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Universidade de Brasília

UFLA
UNIVERSIDADE FEDERAL DE LAVRAS

Modeling Stomatal Conductance and Water-Use Efficiency in Planted Forests in Brazil

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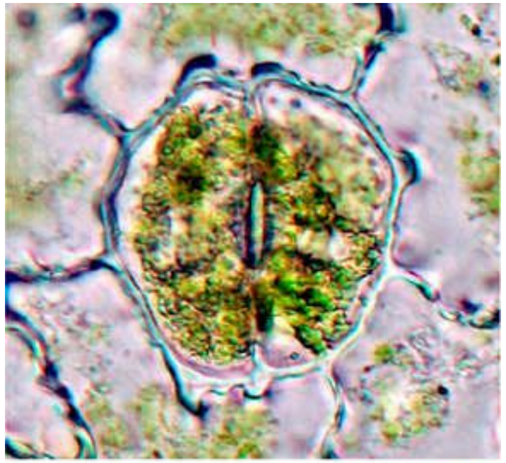
Introduction

- The exchange of carbon and water between the plant and the **atmosphere is regulated by the stomata**;



Balance between photosynthetic

- The stomata are also responsible for regulating the **biogeochemical cycles of carbon and water**;

Water use efficiency

Introduction

- Modeling photosynthesis and stomatal conductance

Essential for **predicting vegetation responses**

- Developing strategies for selecting **species and genotypes** in current and future scenarios.

- Several leaf-level models have been developed to **describe stomatal conductance (gs)**

✔ CO_2 concentration,
✔ Light,
✔ Temperature,
✔ Relative humidity,
✔ Vapor pressure deficit (VPD),
✔ Soil hydraulic potential.

Introduction

- The representation of stomatal conductance (gs)

- Component of **Earth system models (ESMs)**
- **Process-based models (PBMs).**

Understanding and predicting the implications of environmental disturbances at a global level.

Objectives

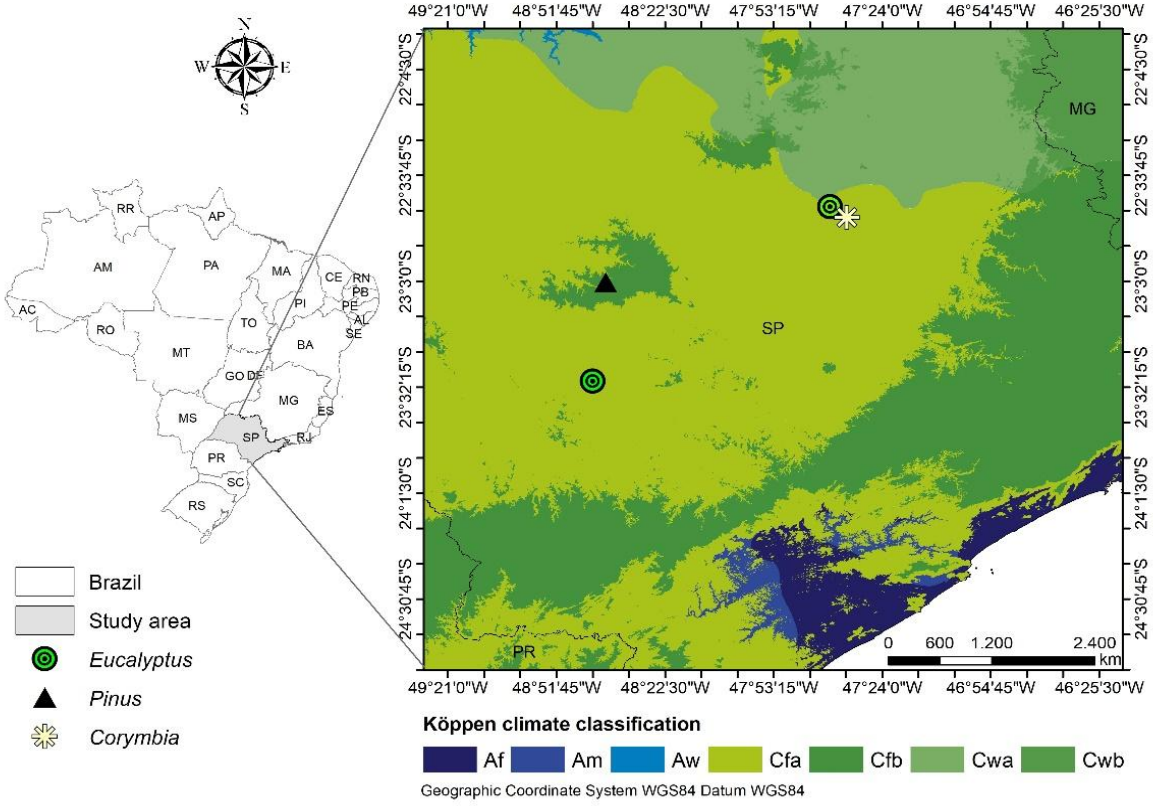
- To evaluate the applicability of three stomatal conductance models: (BB) model, (BBL) model and (USO) model;
- To identify the most suitable model using data collected from planted forests of *Pinus*, *Corymbia*, and *Eucalyptus* in Brazil;
- To analyze how stomatal conductance and water-use efficiency vary among genera (Pinus, Corymbia, and Eucalyptus) and across different Eucalyptus genotypes.

