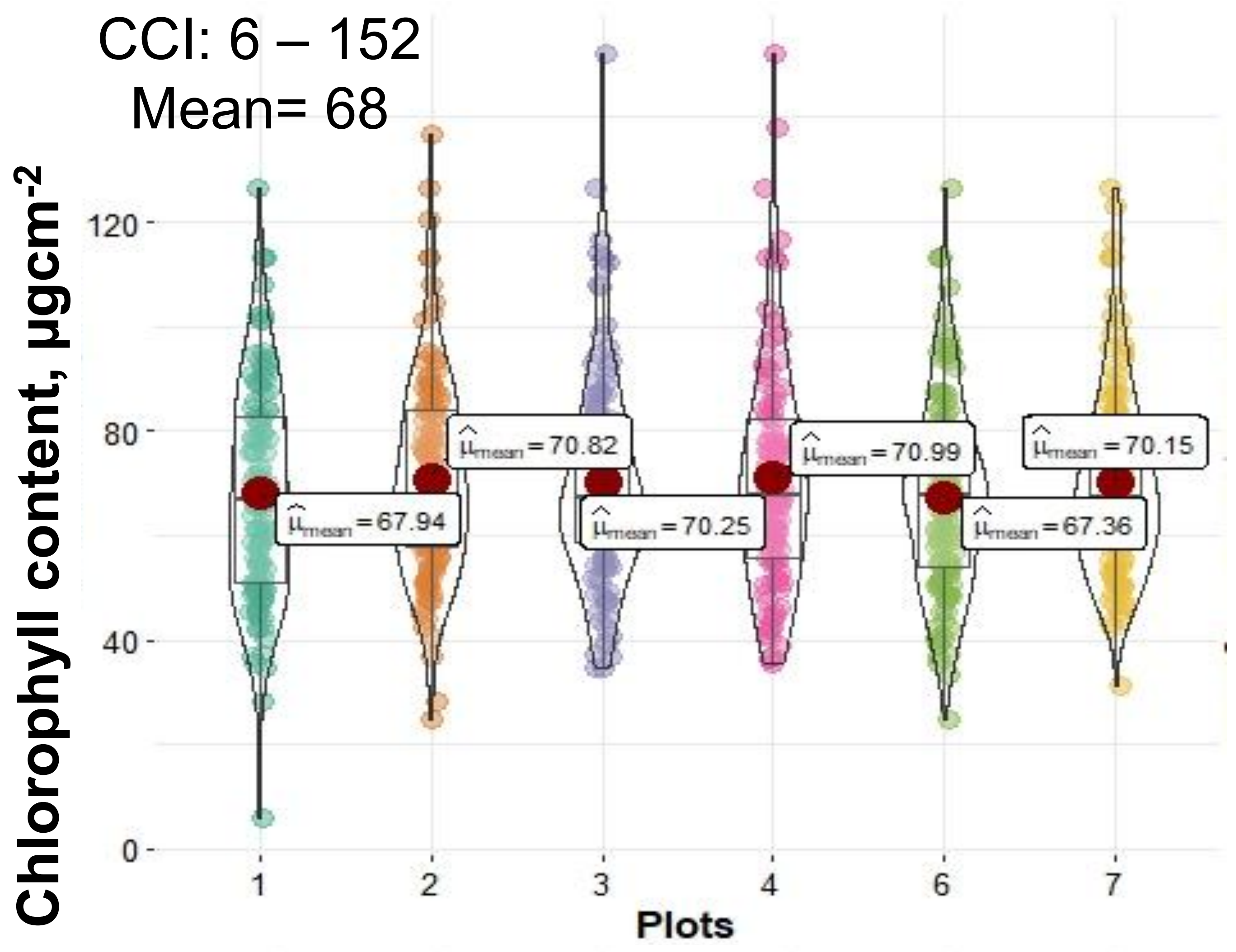

VD: 75 – 1413
Mean= 330
Leaf vein density
1000
500
μmean = 340.94
μmean = 327.13
μmean = 353.81
μmean = 367.35
μmean = 328.70
μmean = 340.55
1 2 3 4 6 7
Plots

