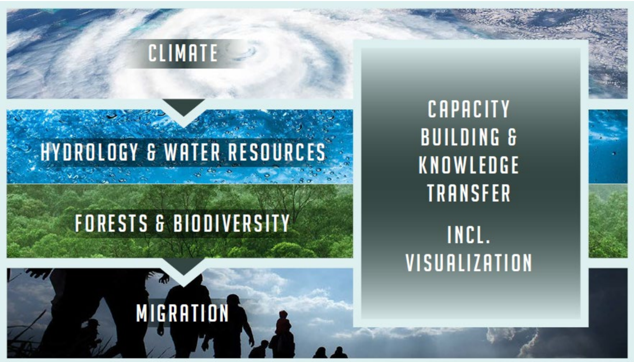
B-EPICC kick-off workshop Brazil Aug 16-18, 2022 @ INPE

Session: ‘Climate Services and Forests&Biodiversity’

9:45am	**Climate Services and Forest & Biodiversity**
	• **Ms Sarah Bereswill** (Potsdam Institute for Climate Impact Research (PIK), GER) *Modeling forest dynamics and biodiversity under climate change* • **Dr. Celso von Bandow** (Center for Earth System Science, Instituto Nacional de Pesquisas Espaciais (INPE), BRA)) *Modeling land use change and impacts in carbon and water fluxes in Brazilian biomes*
10:45am	***Morning Tea***
11:15am	**Climate Services and Forest & Biodiversity** - continued
	• **Dr. Luiz Aragão** (Instituto Nacional de Pesquisas Espaciais (INPE), Head of Earth Observation and Geoinformatics Division, TREES lab) *Dynamics of Forest Carbon from environmental change in Amazônia* • **Prof. Pedro H.S. Brancalion (**Dept. of Forest Sciences, 'Luiz de Queiroz' College of Agriculture, University of São Paulo (USP)) *Restoration of tropical forest multifunctionality (via Zoom)* • **Ms Sarah Bereswill** (Potsdam Institute for Climate Impact Research (PIK), GER) *wrap up and discussion*
12:30pm	**Concluding Remarks**

B-EPICC
BRAZIL EAST AFRICA PERU INDIA CLIMATE CAPACITIES



Modelling tropical forests and biodiversity under climate change

Sarah Bereswill, Kirsten Thonicke, Boris Sakschewski,
Maik Billing, Markus Drüke, Werner von Bloh

B-EPICC

BRAZIL EAST AFRICA PERU INDIA CLIMATE CAPACITIES

PIK

1. Introduction

Ecosystems in Transition (EST)

Tapajós National Forest, Brazil (c) Kirsten Thonicke

- Strong modeling capabilities
- Fire
- Biodiversity

Key research objectives

Our research focuses on the following three aspects

- Functional diversity, elasticity of ecosystems and ecological tipping points
- Impacts of extreme events and (fire) disturbances on ecosystems
- Shifts in ecosystem services, role of natural vegetation and climate regulation services

As each of these research topics shows strong implications on the others, we are aiming for a high level of integration.

Kirsten Thonicke
Deputy Head of Research Department
Earth System Analysis

Ana Cano-Crespo
Scientist
Doctoral Researcher
Earth System Analysis

Werner von Bloh
Senior Scientist
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Sarah Bereswill
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Markus Drüke
Postdoctoral Researcher
Earth System Analysis

Boris Sakschewski
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Maik Billing
Doctoral Researcher
Earth System Analysis

P I K

https://www.pik-potsdam.de/en/institute/departments/earth-system-analysis/research/ecosystems-in-transition

B-EPICC's workpackage on Forests & Biodiversity in Brazil

Important contribution of forest recovery for climate change mitigation

Goals

- Identify contribution of forest recovery to ecosystem services **carbon storage, local climate regulation**
- Investigate **recovery of functional biodiversity**
- Simulate forest recovery trajectories under the impact of **climate change**

Tools

LPJmL FIT model

Communication and application

Stakeholders, communication

Background – Potential of secondary forests: C sink potential

ARTICLE

https://doi.org/10.1038/s41467-021-22050-1 OPEN

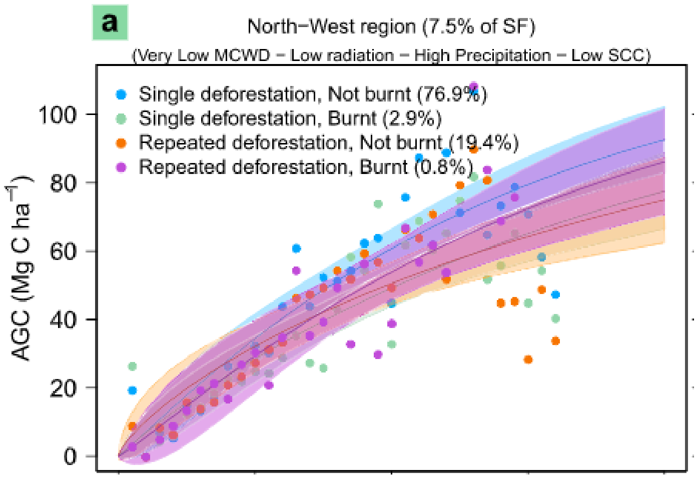
Check for updates

Large carbon sink potential of secondary forests in the Brazilian Amazon to mitigate climate change

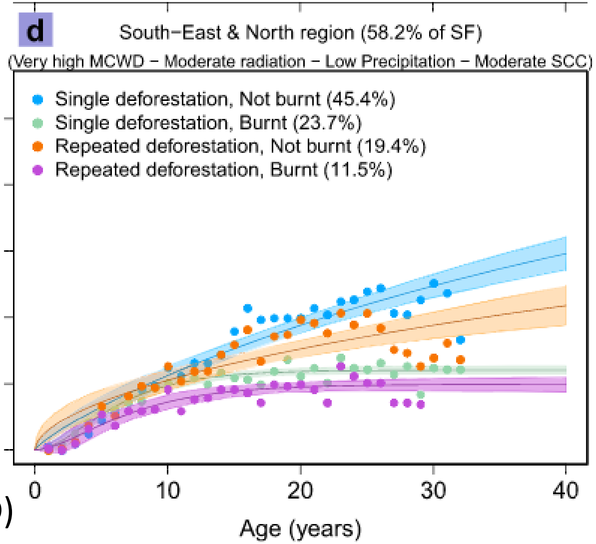
Viola H. A. Heinrich[1✉], Ricardo Dalagnol[2], Henrique L. G. Cassol[2], Thais M. Rosan[3], Catherine Torres de Almeida[2], Celso H. L. Silva Junior[2], Wesley A. Campanharo[2], Joanna I. House[1,4], Stephen Sitch[3], Tristram C. Hales[5], Marcos Adami[6], Liana O. Anderson[7] & Luiz E. O. C. Aragão[2,3]

Climatic conditions and repeated disturbance may lower C sink potential of secondary forests

Heinrich et al., 2021



Low Maximum Climatic Water Deficit (MCWD)

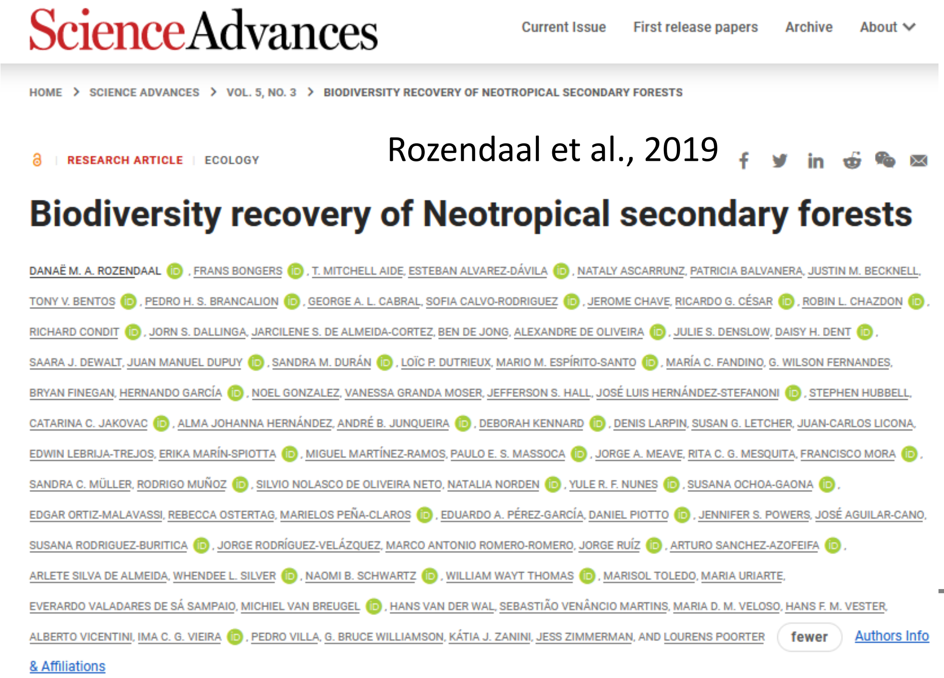


High Maximum Climatic Water Deficit (MCWD)

Single vs. Repeated deforestation, burnt or not burnt

Background – Potential of secondary forests: Biodiversity recovery

- Secondary forests recover remarkably fast in species richness but slowly in species composition
- Secondary forests take a median time of five decades to recover the species richness of old-growth forest (80% recovery after 20 years)
- Full recovery of species composition takes centuries (only 34% recovery after 20 years)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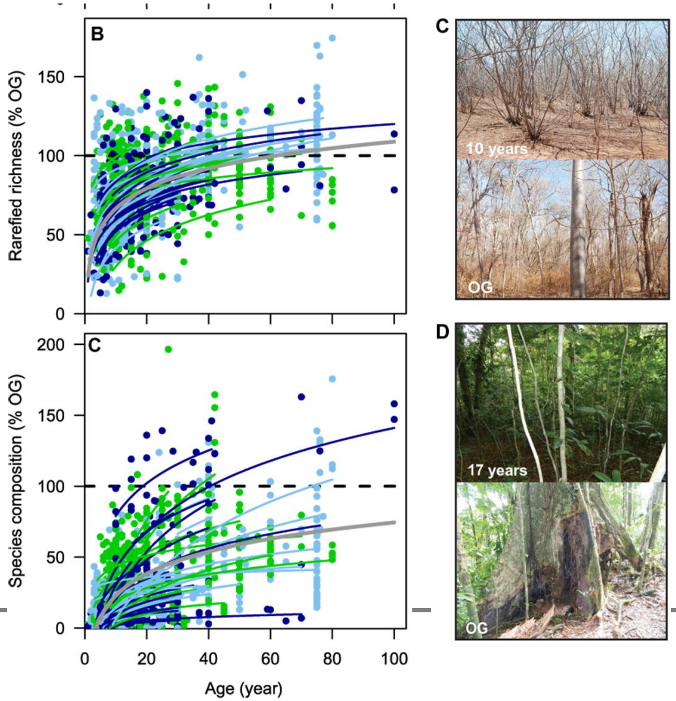
HOME > SCIENCE ADVANCES > VOL. 5, NO. 3 > BIODIVERSITY RECOVERY OF NEOTROPICAL SECONDARY FORESTS

RESEARCH ARTICLE | ECOLOGY

Biodiversity recovery of Neotropical secondary forests

DANAË M. A. ROZENDAAL, FRANS BONGERS, T. MITCHELL AIDE, ESTEBAN ALVAREZ-DÁVILA, NATALY ASCARRUNZ, PATRICIA BALVANERA, JUSTIN M. BECKNELL, TONY V. BENTOS, PEDRO H. S. BRANCALION, GEORGE A. L. CABRAL, SOFIA CALVO-RODRIGUEZ, JEROME CHAVE, RICARDO G. CÉSAR, ROBIN L. CHAZDON, RICHARD CONDIT, JORN S. DALLINGA, JARCILENE S. DE ALMEIDA-CORTEZ, BEN DE JONG, ALEXANDRE DE OLIVEIRA, JULIE S. DENSLOW, DAISY H. DENT, SAARA J. DEWALT, JUAN MANUEL DUPUY, SANDRA M. DURÁN, LOÏC P. DUTRIEUX, MARIO M. ESPÍRITO-SANTO, MARÍA C. FANDINO, G. WILSON FERNANDES, BRYAN FINEGAN, HERNANDO GARCÍA, NOEL GONZALEZ, VANESSA GRANDA MOSER, JEFFERSON S. HALL, JOSÉ LUIS HERNÁNDEZ-STEFANONI, STEPHEN HUBBELL, CATARINA C. JAKOVAC, ALMA JOHANNA HERNÁNDEZ, ANDRÉ B. JUNQUEIRA, DEBORAH KENNARD, DENIS LARPIN, SUSAN G. LETCHER, JUAN-CARLOS LICONA, EDWIN LEBRIJA-TREJOS, ERIKA MARÍN-SPIOTTA, MIGUEL MARTÍNEZ-RAMOS, PAULO E. S. MASSOCA, JORGE A. MEAVE, RITA C. G. MESQUITA, FRANCISCO MORA, SANDRA C. MÜLLER, RODRIGO MUÑOZ, SILVIO NOLASCO DE OLIVEIRA NETO, NATALIA NORDEN, YULE R. F. NUNES, SUSANA OCHOA-GAONA, EDGAR ORTIZ-MALAVASSI, REBECCA OSTERTAG, MARIELOS PEÑA-CLAROS, EDUARDO A. PÉREZ-GARCÍA, DANIEL PIOTTO, JENNIFER S. POWERS, JOSÉ AGUILAR-CANO, SUSANA RODRIGUEZ-BURITICA, JORGE RODRÍGUEZ-VELÁZQUEZ, MARCO ANTONIO ROMERO-ROMERO, JORGE RUÍZ, ARTURO SANCHEZ-AZOFEIFA, ARLETE SILVA DE ALMEIDA, WHENDEE L. SILVER, NAOMI B. SCHWARTZ, WILLIAM WAYT THOMAS, MARISOL TOLEDO, MARIA URIARTE, EVERARDO VALADARES DE SÁ SAMPAIO, MICHIEL VAN BREUGEL, HANS VAN DER WAL, SEBASTIÃO VENÂNCIO MARTINS, MARIA D. M. VELOSO, HANS F. M. VESTER, ALBERTO VICENTINI, IMA C. G. VIEIRA, PEDRO VILLA, G. BRUCE WILLIAMSON, KÁTIA J. ZANINI, JESS ZIMMERMAN, AND LOURENS POORTER fewer Authors Info & Affiliations

