



Regenerative Agriculture: Restoring Ecosystems' Resilience and Productivity: A Review

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ABSTRACT

Regenerative agriculture developed as a response to conventional farming's ecological degradation, emerging from organic farming, permaculture and holistic management principles. It reframes farms as integrated ecosystems rather than mere production units. Unlike conventional agriculture's yield-focused approach through external inputs, regenerative agriculture builds biological capital and ecosystem services to naturally support productivity, fundamentally shifting from extraction to regeneration. Key practices include minimal soil disturbance (no-till/reduced tillage), cover cropping, diverse crop rotations, managed livestock integration, compost application, reduced synthetic inputs and agroforestry systems. Implementation emphasizes context-specific design rather than prescriptive approaches. Monitoring focuses on soil health indicators (organic matter, biological activity, aggregate stability, water infiltration) and ecosystem metrics like biodiversity and carbon sequestration. Research shows promising outcomes: Soil organic carbon increases of 0.5-2% over 3-5 years, water infiltration rates 2-10 times higher than conventional systems, 30-50% increases in soil microbial diversity and 60-80% greater beneficial insect abundance. Carbon sequestration ranges from 0.5 to 3 tons per hectare annually. Economically, regenerative farms demonstrate 20-40% lower input costs with comparable or improved long-term profitability despite potential yield decreases during transition periods. Long-term studies confirm that regenerative systems become increasingly productive and stable over time.

Key words: Agriculture, Ecosystem, Productivity, Regenerative, Resilience, Resources.

Humanity's relationship with the land has been defined by an extractive and exploitative approach to agriculture for centuries. Driven by the relentless pursuit of higher yields and profits, conventional farming practices have systematically depleted the resources our food systems rely on (Lertzman *et al.*, 2005). Fertile soils have been stripped of vitality, water sources have dwindled and the rich tapestry of biodiversity underpinning healthy ecosystems has been unraveled. This unsustainable trajectory has left once-thriving landscapes in a state of degradation, compromising their resilience to environmental stresses and jeopardizing their ability to sustain life and provide essential ecosystem services (Pearce, 2019).

However, amidst this grim reality, a renaissance is stirring a paradigm shift towards regenerative agriculture, a holistic approach that seeks to heal the wounds inflicted upon our planet's ecosystems (Womack, 2018). By mimicking nature's intricate designs and harnessing the power of ecological processes, regenerative agriculture offers a transformative solution to restore our landscapes' vitality, resilience and productivity (Miatton *et al.*, 2020).

Fundamentally, regenerative agriculture acknowledges the delicate balance supporting healthy ecosystems and all living species' inherent interdependence. It recognizes that there are close connections between the vast diversity of flora and fauna, the health of our soils and the integrity of our water systems (Bartel *et al.*, 2019; Karr, 1996). Any disruption to this delicate balance can have far-reaching effects. By implementing regenerative methods, we may

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improve the long-term productivity and resilience of damaged soils, replace diminishing water sources and nurture the rich biodiversity that supports the health of ecosystems (Johnson *et al.*, 2022; Uphoff *et al.*, 2023).

This review delves into the concepts, practices and wide-ranging uses of regenerative agriculture, offering a comprehensive analysis of how we could promote abundance while simultaneously restoring the delicate equilibrium that sustains all life on Earth. We aim to redefine our relationship with the land and pave the way for a truly resilient and sustainable future by unraveling the mysteries of a holistic approach that goes beyond essential nourishment. These trade secrets range from state-of-the-art processes that mimic the regenerative cycles of nature to the fusion of traditional ecological knowledge with new scientific understandings.

Principles of regenerative agriculture (Fig 1)

Awakening the soil: Unlocking nature's powerhouse

The soil is the birthplace of regenerative agriculture, a living, breathing ecosystem teeming with microscopic wonders. By embracing practices that minimize disturbance and nurture the soil's vitality, we unlock a world of abundance (Wallander, 2014; Ohlson, 2014).

- No-till or reduced tillage techniques preserve the intricate web of soil life, allowing beneficial microorganisms, fungi and earthworms to thrive and enrich the soil's fertility (Stagnari *et al.*, 2019).
- Cover crops and diverse crop rotations mimic nature's symbiotic relationships, replenishing nutrients, improving soil structure and breaking pest and disease cycles (Islam *et al.*, 2021).
- Organic amendments, like compost and manure, infuse the soil with a rich tapestry of organic matter, providing a banquet for soil microbes and enhancing water-holding capacity (Euser *et al.*, 2005).

Biodiversity bounty: Harnessing nature's workforce

In the regenerative paradigm, biodiversity is celebrated as a powerful ally, a symphony of life that harmonizes to create resilient and productive ecosystems (Srivastava, 2023).

- Integrated animal, crop and tree components create diverse landscapes that mimic natural systems, fostering intricate ecological relationships (Moraine *et al.*, 2017).
- Agroforestry systems and the integration of trees and Shrubs provide pollinators, beneficial insects and wildlife habitats, enhancing natural pest control and pollination services (Bentrop *et al.*, 2019).
- Ecology-based pest management techniques, like introducing predatory insects and habitat diversification, harnessing nature's defenses against pests and diseases (Stenberg, 2017).

Conserving life's elixir: Water-wise practices

Water is the lifeblood of any ecosystem and regenerative agriculture embraces practices that conserve and replenish this precious resource (Gies, 2022).

