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The cultivation of energy crops for biogas production and the application of digestates are characterized by high variability of CO_2 exchange and soil organic C stock changes

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In Germany, agricultural production accounts for approx. 15% of total anthropogenic greenhouse gas emissions. The cultivation of energy crops is thus considered an important option to reduce the climate impact and maintain or increase soil organic carbon (SOC) stocks. In particular, this applies to the continuously expanding cultivation of energy crops for biogas production and the associated use of residues from anaerobic digestion (digestates) as organic fertilizer. To date, there is only limited and contradicting evidence on the impacts of this management practice on the CO_2 exchange as well as the change of SOC stocks.

We will present results from a 4-year field study at 5 sites in Germany using identical methods to investigate the interacting effects of i) 3 N-fertilizer treatments including calcium ammonium nitrate and digestates and ii) a crop rotation of 7 energy crops like maize, sorghum, triticale, and wheat on net ecosystem CO_2 exchange (NEE) and the change of SOC stocks. We used the manual chamber approach for measuring NEE as the difference between gross primary production and ecosystem respiration. The determination of SOC stock changes was based on a C budget approach, which includes the cumulated annual NEE, the C export by harvest, and the C import by application of anaerobic digestates.

The CO_2 exchange and the change of SOC stocks were influenced by multiple factors like crop, site, fertilization, and climate, as well as their complex interactions. A large proportion of the variability of the CO_2 exchange can be attributed to interannual climatic variability. Productive crops like maize and sorghum generally feature the most intensive CO_2 exchange, while less productive crops can compensate for this by means of longer cultivation times. Regardless of the extreme variability, pronounced and partly significant differences of NEE and C budgets between sites were observed.

On average, SOC stocks declined over a full crop rotation, but with highly variable positive and negative C budgets. This indicates that, in most cases, neither the selected crops nor the application of anaerobic digestates were sufficient to compensate for SOC losses. Apparently, the potential of anaerobic digestates to maintain or increase SOC stocks is considerably smaller than expected. If continuous decreases of SOC stocks due to energy crop cultivation are to be avoided, additional studies on the optimization of crop rotations (selection of plants with high C input), and digestate fertilization (type of digestate, amount and application technique) are required. A continuously improved version of the methodology used in this study promises faster and more precise results than classic long-term field trials.