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Supplement of

A new tropical savanna PFT, variable root growth and fire improve Cerrado vegetation dynamics simulations in a Dynamic Global Vegetation Model

Jéssica Schüler et al.

Correspondence to: Jéssica Schüler (jehschuler@gmail.com)

1. Sect. S1

Table S1: Description of the main climatic characteristics of each Brazilian biome according to Köppen-Geiger classification system (Peel et al. 2007).

Biome	Mean rainfall (mm)	Mean temperature (ºC)	Köppen -Geiger	Description
Amazon	2000 - 3000	26.0	Af	Tropical, rainy with hot summer
Caatinga	500 - 700	27.4	BSh	Tropical, semi-arid with hot summer
Cerrado	1300 - 1600	20.1	Aw	Tropical, rainy, with hot summer and dry winter
Atlantic Forest	2000 - 2500	21.1	Af	Tropical, rainy with hot summer
Pantanal	1000 - 1400	24.8	Aw	Tropical, rainy with hot summer and dry winter
Pampa	1300 - 1700	20.0	Cfa	Subtropical, moist with hot summer

Table S2: List of variables used in the development of TrBS (Tropical Broadleaved Savanna tree) PFT with their respective collection sites and responsible researchers. Variables collected in the field include Tree Diameter at Breast Height (DSH), Tree Height (TH), Canopy Height (CH), Canopy Area (CA), Canopy Volume (CV), and Specific Leaf Area (SLA).

Site	**Year**	**Data collected**	**Reference**
Silvânia - GO	2009	DSH, TH, CH, CA & CV	Gomes et al., (2024)
São Desidero - BA	2009	DSH, TH, CH, CA & CV	Gomes et al., (2024)
Correntina - BA	2009	DSH, TH, CH, CA & CV	Gomes et al., (2024)
Alto Paraíso de Goiás - GO	2009	DSH, TH, CH, CA & CV	Gomes et al., (2024)
Parque Nacional de Brasília - DF	2013	DSH, TH, CH, CA & CV	Not published (responsible: Felipe Lenti and Mercedes Bustamante)
Rota Farm at Nova Xavantina - MT	2015	DSH &TH	Gomes et al., (2024)
Farm at Sinop - MT	2018	DSH & TH	Gomes et al., (2024)
Parque Municipal do Bacaba - MT	2019	DSH, TH e TH/DSH	Gomes et al., (2024)
Jardim Botânico de Brasília - DF	2019	DSH, TH, CH, CA, CV & SLA	Gomes et al., (2024); Machida et al., (2021)
FLONA de Brasília - DF	2019	DSH & TH	Schüler, Jéssica (2020)
Parque Nacional da Chapada dos Veadeiros - GO	2020	DSH, TH, CH, CA & CV	Gomes et al., (2024)
Reserva Ecológica do IBGE - DF	2022	DSH, TH, CH, CA, CV & SLA	Gomes et al. (2024); Costa, Lucas (2020)

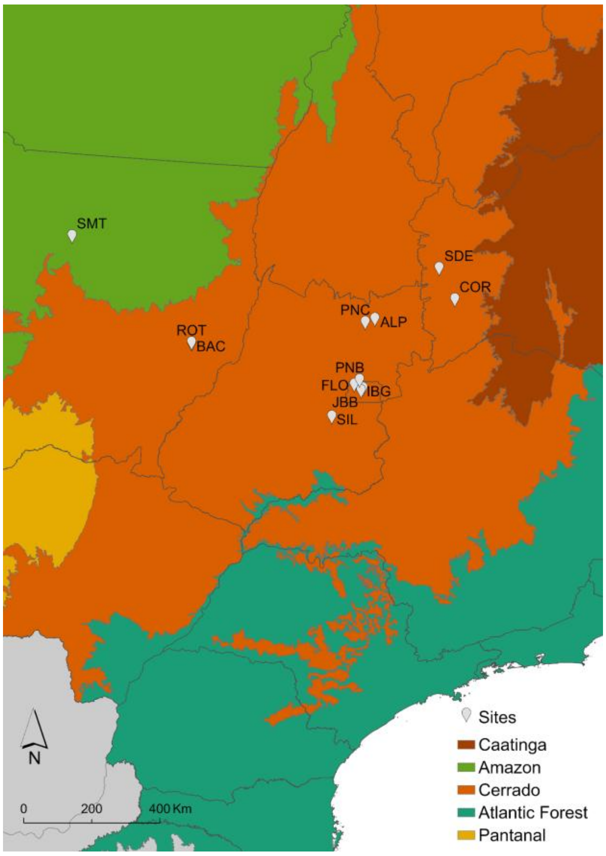

Fig. S1: Map showing the locations where field data, referred on Table S1, were collected. Farm at Sinop (SMT), Rota Farm at Nova Xavantiva (ROT), Parque Municipal do Bacaba (BAC), São Desiderio (SDE), Correntina (COR), Parque Nacional da Chapada dos Veadeiros (PNC), Alto Paraíso de Goiás (ALP), Parque Nacional de Brasília (PNB), FLONA de Brasília (FLO), Reserva Ecológica do IBGE (IBG), Jardim Botânico de Brasília (JBB), and Silvânia (SIL).