- Healthy soils, rich in organic matter, act like sponges, increasing water infiltration and retention and minimizing runoff and erosion (Jiang *et al.*, 2022).
- Two effective irrigation methods that make sure every drop matters, reducing water waste and optimizing resource efficiency, are water harvesting and drip irrigation (Zhang *et al.*, 2021).
- Farms may restore groundwater supplies and provide essential ecosystems by restoring and safeguarding their natural streams, wetlands and riparian zones (Fennessy *et al.*, 1997).

These principles, deeply rooted in nature's wisdom, demonstrate the regenerative approach's holistic vision—a vision that transcends mere sustenance and embraces a harmonious dance with the rhythms of life itself.

Regenerative agriculture practices

A suite of holistic farming practices lies at the heart of regenerative agriculture systems (Toensmeier, 2016). Cover cropping is a foundational technique where soil-nourishing crops like legumes, grasses and brassicas are strategically planted when cash crops are not grown (Weekley *et al.*, 2012). These cover crops provide a protective vegetative canopy that shields the soil from erosion while their roots and residues replenish organic matter and feed the intricate soil food web (Sarita *et al.*, 2024). Complementing this practice, conservation tillage methods minimize soil disturbance through reduced or no-tillage operations, preserving the soil's structural integrity and reducing carbon losses (Hussain *et al.*, 2021).

Crop rotation and polyculture systems are integral to regenerative agriculture, promoting biodiversity and nutrient cycling across the landscape (Levin, 2022). These practices disrupt pest, weed and disease cycles by systematically alternating different cash crop types and integrating diverse plant species while supporting a rich ecological community (Malézieux *et al.*, 2009). Regenerative nutrient management emphasizes on-farm recycling of organic matter through applications of compost, manures and green manures, building long-term soil fertility based

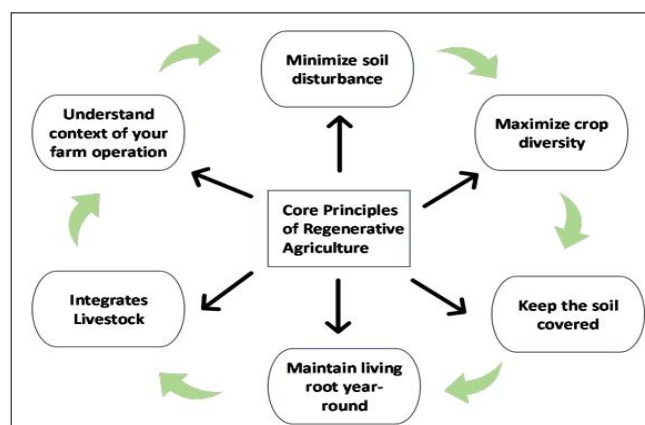


Fig 1: Principles of regenerative agriculture.

on-site-specific testing and crop requirements (Khangura *et al.*, 2023).

Integrated pest management (IPM) strategies in regenerative systems prioritize cultural, biological and mechanical methods over synthetic pesticides. This includes enhancing habitat for beneficial insects, birds and other natural pest predators and harnessing the ecosystem's innate resilience (Baker *et al.*, 2020). Where livestock are integrated, managed grazing techniques mimic natural grazing patterns, rotating animals across different paddocks based on plant growth stages. This stimulates vigorous vegetative regrowth and facilitates nutrient cycling through manure deposition (Teague *et al.*, 2013).

In regenerative agroforestry systems, trees, shrubs and perennial crops are intentionally integrated with livestock and annual crop production, creating a multi-strata, biodiverse and productive ecosystem. The trees provide numerous benefits, including shade, habitat for wildlife, carbon sequestration and nutrient pumping from deep soil layers. Techniques like keyline sub-soiling, which involves deep subsoil plowing along contours, are also employed in dryland areas to alleviate compaction, increase water infiltration and promote root growth (Elevitch *et al.*, 2018; Udawatta *et al.*, 2017 and Maliwal, 2020).

These regenerative strategies are customized and integrated based on every agroecosystem's requirements and circumstances. The ultimate objective is to improve the farming system's general health, productivity and resilience by imitating natural processes, closing nutrient loops and boosting biodiversity (Kumar *et al.*, 2024).

Benefits of regenerative agriculture

Regenerative agriculture is a pioneering approach that delivers environmental, economic and social benefits. At its core, regenerative practices aim to revitalize the soil ecosystem, fostering an intricate web of microbial life that underpins soil health, fertility and productivity. By improving soil health, regenerative agriculture also helps sequester

atmospheric carbon, mitigating climate change (Fig 2). Additionally, these practices can lead to increased water retention in the soil, reducing erosion risk and improving overall ecosystem resilience. Through holistic methods such as cover cropping, reduced tillage and diversified crop rotations, regenerative systems continually replenish and enrich the soil, enhancing its structure, water retention capacity and efficient cycling of nutrients (Timmis *et al.*, 2021; Grover *et al.*, 2024).

