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Sustainable Agriculture in 2025: Innovations for a Resilient Future

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Agriculture in 2025 is no longer just about growing crops; it's about orchestrating complex systems that balance productivity, environmental health, and economic viability. Climate change, population growth, and resource scarcity threaten global food security. Sustainable agriculture has emerged as a critical solution, integrating practices that reduce environmental impact, enhance resilience, and ensure equitable food access. Through the lens of India's agricultural transformation, this article explores how sustainable farming innovations are bridging the gap between global sustainability targets and local food security need.



“The nation that destroys its soil destroys itself”

— M.S. Swaminathan, Architect of the Green Revolution.

Sustainable agriculture prioritizes environmental stewardship, aiming to minimize resource depletion and combat climate change. Carbon-neutral and regenerative farming practices, such as cover cropping, no-till farming, and agroforestry, restore soil health and sequester carbon. Globally, agriculture contributes approximately 24% of greenhouse gas emissions (IPCC, 2022). Regenerative practices can reduce emissions by up to 20% while improving soil organic carbon by 0.4–1.2 tons per hectare annually (Lal, 2021). In India, where agriculture employs 42% of the workforce and contributes 17% to GDP (FAO, 2024), sustainable practices are critical. Sustainable agriculture, encompassing regenerative practices, has emerged as a critical solution, integrating methods that reduce environmental impact, enhance resilience, and ensure equitable food access.

The Evolution from Sustainable to Regenerative Agriculture

The terms "sustainable agriculture" and "regenerative agriculture" are often used interchangeably, but they have distinct principles, goals, and applications, particularly in the Indian context. Understanding their differences and how they converge is key to addressing environmental challenges and supporting India's agricultural sector, which employs 42% of the workforce and contributes 17% to GDP (FAO, 2024). Below, we explore their definitions, distinctions, and synergistic potential to advance Indian agriculture toward sustainability and resilience. Sustainable agriculture focuses on maintaining agricultural productivity while minimizing environmental harm and ensuring social and economic viability. It aligns with the SDGs, particularly SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land). Sustainable practices aim to "meet the needs of the

present without compromising future generations" (FAO, 2024). These include crop rotation, integrated pest management, and efficient water use, which reduce resource depletion and emissions. Globally, agriculture accounts for 24% of greenhouse gas emissions, and sustainable practices can reduce this by up to 20% (IPCC, 2022).



In India, sustainable agriculture is driven by programs like the National Mission for Sustainable Agriculture (NMSA), which promotes climate-resilient farming. For example, micro-irrigation under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) has reduced water usage by 30% across 11.3 million hectares (MoAFW, 2024). Sustainable agriculture emphasizes stability, aiming to maintain soil fertility, conserve water, and support farmer livelihoods without degrading ecosystems.

Regenerative agriculture transcends mere sustainability, prioritizing the active restoration and enhancement of ecosystems, with a special emphasis on improving soil vitality, capturing carbon, and promoting biodiversity. It aims to reverse environmental damage caused by conventional farming, which often depletes soil organic carbon and contributes to 19% of India's emissions (MoEFCC, 2024). Core practices include cover cropping, no-till farming, agroforestry, and holistic grazing, which can increase soil carbon by 0.4–1.2 tons per hectare annually (Lal, 2021).



