Controls of rainfall patterns on C and N emissions and stocks in Australian grasslands

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Acknowledgment:
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THE UNIVERSITY OF SYDNEY

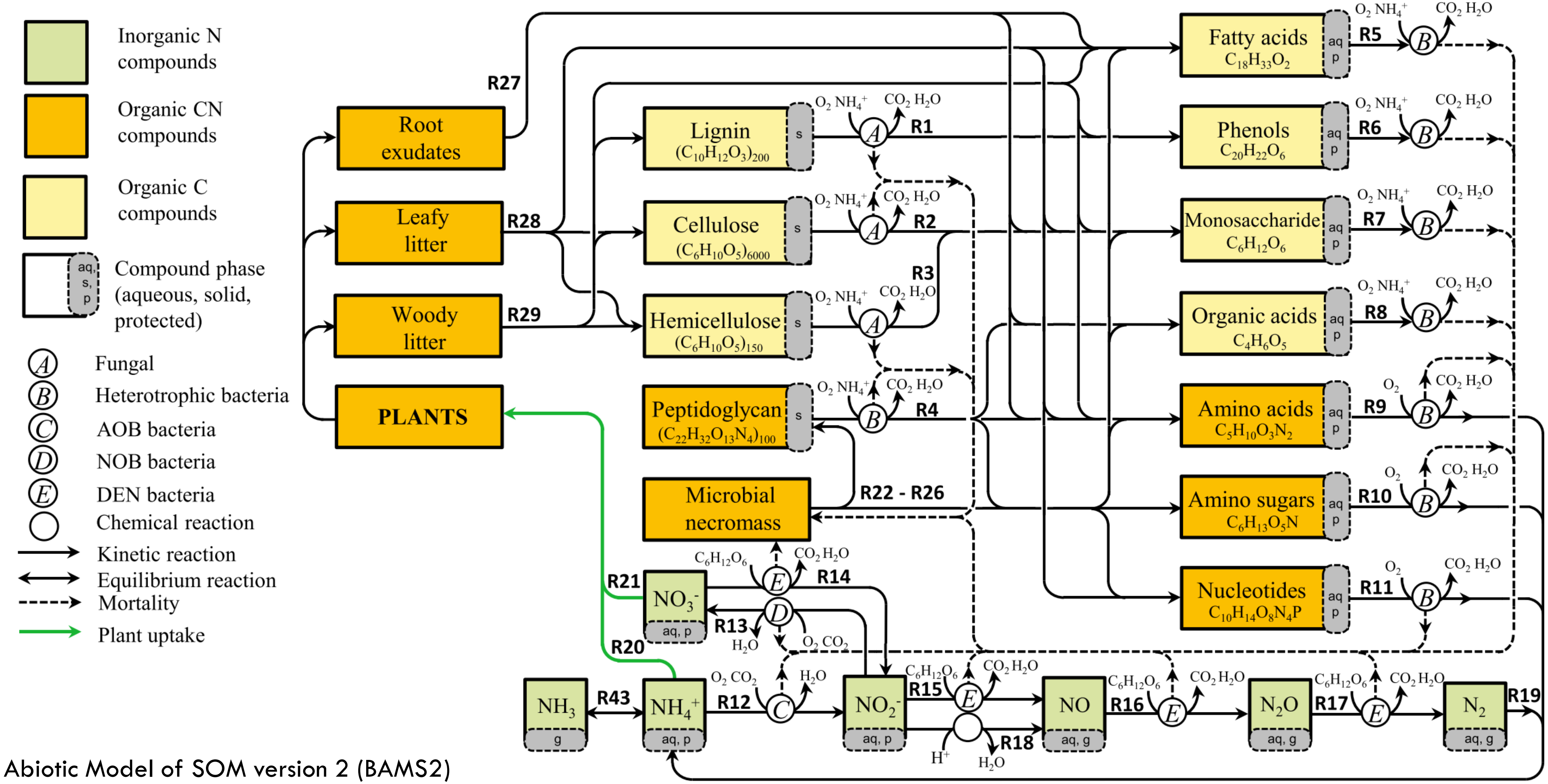
Aim:

To investigate how the expected 21st century changes in hourly and daily rainfall affect carbon and nitrogen emissions, as well as the soil organic stocks in Australian grasslands located in different climatic regions.

Research Method:

We used a coupled carbon and nitrogen cycles mechanistic model (BAMS2) that includes kinetic reactions of 11 soil organic matter (SOM) pools, the transformation of inorganic nitrogen, microbial and plant growth dynamics, biological water stress response, chemical protection, water flow, chemical transport via advection and diffusion, aqueous complexation, and gas dissolution.

Carbon and Nitrogen reaction network (BAMS2)

