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An innovative sensor platform for in-situ studies of dynamics and underlying processes, driving spatio-temporal water, carbon and greenhouse gas flux pattern in a heterogeneous arable landscape

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Improved agricultural practices increasing the water use efficiency (WUE), reducing greenhouse gas emissions (GHG) and/or improving atmospheric C sequestration rates within the soil are crucial for an adaptation and/or mitigation to the global climate crisis. However, processes driving water (H_2O), carbon (C) and GHG fluxes within the soil-plant-atmosphere continuum of agricultural used landscapes are complex and flux dynamics differ substantially in time and space. Hence, to upscale and evaluate the effects/benefits of any new agricultural practice aiming towards improving WUE, soil C sequestration and/or GHG emissions, accurate and precise information on the complex spatio-temporal H_2O, C and GHG flux pattern, their drivers and underlying processes are required.

Current approaches to investigate this topic are usually laborious and have to choose between high spatial or temporal resolution due to methodological constraints. On the one hand, often used eddy covariance systems are not suitable to account for small scale spatial heterogeneities and to separate the soil and farming impact, despite growing evidence of their importance. On the other hand, chamber systems either lack temporal resolution (manual chambers) or strongly interfere with the measured system (static automatic chambers). Hence, none of these systems enable a proper upscaling and evaluation of effects/benefits of new farming practices for WUE, C sequestration and GHG emissions at especially heterogeneous agricultural landscapes, such as present within inter-alia the also globally widespread hummocky ground moraine landscape of NE-Germany.

In an effort to overcome this, a novel, fully automated robotic field sensor platform was established and combined with an IoT network and remote sensing approaches. Here, an innovative, continuously operating, automated robotic field sensor platform is presented. The platform was mounted on fixed tracks, stretching over an experimental field (150m x 16m) which covers three different, distinct soil types. It carries multiple sensors to measure GHG and water vapour concentrations as well as water vapour isotope signatures of $d^{18}O$ and dD. Combined with two chambers which can be accurately positioned in three dimensions at the experimental field below, this system facilitates to detect small-scale spatial heterogeneity and short-term temporal variability of H_2O, C and GHG flux dynamics as well as crop and soil conditions over a range of possible experimental setups. The automated, continuous estimation of $d^{18}O$ and dD of evapotranspiration further provides the basis to partition water fluxes alongside the flux based partitioning of C and GHG fluxes. This particularly promotes to assess not only ecosystem but component specific WUE. Hence, this platform produces a detailed picture of H_2O, C and GHG dynamics across soil and farming practice combinations and crop rotations, with a high-degree of accuracy and reproducibility.

Keywords: innovative sensor platform, greenhouse gases, H_2O isotopes, Evapotranspiration, wate ruse efficiency