Methods

- 22 genotypes:

  - 19 genotypes of *Eucalyptus*,
  - 1 specie of *Corymbia*,
  - 2 species of *Pinus*

- Age: 6 a 60 months.



Map showing the location and distribution of experiments in Sao Paulo state—Brazil

Details of experimental data sets used in this study

Species/genotype	Clone	Experiment ID	Site of Location (city and state)	Age (months)	Condition	Tmean (Cº)	Rainfall (mm)	Lat. (ºS)	Long. (°W)
Eucalyptus sp	E1	1	Piracicaba- SP	36	Field	21.1	1253	-22,71	-47,63
Eucalyptus sp	E2	1	Piracicaba- SP	36	Field	21.1	1253	-22,71	-47,63
Eucalyptus sp	E3	1	Piracicaba- SP	36	Field	21.1	1253	-22,71	-47,63
E.grandis x E.urophylla	UG1	1	Piracicaba- SP	36	Field	21.1	1253	-22,71	-47,63
E. urophylla	U1	1	Piracicaba- SP	36	Field	21.1	1253	-22,71	-47,63
E.grandis	G1	1	Piracicaba- SP	36	Field	21.1	1253	-22,71	-47,63
E.grandis	G2	1	Piracicaba- SP	36	Field	21.1	1253	-22,71	-47,63
E. grandis x E. camaldulensis	GC	2	Buri-SP	14,7	Field	20.5	1180	-23,51	-48,7
E. grandis x E.sp	GS	2	Buri-SP	14,7	Field	20.5	1180	-23,51	-48,7
E. grandis x E.urophylla	UG2	2	Buri-SP	14,7	Field	20.5	1180	-23,51	-48,7
E. grandis x E.urophylla	UG3	2	Buri-SP	14,7	Field	20.5	1180	-23,51	-48,7
E. urophylla	U2	2	Buri-SP	14,7	Field	20.5	1180	-23,51	-48,7
E. urophylla	U3	2	Buri-SP	14,7	Field	20.5	1180	-23,51	-48,7
E. urophylla x E. brassiana	UB	2	Buri-SP	14,7	Field	20.5	1180	-23,51	-48,7
E.urophylla x E.grandis	UG4	3	Buri-SP	14,7	Field	20.5	1180	-23,51	-48,7
E.urophylla	U4	3	Piracicaba- SP	6	Nursery	21.1	1253	-22,71	-47,63
C. citriodora	CC	3	Piracicaba- SP	6	Nursery	21.1	1253	-22,71	-47,63
E.crebra	CB	3	Piracicaba- SP	6	Nursery	21.1	1253	-22,71	-47,63
E. grandis	G3	3	Piracicaba- SP	6	Nursery	21.1	1253	-22,71	-47,63
E.longirostrata	LG	3	Piracicaba- SP	6	Nursery	21.1	1253	-22,71	-47,63
P. caribaea	PC	4	Itatinga -SP	60	Field	22,5	1350	-23,05	-48,64
P. taeda	PT	4	Itatinga -SP	60	Field	22,5	1350	-23,05	-48,64

