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Research Article

Conservation Agriculture, Soil Health, and Minimum Tillage for Restoring Degraded Tropical Soils

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Abstract

Degraded tropical soils lose structure, organic matter, water, and nutrients, and with them the capacity to support stable yields. Repeated ploughing, residue removal, monocropping, and bare fallows accelerate erosion and organic matter loss, while climate change brings more intense rainfall and longer dry spells that expose the damage. This article reviews conservation agriculture as an integrated soil health strategy, covering its three core principles, minimum soil disturbance, permanent soil cover, and crop diversification, and how they interact with soil biology, water, nutrients, weeds, and labour. It shows that minimum tillage alone rarely restores a degraded soil, and that the largest gains come when minimum tillage is combined with residue retention, legume rotations, and cover crops, adapted to local soils, markets, and labour. It proposes a field-scale framework for restoring degraded soils, and it identifies research and policy priorities for making conservation agriculture work for smallholders rather than only for large, mechanised farms.

Keywords: conservation agriculture; soil health; minimum tillage; soil organic matter; residue retention; cover crops

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1. Introduction

Soil degradation is a slow disaster. A field that once held water, crumbled easily, and supported a full crop can, over a decade of ploughing, residue burning, and monocropping, become hard, crusted, and quick to dry. Farmers notice it as more runoff after rain, more weeds, more fertiliser needed for the same yield, and more work to prepare the land. Scientists measure it as lower soil organic carbon, poorer aggregation, lower infiltration, and lower biological activity (Lal, 2004; Blanco-Canqui and Ruis, 2018). In tropical soils, where organic matter decomposes quickly and rainfall is intense, degradation can be especially rapid, and restoration can be slow.

Conservation agriculture was developed as a response to this problem. It is defined by three principles: minimum soil disturbance, permanent soil cover with crop residues or living cover, and diversification through rotations and associations (FAO, 2019; Kassam et al., 2009). The principles are simple, but their application is not. A farmer who stops ploughing but removes all residue for fodder, burns the rest, and grows the same crop every year has adopted only one principle, and should not expect the full benefit. A farmer who keeps residue, rotates with a legume, and uses a cover crop has adopted the system, and is more likely to see soil health improve.

This article reviews conservation agriculture as soil health agronomy. It explains how tillage, residue, and diversity affect soil physics, chemistry, and biology, what evidence exists for yield, soil, and income effects, and what labour, weed, livestock, and market conditions determine whether conservation agriculture is adopted or abandoned.

2. How Degradation Happens and How Soil Recovers

Tillage breaks aggregates, exposes organic matter to decomposition, and creates a loose surface that is vulnerable to erosion. Repeated ploughing at the same depth can create a plough pan, a compacted layer that restricts roots and water movement (Blanco-Canqui and Ruis, 2018; Lal, 2004). Residue removal removes the food that soil organisms need and leaves the surface bare, so raindrops can detach soil particles and crust the surface. Monocropping depletes specific nutrients, builds up specific pests, and produces a

narrow range of root types and exudates, reducing biological diversity.

Recovery reverses these processes, but slowly. Residue retention feeds earthworms, fungi, and bacteria, which produce binding agents that rebuild aggregates. Roots, especially deep and fibrous roots from cover crops and legumes, create pores that improve infiltration and water storage. Legumes fix nitrogen, reducing the need for mineral fertiliser and improving the nitrogen supply to the next crop (Vanlauwe et al., 2010; Kassam et al., 2009). Minimum tillage protects aggregates and fungal networks that tillage would destroy. Figure 1 summarises the pattern from the cited syntheses: soil organic carbon and yield rise as practices are added, from minimum tillage alone to the full combination of minimum tillage, residue, legume, and cover crop.

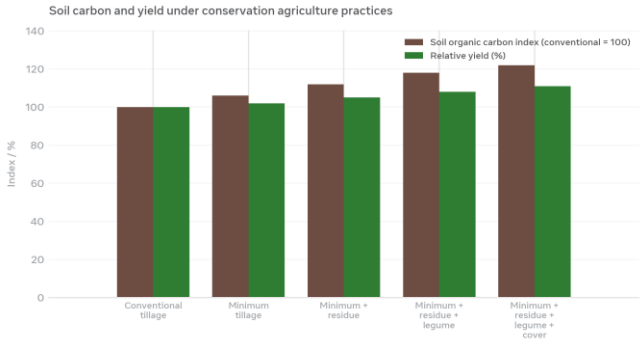

Figure 1. Soil carbon and yield under conservation agriculture practices, based on synthesis of the reviews and meta-analyses cited in the text. Values vary by soil, climate, and management.

