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Istituto per la BioEconomia
Dipartimento di Scienze Bio Agroalimentari

The three major axes of terrestrial ecosystem functions

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MOTIVAZIONE

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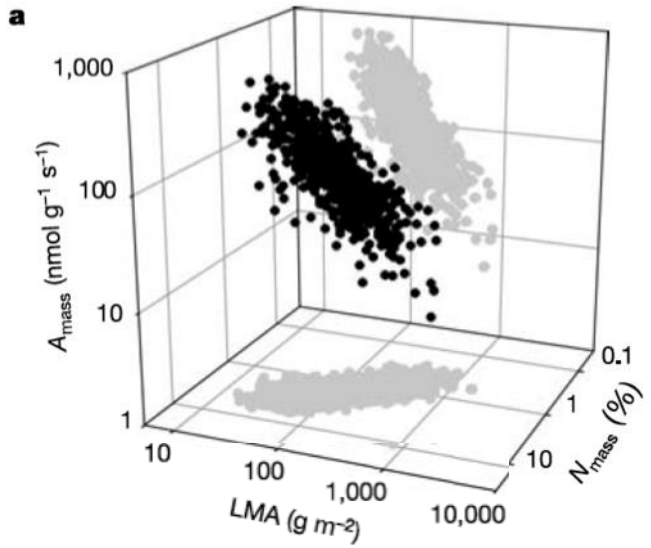
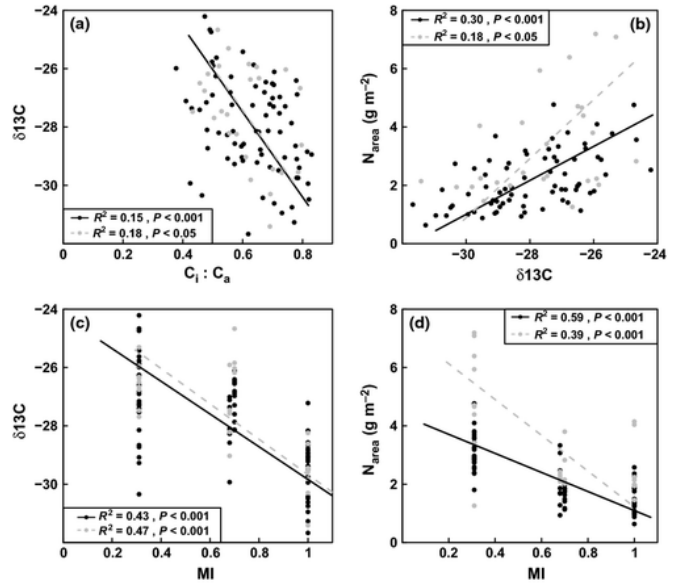
Relationships and coordination among leaf traits and plant organs as shaped by the evolutionary development of plant species and globally constrained by construction costs and growth potential

Examples leaf economic spectrum (Wright et al., 2003; Diaz et al., 2016) or least cost theory



The worldwide leaf economics spectrum

Ian J. Wright[1], Peter B. Reich[2], Mark Westoby[1], David D. Ackerly[3], Zdravko Baruch[4], Frans Bongers[5], Jeannine Cavender-Bares[6], Terry Chapin[7], Johannes H. C. Cornelissen[8], Matthias Diemer[9], Jaume Flexas[10], Eric Garnier[11], Philip K. Groom[12], Javier Gulias[10], Kouki Hikosaka[13], Byron B. Lamont[12], Tali Lee[14], William Lee[15], Christopher Lusk[16], Jeremy J. Midgley[17], Marie-Laure Navas[11], Ülo Niinemets[18], Jacek Oleksyn[2,19], Noriyuki Osada[20], Hendrik Poorter[21], Pieter Poot[22], Lynda Prior[23], Vladimir I. Pyankov[24], Catherine Roumet[11], Sean C. Thomas[25], Mark G. Tjoelker[26], Erik J. Veneklaas[22] & Rafael Villar[27]



ECOLOGY LETTERS
Ecology Letters, (2014) **17**: 82–91 doi: 10.1111/ele.12211

LETTER

Balancing the costs of carbon gain and water transport: testing a new theoretical framework for plant functional ecology

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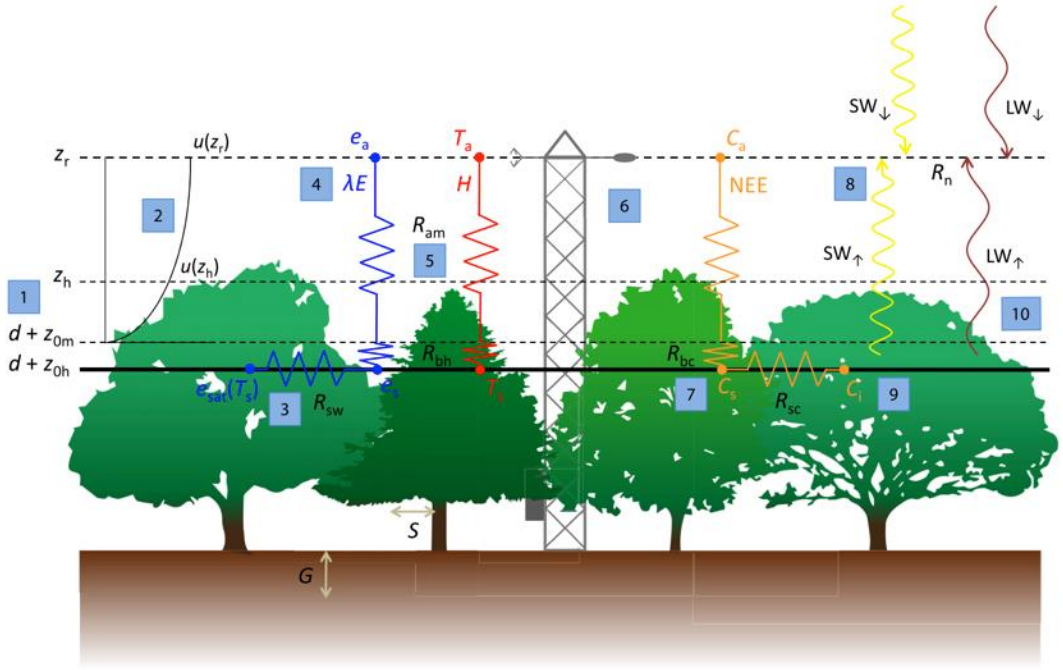
Unclear whether ecosystem functions themselves demonstrate coordination and trade-offs similar to the underlying individual plant and leaf components.