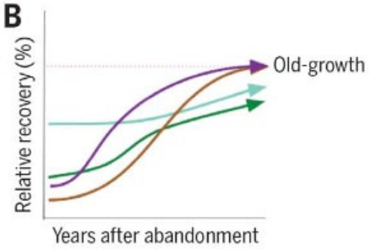
Rozendaal et al., 2019



Background – Potential of secondary forests: C sink and biodiversity recovery

Key questions:

- **Which forest attributes take how long to recover?**
- **Under which conditions?**



Poorter et al., 2021

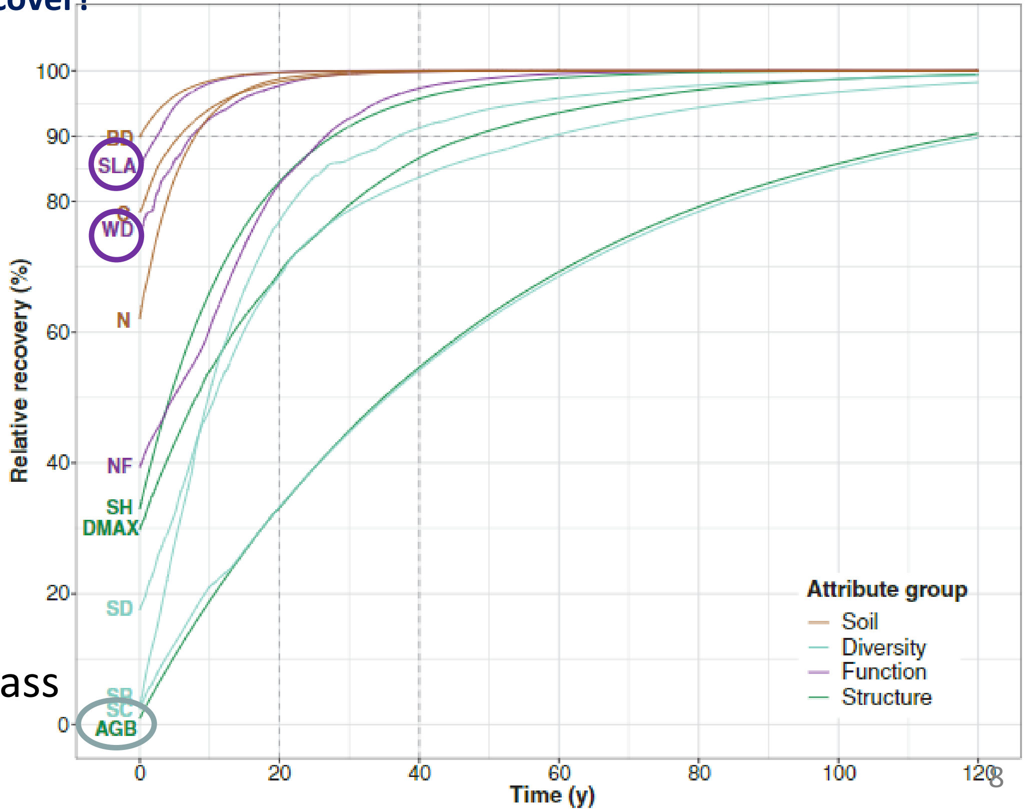
FOREST ECOLOGY

Multidimensional tropical forest recovery

Lourens Poorter[1]*, Dylan Craven[2], Catarina C. Jakovac[1,3], Masha T. van der Sande[1], Lucy Amissah[4], Frans Bongers[1], Robin L. Chazdon[5,6], Caroline E. Farrior[7], Stephan Kambach[8], Jorge A. Meave[9], Rodrigo Muñoz[1,9], Natalia Norden[10], Nadja Rüger[8,11,12], Michiel van Breugel[13,14,15], Angélica María Almeyda Zambrano[16], Bienvenu Amani[17], José Luis Andrade[18], Pedro H. S. Brancalion[19], Eben N. Broadbent[20], Hubert de Foresta[21], Daisy H. Dent[12,22], Géraldine Derroire[23], Saara J. DeWalt[24], Juan M. Dupuy[18], Sandra M. Durán[25,26], Alfredo C. Fantini[27], Bryan Finegan[28], Alma Hernández-Jaramillo[2], José Luis Hernández-Stefanoni[18], Peter Hietz[30], André B. Junqueira[31], Justin Kassi N'dja[32],

diversity

biomass



SSPs for Brazil

Work at INPE:

- regional adaptation of SSPs for Brazil (Bezerra et al., 2022)
- Land-use emissions NDCs (Wiltshire et al., 2022)

RESEARCH ARTICLE

New land-use change scenarios for Brazil: Refining global SSPs with a regional spatially-explicit allocation model

Francisco Gilney Silva Bezerra[1¤]*, Celso Von Randow[1¤], Talita Oliveira Assis[1¤], Karine Rocha Aguiar Bezerra[1¤], Graciela Tejada[1¤], Aline Anderson Castro[1¤], Diego Melo de Paula Gomes[1¤], Rodrigo Avancini[1¤], Ana Paula Aguiar[1,2¤]

1 General Cordination of Earth Sciences, National Institute for Space Research (INPE), São José dos Campos, SP, Brazil, 2 Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden

Received: 29 April 2021 | Revised: 22 December 2021 | Accepted: 26 December 2021

DOI: 10.1002/cli2.31

Climate Resilience and Sustainability
Interdisciplinary Approaches Towards Solutions for Climate Change
Open Access
RMetS

ORIGINAL ARTICLE

Understanding the role of land-use emissions in achieving the Brazilian Nationally Determined Contribution to mitigate climate change

Andrew J. Wiltshire[1,2] | Celso von Randow[3] | Thais M. Rosan[2] | Graciela Tejada[3] | Aline A. Castro[3]

- How can secondary forests (focus on natural regrowth) contribute to Brazils NDCs
- Given the future projections

2. Tools – Modeling Capabilities at PIK
Potsdam Institute for Climate Impact Resesarch

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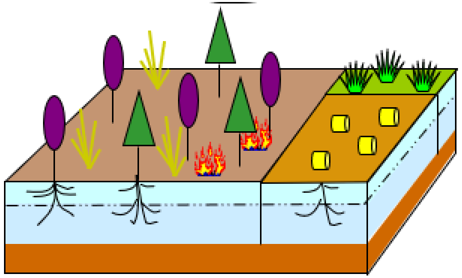
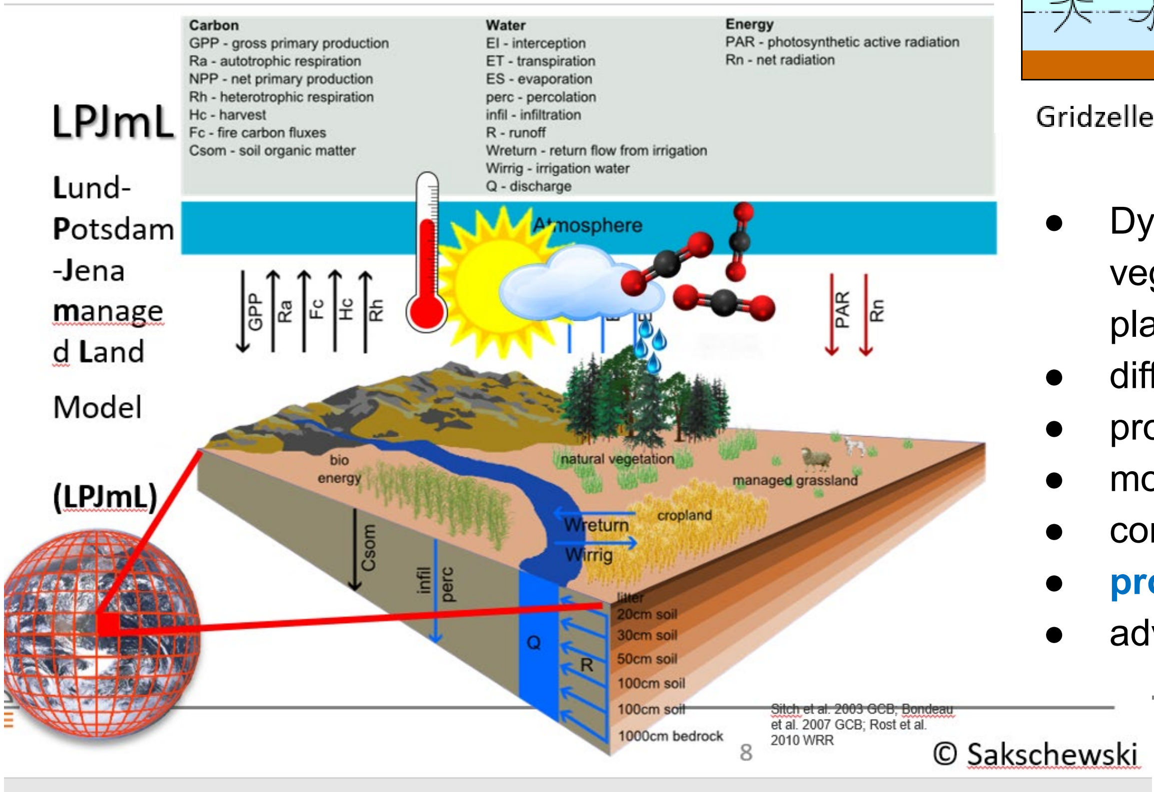
Modeling capabilities at PIK / **Dynamic Global Vegetation Models**

LPJmL (Lund-Potsdam-Jena managed Land)



Gridzelle: 0.5° x 0.5°

- Fire, landuse, natural vegetation
- PFT plant functional types
- Big leaf approach



- Dynamics of both natural and managed vegetation (agriculture, bioenergy plantations, irrigation)
- different plant functional types (PFTs)
- productivity
- mortality
- competition
- **process-based fire model (SPITFIRE)**
- advanced land use

SPITFIRE Model fully coupled to LPJmL

https://gmd.copernicus.org/articles/12/5029/2019/

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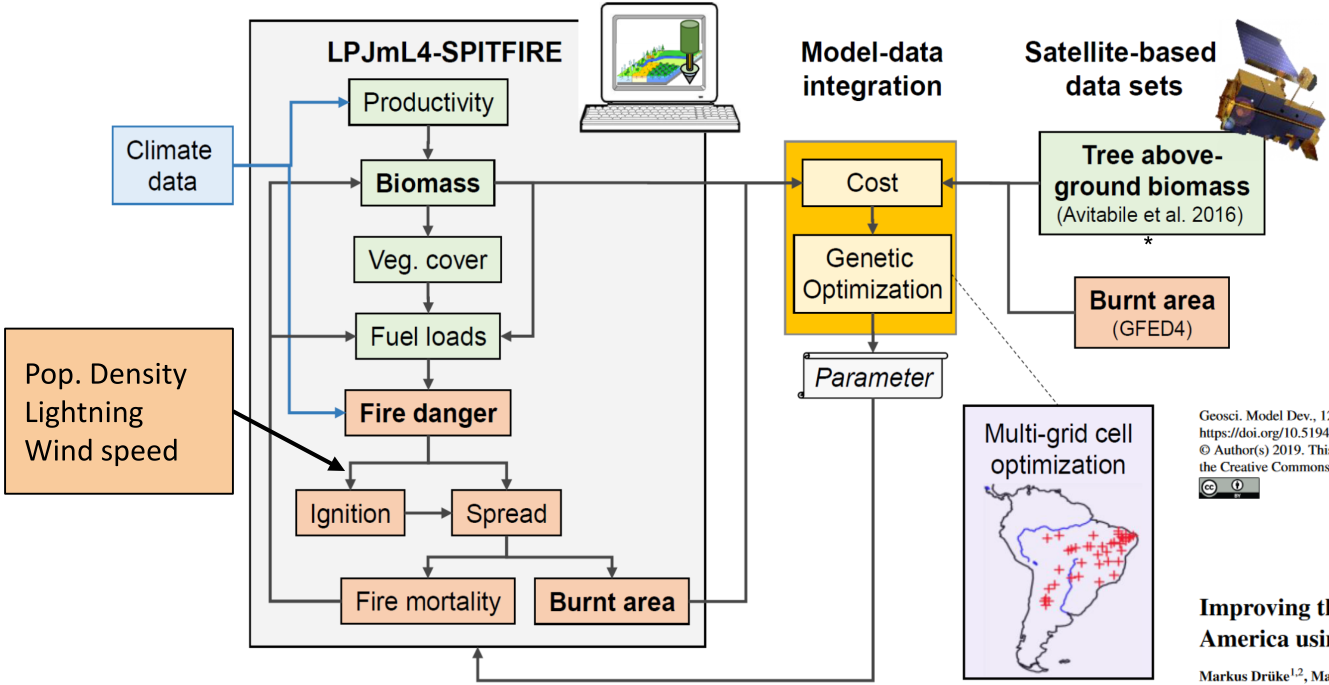
SPITFIRE - SPread and InTensity of FIRE in LPJmL