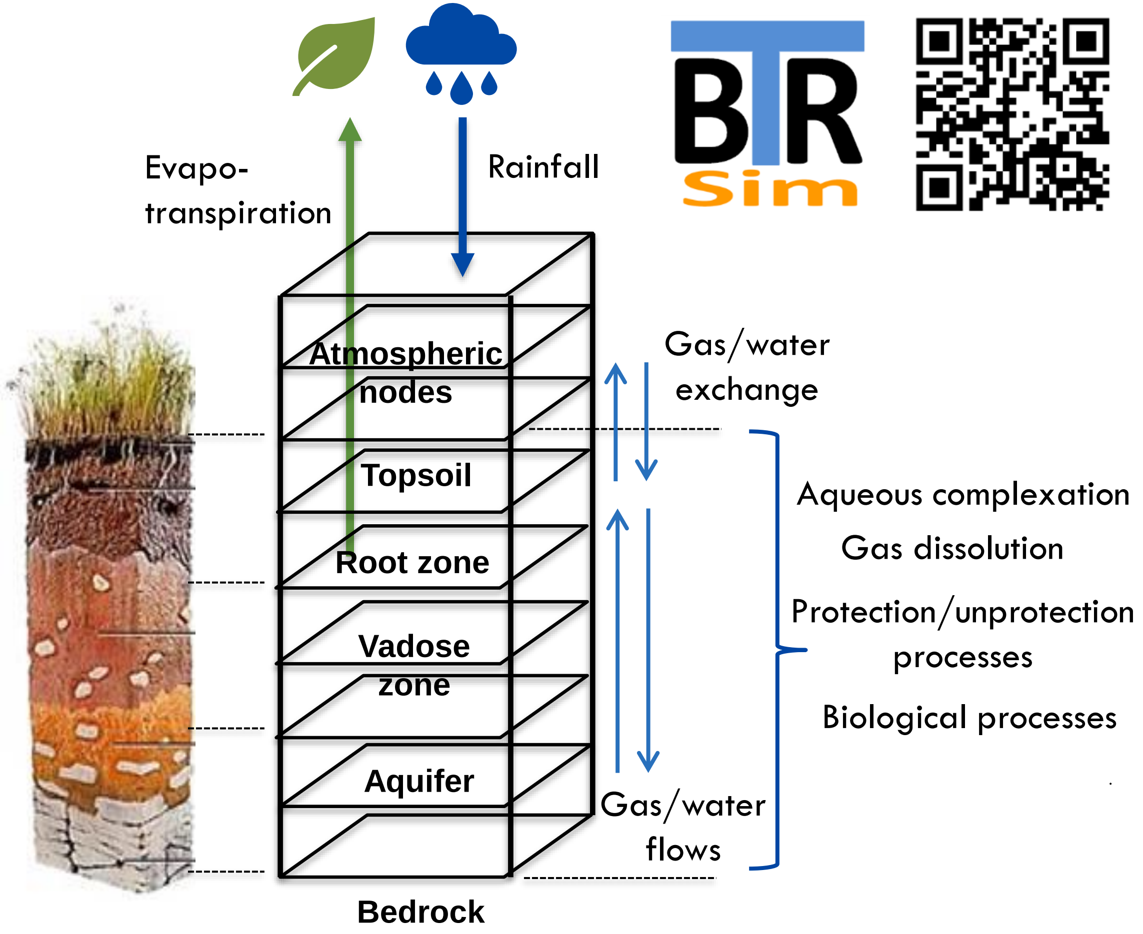


Biotic and Abiotic Model of SOM version 2 (BAMS2)

Tang, F. H.M., Riley, W. J., & Maggi, F. (2019). Hourly and daily rainfall intensification causes opposing effects on C and N emissions, storage, and leaching in dry and wet grasslands. *Biogeochemistry*, *144*(2), 197-214.

Model framework and description

BAMS2 is solved within the general-purpose multi-phase and multi-species **B**io**R**eactive **T**ransport **S**imulator



Water and gas flow

$$\frac{\partial M_\beta}{\partial t} = \int_\Gamma \rho_{\beta e} v_\beta \mathrm{d}\Gamma + \int_V \rho_{\beta e} u_\beta \mathrm{d}V \pm \int_V f_\beta r_B \rho_{\beta e} \mathrm{d}V,$$

$$\text{for} \quad \beta = L, G, B,$$

Transport of dissolved species in any phase

$$\frac{\partial M_\beta^k}{\partial t} = \int_\Gamma \rho_{\beta e}(v_\beta X_\beta^k - D_\beta^k \nabla X_\beta^k)\mathrm{d}\Gamma +$$

$$\int_V \rho_{\beta e} u_\beta X_\beta^k \mathrm{d}V \pm \int_V r_\beta^k \rho_{\beta e} \mathrm{d}V.$$

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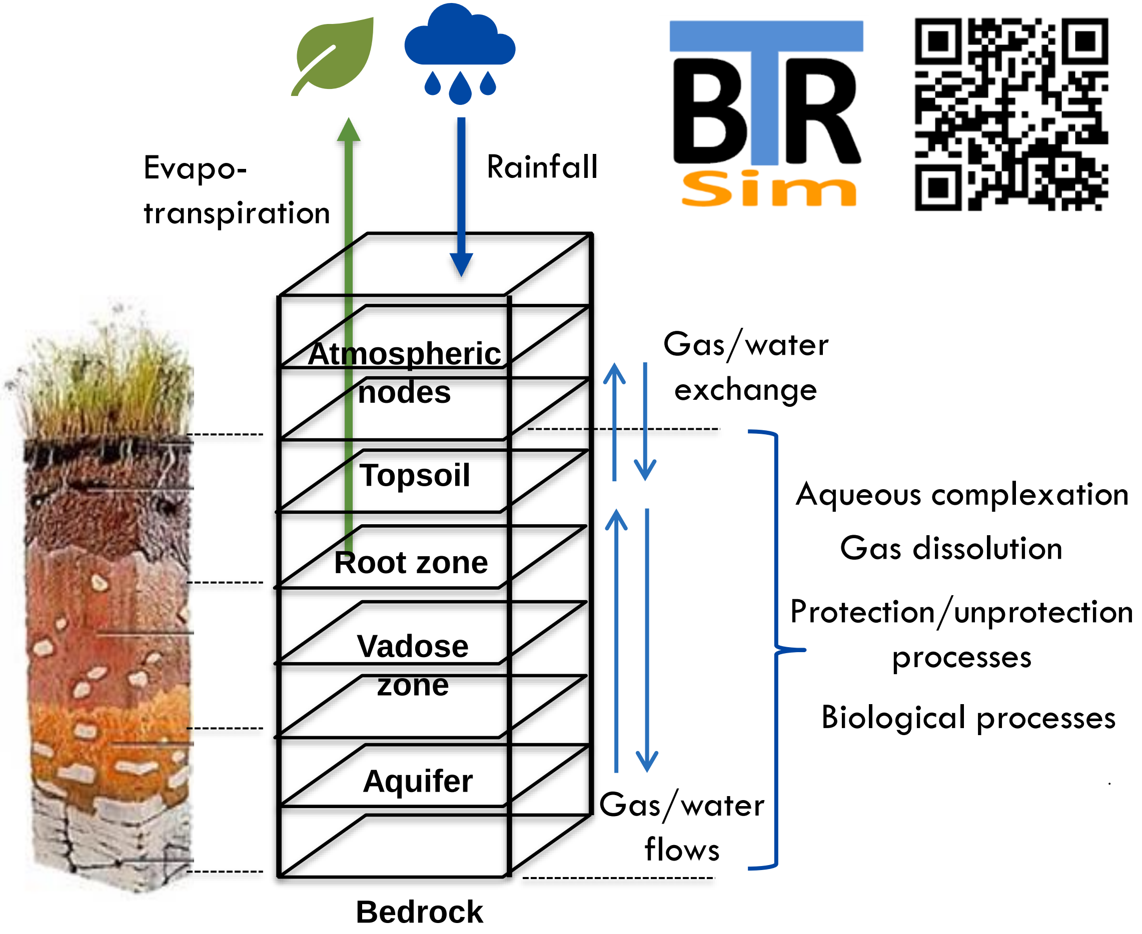


Aqueous complexation and gas dissolution

$$K = \prod_R [\mathrm{X}_R]^{-x_R} \cdot \prod_P [\mathrm{X}_P]^{x_P}$$

Protection/unprotection

$$\frac{\mathrm{d}[\mathrm{X(p)}]}{\mathrm{d}t} = k_a(Q_{max} - [\mathrm{X(p)}])[\mathrm{X(aq)}] - k_d[\mathrm{X(p)}]$$

