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Reconsidering evidence for soil carbon sequestration, soil health improvement, and long-term sustainability under conservation agriculture: Comment on conservation agriculture and its impact on soil health and yield: A review

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Abstract

We read with interest the review article “Conservation Agriculture and its Impact on Soil Health and Yield: A Review” by Hiremath *et al.* (2026). The authors provide a useful synthesis of conservation agriculture (CA) and its reported effects on soil health, carbon sequestration, water conservation, and crop productivity. While such reviews are valuable, several conclusions regarding soil organic carbon (SOC) sequestration and soil health improvement warrant further qualification.

Keywords: Agroecology, soil organic carbon sequestration, soil rehabilitation, degradation, zero tillage

Introduction

Soil organic carbon accumulation: redistribution versus sequestration

The review highlights increased SOC as a major benefit of CA. However, increases in SOC concentration in surface horizons do not necessarily indicate net carbon sequestration. Baker *et al.* (2007) ^[1] demonstrated that apparent gains in topsoil carbon under no-tillage are often offset by losses at depth. Luo *et al.* (2010) ^[10] reported significant SOC accumulation in the upper 10 cm under no-till but simultaneous declines in deeper layers. Long-term experiments in France (Dimassi *et al.*, 2013) ^[4] and synthesis studies (Liang *et al.*, 2020) ^[9] similarly suggest that SOC increases under CA frequently reflect vertical redistribution rather than whole-profile carbon sequestration.

Cover crops and SOC sequestration

Cover crops are frequently promoted as a mechanism for SOC accumulation. While Poeplau and Don (2015) ^[11] reported positive average sequestration rates, Chaplot and Smith (2023) ^[3] demonstrated that many underlying studies relied on shallow sampling depths, lacked equivalent soil mass corrections, or involved short experimental durations. Among studies meeting stricter methodological criteria, SOC gains were considerably smaller and often statistically insignificant, suggesting that carbon sequestration under cover crops may be more context dependent than generally assumed.

Soil health indicators and functional interpretation

The review presents improvements in aggregation, microbial biomass, enzyme activity, biodiversity, and SOC as evidence of enhanced soil health. However, many of these indicators respond rapidly to residue accumulation in surface horizons and do not necessarily reflect improvements in ecosystem functioning across the entire soil profile. Soil health encompasses nutrient cycling, water regulation, productivity, erosion resistance, and resilience to climatic stress. Improvements in individual indicators should therefore not automatically be interpreted as improvements in all soil functions. Besides, Hénin (1969) ^[5] was probably one of the first to indicate that cover crops do provide ephemeral effects on soil aggregate stability and little or no

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impact on SOC.

Potential trade-offs associated with conservation agriculture

Surface SOC enrichment may provide agronomic benefits, but it may also involve trade-offs. Chaplot *et al.* (2019) ^[2] showed that carbon-rich surface material can be preferentially mobilized during rainfall events through erosion processes. Reduced tillage may also encourage nutrient and carbon stratification, potentially influencing rooting depth and crop access to deeper water reserves during drought. Furthermore, practical challenges including residue management, weed control, and nutrient immobilization remain important constraints to CA adoption.

The importance of nutrient constraints

The review attributes SOC gains primarily to residue retention and reduced tillage. However, increasing evidence suggests that nutrient availability strongly regulates SOC stabilization. Kirkby *et al.* (2013) ^[7], Poeplau *et al.* (2016) ^[12], and Kirkegaard *et al.* (2023) ^[8] demonstrated that balanced nutrient supply can substantially increase the efficiency with which crop residues are transformed into stable soil organic matter (from 8 to 30% following Kirkegaard *et al.* 2023) ^[8]. Carbon sequestration should therefore be viewed as a stoichiometrically constrained process rather than solely a function of carbon inputs.

Conclusion

Conservation agriculture undoubtedly offers important opportunities to improve resource-use efficiency and resilience in agricultural systems. Nevertheless, the magnitude and permanence of its effects on soil carbon sequestration, soil health, and crop productivity remain uncertain and highly dependent on methodological design and environmental context. Future assessments should distinguish between surface SOC enrichment and whole-profile carbon sequestration, emphasize stock-based measurements corrected using equivalent soil mass approaches, and integrate nutrient constraints and ecosystem functioning into evaluations of soil health.

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