The significance of soil vitality cannot be overstated when tackling the urgent problem of climate change. Rich in various plant life and little disturbed, regenerative landscapes are compelling carbon sinks that store atmospheric carbon dioxide in stable soil organic matter (Buss *et al.*, 2021). These practices improve soil health and contribute to mitigating greenhouse gas emissions, making regenerative agriculture a crucial tool in the fight against climate change. By promoting biodiversity and fostering healthy ecosystems, regenerative systems offer a sustainable food production and environmental conservation solution. Regenerative cropping systems have the potential to sequester up to one billion tons of carbon a year in agricultural areas around the world, according to some estimations (Searchinger *et al.*, 2020). This would significantly aid in attempts to mitigate climate change. Furthermore, regenerative cropping systems sequester carbon and improve soil health, water retention and biodiversity. These systems also have the potential to increase resilience to extreme weather events and reduce the need for chemical inputs, ultimately leading to a more sustainable and environmentally friendly agricultural industry. Overall, regenerative cropping systems present a promising solution in the fight against climate change by addressing food production and environmental conservation. Promoting and adopting these practices globally can create a more sustainable and resilient agricultural system for future generations, ensuring food security and reducing the negative impacts of agriculture on the environment. By improving soil health and

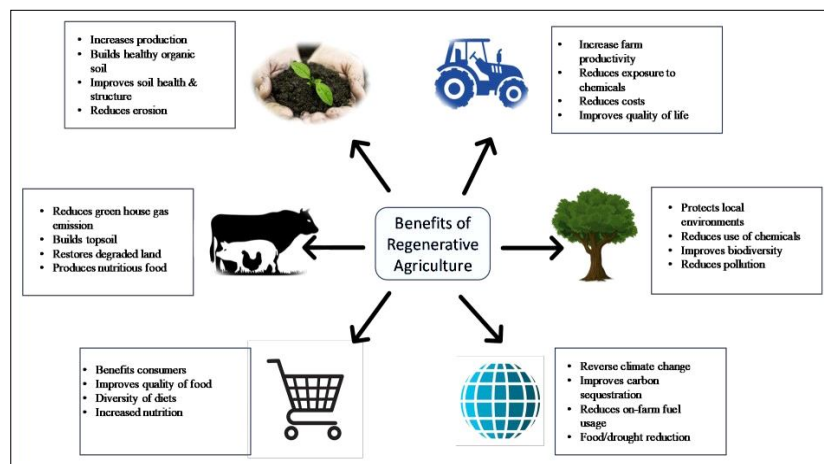


Fig 2: Benefits of regenerative agriculture.

biodiversity, regenerative cropping systems can also help sequester carbon from the atmosphere, contributing to efforts to mitigate climate change. Additionally, these practices can improve water retention in soil, reducing the risk of drought and erosion in agricultural areas. By integrating regenerative cropping systems into farming practices, we can work towards a more sustainable future that benefits both people and the planet. This shift towards regenerative agriculture can also help farmers adapt to changing climate conditions and reduce their reliance on synthetic inputs. Transitioning to regenerative cropping systems is crucial to building a more sustainable and environmentally friendly food system. Regenerative agriculture focuses on restoring soil health, increasing biodiversity and sequestering carbon to create a more resilient ecosystem. By prioritizing soil health and natural processes, regenerative cropping systems can improve crop yields and long-term productivity while promoting environmental stewardship. This approach not only benefits the environment but also the farmers themselves by reducing costs and increasing profitability. It is essential for ensuring food security and mitigating the impacts of climate change on agriculture (Mathew *et al.*, 2023).

Moreover, regenerative agriculture bestows remarkably resilient agricultural systems against the escalating impacts of a changing climate. These practices foster improved soil health, which enhances water infiltration and retention, bolstering drought resilience. In contrast to monocultures, diversified regenerative polycultures are less susceptible to pest outbreaks, diseases and weather extremes that can devastate entire crops. This resilience is further fortified by the biodiversity supported within regenerative landscapes, which provide valuable ecosystem services such as pollination, biological pest control and nutrient cycling (Meetei *et al.*, 2023).

Regenerative practices also offer a pathway to address water scarcity and conserve this precious resource. By minimizing soil disturbance and maintaining vegetative cover, regenerative methods increase soil porosity and water infiltration, reducing erosion and runoff (Gibbons *et al.*, 2018). Notably, research has shown that regenerative crop rotations can increase plant-available water by up to 20% compared to conventional systems, lessening the need for irrigation (Ouda *et al.*, 2018).

Beyond their environmental benefits, regenerative systems have great economic potential for farmers. Regenerative operations can increase profitability and financial resilience by utilizing nature's services and lowering dependency on expensive external inputs like synthetic fertilizers and pesticides (Suparak *et al.*, 2022). Research has indicated that regenerative farms can yield profits between 78 and 116% higher than traditional farms, highlighting the practicality of this strategy from a financial standpoint (Sánchez *et al.*, 2022).

Most crucially, regenerative agriculture contributes to the pressing goal of ensuring food and nutrition security

for the world's growing population. Regenerative systems continually improve soil fertility through natural processes, which can lead to higher crop yields and nutrient densities. Ultimately, this will enhance food diversity, availability and quality (McLennon *et al.*, 2021; Francis *et al.*, 1986). In contrast to traditional agriculture, dominated by monocultures, regenerative agriculture prioritizes diverse polycultures. Food security depends on dietary diversity, which is further encouraged by this (Langat *et al.*, 2010).