Biological processes

$$R = kf_S \frac{[B_X]}{Y} \prod_i \frac{[\mathrm{X}_i]}{[\mathrm{X}_i] + K_{M_i}} \prod_m \frac{K_{I_m}}{K_{I_m} + [\mathrm{X}_m]}$$

$$\frac{\mathrm{d}[B_X]}{\mathrm{d}t} = \sum_i Y_i R_i - \delta[B_X]$$

$$R_{N_{plant}} = f_S \left(k_{\mathrm{NH}_4^+} \frac{[\mathrm{NH}_4^+]}{[\mathrm{NH}_4^+] + K_{M_{\mathrm{NH}_4^+}}} + k_{\mathrm{NO}_3^-} \frac{[\mathrm{NO}_3^-]}{[\mathrm{NO}_3^-] + K_{\mathrm{MNO}_3^-}} \right)$$

Model framework and description

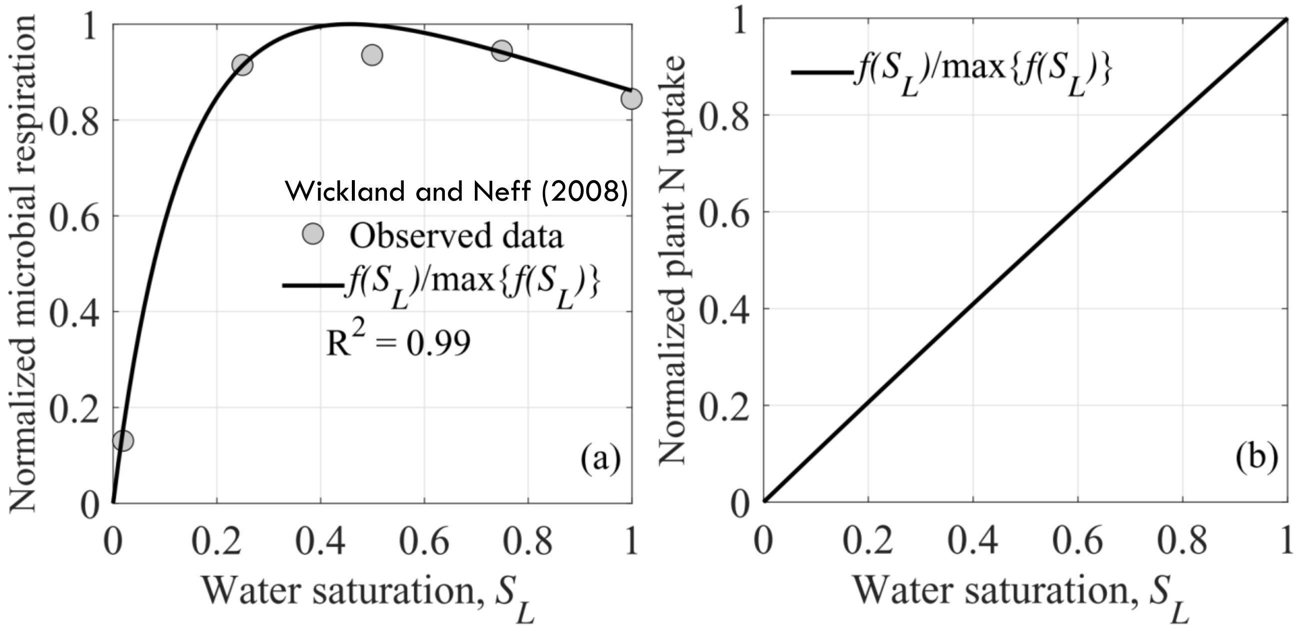
Water stress response function $f_S = \min\{f(S_B), f(S_L)/\max\{f(S_L)\}\}$

$$f(S_B) = \min\left\{1 - \frac{S_B}{1 - S_{Lr} - S_{Gr}}, 1 - \frac{f_L S_B}{S_L - S_{Lr}}, 1 - \frac{(1 - f_L) S_B}{S_G - S_{Gr}}\right\}$$

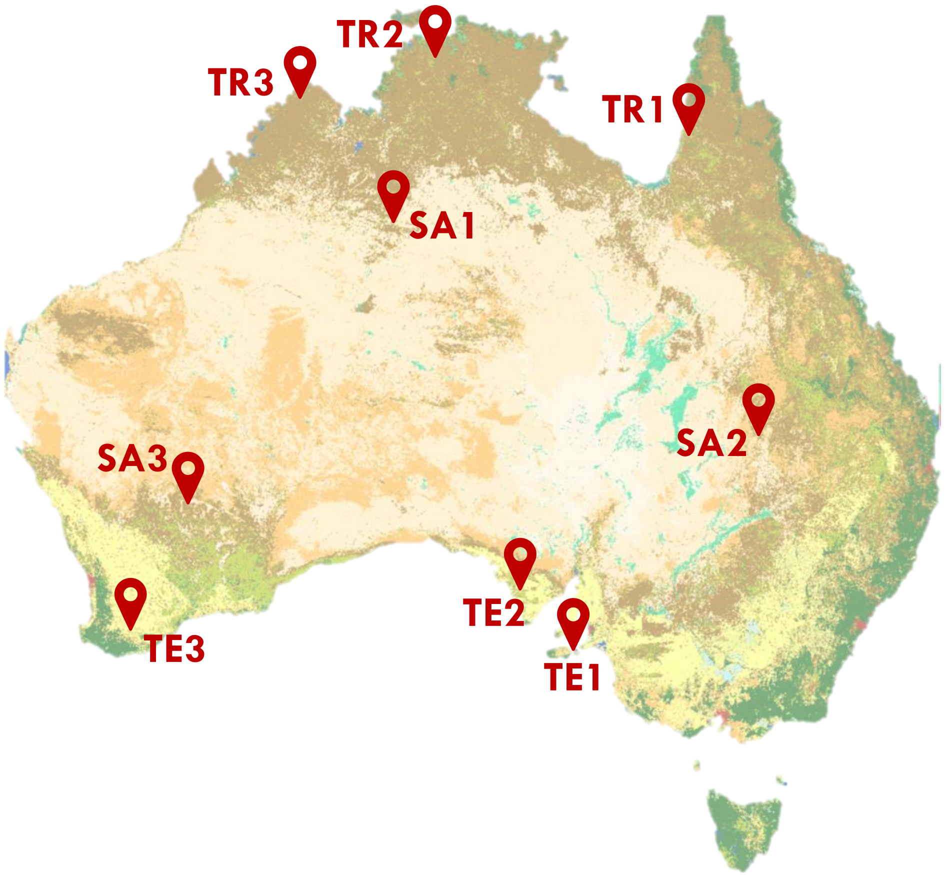
Describes the immobilization of water into microbial biomass and space availability for growth

$$f(S_L) = \frac{S_L}{S_{L,LB} + S_L} \frac{S_{L,UB}}{S_{L,UB} + S_L}$$

Describes the activity reduction as a result of physiological stress and limited substrate diffusion within a soil layer



