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Review

Regenerative agriculture in the 2020s: A global review of soil, climate, productivity, and socio-economic evidence (2020–2025)

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Abstract

Regenerative agriculture (RA) has emerged as a transformative approach to sustainable farming, emphasizing soil health, biodiversity, climate resilience, and socio-economic benefits. This review synthesizes findings from peer-reviewed studies and meta-analyses published between 2020 and 2025, evaluating the effects of RA on soil organic carbon (SOC), greenhouse gas (GHG) emissions, crop productivity, biodiversity, and socio-economic outcomes. Evidence indicates that RA practices - such as reduced tillage, cover cropping, agroforestry, crop diversification, and livestock integration - enhance soil quality, mitigate climate change, increase biodiversity, and improve farm profitability. Effectiveness is context-dependent, influenced by soil type, climate, landscape structure, and socio-economic conditions. Trade-offs, adoption challenges, and research gaps are highlighted, providing a framework for optimizing RA globally.

Keywords: Regenerative agriculture; Soil health; Greenhouse gas emissions; Crop productivity; Biodiversity; Socio-economic outcomes; Global review; 2020–2025

Introduction

Agriculture faces unprecedented challenges due to soil degradation, biodiversity loss, and climate change. Conventional farming practices—excessive tillage, chemical fertilizers, and monocropping—have intensified these problems. Regenerative agriculture (RA) offers a holistic solution by restoring soil health, enhancing ecosystem services, and improving socio-

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economic resilience. RA practices include cover cropping, reduced or no-tillage, organic amendments, agroforestry, crop diversification, and integrated livestock management. Between 2020 and 2025, a growing body of research evaluated RA's environmental and socio-economic impacts globally. This review synthesizes evidence on RA practices, highlighting key outcomes, patterns, trade-offs, and gaps.

Literature Review

Soil Health and Carbon Sequestration

Recent studies (2020–2025) consistently report that RA practices enhance soil organic carbon (SOC) and improve soil structure. Patil et al. (2025) [1] analyzed 147 studies across India, showing SOC gains of 10–25% over 3–5 years under cover crops, organic amendments, and reduced tillage. Similar results were observed globally: agroforestry, multi-species cover cropping, and organic amendments improved water infiltration, nutrient retention, and soil aggregation. These studies indicate that SOC accumulation depends on baseline fertility, soil texture, and climatic conditions.

Greenhouse Gas Emissions

Meta-analyses [2,3] examined RA's effects on greenhouse gas fluxes. No-till systems and organic amendments reduced CO_2 emissions by 10–20%, while N_2O and CH_4 fluxes were more variable, influenced by fertilization strategy, crop type, and livestock integration. Regional and management differences highlight the need for site-specific strategies to balance carbon sequestration and emissions reductions.

Crop Productivity

Evidence shows that crop yields under RA vary by region, soil condition, and duration of practice adoption. Short-term declines (5–10%) are commonly reported during the initial transition period due to changes in soil nutrient availability and management adjustments. Over the long term, yields stabilize or improve, particularly under diversified rotations and cover cropping. Vendig et al. (2023) [4] noted that in 60% of global cases, yields surpassed conventional systems after the transition period, emphasizing the importance of adaptive management.

Biodiversity and Ecosystem Services

Studies indicate that RA supports both above- and below-ground biodiversity. Soil microbial diversity, pollinator populations, and predator insects often increase under cover cropping, reduced tillage, and agroforestry practices. The magnitude of these benefits is influenced by landscape complexity: farms in heterogeneous, habitat-rich landscapes consistently achieved higher biodiversity gains than isolated farms in simplified landscapes.

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Socio-Economic Outcomes

Research from Europe, India, and other regions highlights that RA adoption can reduce input costs, increase net income, and enhance resilience to climate variability. Berthon et al. (2025) [5] reported 15% lower chemical input costs and 20% higher net income over five years for farmers practicing RA. Adoption barriers include knowledge gaps, high initial investment, and limited market access. Supportive policies, extension services, and financial incentives are critical for wider adoption.

Findings and Discussion

The synthesis of studies from 2020–2025 highlights that regenerative agriculture (RA) delivers multi-dimensional benefits, though outcomes are context-dependent.

Soil Health and Carbon Sequestration

RA practices enhance SOC and soil structure, with degraded or nutrient-poor soils showing the largest proportional gains. Long-term adoption of cover cropping, reduced tillage, and organic amendments stabilizes SOC and improves water infiltration, nutrient retention, and microbial diversity.