Beyond the tangible benefits, regenerative agriculture represents a paradigm shift in our relationship with the land and ecosystems that sustain us (Kassam *et al.*, 2021). By harmonizing food production with nature's intricate processes, regenerative methods offer a holistic solution to our intertwined challenges, paving the way for a future where agriculture coexists in balance with the environment, ensuring our food systems' long-term sustainability and resilience.

Case studies and success stories

While the principles of regenerative agriculture are grounded in ecological theory, an increasing number of farms and ranches worldwide are demonstrating the transformative impacts of these practices on the ground (Bless *et al.*, 2023). By focusing on building soil health, increasing biodiversity and enhancing ecosystem services, regenerative agriculture offers a promising solution to address climate change and food security challenges. This holistic approach improves the resilience of agricultural systems and promotes long-term sustainability for future generations. From reviving degraded landscapes to enhancing biodiversity, water retention and yields, these case studies offer a compelling testament to the potential of regenerative systems in restoring ecosystem resilience and productivity (Gordon *et al.*, 2022). Furthermore, the success stories of regenerative agriculture highlight the importance of adopting holistic approaches that prioritize soil health and biodiversity. By mimicking natural ecosystems, these practices have the potential to mitigate climate change and sustainably improve food security.

• Gabe Brown's Ranch - North Dakota, USA (Brown, 2018)

Gabe Brown's remarkable journey from conventional farming to a thriving regenerative ranch is an inspiring success story. On his 5,000-acre farm in North Dakota, Brown transitioned to a suite of regenerative practices, including no-till cultivation, diverse cover cropping and multi-species rotational grazing. The results have been nothing short of transformative. Brown has seen an increase in soil health and biodiversity on his farm and a significant improvement in crop yields and overall profitability. His success has garnered attention from farmers worldwide seeking to adopt similar regenerative practices. Soil organic matter levels, a key indicator of soil health, skyrocketed from a mere 1.7% to over 6% across his fields. This dramatic increase in soil fertility has had far-reaching implications for the ranch's ecosystem resilience and

productivity. Brown's Farm has become a shining example of the benefits of regenerative agriculture, proving that sustainable practices can lead to both environmental and economic success. As more farmers take note of his achievements, the potential for widespread adoption of regenerative practices continues to grow. Brown's fields can now absorb up to 8 inches of rainfall without experiencing any erosion or runoff, even during periods of severe drought. This is evidence of the regenerated soils' improved water infiltration and retention capacity. As a result, the ranch has grown extraordinarily resistant to drought and its profitability has increased, demonstrating the profitability of regenerative agriculture. Brown's success is a powerful example of how regenerative agriculture can benefit the environment and improve farmers' financial outcomes. By showcasing the economic viability of these practices, Brown is helping to pave the way for a more sustainable and profitable future in agriculture.

· **YI-Les-Arcs Farm-Normandy, France**

In the heart of Normandy, France, the YI-Les-Arcs Farm is a shining example of regenerative agriculture's potential to revive degraded landscapes and boost productivity. Over two decades, this 1,400-acre farm underwent a transformative transition, adopting regenerative practices focused on year-round soil cover, no-till cultivation, complex crop rotations and holistic grazing management. The results have been nothing short of remarkable. Soil organic carbon levels, a crucial indicator of soil health and fertility, have increased by over 100%, laying the foundation for enhanced ecosystem resilience and productivity. Even during severe droughts, the regenerative plots on the farm have vastly outperformed conventional monocrop plots, a testament to the improved water retention and resilience conferred by regenerative practices. Importantly, these ecological benefits have translated into tangible economic gains, with the regenerative systems driving increased yields and profitability for the farm.

· **Sacrabaja Farm - Boyacá, Colombia**

From a once-degraded landscape, the Sacrabaja Farm in Boyacá, Colombia, has emerged as a vibrant, biodiverse ecosystem thanks to the implementation of regenerative agriculture practices. On this 12-acre farm, regenerative vegetable cultivation, agroforestry, silvopasture and rotational grazing have been seamlessly integrated, resulting in a remarkable revival of soil health. Soil organic matter levels have increased by 40%, while water retention capacity has quadrupled, underscoring the farm's enhanced resilience against drought and erosion. Remarkably, over 200 crop varieties now thrive in this highly productive and biodiverse ecosystem, a stark contrast to the degraded state of the land just a few years prior.

· **Tangmang Farms - Bukidnon, Philippines**

Adopting regenerative principles has yielded remarkable results in the farming communities of Bukidnon, Philippines. Over five years, farmers transitioned to practices such as

no-till cultivation, cover cropping and the integration of crops with livestock and trees. The outcomes have been transformative, with maize yields increasing by 25-50% and rice yields doubling compared to conventional methods. Beyond boosting productivity, these regenerative systems have also enhanced the resilience of these communities against environmental challenges such as droughts, floods and typhoons. Consequently, farmers have experienced increased profitability and improved food security.

· **Jalupura Farms - Andhra Pradesh, India**

The 100-acre Jalupura Farms in Andhra Pradesh, India, is a testament to regenerative agriculture's potential to reduce input costs while enhancing yields and food quality. The farm shifted to a system known as zero-budget natural farming, a regenerative approach that relies on cover crops, mulches, microbial inoculants and botanical products. Over seven years, input costs plummeted by a staggering 80%, while yields rose by 35-40%. Notably, biodiversity flourished across the farm, contributing to the overall resilience of the ecosystem. Perhaps most significantly, the quality of the produce improved substantially, translating into higher market prices and increased profitability for the farm.

