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Quantifying the importance of biotic and abiotic drivers in creating lags in soil CO_2 efflux

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Soil respiration influences regional carbon dynamics, yet our limited understanding of drivers of soil respiration currently constrains robust modeling of soil CO_2 efflux. There is evidence that soil respiration does not follow the standard Arrhenius relationship with soil temperature at the daily scale, as used in many ecosystem models, but demonstrates a hysteretic response. The understanding of this hysteretic response is critical to soil carbon and greenhouse gas emission modeling. Why soil respiration deviates from monotonic temperature dependence may depend on lag effects and antecedent features of abiotic and biotic drivers associated with above- and belowground process linkages.

We set up a 6 months long experiment to determine the biotic and abiotic drivers of the hysteretic relationship between soil respiration and soil temperature. The experiment took place at Ecotron IleDeFrance (France) using replicated closed environmental facilities allowing the simultaneous control of environmental conditions and on-line measurement of ecosystem processes. We reproduced semi-arid ecosystems using basalt soil mesocosms planted with two functional groups of plants (shrubs and grasses) in monocultures and in a mixture. We independently controlled above- and belowground temperatures and rainfall intensity. The split-plot, repeated-measures design allowed for diel aboveground and temperature cycle treatments to mimic natural conditions or for diel cycle aboveground temperature and constant soil temperature treatments to constrain vertical soil temperature gradients, yet mimic natural aboveground conditions. Soil CO_2 concentrations were measured under mild and heavy precipitations conditions that represent current and project conditions. We calculated the soil respiration every 30 minutes using the gradient method and conducted additional plant photosynthesis measurements to better target the role of biotic factors.

Our data show that abiotic and biotic treatments affect the total soil respiration but also diel patterns and the strength of the hysteretic effect. This demonstrates the power of experimental approaches to disentangle physical and biological drivers of soil respiration and better predict future CO_2 efflux from soils.