Eq. S1: Allometric relation between crown area and stem diameter in LPJmL-VR-SPITFIRE (Schaphoff et al. 2018).

$$CA_{ind} = min(allom1 * D^{krp}, CA_{max}) \quad \text{(Eq. S1)}$$

Eq. S2: Allometric relation between tree height and stem diameter in LPJmL-VR-SPITFIRE (Schaphoff et al. 2018).

$$H = allom2 * D^{allom3} \quad \text{(Eq. S2)}$$

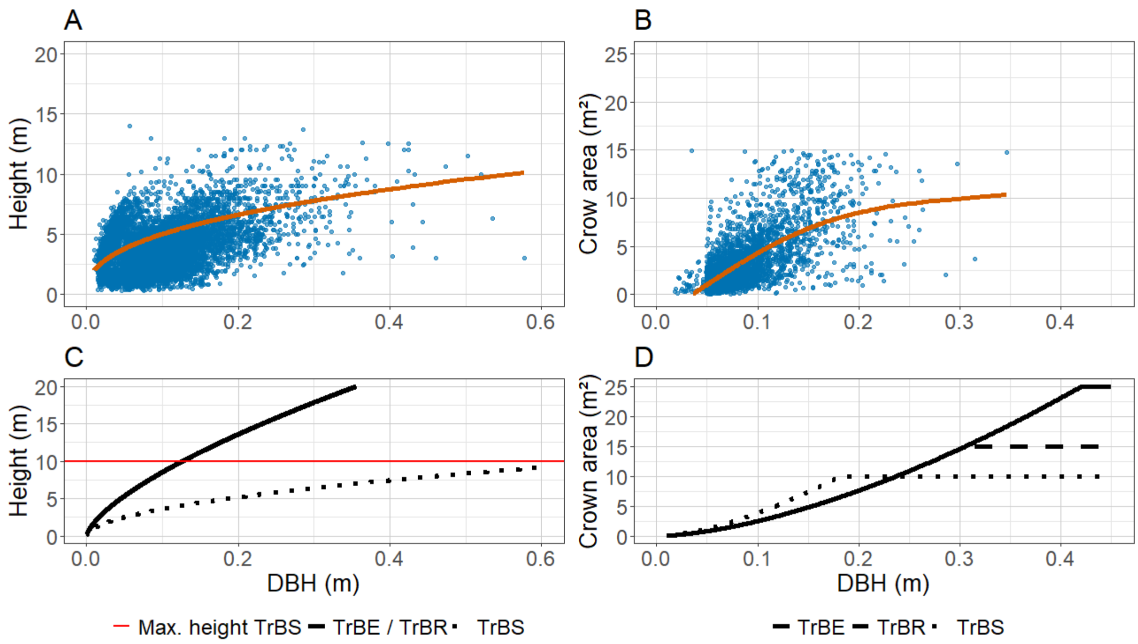

Fig. S2. Allometric relation between tree height and stem diameter (DBH) (A and C), and between crown area and DBH (B and D), for different PFTs (TrBE = tropical broadleaved evergreen, TrBR = tropical broadleaved raingreen, TrBS = tropical broadleaved savanna). Graphs A and B are fitted curves based on field data, and C and D are the allometric curves for each PFT.

Eq. S3: Investment in leaf vs. root biomass related to water stress (Schaphoff et al. 2018)

$$C_{leaf,ind} = lr_{max} * \omega * C_{root,ind} \qquad \text{(Eq. S3)}$$

where $C_{leaf,ind}$ is the leaf mass per individual [gC indiv-1], $C_{root,ind}$ the fine root mass per individual [gC indiv-1], ω a water stress index (from 1 = no water stress, to 0 = maximum water stress), and $lr_{max}$is the PFT-specific maximum leaf to root mass ratio.

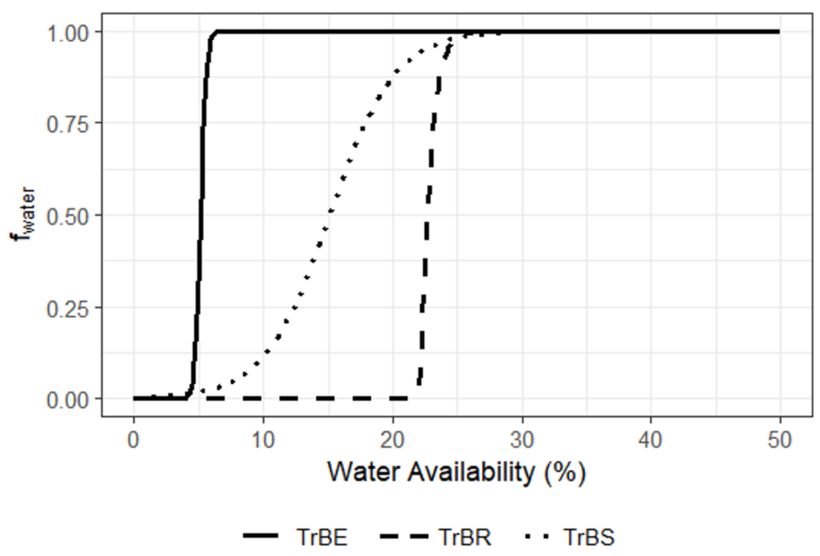

Fig. S3: Water limited component f_{water} of the phenology status (0 = no leaves, 1 = full leaf cover) for the three tropical PFTS TrBE (Tropical Broadleaved Evergreen tree), TrBR (Tropical Broadleaved Raingreen tree) and the new TrBS (Tropical Broadleaved Savanna tree).