Markus Drüke

Postdoctoral Researcher

Earth System Analysis

Geosci. Model Dev., 12, 5029–5054, 2019
https://doi.org/10.5194/gmd-12-5029-2019

Geoscientific Model Development
Open Access

Improving the LPJmL4-SPITFIRE vegetation–fire model for South America using satellite data

Markus Drüke[1,2], Matthias Forkel[3], Werner von Bloh[1], Boris Sakschewski[1], Manoel Cardoso[4], Mercedes Bustamante[5], Jürgen Kurths[1,2], and Kirsten Thonicke[1]

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[4]Instituto Nacional de Pesquisas Espaciais, Av. dos Astronautas, 1.758 – Jardim da Granja, 12227-010, São José dos Campos, São Paulo, Brazil
[5]Instituto de Ciências Biologicas, Universidade de Brasília, Campus Universitário Darcy Ribeiro – Asa Norte, 70910-900, Brasília, Brazil

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LPJmL: Schaphoff et al. (2018 a and b)

* LPJmL-mdi: Forkel et al. (2014)

Geosci. Model Dev., 14, 4117–4141, 2021
https://doi.org/10.5194/gmd-14-4117-2021

https://gmd.copernicus.org/articles/14/4117/2021/

Studying the Earth system with the ESM CM2Mc-LPJmL

Article | Assets | Peer review | Metrics | Related articl

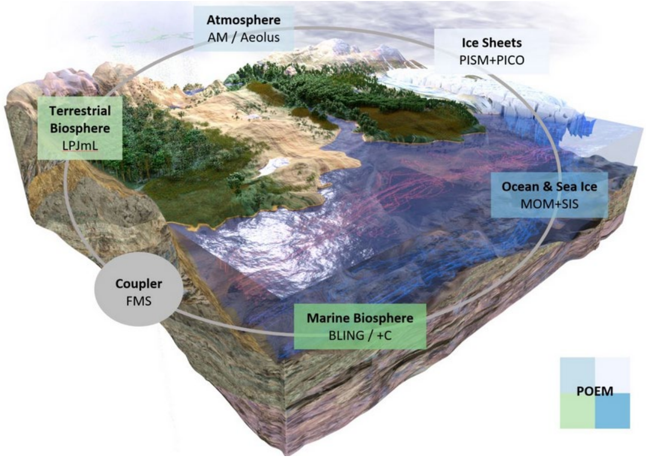
Model description paper

01 Jul 2

CM2Mc-LPJmL v1.0: biophysical coupling of a process-based dynamic vegetation model with managed land to a general circulation model

Markus Drüke[1,2], Werner von Bloh[1], Stefan Petri[1], Boris Sakschewski[1], Sibyll Schaphoff[1], Matthias Forkel[3], Willem Huiskamp[1], Georg Feulner[1], and Kirsten Thonicke[1]
[1]Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, 14412 Potsdam, Germany
[2]Humboldt University of Berlin, Department of Physics, 12489 Berlin, Germany
[3]Institute of Photogrammetry and Remote Sensing, Dresden University of Technology, 01069 Dresden, Germany
Correspondence: Markus Drüke (drueke@pik-potsdam.de)

POEM (Potsdam Earth System Model)

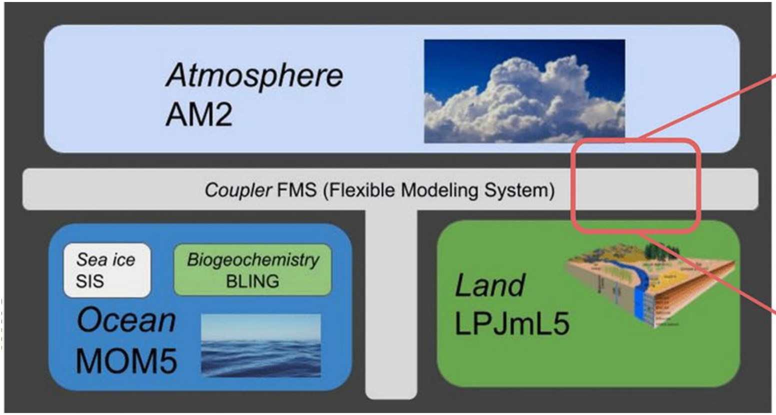


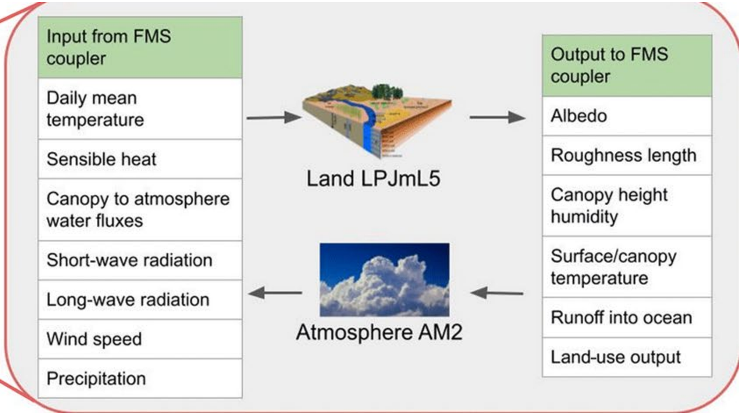
- Comprehensive biophysical feedbacks
- Process-based fire model
- Advanced land use modeling

Vegetation feedback to atmosphere

https://www.pik-potsdam.de/en/institute/departments/earth-system-analysis/models/poem

Markus Drüke
Postdoctoral Researcher
Earth System Analysis



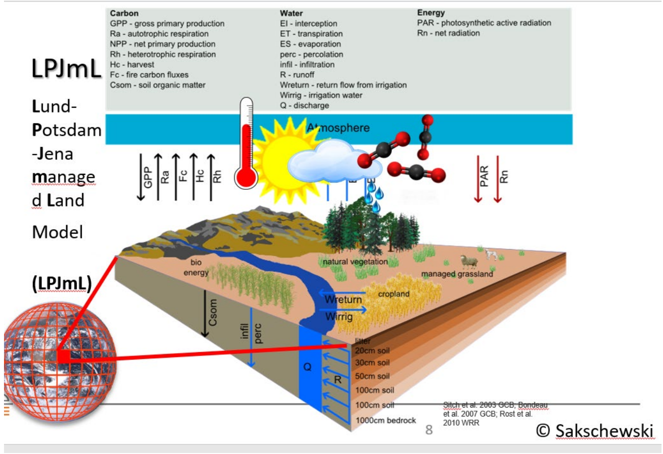


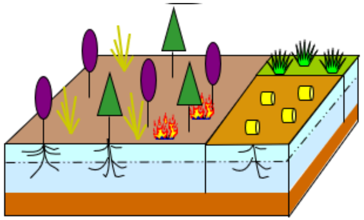
Modeling capabilities at PIK

Tools @ PIK: Dynamic Global Vegetation Models

- LPJmL (Lund-Potsdam-Jena managed Land)

PFT based model





Gridzelle: 0.5° x 0.5°

Schaphoff et al., 2018

- PFT plant functional types
- Big leaf approach

LPJmL Model

Vs.

LPJmL-FIT:
LPJmL with **F**lexible **I**ndividual **T**raits

© Sakschewski

LPJmL FIT

- All basic processes of LPJmL
- Gap model approach to simulate individual trees
- Each tree has a unique set of **traits** (SLA, WD)

Plant traits – **morphological, anatomical, physiological or phenological features measurable at the individual level** (Violle et al. 2007)

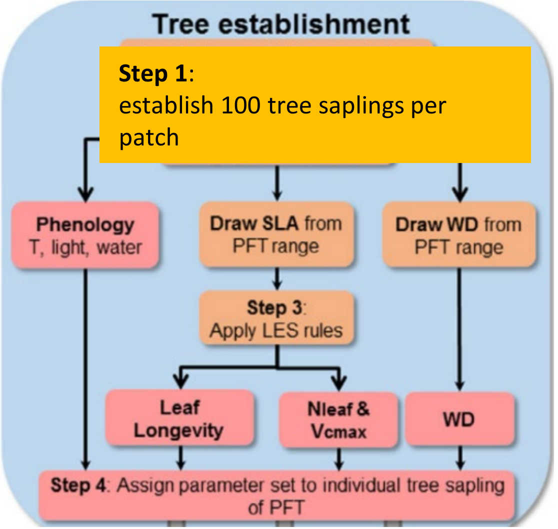
Individual trees characterized by unique set of functional traits compete and form a forest community adapted to local climate and resources

Functional diversity

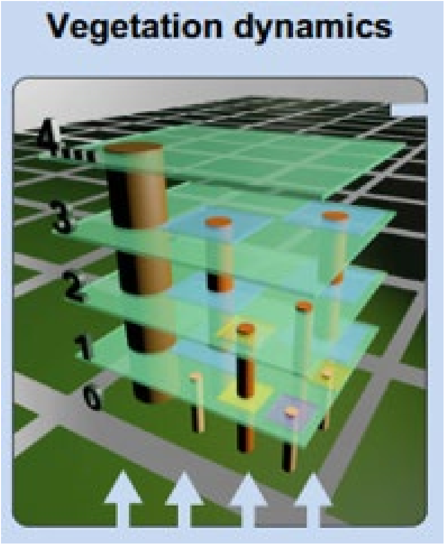
Sakschewski et al., 2015
https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.12870

The LPJmL-FIT model (flexible individual traits)

Functional Unit: Individual tree



Saplings grow and compete for light and water resources



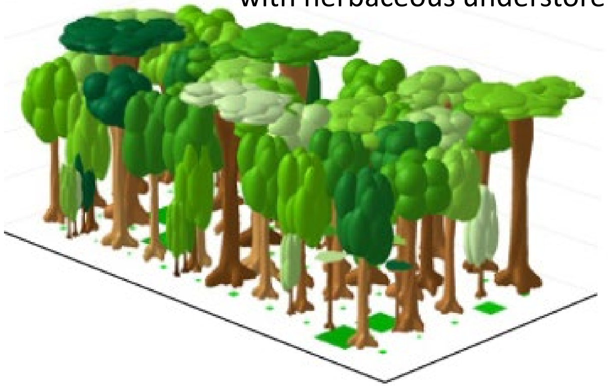
Light competition: reaching canopy layers

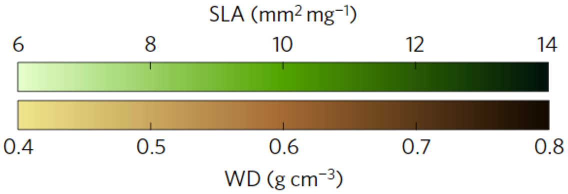
phenology

$$\mathrm{phen}_{\mathrm{PFT}} = f_{\mathrm{cold}} \cdot f_{\mathrm{light}} \cdot f_{\mathrm{water}} \cdot f_{\mathrm{heat}}$$

where $\mathrm{phen}_{\mathrm{PFT}}$ is the daily phenological status (ranging between 0 and 1) representing the fraction of full leaf coverage currently attained by the PFT, reduced by the green-leaf

Established forest community with herbaceous understorey





- LPJmL-FIT establishes individual trees with a number of variable traits
- These traits range within their globally observed boundaries in natural ecosystems because their range are constrained by empirically derived trade-offs following the theory of LES and SES.

