

# *Regenerative Agriculture: Reviving Sustainability in a Climate-Crisis Era*

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## **ABSTRACT**

Regenerative agriculture has re-emerged as a transformative paradigm in response to intensifying climate change, widespread soil degradation, and the ecological limitations of conventional agricultural systems. Approximately one-third of global agricultural land is degraded, while agriculture contributes nearly 25% of global greenhouse gas emissions. Regenerative agriculture emphasizes ecosystem restoration, soil carbon sequestration, biodiversity enhancement, and farm resilience. This review synthesizes recent scholarly evidence (2022–2025), market assessments, and global case studies to evaluate regenerative agriculture's environmental, economic, and climate-mitigation potential. Findings indicate that practices such as no-till farming, cover cropping, diversified rotations, livestock integration, compost application, and agroforestry can sequester up to  $8.4 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$ , improve water-use efficiency by 20–30%, and reduce external input dependence by 20–50%. Case studies from the United States, Europe, and India demonstrate scale able transitions with co-benefits including carbon credits, drought resilience, and improved farmer livelihoods. Despite adoption challenges, policy incentives, carbon markets, and technological integration position regenerative agriculture as a critical pathway toward net-zero and nature-positive food systems.

## INTRODUCTION

The global agri-food system faces unprecedented challenges from climate change, land degradation, biodiversity loss, and water scarcity. Conventional, input-intensive agriculture has increased yields but at significant environmental cost, contributing to soil erosion, declining soil organic carbon, and greenhouse gas emissions (Congreves *et al.*, 2025). With nearly one-third of global farmland degraded, restoring soil function has become a priority for sustainable food security.

Regenerative agriculture has gained renewed attention as a holistic, outcome-oriented approach that restores ecosystem processes while sustaining productivity. Its resurgence aligns with post-2020 climate urgency and 2025 global policy momentum toward net-zero emissions and nature-positive agriculture (Rosier *et al.*, 2025). Unlike sustainability frameworks that focus on reducing harm, regenerative agriculture emphasizes active regeneration of soil, biodiversity, and water cycles.

### 1. Conceptual Framework of Regenerative Agriculture

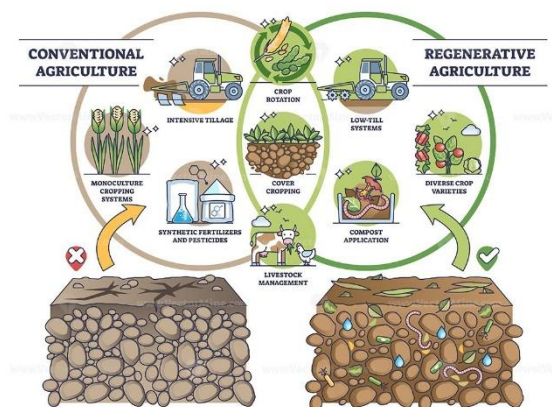
Regenerative agriculture is increasingly framed as a philosophy rather than a fixed set of practices (Congreves *et al.*, 2025). It integrates ecological principles such as soil cover, biodiversity, minimal disturbance, and nutrient cycling to enhance ecosystem services.

#### Core Principles

1. Restoration of soil organic carbon and microbial activity
2. Enhancement of on-farm biodiversity
3. Reduction of synthetic inputs

4. Strengthening climate resilience and farmer livelihoods

This systems-based approach positions farms as dynamic ecosystems capable of climate mitigation and adaptation simultaneously.



## 2. Review of Recent Literature and Expert Assessments

### 2.1 Soil Health, Nutrition, and Human Well-being

Rosier *et al.* (2025) reviewed emerging evidence linking regenerative practices to improved soil carbon storage, enhanced biodiversity, and increased micronutrient density in crops. Their study highlighted downstream health benefits, suggesting reduced reliance on ultra-processed foods and lower incidence of non-communicable diseases.

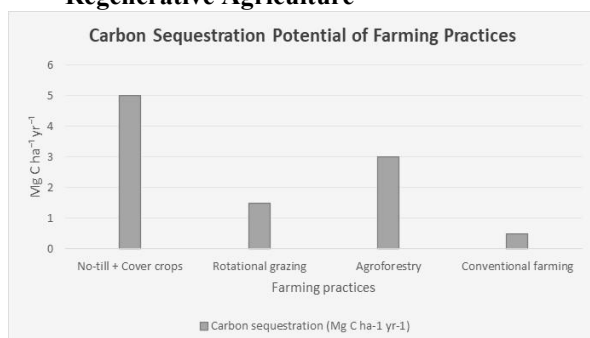
Congreves *et al.* (2025), in *Nature*, provided a widely cited definition of regenerative agriculture, emphasizing ecosystem restoration as the primary outcome. The authors documented a dramatic rise in scientific and policy discourse after 2020, driven by climate and biodiversity crises.