3. Minimum Tillage, Residue, and Cover

Minimum tillage includes reduced tillage, strip tillage, and no-till, where soil is disturbed only in the planting row. It can reduce labour, fuel, and erosion, and can allow earlier planting because the farmer does not need to wait for ploughing (Kassam et al., 2009; FAO, 2019). In the first seasons, however, minimum tillage can increase weed pressure, because weeds are no longer buried, and can lead to compaction if traffic is not controlled. Farmers often need new weed management, including mulching, cover crops, and, where appropriate, herbicides, and new planting equipment, such as rippers, jab planters, or direct seeders.

Residue retention is often the hardest principle for smallholders, because residues are also livestock feed, fuel, and building material (Giller et al., 2009; Kassam et al., 2009). Where livestock roam freely, residues left on the field may be grazed before they can protect the soil. Solutions include negotiated grazing rules, partial residue retention, fodder banks, and dual-purpose varieties that produce both grain and fodder. Cover crops, such as mucuna, lablab, cowpea, and sunn hemp, can provide living cover, fix nitrogen, suppress weeds, and produce fodder, but they require seed, labour, and a window in the rotation, and they must not compete with the main crop for water (Giller et al., 2009; FAO, 2019).

Soil cover also moderates temperature and moisture. A mulch layer reduces evaporation, protects the surface from raindrop impact, and keeps soil cooler in hot periods. In dry areas, this can be the difference between a crop that survives a dry spell and one that fails. In wet areas, mulch can keep soil too wet and favour slugs and diseases, so cover must be matched to drainage and climate.

4. Soil Biology, Water, and Nutrients

Soil health is biological as well as physical and chemical. Earthworms, fungi, bacteria, and other organisms decompose residues, cycle nutrients, and create pores. Tillage, residue removal, and monocropping reduce their abundance and diversity, while residue retention, diversity, and minimum disturbance increase them (Blanco-Canqui and Ruis, 2018; Lal, 2004). Mycorrhizal fungi, which help plants take up phosphorus and water, are especially sensitive to tillage and to long bare fallows. A soil with a diverse, active biology can supply nutrients more steadily, suppress some soil-borne diseases, and recover more quickly from drought.

Water is the link between soil health and yield. Soils with good aggregation and organic matter infiltrate more rain, store more water, and lose less to runoff and evaporation (Lal, 2004; Kassam et al., 2009). In a dry season, that extra stored water can be decisive. In a wet season, better infiltration can reduce flooding and erosion. Nutrients also depend on soil health: organic matter is a store of nitrogen, phosphorus, and sulphur, and a source of cation exchange capacity that holds nutrients against leaching. Conservation agriculture does not replace fertiliser, but it can make fertiliser more efficient, because nutrients are less likely to be lost by erosion and leaching in a healthy soil (Vanlauwe et al., 2010).

Weeds are the most common short-term cost. Minimum tillage can increase weed pressure in the first years, and farmers may need more labour for weeding or more herbicide (Giller et al., 2009; Kassam et al., 2009). Cover crops and mulch can suppress weeds over time, but they do not eliminate them. A conservation agriculture system that ignores weeds will be abandoned, however good its soil effects. Weed management must be planned as part of the system, with attention to labour, cost, and herbicide safety.

5. Economics, Labour, Livestock, and Gender

Economics determine adoption. Conservation agriculture can reduce labour and fuel for land preparation, but can increase labour for weeding, residue management, and cover crop establishment, at least in the first seasons (Giller et al., 2009; Kassam et al., 2009). Yields may fall, stay the same, or rise in the first years, depending on soil, weeds, and management, and may rise more clearly after several seasons as soil health improves. A farmer who needs a higher yield this season to feed the household cannot wait three seasons for soil health to improve, however sound the long-term logic. Short-term benefits, such as earlier planting, lower land preparation cost, and a legume harvest, are therefore essential for adoption.

Livestock and gender shape who can adopt. Where livestock are a major asset, residue retention competes with feed, and free grazing can destroy a mulch layer (Giller et al., 2009). Community rules on grazing, fodder production, and residue sharing are needed. Women may do much of the weeding, residue handling, and cover crop work, but may have less control over decisions to adopt conservation agriculture, less access to equipment, and less access to extension (Farnworth et al., 2017; Huyer et al., 2015). Programmes that involve women in design, that provide equipment women can use, and that schedule training accessibly are more likely to produce durable adoption. Table

1 summarises conservation agriculture bundles, while Table 2 proposes indicators for monitoring. The decisions in Table 1 and the indicators in Table 2 should be used together when planning and reviewing a conservation agriculture system.