Climate Mitigation Potential

Cover cropping and organic amendments increase carbon sequestration; reduced tillage lowers CO_2 emissions. However, N_2O and CH_4 emissions can offset these benefits if nitrogen management or livestock integration is suboptimal. Integrated RA systems combining crop diversification, soil amendments, and optimized livestock management maximize net GHG mitigation. Regional differences are notable, with temperate regions achieving higher CO_2 sequestration rates, while CH_4 emissions are more significant in tropical livestock systems.

Crop Productivity and Yield Stability

Short-term yield penalties (5–10%) are common during the transition to RA. Adaptive management, diversified rotations, and extension support facilitate recovery and often improve long-term yields, especially in previously degraded or intensively managed soils.

Biodiversity and Ecosystem Function

RA enhances above- and below-ground biodiversity. Soil microbial biomass, pollinators, and predator populations increase under cover cropping, reduced tillage, and agroforestry. Benefits are amplified in heterogeneous, habitat-rich landscapes, highlighting the importance of landscape-scale planning.

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Socio-Economic Implications

RA adoption reduces input costs, increases net income, and enhances resilience to climate variability. Adoption is constrained by knowledge gaps, investment requirements, and market access. Policies, incentives, and extension services are critical for scaling RA effectively, particularly for smallholders.

Trade-Offs and Integration

Trade-offs exist between short-term productivity and long-term sustainability, and between climate mitigation and other ecosystem services. Integrated, context-specific RA strategies are essential to optimize multi-dimensional outcomes.

Tables Summarizing Key Findings (2020–2025)

Study / Region	RA Practices	Duration	SOC Change (%)	Notes
Patil et al., 2025 (India)	Cover crops, FYM, biochar, green manure	3–5 years	10–25%	Higher gains in degraded soils
Kumar et al., 2024 (Global)	Reduced tillage + organic amendments	2–7 years	8–20%	SOC plateau observed after 5–7 years
Vendig et al., 2023 (USA & Europe)	Agroforestry + crop rotations	4–6 years	12–18%	Highest gains with tree-crop integration

Table 1: Impact of RA on Soil Organic Carbon (SOC)

Study / Region	RA Practices	GHG Type	Change	Notes
Vejendla et al., 2025 (Global)	No-till, cover crops, organic amendments	CO_2	–10 to –20%	Reduced carbon emissions
Vejendla et al., 2025	Same	N_2O	+2–5%	Dependent on fertilizer management
Garbisu et al., 2025 (Europe)	Cover crops + manure	CH_4	+1–3%	Livestock integration increased CH_4

Table 2: Effects of RA on Greenhouse Gas Emissions

Study / Region	RA Practices	Duration	Yield Change (%)	Notes
Vendig et al., 2023 (Global)	Cover crops + crop rotation	2–5 years	Initial –5%, Long-term +10–15%	Yield penalty during transition
Kumar et al., 2024	Reduced tillage + organic amendments	3–6 years	+5–12%	Adaptive management improves outcomes
Patil et al., 2025	Multi-species cover crops	3–5 years	+8–18%	Higher response in nutrient-poor soils

Table 3: Impact on Crop Productivity

Study / Region	RA Practices	Metrics	Change (%)	Notes
Berthon et al., 2025 (Europe)	Cover crops + reduced tillage	Soil microbial biomass	+15–30%	Enhances nutrient cycling
Kumar et al., 2024	Agroforestry + crop rotation	Pollinator abundance	+20–35%	Greater gains in heterogeneous landscapes
Vendig et al., 2023	Integrated livestock + multi-species crops	Predator insects	+10–25%	Landscape context-dependent

Table 4: Effects on Biodiversity and Ecosystem Services

Study / Region	RA Practices	Duration	Economic Impact	Notes
Berthon et al., 2025 (Europe)	Cover crops + reduced chemical inputs	3–5 years	Input costs –15%, Net income +20%	Smallholders may face adoption barriers
Patil et al., 2025	Biochar + FYM + crop rotation	4–6 years	Cost savings 10–18%	Market access influenced adoption
Kumar et al., 2024	Integrated livestock + agroforestry	3–7 years	Net income +15%	Requires training and extension support

Table 5: Socio-Economic Outcomes

Conclusion and Future Directions

Regenerative agriculture offers a viable approach for sustainable food production, improving soil health, climate mitigation, biodiversity, and socio-economic resilience. Evidence from 2020–2025 demonstrates consistent benefits across multiple dimensions. Outcomes are context-dependent, and adoption barriers—knowledge gaps, market access, and initial investment—must be addressed. Future research should focus on:

- Long-term, landscape-scale experiments
- Optimization of RA practice combinations for different regions
- Integration of socio-economic, environmental, and policy analyses
- Mechanisms for scaling adoption among smallholders and resource-poor farmers

Supportive policies, financial incentives, and training programs are essential to maximize global RA impacts.

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