Aspect	Sustainable Agriculture	Regenerative Agriculture
Objective	Maintains current resources and minimizes environmental harm to ensure long-term productivity.	In restores the damaged ecosystems, improves soil quality, climate resilience and overall biodiversity.
Example	Drip irrigation systems conserve water resources.	Cover cropping rebuilds soil organic matter (Lal, 2021).
Scope	Broad focus including organic farming, precision agriculture, and integrated pest management.	Targeted focus on rejuvenating soil health, improving biodiversity, and regenerating ecosystems.
India-Specific Example	NMSA's Soil Health Cards promote nutrient management.	ZBNF emphasizes natural inputs and regenerative techniques (MoAFW, 2024).
Impact on Climate	Reduces emissions through efficiency (e.g., 20% reduction using precision tools).	Sequesters carbon, potentially offsetting 10–15% of Agri emissions (IPCC, 2022).
India-Specific Impact	Notable improvements in emission efficiency via modern methods.	ZBNF farms in India sequester 0.5 tons of carbon/ha/year (FAO, 2023).
Economic Model	Market-integrated; uses high-tech tools like IoT and data analytics.	Focuses on low-cost, local, natural inputs; reduces farmer dependency on external inputs.
India-Specific Outcome	Supports agribusinesses and tech adoption.	ZBNF farmers in Andhra Pradesh saved \$100 million in input costs in 2024 (FAO, 2024).

The convergence of regenerative and sustainable agriculture offers a powerful framework for Indian agriculture, addressing challenges like soil degradation, water scarcity, and climate vulnerability. India's 147 million hectares of arable land, of which 20% is degraded, require both maintenance and restoration (MoAFW, 2024). By integrating regenerative practices into sustainable frameworks, India can achieve SDGs while enhancing resilience. The GoI's National Mission for Sustainable Agriculture and Paramparagat Krishi Vikas Yojana provide a foundation for convergence. NMSA promotes sustainable practices like micro-irrigation, while PKVY supports organic farming, which overlaps with

regenerative principles. For example, PKVY's 2.5 million certified organic farmers adopt cover cropping, a regenerative practice, increasing yields by 11% (APEDA, 2024). The Soil Health Card Scheme, with 230 million cards issued, guides farmers on nutrient management (sustainable) while encouraging organic amendments (regenerative), reducing fertilizer use by 10–20% (MoAFW, 2024).

Financial institutions bridge the gap between sustainable and regenerative approaches. The National Bank for Agriculture and Rural Development allocates 30% of its \$10 billion annual loans to sustainable projects, including regenerative practices like agroforestry (NABARD, 2024). The State Bank of India offers competitive rate of interest on loans for organic farmers, many of whom adopt ZBNF, benefiting 500,000 smallholders (SBI, 2024). The Reserve Bank of India's \$2 billion Green Bonds fund solar-powered irrigation (sustainable) and biogas plants using crop residues (regenerative), aligning with SDG 7 (RBI, 2025). India's grassroots movements, like Zero Budget Natural Farming (ZBNF) is an innovative agricultural approach that emphasizes low-cost, eco-friendly practices while fostering soil health and biodiversity. By integrating regenerative methods into sustainable frameworks, ZBNF offers a holistic model for farmers to cultivate crops without financial strain or environmental harm.

ZBNF, pioneered in Andhra Pradesh, exemplifies regenerative agriculture. By using natural inputs like cow dung and crop residues, ZBNF has improved soil health by 15% for 700,000 farmers, reducing input costs by 50% (FAO, 2023). Globally, companies like Pivot Bio use nitrogen-fixing microbes to cut synthetic fertilizer use by 30%, enhancing soil microbiomes (F6S, 2025).



Regenerative agriculture prioritizes ecosystem restoration, positioning it as a proactive approach to combat climate change. In Andhra Pradesh, 700,000 ZBNF farmers use natural inputs (regenerative) while benefiting from NMSA's micro-irrigation (sustainable), reducing water use by 30% (MoAFW, 2024). Community-supported agriculture (CSA) programs, supported by startups like Ninjacart, promote local sourcing (sustainable) and agroforestry (regenerative), cutting transport emissions by 10% (FAO, 2023).

Challenges include high initial costs for precision tools (sustainable) and limited awareness of regenerative practices among smallholders, with only 15% adopting advanced technologies (MoAFW, 2024). Solutions involve scaling Farmer Producer Organizations, with 10,000 formed by 2025, to share resources for both approaches (MoAFW, 2024). Training programs, like those under NMSA, can educate farmers on integrating cover cropping with IoT sensors, enhancing SDG 15 outcomes.