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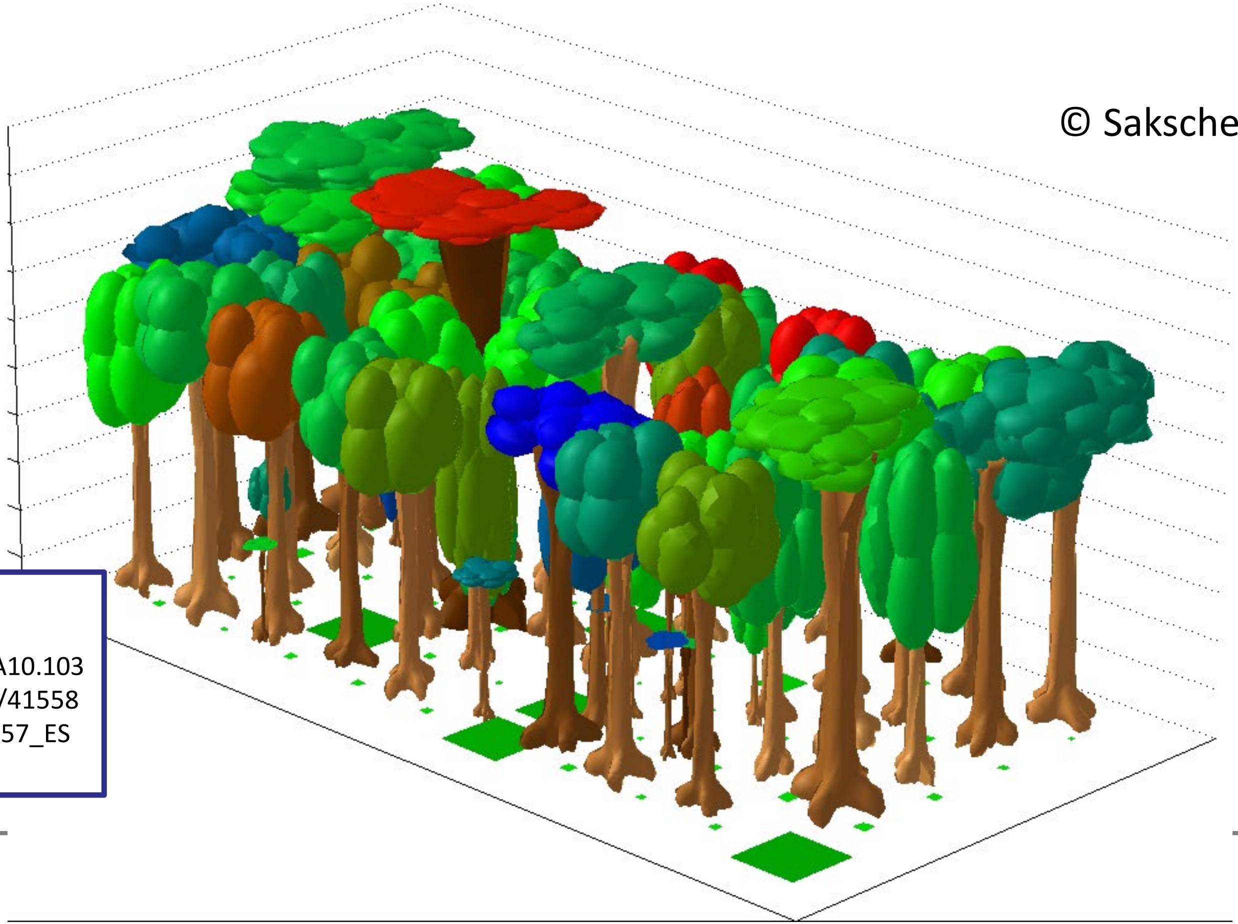
The LPJmL-FIT model (flexible individual traits)



© Sakschewski

Watch animation at: https://static-content.springer.com/esm/art%3A10.1038%2Fnclimate3109/MediaObjects/41558_2016_BFnclimate3109_MOESM457_ESM.mov

P I K

The LPJmL-FIT model (flexible individual traits)

Global Change Biology

Global Change Biology (2015) 21, 2711–2725, doi: 10.1111/gcb.12870

Leaf and stem economics spectra drive diversity of functional plant traits in a dynamic global vegetation model

BORIS SAKSCHEWSKI[1,2], WERNER VON BLOH[1,2], ALICE BOIT[1,2], ANJA RAMMIG[1,2], JENS KATTGE[3], LOURENS POORTER[4], JOSEP PEÑUELAS[5,6] and KIRSTEN THONICKE[1,2]

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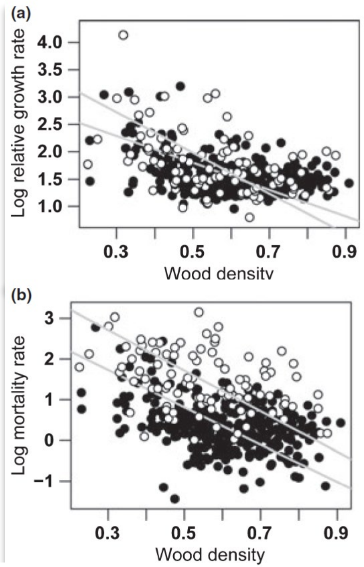
Dynamic Global Vegetation Models: PFTs (plant functional types) with **fixed** set of functional traits

- LPJmL-FIT incorporates empirical ranges of **five traits** of tropical trees extracted from the TRY global plant trait database
- specific leaf area (**SLA**), leaf longevity (**LL**), leaf nitrogen content (N_{area}), maximum carboxylation rate of Rubisco per leaf area ($v_{cmax,area}$), and wood density (**WD**).

Leaf traits and stem traits

2.1 The LPJmL-FIT model (flexible individual traits)



Incorporation of two ecological concepts to diversify functional traits

Wright *et al.* 2004

Chave *et al.* 2009

Published: 22 April 2004

The worldwide leaf economics spectrum

Ian J. Wright, Peter B. Reich, ... Rafael Villar + Show authors

Nature **428**, 821–827 (2004) | Cite this article

42k Accesses | **5147** Citations | **61** Altmetric | Metrics

ECOLOGY LETTERS

Full Access

Towards a worldwide wood economics spectrum

Jerome Chave, David Coomes, Steven Jansen, Simon L. Lewis, Nathan G. Swenson, Amy E. Zanne

First published: 10 March 2009 | https://doi.org/10.1111/j.1461-0248.2009.01285.x | Citations: 1,737

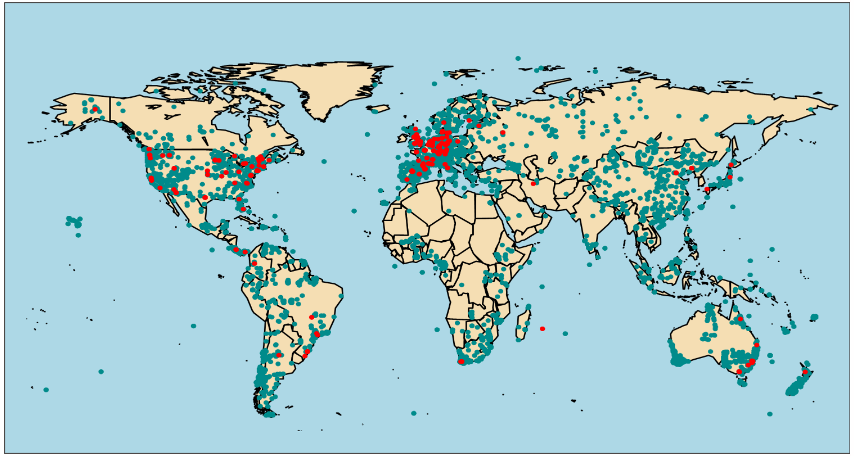
The leaf traits are linked by empirically established trade-offs based on the **leaf economics spectrum (LES)** (Reich *et al.*, 1997, 1999; Wright *et al.*, 2004; Shipley *et al.*, 2006) which describes a set of leaf trade-offs explaining worldwide leaf investment strategies

WD is linked to tree mortality following the idea of **the stem economics spectrum (SES**, Baraloto *et al.*, 2010).

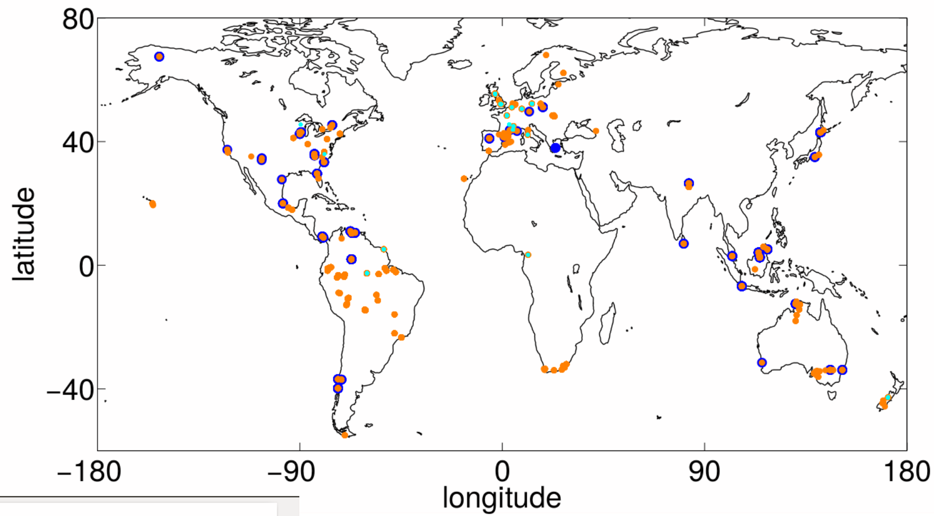
2.1 The LPJmL-FIT model (flexible individual traits)

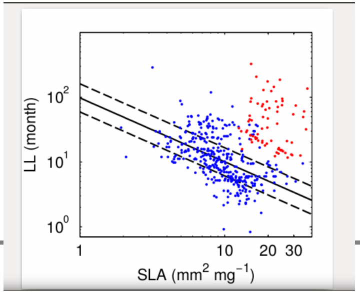
TRY database – filter for global entries for broadleaved-trees

Sakschewski et al., 2015



- Measurement sites
- Institutes





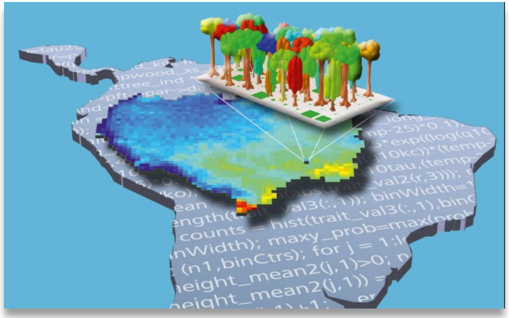
- Regression LL-SLA fit derived from TRY data
- ‚trade-off‘: thin/soft leaves (high SLA) highly productive but shortlived; thicker leaves (low SLA) higher LL as more resistant to physical stress and herbivory

https://www.try-db.org/TryWeb/Home.php

3. Case studies

Case study I: Resilience of forests to climate change

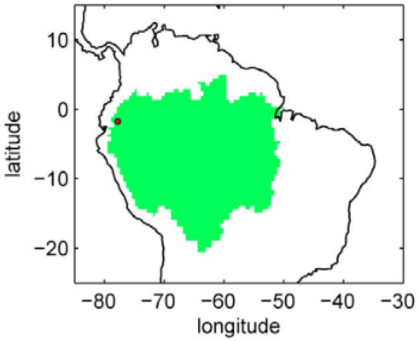
Case study I: Resilience of forests to climate change

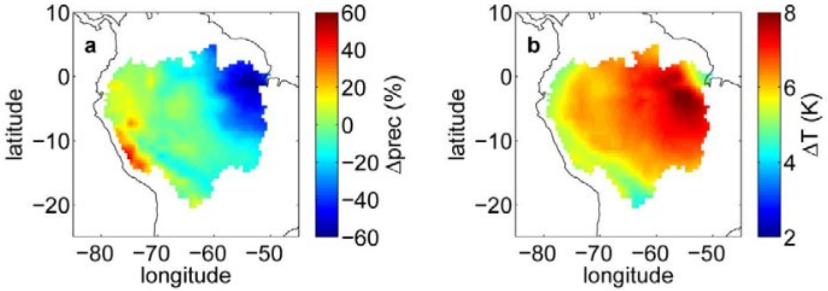


LETTERS
PUBLISHED ONLINE: 29 AUGUST 2016 | DOI: 10.1038/NCLIMATE3109
nature climate change

Resilience of Amazon forests emerges from plant trait diversity

Boris Sakschewski[1,2]*, Werner von Bloh[1,2], Alice Boit[1,2], Lourens Poorter[3], Marielos Peña-Claros[3], Jens Heinke[1,2], Jasmin Joshi[4] and Kirsten Thonicke[1,2]





Climate input: Strong CC scenario (RCP 8.5)

400ha of forest simulated in Ecuador

Biodiversity as an ‚insurance' for the resistance of forests under climate change?

