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From microhabitat to ecosystem: analysing the spatio-temporal variability of soil CO_2 in a karst shrubland.

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The soil CO_2 efflux (F_s) remains the least constrained component of the terrestrial carbon cycle and its estimates are still largely uncertain, mainly because of its high variability responding to multiple drivers that interact over different temporal and spatial scales. However, for financial reasons, F_s studies generally face a trade-off between temporal resolution and spatial coverage. Considering simultaneously the spatial and temporal variability of F_s is particularly challenging in drylands because they are prone to "hot-spots" and "hot-moments" of CO_2 emissions. Therefore, in this study, we aimed (1) to characterize the spatio-temporal variability of the soil CO_2 molar fraction (χ_s) in relation to its biophysical drivers in a karst dryland and (2) to take into account this variability to estimate F_s at the ecosystem scale.

To this end, continuous measurements of aboveground variables, including net CO_2 exchanges at ecosystem level, were crossed with soil variables monitored among four microhabitats (*Festuca scariosa*, *Hormathophylla spinosa*, *Genista pumila* and bare soil) during more than one year. The microhabitat-scale drivers of $\chi_s$were identified through "top-down" statistical modelling (mixed models), and time-frequency patterns were decrypted by wavelet analysis. Finally, $F_s$was upscaled from microhabitat to ecosystem by considering the spatial heterogeneity of ground cover.

Soil water content was the main driver of χ_s dynamics and strongly interacted with soil temperature, thus corroborating that traditional models strictly based on temperature are inappropriate in water-limited conditions. In addition, wind speed and vapour pressure deficit were also identified as significant but still poorly regarded drivers of χ_s dynamics. Furthermore, the sensitivity of χ_s to the main drivers identified here varied with microhabitat, hence confirming the importance of considering spatial heterogeneity for estimating F_s at the ecosystem scale. Over a year, our ecosystem-F_s estimate highlights a potential problem in the widely used ecosystem respiration calculation. These results provide new insight into mechanisms of soil CO_2 production and transport, questioning and improving models regularly used to quantify ecosystems CO_2 emissions.