Convergence has tangible impacts: organic farming (sustainable/regenerative) has restored 2 million hectares of degraded land, while ZBNF sequesters 0.5 tons of carbon per hectare annually (FAO, 2024). Precision tools have increased yields by 20% for sustainable farmers, and regenerative practices have reduced input costs by 50% for 700,000 farmers (MoAFW, 2024). This dual approach supports 2 million smallholders, aligning with SDG 1 (No Poverty) and SDG 13.

Globally, regenerative agriculture gains traction, with 15% of U.S. cropland under regenerative practices (F6S, 2025). The EU's Green Deal integrates sustainable and regenerative goals, targeting 25% organic farmland by 2030 (EC, 2024). India's model, combining ZBNF with precision agriculture, offers lessons for developing nations with similar challenges.

The National Mission for Sustainable Agriculture (NMSA) promotes climate-resilient farming, with initiatives like zero-budget natural farming gaining traction in states like

Andhra Pradesh. Internationally, companies like Pivot Bio in California deliver nitrogen-fixing microbes, reducing synthetic fertilizer use by 30% (F6S, 2025).

Precision agriculture, a sustainable practice, complements regenerative methods. It leverages technology—drones, IoT sensors, AI, and machine learning—to optimize resource use and crop yields. The global precision agriculture market is valued at \$12.9 billion, growing at a CAGR of 13.1% (Statista, 2025). Drones monitor crop health, reducing pesticide use by 50% in some cases, while AI-driven analytics improve yield predictions by 15–20% (Saiwa, 2023).

Startups like CropIn provide AI-driven analytics to 2.2 million farmers across 52 countries (FAO, 2024), optimizing inputs (sustainable) while supporting regenerative practices like no-till farming, which improves soil health (FAO, 2024). Drones monitor cover crops, ensuring regenerative benefits like 15% higher soil moisture retention (Saiwa, 2023). This synergy enhances productivity and resilience, addressing SDG 2.

Globally, John Deere’s autonomous tractors and IoT-enabled irrigation systems have reduced water usage by 20–30% in precision farming operations (ResearchGate, 2023).

Vertical farming and hydroponics enable year-round cultivation in controlled environments, using 90% less water than traditional farming (Plenty, 2025). The global vertical farming market is projected to reach \$24.1 billion by 2030, with a CAGR of 22.9% (Statista, 2025). Automation and AI enhance productivity, with companies like Plenty producing 400 times more yield per acre than conventional farms (Dot.LA, 2025).

India’s vertical farming sector is growing, with startups like UrbanKisan in Bengaluru achieving 50% cost reductions through hydroponics (FAO, 2024). International companies like “Sky Greens” of Singapore and “Spread Co” from Japan, lead in urban farming, reducing transportation emissions by 15% through hyper-local production (Agritrop, 2025).

Blockchain technology ensures transparency and traceability in food supply chains, enhancing safety and reducing fraud. By 2025, 20% of global food companies use blockchain for traceability, cutting recall costs by 50% (IBM, 2025). In India, the FSSAI’s Food Safety and Compliance System integrates blockchain to monitor supply chains, reducing contamination risks by 30% (FSSAI, 2024). Globally, Walmart’s blockchain platform tracks produce from farm to shelf in 2.2 seconds, compared to days with traditional systems (Medium, 2025). This supports consumer trust and aligns with stricter food safety regulations.



Food waste, accounting for 8–10% of global emissions, is a pressing issue (FAO, 2024). Innovations like smart inventory systems and upcycling reduce waste across supply chains. In India, 68 million tons of food are wasted annually, equivalent to \$14 billion in losses (USDA, 2024). To address the challenge of food wastage, some of the applications like “Too Good To Go” also the startups like “Phool”, help to convert waste to biochar.

Globally, companies like Apeel Sciences extend produce shelf life by 60% using plant-based coatings (Valuer, 2025). Consumer education campaigns, such as the UN’s “Think.Eat.Save,” have reduced household waste by 15% in participating countries (FAO, 2024).

