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Reduced tillage, not residue retention, drives soil fauna recovery: A global meta-analysis

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Abstract

Conservation agriculture (CA), defined by minimum soil disturbance, permanent soil cover, and diversified rotations, is adopted on about 200 million hectares of tropical, subtropical, and temperate croplands and is promoted as a cornerstone of sustainable intensification. Despite nearly four decades of adoption, its effects on non-harvested agrobiodiversity remain debated, largely because the contributions of reduced tillage and residue retention are difficult to isolate. This gap matters for smallholders, where residues compete with fodder and fuel uses, and where no-till's substitution of herbicides for mechanical weed control raises non-target biodiversity concerns.

We synthesize global evidence on soil faunal diversity under CA versus paired conventional tillage controls, to decouple the contributions of reduced tillage from residue retention. We compiled 682 effect sizes from 51 field studies spanning six continents (1986–2025), distinguishing reduced tillage alone (Decoupled Framework; 254 effect sizes, 16 studies) from the composite tillage-residue package (Composite Framework; 579 effect sizes, 40 studies). Rotation, the third CA pillar, was held constant within paired comparisons and tested only as a moderator across studies.

CA increased overall faunal biodiversity by 44.4 % (95 % CI: 12.6 to 85.2) under the Decoupled Framework and 36.2 % (CI: 17.46 to 57.9) under the Composite Framework, with residue retention adding no detectable additional benefit. Our results indicate that reduced mechanical disturbance, not residue retention, is the primary driver of biodiversity recovery. Abundance and biomass recovered significantly, but species richness did not, indicating numerical rather than compositional restoration. Responses were strongest on highly weathered tropical soils (Ferralsols, Acrisols, Lixisols: 145.8 %, Composite), cereal rotations (115.3 %, Composite), and soil-dwelling taxa (52.6 %, Decoupled). Concurrent herbicide and insecticide use did not systematically offset these gains.

The findings suggest that recognising tillage reduction as a valuable component independent of residue retention within CA programmes could provide flexibility for farmers. This would be especially beneficial in tropical mixed crop-livestock systems where residue retention is constrained by fodder demands, and tillage reduction has the highest positive ecological effect per hectare. For tropical smallholders facing residue-allocation trade-offs,

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reducing tillage alone within prevailing agrochemical regimes is sufficient to initiate measurable soil faunal recovery.

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