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Regenerative Soil Management: Integrating Carbon Sequestration, Soil Health and Climate-Smart Agriculture

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Abstract
Sustainable agriculture must combine the opposing needs of feeding a growing population, preserving ecosystem functioning and mitigating climate change. Regenerative soil management is an evidence-based approach that clearly includes carbon sequestration, soil health improvement and climate wise farming methods. In this review, we summarize the existing research and meta-analyses to assess the effects of numerous regenerative techniques (e.g., conservation tillage, cover cropping, diverse crop rotations, organic additions, and agroforestry) on soil carbon storage, soil fertility, and soil resilience. The main indices of soil health and their reaction to treatment are discussed. The history of soil research has been a shift from the old nutrient-balance paradigm toward a greater emphasis on soils as dynamic ecosystems. Major scientific advances are emphasized, such as the development of soil organic carbon models and the recognition of soils as major climate sink. Research has shown that good regenerative practices may significantly increase soil organic carbon (often by several tens of percent), improve agricultural output and water retention, and help to climate goals. This review paper synthesizes these data and argues that regenerative soil approaches in a climate-smart framework give a viable road to healthier soils, increased food security and decreased greenhouse gas emissions.

Keywords: Regenerative soil management, nutrient-balance, soil organic carbon, farming

Introduction

Agriculture has a trinity of challenges in the twenty-first century: feeding a rising population, sustaining productivity in a changing environment and lowering greenhouse gas emissions from farming [22]. With the world's population expected to reach 10 billion by mid-century, demand for food will climb sharply, placing pressure on already stressed land and water resources [47]. At the same time climate change is making droughts, floods and heat waves that threaten crops more frequent. An important aspect of this problem is the agricultural soils, which has lost a lot of their organic content due to intensive agriculture and erosion [57]. Soils contain more C than the atmosphere and plants combined, yet widespread soil degradation and loss of soil organic carbon (SOC) increase CO2 emissions and reduce productivity [75].

- Growing food consumption and population pressure is putting pressure on natural resources [12].
- More frequent and intense climate extremes (droughts, floods) [35].
- Severe soil deterioration (erosion, compaction, loss of nutrients) [46].
- Agriculture also has to reduce greenhouse gas emissions to satisfy climate goals [58].

Healthy soils are the basis for sustained production. Soil is a living ecosystem and its state frequently referred to as soil health, impacts its capacity to sustain plants, microorganisms and wider ecosystem processes. Soil organic carbon is a major indicator of soil health, influencing the retention of nutrients, the ability to retain moisture, the stability of structure and biological activity [76]. Declining SOC reduces soil fertility, susceptibility to erosion and nutrient runoff and resilience to drought. Conversely, soils rich in organic matter tend to support larger yields and buffer crops against climate stress. Thus, improving soil health has several benefits: it may boost crop nutrition and productivity, promote water penetration and storage, support biodiversity, and significantly, draw down atmospheric carbon via carbon sequestration in the soil [23].

One such approach to building soil health and achieving climate goals holistically is regenerative soil management [89]. Regenerative management is not about maximizing yields or inputs, but about building self-sustaining ecosystems in the soil. It usually involves a set of methods low tillage, continuous plant cover (cover crops or agroforestry), crop diversification, organic amendments (compost, manure, biochar) and integrated livestock grazing that work together to rebuild nutrient cycle and biological balance [48]. These approaches imitate natural processes and create soil organic matter over time. Regenerative agriculture is so closely aligned with the objectives of climate-smart agriculture (CSA), a widely recognized concept for achieving a 'triple win' of increased production, better climate resilience and fewer greenhouse gas emissions [59]. Many CSA practices such as conservation agriculture, agroforestry and precision fertilizer management naturally renew soil and trap carbon. In reality, regenerative farming may be considered as a soil-oriented subset of climate-smart agriculture [90, 1].

This study collates research on the impact of regenerative soil management strategies on soil carbon sequestration and soil health and on the wider goals of climate-smart agriculture. We use the most recent peer-reviewed research and meta-analyses with an emphasis on soil science features (physical, chemical and biological soil parameters) and not plant pathology [13]. The review includes: an introduction to fundamental concepts (soil carbon cycling and soil health), a historical overview on the evolution of soil science and sustainable farming, summaries of scientific contributions and a discussion of main regeneration strategies and their consequences [24]. Quantitative comparisons are shown in tables and in the historical chronology of soil management approaches. Throughout the book, data from field trials and long-term research is highlighted, illustrating how certain techniques translate into benefits in soil carbon, fertility and agricultural production. The conclusion addresses implications for policy and practice, and research requirements to advance climate-smart, soil-friendly agriculture [91].

