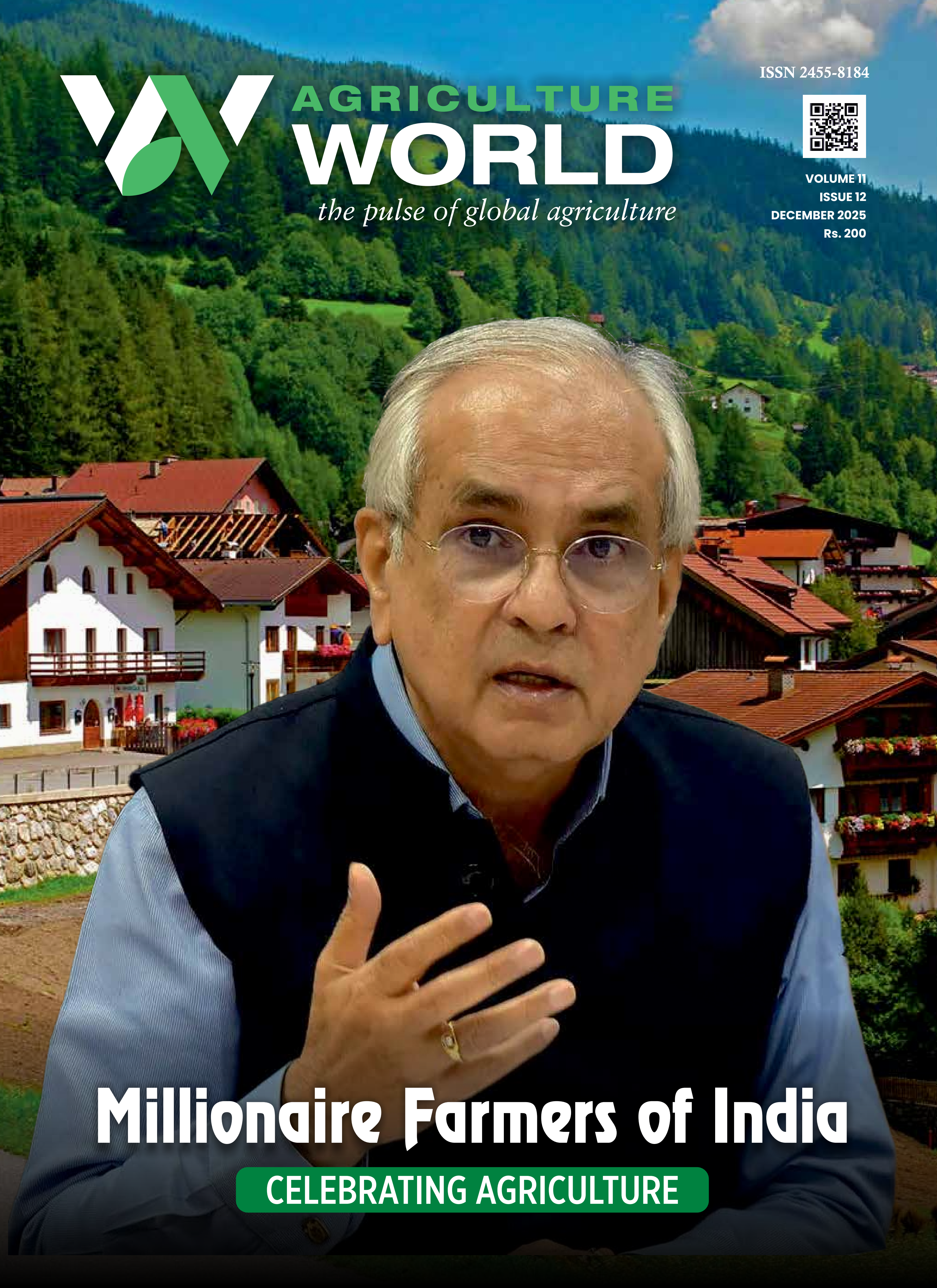

AGRICULTURE WORLD

the pulse of global agriculture

ISSN 2455-8184

VOLUME 11
ISSUE 12
DECEMBER 2025
Rs. 200

Millionaire Farmers of India

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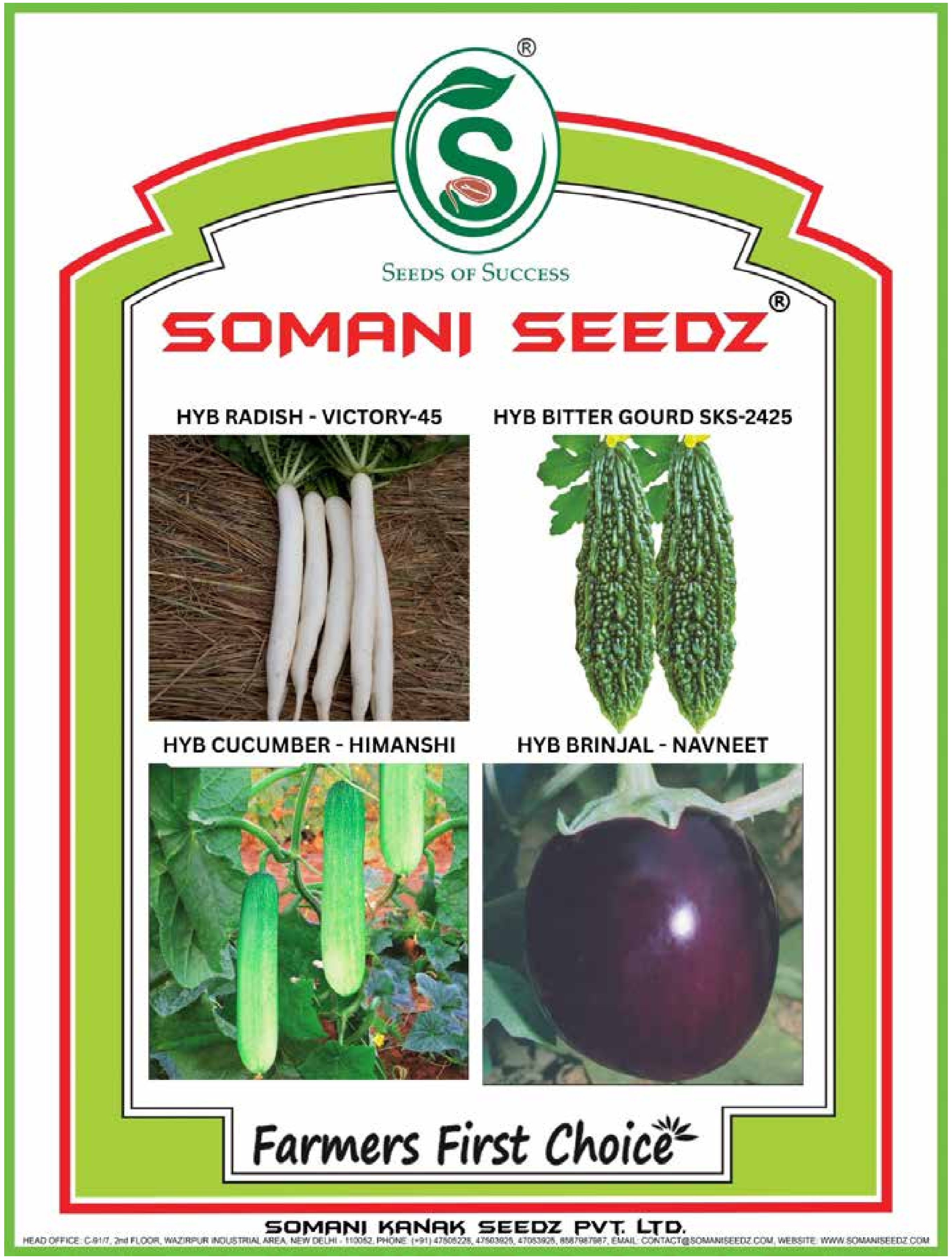
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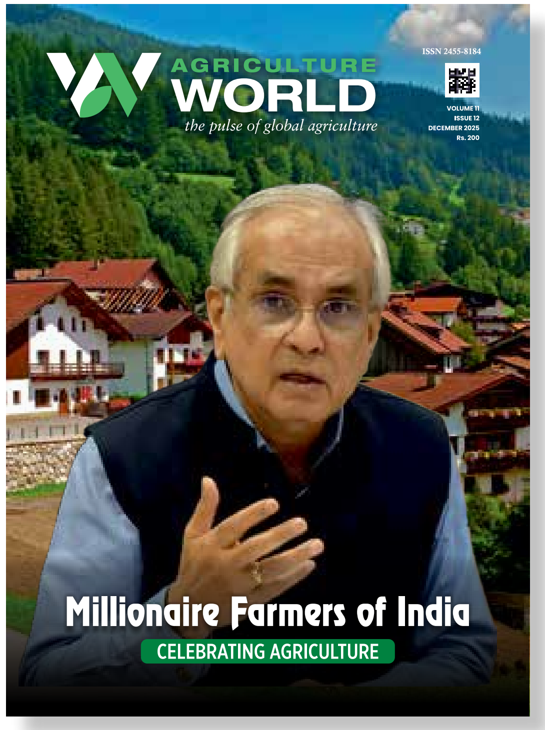

Founder & Editor-in-Chief	MC Dominic
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Circulation	Abdus Samad
Sr. Graphic Designer	Anish Ahmed

Printed and Published by :
MC Dominic
60/9, 3rd Floor, Yusuf Sarai Market, Near Green Park Metro Station, New Delhi-110016

Printed at :
Pushpak Press Pvt. Ltd.
Shed No. 203, 204, DSIDC Complex Indl. Area, Okhla Phase-I, New Delhi-110020

CONTENT

THE VISION

M C Dominic
Founder & Editor-in-Chief

Renewable Energy - A Game-Changer For Indian Agriculture

India's agricultural sector, a cornerstone of its economy, is on the cusp of a transformative revolution through the adoption of renewable energy. Renewable energy sources, such as solar, wind, and biomass, promise to address some of the most persistent challenges faced by Indian farmers, from erratic power supply to escalating fuel costs, while fostering sustainable agricultural practices.

