Available online at www.agrifarming.org

DOI: http://dx.doi.org/10.18782/2582-7146.332

ISSN: 2582 – 7146

Current Research in Agriculture and Farming

Curr. Rese. Agri. Far. (2022) *3*(4), 16-24

Review Article

Peer-Reviewed, Refereed, Open Access Journal

Natural Farming and Regenerative Agriculture: Principles, Practices, and Impact on Soil Health

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Received: 12.06.2022 | Revised: 17.07.2022 | Accepted: 6.08.2022

ABSTRACT

Natural farming and regenerative agriculture have emerged as sustainable approaches to address soil degradation, biodiversity loss, and environmental challenges associated with conventional farming systems. These practices emphasize minimal external inputs, conservation of natural resources, enhancement of soil biological activity, and restoration of ecosystem functions. Techniques such as crop diversification, cover cropping, mulching, composting, reduced tillage, and integration of livestock contribute to improved soil structure, nutrient cycling, water retention, and carbon sequestration. By fostering healthy soil ecosystems, these approaches enhance crop resilience, productivity, and long-term sustainability while reducing dependence on synthetic fertilizers and pesticides. Promoting natural and regenerative farming is essential for achieving climate-resilient agriculture, environmental conservation, and global food security.

Keywords: *Natural farming; regenerative agriculture; soil organic carbon; soil microbiome; sustainable agriculture.*

INTRODUCTION

Global croplands cover roughly 12 percent of the ice-free land surface and supply more than 95 percent of human food energy, yet decades of intensive cultivation have left an estimated one-third of the world's soils moderately to severely degraded (FAO & ITPS, 2015). Loss of soil organic carbon (SOC), erosion, compaction, salinization, and decline of soil biodiversity reduce productivity and undermine the ecosystem services on which agriculture itself depends. Against this backdrop, two related movements—natural farming and regenerative agriculture—have gained scientific and policy attention as production systems that aim to rebuild, rather than deplete, the soil resource base (Rhodes, 2017; & LaCanne & Lundgren, 2018).

Cite this article: Kumar, S., Kumar, N., & Singh, DD. (2022). Natural Farming and Regenerative Agriculture: Principles, Practices, and Impact on Soil Health, *Curr. Rese. Agri. Far. 3*(4), 16-24. doi: http://dx.doi.org/10.18782/2582-7146.332

Natural farming, popularized by Fukuoka (1978) in Japan and by Palekar in India as Zero Budget Natural Farming, emphasizes minimal external inputs, on-farm preparations using locally available cow-derived materials, and continuous soil cover. Regenerative agriculture, articulated by Rodale (1984) and refined by later researchers, is a principles-based framework that explicitly seeks to enhance soil health, biodiversity, and water cycles while producing food (Schreefel et al., 2020). Although the two traditions differ in vocabulary and cultural origins, their field practices overlap substantially and both treat the soil as a living system. This review brings together literature published up to 2022 to clarify the conceptual basis of these systems, describe their core practices, and assess the strength of evidence linking them to improved soil health.

The scope of the present review is restricted to peer-reviewed and grey-literature sources published between 1978 and 2022. Three guiding questions structure the synthesis: (i) what theoretical principles distinguish natural farming and regenerative agriculture from conventional and even from earlier organic systems; (ii) which on-farm practices operationalize those principles across diverse agro-ecological zones; and (iii) what does the long-term experimental evidence say about the response of soil health indicators such as soil organic carbon, microbial biomass, aggregate stability, infiltration, and biological diversity. By integrating findings from temperate, tropical, and Indian contexts, the review aims to provide a balanced foundation for researchers, extension professionals, and policy makers.

The urgency of the topic is reinforced by recent global assessments. The Food and Agriculture Organization (FAO & ITPS, 2015) ranks soil erosion, organic carbon loss, and nutrient imbalance as the three most severe threats to soil function worldwide, with annual losses of productive land estimated at several million hectares. In India, the Indian Council of Agricultural Research has reported that approximately 120 million hectares are affected by some form of land degradation. Such figures underscore that the long-term viability of food systems cannot rely on continued mining of soil capital; instead, production systems that explicitly rebuild soil are required. Natural farming and regenerative agriculture offer one such pathway. They are not a return to pre-industrial agriculture but a scientifically informed reimagining of how food can be produced while restoring the ecological foundations on which production depends. Mitchell (2017) emphasizes that the success of such systems hinges on understanding the soil as a complex, self-organizing ecosystem rather than as an inert substrate to be amended.