Site description



Tropical grasslands (TR)

Annual rainfall : 1100 – 1450 mm/yr

No. of wet days per year : 140 – 175

Temperate grasslands (TE)

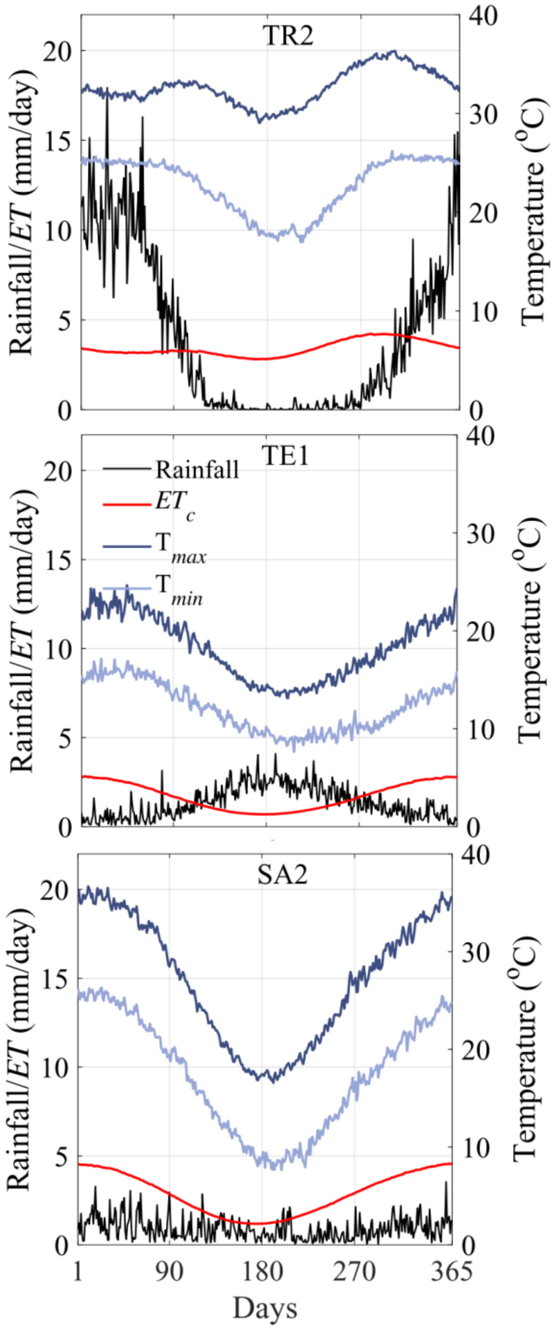
Annual rainfall : 380 – 560 mm/yr

No. of wet days per year : 160 – 233

Semi-arid grasslands (SA)

Annual rainfall : 290 – 610 mm/yr

No. of wet days per year : 89 – 110



Rainfall scenarios

Scenario 1 : change in annual cumulative rainfall amount

- Annual cumulative rainfall ranged +/- 20%
- Annual no. wet days remained constant

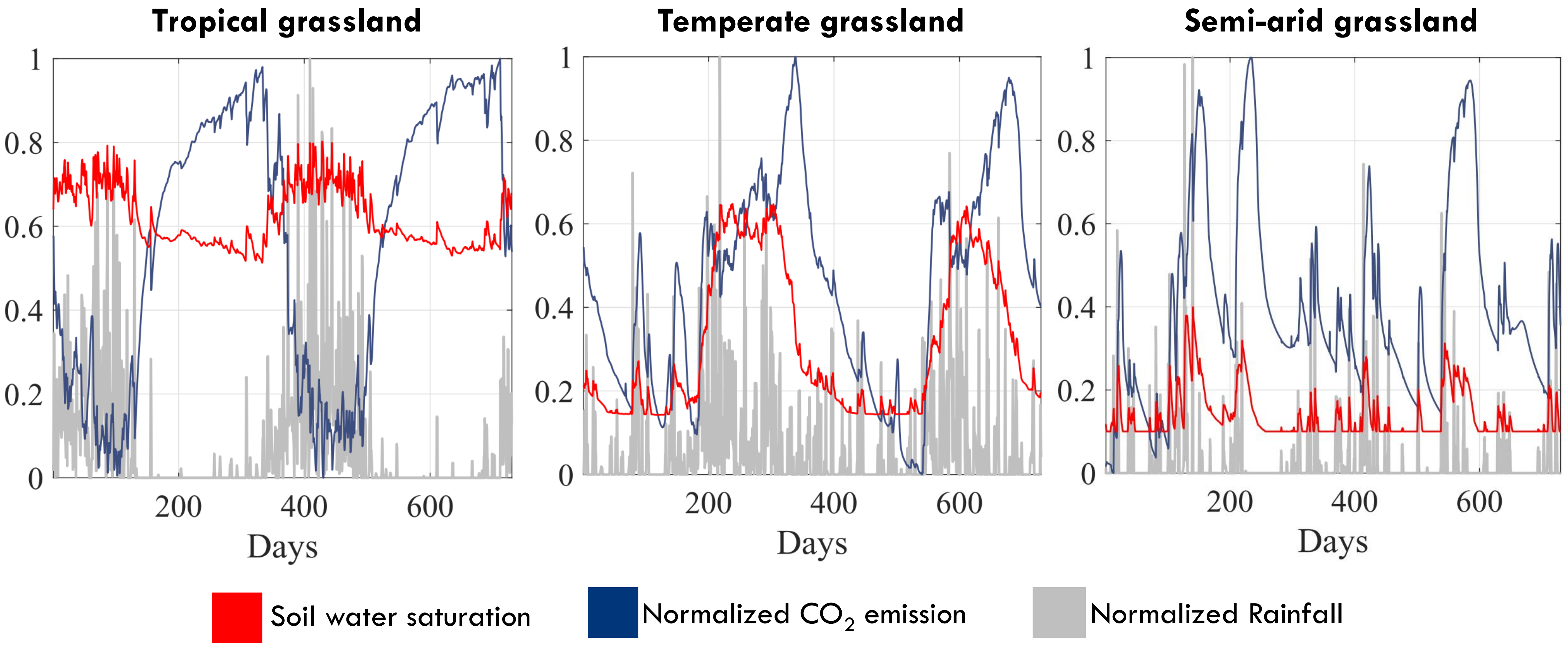
Scenario 2 : change in daily rainfall amount and frequency