Stomatal conductance models

Ball-Berry (BB- Berry 1987)
Relative humidity

$$g_s = m + \frac{A_n H_s}{Cs} + g_0$$

Ball-Berry-Leuning (**BBL** – Leuning 1995)
leaf-to-air vapor pressure deficit (VPD)

$$g_s = g_0 \frac{mA_n}{\left(C_s - \Gamma\right)\left(1 + \frac{D}{D_0}\right)}$$

Model de otimização (**USO** – Medlyn et al. 2011)
theory of optimal stomatal behavior

$$g_s^* \approx 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a}$$

Methods

Database

- Gas Exchange Measurements: **(IRGA)**

- Leaf Selection
  - Fully expanded and Healthy condition

- Measurement Conditions: Time window: 8:00 a.m. – 15:00.
  Vapor Pressure Deficit (VPD)

Methods

Statistical analyses

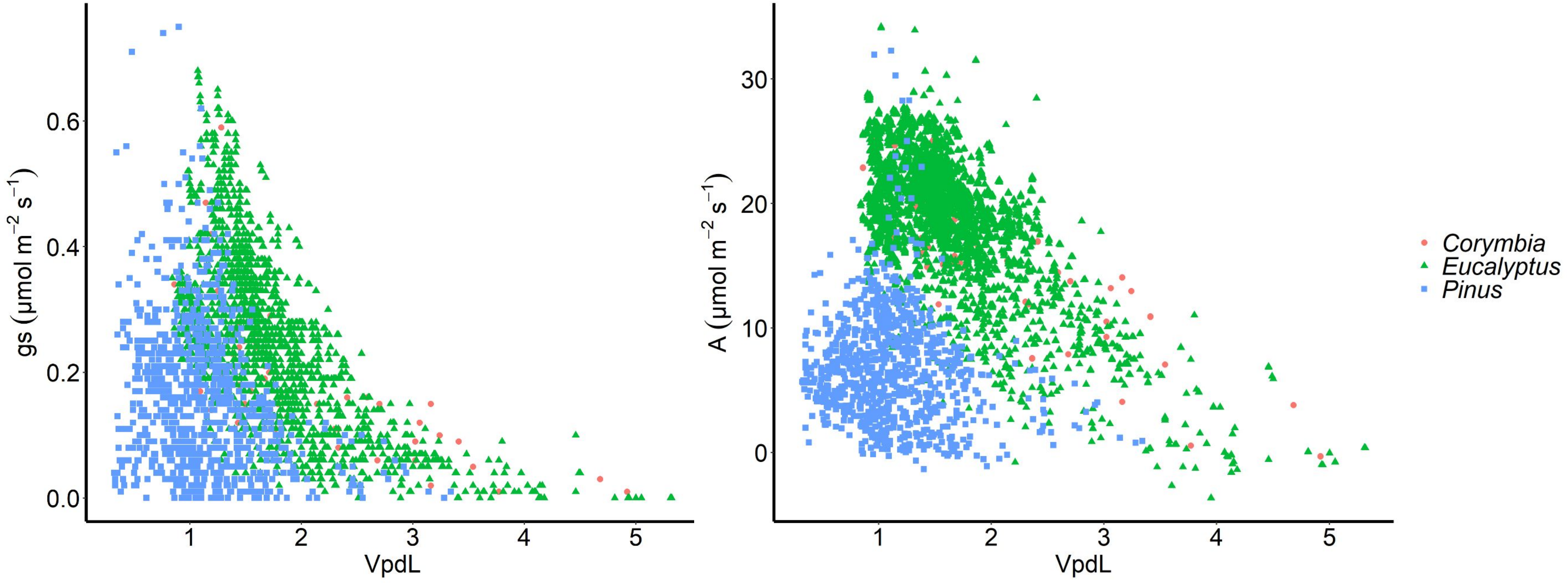
- Each dataset: using the **three stomatal conductance models: BB, BBL, and USO**.

- To evaluate the performance of the models: The R2, RMSE, and AIC.

- Models were fitted: **PLANTECOPHYS in R**
- We analyzed the effects of the genus (**Eucalyptus, Corymbia and Pinus), age, air temperature and precipitation on parameter g1**: (GLMM).