Knauer et al., 2018 PlosOne

Courtesy: M.Migliavacca

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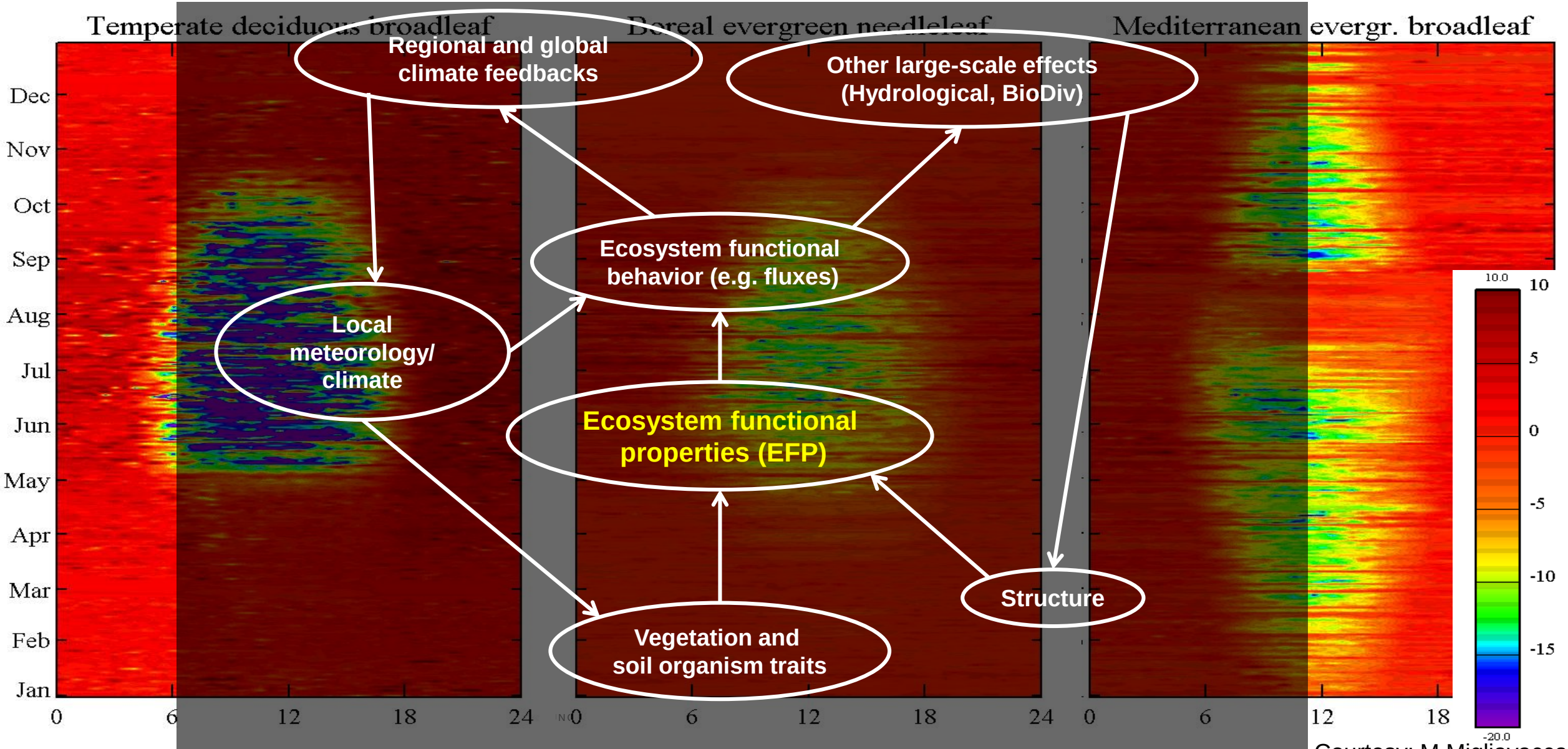
RESEARCH GAP:

Multifunctionality is rarely measured on the large spatial scales

- Typically at small plot scale
- Often major biomes not simultaneously measured
- Functions are not measured consistently
- FLUXNET and the concept of ecosystem functional properties (EFPs, Reichstein et al., 2014) can help!
- **Consistent functions estimated across biomes and in time to better understand multifunctionality**

Courtesy: Markus Reichstein
Reichstein et al., 2014 PNAS, Musavi et al., 2015, 2016, 2017, Knauer et al., 2018

EDDY COVARIANCE AND ECOSYSTEM FUNCTIONAL PROPERTIES



Courtesy: M Migliavacca

QUESTIONS

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- What are the key dimensions of **ecosystem multifunctionality** across major biomes?
- What are the **causes of variation and controlling factors** of the key dimensions of ecosystem multifunctionality?
- Do land surface models reproduce the key dimensions of ecosystem multifunctionality?