LETTERS
PUBLISHED ONLINE: 29 AUGUST 2016 | DOI: 10.1038/NCLIMATE3109
nature climate change

Resilience of Amazon forests emerges from plant

los Peña-Claros[3],

Case study I: Resilience of forests to climate change

2 PFTs: ‘tropical broadleaved evergreen tree’ and ‘tropical broadleaved rain-green tree’ (fixed trait values)

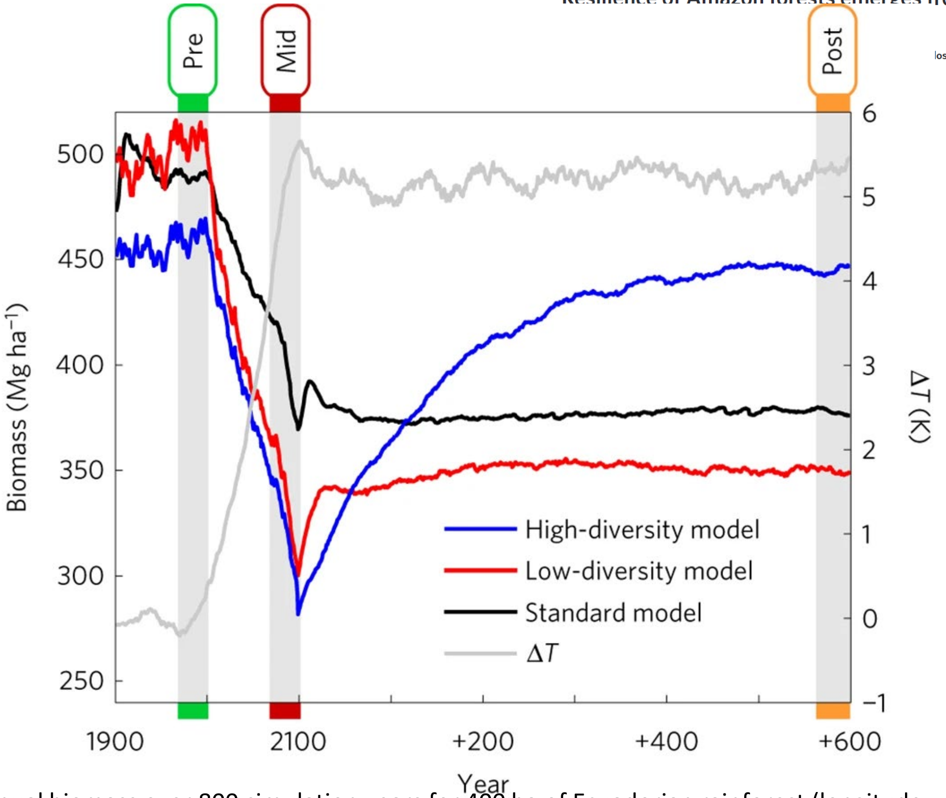
Low-diversity model (individual trees)

Standard model (average individuals)

Vs. Individual trees with randomly assigned different trait combinations →

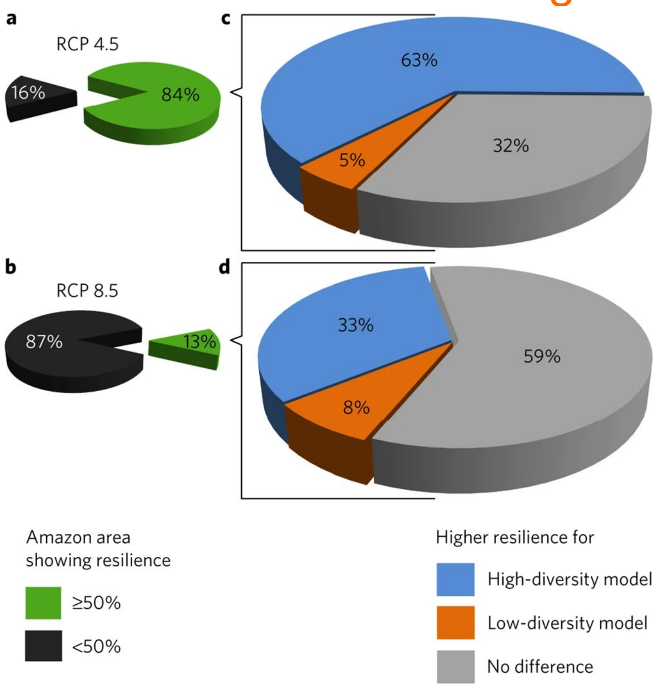
High-diversity model

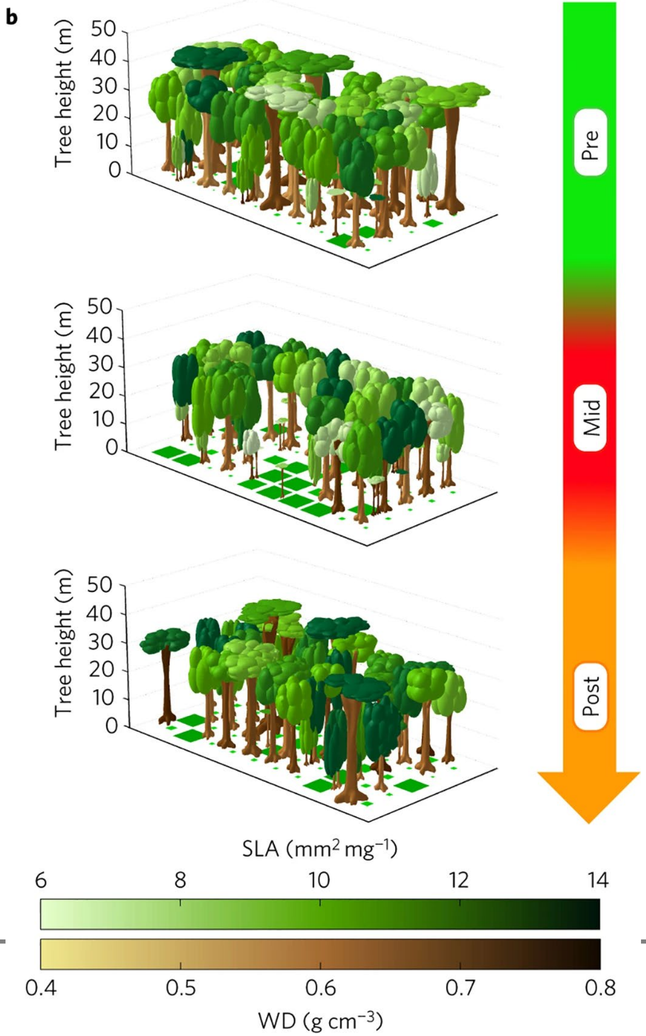
Plant trait	min	max
SLA ($mm^2\ mg^{-1}$)	2.28	31.85
LL (month)	1.70	91.60
N_{area} ($g\ m^{-2}$)	0.96	4.30
$Vcmax_{area25°}$ ($\mu mol\ m^{-2}\ s^{-1}$)	30.47	101.88
WD ($g\ cm^{-3}$)	0.14	1.30



Annual biomass over 800 simulation years for 400 ha of Ecuadorian rainforest (longitude: 77.75° W; latitude: 1.25° S, Supplementary Fig. 10) from three different versions of the vegetation model LPJmL under a severe climate change scenario (RCP 8.5 HadGEM2). Δ*T*: annual temperature difference to the mean temperature of pre-impact time (1971–2000) in K.

Case study I: Resilience of forests to climate change





a, Mean biomass contribution of tree height classes for pre-, mid- and post-impact time (Methods). **b**, Visualization of model output (also see Supplementary Movie 1) showing 0.5 ha of the 400 ha of Ecuadorian rainforest in a selected year during pre-, mid-, and post-impact time, respectively (top to bottom). Different crown (stem) colours denote different SLA (WD) values of individual trees. Crown size, stem diameter and tree height are scaled by model output. Green squares indicate tree gaps covered by herbaceous plants.

high-diversity model is always more resilient, even though the positive contribution of plant trait diversity to biomass resilience is **limited by climate change intensity**

Case study II: Functional diversity of forests along a climate gradient

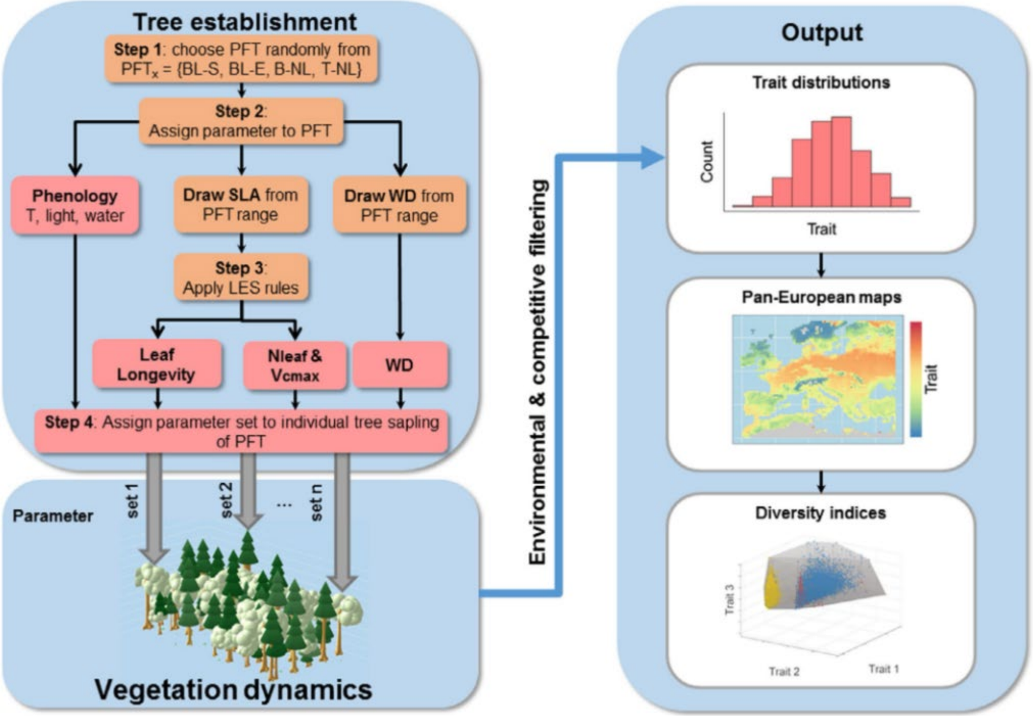
Case study II: Functional diversity of forests along a climate gradient

Received: 6 May 2019 | Revised: 5 December 2019 | Accepted: 12 December 2019
DOI: 10.1111/jbi.13809

RESEARCH PAPER

Journal of Biogeography WILEY

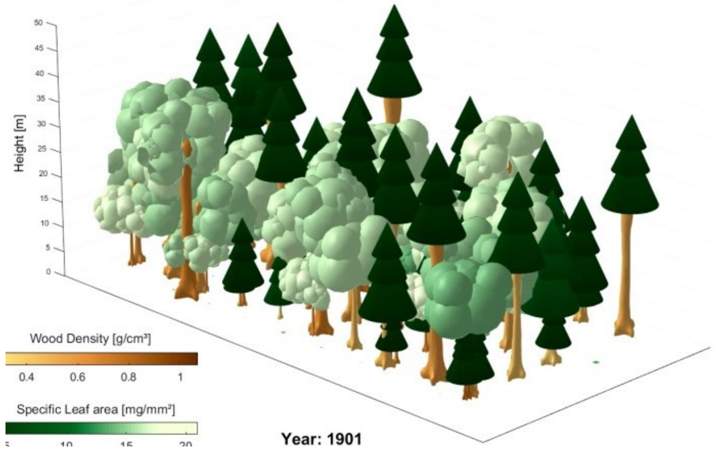
Simulating functional diversity of European natural forests along climatic gradients



Maik Billing
Doctoral Researcher
Earth System Analysis

LPJmL-FIT model
adapted for Europe

boreal vs. temperate
broadleaved vs. needle-leaved



Thonicke, Billing et al., J Biogeogr 2020, https://doi.org/10.1111/jbi.13809

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RESEARCH PAPER

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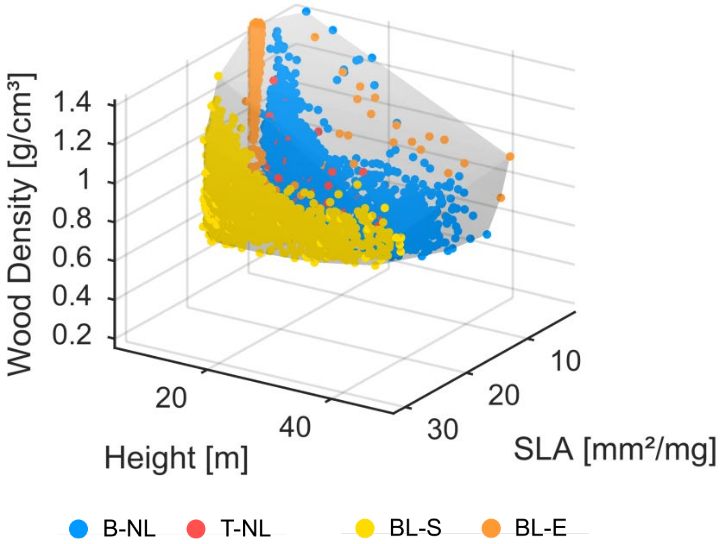
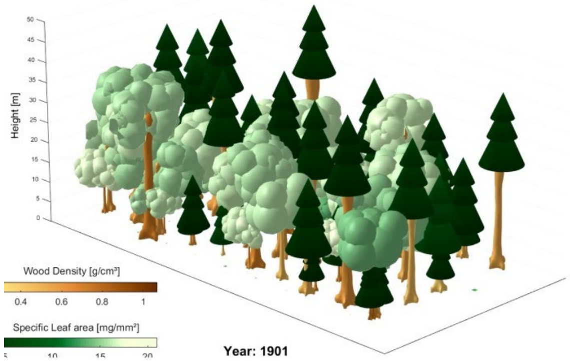
Simulating functional diversity of European natural forests along climatic gradients