Eq. S4: Calculation for bark thickness related to stem diameter

$$bark\ thickness = barkpar1 * D * 100 * barkpar2 \qquad \text{(Eq. S4)}$$

where bark thickness [cm] is calculated from the PFT-specific parameters barkpar1 and barkpar2 (Table 2), and D = stem diameter [m]

Equation S5: Calculation of PFT-specific scorch height

$$SH = F * I^{2/3} \qquad \text{(Eq. S5)}$$

where SH is the scorch height [m], F is a PFT-specific scaling parameter (Table x), and I is the fireline intensity [kWm-1]

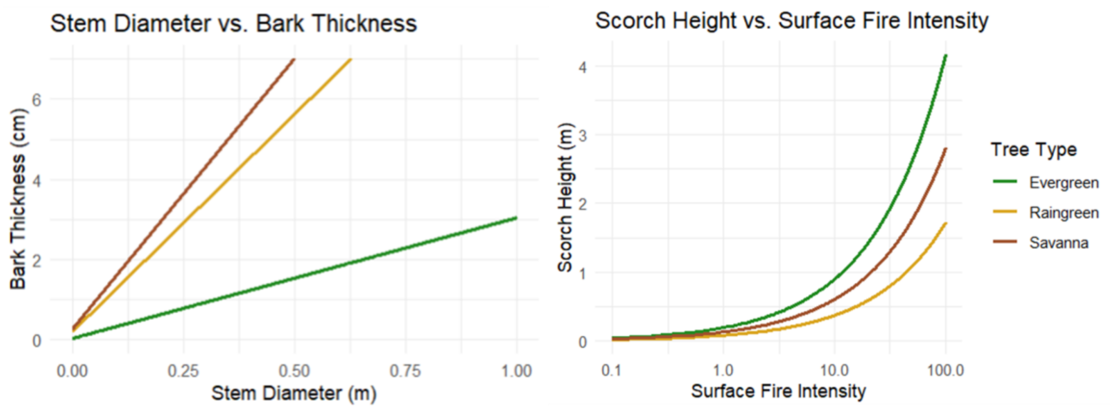

Fig. S4: Graphs showing PFT specific parameters mediating fire mortality for the tropical trees PFTs. The relationship between bark thickness and stem diameter (right) was based on Hoffmann et al. (2009), and the relationship between scorch height and surface fire intensity (left).

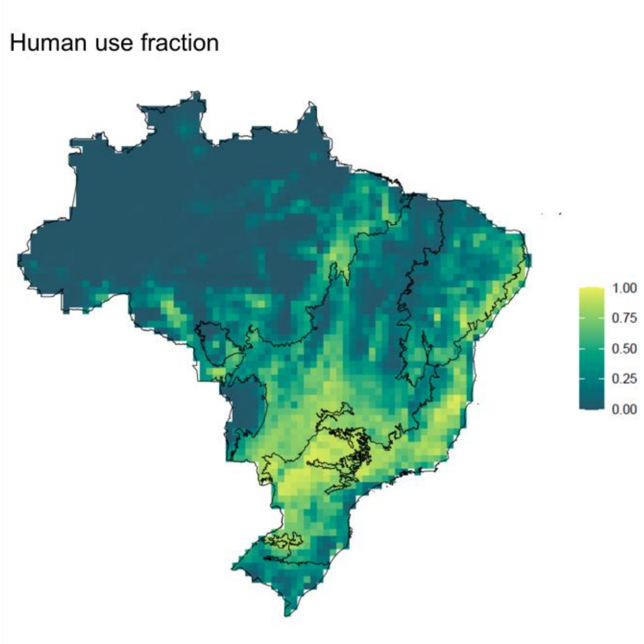

Fig. S5: Human land-use fraction map used to weigh burned area and fire C emission (MapBiomas, 2024).