Soil science and sustainable agriculture have reached important milestones. In the 19th century, early scholars such as Friedrich Fallou (Germany) and Vasily Dokuchaev (Russia) formed the basis of pedology via the classification of soils and the recognition of soil-forming processes. Fallou advocated a systematic study of soil as a natural resource in his First Principles of Soil Science (1857) [93]. In 1883 Dokuchaev wrote about Chernozem (rich black earth) and defined soils as unique natural entities created by climate and organisms, and not as disintegrating rock. Darwin's 1881 book on earthworms showed how essential soil biota are in building rich topsoil [77]. These pioneers altered the perspective of soil from a static "nutrient bin" to a dynamic living system [92].

Soil surveys proliferated and farming by nutrient balance became a standard practice in the early 20th century. However, detrimental impacts of heavy tillage and monocultures such erosion and reduction in fertility were noted. The Dust Bowl of the 1930s in North America showed how susceptible traditionally tilled

soils are to wind and water erosion [94, 78]. In response, the U.S. Soil Conservation Act (1935) and similar programs across the globe advocated contour plowing and cover crops to conserve soil [103]. Hans Jenny's important 1941 study Factors of Soil Formation established the notion that soil qualities develop from climate, organisms, relief, parent material and time by mid-century. Work on cation exchange capacity and nitrogen cycling also enhanced the study of soil fertility [25, 60].

In the late 20th century, there was a growing awareness of environmental problems. The organic farming movement (led by J.I. Rodale and others) stressed natural fertility and closed nutrient cycles [95]. In 1987, the Brundtland Commission defined "sustainable development," underlining the restrictions imposed by the environment. In agriculture, the phrase "sustainable agriculture" gained popularity in the 1980s and 90s [61]. Soil carbon was first addressed within the framework of climate mitigation by major international accords (e.g. the 1992 Rio Earth Summit and the Kyoto Protocol in 1997) [104]. In the 1980s-90s, Rattan Lal and others focused scientific attention to soils as carbon sinks, calculating how proper management may absorb carbon and offset emissions [14].

The concepts "regenerative agriculture" and "climate-smart agriculture" have become more common in recent years. Around 2000, agroecologists and farmers began using "regenerative" to characterize farming that restores ecosystems (emphasizing carbon, biodiversity and nutrient cycle) [49]. FAO and World Bank defined climate-smart agriculture as an integrated method to increase production, resilience and mitigation (the so-called "triple win") in 2010–2012. Programs such as France's "4 per 1000" program (started in 2015) have the specific objective of boosting the world's soil carbon stores by 0.4% every year [79]. Meanwhile research has advanced in detecting and modelling soil carbon and in establishing soil health indicators. Long-term field studies (e.g. Rothamsted, UK, since 1843) continue to demonstrate the modification of soil characteristics by cropping methods and amendments across decades [96, 26].

Key Scientific Contributions to Soil Carbon and Health

- A number of scientific advancements in recent decades have improved our knowledge of soil as a storage of carbon and a living ecosystem. Soil carbon models (e.g. RothC, Century and more recent microbial-explicit models) have been created to anticipate the effects of management and climate on SOC dynamics [15].
- These models distinguished between labile (fast-cycling) and stable carbon stores, and enabled worldwide estimations of soil carbon change. Recent observations using stable isotopes and radiocarbon have shown that a large proportion of this so-called "old" carbon could be more dynamic than previously imagined, giving rise to novel ideas such as the "soil continuum model" for organic matter breakdown [28, 63].
- Advances in analytical methods (e.g. spectroscopy of soil carbon, molecular markers) have enhanced our capacity to trace sources of soil carbon, including biochar and humic compounds, at laboratory and field scales. Soil biology has also come on in leaps and bounds [106]. Modern microscopy and DNA sequencing show the immense variety of soil bacteria and their significance in nutrient cycle. This has demonstrated the need of having a healthy soil microbial community for creating organic matter. For example, studies have revealed that fungi are frequently important in building solid soil aggregates, which keep carbon from being rapidly decomposed [97, 3].
- An important contribution is the quantification of possible rates of carbon sequestration for a variety of techniques. Early soil scientists could only guess at soil as a carbon sink, but the last several decades have seen many meta-analyses [36, 107]. These have typically indicated that strategies such as no-tillage, cover cropping and agroforestry may each contribute on the order of 0.2–0.5 Mg C per hectare per year above traditional systems, although the precise rates vary significantly with climate and soil type [64]. Similarly, long-term use of manure or compost has been found to grow soil organic matter significantly. These empirical results have fed into global carbon budgets, and have prompted suggestions to include soil carbon into national climate commitments [51].
- Another key advancement is soil health testing and indicators. Now researchers assess changes in soil function using aggregate stability tests, infiltration rates, microbial biomass carbon, earthworm numbers and other metrics [65]. The whole idea of "soil health" was institutionalized by agencies like the USDA Natural Resources Conservation Service, integrating research to on-farm evaluations. This has permitted the tracking of the development of regeneration