DATA

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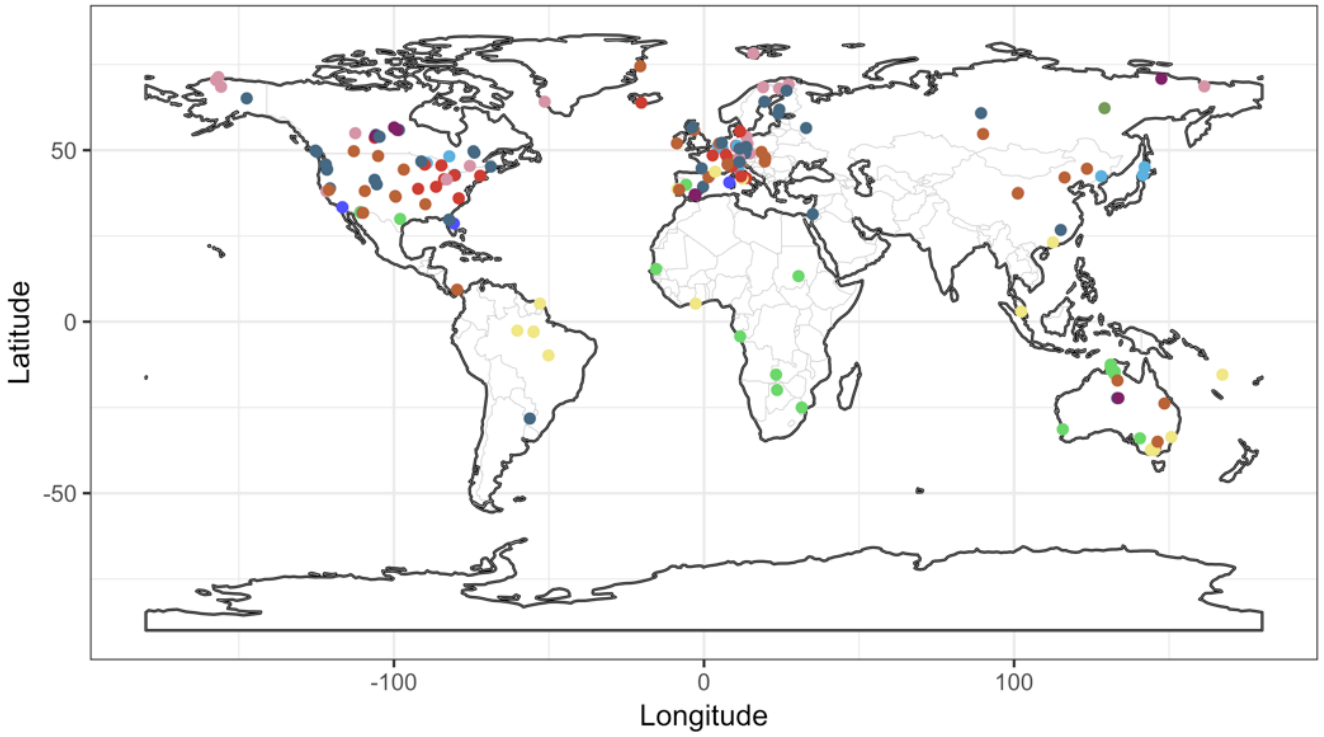

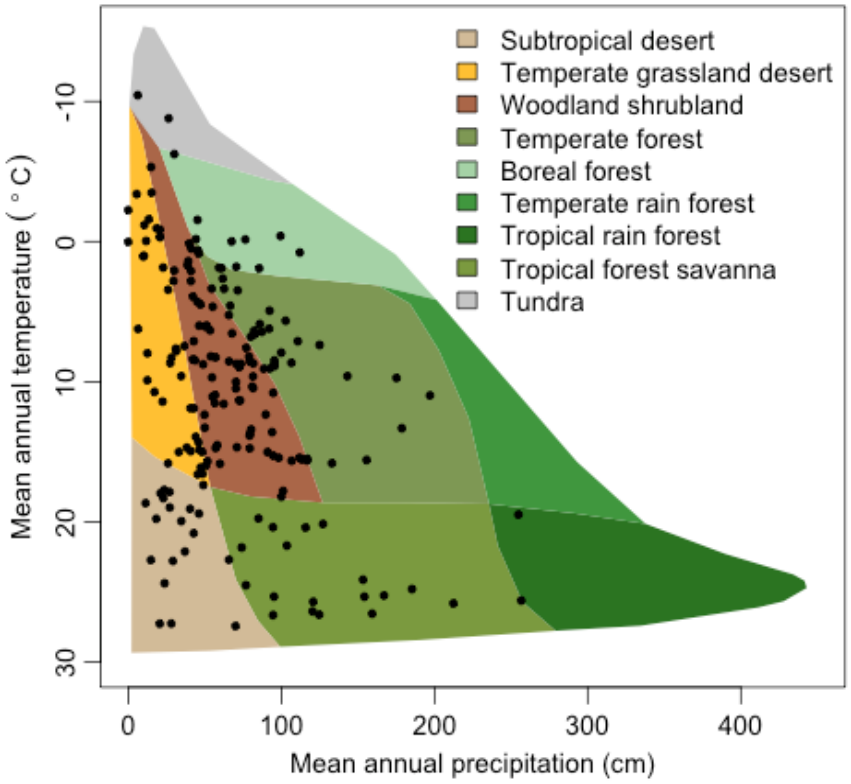

203 siti di cui 16 in Italia (4 del Cnr)