Kirsten Thonicke[1] | Maik Billing[1,2] | Werner von Bloh[1] | Boris Sakschewski[1] | Ülo Niinemets[3] | Josep Peñuelas[4,5] | J. Hans C. Cornelissen[6] | Yusuke Onoda[7] | Peter van Bodegom[8] | Michael E. Schaepman[9] | Fabian D. Schneider[10] | Ariane Walz[2]



Functional Diversity

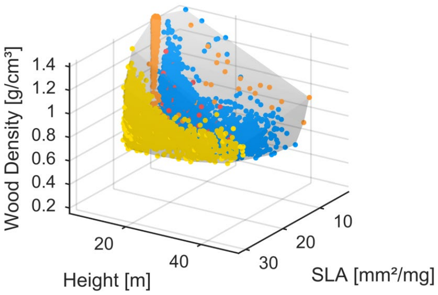


- 3D trait space – each tree is one point
- High functional richness means that in the ecosystem a broad range of nices is occupied
- It can be an indicator of resilience of ecosystems to disturbance

Thonicke, Billing et al., J Biogeogr 2020, https://doi.org/10.1111/jbi.13809

Components of Functional Diversity

- **Functional Richness:**
  - ***Span*** **of occupied niches**
  - **size of potentially available, environmental niches**
- **Functional Evenness:**
  - ***Regularity*** **of the distribution within trait space**
  - **High Evenness -> efficient resource use**
- **Functional Divergence:**
  - **Degree of *niche differentiation***
  - **High Divergence -> high competitive exclusion**



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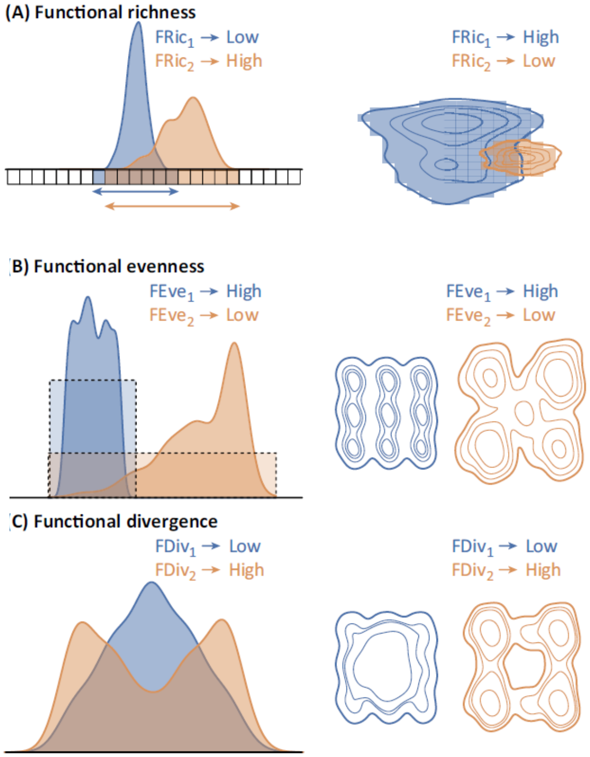
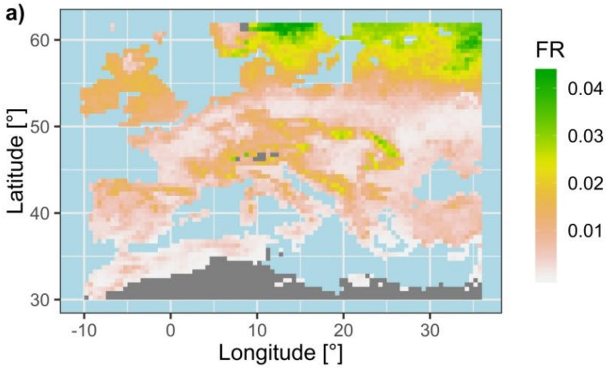


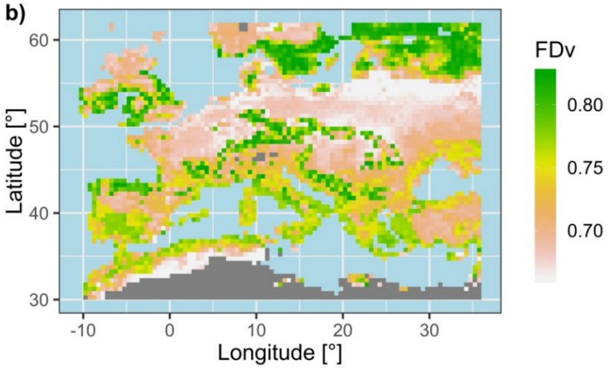
Carmona et al. TREE 2016

Case study II: Functional diversity of forests along a climate gradient

Functional richness



Functional Divergence



In megadiverse ecosystems, **functional diversity** is an important measure

Functional Richness:

Span of occupied niches
size of potentially available, environmental niches

Functional Divergence:

Degree of *niche differentiation*
High Divergence -> high competitive exclusion

PIK

Thonicke, Billing et al., J Biogeogr 2020, https://doi.org/10.1111/jbi.13809

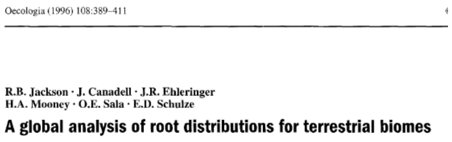
Case Study III: Flexible rooting schemes improve evapotranspiration simulation

Flexible rooting schemes improve evapotranspiration simulation

- DGVMs **oversimplify** representation of belowground dynamics (root growth, distribution, water uptake, nutrient dynamics)

BEFORE:

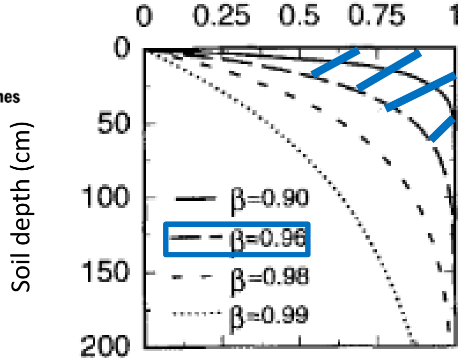
- LPJmL4.0: fixed root biomass distribution with depth and fixed rooting depth for all trees and tree saplings!
- Limits the access of trees to water


Oecologia (1996) 108:389–411

R.B. Jackson · J. Canadell · J.R. Ehleringer
H.A. Mooney · O.E. Sala · E.D. Schulze

A global analysis of root distributions for terrestrial biomes

Jackson et al 1996



PFT	β_{root}
TrBE	0.962
TrBR	0.961
TeNE	0.976
TeBE	0.964
TeBS	0.966
BoNE	0.943
BoBS	0.943
BoNS	0.943
TrH	0.972
TeH	0.943
PoH	0.943

Sakschewski et al., 2021
Improved root growth and biomass distribution in LPJmL model


Biogeosciences, 18, 4091–4116, 2021
https://doi.org/10.5194/bg-18-4091-2021
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Research article

12 Jul 2021

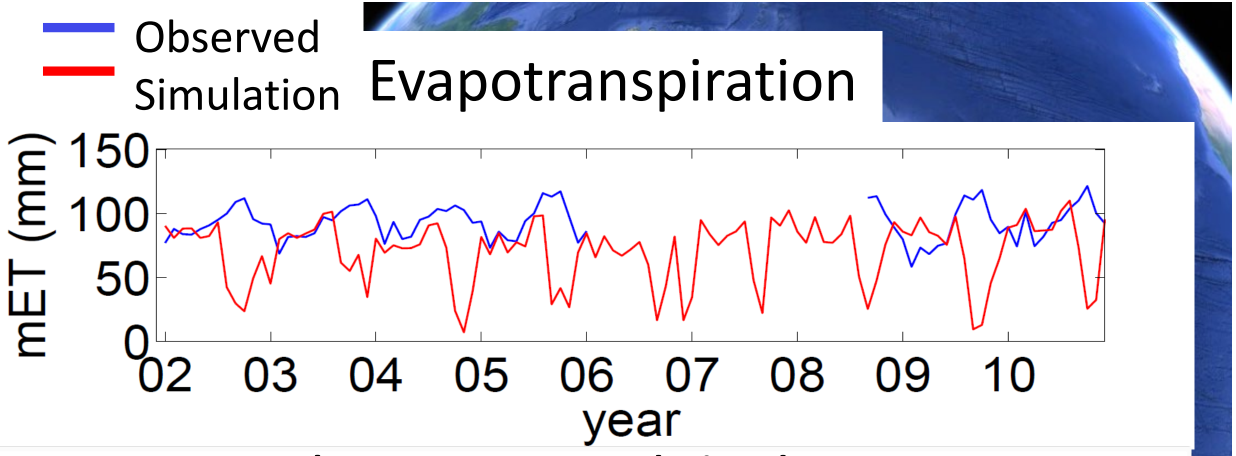
Variable tree rooting strategies are key for modelling the distribution, productivity and evapotranspiration of tropical evergreen forests

Boris Sakschewski[1], Werner von Bloh[1], Markus Drüke[1,2], Anna Amelia Sörensson[3,4], Romina Ruscica[3,4], Fanny Langerwisch[5], Maik Billing[1], Sarah Bereswill[6], Marina Hirota[7,8], Rafael Silva Oliveira[8], Jens Heinke[1], and Kirsten Thonicke[1]

https://bg.copernicus.org/articles/18/4091/2021/bg-18-4091-2021-discussion.html

Flexible rooting schemes improve evapotranspiration simulation

The problem with the ‚fixed roots' approach



Santarém, Brazil
Up to 4 months with P < 100 mm

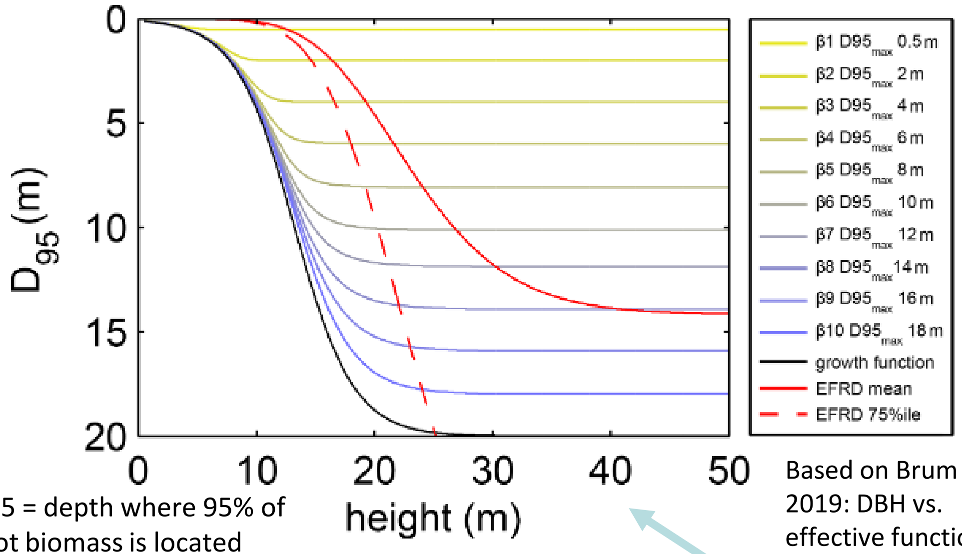
Trees have water access during dry season

© Sakschewski

Photo: Boris S.