- Annual cumulative rainfall remained constant
- Annual no. wet days ranged +/- 50%

Scenario 3 : change in hourly rainfall

- Daily cumulative rainfall remained constant
- Daily rainfall was distributed to different no. of wet hours

Results – The *Birch effect*



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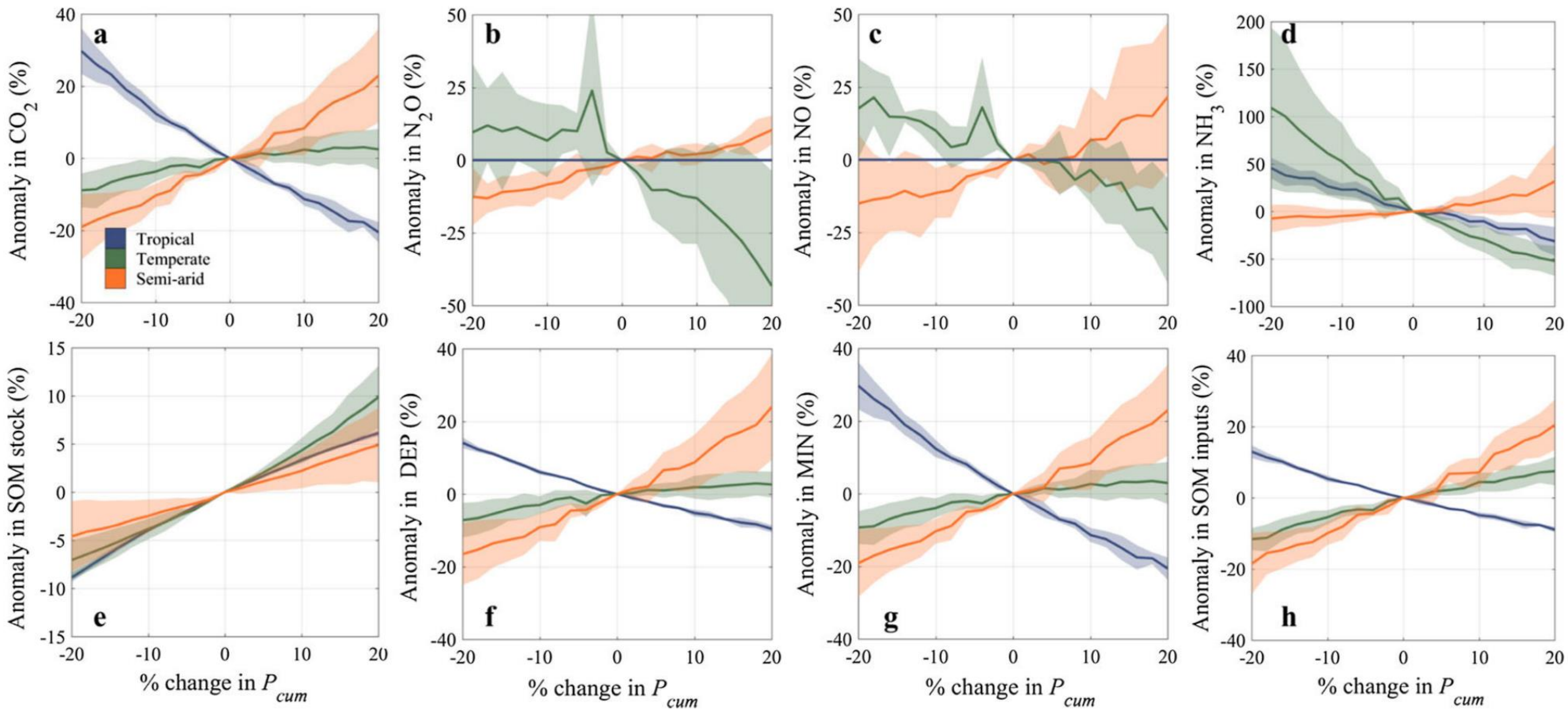
Results – Scenario 1: change in annual cumulative rainfall amount



DEP = depolymerization   MIN = mineralization

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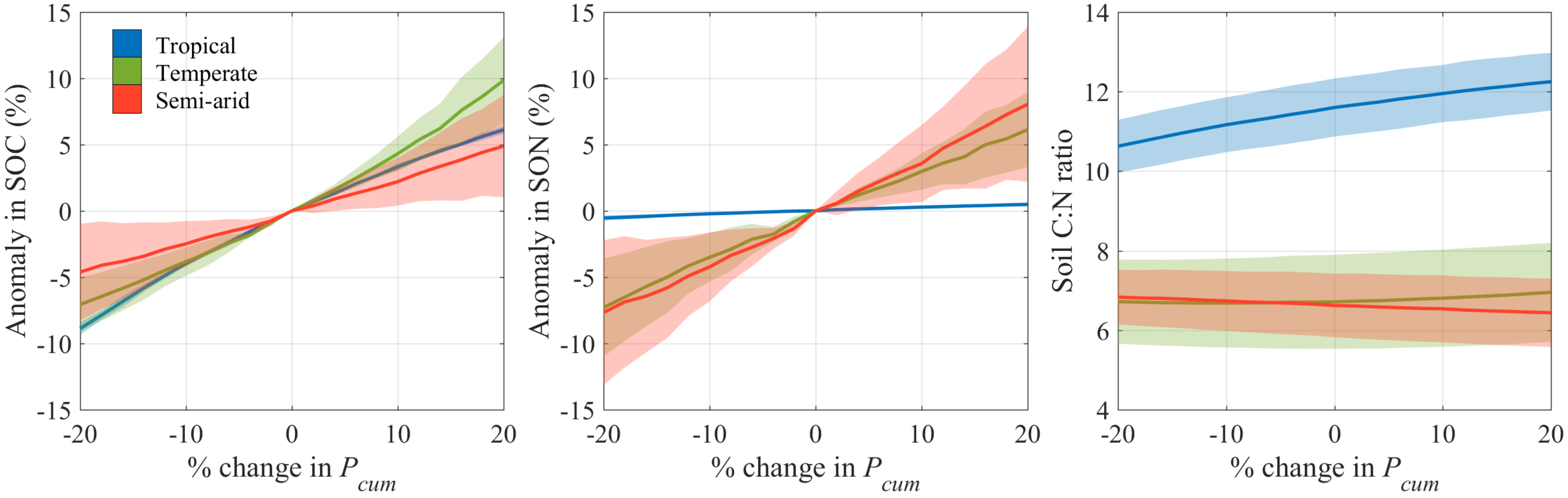
Results – Scenario 1: change in annual cumulative rainfall amount