Migliavacca et al., 2021 Nature

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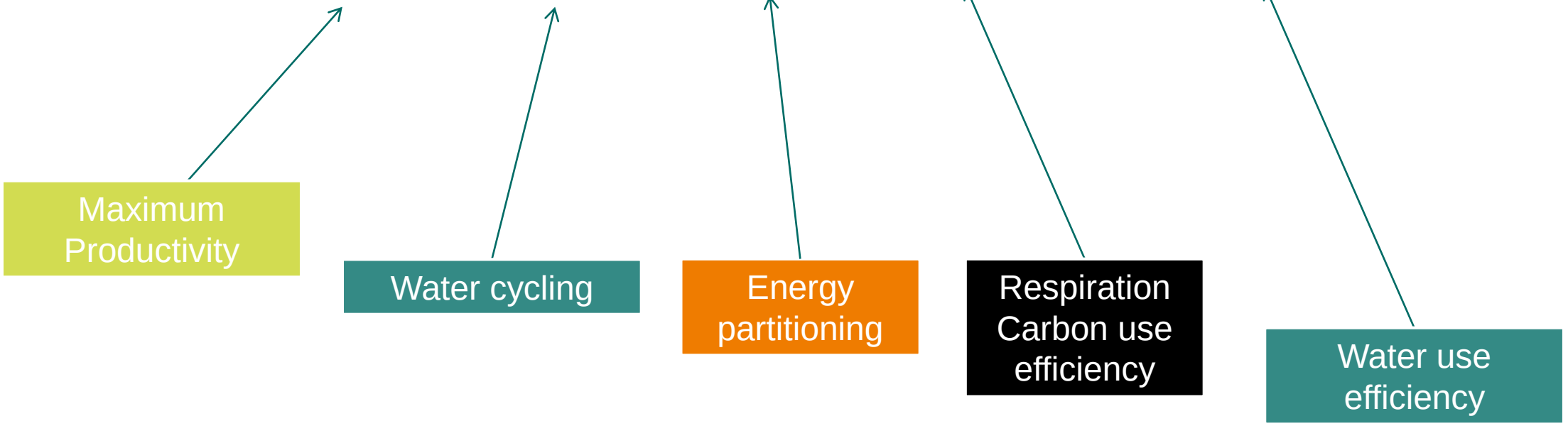
Single set of ecosystem functional properties for each site

$$EFP = [GPP_{sat}, NEP_{max}, ET_{max}, GS_{max}, EF_{max}, EF_{ampl}, Rb_{max}, Rb, G_1, aCUE, WUE, uWUE, uWUEt]$$



EFPs definition Reichstein et al. 2014; Migliavacca et al., 2011, 2015; Musavi et al., 2016a,2016b,2017; Knauer et al., 2018; Nelson et al., 2019

Courtesy: M.Migliavacca

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Ancillary information

- foliar N concentration (N%) (Flechard et al., 2020, Musavi et al., 2015, **BADM**)
- maximum leaf area index (LAI_{max}) (Migliavacca et al., 2011; Flechard et al., 2020; **BADM**)
- Age since last stand replacing disturbance or plantation in absence of disturbance (Migliavacca et al., 2011, Musavi et al., 2017, Besnard et al., 2018, Flechard et al., 2020)
- Canopy height (Hou et al., 2018; **BADM**)
- Aboveground Biomass ESA CCI (Uli Weber and Nuno Carvalhais)
- Long term Climate variables (mainly **BADM**)

KEY DIMENSIONS OF ECOSYSTEM MULTIFUNCTIONALITY

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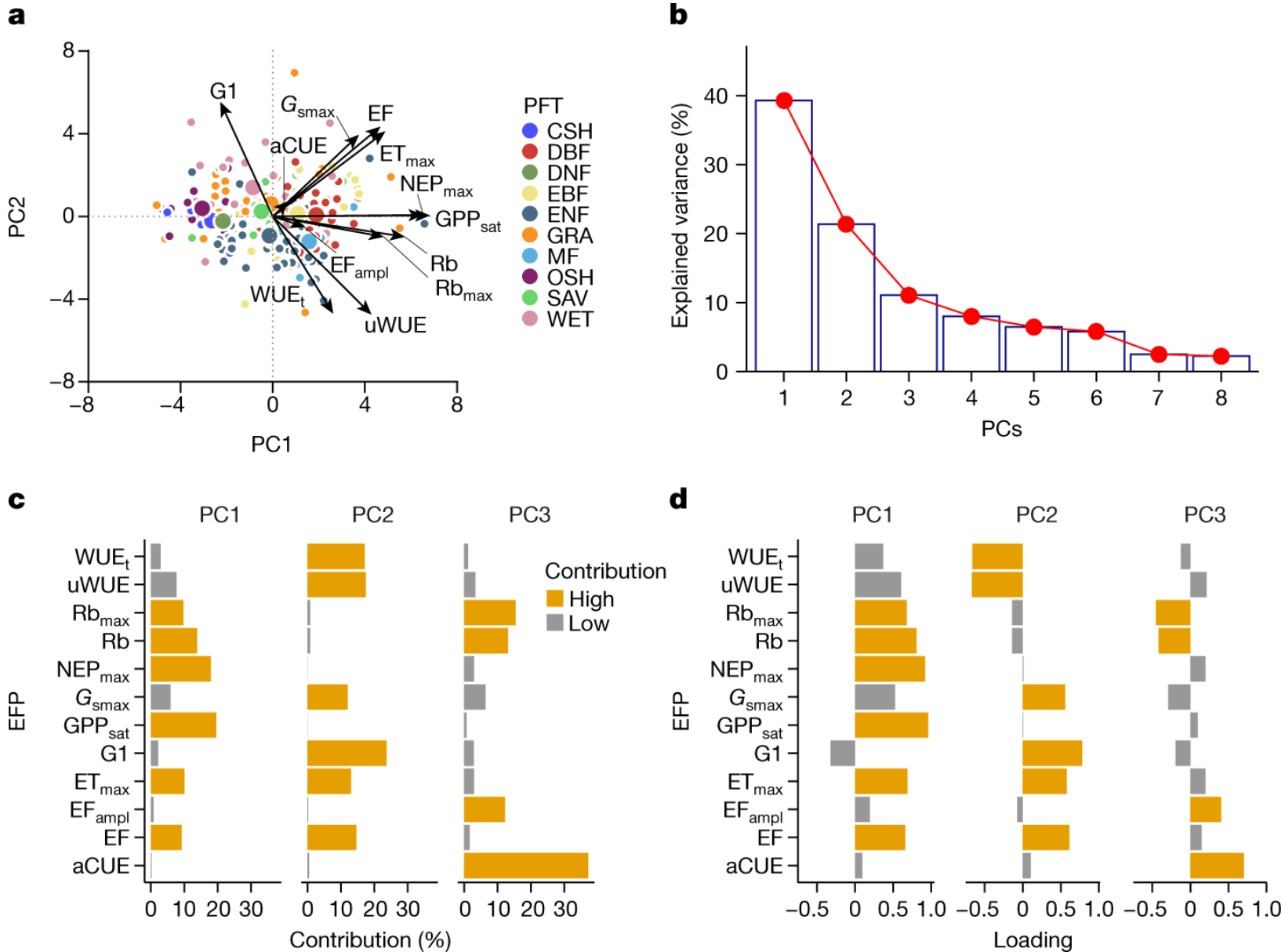