The integration of solar energy, in particular, is poised to be a game changer. Solar-powered irrigation systems are reducing dependence on diesel and grid electricity, offering a reliable and cost-effective solution for farmers. These systems not only lower operational costs but also enhance productivity by ensuring timely and adequate water supply. The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme aims to install solar pumps and grid-connected solar power plants, reflecting a strong governmental push towards this transition.

Wind energy, though less prevalent in the agricultural context, holds significant potential, especially in regions with favorable wind conditions. Small-scale wind turbines can complement solar power, providing a consistent energy supply that is crucial for operations like milling, drying, and cold storage, which are essential for value addition and reducing post-harvest losses.

Biomass energy, derived from agricultural waste, presents another opportunity. Converting crop residues into biogas or biofuels can mitigate the pollution caused by stubble burning. This not only provides a cleaner energy source but also adds an income stream for farmers through the sale of biomass.

The shift to renewable energy in agriculture is more than just an economic necessity; it is a path to sustainability. It aligns with India's commitments to reducing carbon emissions and combating climate change.

By embracing renewable energy, Indian agriculture can achieve higher resilience, improved livelihoods for farmers, and a sustainable future. This energy transformation is not merely an option; it is an imperative for the prosperity of India's agricultural sector and the overall well-being of its rural communities.

Millionaire Farmers of India

Gateway to Rural India's Prosperity

India's agricultural landscape is witnessing a remarkable transformation with the emergence of millionaire farmers, heralding a new era of prosperity in rural areas. These successful farmers, who have leveraged modern techniques, innovative practices, and strategic market linkages, are not only elevating their own economic status but also serving as beacons of hope and inspiration for their communities.

The success stories of "Krishi Jagran Millionaire Farmers of India" are rooted in diversification and value addition. By moving beyond traditional crops and embracing high-value produce like exotic vegetables, fruits, organic products, and floriculture, these farmers have tapped into lucrative markets both domestically and internationally.

Technological adoption has been a critical factor in this transformation. Precision farming, use of advanced machinery, drip irrigation, and greenhouse farming have significantly enhanced productivity and efficiency. Access to real-time market information and direct-to-consumer platforms through digital technology has enabled these farmers to fetch better prices, bypassing intermediaries and reducing losses.

Government policies and schemes have played a supportive role. Initiatives like the Pradhan Mantri Fasal Bima Yojana (PMFBY) and the Kisan Credit Card (KCC) scheme provide financial security and credit access, empowering farmers to invest in modern agricultural practices. The establishment of Farmer Producer Organizations (FPOs) has also fostered collective bargaining and improved market access.

The ripple effects of millionaire farmers' success extend beyond individual prosperity. They create employment opportunities, stimulate local economies, and inspire neighboring farmers to adopt progressive methods. Moreover, their success underscores the potential of agriculture as a viable and lucrative career, especially for the younger generation.

As millionaire farmers continue to pave the way for rural prosperity, their journey highlights the importance of innovation, education, and supportive policies in transforming the agricultural sector. Their success is not just a personal achievement but a testament to the potential of rural India to thrive and contribute significantly to the nation's economic growth.

"Krishi Jagran Millionaire Farmers of India" showcases the transformative journeys of India's most successful farmers. These visionary agriculturists have harnessed advanced techniques, innovative practices, and strategic market connections to achieve unprecedented prosperity.

Their stories not only highlight the potential of modern agriculture but also inspire countless others in rural communities. By embracing technology, diversification, and sustainable practices, these millionaire farmers exemplify how agriculture can be a lucrative and empowering career.

Their achievements underscore the crucial role of progressive farming in driving rural economic growth and shaping a prosperous future for India's agrarian landscape.

Shiny Dominic
Managing Director

A New Paradigm for Growth

In today's rapidly evolving world, the demand for Energy is escalating every day. Agriculture is no different! Adopting renewable energy sources not only contributes to a greener environment but also has a positive impact on the economics of farming. By harnessing the potential of solar panels, wind turbines, or biofuel production, farmers can decrease their reliance on expensive conventional options and lower operational costs.

Renewable energy sources such as solar, wind, and biomass, farmers can reduce their dependence on fossil fuels and mitigate greenhouse gas emissions. Solar panels can be installed on farm buildings or integrated into crop canopies to generate electricity, while wind turbines can be strategically placed in open fields to capture wind energy. Additionally, biomass resources such as agricultural residues and organic waste can be utilized to produce biofuels or biogas for on-farm energy production.

Furthermore, renewable energy deployment in agriculture opens up new avenues for income generation and economic growth in rural communities. Farmers can participate in energy markets by selling surplus electricity generated from renewable sources, thereby diversifying their revenue streams and enhancing financial stability. Renewable energy sources, such as solar, wind, and biofuels, offer numerous benefits to private farm operations and large-scale commercial agriculture. Our Farmers are embracing renewable energy as a pathway to a sustainable and economically viable future.