2. Sect. S2

2.1 PFT distribution

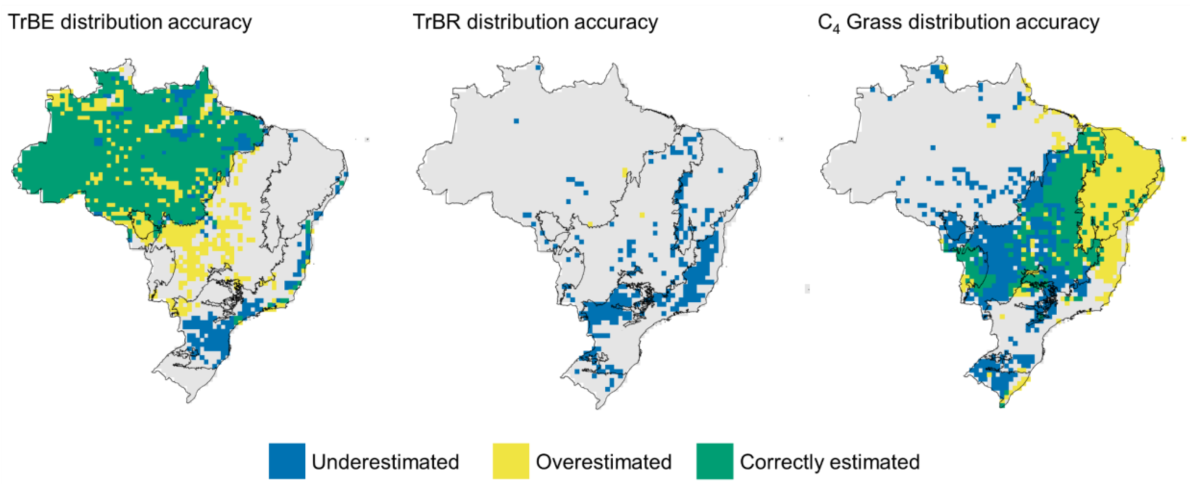

Fig. S6: Simulated distribution accuracy, according to IBGE vegetation map, for Tropical Broadleaved Evergreen Tree (TrBE), Tropical Broadleaved Raingreen Tree (TrBR) and C_4 Grass PFTs with the introduction of the new Tropical Broadleaved

Savanna Tree (TrBS). To determine accuracy, we used a threshold of 30% FPC cover for each PFT.

2.2 Total Carbon and Above and belowground structure

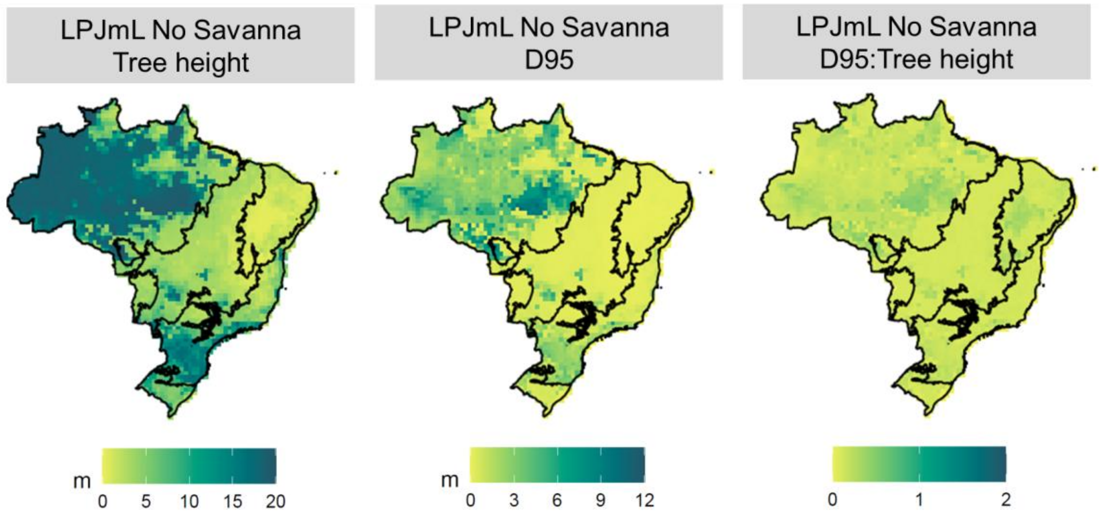

Fig. S7: FPC-weighted tree height and D95, and their ratio (D95:Tree height) from LPJmL 'No Savanna' simulation.