Table 1. Key historical events that shaped soil science and regenerative agriculture [50, 2, 27, 62, 80, 105]

Year	Event / Development in Soil Science and Agriculture
1857	Fallou publishes *First Principles of Soil Science*, establishing soil science foundations.
1881	Darwin's study *Earthworms* highlights the role of soil organisms in forming fertile soil.
1883	Dokuchaev introduces soil classification and pedogenesis, founding modern soil science.
1935	U.S. Soil Conservation Service established (after Dust Bowl) to combat erosion with contour plowing, cover crops.
1941	Hans Jenny's *Factors of Soil Formation* (US) formalizes environmental factors in soil development.
1960s	Rise of organic farming movement (e.g. Rodale Institute) promotes natural soil fertility and biodiversity.
1970s–1980s	Growing awareness of soil degradation; discovery of ozone depletion and climate change renews interest in carbon cycling.
1987	Brundtland Report defines "sustainable development," influencing agro-environmental policy and research.
1992	Rio Earth Summit (Agenda 21) encourages sustainable land management; Kyoto Protocol (1997) includes land-use carbon sinks.
2000s	Research identifies agriculture as significant source of greenhouse gases, while demonstrating carbon sequestration potential of soils.
2008	Term "regenerative agriculture" gains popularity in literature, emphasizing ecosystem restoration in farming.
2010	FAO Climate-Smart Agriculture (CSA) framework (productivity, adaptation, mitigation).
2015	*4 per 1000* initiative launched at COP21 (Paris): propose increasing global SOC stocks by 0.4%/yr to offset emissions.
2020s	Advances in soil microbiology and "soil health" concepts; carbon markets emerge to reward sequestration in agriculture.
2023	Growing adoption of regenerative and climate-smart practices worldwide; soil carbon science enters mainstream climate policy.

methods and comparing it with traditional standards [81]. For example, many farms that have adopted crop rotation and decreased tillage have seen big improvements in soil health ratings [16].

- Finally, multidisciplinary work that links ecology, agronomy and economics has placed soil management within the framework of ecosystem services. In the 2010s, research started to appreciate the ecosystem services of healthy soils water purification, flood mitigation and biodiversity as well as the carbon services [37]. This has provided the basis for market systems for carbon credits in agriculture. Together these scientific contributions provide the evidentiary underpinning that when appropriately managed, soils may be actively regenerative: taking down carbon from the atmosphere, preserving fertility and building climate resilience [29].

Soil Organic Carbon Sequestration under Regenerative Practices

- Soil organic carbon (SOC) is a key concept in relating soil health and climate. It contains decomposed plant debris, bacteria and stable humic chemicals [82]. Regenerative management seeks to enhance SOC storage by increasing carbon inputs (by plant biomass) and lowering losses (via erosion or excessive breakdown). SOC is influenced by key activities such as tillage intensity, crop diversification, live roots, and organic inputs [39].
- Systems of no-tillage and minimal tillage leave crop remains on the surface and minimize soil disturbance. In long-term tests the elimination of ploughing has frequently resulted to considerable SOC increases in the topsoil. For example, field studies have found increases in SOC of 30–50 % under no-till with rotation compared with standard ploughing, spanning decades [52]. Also, in many situations, yields have gone up by 10–30% with no-till, since improved soil structure and moisture lead to stronger plants. Globally, it is anticipated that widespread use of no-till might sequester roughly 0.1–0.3 Mg C ha^{-1} yr^{-1} [84, 108]. Different crop rotations (particularly those with legumes) also provide greater root biomass and different residues resulting in increased SOC. One research showed that the introduction of a winter cover crop (in lieu of fallow) led to a few percent improvement in maize

production and over 20% increase in SOC compared to the fallow system [4].