Renewable Energy: A New Paradigm for Growth in Agriculture presents a transformative vision for agricultural sustainability by integrating renewable energy technologies into farming practices. This paradigm shift not only addresses the pressing need for clean energy but also offers multifaceted benefits for agricultural productivity, environmental conservation, and rural development.

The adoption of renewable energy technologies in agriculture fosters resilience against climate change impacts by diversifying energy sources and reducing vulnerability to energy price fluctuations. Moreover, it promotes energy independence and self-sufficiency, empowering farmers to become net energy producers and contribute to the decentralization of energy systems.

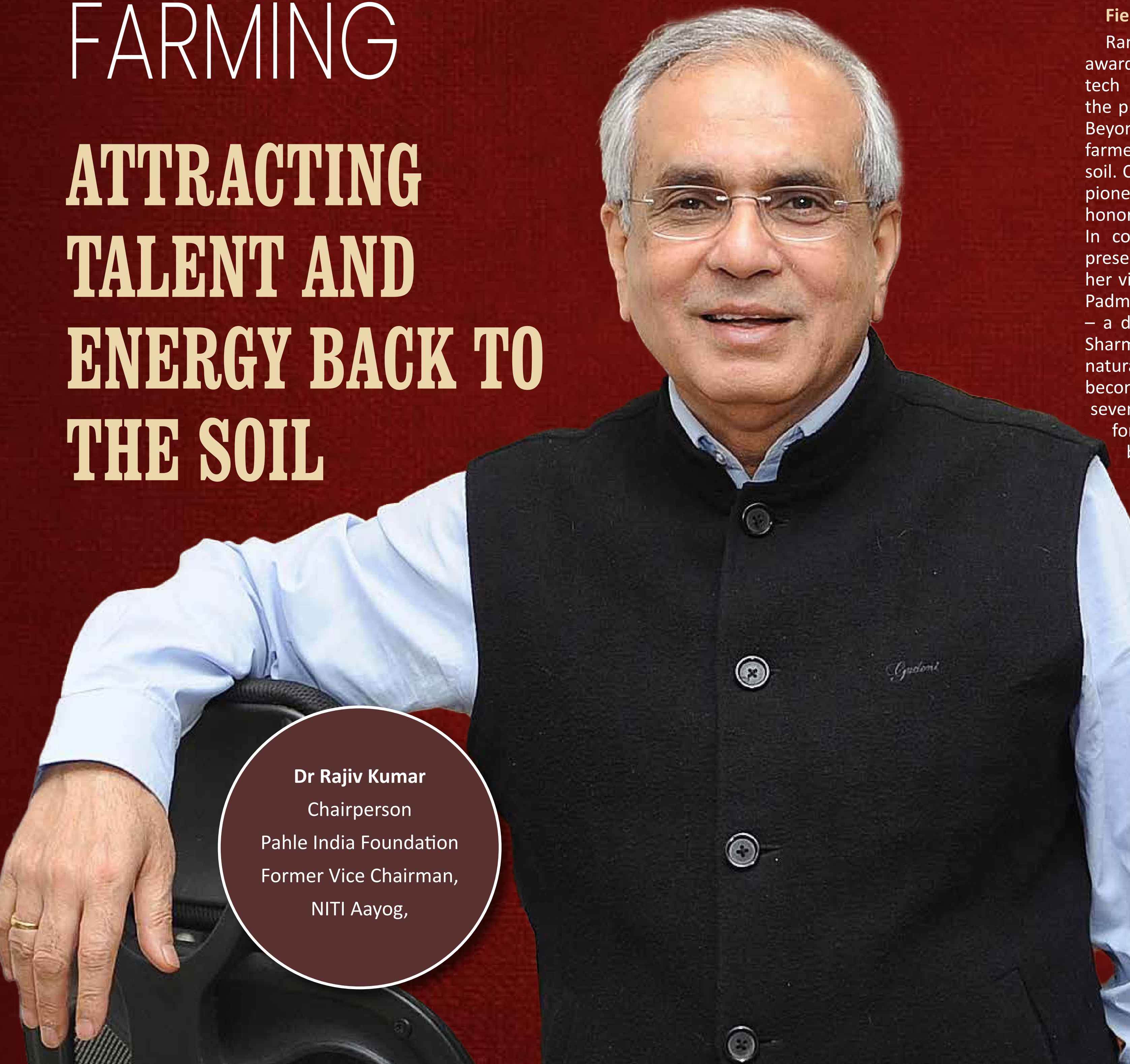
The synergy between renewable energy and agriculture extends beyond energy production to encompass sustainable land management practices and environmental stewardship. Agroecological principles can be integrated with renewable energy projects to promote soil health, biodiversity conservation, and water resource management. For instance, agroforestry systems combining tree planting with solar energy installations can enhance carbon sequestration, improve microclimate regulation, and provide additional sources of income for farmers.