Soil organic carbon stock | **Soil organic nitrogen stock** | **Soil C:N ratio**



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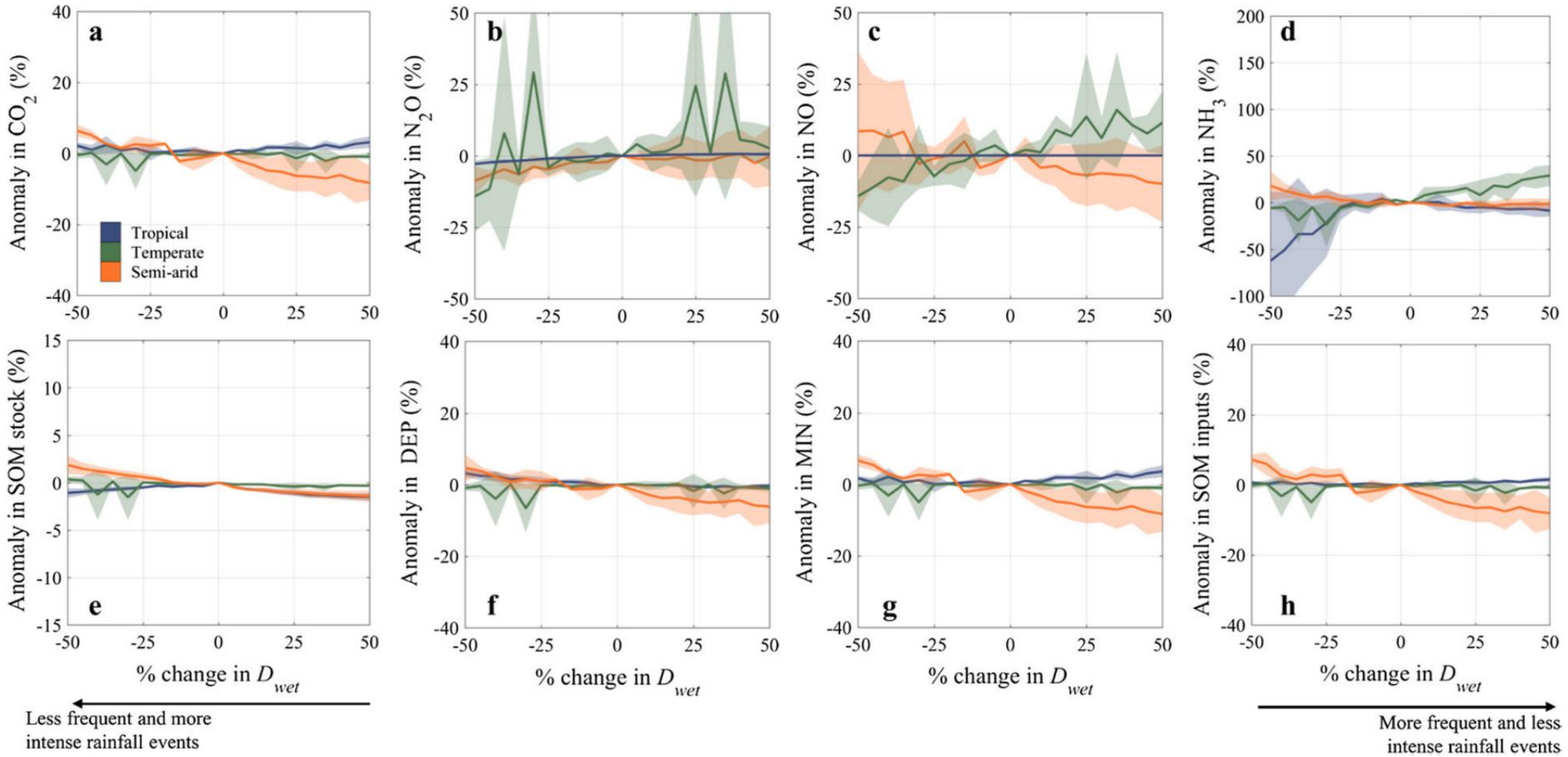
Results – Scenario 2: change in daily rainfall amount and frequency



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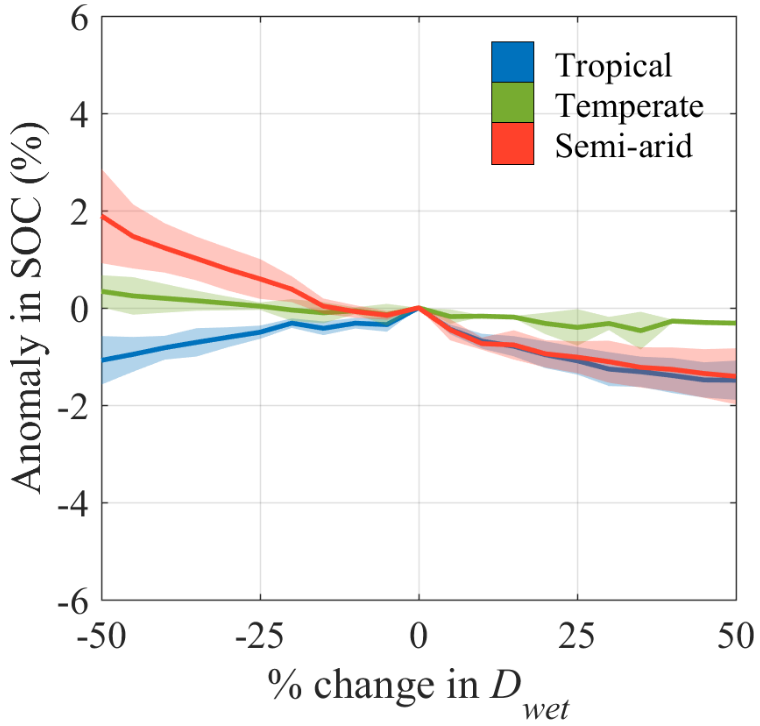
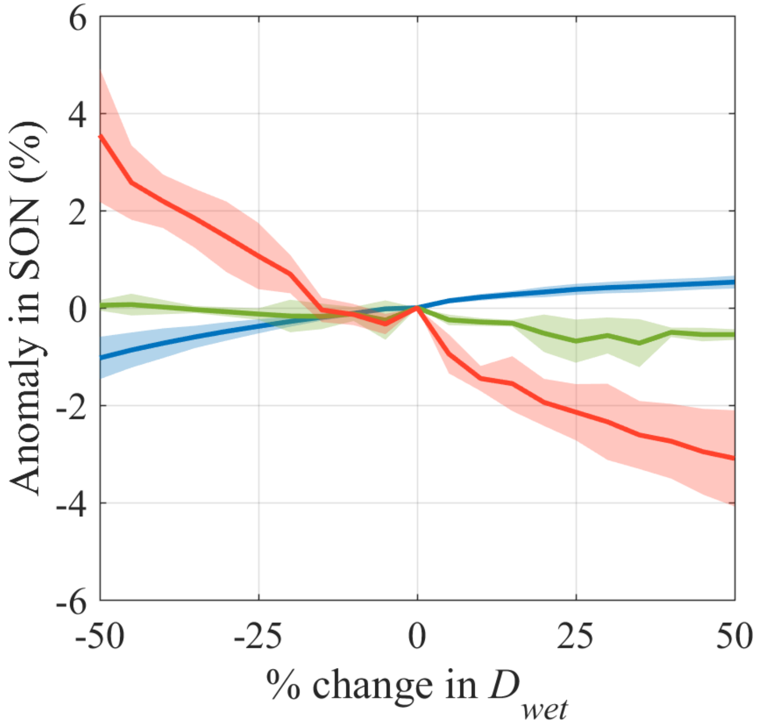
Results – Scenario 2: change in daily rainfall amount and frequency

