Tropentag, September 16-18, 2026, hybrid conference

"Towards multi-functional agro-ecosystems
promoting climate resilient futures"

Toward optimised soil tillage: exploring biophysical drivers of yield variability under conservation agricultural practices

Mosisa Tujuba Wakjira[1], Renske Hijbeek[2], Joost van Heerwaarden[3], Johan Six[4], John Koestel[5], Sara Bonetti[6], Katrien Descheemaeker[7]

[1] *Wageningen University & Research, Plant Production Systems Group, The Netherlands*
[2] *Wageningen University & Research, Plant Production Systems Group, The Netherlands*
[3] *Wageningen University & Research, Plant Production Systems, The Netherlands*
[4] *ETH Zurich, Dept. of Environmental System Science, Switzerland*
[5] *Agroscope, Soil Quality and Soil Use, Switzerland*
[6] *EPFL, Laboratory of Catchment Hydrology and Geomorphology, Switzerland*
[7] *Wageningen University & Research, Plant Production Systems Group, The Netherlands*

Abstract

Conservation agriculture (CA) is widely promoted as a sustainable farming system that supports soil health, environmental protection, and climate adaptation and mitigation in agricultural landscapes. It is based on three core practices: minimised soil disturbance (no-till or reduced tillage), permanent soil cover through crop residues or cover crops, and crop rotation. When implemented together, these practices are expected to deliver multiple agronomic and environmental benefits. However, the universal applicability of CA across diverse biophysical and socioeconomic contexts remains contested due to inconsistent agronomic performance, and the underlying biophysical drivers of this variability are not yet well understood. Here, we investigate these drivers, particularly those related to changes in soil-plant-water relationships, that underpin yield variability under no-till (NT) and reduced tillage (RT) with and without residue retention (RR) relative to conventional tillage (CT), based on a global meta-analysis of 328 studies spanning 361 experimental sites. Our findings reveal clear trade-offs associated with adopting minimised tillage alone, alongside agronomic benefits when combined with residue retention. Overall yield outcomes relative to CT ranged from a significant reduction of 6.3 % ($p = 0.02$) under NT without RR to near-neutral effects under RT with RR, with yield penalties diminishing as tillage intensity increased (from NT to CT) and with the inclusion of residue retention (trend $p = 0.046$). Sensitivity analysis indicates that yield reductions under NT are primarily linked to compaction-induced changes in soil hydraulic and mechanical properties, which constrain soil water movement (infiltration, redistribution, and drainage), retention, plant availability, and root growth. In particular, NT increased soil penetration resistance by 39.6 % ($p < 0.001$) and altered pore size distribution, resulting in smaller air capacity and larger wilting points. In contrast, when NT or RT is combined with RR, soil organic matter emerges as a key driver of yield variability, reflecting its multiple benefits, including alleviation of compaction, improved nutrient supply, and enhanced biological activity. However, in many contexts, such as smallholder farming systems, residue retention is often not feasible, limiting these benefits. This underscores the need to optimise tillage practices

Contact Address: Mosisa Tujuba Wakjira, Wageningen University & Research, Plant Production Systems Group, Snipstraat 104, 6708PB Wageningen, The Netherlands, e-mail: mosisatujuba@gmail.com

in a context-specific manner to reduce yield penalties where residue retention cannot be implemented.

Keywords: Infiltration, no-till, plant-available water, reduced tillage, residue retention, yield