In conclusion, "Renewable Energy: A New Paradigm for Growth in Agriculture" advocates for a holistic approach to agricultural development that leverages renewable energy as a catalyst for innovation, resilience, and prosperity. By embracing this new paradigm, stakeholders across the agricultural value chain can collectively contribute to building a sustainable future for agriculture, energy, and the environment.

Mamta Jain
Group Editor & CEO

REBRANDING THE STORY OF INDIAN FARMING

ATTRACTING TALENT AND ENERGY BACK TO THE SOIL



Dr Rajiv Kumar
Chairperson
Pahle India Foundation
Former Vice Chairman,
NITI Aayog,

The narrative of relentless tragedy and poverty in Indian agriculture, perhaps rooted in real challenges, is only half the truth. The other half is growing quietly in our fields, where farmers are defying stereotypes and achieving astonishing successes. It's time we tell their stories. People need to focus on the positive side of agriculture because those positives are transformative. Spreading the positive narrative about our agriculture may not only save the future of Indian farming but could usher in a new era of sustainable and equitable economic growth.

Fields of Success: From Distress to Distinction

Ram Saran Verma of Uttar Pradesh, a Padma Shri awardee, turned his 5-acre farm into 200 acres of high-tech banana and tomato cultivation – exemplifying the prosperity possible in modern Indian agriculture. Beyond the headlines of droughts and debt are farmers who have rewritten what is possible on Indian soil. Consider Hukumchand Patidar of Rajasthan, who pioneered organic farming in the desert and was honored with a Padma Shri in 2018 for his innovations. In coastal Odisha, Kamala Pujari, a tribal farmer, preserved 100+ indigenous varieties of rice and led her village's shift to organic methods – earning her a Padma Shri in 2019. And in Maharashtra's Yavatmal – a district infamous for farmer suicides – Subhash Sharma turned away from chemicals to embrace natural farming, boosting his yields eightfold and becoming a beacon of hope. This year, while in his seventies, Sharma was recognized with a Padma Shri for showing that harmony with nature can bring both ecological and economic well-being. These are not isolated miracles; they are part of a growing class of agrarian achievers who have been there all along, largely ignored by the mainstream narrative.

The tide is turning, albeit slowly. Only recently have we started celebrating such success stories in agriculture. In 2023, agriculture media group Krishi Jagran launched the "Millionaire Farmers of India" (MFOI) Awards, a platform explicitly designed to honor prosperous farmers. In its last edition, the awards drew 22,000 applicants and recognized 1,400 of India's most innovative and profitable farmers. The very idea sprang from a provocative question – "Who is the richest Indian farmer?" – a question that uncovered "an untold narrative of resilience, determination, and triumph amidst adversity". The answers were illuminating. Take Nituben Patel of Gujarat, for example: crowned the "Richest Farmer of India" in 2024, this visionary woman runs a natural farming enterprise with an annual turnover in crores. Or Yuvraj Parihar of Uttar Pradesh, a young 'agripreneur' who uses technology for eco-friendly potato farming, winning international accolades and earning crores in the process. Such profiles show that with "clever methods, creativity, and commercial savvy," farming can surely be a lucrative business.

Youth at the Crossroads: Why Farming Loses the Young

If these success stories are so inspiring, why are rural youth still turning away from agriculture? Many farm children have watched their parents toil from predawn to dusk, often for meager returns, and decided to seek a different path. In village after village, one hears of sons and daughters opting to become security guards, clerks, delivery boys, anything but farmers. A farmer's life is seen as hard, dirty, risky, and above all, undervalued. It's a bitter irony – the provider of our country's food security becoming a migrant manual laborer – yet it's a reality born of farming's low prestige and fairly widespread incidence of low farmers' incomes.

State of rural youth employment, 2024 (Global Development Incubator) found that 70–85% of rural youth surveyed wanted to leave agriculture and find jobs in small businesses, manufacturing or trade. They desire better income and a more "modern" life, even if it's a low-paying gig in a city, over the uncertainties of the farm. At the same time, about 60% of those young men don't want to migrate far from home suggesting that if viable opportunities existed in the village, they would happily stay.

The challenge is clear: right now, too few see farming as that viable opportunity. The Chief Economic Adviser V. Anantha Nageswaran recently observed that "agriculture has to be brought back into fashion" to make it a viable employment option again. Farming needs to be seen as profitable, purposeful and cool– not a dead-end and an employer of last resort. Until that perception shifts, India risks a generation of youth distancing themselves from the land, even as the nation's food security, our soil's health and rural economies hang in the balance.

When Crisis Brought the Farm Back to Life

Interestingly, it took a crisis to momentarily jolt this narrative. In 2020, as COVID-19 lockdowns brought cities to a standstill, millions of young migrant workers returned to their home villages. With factories closed and no wages, many did something they never expected: they took up farming. For a brief period, fields that had long lain fallow sprang to life. In the Kharif season of 2020, India's sown crop area surged over 21% higher than the previous year, a jump almost unimaginable in normal times. In Andhra Pradesh, farmers noted that lands which used to be left uncultivated were now fully planted, thanks to the influx of labor and hands eager to earn from the soil. Similar anecdotes echoed across India due to COVID induced reverse-migration.