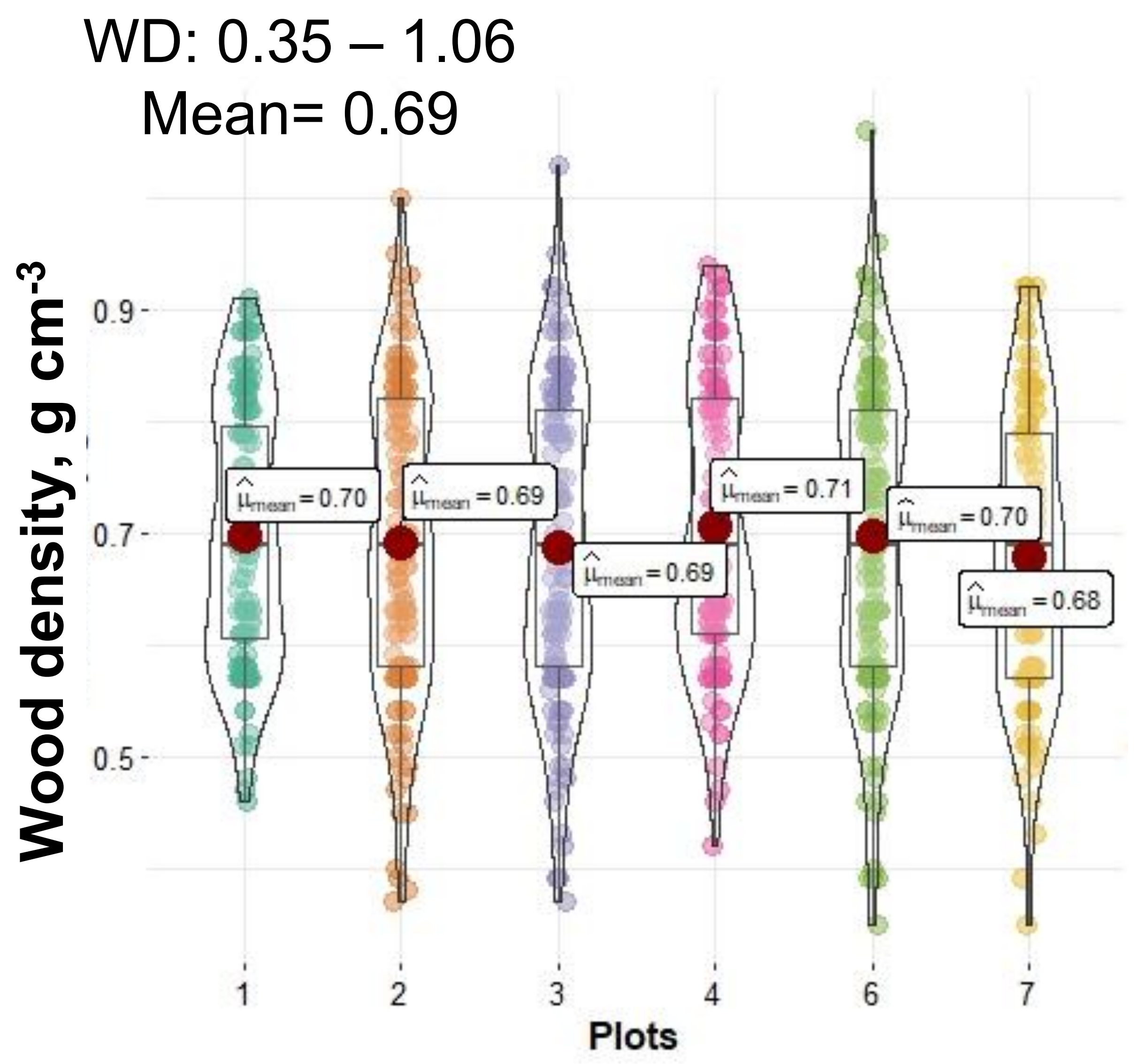


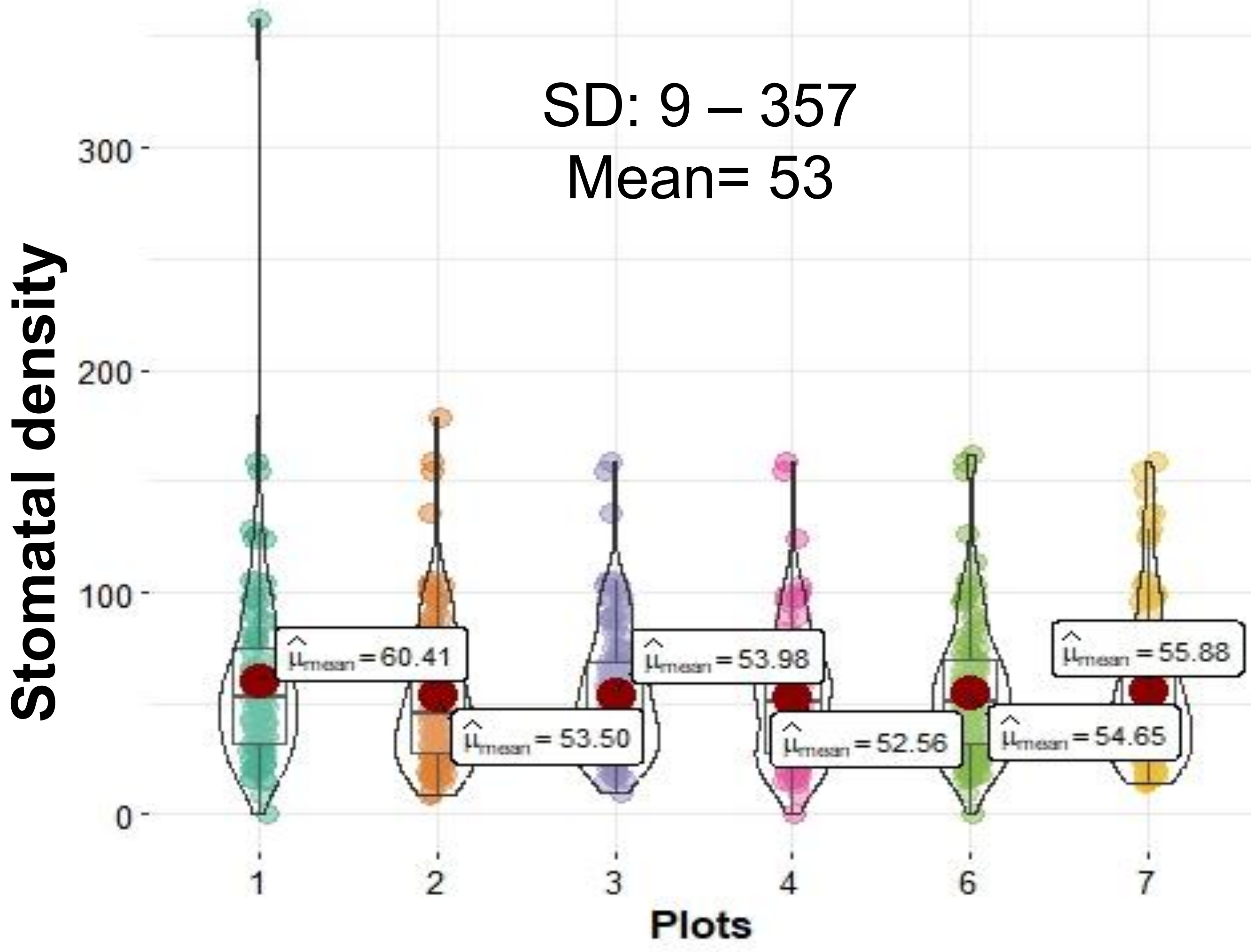


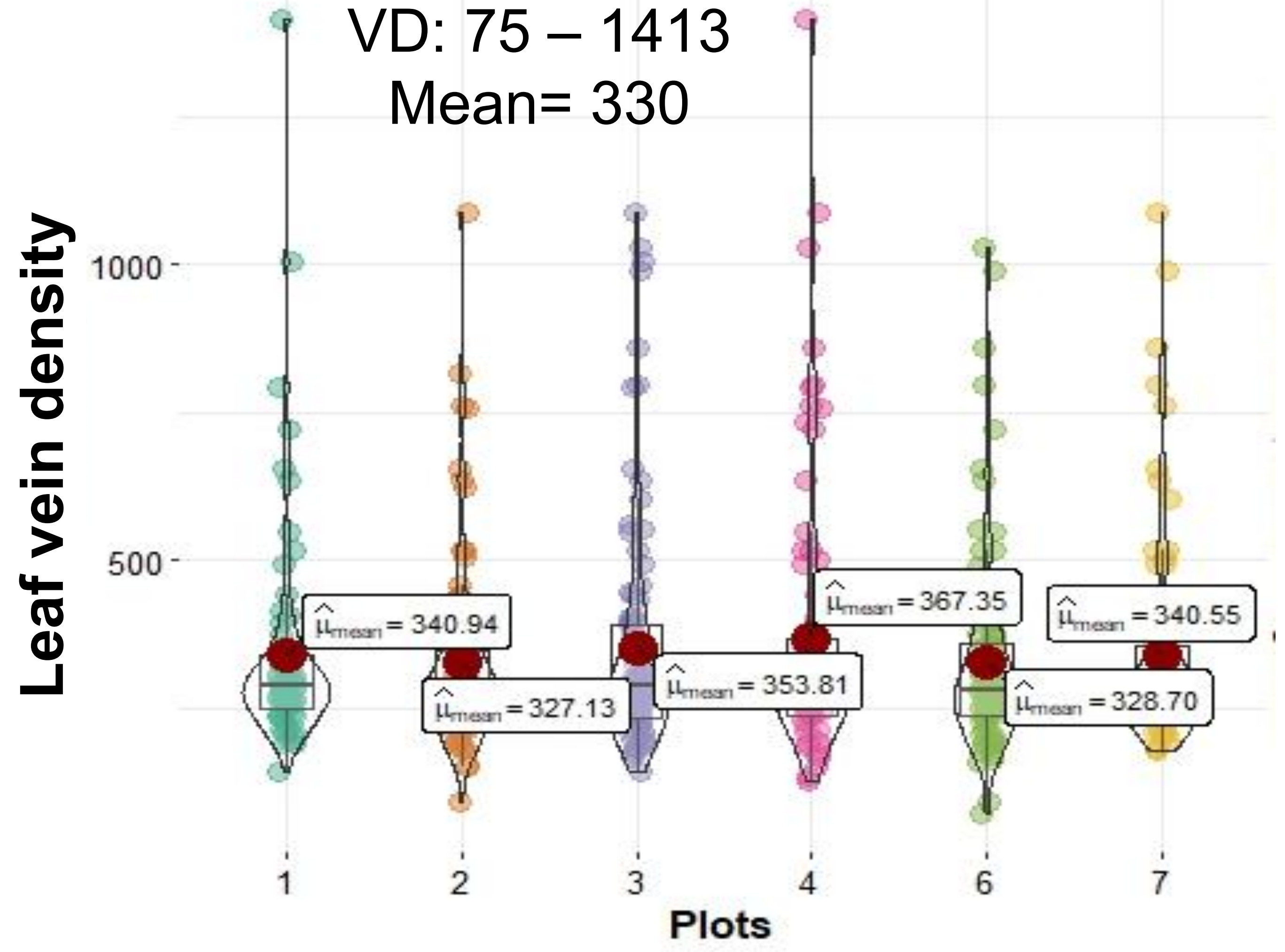


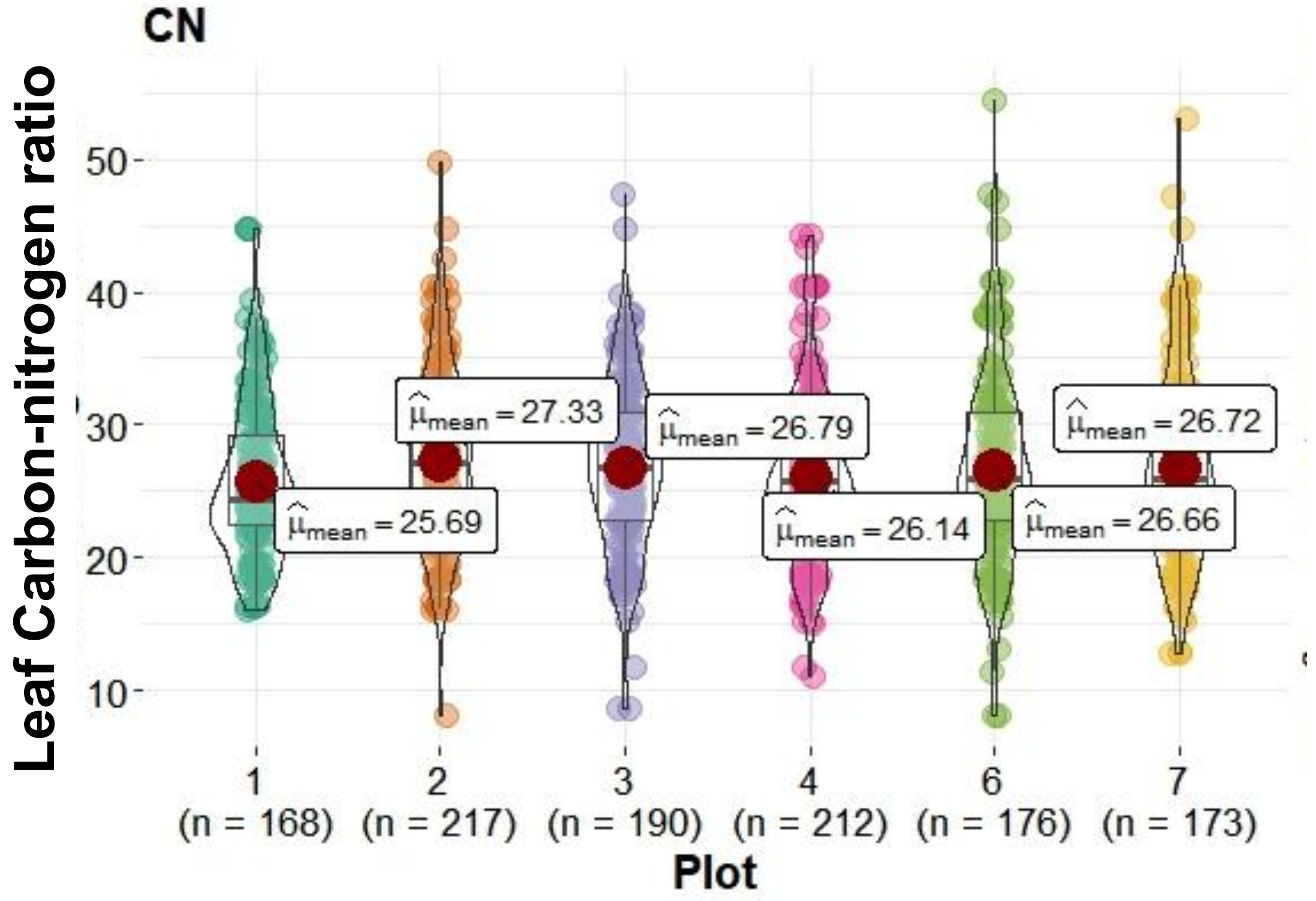










