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A systematic synthesis of agricultural management impacts on crop yield, soil quality, and environment

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Management practices aiming to improve crop yields may have adverse effects on soil or environmental quality, whereas the reverse can also be true. There is a need for a better understanding of synergies and trade-offs of nutrient, crop and soil management impacts on agronomic and environmental indicators , taking into account a variety of regional agro-ecosystem properties.

Well-known key indicators in this context are crop yield, nutrient uptake and use efficiency, soil organic carbon (SOC) and nutrient content, soil compaction, GHG emissions, and nutrient surpluses. Meta-analysis is a valuable way to assess the magnitude of agricultural management impacts over multiple sites and years, assessing the overall effect from many empirical observations. As many meta-studies exist in the literature to quantify the effects of agricultural management practices, we are the first presenting an integrated overview of those published studies on the above-mentioned impacts simultaneously. We focused on management principles for sustainability, including crop rotation and residue incorporation, irrigation, tillage, the “4R” principles of right fertilizer source, rate, timing, and placement, as well as enhanced efficiency and biochar amendments.

We find that various management-impact relationships are covered by meta-studies, but there is a lack of holistic analysis of site properties (and their interactions), which control the effects of management measures. Since current meta-studies allow limited conclusions on the effects of specific soil and climate agro-ecosystem properties, better analyses of site-specific conditions are needed.

When multiple meta-studies report effect sizes for the same management impact and given indicators, we further synthesized the results by a weighted mean based on reported measures of variation. Our synthesis produced almost 2000 impact assessments of agronomic measures from meta-analysis papers, providing a valuable quantitative resource for scientists and stakeholders in agriculture. For example, when comparing best management practices relating to fertilizer source, tillage, and crop rotation, our results indicate combined fertilizer as most effective in reducing N surplus, organic fertilizer as most effective in increasing SOC, and no tillage as most effective in increasing yields.

Our review also focuses on key characteristics relating to quality and methodological approaches in meta-analysis. For example, a surprising number of meta-studies do not perform a weighted analysis, which we consider an important quality standard. In general, our insights are relevant for the state of meta-analysis in agricultural science, which can be considered a recently developed focus of research.