Flexible rooting schemes improve evapotranspiration simulation

NEW: logistic growth function: root systems grows with tree height



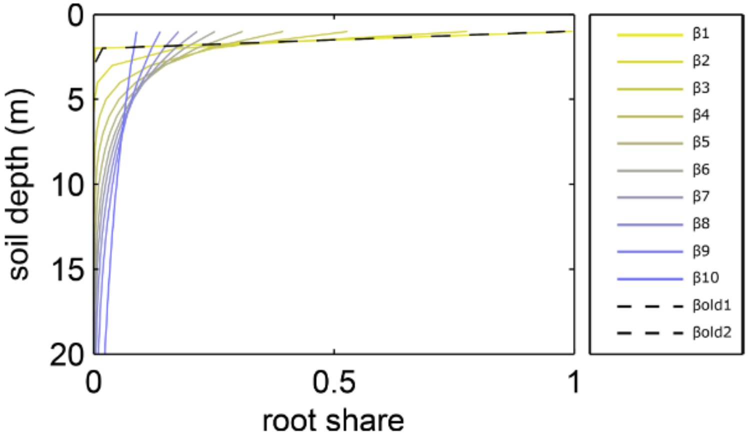
D95 = depth where 95% of root biomass is located

Figure A2. Relation between tree height and rooting depth in LPJmL4.0-VR. Black line: implemented general growth function of rooting depth (Eq. A5). Lines with colour scale from yellow to blue: growth functions of rooting depth for each of the 10 sub-PFTs (Sect. 2.2.3). Here temporal rooting depth is expressed as D_{95} and eventually reaches D_{95_max} (Eq. A3). Solid red line: mean effective functional rooting depth over tree height (EFRD) adapted from Brum et al. (2019) using Eq. (A5). Dashed red line: respective 75th-percentile EFRD over tree height adapted from Brum et al. (2019). Please also see Supplementary Video 1 for a visualization of root growth and development of below-ground carbon pools over time available at http://www.pik-potsdam.de/~borissa/LPJmL4_VR/Supplementary_Video_1.pptx.

$$D = \frac{S}{1 + e^{-kSh} \cdot \left(\frac{S}{D_0} - 1\right)},$$

Based on Brum et al., 2019: DBH vs. effective functional rooting depth

NEW: introduce various possible root biomass distributions (ß parameter)– competition for water



Journal of Ecology

BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE | Free Access

Hydrological niche segregation defines forest structure and drought tolerance strategies in a seasonal Amazon forest

Mauro Brum, Matthew A. Vadeboncoeur, Valeriy Ivanov, Heidi Asbjornsen, Scott Saleska, Luciana F. Alves, Deliane Penha, Jadson D. Dias, Luiz E. O. C. Aragão, Fernanda Barros, Paulo Bittencourt, Luciano Pereira, Rafael S. Oliveira ... See fewer authors

Flexible root growth scheme I

10 different ß paramters describe fine root biomass distribution with depth

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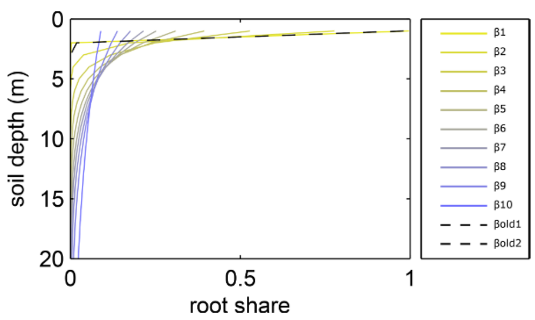

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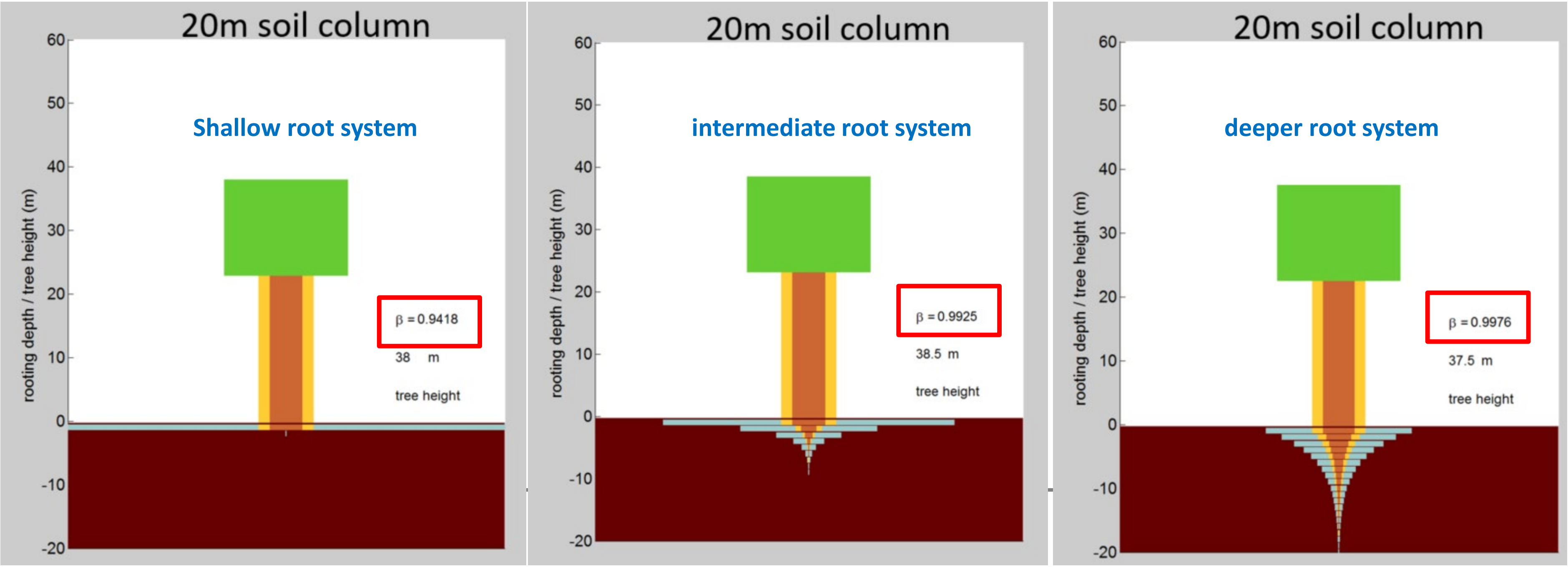

Flexible root growth scheme II

Depth of root system grows with increasing tree height (logistic function), root biomass distribution depends on ß parameter

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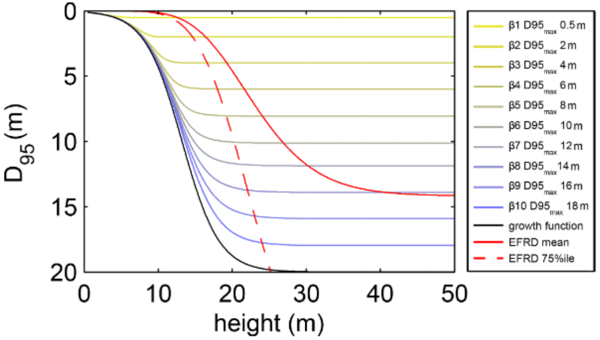

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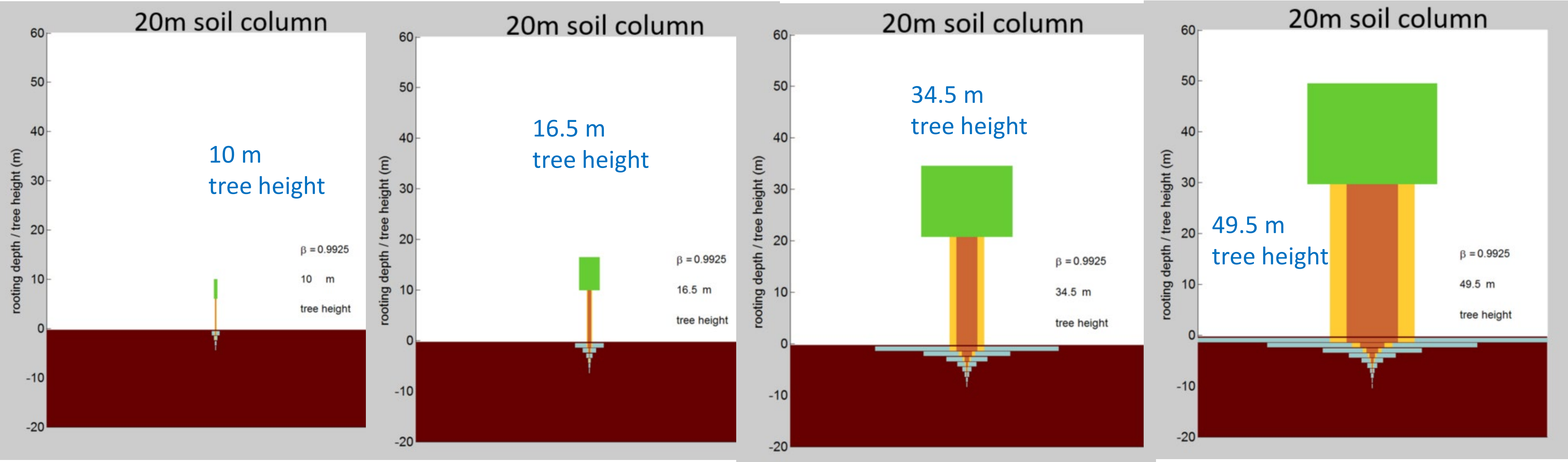
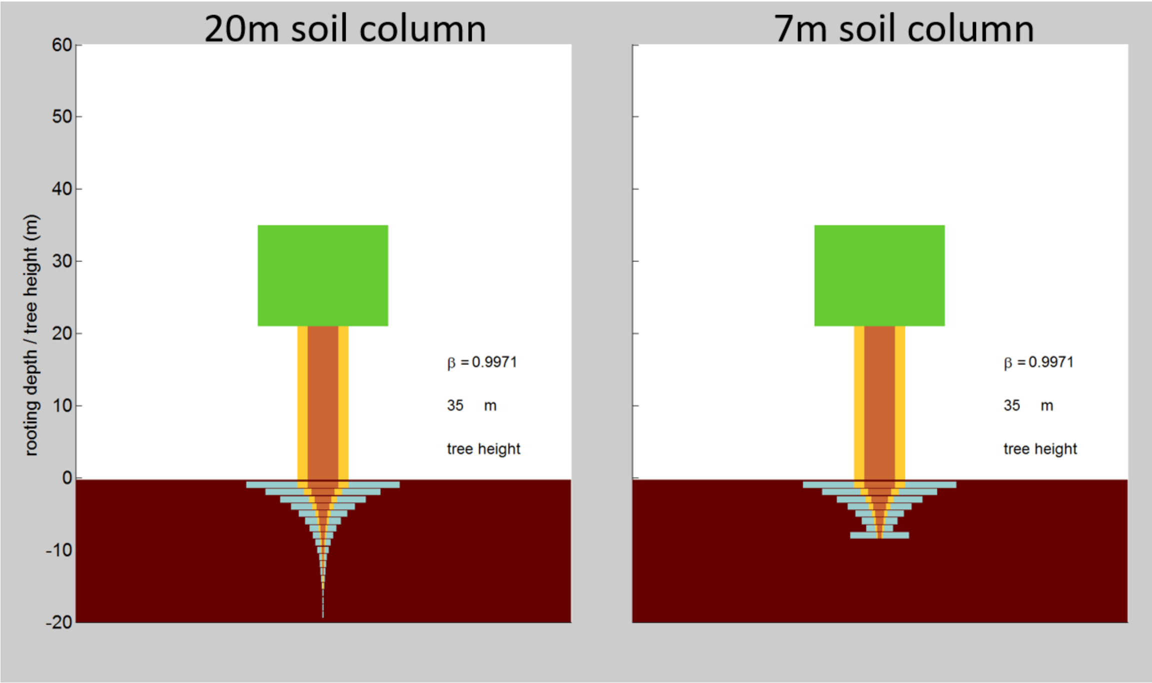


Flexible root growth scheme III



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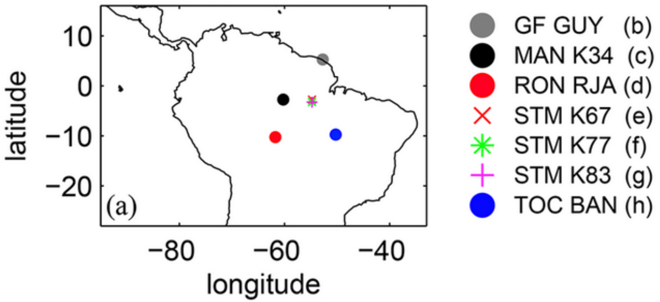
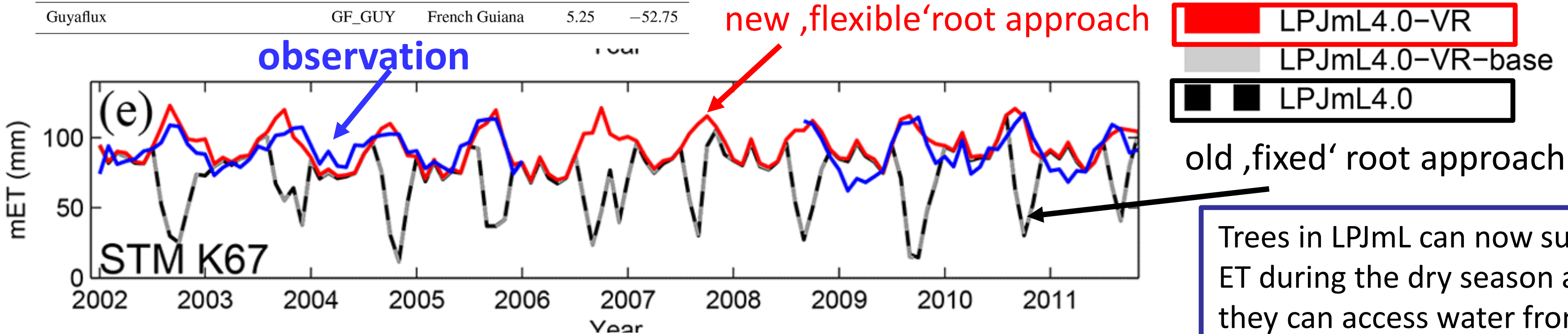
Once bedrock layer is reached, new root biomass is allocated to last soil layer until tree reaches its final height