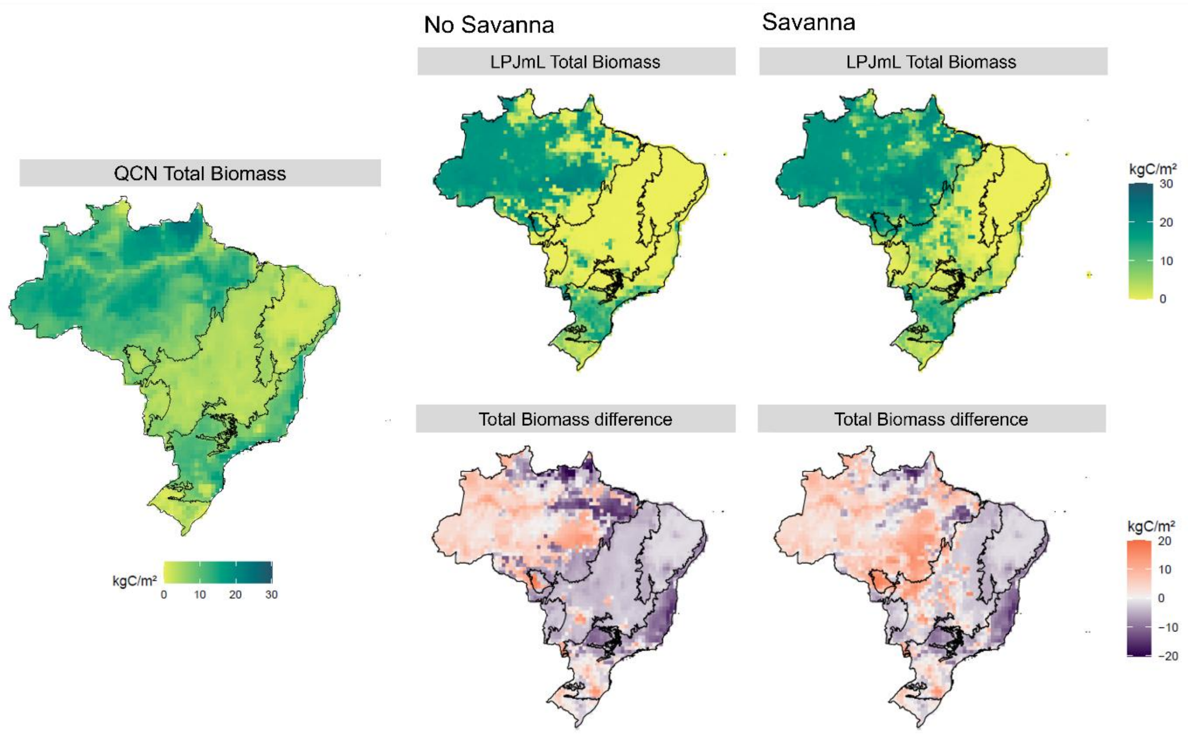

Fig. S8: LPJmL simulations of Total Biomass in Brazil for ‘No Savanna’ and ‘Savanna’ scenarios (top row), the validation data by QCN (left) (MCTI 2020), and the respective difference between simulated results and QCN validation (bottom row).

2.4 Global Simulations

To test the implementation of the new savanna TrBS PFT, we performed a global simulation using LPJmL-VR-SPITFIRE (Fig. S9). Comparison with estimates of tropical savanna biome extent from Hengl et al. (2018) shows good agreement with the simulated global extent of TrBS.In the Caatinga region, our model simulates a predominance of C_4 grass cover (see Fig. 2, main manuscript), which does not accurately reflect the region’s characteristic vegetation. Similarly, the savanna classification observed in Hengl et al. (2018) also misrepresents the Caatinga, which is more accurately described as a seasonal dry tropical forest (de Queiroz et al 2017).