Of course, as cities reopened, some of these gains receded; many migrants went back to urban jobs. But the episode was instructive. It showed that if circumstances (or compulsion) bring youth back to farming, many can and will engage productively – provided farming can yield a decent livelihood and self-esteem. The challenge is to make that engagement stick in good times, not just bad.

Rebranding Agriculture: From Grim to Glorious

How do we permanently change farming's image from a profession with low incomes and low social status to an aspirational one? The solutions go beyond any single policy – we need a cultural shift. Here are four pillars to revitalize Indian agriculture:

1. Shine a Search Light on Success: We must celebrate farmers publicly and enthusiastically. Expand initiatives that honor farmers – from national awards like the Padma Shri to specialized honors. When a millionaire farmer or an organic farming hero is feted on stage and in the social media, it not only validates that individual's work, it sends a powerful signal to all farmers (and their children) that their achievements matter. The goal is to make household names of Hukumchand Patidar, Nituben Patel, Subhash Sharma and others, so that aspiring young farmers have role models to look up to.

2. Train the "Agripreneurs": Farming in the 21st century is as much about knowledge and entrepreneurship as about weather and soil. To attract the youth, we need to equip them with modern skills. This means entrepreneurship training tailored for agriculture – how to select high-value crops, access credit, use technology, manage risk, and market produce. Successful farmers often act as grassroots teachers, proving the impact of peer learning. Now, agricultural universities, , and NGOs should scale up formal mentorship programs and incubators for young farmers. Krishi Vigyan Kendras have to be renovated and rejuvenated to align them with current demands for modern skills and technologies. If a rural youth learns how to run a polyhouse for exotic vegetables or process millet into snacks, farming transforms into a savvy business opportunity. Knowledge turns farm work from drudgery into a challenge to innovate.

3. Private Sector Partnerships: The private sector can bring investment, tech, and market linkages that make farming profitable. Engage companies and startups in the agricultural value chain to partner with farmers. Linking up with markets ensures better prices and reduces risk. Agri-tech startups, meanwhile, are already offering solutions – from apps for getting the best price to drone services for precision farming. Embracing these can make farming more efficient and cool in the eyes of the tech-savvy youth. Importantly, corporate sponsorships of farming events and reality shows or contests around farming success could further glamorize the sector.

4. Value Chain Development: A farmer's income shouldn't stop at the farm gate. There is money in moving up the value chain – cleaning, packaging, processing, and branding agricultural produce. By developing local processing facilities and food businesses, we can create rural jobs and boost farmers' earnings. The necessary condition for progress in agro-processing is bringing the small and marginal farmers together as equity partners by pooling their land and establishing farmers' producers' organizations (FPOs). The agripreneurs, trained in agriculture universities and institutions such as IRMA, can then convert these FPOs into modern, hi-tech supply chains that extend from cultivation to marketing high quality finished products. There is sufficient evidence from different regions of the country that this is a viable and successful model that can be replicated across the country. If farming families become stakeholders in producing these high-value and processed foods (which India's growing middle class is demanding,) the profitability of farming will soar. In short, we must help farmers not just grow raw crops, but capture value from "farm to fork."

Some State governments have recognized this, rolling out programs to fund micro food enterprises and promote "One District, One Product" for agro-processing. We need to fast-track investments in rural storage, cold chains, and food parks so that farmers can store and sell later at better prices or turn perishable produce into finished agro-processed or ready-to-eat products. High-value crops and products – be it dairy cheese, organic turmeric, or processed fruits – fetch higher margins.

Ultimately, none of these changes can occur in isolation. We need a narrative shift to accompany on-ground reforms. Rural youth need to see examples of peers who have made it big in farming, and hear a new conversation around agriculture as a sector of innovation and wealth, not just subsistence. It will mark a much-needed transformation when the news of a major success like a farmer growing export-quality strawberries or flowers for the Rotterdam market, or a group of women turning forest produce into a global brand, become viral on the social media and capture the headlines in mainstream media. India can and will then emerge as a major player in global agro-products markets.

We should be making celebrities of our farmers and modernize our agriculture on a fast track. We need to draw talent and energy back to the soil. It will transform our economy and our society by removing the dualism that currently characterizes the urban-rural divide. We will achieve growth with ecological security, which is the pressing need of the hour. A modernized agriculture and agro-processing sector will emerge as significant contributor in our journey towards Vikasit Bharat.