2. Conceptual Principles

Despite a diversity of regional schools, contemporary frameworks converge on five interlocking principles (Figure 1). First, minimize soil disturbance: tillage accelerates the oxidation of soil organic matter and disrupts fungal hyphae and aggregate structure (Six et al., 2004). Second, keep the soil covered: continuous residue and living cover protect the surface from raindrop impact, moderate soil temperature, and reduce evaporation. Third, maintain living roots in the ground for as much of the year as possible, because root exudates feed the rhizosphere microbiome that drives nutrient cycling (Jansson et al., 2021). Fourth, maximize species diversity through polycultures, intercrops, and diverse rotations to disrupt pest cycles and broaden the microbial niche space. Fifth, integrate livestock where possible so that grazing and manuring close nutrient loops (LaCanne & Lundgren, 2018).

Natural farming adds two cultural emphases: a precautionary stance toward synthetic agrochemicals, and the use of fermented on-farm preparations such as jeevamrutha and beejamrutha that introduce diverse microbial consortia and dilute organic substrates to the soil (Khadse et al., 2018). Palekar (2006) argues that these preparations stimulate native soil microbiota rather than acting as conventional fertilizers, a hypothesis that is consistent with the broader microbial-ecology literature on inoculants and root exudates (Mitchell, 2017).

Figure1. The five core, mutually reinforcing principles of regenerative agriculture, with healthy soil as the central outcome

3. Field Practices

3.1 Conservation tillage and no-till

No-till and reduced-tillage systems leave most crop residues on the surface and limit soil inversion. Long-term meta-analyses show that adoption of no-till consistently raises topsoil SOC by about 8–12 percent compared with conventional tillage, with the largest gains under semi-arid and humid temperate conditions (Lal, 2015; & Bai et al., 2019). Reduced disturbance also favors arbuscular mycorrhizal fungi and earthworms, which in turn improve macroaggregate formation (Six et al., 2004). Importantly, no-till must be coupled with surface residue retention and diversified rotations; otherwise SOC gains may concentrate only at the surface while subsoil carbon stagnates or declines (Powlson et al., 2014). In the Indo-Gangetic Plains, conservation agriculture combining zero tillage with residue mulch and rotation has improved both wheat yields and SOC stocks within five to seven years of adoption.

3.2 Cover cropping and continuous cover

Cover crops occupy the field during periods that would otherwise be fallow. Poeplau and Don (2015) synthesized 139 plots from 37 sites and reported a mean SOC sequestration rate of 0.32 ± 0.08 Mg C ha^{-1} yr^{-1} under cover cropping. Legume covers add biologically fixed nitrogen, while deep-rooted brassicas can break compacted layers and recycle leached nutrients. Multispecies cover crop mixtures appear especially effective at supporting belowground biodiversity because each species contributes a distinct rooting depth, exudate profile, and litter quality. In smallholder Indian systems, summer green manures such as Sesbania, Crotalaria, and Sunhemp turned into the soil before kharif planting can substitute for a substantial share of the synthetic nitrogen requirement of the following rice or maize crop.

3.3 Diversified crop rotations and intercropping

Rotation diversity influences both yield stability and soil biology. McDaniel et al. (2014) reviewed 122 studies and showed that adding one or more crops to a rotation increased microbial biomass carbon by 21 percent and total soil carbon by 3.6 percent. Intercropping cereals with legumes such as pigeonpea or chickpea further raises land equivalent ratios and protein output per unit area in Indian systems (Layek et al., 2018). Diversified rotations also disrupt soil-borne disease and pest cycles, reducing reliance on chemical pesticides and supporting natural enemy populations. From a soil-microbial perspective, diverse plant communities deliver a wider spectrum of root exudates, which sustains a richer and more functionally redundant microbiome capable of buffering biogeochemical processes against perturbation.

3.4 Organic amendments and on-farm preparations

Compost, farmyard manure, vermicompost, and biochar add stable carbon and a diverse microbial inoculum. A global meta-analysis by Maillard and Angers (2014) found that manure applications increased SOC stocks by an average of 12.8 percent relative to mineral-fertilized controls. In Indian natural-farming contexts, jeevamrutha applications have been associated with higher microbial counts and dehydrogenase activity in field studies, although the magnitude of yield effects remains contested (Khadse et al., 2018; & Smith et al., 2020). Biochar deserves particular mention because pyrogenic carbon is highly resistant to microbial decomposition and can persist in soils for centuries, while simultaneously improving cation exchange capacity, water retention, and habitat for soil microorganisms. The choice of amendment should be matched to soil type, climate, and the limiting constraint on the farm; for example, acidic tropical soils often respond more strongly to lime-stabilized composts than to raw manures.

