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Energy balances of bioenergy crops (Miscanthus, maize, rapeseed) and their CO_2-mitigation potential on a regional farm scale

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Increasing cultivation of energy crops in agriculture reveals the progressive substitution of fossil fuels, such as crude oil or brown coal. For the future development of renewable resources, the efficiency of different cropping systems will be crucial, as energy crops differ in terms of the energy needed for crop cultivation and refinement and the respective energy yield, e.g. per area. Here, balancing is certainly the most suitable method for the assessment of cropping system efficiency, contrasting energy inputs with energy outputs and the related CO_2 emissions with potential CO_2 credits due to substitution of fossil fuels, respectively.

The aim of the present study was to calculate both energy and CO_2 balances for rapeseed and maize, representing the recently most often cultivated energy crops in Germany, on a regional farm scale. Furthermore, special emphasis was made on perennial Miscanthus x giganteus, which is commonly used as a solid fuel for combustion. This C4-grass is of increasing interest due to its high yield potential accompanied by low requirements for soil tillage, weed control, and fertilization as well as long cultivation periods up to 25 years. In contrast to more general approaches, balances were calculated with local data from commercial farms. The site-specific consumption of diesel fuel was calculated using an online-based calculator, developed by the German Association for Technology and Structures in Agriculture (KTBL).

By balancing each of the aforementioned cropping systems, our research focused on (i) the quantification of energy gains and CO_2 savings due to fossil fuel substitution and (ii) the assessment of energy efficiency, expressed as the ratio of energy output to input.

The energy input was highest for maize sites (33.8 GJ ha-1 yr-1), followed by rapeseed (18.2 GJ ha-1 yr-1), and Miscanthus (1.1 GJ ha-1 yr-1); corresponding energy yields were 129.5 GJ ha-1 yr-1 (maize), 83.6 GJ ha-1 yr-1 (rapeseed), and 259.7 GJ ha-1 yr-1 (Miscanthus), respectively. The energy output:input ratios were 3.83 (maize), 4.59 (rapeseed), and 236 (Miscanthus). The cultivation of rapeseed for biodiesel led to reduced CO_2 emissions of 3.552 Mg ha-1 yr-1 due to substitution of diesel fuel. An amount of 9.312 Mg CO_2 ha-1 yr-1 was saved by maize as co-ferment for biogas. Thereby, biogas was a substitute for electrical power from German energy mix (esp. nuclear power, utilization of coal), whereas the simultaneously used thermal energy was assumed to replace heating oil. Miscanthus cropping saved up to 18.540 Mg CO_2 ha-1 yr-1 as a substitute for heating oil, including approx. 4 Mg CO_2 ha-1 from organic carbon, which got sequestered within the soil organic matter due to site-remaining crop residues.

In sum, each cropping system gained energy and reduced greenhouse gas emissions, although energy inputs and outputs differed significantly. High energy inputs for maize and rapeseed were mainly related to mineral N-fertilization. Also the need of methanol for biodiesel refining and the energy consumed by the biogas plant increased the total energy consumption markedly. Due to its low-input character, Miscanthus seems promising to fulfill several demands in the context of sustainability.