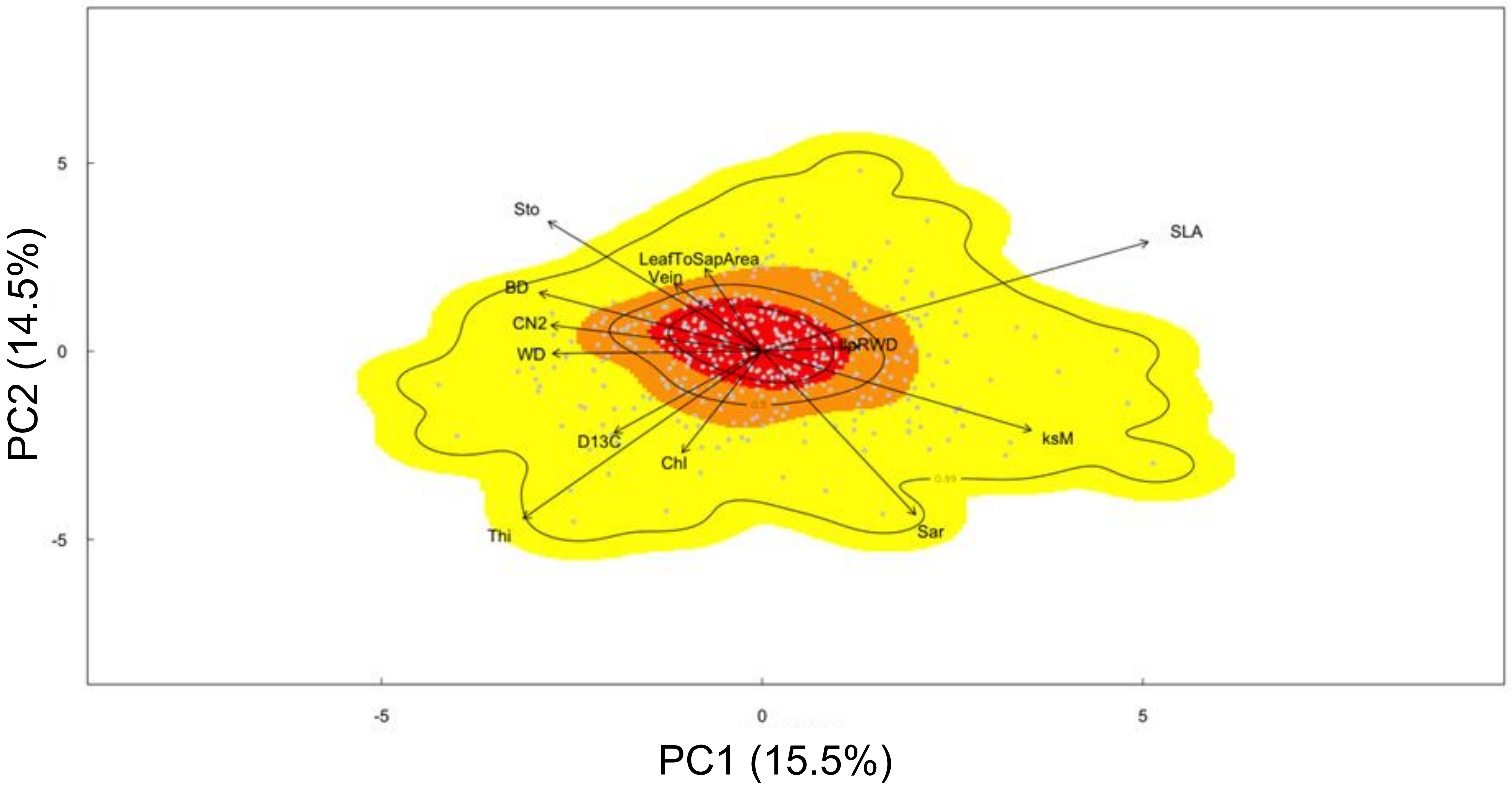


→ Large variation of functional traits between species

→ No significant difference between the plots

→ Functional diversity of AmazonFACE may play a key role on the ecosystem responses to eCO_2