· **Bionca Farm - Tamahere, New Zealand (Grelet *et al.*, 2021)**

Bionca Farm, a 600-acre sheep and beef operation in Tamahere, New Zealand, has been radically transformed by implementing regenerative agriculture practices. The farm has witnessed a resurgence of soil health and biodiversity by adopting holistic grazing management, diverse cover cropping and minimal tillage. Soil organic matter levels have more than doubled and the once-degraded landscapes have been revived, supporting a rich array of plant and animal species. Notably, the farm's productivity has not been compromised; animal performance and weight gain have improved, while input costs have been reduced, contributing to increased profitability.

· **White Oak Pastures-Bluffton, Georgia, USA (Jordan *et al.*, 2013)**

White Oak Pastures, a 3,200-acre farm in Bluffton, Georgia, is a shining example of the advantages of regenerative agriculture, environmental preservation and financial sustainability. The farm has used silvopasture, rotational grazing and on-farm composting to restore biodiversity and soil health. A closed-loop system that minimizes waste and outside inputs has also been established. Consumer demand for the farm's diverse range of products, which includes nutrient-dense, sustainably produced beef, lamb, chicken and vegetables, has proven to be strong, contributing to the farm's financial success.

These diverse case studies, spanning different regions, climates and production systems, illustrate the transformative potential of regenerative agriculture. By working in harmony with nature's processes, regenerative practices have proven capable of reviving degraded landscapes, enhancing

biodiversity, improving water retention, boosting yields and increasing profitability—all while fostering resilient and sustainable agricultural ecosystems.

Challenges and barriers

While regenerative agriculture holds immense promise for restoring ecosystem resilience and productivity, its widespread implementation faces significant hurdles. A major obstacle lies in the transitional challenges, as shifting from conventional to regenerative systems often requires a steep learning curve and farmers may experience yield declines during an initial 3-5-year transition period. Limited access to technical training, advisory services and farmer networks exacerbates this challenge in many regions. Financial barriers can strain farmers during the transition phase, including upfront costs for new equipment, seeds and infrastructure and constrained access to affordable credit and risk management tools. Additionally, existing agriculture policies and subsidies largely favor conventional, input-intensive systems, while regenerative certification programs are nascent, with unclear market advantages. Supply chains and infrastructure geared toward monoculture commodity production further hinder the integration of regenerative products. On the research front, historically limited funding has left gaps in understanding context-specific practices, quantifying impacts on soil health, ecosystem services and climate resilience and conducting long-term, systems-level studies across diverse regions. Deeply entrenched productivist mindsets, skepticism towards transformative change and traditional land tenure systems can also inhibit the adoption of regenerative approaches. Finally, the lack of standardized frameworks to measure soil health, biodiversity, carbon sequestration and data deserts in many developing regions poses significant challenges in attributing environmental impacts to regenerative practices.

The future of regenerative agriculture

The future of regenerative agriculture burns with promise, offering a pathway toward a sustainable, resilient and productive food system that harmonizes with the natural world (Cummins, 2020). As we confront the escalating challenges of climate change, environmental degradation and food insecurity, the regenerative paradigm presents a holistic solution rooted in restoring ecosystem health and the mimicry of nature's intricate processes (Hermani, 2020).

In the decades ahead, we can envision a global agricultural landscape where regenerative practices are the norm, not the exception. Diverse polycultures and agroforestry systems will replace monocultures, fostering biodiversity and creating habitats for various plant and animal species. These biodiverse ecosystems will provide invaluable services, from pollination and pest control to nutrient cycling and carbon sequestration, enhancing the productivity and resilience of our farms and ranches (Altieri *et al.*, 1999; Garbach *et al.*, 2014).

Soil health will be at the forefront, with regenerative methods continuously replenishing organic matter, nurturing the soil food web and unlocking the earth's inherent fertility (Everard *et al.*, 2020). Farmers will leverage nature's services, reducing reliance on costly external inputs and closing nutrient loops through on-farm recycling of organic matter (White *et al.*, 2021). Precision technologies and data-driven insights will optimize these regenerative systems, tailoring practices to local conditions and maximizing efficiency (Balyan *et al.*, 2024).

Regenerative agriculture will restore ecosystem vitality and contribute to climate change mitigation and adaptation (Vamshi *et al.*, 2024). Carbon-rich soils will act as powerful sinks, drawing down atmospheric carbon dioxide. At the same time, the improved water retention and resilience conferred by these practices will buffer agricultural systems against the impacts of drought, floods and extreme weather events (Raj *et al.*, 2025).

Moreover, the future of regenerative agriculture extends beyond environmental sustainability to encompass economic viability and social equity. Farmers and ranchers will reap the rewards of reduced input costs, higher yields and access to premium markets for nutrient-dense, regeneratively-grown products. Rural communities will thrive with regenerative systems supporting diverse livelihoods, food sovereignty and cultural traditions interwoven with land stewardship.

Crucially, this transformative vision will require a concerted effort from all stakeholders—policymakers, researchers, industry leaders and consumers. Supportive policies, increased research funding, market incentives and consumer demand for regenerative products will catalyze and accelerate this transition (Singh *et al.*, 2021). Education and knowledge-sharing platforms will empower farmers with the skills and resources to adopt and refine regenerative practices suited to their local contexts (Van *et al.*, 2024).