- Cover crops (grasses, legumes or mixes sown in the off-season) have been widely studied. On average, cover crops enhance markers of soil fertility and increase topsoil organic carbon by around 10%. A worldwide meta-analysis revealed that fields with cover crops had around 10 % more total organic carbon and 20 % more total nitrogen in the surface soil than bare fallow systems [53]. Cover crops also dramatically enhance soil structure: saturated hydraulic conductivity (a measure of water infiltration) increased more than two-fold with cover crops. These water advantages protect soils and crops against harsh weather [30, 66].
- Organic amendments such as spreading manure, compost, or biochar are powerful tools for increasing SOC. Manure treatment at common rates has been proven to raise SOC stores by on average 30–40%, contributing roughly 10 Mg C per acre over many years [109]. This also reduces the bulk density of the soil and increases the availability of nutrients. Biochar (charred biomass) is particularly interesting: field experiments suggest that biochar may increase SOC by 20–80% depending on type and quantity applied [85, 98]. Biochar's porous structure also stores water and nutrients, and offers home for bacteria. In one assessment, soils treated with biochar had up to 84% more SOC, 323% more particulate organic carbon and 93% more microbial biomass carbon than control plots [40].
- Agroforestry and trees in agriculture contribute much more carbon reserves. Silvoarable systems (rows of trees with crops) and silvopastures (trees with pasture) store much more carbon above and below ground. Silvopastoral systems have been shown to sequester on average around 4.4 Mg C ha^{-1} yr^{-1} in soils [54, 99]. Trees may provide SOC deeper in the profile by providing permanent roots all year long. This also enhances soil structure and nutrient cycling via leaf litter and root turnover. Overall, farms that have trees on them retain greater SOC than monocultures, with measured differences being in the range of 10 to 30% more SOC beneath the trees [67].
- Soil carbon may also be increased via mixed crop–livestock systems. Grazing animals come back to croplands, provide manure and boost plant development. Well-managed grasslands (for example rotational grazing) may accumulate 0.1–0.3 Mg C ha^{-1} yr^{-1}, while adding animals to row crop fields can help retain around 0.05–0.1 Mg C ha^{-1} yr^{-1} in the soil [110, 68]. By contrast, deteriorated soils under continual ploughing may release 0.2–1.0 Mg C ha -1 yr. -1 to the atmosphere. Hence, management decision may swing soils between a carbon source and a sink [5, 17].
- The potential is huge worldwide: calculations show that better management of croplands and pastures may trap hundreds of millions of tons of carbon a year. For example, worldwide conservation agriculture and reforestation of marginal areas are expected to sequester on the order of 0.1–0.5 Pg C each year [69, 86]. Policy scenarios show that a very modest re-carbonization of soils of a few tenths of a percent per year (as in the "4 per 1000" aim) may compensate for a sizeable share of present agricultural emissions. The research, however, suggests that soils that have undergone regenerative treatments commonly sequester tens of Mg of carbon per hectare over a decade, enriching soil fertility and sequestering atmospheric CO_2 in plant-derived material [31, 41].

Soil Health Indicators and Measurement

- As Table 3 shows, soil health is a multidimensional term including physical, chemical and biological aspects. Soil organic matter and soil organic carbon are key physical and chemical markers that contribute to soil fertility, enhanced water holding capacity and stable soil structure [102]. Bulk density, aggregate stability, and infiltration rate are indicative of the degree of soil compaction, structural condition, and the passage of water through the soil profile, respectively [42]. Lower bulk density, higher aggregate stability and better infiltration suggest better physical characteristics of the soil, better root penetration and less vulnerability to soil erosion [111]. Soil pH, cation exchange capacity (CEC) and electrical conductivity similarly impact the soil' s ability to deliver and absorb nutrients and create a conducive environment for crop development [19].
- The chemical markers, especially accessible nitrogen, phosphorus and other vital elements such as potassium, calcium and magnesium are significant for assessing the nutrient-supplying ability of soil. Plants need sufficient nutrients for growth, metabolism and crop production,