Functional space



13 traits are used to assess AmazonFACE functional space

PC1: Resource-use strategy

→ Fast-growing, acquisitive species
Specific Leaf Area (SLA, 55.99%)
Xylem Conductivity (kmax, 27.19%)

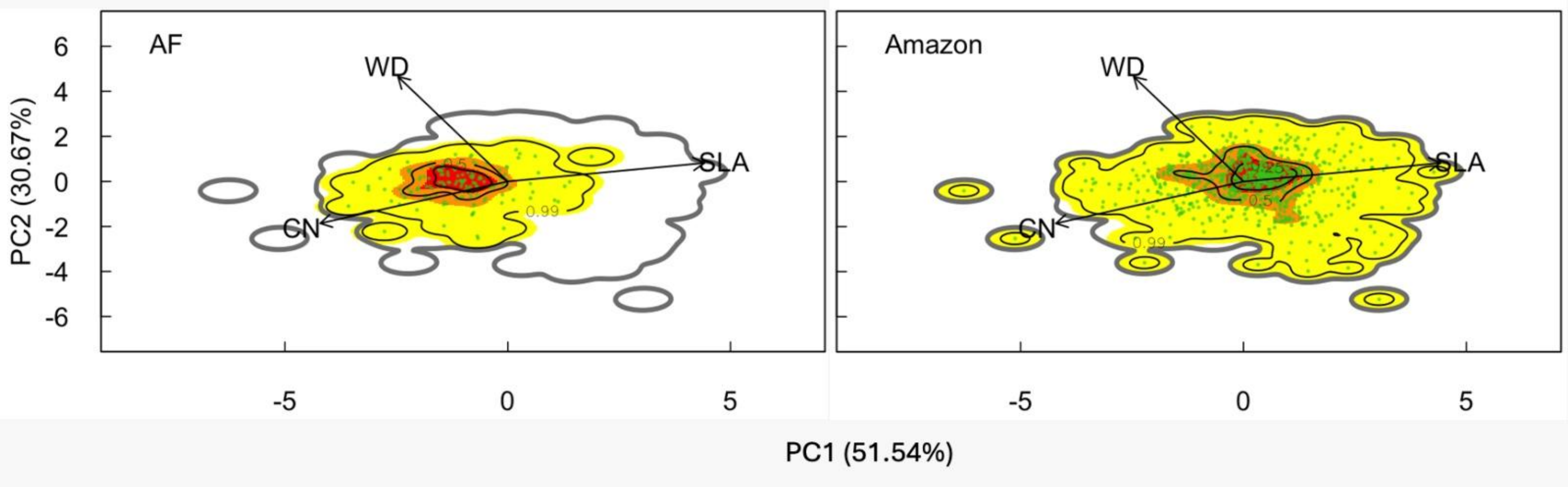
→ Conservative, drought-tolerant, structurally robust species
Wood Density (WD), Branch Density (BD), C:N ratio