A global market assessment by Research And Markets (2025) projected rapid expansion of regenerative agriculture, fueled by consumer

demand for sustainable food and corporate commitments to resilient supply chains. The report identified soil health metrics and carbon accounting as key investment drivers as

1. **No-Till Farming:** No-till systems minimize soil disturbance, preserving aggregate stability and microbial habitats. Studies report annual increases of 0.5–1.0% in soil organic matter under sustained adoption.
2. **Cover Cropping:** Leguminous and multi-species cover crops fix atmospheric nitrogen, reduce erosion, and suppress weeds, decreasing fertilizer use by 50–100 kg. ha<sup>-1</sup>.
3. **Crop Rotation and Diversification:** Diverse rotations disrupt pest cycles, enhance nutrient cycling, and improve yields by 10–20% compared to monoculture systems.
4. **Livestock Integration :** Managed rotational grazing mimics natural herd movements, improving nutrient recycling and increasing soil carbon by 1–2 t ha.<sup>-1</sup> yr<sup>-1</sup>.
5. **Compost Application and Agroforestry:** Organic amendments and tree-based systems enhance water retention, microclimate regulation, and biodiversity while stabilizing long-term carbon stocks.

### 1. Case Studies of Transition and Adoption of Regenerative Agriculture

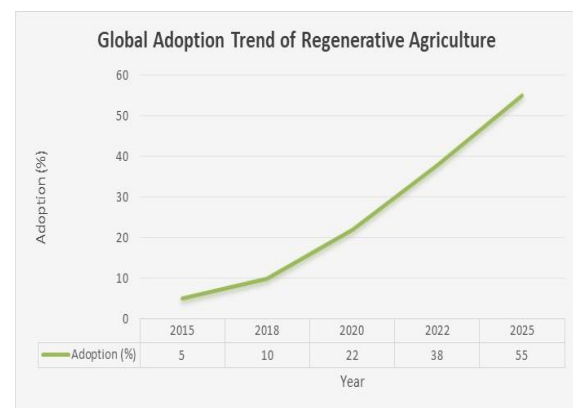


**Figure 1. Carbon sequestration potential of different farming systems**

4.1 In the United States (Vermont), Wiltshire (2022) reported that transitioning dairy farms to rotational grazing in Vermont resulted in sequestration of 1,269 kt. carbon over ten years, exceeding baseline levels by 5.3 %. Farmers simultaneously reduced chemical inputs by 20–30 %.

4.2 In the Europe, Villat *et al.* (2024) analyzed 345 European sites, demonstrating that agroforestry and cover cropping added 1 to 4 t C. ha.<sup>-1</sup> yr.<sup>-1</sup>. Vineyards adopting combined practices achieved fourfold increases in sequestration while phasing out synthetic inputs within 3 to 5 years.

4.3 In India, The KhetiBuddy initiative (2025) restored degraded farmland through mulching and crop rotation, increasing soil carbon sequestration by 41 % and water retention by 25 % within four years, significantly improving drought resilience.



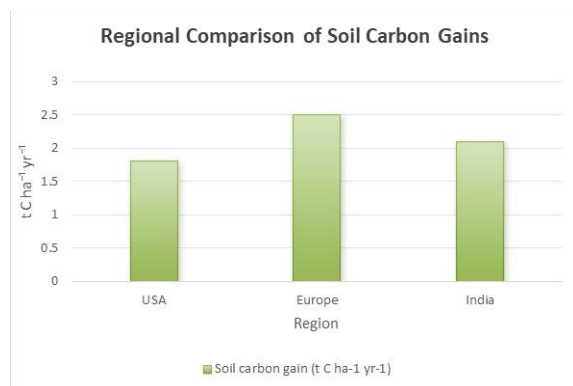
**Fig. 2 Global adoption trend of regenerative agriculture (2015–2025)**

## 5. Carbon Sequestration Potential and Climate Mitigation

Regenerative agriculture offers substantial climate mitigation potential by addressing agriculture's 25% share of global emissions. Empirical studies indicate:

1. No-till and cover crops: 0.9–8.4 Mg. C. ha.<sup>-1</sup> yr.<sup>-1</sup>.

2. Rotational grazing: 1–2 t. C. ha.<sup>-1</sup> yr.<sup>-1</sup>. Scaling these practices globally could sequester approximately 1.85 Gt. CO<sub>2</sub> annually comparable to afforestation while maintaining food production. Improved soil structure also reduces irrigation demand by 20–30 %.



**Figure 3. Regional comparison of soil carbon gains under regenerative agriculture**

## 6. Challenges and Pathways Forward

Despite clear benefits, adoption barriers persist, including transition costs, limited technical knowledge, and uncertain short-term returns. However, emerging carbon markets—valued at an estimated €500 billion—policy incentives, and digital advisory platforms are accelerating uptake. Future success depends on farmer capacity building, robust carbon measurement frameworks, and supply-chain integration for regenerative produce.

## CONCLUSION

Regenerative agriculture represents a scientifically grounded, economically viable

pathway to address climate change, soil degradation, and food-system vulnerability. Evidence from recent reviews and global case studies confirms its capacity to regenerate ecosystems while sustaining productivity. As climate pressures intensify, regenerative agriculture is poised to shift from an alternative model to a foundational pillar of sustainable agriculture.

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