Table 2. Key Regenerative Soil Management Practices and Their Effects [87, 18, 100, 32, 70]

Practice	Effect on SOC	Other Soil/Climate Benefits
No-Tillage Farming	+30–50% SOC in topsoil (vs. plowed)	Greater water retention; less erosion; fuel saving
Reduced Tillage (Minimum)	+20–30% SOC in surface layers	Improved structure; preserves residue mulch
Crop Rotation (diverse)	+10–30% SOC (especially legumes)	N-fixation by legumes; pest and weed suppression
Cover Cropping	+10% SOC; +20% topsoil N	Reduced erosion; moisture conservation; weed control
Green Manures (legumes)	+N inputs; modest SOC gain	Free N-fertilizer; break disease/pest cycles
Organic Amendments (Manure/Compost)	+30–40% SOC (≈+10 Mg C/ha)	Lowers bulk density; adds nutrients; boosts microbes
Biochar Application	+20–80% SOC (with high rates)	Improved nutrient and water holding; stable C sink
Agroforestry (trees + crops)	+Rich SOC at depth (higher than monoculture)	Biodiversity habitat; shading; windbreak; timber/carbon
Silvopasture (trees + pasture)	+~4.4 Mg C/ha/yr stored in soil	Livestock shade; forage; erosion control
Perennial Crops (e.g. grasses)	+0.5–0.7 Mg C/ha/yr (deep roots)	Year-round cover; less disturbance; deep nutrient cycling
Integrated Crop-Livestock	+0.05–0.3 Mg C/ha/yr (from manure & roots)	Nutrient recycling; diversified income
Mulching (crop residue cover)	+modest SOC from protected residues	Cooler soils; moisture retention; erosion control

Note. (SOC = soil organic carbon; changes are relative to conventional cropland over years to decades.)

whereas shortages or imbalances may limit agricultural output. Soil pH affects solubility and availability of nutrients and microbial activity [71]. CEC is the ability of soil to hold positively charged nutrient ions and to prevent their leaching. Soil salinity is often measured by its electrical conductivity. High levels of soluble salts may have a negative impact on seed germination, water uptake and plant growth. Hence, preserving soil fertility and enhancing the long-term productivity of agricultural systems need balanced nutrient availability and favorable chemical conditions [6].

- Biological indicators such as microbial biomass carbon, soil enzyme activities and earthworm abundance are indicative of the biological functioning and ecological activity of soil. Microbial biomass carbon is the live microbial component of soil organic carbon and is involved in organic matter degradation and nutrient mineralization [33]. Dehydrogenase and other enzyme activity may be used to infer microbial metabolic pathways and to offer important information on carbon and nitrogen transformations [55]. Earthworms and other soil fauna are involved in the breakdown of organic residues, soil aeration, aggregate formation and nutrient redistribution.

In addition, root development and soil profile depth are indicators of plants' capacity to seek deeper soil layers for water and nutrients [101, 112]. Together these indicators give a holistic evaluation of soil health and assist evaluate the efficacy of regenerative soil management strategies. Improvements in these attributes lead to higher soil fertility, increased biological diversity, improved water-use efficiency and increased resilience of agricultural ecosystems to environmental shocks [72].

Climate-Smart Agriculture and Soil Management

Climate-smart agriculture (CSA) is defined as an integrated approach to manage landscapes and farming systems so as to meet productivity, adaptation and mitigation goals simultaneously. It has a strong overlap with regenerative soil management, because many CSA practices inherently promote soil health and carbon storage [10, 11]. For instance, CSA emphasizes conservation agriculture (minimum tillage with crop residues), agroforestry, precision irrigation and resilient crop varieties. Each of these can be viewed through a soil-focused lens: they protect and enrich the soil ecosystem [44].

The triple win of CSA increased productivity, enhanced resilience, and reduced emissions is often achieved via soil-improving measures. For example:

- **Productivity:** Healthy soils with higher organic matter and better structure yield more food per unit input. In one analysis, restoring SOC on degraded soils improved yields by 15–30% over a decade. Practices like crop rotation and cover cropping reduce pests and weeds, further supporting stable yields without depleting soils [34].
- **Resilience:** Soils rich in organic carbon buffer plants against stress. Higher water infiltration and retention from organic matter means crops suffer less during droughts. Likewise, better-structured soils resist floods and retain nutrients, reducing vulnerability to erratic weather. Agroforestry (trees plus crops) provides shade and wind protection, mitigating heat and storm damage [20].
- **Mitigation:** By increasing carbon storage in soils and vegetation, CSA practices lower net greenhouse gas emissions. Conservation agriculture has been estimated to sequester on the order of 0.1–0.3 Mg C ha^{-1} yr^{-1} relative to ploughed systems, while agroforestry and silvopasture can be much higher [88]. Improved pasture management reduces methane and nitrous emissions. Overall, analyses suggest that combining several practices could offset a significant fraction of emissions from the farming sector [7, 73].