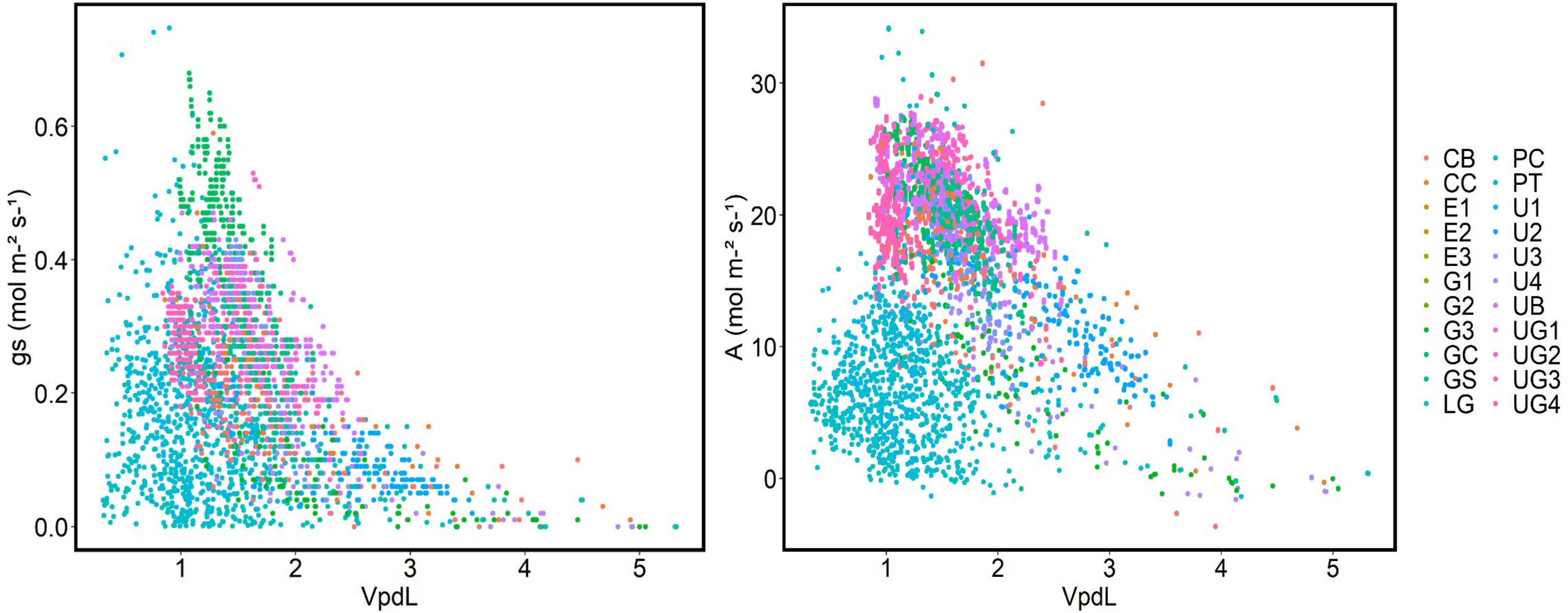
g1 ~ gênero * (idade + temp_mim + temp_máx + prec) + (1|Local)

Results



gs (μmol m^{-2} s^{-1})
0.6
0.4
0.2
0.0
1
2
3
4
5
VpdL
A (μmol m^{-2} s^{-1})
30
20
10
0
1
2
3
4
5
VpdL
Corymbia
Eucalyptus
Pinus

Results



0.0
0.2
0.4
0.6
gs (mol m⁻² s⁻¹)
1
2
3
4
5
VpdL
0
10
20
30
A (mol m⁻² s⁻¹)
VpdL
CB
CC
E1
E2
E3
G1
G2
G3
GC
GS
LG
PC
PT
U1
U2
U3
U4
UB
UG1
UG2
UG3
UG4

Results

Fitted models:

- The USO and BBL models showed good fits;

- BBL did not fit three datasets (eucalyptus U3, CC, ar
  - R^2 ranged from 0.47 to 0.95;

- The USO model had good metrics and fit all datasets
  - R^2 ranged from 0.43 to 0.95;

- The BB model performed worse than both the BBL and USO models.
  - R^2 ranged from 0.31 to 0.86.