Three key axis represent ecosystem multifunctionality (**PCA**)
~ 70% explained variability

Axis:

- Potential productivity
- Water use strategies
- Carbon use strategies/efficiency

Migliavacca et al., 2021 Nature

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CONTROLLING FACTORS OF THE KEY AXES

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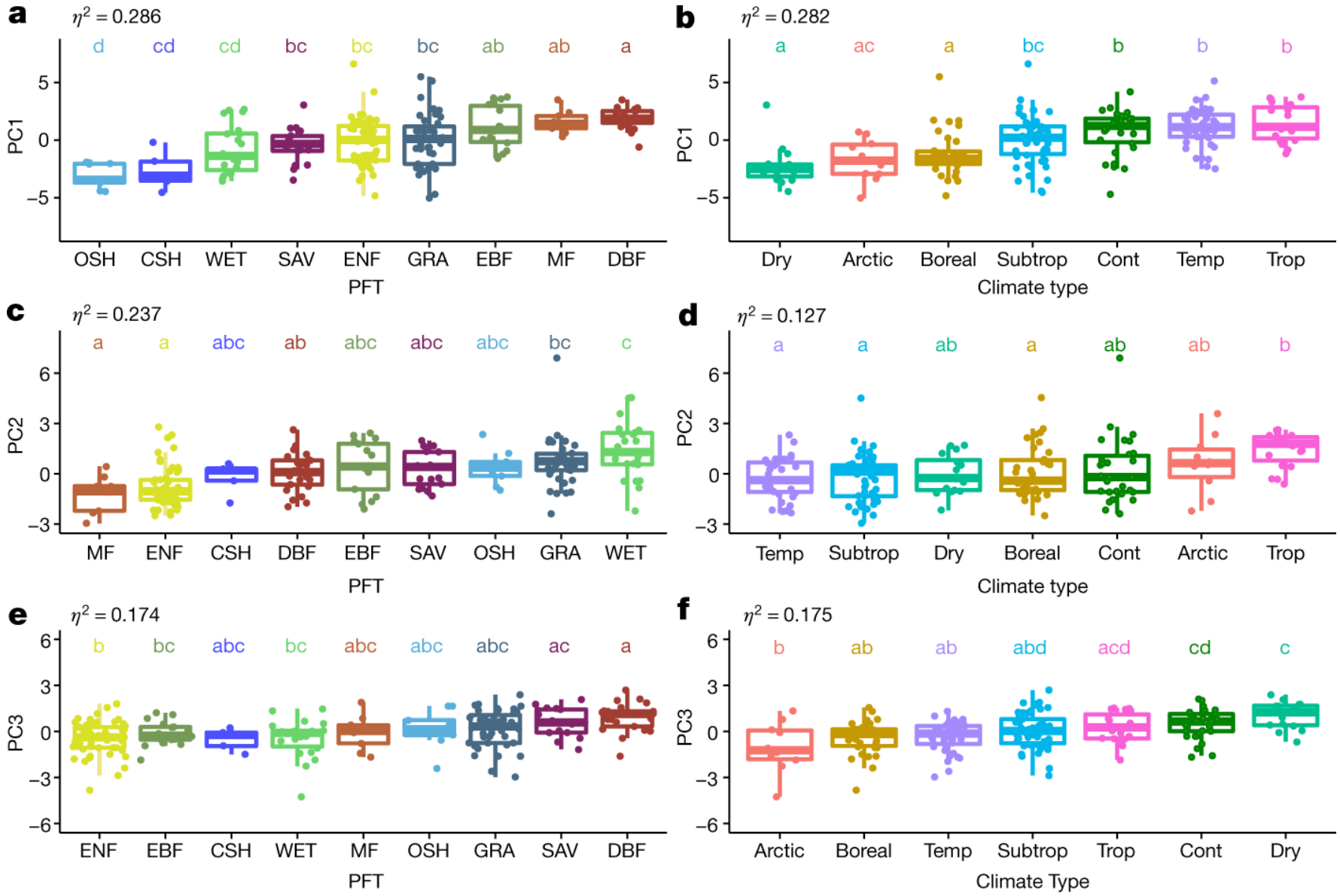
Plant Functional Types

