

DFG-Project “Sensing the soil”:

a CO₂-O₂ monitoring network system to study soil processes

The DFG Project „*Sensing the soil*“: This is a collaboration between the research groups of Dr. Levintal, Israel, and Prof. Freudiger within the DFG program Middle East Collaboration, featuring a joint research program and field measurements.

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Soil Physics

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Soil respiration is a key process underpinning many other functions in soils. Although it is fundamental to understanding carbon turnover, the “forgotten half” of this flux – the counter-diffusion of atmospheric oxygen (O₂) into the soil – has received comparatively little attention. The ratio of carbon dioxide (CO₂) produced to oxygen consumed (qO₂) is referred to as the respiration quotient (RQ; qCO₂/qO₂). Recent studies indicate that the RQ has an average value of approximately 1.1 but can vary substantially among sites. This variability suggests that the RQ may serve as an important indicator for identifying, and potentially quantifying, additional soil processes. However, a range of abiotic processes can influence CO₂ and O₂ fluxes, thereby obscuring the underlying biotic RQ signal (Figure 1).

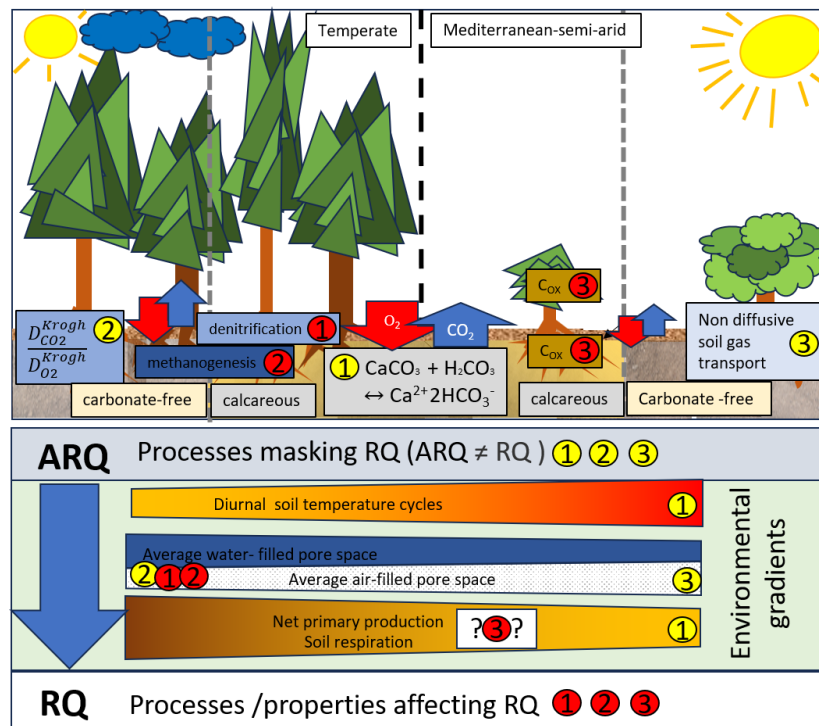


Figure 1: schematic of various processes that influence the apparent respiratory quotient (ARQ) and thereby overlay the actual respiratory quotient (RQ). Yellow circles symbolize non-biological processes, red circles symbolize the expected main processes and properties that control the RQ signals. Both types of processes typically occur under different environmental conditions, for example depending on soil aeration, soil type, temperature and soil moisture regime. Only the expected main processes are shown; processes such as mineral weathering, oxidation of metal ions, or similar reactions are not taken into account here.

While CO₂ fluxes can be reliably measured using approaches such as micrometeorological techniques or chamber-based methods, the estimation of O₂ fluxes is considerably more challenging due to the high atmospheric background

concentration of 20.95% O₂. An alternative approach is the in situ monitoring of CO₂ and O₂ concentrations within the soil profile, which enables the investigation of soil–atmosphere gas exchange and the RQ, and provides valuable insights into ongoing soil processes.