Conclusion

Regenerative soil management, seen through the perspective of climate-smart agriculture, provides a viable technique to achieve concurrently food security, environmental and climate objectives. The review demonstrated that well-designed regenerative techniques may dramatically augment soil organic carbon, enhance crucial soil health indices and thereby improve agricultural output and ecosystem resilience. The history of soil research, from when it was first recognized as a living ecosystem to the present-day establishment of long-term studies of carbon, has led to the conclusion that soils are dynamic resources that must be nurtured. The research suggests that the synergistic effects of integrating methods, such as decreased tillage, different rotations, cover cropping, organic amendments and agroforestry, lead to increased soil carbon accumulation, more efficient nutrient cycling and improved farm resilience to weather extremes. Quantitatively, numerous studies find SOC improvements of tens of percent and considerable yield benefits for regeneration regimens. These results are mirrored in climate-smart agricultural paradigms that emphasize the “triple win” of sustainable production, adaptation and mitigation. But there are still obstacles. Implementation will need to be adapted to local circumstances and supported by education and incentives. Soil carbon increases are slow and must be carefully monitored. Economic and social variables, like initial investments or changes in the habits of farmers, have to be addressed. From a scientific viewpoint, additional long-term trials in different climates are required, as well as socio-economic analyses. To summarize, the synergy of carbon sequestration and soil health in regenerative agriculture is not only a theory, but a subject in which actual evidence is mounting. As climate regulations begin to acknowledge land-based sinks, regenerative soil management offers a promising avenue to ensure sure agriculture is part of the answer. Better soil health and carbon management leads to better food systems, more robust crops and a significant contribution to climate change mitigation. That history, from static ideas of nutrients to dynamic thinking about ecosystems, has now brought farmers and scientists together on this regenerative frontier.

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Table 3. Climate-Smart Agriculture Practices and Their Impacts [8, 21, 35, 45, 56, 74]

Practice / Technique	Impact on Mitigation / Carbon Sink	Impact on Adaptation / Resilience
Conservation Agriculture (no-till, crop residue retention)	↑SOC storage (~+0.1–0.3 Mg C/ha/yr); ↓ fuel use	↑Soil moisture; ↓ erosion; improves soil structure
Crop Rotation and Diversification (including legumes)	Modest ↑SOC from root diversity; ↓N fertilizer use (legumes)	Buffers pests/diseases; spreads risk; maintains fertility
Cover Cropping	↑SOC by ~10%; legumes fix N, reducing N_2O risk	Protects soil in fallow season; maintains cover for biota
Agroforestry / Silvopasture	Large ↑SOC (trees + shrubs store carbon in biomass and soil)	Shade/protection for crops and animals; diversified income
Improved Irrigation Efficiency (drip, scheduling)	↓Energy/CH_4 from flooded fields; better N usage	Sustains crops during drought; stabilizes yields
Integrated Soil Fertility Management (organic+mineral fertilizers)	Improved nutrient use, ↓N_2O emissions; builds SOC via organics	Maintains soil fertility; supports long-term productivity
Drought-Resistant/Quick-Growing Varieties	Indirect: stable yields may reduce land expansion	Provides yields under stress; shorter seasons avoid peak heat
System of Rice Intensification (SRI)	↓CH_4 emissions (intermittent flooding)	Lower water needs; higher yields on less water
Reduced Synthetic Fertilizer Use (precision N management)	↓N_2O emissions; ↑efficiency means less excess N	Reduces chemical runoff; improves soil microbiome balance
Integrated Pest Management (IPM)	↓GHG from pesticide production and use	Less crop loss; healthier soils from reduced chemicals
Contour Farming / Terraces	Minimal direct C effect	Prevents erosion on slopes; conserves rainwater
Rainwater Harvesting / Storage	Indirect (less need to expand irrigation)	Provides water in dry spells; reduces crop stress

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