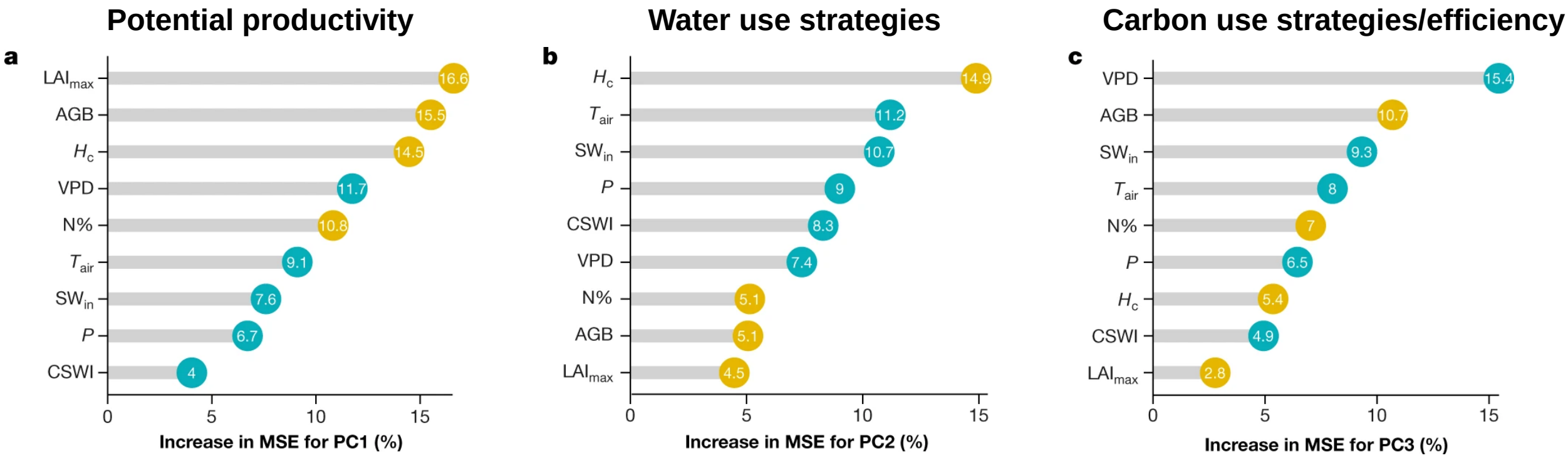
Climate Types



Low productivity ⟷ High productivity

High WUE Lower Wetness ⟷ Low WUE Higher Wetness

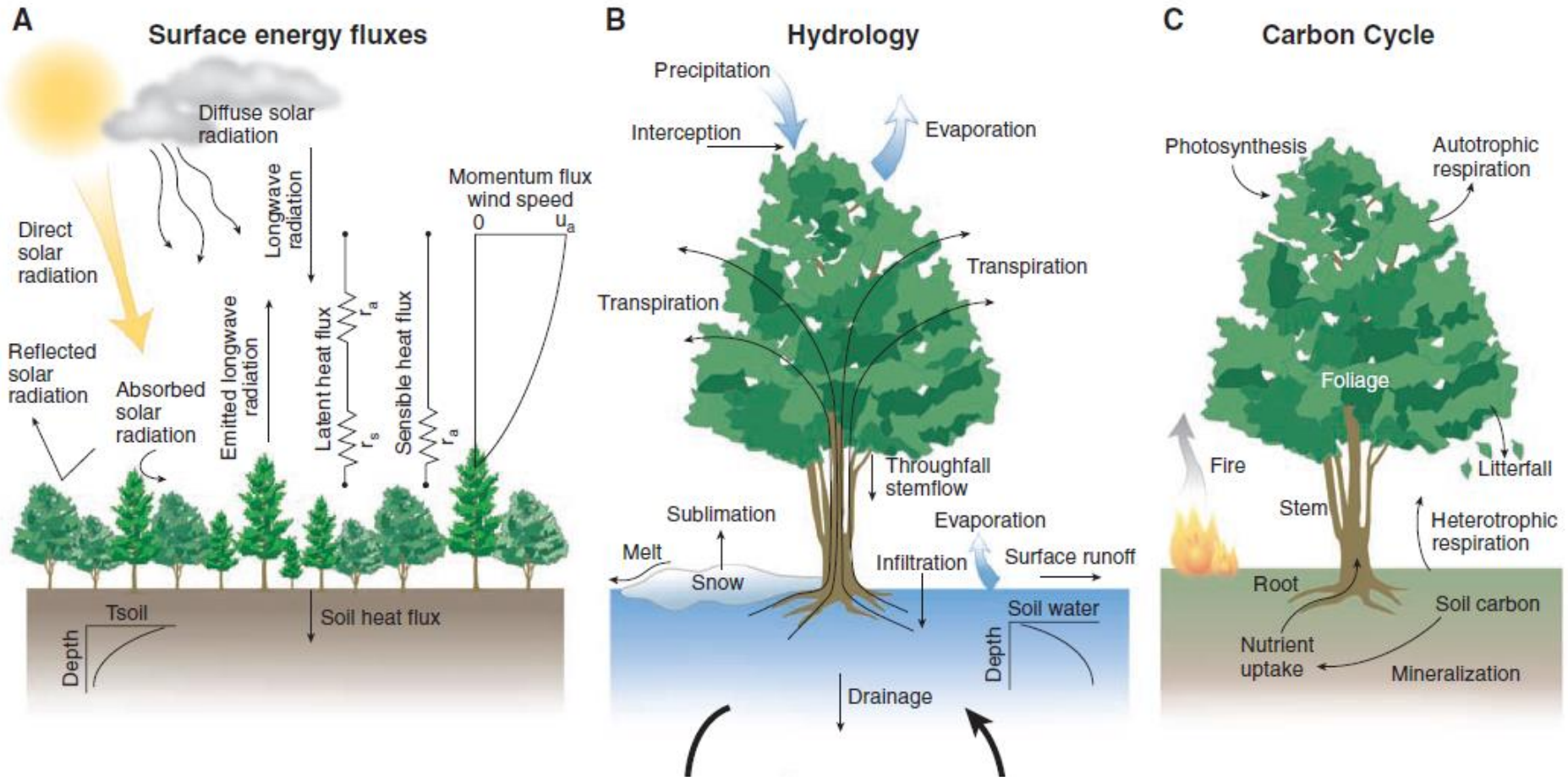
Low CUE ⟷ High CUE



a–**c**, Predictive relative importance for PC1 (**a**), PC2 (**b**) and PC3 (**c**). Numbers in the circles represent the percentage increase in mean squared error (MSE). Yellow circles represent vegetation structural variables; light blue circles represent climate variables.