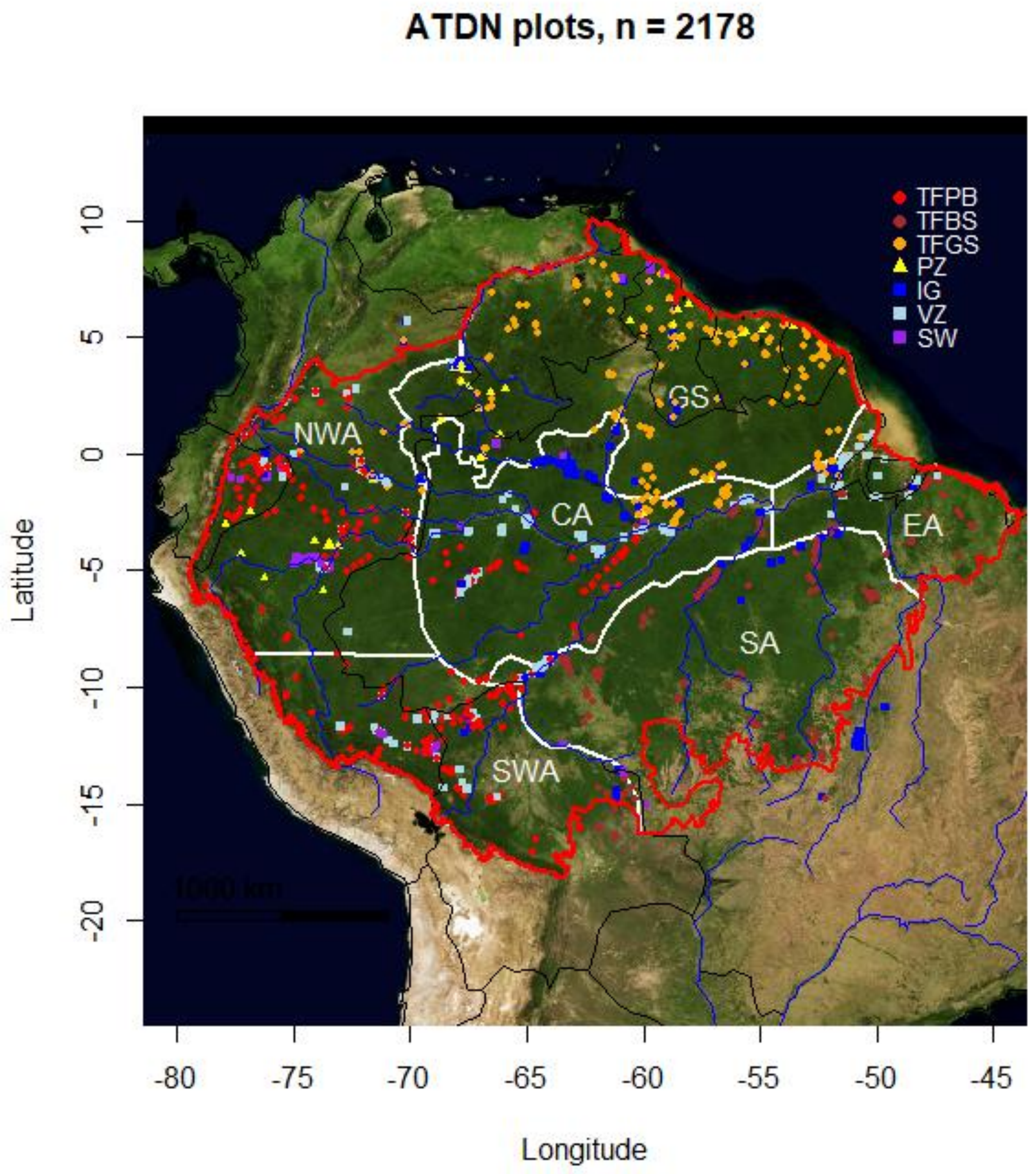
PC2: Leaf structure and gas exchange traits
→ Trade-offs in gas exchange strategies
Leaf Thickness (43.03%)
Stomatal Size (41.05%)
Density (25.88%)
Chlorophyll (15.81%)

Thick leaves + large stomata vs. High stomatal density + chlorophyll

🌿 Functional differentiation emerges even within a small spatial scale (>0,5 ha), highlighting diverse ecological strategies co-occurring in the same environment

