

Combining Sustainability with Modern Agricultural Technology to Address Climatic Change

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OPEN ACCESS

Keywords

Agriculture, Climate Change, Sustainability

How to cite this article:

Jandyal, M. and Kaur, A. 2025. Combining Sustainability with Modern Agricultural Technology to Address Climatic Change. *Vigyan Varta* 6 (9): 196-200.

ABSTRACT

As climatic disruption intensifies, manifesting itself in the form of erratic rainfall, land degradation, and water stress, traditional farming systems are under severe strain. Through this paper, we can reimagine an alternative ending through inclusive agricultural growth, where the future lies in technological empowerment, environmental sustainability and social equity. From AI-driven crop advisories and solar powered irrigation systems to precision farming and biotechnology, modern tools hold the potential to ease labour, optimise inputs, and restore harmony between cultivation and climate. Yet, technology alone is not enough, it must be accessible, affordable, and tailored to the needs of those who till the smallest plot. This article highlights how blending sustainability with modern agricultural innovations can guide Indian farmers towards resilience and long-term food security.

INTRODUCTION

For generations, farmers have lived by the rhythm of the earth, planting when the rains arrived, harvesting when the

sun was just right while trusting nature to provide the required nutrients. It is a quiet partnership, built on patience, hard work, and

hope. But now, the rhythm is breaking. The rains come late or not at all. The sun scorches instead of nurturing. The soil, once rich and forgiving, is growing thin. For millions of small farmers, these changes aren't predictions, they are lived, felt and endured season after season.

Climate change has become the greatest challenge to food security and rural livelihoods in the 21st century. Rising temperatures, erratic monsoons, prolonged droughts, and frequent floods are pushing traditional farming practices to the brink. Agriculture, which itself contributes nearly a quarter of global greenhouse gas emissions, is caught in a paradox—it is both a victim of climate change and a key contributor to it. The question, therefore, is not whether agriculture should change, but how it can transform into a resilient, sustainable system that feeds billions without exhausting the planet.

This is where the convergence of sustainability and modern agricultural technology offers hope. From precision farming that uses satellite data to optimize use of water and fertilizers, to climate-smart crops bred for heat and drought resistance, to renewable-energy-powered irrigation systems and digital platforms connecting farmers to real-time weather forecasts—the future of farming is being rewritten. These innovations not only reduce the carbon footprint of agriculture but also empower farmers, especially smallholders, to adapt and thrive amidst uncertainty.

But technology alone cannot be the answer. True transformation requires balancing innovation with ecological wisdom—restoring soil health through organic matter, protecting biodiversity, reducing food waste, and ensuring that advances are accessible and affordable to those who need them most. When sustainability and technology move

hand in hand, farming can once again align with nature's rhythm, this time with resilience against climate extremes.

Understanding the dual challenge:

Despite its flair, the acceptance of modern technology in agriculture faces deep rooted challenges that go beyond the infrastructure and touch the very lives, habits and in some cases, culture of the farmers. A study on commercialisation of agricultural technologies in India found that while small and medium scale farmers exhibited generally positive perceptions toward adopting new technologies, the actual adoption rates remained significantly low (Johnpaul, 2024) The low adoption rate can be linked to the strain of financial burdens, given the high cost of entry and investments in AI-based tools and precision equipment.

Awareness, digital literacy, along with adaptability also play an important role. Many farmers remain unaware of the technologies available. Moreover, technologies built in labs for large-scale farms do not always align with the needs of small-scale farm holders.

Understanding these aspects is important because unless the upcoming advancements meet the farmers ensuring both profitability and comfort and the above-mentioned problems are dealt with, it will remain out of reach of the farmers it is meant to empower.

Precision farming:

Precision farming is an advanced agriculture approach which uses modern technologies like Global Positioning System, sensors, and data analytics, to optimize field-level handling of crops. A study finds that Hungarian farmers who adopt precision farming view it primarily as a means of achieving more precise planning and cost saving (Balogh *et al.*, 2020).

Mobile sensors and related technology:

Mobile sensors are quickly becoming the most sought-after tools, helping farmers make smarter and faster decisions in the fields. These technologies provide farmers with up-to-date information on things like soil quality, crop health, pest outbreaks and most importantly changing climate. This timely data ensures quick response and efficiency even to the smallest task.

A prominent example is Krishi™, a mobile-based agro-advisory platform developed by Tata Consultancy Services. It allows farmers to ask questions using voice, text, or images in their local language. It provides real-time, location-specific advice on issues like pests, irrigation, and fertilisation and this, helps farmers respond quickly to problems and use their resources more effectively, especially in rural areas (Tata Consultancy Services, 2010).

Carbon farming:

Carbon farming, or carbon sequestration, is an agricultural practice designed to increase the land's capacity to store carbon while reducing greenhouse gas emissions released into the atmosphere. For instance, farmers in India can manage grazing lands in ways that protect and regenerate vegetation, such as maintaining tree cover along riverbanks and waterways. One of the initiatives, Boomitra's Carbon Farming project, works with small farmers to improve soil health and increase carbon sequestration through sustainable practises like residue management and enhanced cropping. The initiative spans over 200,00 acres, aiming to restore soil, boost productivity, and generate carbon credits for farmers (Boomitra, n.d.).