A practical framework for restoring degraded soils can be stated in six steps. First, diagnose: measure soil organic carbon, infiltration, compaction, and erosion, and ask farmers what they observe. Second, protect the surface: retain residue, use cover crops, and negotiate grazing. Third, disturb less: reduce tillage and avoid traffic on wet soil. Fourth, diversify: rotate with legumes and include cover crops. Fifth, manage weeds and nutrients: plan weeding, fertiliser, and lime where diagnosed. Sixth, monitor: track soil, yield, labour, and cost over several seasons, and adjust. Table 1 summarises the bundles that farmers can choose from, while Table 2 proposes the indicators to track. The bundles in Table 1 and the indicators in Table 2 should be read together.

Tables

Table 1. Conservation agriculture bundles and their main mechanisms. If continued overleaf, the continuation is headed Table 1 (continued) and repeats the column headings.

Bundle	Core practices	Main mechanism	Likely outcome
Minimum tillage only	Strip tillage, no plough	Less disturbance	Lower fuel, variable soil gain
Minimum + residue	Minimum tillage, mulch	Cover, organic matter	Better infiltration, less erosion
Minimum + residue + legume	Minimum, residue, legume rotation	Nitrogen, diversity	Higher fertility, steadier yield
Full conservation agriculture	Minimum, residue, legume, cover	All mechanisms	Soil health, resilience
Conservation + integrated fertility	Full CA, fertiliser, lime	Soil + nutrients	Higher, more stable yield

Table 2. A balanced indicator set for conservation agriculture. If continued overleaf, the continuation is headed Table 2 (continued) and repeats the column headings.

Dimension	Indicator	Practical measurement
Soil health	Organic carbon, infiltration, aggregation	Soil test, infiltration test
Yield	Yield, stability	Harvest records
Water	Runoff, soil moisture	Field observation
Labour and cost	Hours, cost per hectare	Farmer records
Weeds	Weed biomass, weeding labour	Field scores, records
Equity	Use by women, poor, remote	Disaggregated survey

6. Future Research and Policy Priorities

Future research should report soil, yield, labour, cost, weeds, and income together, over several seasons, rather than yield in one season alone. Long-term trials are needed because soil health changes slowly, and a system that looks poor in year one may look good in year five. Research on weed management without heavy herbicide dependence, on residue and livestock trade-offs, and on equipment that women and smallholders can use is more valuable than further trials of minimum tillage alone (Giller et al., 2009; Kassam et al., 2009). Research on soil health measurement that is affordable and interpretable by farmers, such as infiltration tests and visual soil assessment, can help farmers see change. Policy should support conservation agriculture through extension on the full system, not only on tillage, through community grazing and residue rules, through access to cover crop seed and appropriate equipment, and through markets for legumes and cover crop products. Subsidies for equipment should be paired with training on weed, residue, and nutrient management.

7. Conclusion

Conservation agriculture is not a single practice; it is a system. Minimum tillage alone rarely restores a degraded soil. When minimum tillage is combined with residue retention, legume rotations, and cover crops, adapted to local soils, livestock, labour, and markets, soil health can improve, water can be stored, and yields can become more stable. When those elements are missing, or when weeds, labour, and livestock are ignored, conservation agriculture will be abandoned, however good its soil logic. The priority is practical: diagnose the soil, protect the surface, disturb less, diversify, manage weeds and nutrients, and monitor over several seasons.

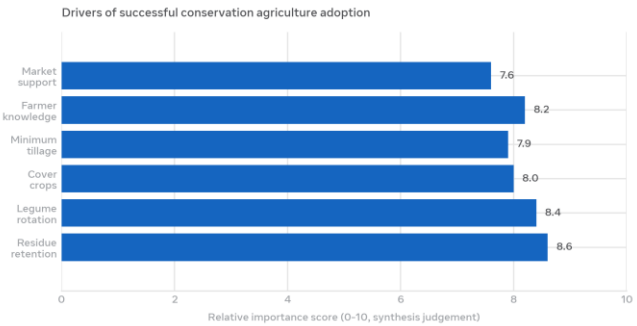

Figure 2. Drivers of successful conservation agriculture adoption, based on synthesis judgement from the cited evidence. Residue retention and legume rotation are central.

Figure 2 summarises the drivers that distinguish systems that persist from systems that are abandoned. Residue retention and legume rotation score highest, because they feed the soil and the household at the same time, while market support and farmer knowledge determine whether those practices can be sustained.

The practical implication is that conservation agriculture should be introduced as a sequence, not as a package to be adopted all at once. A farmer who first tries residue retention on one plot, then adds a legume rotation, then reduces tillage, can learn what works on that soil, with that labour, and with those livestock, without risking the whole farm. A farmer who is told to adopt all three principles at once, with new equipment and new seed, may abandon the whole system after one difficult season. Extension should therefore help farmers design a sequence that fits their farm, starting with the practice that gives the clearest short-term benefit, whether that is a legume that provides food and income, a cover crop that suppresses weeds, or residue that keeps soil moist through a dry spell.