3.5 Agroforestry and integrated crop–livestock systems

Trees in cropping landscapes—whether as alley crops, boundary plantings, or silvopastoral systems—provide deep-root carbon inputs, microclimate moderation, and additional biomass. Cardinael et al. (2017) reported SOC accrual rates of 0.24 to 0.75 Mg C ha^{-1} yr^{-1} in temperate alley-cropping systems. Integrated crop–livestock systems combine grazing with annual cropping, and have been shown to enhance both particulate and mineral-associated organic carbon pools through synergistic interactions among practices. Indian traditions such as agri-horti-silviculture, home gardens of Kerala, and the boundary plantings of Punjab combine timber, fodder, fruit, and field crops on the same parcel, demonstrating that tree integration is compatible with food production and can diversify household income while regenerating soils.

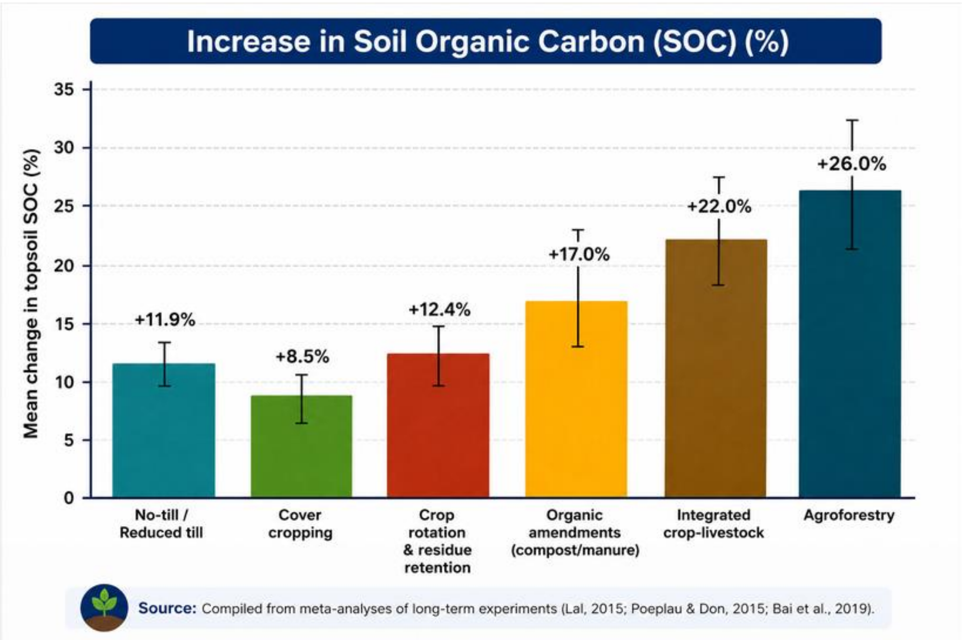

Figure2. Mean change in topsoil (0–20 cm) soil organic carbon under six regenerative practices, compiled from long-term experiments and meta-analyses. Error bars denote one standard deviation across studies

4. Impact on Soil Health

4.1 Soil organic carbon and aggregate stability

SOC is the single most informative indicator of soil health because it influences nutrient supply, water retention, structure, and biological activity. Lal (2004) estimated that historic SOC loss from world croplands amounts to 78 ± 12 Gt of carbon, much of which could in principle be restored through regenerative management. Field comparisons consistently show greater macroaggregate stability under reduced disturbance and high residue inputs, with aggregate mean weight diameters 20–40 percent higher than under conventional tillage (Six et al., 2004). Aggregate stability matters because well-formed aggregates physically protect organic matter from microbial decomposition, store water in their internal pore space, and create the architecture through which roots and soil fauna move. A stable soil structure is therefore both a cause and a consequence of high organic matter, creating a self-reinforcing feedback that regenerative practices exploit.