As we embrace this regenerative future, we will witness a paradigm shift in our relationship with the land and the ecosystems that sustain us. Agriculture will no longer be an extractive force but a harmonious partner in nature's grand symphony, ensuring our food systems' long-term resilience, productivity and sustainability for future generations (Gorbachev *et al.*, 2006).

CONCLUSION

Regenerative agriculture emerges as a compelling solution to address the intertwined challenges of environmental degradation, food insecurity and climate change. By mimicking nature's intricate processes and harnessing the power of biodiversity, regenerative practices can restore degraded lands, rebuild soil health and fertility, improve water retention capacity and enhance overall ecosystem resilience. Through holistic methods such as cover cropping, minimal tillage, integrated pest management and rotational grazing, regenerative agriculture cultivates a

vibrant soil food web, sequesters atmospheric carbon and promotes efficient nutrient cycling. This boosts productivity and yields and creates a more sustainable and resilient agricultural system capable of withstanding the escalating pressures of climate extremes, pest outbreaks and diseases. Crucially, regenerative agriculture extends beyond environmental sustainability to encompass economic viability for farmers, reducing reliance on costly external inputs while leveraging the invaluable services provided by thriving ecosystems. A possible path forward appears to be the widespread adoption of regenerative agricultural techniques as we face the increasing difficulties of our day. However, various stakeholders must work together to achieve this shift, including farmers, legislators, academics and consumers. These efforts can be encouraged by market demand for regeneratively cultivated products, reward programs and education campaigns. By enabling this change, we can ensure that agriculture and the natural world can coexist for the long term, protecting our food systems and the ecosystem that supports us all.

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Author contribution

Conceptualization, Sakshi Balyan; Writing-Original Draft Preparation, Dhananjay Kumar, S.S., Vishal Balyan and Sakshi Balyan; Writing-Review and Editing, Sakshi Balyan, Dhananjay Kumar, Aakash Sheroran. All authors have read and agreed to the published version of the manuscript.

Disclaimers

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Conflict of interest

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REFERENCES

Altieri, M.A. (1999). The ecological role of biodiversity in agroecosystems. Invertebrate biodiversity as bioindicators of sustainable landscapes. Elsevier. pp: 19-31.

- Baker, B.P., Green, T.A. and Loker, A.J. (2020). Biological control and integrated pest management in organic and conventional systems. *Biological Control*. **140**: 104095.
- Balyan, S., Jangir, H., Tripathi, S.N., Tripathi, A., Jhang, T. and Pandey, P. (2024). Seeding a sustainable future: Navigating the digital horizon of smart agriculture. *Sustainability*. **16**(2): 475.
- Bartel, R. and Graham, N. (2019). Ecological reconciliation on private agricultural land: Moving beyond the human-nature binary in property-environment contests. In *Ecological Restoration Law* Routledge. pp: 93-118.
- Bentrop, G., Hopwood, J., Adamson, N.L. and Vaughan, M. (2019). Temperate agroforestry systems and insect pollinators: A review. *Forests*. **10**(11): 981.
- Bless, A., Davila, F. and Plant, R. (2023). A genealogy of sustainable agriculture narratives: Implications for the transformative potential of regenerative agriculture. *Agriculture and Human Values*. **40**(4): 1379-1397.
- Brown, G. (2018). Dirt to soil: One family's journey into regenerative agriculture. Chelsea Green Publishing. pp: 97-224.
- Buss, W., Yeates, K., Rohling, E.J. and Borevitz, J. (2021). Enhancing natural cycles in agroecosystems to boost plant carbon capture and soil storage. *Oxford Open Climate Change*. **1**(1): 006.
- Cummins, R. (2020). Grassroots Rising: A Call to Action on Climate, Farming, Food and a Green New Deal. Chelsea Green Publishing. pp: 2-47.
- Elevitch, C.R., Mazaroli, D.N. and Ragone, D. (2018). Agroforestry standards for regenerative agriculture. *Sustainability*. **10**(9): 3337.
- Euser, B.J. Ed. (2005). Bay Area Gardening: 64 Practical Essays by Master Gardeners. Travelers' Tales. pp: 5-56.
- Everard, M. and Everard, M. (2020). Rebuilding the Ark. Rebuilding the Earth: Regenerating Our Planet's Life Support Systems for a Sustainable Future. pp: 31-179.
- Francis, C.A., Harwood, R.R. and Parr, J.F. (1986). The potential for regenerative agriculture in the developing world. *American Journal of Alternative Agriculture*. **1**(2): 65-74.
- Fennessy, M.S. and Cronk, J.K. (1997). Riparian ecotones' effectiveness and restoration potential for managing nonpoint source pollution, particularly nitrate. *Critical Reviews in Environmental Science and Technology*. **27**(4): 285-317.
- Garbach, K., Milder, J.C., Montenegro, M., Karp, D.S. and DeClerck, F.A.J. (2014). Biodiversity and ecosystem services in agroecosystems. *Encyclopedia of Agriculture and Food Systems*. **2**: 21-40.
- Gibbons, L.V., Cloutier, S.A., Coseo, P.J. and Barakat, A. (2018). Regenerative development as an integrative paradigm and methodology for landscape sustainability. *Sustainability*. **10**(6): 1910.
- Gies, E. (2022). Water always wins: Thriving in an age of drought and deluge-University of Chicago Press.
- Gorbachev, M.S. (2006). Manifesto for the earth: Action now for peace, global justice and a sustainable future. *Clairview Books*. pp: 29-76.
- Gordon, E., Davila, F. and Riedy, C. (2022). We are transforming landscapes and mindscapes through regenerative agriculture. *Agriculture and Human Values*. **39**(2): 809-826.