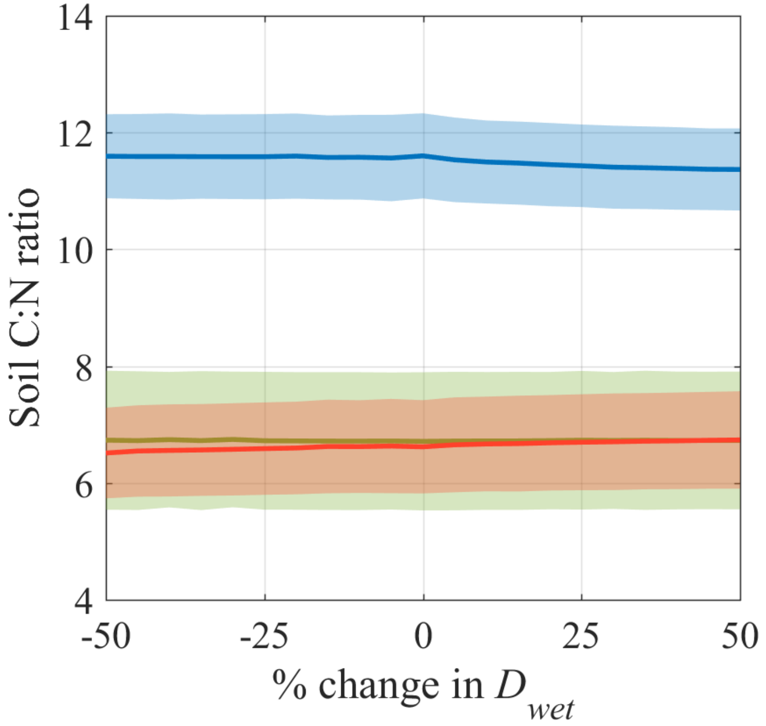
Soil organic carbon stock



Soil organic nitrogen stock



Soil C:N ratio



← Less frequent and more intense rainfall events

More frequent and less intense rainfall events →

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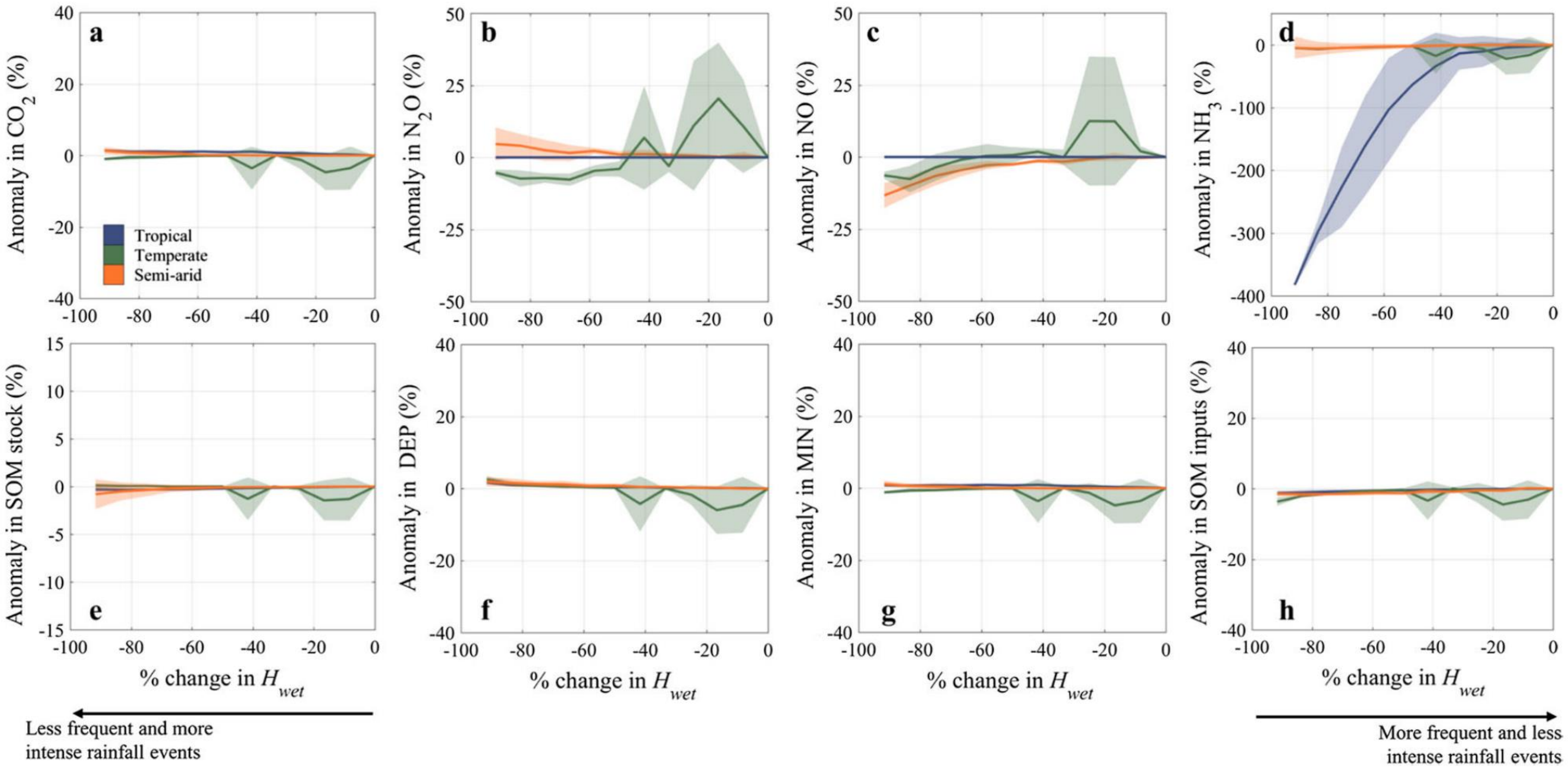
Results – Scenario 3: change in hourly rainfall