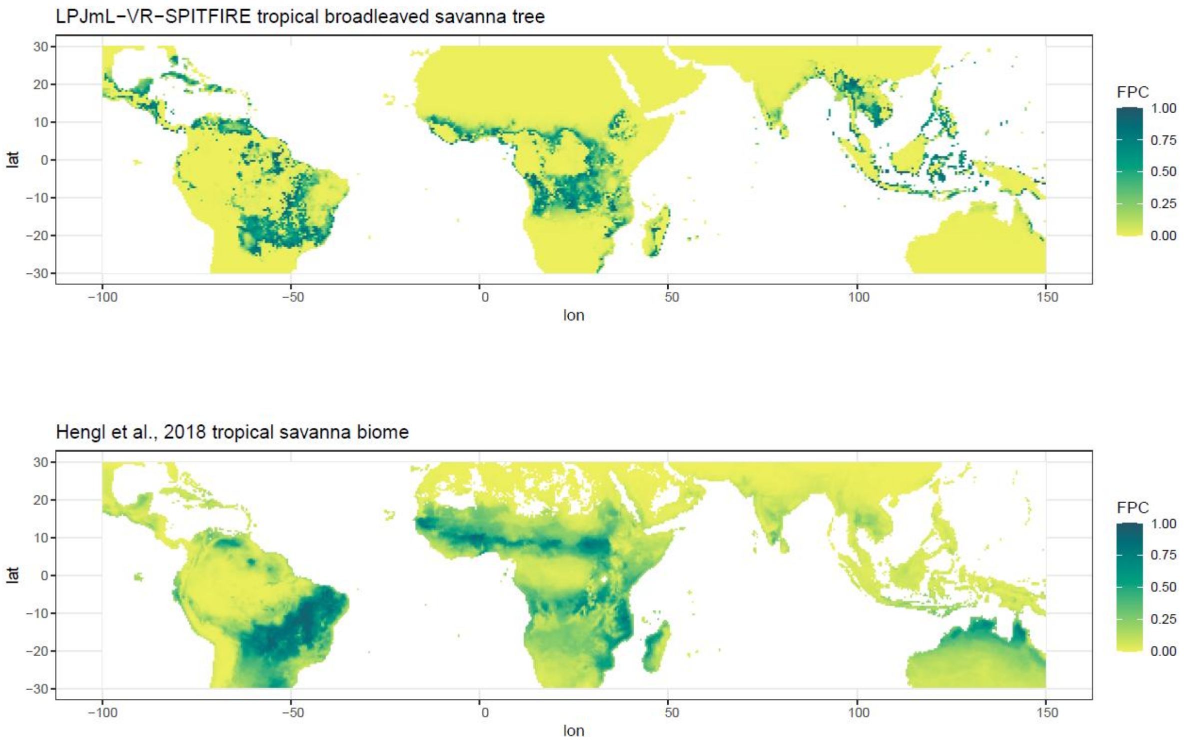

Fig S9: Comparison of the foliage projective cover (FPC) of the new Tropical Broadleaved Savanna tree PFT (TrBS) from a LPJmL-VR-SPITFIRE global simulation with the estimated biome distribution of tropical savannas from Hengl et al. (2018).

2.4 Validation of Gross Primary Production (GPP) and evapotranspiration (ET)

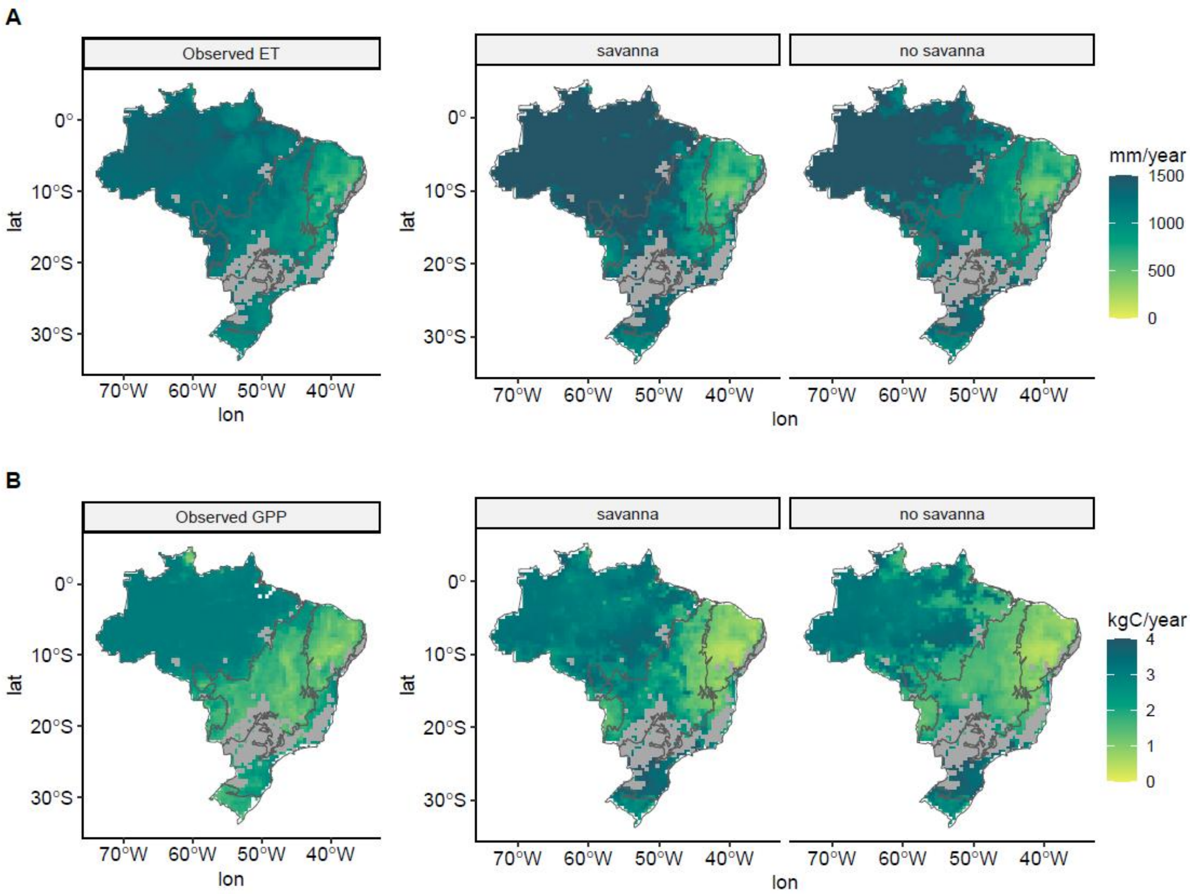

Fig S10: A) Comparison of the mean annual sum of evapotranspiration (years 1990-2019) of the model versions (right panel) with data from ERA5 (Hersbach et al., 2020; see also Sakschewski et al., 2021). B) Comparison of the mean annual sum of GPP (years 1990-2019) of the model versions (right panel) with data from Carvalhais et al., 2014. Grid cells where the human land use fraction according to MapBiomas (Fig. S5) was ≥ 75% are masked in gray and should be excluded from the comparison, as we simulated PNV (potential natural vegetation) only.