That sequence also matters for measurement. Farmers who can see change, a soil that infiltrates faster, a field that holds water longer, a legume that adds nitrogen, are more likely to persist than farmers who are told that soil health will improve in five years. Simple, visible indicators, a water infiltration test with a tin ring, a count of earthworms in a soil pit, a comparison of runoff after rain, can make soil health concrete. When farmers measure their own soil, they become researchers on their own fields, and conservation agriculture becomes a system they adapt, rather than a package they receive.

The same logic applies to policy. A policy that subsidises a no-till planter but ignores residue, grazing, and weed management will produce a planter that sits unused. A policy that supports the whole system, cover crop seed, community grazing rules, weed management training, and markets for legumes, will produce a system that farmers can sustain. Conservation agriculture, in the end, is not about a machine or a mulch; it is about a farmer, a soil, and a season, repeated until the soil can support the farmer again. That is the test that matters: not how many farmers adopt a practice in year one, but how many still use it, and benefit from it, in year five.

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Conflict of Interest

The authors declare no conflict of interest.

References

Blanco-Canqui, H. and Ruis, S.J. (2018). No-tillage and soil physical environment. Geoderma, 326, pp. 164-200.

FAO (2019). Conservation Agriculture: A Training Manual. Rome: FAO.

Farnworth, C.R., et al. (2017). Gender and climate-smart agriculture. In: Huyer, S. et al. eds. Gender, Climate Change and Agriculture. Wallingford: CABI, pp. 1-18.

Giller, K.E., et al. (2009). Conservation agriculture and smallholder farming in Africa. Field Crops Research, 114(1), pp. 23-34.

Huyer, S., et al. (2015). Gender and climate change in agriculture. CCAFS Working Paper. Copenhagen: CGIAR.

Kassam, A., Friedrich, T., Shaxson, F. and Pretty, J. (2009). The spread of conservation agriculture. International Journal of Agricultural Sustainability, 7(4), pp. 292-320.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. Science, 304(5677), pp. 1623-1627.

Vanlauwe, B., et al. (2010). Integrated soil fertility management. Outlook on Agriculture, 39(1), pp. 17-24.

FAO (2020). The State of Food and Agriculture 2020: Overcoming Water Challenges in Agriculture. Rome: FAO.

IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Cambridge: Cambridge University Press.

Chivenge, P., et al. (2007). Long-term impact of reduced tillage and residue management on soil carbon. Soil and Tillage Research, 94(1), pp. 1-10.

Corbeels, M., et al. (2014). Understanding the impact and adoption of conservation agriculture. Agriculture, Ecosystems & Environment, 187, pp. 1-10.

Dumanski, J., et al. (2006). The paradigm of conservation agriculture. In: Proceedings of the World Association of Soil and Water Conservation. Bangkok: WASWC, pp. 1-12.

Erenstein, O., et al. (2012). Conservation agriculture in Africa. Field Crops Research, 132, pp. 1-12.

Friedrich, T., Derpsch, R. and Kassam, A. (2012). Overview of the global spread of conservation agriculture. Field Actions Science Reports, 6, pp. 1-12.

Hobbs, P.R., Sayre, K. and Gupta, R. (2008). The role of conservation agriculture. Philosophical Transactions of the Royal Society B, 363(1491), pp. 543-555.

Knowler, D. and Bradshaw, B. (2007). Farmers' adoption of conservation agriculture. Land Use Policy, 24(1), pp. 191-206.

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. Sustainability, 7(5), pp. 5875-5895.

Powlson, D.S., et al. (2014). Limited potential of no-till agriculture for climate change mitigation. Nature Climate Change, 4(8), pp. 678-683.

Powlson, D.S., et al. (2016). Soil carbon dynamics and climate change. Soil Use and Management, 32(1), pp. 1-12.

Rusinamhodzi, L., et al. (2011). A meta-analysis of maize yield under conservation agriculture. Field Crops Research, 124(3), pp. 340-354.

Stevenson, J.R., et al. (2014). Adoption of conservation agriculture. Agricultural Systems, 127, pp. 1-10.

Thierfelder, C., et al. (2013). Conservation agriculture in southern Africa. Field Crops Research, 151, pp. 1-12.

Thierfelder, C., et al. (2015). Conservation agriculture and drought. Agriculture, Ecosystems & Environment, 212, pp. 1-12.

Tittonell, P., et al. (2012). Conservation agriculture in Africa. Field Crops Research, 132, pp. 1-12.

Wall, P.C., et al. (2014). Conservation agriculture in Africa. In: Francis, C. ed. Advances in Agronomy. Amsterdam: Elsevier, pp. 1-40.