Building Resilience and Sustaining our Future

Dr. RS Paroda

Chairman

Trust for the Advancement of Agricultural Sciences

Introduction

Today, agriculture is confronted with serious challenges due to multiple factors, including ever-increasing population pressure on limited natural resources. From depletion of soil health to water scarcity to the increasing impact of climate change, the current farming systems are under pressure to meet the future food demands without compromising soil and environmental health. Non-scientific farming and livestock rearing practices, intensive imbalanced use of chemical fertilizers and pesticides, and soil degradation are all contributing to greenhouse gas emissions (TAAS, 2021).). Hence, the need for a transformative approach to food production is more urgent now than ever. Regenerative agriculture (RA) offers a solution—one that works with nature, restores ecosystems, and helps combat climate change by rebuilding our soil health (Khangura et al., 2023; Choudhari et al., 2024). Unlike conventional practices that drain the land, regenerative farming is based on the principle that agriculture practices should serve as tools for healing and restoring the ecosystems, rather than exploiting our natural resources. This holistic approach to agriculture aims not only to restore soil health but also to boost biodiversity, improve water retention capacity, and mitigate the impacts of climate change. In this article, an attempt has been made to examine the real-world applications and benefits of regenerative agriculture, the challenges involved in transitioning towards regenerative methods, and discuss the potential of regenerative agriculture to create a more sustainable, resilient, and productive food system.

What is Regenerative Agriculture?

At its core, regenerative agriculture (RA) is an agricultural system that focuses on regenerating the soil and restoring ecological balance. Unlike conventional farming, which often deteriorates the soil through excessive tilling, chemical inputs, and monocropping, regenerative agriculture works in harmony with nature to improve soil health, increase biodiversity, and sequester carbon in the soil (TAAS, 2021). Regenerative agriculture emphasizes practices that build long-term soil fertility and ecosystem health. The regenerative agricultural framework comprising the principles, practices, benefits and operative microbial mechanisms are given in Table 1.

Table 1. Regenerative agriculture framework

RA Principles	RA Practices	RA Benefits	Microbial Mechanisms
Minimise soil disturbance	No/minimum tillage	Improved soil health through: • Increased soil carbon • Improved microbial functions and associated nutrient cycling • Improved soil moisture • Improved resilience to pests and diseases	Liquid carbon pathway
Keep soils covered	Stubble retention		Improved uptake of water and minerals
Keep living roots in soil year-round	Diverse crop rotations		Enhanced soil aggregation, plant growth, and photosynthesis
Encourage diversity	Multispecies cover crops		
Integrate livestock	Intercropping		
	Composting and use of bio-stimulants	Nutrient-rich food	
	Rotational grazing	Reduced greenhouse gas emissions	
	Reduce synthetic inputs		

Origin of Regenerative Agriculture

The Rodale Institute originally articulated the concept of regenerative agriculture during the early 1980s as a farming paradigm that goes beyond the notion of sustainability. Publications by Rodale Press in 1987 and 1988 laid the foundation for defining regenerative systems of agriculture as those that continuously restore, renew, and revitalize ecosystem functions rather than merely maintaining existing productivity levels (Taylor et al., 2025). Robert Rodale emphasized that the dominant discourse of sustainability in agriculture is inherently limited because it implies merely preserving the status quo rather than restoring or improving the underlying ecological and social systems. In contrast, regenerative agriculture was envisioned as a dynamic, proactive approach aimed at enhancing soil fertility, biodiversity, and ecological resilience through continuous improvement processes (Tindwa et al., 2024). The term experienced a decline in mainstream usage during the late 1980s. However, it regained prominence following the publication of a white paper in 2014 titled 'Regenerative Organic Agriculture and Climate Change' by the Rodale Institute. This seminal document positioned regenerative agriculture as a key strategy for mitigating climate change. It outlines practices such as diverse crop rotations, use of organic manure and compost, cover cropping, reduced tillage, and other organic management approaches. These practices collectively enhance carbon sequestration, improve nutrient cycling, stimulate soil microbial activity, and strengthen resilience against climatic variability. By integrating these regenerative methods, agricultural systems can contribute meaningfully to both environmental sustainability and climate adaptation objectives.

Current Scenario of Regenerative Agriculture

In the contemporary context, regenerative agriculture has evolved into a globally recognized framework for sustainable intensification and climate-resilient farming systems. Multiple institutions and organizations are promoting adoption across varied agro-ecosystems:

- The Savory Institute, founded by Allan Savory, has advanced the principles of holistic management, with a focus on large-scale grazing systems. Its approach emphasizes the integration of managed livestock, the restoration of degraded rangelands, and the reversal of desertification through soil carbon sequestration and improved water retention.
- Kiss the Ground, a nonprofit organization, has played a key role in popularizing regenerative agriculture through educational programs, media campaigns, farmer support networks, and policy advocacy platforms. Central to its mission is the improvement of soil organic matter, soil carbon pools, and the resilience of farmers' livelihoods.

In India, regenerative agriculture is being increasingly integrated into policy frameworks and development programs. Both Union and State Governments are promoting initiatives aimed at reducing dependency on chemical fertilizers and pesticides, lowering input costs, and enhancing long-term soil fertility. These policies emphasize the use of organic amendments, biofertilizers, crop diversification, integrated nutrient management, and ecological pest regulation (TAAS, 2021). The broader objective is to transform conventional high-input systems into low-external-input, climate-smart, and resource-efficient production systems that ensure food security, ecosystem sustainability, and farm profitability. Regenerative agriculture has now emerged as a multifunctional paradigm capable of simultaneously addressing the challenges of soil degradation, biodiversity loss, greenhouse gas emissions, and the vulnerability of rural livelihoods, while contributing to the global agenda of sustainable development and climate resilience.