The overarching goal of the proposed collaboration in the Middle East is to conduct a systematic field-based investigation of CO₂–O₂ fluxes and to evaluate the suitability of the RQ as an ecophysiological key for understanding spatio-temporal patterns and underlying processes in soils. To this end, we aim to develop a sensor network consisting of soil CO₂–O₂ profile probes, complemented by a chamber system for measuring CO₂–O₂ fluxes.

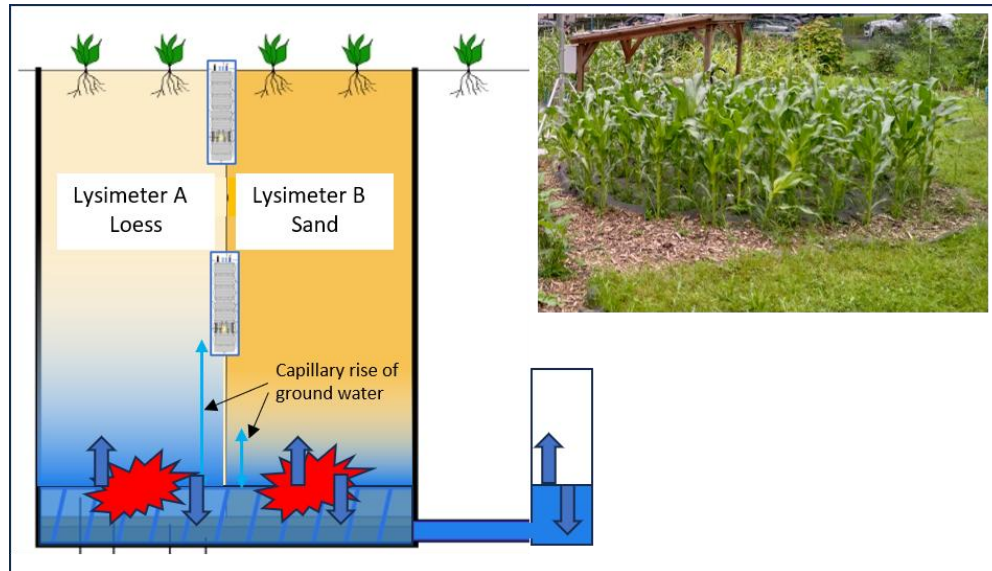


Figure 2: Cross-section of a planned experimental setup in the large lysimeter of the soil physics department, aimed at investigating the effects of groundwater level changes on the RQ. With rising groundwater levels, local sub- to anoxic conditions in the saturated zone are to be expected; with lowering, increased mineralization.

These tools will first be deployed in a semi-controlled experiment using a large lysimeter facility to assess the effects of groundwater fluctuations (Figure 2). In a subsequent field study, spatial and temporal patterns will be characterized at forest sites using the CO₂–O₂ sensor network, while CO₂–O₂ fluxes will be quantified with a mobile respiration chamber. Four contrasting sites have been selected for this purpose: two carbonate and two acidic soils, each represented by one site in a temperate forest and one in a Mediterranean forest.

References

- Maier, M.; Osterholt, L.; Levintal (2024). Development of an online O₂-CO₂ soil profile probe for flux estimations, EGU General Assembly 2024, EGU24-6777; <https://doi.org/10.5194/egusphere-egu24-6777>, 2024.
- Maier, M., Schirrmeister, F., and Levintal, E.: How and how accurately can we measure soil O₂-CO₂ fluxes?, EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025, EGU25-5232, <https://doi.org/10.5194/egusphere-egu25-5232>, 2025.
- Nguyen, T. T., Bekin, N., Altman, A., Maier, M., Agam, N., Levintal, L. (2025). Overcoming barriers in long-term, continuous monitoring of soil CO₂ flux: a low-cost sensor system Soil 11 (2), 639-653. <https://doi.org/10.5194/soil-11-639-202>
- Osterholt, L.; Kolbe, S.; Maier, M. (2022): A differential CO₂ profile probe approach for field measurements of soil gas transport and soil respiration #. In J. Plant Nutr. Soil Sci. 185 (2), pp. 282–296. DOI: 10.1002/jpln.202100155 .