- Grelet, G., Lang, S., Mirfield, C., Calhoun, N., Robson-Williams, M., Horrocks, A., Dewes, A., Clifford, A., Stevenson, B., Saunders, C.M. and Lister, C. (2021). Regenerative Agriculture in Aotearoa, New Zealand-Research Pathways to Build Science-based Evidence and National Narratives. pp: 4-57.
- Grover, D., Mishra, A.K., Rani, P., Kalonia, N., Chaudhary, A. and Sharma, S. (2024). Soil management in sustainable agriculture: Principles and techniques. In *Technological Approaches for Climate Smart Agriculture*, Cham: Springer International Publishing. pp: 41-77.
- Hermani, C. (2020). Regenerative Agriculture and the Quest for Sustainability-Inquiry of an Emerging Concept. Humboldt University of Berlin. pp: 1-137.
- Hussain, S., Hussain, S., Guo, R., Sarwar, M., Ren, X., Krstic, D., Aslam, Z., Zulfiqar, U., Rauf, A., Hano, C. and El-Esawi, M.A. (2021). Carbon sequestration to avoid soil degradation: A review on the role of conservation tillage. *Plants*. **10(10)**: 2001.
- Islam, R. Ed. (2021). *Cover Crops and Sustainable Agriculture*. Boca Raton, FL, USA: CRC Press.
- Jiang, C., Li, J., Hu, Y., Yao, Y. and Li, H. (2022). Construction of water-soil-plant system for rainfall vertical connection in the concept of sponge city: A review. *Journal of Hydrology*. **605**: 127327.
- Johnson, K.L., Gray, N.D., Stone, W., Kelly, B.F., Fitzsimons, M.F., Clarke, C., Blake, L., Chivasa, S., Mtambanengwe, F., Mapfumo, P. and Baker, A. (2022). A nation that rebuilds its soils rebuilds an engineer's perspective-soil Security. **7**: 100060.
- Jordan, C.F. and Jordan, C.F. (2013). Case Studies of Contemporary, Sustainable Farms in the South. An Ecosystem Approach to Sustainable Agriculture: Energy Use Efficiency in the American South. pp: 199-216.
- Karr, J.R. (1996). Ecological integrity and ecological health are not the same. *Engineering within ecological constraints*. **97**: 109.
- Kassam, A. and Kassam, L. (2021). Paradigms of agriculture. In *Rethinking food and agriculture*. Woodhead Publishing. pp: 181-218.
- Khangura, R., Ferris, D., Wagg, C. and Bowyer, J. (2023). Regenerative agriculture-A literature review on the practices and mechanisms used to improve soil health. *Sustainability*. **15(3)**: 2338.
- Kumar, H. and Singh, S.K. (2024). Simple Techniques for Improving Sustainability in Agriculture: Practical Solutions for Farmers. **10(12)**: 1-12.
- Langat, B.K., Sulo, T.K., Nyangweso, P.M., Ngéno, V.K., Korir, M.K. and Kipsat, M.J. (2010). Household food security in commercialized subsistence economies: Factors influencing dietary diversity of smallholder tea farmers in Nandi South, Kenya. pp: 3-15.
- Lertzman, D.A. and Vredenburg, H. (2005). Indigenous peoples, resource extraction and sustainable development: An ethical approach. *Journal of Business Ethics*. **56**: 239-254.
- Levin, B. (2022). Regenerative agriculture as biodiversity islands. In *Biodiversity islands: Strategies for conservation in human-dominated environments*. Cham: Springer International Publishing. pp: 61-88.
- Mathew, R., Sarojini, G.S., Smita, S., Shaji, A.J. (2023). Urban agriculture: An approach towards creating sustainable smart cities: A review. *Agricultural Reviews*. **46(3)**: 349-358. doi: 10.18805/ag.R-2629.
- Malézieux, E., Crozat, Y., Dupraz, C., Laurans, M., Makowski, D., Ozier-Lafontaine, H., Rapidel, B., De Tourdonnet, S. and Valantin-Morison, M. (2009). Mixing plant species in cropping systems: Concepts, tools and models: A review. *Sustainable Agriculture*. pp: 329-353.
- Maliwal, P.L. (2020). *Text Book of Rainfed Agriculture and Watershed Management*. Scientific Publishers. pp: 1-83.
- McLennon, E., Dari, B., Jha, G., Sihi, D. and Kankarla, V. (2021). Regenerative agriculture and integrative permaculture for sustainable and technology-driven global food production and security. *Agronomy Journal*. **113(6)**: 4541-4559.
- Meetei, K.B., Tsopoe, M., Giri, K., Mishra, G., Verma, P.K. and Rohatgi, D. (2023). Climate-resilient pathways and nature-based solutions to reduce vulnerabilities to climate change in the Indian Himalayan Region. In *Climate change in the Himalayas*. Academic Press. pp: 89-119.
- Miatton, M. and Karner, M. (2020). Regenerative Agriculture in Latin America. Mustardseed Trust Research Reports. pp: 1-56.
- Moraine, M., Duru, M. and Therond, O. (2017). A social-ecological framework for analyzing and designing integrated crop-livestock systems from farm to territory levels. *Renewable Agriculture and Food Systems*. **32(1)**: 43-56.
- Ohlson, K. (2014). *The soil will save us: How scientists, farmers and foodies are healing the soil to save the planet*. Rodale Books. pp: 1-22.
- Ouda, S., Zohry, A.E.H., Noreldin, T., Ouda, S., Zohry, A. and Noreldin, T. (2018). Crop rotation maintains soil sustainability. *Crop Rotation: An Approach to Secure Future Food*. pp: 55-76.
- Pearce, L.M. (2019). *Critical histories for ecological restoration* (Doctoral dissertation, The Australian National University (Australia)).
- Raj, P., Prerna, Kumar, A. (2025). A sustainable approach: Biochar and its potential use in agriculture. *Bhartiya Krishi Anusandhan Patrika*. **40(2)**: 145-151. doi: 10.18805/BKAP803.
- Sarita, Bhupesh, Goyal, V. (2024). Promoting sustainable agriculture: Approaches for mitigating soil salinity challenges: A review. *Agricultural Reviews*. **46(3)**: 444-450. doi: 10.18805/ag.R-2648.
- Sánchez, A.C., Kamau, H.N., Grazioli, F. and Jones, S.K. (2022). Financial profitability of diversified farming systems: A global meta-analysis. *Ecological Economics*. **201**: 107595.
- Searchinger, T. and Ranganathan, J. (2020). INSIDER: Further explanation on the potential contribution of soil carbon sequestration on working agricultural lands to climate change mitigation.
- Singh, P.K. and Chudasama, H. (2021). Conceptualizing and achieving industrial system transition for a dematerialized and decarbonized world. *Global Environmental Change*. **70**: 102349.
- Srivastava, B. (2023). Comparative analysis of biodiversity indexes software for accurate assessment. National webinar on biodiversity and conservation. 53.
- Stagnari, F., Galieni, A., D'Egidio, S., Pagnani, G. and Pisante, M. (2019). Sustainable soil management. *Innovations in sustainable agriculture*. pp 105-131.