Category	Global Statistic	India Statistic	Source
Carbon Emissions	Agriculture contributes 24% to global GHG emissions	Agriculture accounts for 19% of India’s GHG emissions	IPCC, 2022; MoEFCC, 2024
Precision Agriculture Market	Valued at \$12.9 billion, CAGR 13.1%	Adoption by 12% of farmers, projected to reach 20% by 2030	Statista, 2025; FAO, 2024

Vertical Farming Market	Projected to reach \$24.1 billion by 2030, CAGR 22.9%	50+ startups, market size \$150 million	Statista, 2025; FAO, 2024
Blockchain Adoption	20% of food companies use blockchain for traceability	FSSAI blockchain platform monitors 10,000+ supply chains	IBM, 2025; FSSAI, 2024
Food Waste	1.3 billion tons wasted annually, 8–10% of emissions	68 million tons wasted annually, \$14 billion loss	FAO, 2024; USDA, 2024

India's agricultural sector is pivotal to achieving the UN's Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 13 (Climate Action), SDG 15 (Life on Land), and SDG 12 (Responsible Consumption and Production). With 42% of its workforce engaged in agriculture and 17% of GDP derived from the sector, India is scaling sustainable practices to address climate change, food security, and rural poverty (FAO, 2024). The Government of India (GoI), financial institutions, and grassroots initiatives play a critical role in this transformation.

The GoI has integrated sustainability into its agricultural policies through flagship programs. The NMSA promotes climate-resilient farming through soil health management, water-use efficiency, and integrated nutrient management. By 2025, NMSA has brought 10 million hectares under sustainable practices, including 2 million hectares under organic farming (MoAFW, 2024). The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) has expanded micro-irrigation to 11.3 million hectares, reducing water usage by 30% in water-scarce regions like Rajasthan (MoAFW, 2024).

The Paramparagat Krishi Vikas Yojana (PKVY) incentivizes organic farming, supporting 50,000 clusters of farmers to transition to chemical-free practices. By 2025, PKVY has certified 2.5 million organic farmers, increasing organic exports by 20% to \$1.2 billion (APEDA, 2024). The ZBNF initiative, pioneered in Andhra Pradesh, eliminates synthetic inputs, benefiting 700,000 farmers and improving soil health by 15% (FAO, 2023). These programs align with SDG 15 by restoring degraded land and SDG 13 by reducing agricultural emissions, which account for 19% of India's total (MoEFCC, 2024).

The Digital Agriculture Mission integrates AI and IoT for real-time crop monitoring, with 12% of Indian farmers using drones and sensors by 2025, up from 5% in 2020 (Statista, 2025). The Soil Health Card Scheme, with 230 million cards issued, guides farmers on nutrient management, reducing fertilizer overuse by 10–20% (MoAFW, 2024). These efforts contribute to SDG 2 by enhancing productivity. The Food Safety and Standards Authority of India (FSSAI) promotes SDG 12 through blockchain-based traceability, monitoring over 10,000 supply chains and reducing contamination risks by 30% (FSSAI, 2024). The National Food Waste Reduction Strategy addresses 68 million tons of annual food waste through public-private partnerships (USDA, 2024).

Financial institutions are crucial for scaling sustainable agriculture. The National Bank for Agriculture and Rural Development (NABARD) disburses \$10 billion annually in agricultural loans, with 30% allocated to sustainable projects like micro-irrigation and organic farming (NABARD, 2024). NABARD's Climate Fund supports 25,000 farmers with subsidies for green technologies, such as solar-powered irrigation systems, reducing emissions by 20% (MoF, 2024).