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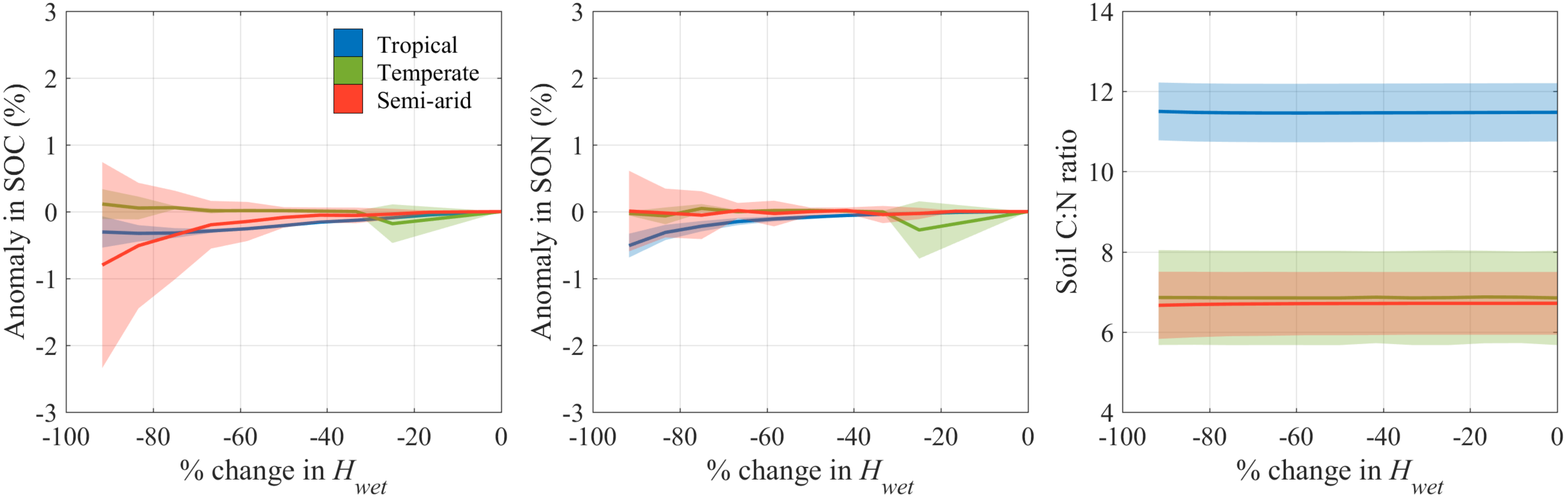
Results – Scenario 3: change in hourly rainfall

Soil organic carbon stock | **Soil organic nitrogen stock** | **Soil C:N ratio**



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Conclusions

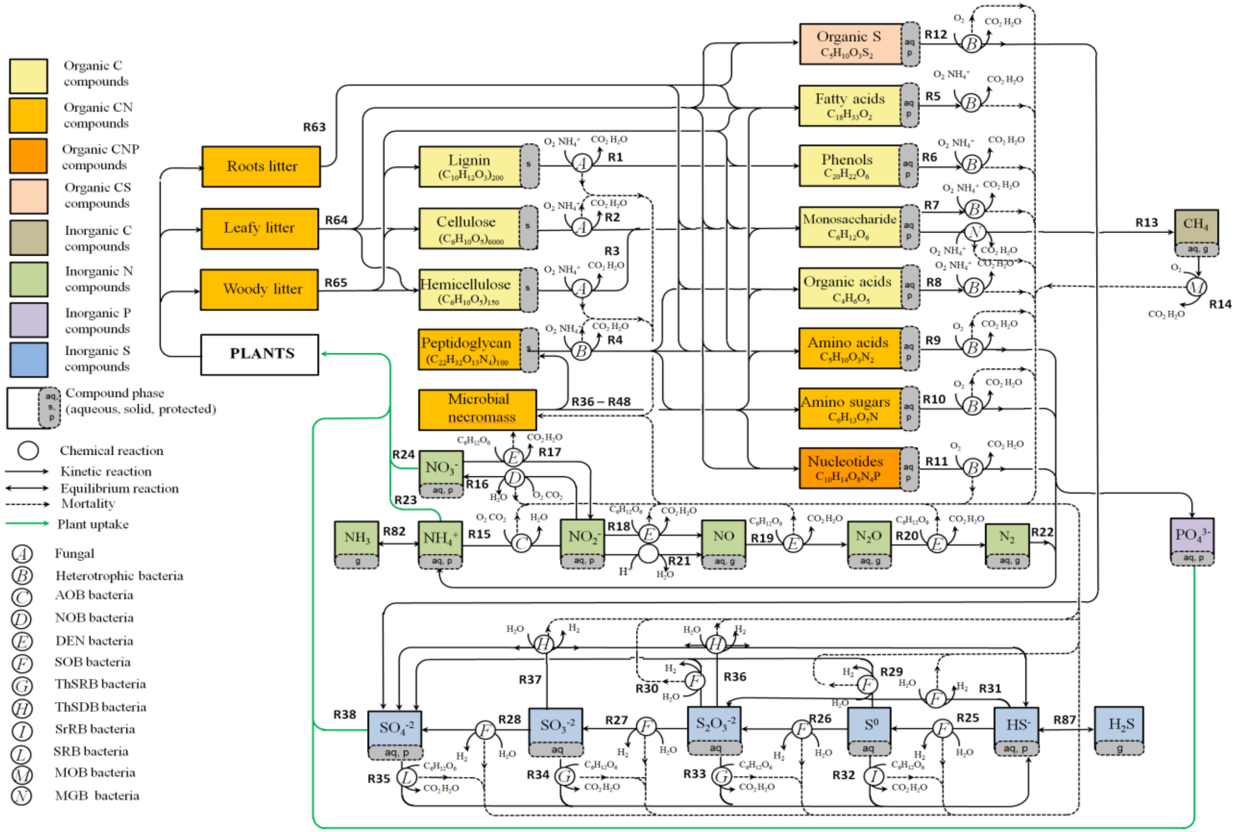
Changes in rainfall regimes alter both the total amount and stoichiometry of SOM

Dry and wet grasslands responded differently to variations in rainfall patterns

Hourly rainfall intensification did not cause a substantial impact on CO_2 emissions and soil organic C and N stocks

Work in press

- coupling to Phosphate and Sulphur cycles



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Artemis HPC facility

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For more information:

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https://sites.google.com/site/thebrtsimproject/

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