4.2 Soil microbiome and biological activity

Organically managed and natural farming soils support higher microbial biomass, greater fungal-to-bacterial ratios, and increased enzymatic activity (Lori et al., 2017). Reganold and Wachter (2016) reviewed forty years of comparative studies and concluded that organic and regenerative systems improve indicators of biological soil quality without proportional yield penalties when systems are well managed. Earthworm densities are also typically two- to threefold higher under no-till and cover-cropped systems (Briones & Schmidt, 2017). The diversity of arbuscular mycorrhizal fungi, which form symbiotic associations with most crop plants and mediate phosphorus uptake, is similarly elevated under reduced disturbance and continuous root cover. Higher microbial activity translates into faster cycling of crop residues, more efficient nutrient release synchronized with plant demand, and suppression of soil-borne pathogens through competitive exclusion and antagonism.

4.3 Water dynamics and erosion control

Improved structure and surface cover dramatically increase water infiltration. Basche and DeLonge (2019) synthesized 89 studies and reported infiltration rates 35 percent higher under perennial covers and cover crops than under conventional management. Reduced erosion, combined with greater plant-available water, makes regenerative fields more resilient to droughts and intense rainfall events (Altieri et al., 2015). Lower runoff also reduces off-site impacts such as siltation of reservoirs and nutrient enrichment of downstream water bodies. In monsoonal climates such as much of India, where a large fraction of annual rainfall is delivered in a few intense events, the capacity of the soil to capture, hold, and release water slowly is a decisive determinant of crop performance and groundwater recharge.

4.4 Nutrient cycling and plant nutrition

Higher organic-matter status raises cation exchange capacity, improves phosphorus availability through mycorrhizal pathways, and reduces nitrate leaching when synthetic inputs are minimized. Comparative indicators across seven key soil-health metrics show systematic advantages for regenerative systems (Figure 3), although the absolute magnitude of differences varies with climate, soil type, and management history. Long-term experiments such as the DOK trial in Switzerland and the Rodale Farming Systems Trial in the United States have shown that, after an initial transition period, organic and regenerative plots can match or exceed conventional yields while sustaining higher soil quality, lower energy use, and better nutrient retention (Reganold & Wachter, 2016). Such findings counter the assumption that ecological intensification necessarily entails large yield trade-offs.

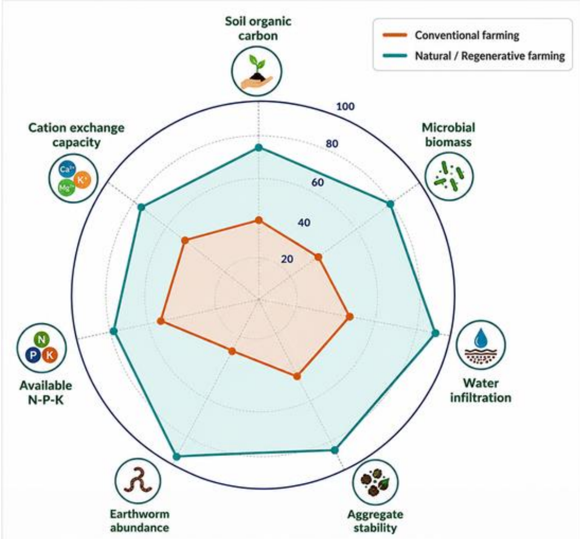

Figure3. Comparative performance on seven soil-health indicators between conventional and natural / regenerative farming systems, expressed on a normalized 0–100 index

4.5 Climate change mitigation and resilience

By rebuilding SOC, regenerative agriculture transfers atmospheric carbon into stable soil pools. Minasny et al. (2017) estimated that an annual SOC accrual of 0.4 percent in the top 30–40 cm of global croplands could offset a meaningful share of anthropogenic emissions, although the realized potential is moderated by soil saturation and permanence concerns. Beyond mitigation, regenerative soils confer adaptation benefits: deeper rooting, improved water-holding capacity, and microbial diversity buffer farms against weather extremes (Altieri et al., 2015).

4.6 Socio-economic dimensions

Although the focus of this review is biophysical, soil-health outcomes cannot be separated from the livelihoods of the farmers who manage the soil. Studies from Karnataka and Andhra Pradesh report reductions of 60–90 percent in cash input costs under Zero Budget Natural Farming, with comparable or modestly lower yields after a transition period (Khadse et al., 2018). LaCanne and Lundgren (2018) showed that regenerative maize fields in the United States generated higher profit per hectare than neighbouring conventional fields despite lower yields, because of reduced input costs and value-added marketing. These economic findings are important because farmer adoption ultimately depends on financial viability, risk profile, and labour requirements, not on soil indicators alone.