Functional space
AmazonFACE x Amazon Basin





- subset of 3 common functional traits (C:N, WD and SLA)

→ 47% of overlapping

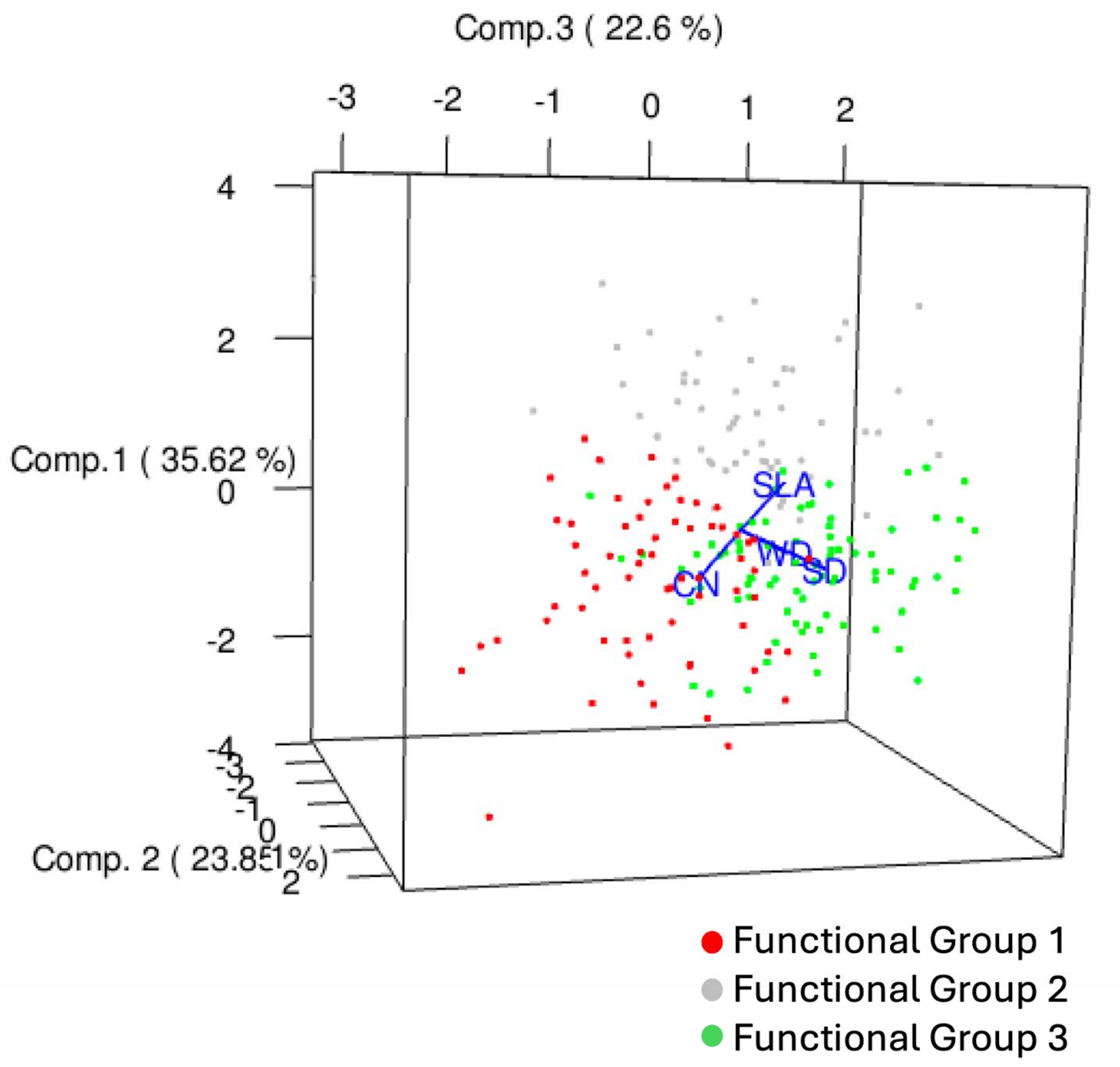
ter Steege, et al. 2025

Functional approach

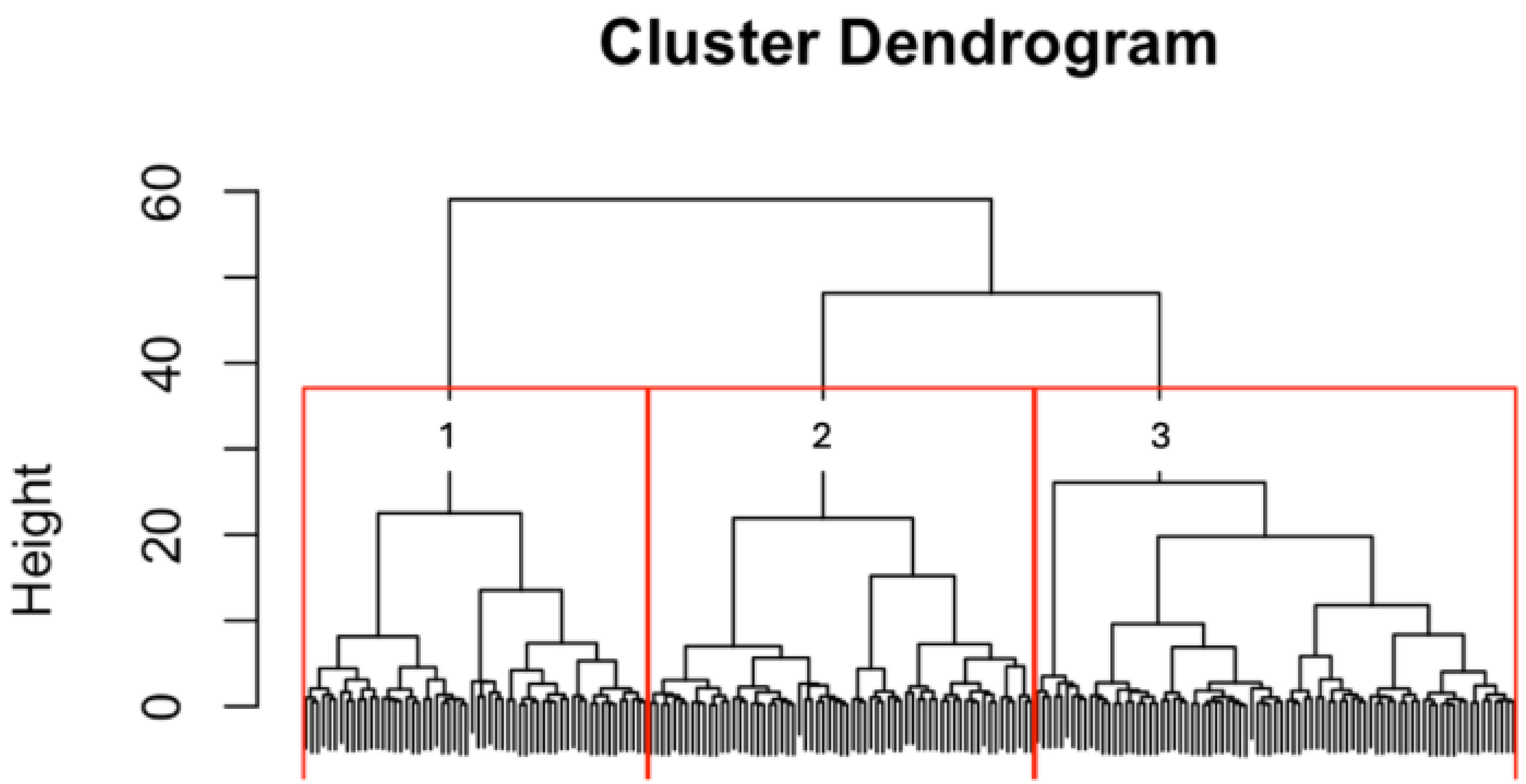
Ward's hierarchical method (R function 'hclust')

- Species are grouped based on:

  SLA, WD, C:N and **SD** traits



Group1 (red): resource-acquisitive species
Group2 (grey): Intermediate species
Group3 (green): resource-conservative



Group 1	Group 2	Group 3
Abuta grandifolia	Adenocalymma	Aniba canelilla
Alibertia claviflora	adenophorum	Aspidosperma excelsum
Amaioua glomerulata	Aniba santalodora	Astronium lecointei
Aniba megaphylla	Annona ambotay	Bocoa viridiflora
Aniba terminalis	Buchenavia grandis	Brosimum rubescens
Anisophyllea manausensis	Cedrelinga catenaeformis	Casearia javitensis
Calyptranthes paniculata	Chrysophyllum argenteum	Cordiera myrciifolia
Dacryodes cuspidata	Compsoneura ulei	Corythophora alta
Diospyros bullata	Cordia fallax	Couepia canomensis
Dodecastigma integrifolium	Cordia panicularis	Cupania hispida

Why it matters: Functional groups capture trait-based ecological strategies, enabling robust comparison of plant responses to elevated CO_2 despite high species diversity

Conclusions…

High **species diversity** is accompanied by **divergent trait strategies**, suggesting niche differentiation and functional complementarity even within small spatial area of tropical forest.

The AmazonFACE experiment captures around **47% of the functional diversity** observed across the Amazon.

Functional grouping is essential to evaluate CO_2 effects in hyperdiverse forests where **species-level replication is not feasible.**

In summary:

- ✓ **High species diversity** is accompanied by **divergent trait strategies**, suggesting niche differentiation and functional complementarity even within small spatial area of tropical forest.
- ✓ The AmazonFACE captures **~47% of the functional diversity** observed across the Amazon Basin.
- ✓ **Functional grouping** is help to evaluate CO_2 effects in hyperdiverse forests where species-level replication is not feasible

AmazonFACE
2025-2030
Science Plan

OBRIGADA!

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Scientific coordination:

AMAZONFACE
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UNICAMP
Met Office

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FNDCT Fundo Nacional de Desenvolvimento Científico e Tecnológico
Finep INOVAÇÃO E PESQUISA EMPRESA PÚBLICA DO MCTI
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GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

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