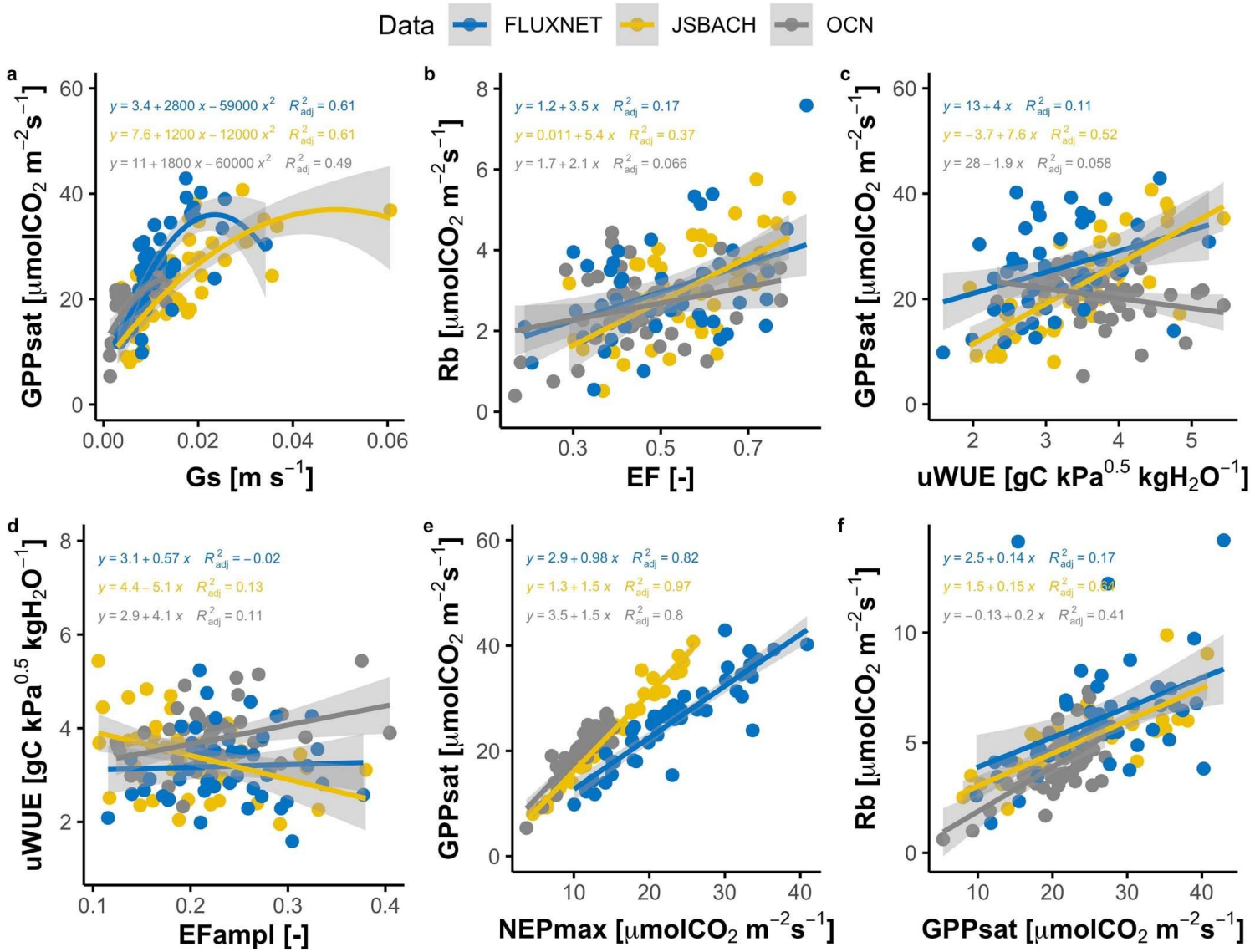
- Variable importance based on RF and partial dependence plots
- Causal variable importance confirmed the results of predictive model

DO LAND SURFACE MODELS REPRESENT MULTIFUNCTIONALITY?



Bonan (2008), Science

DO LAND SURFACE MODELS REPRESENT MULTIFUNCTIONALITY?