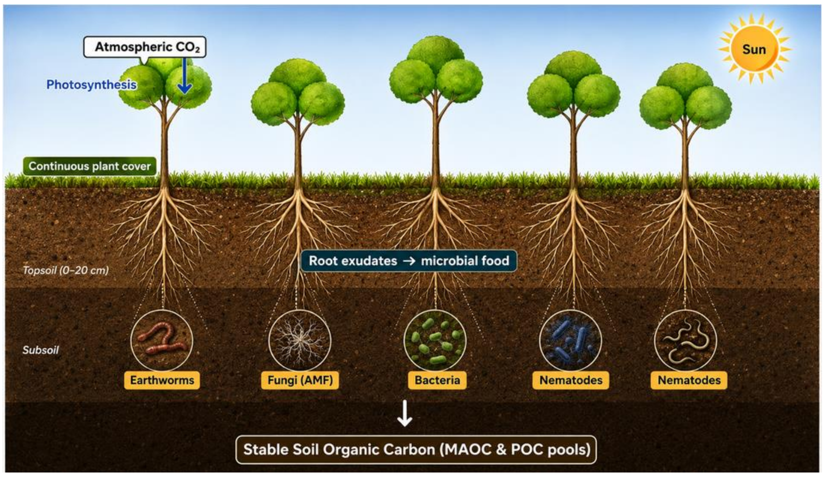

Figure4. Conceptual schematic of the carbon flow and soil-health processes that operate within a regenerative farming system, linking photosynthesis, root exudation, soil biota, and stable carbon storage

5. Challenges and Knowledge Gaps

Despite encouraging evidence, several caveats temper enthusiasm. Yield outcomes under natural farming remain mixed; transition periods of three to five years are common, during which yields may decline before recovering (Smith et al., 2020). The permanence of soil-carbon gains is sensitive to future tillage events and climate (Powlson et al., 2014). Measurement standards for soil health vary across studies, complicating meta-analysis. Finally, policy frameworks, certification, and farmer training systems remain underdeveloped in many regions, including parts of India where Zero Budget Natural Farming is being scaled up.

Several research priorities emerge from this review. First, more long-term experiments are needed in tropical and subtropical contexts, where most existing meta-analyses are still dominated by temperate-region data. Second, soil sampling protocols should extend to at least one metre depth in order to capture full-profile carbon dynamics and avoid overestimating shallow gains. Third, the microbial and biochemical mechanisms by which on-farm preparations such as jeevamrutha influence soil function deserve systematic study using metagenomic and metabolomic approaches. Fourth, socio-economic evaluations should accompany agronomic trials so that yield, input cost, labour requirement, and risk are jointly assessed. Addressing these gaps will help convert the qualitative narrative of regenerative agriculture into quantitative, regionally calibrated decision-support tools for farmers and planners.

CONCLUSION

Natural farming and regenerative agriculture represent convergent responses to the soil-degradation crisis of modern agriculture. The peer-reviewed evidence available up to 2022 supports the conclusion that their core practices—reduced disturbance, continuous cover, living roots, diversified rotations, organic amendments, and integrated livestock—consistently improve soil organic carbon, microbial activity, aggregate stability, and water dynamics. Topsoil SOC gains of 8–26 percent across practices, alongside two- to three-fold increases in earthworm populations and 35 percent higher infiltration rates, indicate that these systems can rebuild the biological and physical fabric of agricultural soils. Realizing this potential at scale will require region-specific agronomic refinement, longer-term field studies, supportive policy instruments, and farmer-centered extension. When deployed with scientific rigor and contextual sensitivity, natural farming and regenerative agriculture can serve as cornerstones of a soil-first transition to climate-resilient, food-secure farming systems.

The way forward calls for closer collaboration between agronomists, soil microbiologists, ecologists, social scientists, and farmer communities. Investment in monitoring networks that track soil organic carbon, biological activity, and yield across managed landscapes will allow practitioners and policy makers to evaluate progress against measurable benchmarks. Integration of regenerative principles into national agricultural research agendas, undergraduate curricula, and farmer field schools will help institutionalize the approach. Crucially, regenerative agriculture should not be promoted as a one-size-fits-all prescription. Each agro-ecological zone, soil type, and socio-economic setting demands locally adapted combinations of practices, validated through participatory experimentation. With such grounded efforts, the principles synthesized in this review can translate into measurable gains in soil health, farmer prosperity, and ecosystem resilience over the coming decades.

Acknowledgements:
The authors thank all co-authors for their contributions.

Funding:
Nil.

Conflict of Interest:
None declared.

Author Contributions:

All authors approved the final manuscript.

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