Flexible rooting schemes improve evapotranspiration simulation

FLUXNET sites used for ET and NPP validation

Site name	Short name	Country	LPJmL coordinate	
			latitude	longitude
Ecotone Bananal Island (BR-Ban)	TOC_BAN	Brazil	−9.75	−50.25
Manaus-ZF2 K34/BR-Ma2	MAN_K34	Brazil	−2.75	−60.25
Santarem-Km67-Primary Forest/BR-Sa1	STM_K67	Brazil	−2.75	−54.75
Santarem-Km77-Pasture/BR-Sa2	STM_K77	Brazil	−3.25	−54.75
Santarem-Km83-Logged Forest/BR-Sa3	STM_K83	Brazil	−3.25	−54.75
Rond.-Rebio Jaru Ji Parana-Tower B/BR-Ji3	RON_RJA	Brazil	−10.25	−61.75
Guyaflux	GF_GUY	French Guiana	5.25	−52.75





Trees in LPJmL can now sustain ET during the dry season as they can access water from deeper soil layers

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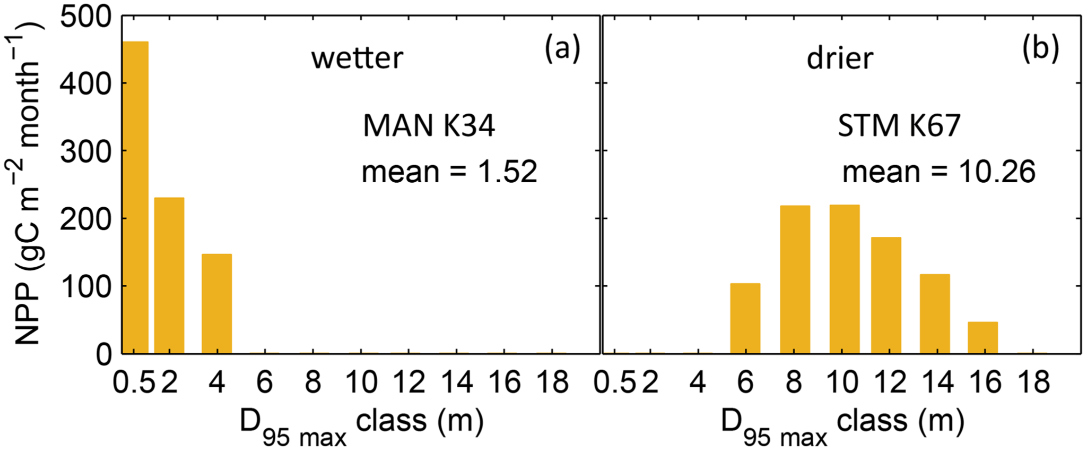
Flexible rooting schemes improve evapotranspiration simulation



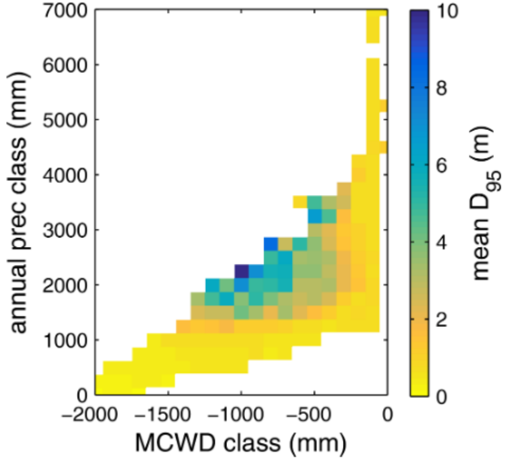


Figure B5. Mean rooting depth depicted as mean $\overline{D_{95}}$ over classes of MCWD and annual precipitation sums. Class step size for precipitation was set to 250 mm, and class size for MCWD was set to 50 mm. Regions with high amounts of annual rainfall and lower seasonality exclusively favour shallow-rooted forests (low $\overline{D_{95}}$). $\overline{D_{95}}$ increases with decreasing MCWD (increasing seasonal drought stress) and decreasing sums of annual precipitation. Below 1200 mm of annual rainfall or −1100 mm of MCWD, $\overline{D_{95}}$ sharply decreases again. Note this figure does not consider soil depth. The colour-scale maximum is set to 10 m.

Manaus:
mean annual precipitation: 2609 mm
Mean MCWD: -222 mm
Sub-PFT with D95_max = 0.5m contributes most to overall NPP
NPP-weighted D95_max = 1.52 m

Santarém:
mean annual precipitation: 2144 mm
Mean MCWD: -465 mm
Sub-PFT with D95_max = 10m contributes most to overall NPP
NPP-weighted D95_max = 10.26 m

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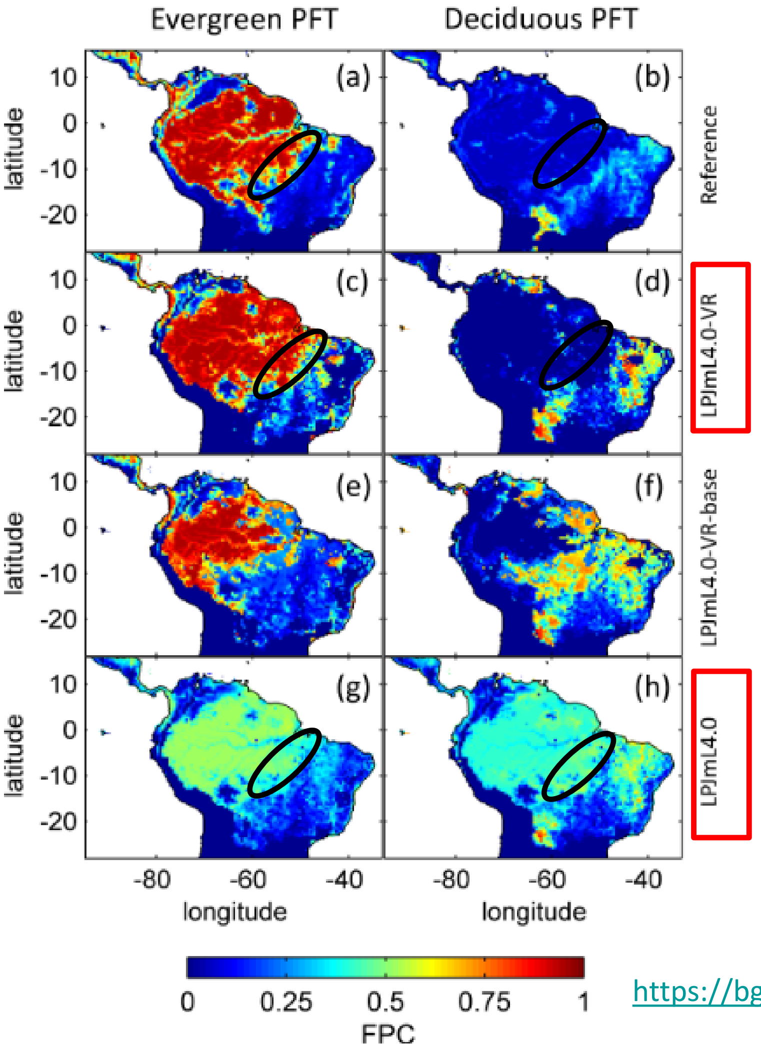


Figure 4. Foliage projective cover (FPC) of evergreen (**a, c, e, g**) and deciduous (**b, d, f, h**) PFTs over the study region. (**a–b**) Satellite-derived vegetation composition from ESA Land Cover CCI V2.0.7 (Li et al., 2018) reclassified to the PFTs of LPJmL as in Forkel et al. (2014). (**b–c**) LPJmL4.0-VR. (**d–e**) LPJmL4.0-VR-base. (**f–g**) LPJmL4.0. All LPJmL model versions were forced with CRU climate input. The FPC shown for all models refers to 2001–2010. For statistical measures of individual comparisons between model versions (**c–h**) and satellite-derived vegetation composition (**a–b**), see Table B4.

- FPC (foliage projective cover) for tropical evergreen vs deciduous trees
- Evergreen forests extend in regions with a dry season
- LPJmL fixed roots (LPJmL 4.0) underestimates extent of evergreen trees in eastern Amazon basin
- Variable root version LPJmL VR best vs. observed

https://bg.copernicus.org/articles/18/4091/2021/bg-18-4091-2021-discussion.html

4. Outlook

Outlook on planned activities for B-EPICC Project in Brazil

Workpackage I: Validation of LPJmL-FIT VR (variable roots) in Brazil

- Validate LPJmL-FIT with new flexible tree roots for selected forest sites in Brazil
- Selection of sites along gradient in seasonality
- Validation: Biomass, functional traits (SLA, WD, height), ET and NPP measurements, rooting depth and distribution
- Simulations with historical climate
- Amazon basin runs

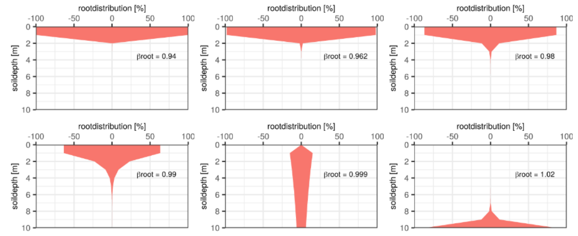
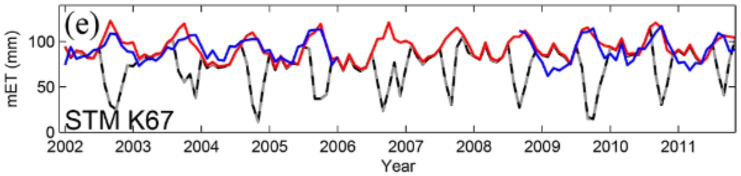
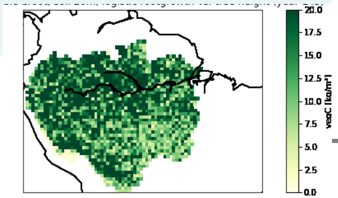


Figure 2: Different β_{root} values describe the shape of the rooting profile, given as the fraction of all roots in % relative to the respective soil depth. The first 3 soil layers (200, 300 and 500 mm) were summarized, so that each plot shows the cumulative root fraction for soil layers of 1 m thickness.





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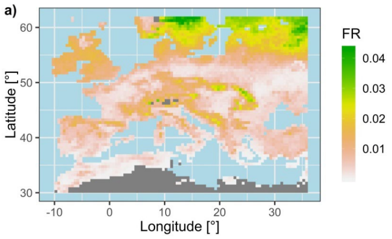
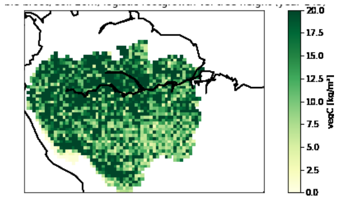
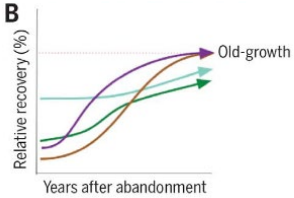
Outlook on planned activities for B-EPICC Project in Brazil

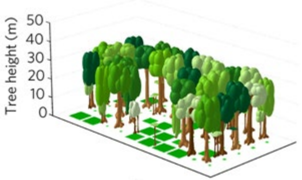
Workpackage II: Modeling the potential of Brazils secondary forests for climate change mitigation and biodiversity recovery

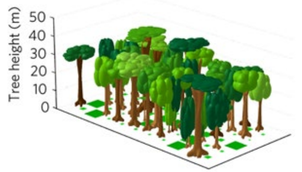
- Apply adapted LPJmL-FIT for Amazon
- Set-up trajectories of forest recovery
- Consider land-use history and future
- Transient runs under future climate change scenarios
- Derive maps of functional diversity for Brazil











CAPACITY BUILDING AND KNOWLEDGE TRANSFER: THE WEB PORTAL CLIMATEIMPACTSONLINE

ClimateImpactsOnline is a web portal that "illustrates the possible impacts of climate change on various countries in different regions of the world on sectors like agriculture, forestry, tourism and health care." Visualization is a key technique to ensure broad accessibility to climate data and information for different types of users.

Open questions

- **Needs**
- **Stakeholders**
- **Link to existing modeling efforts in Brazil**
- **Collaboration with researchers in Brazil**

Thank you!

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