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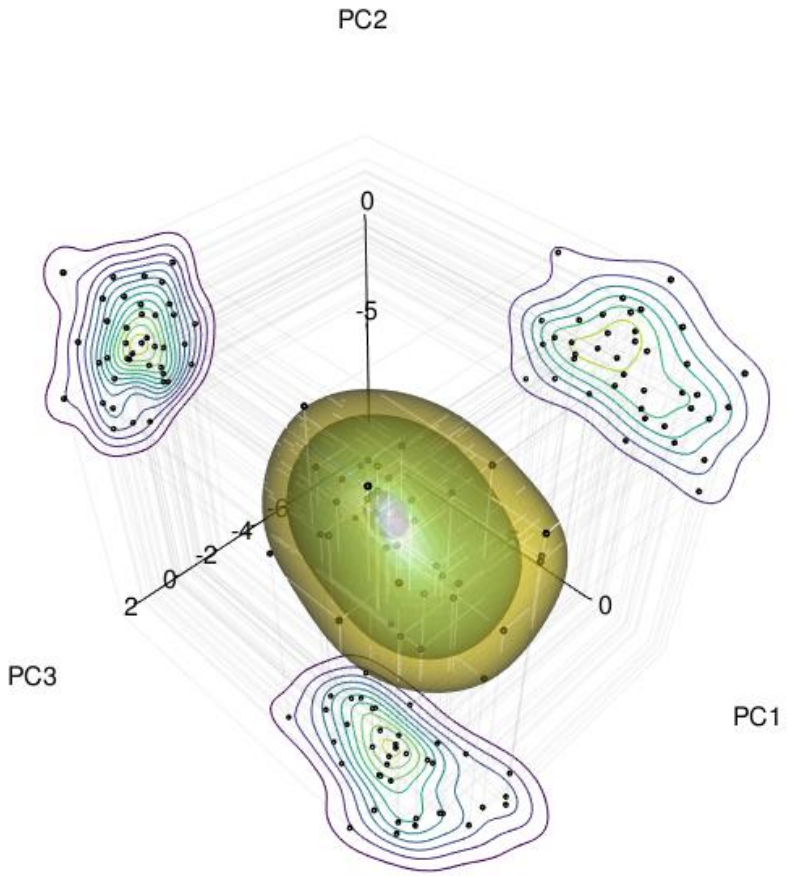
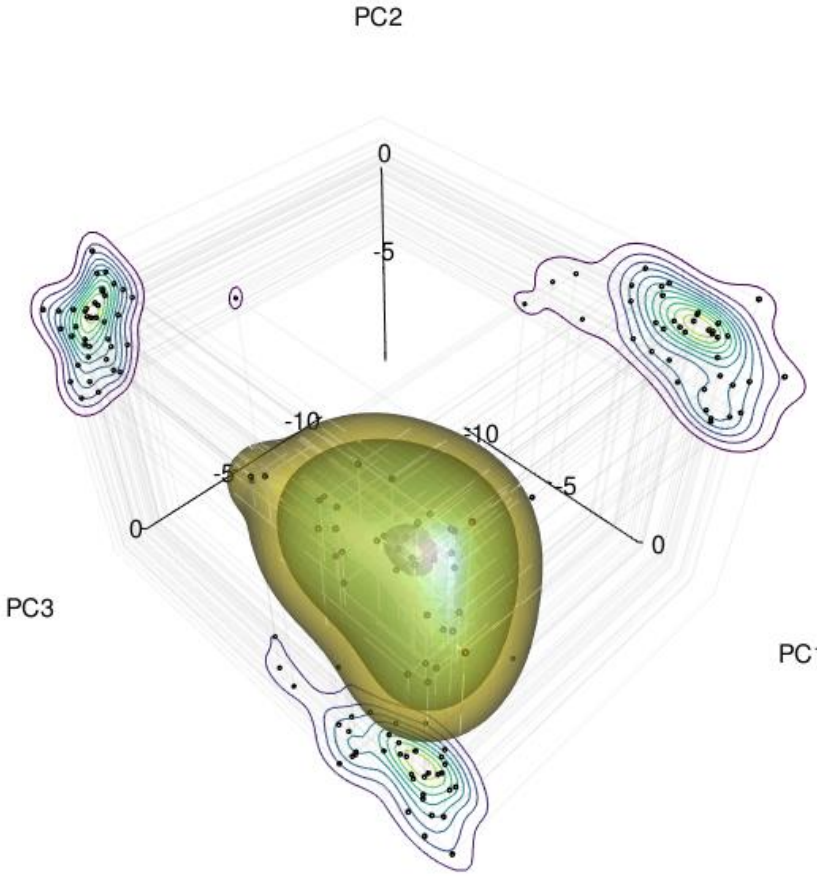
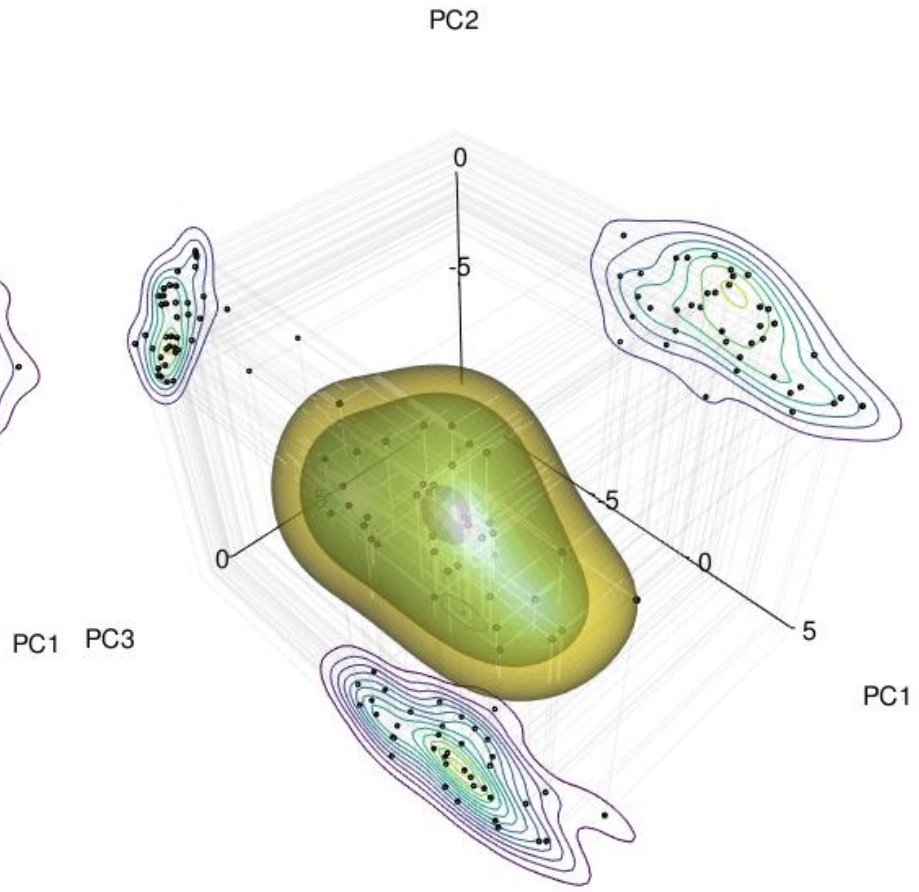


FLUXNET



O-CN



JSBACH

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