- Stenberg, J.A. (2017). A conceptual framework for integrated pest management. *Trends in Plant Science*. **22(9)**: 759-769.
- Suparak Gibson, A. (2022). The Underground Economy: regenerative farming's hidden economic, ecological and social value (Doctoral dissertation).
- Teague, R., Provenza, F., Kreuter, U., Steffens, T. and Barnes, M. (2013). Multi-paddock grazing on rangelands: Why the perceptual dichotomy between research results and rancher experience? *Journal of Environmental Management*. **128**: 699-717.
- Timmis, K. and Ramos, J.L. (2021). The soil crisis: The need to treat as a global health problem and the pivotal role of microbes in prophylaxis and therapy. *Microbial Biotechnology*. **14(3)**: 769-797.
- Toensmeier, E. (2016). The carbon farming solution: A global toolkit of perennial crops and regenerative agriculture practices for climate change mitigation and food security. Chelsea Green Publishing. pp: 1-39.
- Udawatta, R.P., Gantzer, C.J. and Jose, S. (2017). Agroforestry practices and soil ecosystem services. In *Soil health and intensification of agroecosystems*. Academic Press. pp: 305-333.
- Uphoff, N. and Thies, J. Eds. (2023). *Biological approaches to regenerative soil systems*. CRC Press. 13.
- Vamshi, M., Jagadeesan, R., Lamani, H.D., Rout, S., Vijay Kumar, R., Jagadesh, M. and Sachan, K. (2024). The revolutionary impact of regenerative agriculture on ecosystem restoration and land vitality: A review. *Journal of Geography, Environment and Earth Science International*. **28(4)**: 1-14.
- Van Ewijk, E., Ataa-Asantewaa, M., Asubonteng, K.O., Van Leynseele, Y.P., Derkyi, M., Laven, A. and Ros-Tonen, M.A. (2024). Farmer-centered multi-stakeholder platforms: From iterative approach to conceptual embedding. *Journal of the Knowledge Economy*. pp: 1-31.
- Wallander, H. (2014). *Soil: Reflections based on our Existence*. Springer. 123-136.
- Weekley, J., Gabbard, J. and Nowak, J. (2012). Micro-level management of agricultural inputs: Emerging approaches. *Agronomy*. **2(4)**: 321-357.
- White, A., Faulkner, J.W., Conner, D., Barbieri, L., Adair, E.C., Niles, M.T., Mendez, V.E. and Twombly, C.R. (2021). Measuring the supply of ecosystem services from alternative soil and nutrient management practices: A transdisciplinary, field-scale approach. *Sustainability*. **13(18)**: 10303.
- Womack, R.L. (2018). *A Regenerate Science: Paradigms for Science and Theology in Recent American Fiction* (Doctoral dissertation, Baylor University).
- Zhang, W., Sheng, J., Li, Z., Weindorf, D.C., Hu, G., Xuan, J. and Zhao, H. (2021). Integrating rainwater harvesting and drip irrigation for water use efficiency improvements in apple orchards of northwest China-*Scientia Horticulturae*. **275**: 109728.