Organic farming with data-driven nutrient management:

Data-driven nutrient management in organic farming uses modern technology to help

farmers apply the needed amount of nutrients at the appropriate time, just like nature intended. By using tools like soil sensors and satellite images, farmers can get live insights into soil health, nutrient levels, and crop needs. This allows them to use resources more efficiently, reduce waste, and minimise harm to the environment, all while boosting crop yields and keeping the soil healthy for the long term.

A study in Udaipur, India examined how different organic nutrient management strategies and sowing methods affect wheat productivity and soil health in organic farming systems. It showed that using organic fertilisers like Jeevamrut, Panchagavya, and Farmyard Manure improves soil quality and increased wheat yields (Sai *et al.*, 2024).

Policies and schemes by the government:

In 2021, the Ministry of Agriculture and Farmers' Welfare (MoA&FW) released a consultation paper on the India Digital Ecosystem of Agriculture (IDEA), highlighting a vision for a digital transformation in the agricultural sector and outlining the following initiatives such as the Digital Agriculture Mission, Unified Farmer Service Platform (UFSP), and the NAMO Drone Didi Scheme (Ministry of Agriculture & Farmers' Welfare, 2021).

Digital Agriculture Mission:

It is an umbrella initiative built on the framework of Digital Public Infrastructure (DPI), designed to leverage technology for improving farmers' livelihoods. Launched for the period 2021–2025, the scheme focuses on projects that incorporate emerging technologies such as artificial intelligence, blockchain, remote sensing, Geographic Information System (GIS), as well as the use of drones and robotics.

Unified farmer service platform (UFSP):

The Unified Farmer Service Platform (UFSP) integrates core infrastructure, data, applications, and tools to ensure smooth interoperability between diverse public and private IT systems within the agricultural ecosystem across India. It ensures a single digital window that brings together all farmer-related services under one roof. Think of it as a “one-stop shop” for farmers, where they can easily access everything they need without confusion. In simple terms, UFSP is like a digital bridge between farmers and the government. Instead of dealing with scattered departments and paperwork, farmers get a unified, transparent, and faster service system.

NAMO Drone Didi Scheme:

The NAMO (New Agriculture Market Order) Drone Didi Scheme provides specialized training in drone technology, equipping women with vital skills for modern farming. By nurturing a strong drone ecosystem, the initiative aims to strengthen women’s participation in agriculture while advancing the sector’s digitization. The scheme has a simple but powerful idea: train women Self-Help Groups (SHGs) to operate drones for farming purposes. These “Drone Didis” will not only bring efficiency and precision to agriculture but will also become role models in their communities.

Other Digital Initiatives: Kisan Call Centres, Kisan Suvidha App, Agri-Market App, Soil Health Card (SHC) Portal etc.

Future outlook:

Carbon credit:

The central concept is that organizations emitting CO₂ must either lower their own emissions or compensate farmers and others who contribute to removing CO₂ from the

atmosphere. Each credit represents one metric ton of carbon reduced or removed (Press Information Bureau, 2024).

The Ministry of Agriculture & Farmers’ Welfare has established a framework to promote the Voluntary Carbon Market (VCM) in India’s agricultural sector, aimed at enabling small and marginal farmers to benefit from carbon credits. The length of time carbon stays in the soil before going back to the air varies. For example, disrupting the soil structure, like converting forestland or grassland to farmland, can speed up the release of the captured carbon. On the other hand, carbon farming methods like no-till farming and planting cover crops can slow down carbon loss.

Traditional methods with new tools:

Traditional knowledge also plays an important role. Studies emphasise that combining indigenous farming techniques with contemporary technologies can lead to sustainable agriculture, especially in the face of climate change and socio-economic challenges (Kumar *et al.*, 2024; Sharma & Patel, 2023).

Natural farming in Andhra Pradesh:

In Guntur, India, farmers are embracing natural farming practices that rely on organic inputs like cow urine, dung, jaggery, pulse flour, and fermented plant extracts to nourish their crops and protect them from pests. These practices, rooted in traditional knowledge, have improved soil water retention and crop resilience against extreme weather events. One of the most popular approaches, the Andhra Pradesh Community Managed Natural Farming (APCNF) program, has been supported by the state government and adopted by thousands of farmers (Sainath, 2023).

Its philosophy is simple: farming should work with nature, not against it. By reviving soil

health, enhancing biodiversity, and reducing dependence on costly external inputs, natural farming not only cuts production costs but also improves food safety and farmers' incomes. Similar outcomes have been highlighted in broader studies, which show blending indigenous practises with sustainable innovations strengthens resilience to climate change and reduces the environmental burden of agriculture (Kumar *et al.*, 2024; Singh *et al.*, 2020)..

CONCLUSION:

India stands at a crossroad where the future of the agriculture industry must be reimagined as the preservation of a clean environment and healthy climate for the future generation lies in our hands. Inclusive agricultural growth is not only an economic necessity but a moral imperative. It means that the smallest farmer must have the same support, knowledge as that available to larger stakeholders. For that to be brought into reality needs a collective action where all the stakeholders show their support so that we step into a future where innovations grow from the soil up, and every harvest is a step towards dignity, equity, and resilience.

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