Results

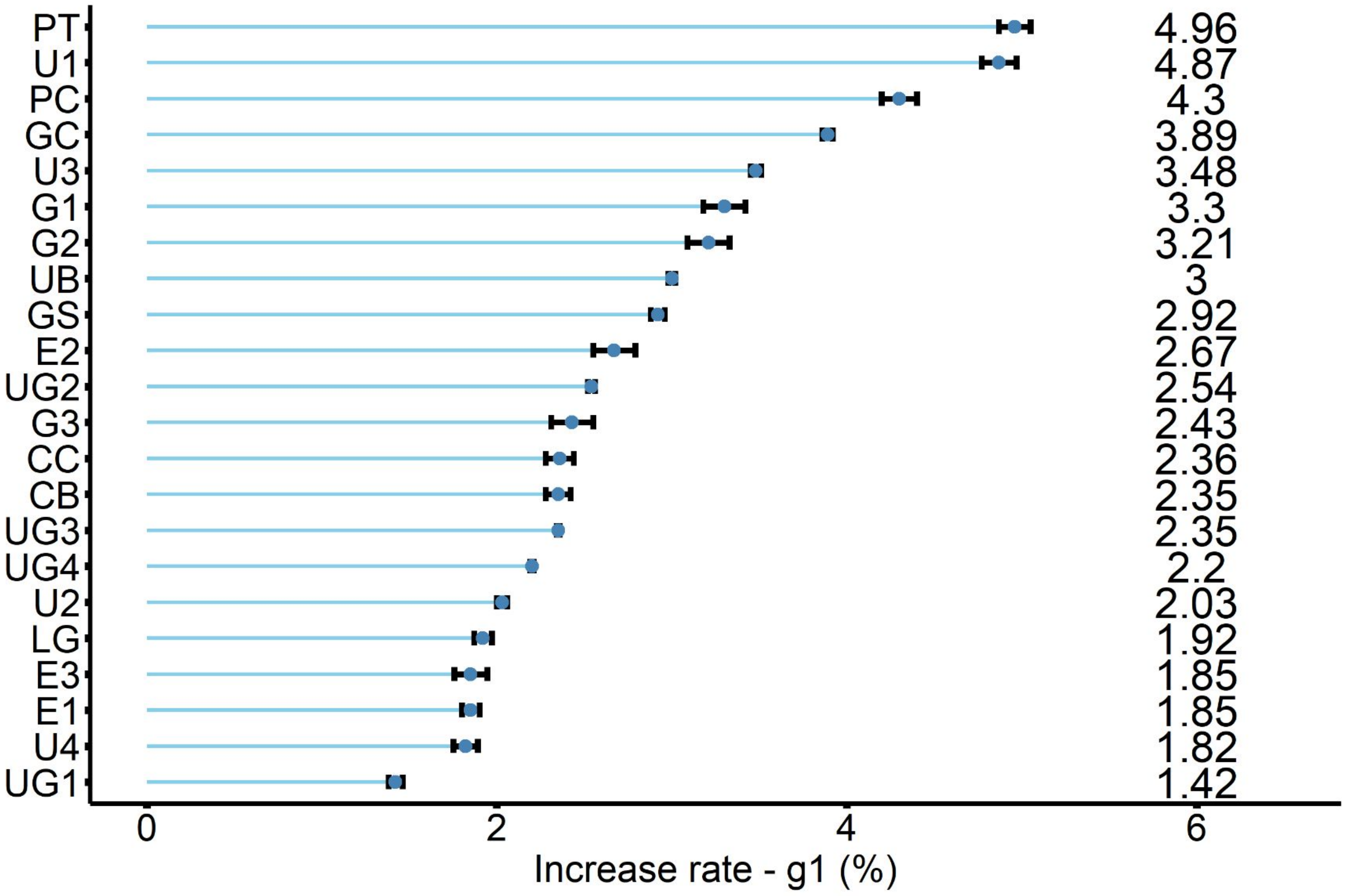
Average values and standard errors for g1 parameter in each genus

Genus	g1
Pinus	4.63 ±0.46a
Eucalyptus	2.63 ±0.84b
Corymbia	2.36b

The parâmetro g1: proxy for WUE.

Results

Water-use efficiency and g1 across genotypes



E. grandis × E. urophylla

Conclusions

- The BBL and USO models showed the best performance for Brazilian forest plantations;
- Eucalyptus genotypes and the *Eucalyptus* and *Pinus* groups exhibited different stomatal responses;
- gl database was obtained using the three most commonly used models in ESMS and PBMs;
- There is a need to expand stomatal conductance **modeling studies in planted forests in Brazil.**

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Agradecimentos

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Obrigada!
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