Table S3: Normalized mean square error (NMSE) and Pearson correlation (R^2 and p-value) calculated for modelled evapotranspiration (ET) and gross primary production (GPP) for Brazil, excluding cells with ≥ 75% human land use fraction according to MapBiomas (Fig. S5).

Variable	Statistic	'No savanna'	'Savanna'
ET	NMSE	1.56	1.89
	R^2	0.620	0.691
	p-value	< 0.001	< 0.001
GPP	NMSE	0.714	0.686
	R^2	0.512	0.525
	p-value	< 0.001	< 0.001

2.5 Water stress mortality

The inclusion of the water stress mortality function improved the modeled distribution of tropical broadleaved evergreen trees (TrBE), producing FPC patterns that better reflect observed vegetation gradients across Brazil (Fig. S11). Even without the tropical broadleaved savanna tree (TrBS) PFT, this process enhanced the realism of forest–savanna transitions by allowing tree cover to decline under dry or water-limited conditions.

However, the increased sensitivity of trees to drought also favored an unrealistic expansion of C_4 grasses across northeastern and central Brazil (Fig. S11). Introducing the TrBS PFT mitigated this imbalance by establishing a drought-tolerant tree layer in central Brazil, effectively limiting grass dominance and generating more plausible savanna-like structures.

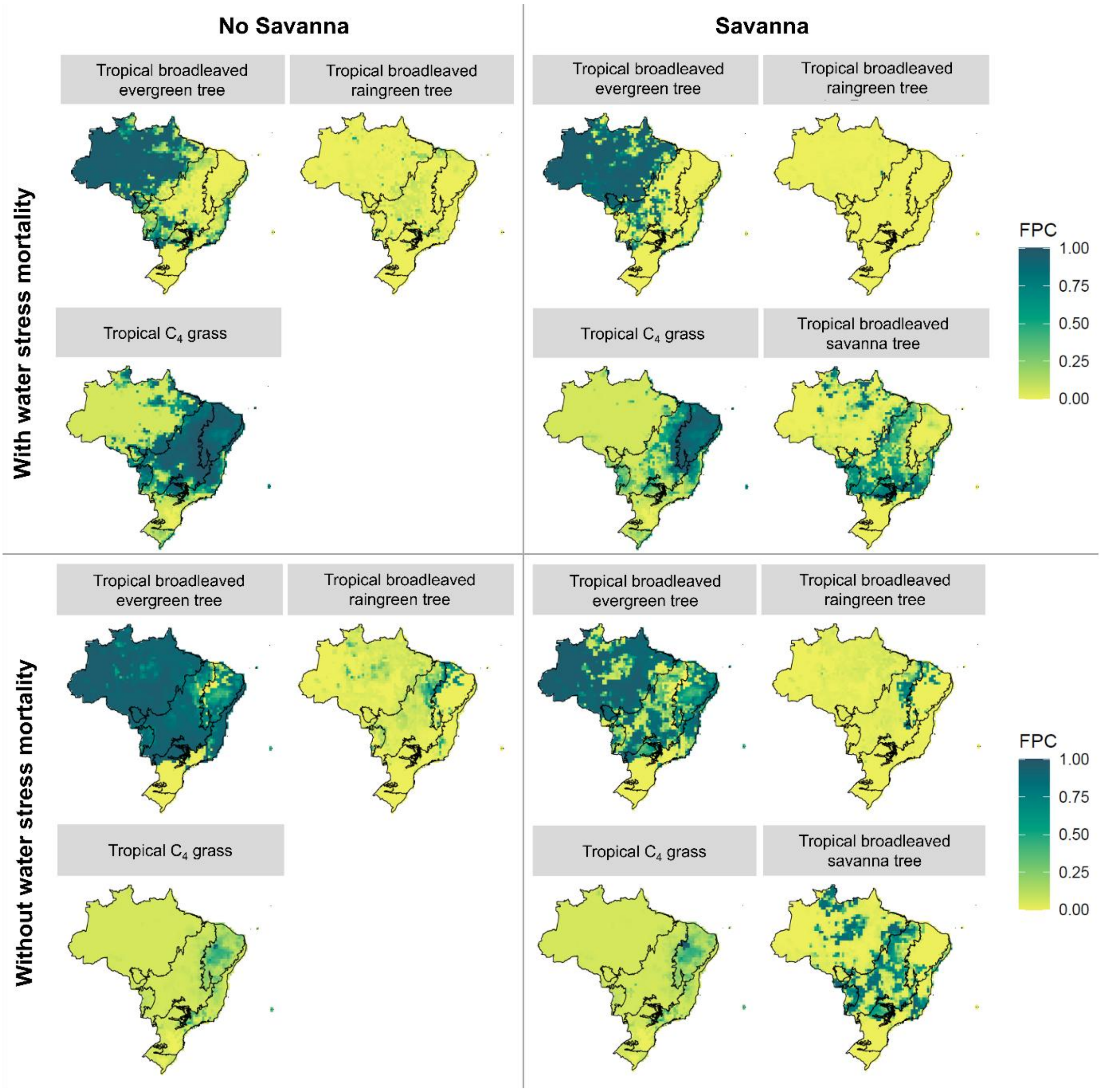

Fig. S11: Comparison of foliar projected cover (FPC) for the main plant functional types (PFTs) in Brazil across four scenarios: *No Savanna + With water stress mortality*, *Savanna + With water stress mortality*, *No Savanna + Without water stress mortality*, and *Savanna + Without water stress mortality*.

