Soil Health: Regenerative and Conventional Crop Production Systems

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21 January 2026

Regenerative agriculture (RA) crop production systems have recently been popularized in many agricultural communities. Claims are often made that RA systems are better than conventional agriculture (CA) crop production systems, which are commonly considered to be input intensive.

The definition of an RA system is highly dependent on the practitioner, and many definitions can be found. In general, RA is a principles-based approach that aims to restore and enhance soil health, biodiversity, and ecosystem services through practices such as reduced tillage, cover cropping, diverse rotations (including fallow or resting periods), crop residue retention. In some cases, it includes agroforestry and/or the integration of livestock.

Proponents of RA argue that it can increase soil organic carbon (SOC), which is a proxy measurement related to stable soil organic matter (SOM). They also contend that RA practices improve soil water-holding capacity and soil systems resilience (which is an extremely broad category).

Regenerative agriculture systems have the basic objective of increasing on-farm biodiversity and delivering long-term improvement in productivity and soil health as compared to conventional crop production systems.

Recent reviews of the literature have addressed the overall trends in field research associated with RA systems in comparison to CA crop production systems. Some studies have demonstrated some positive effects of RA systems on soil condition and soil health.

Research reviews clearly illustrate that the context of the studies is very important in interpretation and there is clear evidence of major gaps in describing and quantifying effects from RA systems (Montgomery and Biklé, 2021 and Khangura, et al., 2023).

BLUF (Bottom Line Up Front) Statement:

Regenerative systems promote crop and soil management practices that have been recognized and utilized for many years, hundreds of years in fact. Current research comparing RA and CA systems are highly variable. All asserted benefits of RA systems are highly dependent on climate conditions and the CA systems used for comparison.

Overall, RA practices generally contribute positively to soil health. However, there is no definitive evidence of RA systems being superior to CA crop production systems.

Pros – Objectives of RA systems:

- **Soil carbon and structure.** A meta-analysis of temperate systems found that reduced tillage and inclusion of grass-based rotation and resting/fallow periods could increased SOC relative to CA. Studies in cooler and humid climates show that RA practices can build SOC stocks over several decades (Jordan, et al., 2022). This does not transfer to other agroecosystems in drier and warmer environments.

- **Soil health and resilience.** Practices that increase incorporation into soil crop residues (organic material), crops with different types of root systems, and crop rotations that include legume crops can improve soil aggregate stability, infiltration, internal soil drainage, and retention has been found in some studies and reviews (Khangura, et al., 2023).

- **Biodiversity and ecosystem services.** Diversified crop rotations, the use of cover crops, and crop–livestock integration can increase soil biodiversity. It is also contended that crop pollination and pest-regulation (insects, weeds, and diseases) can be improved with RA systems versus CA. However, these effects are commonly poorly quantified in most studies (Sher, et al., 2024). Thus, some of these benefits are quite speculative.

- **Co-benefits and livelihoods.** There are some publications that conclude that RA systems can be more profitable or financially resilient for farmers. But from these studies it is only possible for RA superiority to CA systems when there are price premiums, reduced input costs, or ecosystem payment schemes that are available. Highly variable yields, the need for policy support and payment mechanisms are commonly needed to make RA systems viable at scale (Reuters, 2024).

Cons / limitations compared to conventional cropping systems:

- **Yield uncertainty and trade-offs.** In most studies, RA practices do not consistently or significantly change crop yields relative to CA systems, particularly in short-term studies, anything less than a decade. Overall, review of the literature shows no consistent or general “win-win” RA situation that will reliably increase yields while increasing SOC. Yield responses are highly variable by crop, region, and the time elapsed since RA systems were adopted. In many cases, the transition years into RA systems cause yield reductions. The site-specific constraints can be quite variable it is difficult to identify consistent positive trends in RA system benefits over CA systems (Jordan, et al., 2022).

- **Greenhouse gas and livestock trade-offs.** RA systems that integrate livestock or increasing manure inputs can boost SOC and encourage soil biodiversity. These

types of RA systems have been shown to raise methane and nitrous oxide emissions. As a result, any net climate benefits are dependent on whole-system greenhouse-gas accounting, which is often not done or effectively included in most RA studies (Sher, et al., 2024).

- **Evidence gaps and heterogeneity.** Most of the cases found in the current literature on RA systems evaluation address single practices such as no-till versus conventional tillage, the use of cover crops, and animal manure application regimes. There is a substantial absence of long-term, fully integrated RA/CA systems comparisons. Accordingly, the results found in the current literature are highly variable and context dependent (soil type, climate, access to RA-friendly market benefits, etc.). As a result, generalization is extremely limited in comparing RA and CA systems (Jordan, et al., 2022).

- **Adoption barriers.** Moving to RA systems often requires new knowledge, increased and different levels of labor reallocation, equipment changes, and often many upfront investments to access unique markets and secure technical support. Incentive structures (i.e., subsidies) are commonly needed to make RA system transitions from CA systems and without that, adoption can be slow and highly variable (Reuters, 2024).

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There is a definite need for long-term, system-level experiments. The appropriate measurement and quantification of RA and CA system management comparisons and soil health parameters are essential priorities to help resolve the many remaining uncertainties associated with RA systems (Jordan, et al., 2022).

Overall, RA practices can potentially improve soil health. However, there is no definitive evidence of RA systems being superior to CA crop production systems.

References

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