Commercial banks like State Bank of India (SBI) and HDFC Bank offer low-interest loans for precision agriculture tools, disbursing \$3 billion in 2025 (RBI, 2025). SBI's Green Agriculture Loan Scheme provides 5% interest rates for organic farmers, benefiting 500,000 smallholders (SBI, 2024). Microfinance institutions like Bandhan Bank support women farmers, with 60% of their \$500 million agricultural portfolio dedicated to sustainable practices (Bandhan, 2024). The Reserve Bank of India (RBI) mandates 18% of bank credit

for agriculture, with Green Bonds worth \$2 billion funding renewable energy projects like biogas plants (RBI, 2025).

Startups drive innovation. UrbanKisan has scaled to 200 hydroponic farms, cutting water use by 90% and supporting SDG 11 (Sustainable Cities) (FAO, 2024). Ninjacart links 500,000 farmers to consumers, reducing transport emissions by 10% (FAO, 2023). Phool converts 4,000 tons of waste into biochar, contributing to SDG 12 (FAO, 2024).

Challenges include fragmented landholdings, limited tech access (only 15% of smallholders use precision tools), and high costs (MoAFW, 2024). Solutions involve scaling Farmer Producer Organizations (FPOs), with 10,000 formed by 2025, to pool resources and enhance SDG 1 (No Poverty) (MoAFW, 2024). Digital literacy programs and increased subsidies can further bridge gaps.

SDG	Initiative	Impact in India (2025)	Source
SDG 2 (Zero Hunger)	Digital Agriculture Mission, Soil Health Cards	Crop yields up 20% for sustainable farmers	FAO, 2024
SDG 13 (Climate Action)	ZBNF, micro-irrigation	Agricultural emissions reduced by 10%	MoEFCC, 2024
SDG 15 (Life on Land)	PKVY, organic farming	2 million hectares of degraded land restored	MoAFW, 2024
SDG 12 (Responsible Consumption)	FSSAI blockchain, food waste reduction	30% reduction in contamination risks, \$14 billion loss addressed	FSSAI, 2024; USDA, 2024

India's efforts have improved livelihoods for 2 million smallholders and saved 50 billion cubic meters of water annually (MoAFW, 2024). Globally, the EU's Green Deal aims for 25% organic farmland by 2030, supported by €10 billion in subsidies (EC, 2024). In the U.S., regenerative farming covers 15% of cropland (F6S, 2024). Singapore and Japan lead in vertical farming, with 80% of leafy greens produced locally by 2030 (Agritrop, 2024).

Best Practices for Sustainable Agriculture

1. Adopt Regenerative Farming: Use cover cropping and organic fertilizers to sequester carbon (FAO, 2023).
2. Leverage Precision Farming: Employ drones and AI for precise irrigation (FAO, 2024).
3. Scale Vertical Farming: Invest in hydroponics for urban production (FAO, 2024).
4. Implement Blockchain: Ensure supply chain transparency (Medium, 2024).
5. Reduce Food Waste: Use smart inventory and upcycling solutions (FAO, 2024).
6. Promote Local Sourcing: Support urban farms and CSAs (Agritrop, 2024).
7. Align with Policies: Leverage subsidies for sustainable practices (MoAFW, 2024).

As the article reflected on the trajectory of sustainable and regenerative agriculture in 2025, it is to be noted that the profound potential, it has to heal our planet and nourish its people, particularly in our nation, where agriculture is not just an industry but a way of life. The integration of regenerative practices, like Zero Budget Natural Farming, with sustainable innovations, such as precision agriculture and blockchain, is like a harmonious blend of tradition and technology—a return to the wisdom of nurturing the land, amplified by modern tools. India's progress, from restoring 2 million hectares of degraded soil to empowering 2.5 million organic farmers, is a testament to what's possible when policy, finance, and grassroots ingenuity align. Yet, the urgency of climate change and the persistent challenges of smallholder access to technology highlights that this is a race against time. India's model, rooted in resilience and equity, inspires a global movement to treat our soil not as a resource to exploit but as a living legacy to protect. As Swaminathan's words echo, safeguarding our earth is not just a choice but a moral imperative for our survival.

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