3. Sect. S3

Carvalhais, N., Forkel, M., Khomik, M., Bellarby, J., Jung, M., Migliavacca, M., Mu, M., Saatchi, S., Santoro, M., Thurner, M., Weber, U., Ahrens, B., Beer, C., Cescatti, A., Randerson, J. T., & Reichstein, M. (2014). Global covariation of carbon turnover times with climate in terrestrial ecosystems. *Nature*, *514*(7521), 213–217. https://doi.org/10.1038/nature13731

Costa, Lucas (2020). Nutrient enrichment changes water transport structures of savanna woody plants. figshare. Dataset. https://doi.org/10.6084/m9.figshare.13252052.v1

de Queiroz, L.P., Cardoso, D., Fernandes, M.F., Moro, M.F. (2017). *Diversity and Evolution of Flowering Plants of the Caatinga Domain*. In: Silva, J.M.C., Leal, I.R., Tabarelli, M. (eds.) Caatinga. Springer, Cham. https://doi.org/10.1007/978-3-319-68339-3_2

Gomes, L., Schüler, J., Silva, C., Alencar, A., Zimbres, B., Arruda, V., Silva, W. V. da, Souza, E., Shimbo, J., Marimon, B. S., Lenza, E., Fagg, C. W., Miranda, S., Morandi, P. S., Marimon-Junior, B. H., & Bustamante, M. (2024). Impacts of Fire Frequency on Net CO2 Emissions in the Cerrado Savanna Vegetation. *Fire*, *7*(8), Artigo 8. https://doi.org/10.3390/fire7080280

Hengl, T., Walsh, M. G., Sanderman, J., Wheeler, I., Harrison, S. P., & Prentice, I. C. (2018). Global mapping of potential natural vegetation: An assessment of machine learning algorithms for estimating land potential. *PeerJ*, *6*, e5457. https://doi.org/10.7717/peerj.5457

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., … Thépaut, J. N. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society,* 146, 1999 2049. https://doi.org/10.1002/qj.3803

Hoffmann, W. A., Adasme, R., Haridasan, M., T. De Carvalho, M., Geiger, E. L., Pereira, M. A. B., Gotsch, S. G., & Franco, A. C. (2009). Tree topkill, not mortality, governs the dynamics of savanna–forest boundaries under frequent fire in central Brazil. *Ecology*, *90*(5), 1326–1337. https://doi.org/10.1890/08-0741.1

IBGE. (2017). *Brazilian Vegetation*. https://www.ibge.gov.br/en/geosciences/maps/state-maps/19470-brazilian-vegetation.html?=&t=downloads

Machida, W. S., Gomes, L., Moser, P., Castro, I. B., Miranda, S. C., da Silva-Júnior, M. C., & Bustamante, M. M. C. (2021). Long term post-fire recovery of woody plants in savannas of central Brazil. *Forest Ecology and Management*, *493*, 119255. https://doi.org/10.1016/j.foreco.2021.119255

MapBiomas 9.0. (2024). *MapBiomas Uso e Cobertura 9.0.* https://brasil.mapbiomas.org/colecoes-mapbiomas/

MCTI: Quarto inventário nacional de emissões e remoções antrópicas de gases de efeito estufa setor uso da terra, mudança do uso da terra e florestas, Available at: https://repositorio.mcti.gov.br/handle/mctic/4782, 2020.

Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, *11*(5), 1633–1644. https://doi.org/10.5194/hess-11-1633-2007

Sakschewski, B., von Bloh, W., Drüke, M., Sörensson, A. A., Ruscica, R., Langerwisch, F., Billing, M., Bereswill, S., Hirota, M., Oliveira, R. S., Heinke, J., & Thonicke, K. (2021). Variable tree rooting strategies are key for modelling the distribution, productivity and evapotranspiration of tropical evergreen forests. *Biogeosciences*, *18*(13), 4091–4116. https://doi.org/10.5194/bg-18-4091-2021

Schaphoff, S., Von Bloh, W., Rammig, A., Thonicke, K., Biemans, H., Forkel, M., Gerten, D., Heinke, J., Jägermeyr, J., Knauer, J., Langerwisch, F., Lucht, W., Müller, C., Rolinski, S., & Waha, K. (2018). LPJmL4 – a dynamic global vegetation model with managed land – Part 1: Model description. *Geoscientific Model Development*, *11*(4), 1343–1375. https://doi.org/10.5194/gmd-11-1343-2018

Schüler, Jéssica (2020). Áreas prioritárias para a restauração no Cerrado: aumentando os benefícios e reduzindo os conflitos. Masters dissertation, Universidade de Brasília. 105 p. Available at http://repositorio.unb.br/handle/10482/39518