Principles of Regenerative Agriculture

The guiding principles of regenerative agriculture centre on nurturing the soil, enhancing biodiversity, and establishing systems that promote environmental and social sustainability.

1. Minimizing soil disturbance

In conventional farming, tillage is often used to prepare the soil for planting. This practice disturbs the soil structure, disrupts beneficial microbial communities, and releases carbon dioxide into the atmosphere. One of the main principles of regenerative agriculture is to minimize soil disturbance (TAAS, 2021). Practices such as no-till farming or low-till farming minimize soil disturbance which has several benefits, namely, soil structure preservation, carbon sequestration, improved water retention and habitat protection for soil life enabling beneficial soil organisms, including worms, fungi, and bacteria, to thrive. These organisms help break down organic material, cycle nutrients, and improve soil structure over time (Davis et al., 2025). By keeping soil undisturbed, regenerative farmers can increase soil organic matter, which improves soil structure and enhances its ability to store water and nutrients. Healthy soil also sequesters carbon, playing a vital role in mitigating climate change.

2. Maximizing crop diversity

Monocropping, the continuous cultivation a single crop increases efficiency but depletes soil nutrients and encourages pest and disease outbreaks making farming less sustainable over time. Regenerative agriculture promotes crop diversity, which is essential for the health of the soil and the surrounding ecosystem. Crop diversification can be achieved through crop rotations, where different crops are planted in a specific sequence over several seasons. Polyculture, or planting different crops together, also plays a role in enhancing biodiversity and soil health (TAAS, 2021). For example, growing a mix of legumes, cereals, and root vegetables provides a variety of nutrients and root structures, enriching the soil and promoting the health of beneficial organisms. Crop diversity can also be expanded through agroforestry, which integrates trees into farming systems. Trees can help prevent soil erosion, improve water retention, and provide habitat for wildlife. By incorporating various species and plants, regenerative farmers can enhance ecosystem services such as pollination and pest control.

3. Maintaining living roots year-round

The health of the soil is closely linked to the presence of living roots (TAAS, 2021). In conventional farming systems, fields are often left bare between planting seasons, exposing the soil to erosion, nutrient depletion, and the loss of organic matter. Regenerative agriculture, however, encourages keeping living roots in the soil year-round. This can be achieved through practices like cover cropping, where plants are grown specifically to cover the soil during the off-season. Cover crops such as legumes, grasses, and Brassicas help maintain soil structure, prevent erosion, and provide organic matter that enriches the soil. Additionally, many cover crops are nitrogen-fixing, and they have the potential to replenish vital nutrients for the soil, reducing the need for synthetic fertilizers.

4. Keeping the soil covered

Soil erosion is a significant challenge in conventional agriculture, particularly in areas prone to wind and water erosion. In regenerative agriculture, one of the key principles is to keep the soil covered at all times. This practice is essential for maintaining and improving soil health. This can be achieved by planting cover crops or leaving crop residues, such as straw or leaves, on the soil's surface. The benefits of keeping the soil covered are manifold (TAAS, 2021; Choudhari et al., 2024). First, it helps to prevent soil erosion by protecting the surface from wind and water. Second, it helps to conserve moisture, reducing the need for irrigation. Third, organic matter from crop residues and cover crops breaks down over time, enriching the soil with nutrients and improving its structure.

5. Integrating livestock

While industrial farming often separates crop production from livestock, regenerative agriculture encourages the integration of animals into farming systems. Properly managed livestock can play a crucial role in maintaining healthy soils and ecosystems. Through rotational grazing, where animals are moved between pastures, livestock can help to recycle nutrients, control weeds, and improve soil fertility by dispersing manure evenly across the land (Davis et al., 2023). Livestock can also break down organic matter, which contributes to the improvement of soil structure and nutrient cycling. Moreover, they can help to diversify the farm system, making it more resilient to climate change and market fluctuations.

Benefits of Regenerative Agriculture

The benefits of regenerative agriculture extend far beyond the farm and have the potential to positively impact the global ecosystem and society at large. Some of the most significant advantages of regenerative farming are as follows:

1. Improved soil health

Regenerative agriculture focuses on rebuilding soil health by increasing organic matter, improving soil structure, and encouraging biodiversity (TAAS, 2021). Healthy soils are more resilient to environmental stresses such as droughts and floods. They also sequester more carbon, contributing to climate change mitigation. As soil health improves, it enhances the soil's ability to retain water and nutrients, which results in higher crop yields (Choudhari et al., 2024). "Over time, regenerative practices such as cover cropping, crop rotation, reduced tillage, and compost application can lead to healthier, more productive, and more resilient soils that support greater biodiversity and long-term agricultural sustainability

2. Mitigating climate change through carbon sequestration

One of the key environmental benefits of regenerative agriculture is its ability to sequester carbon. Regenerative practices such as no-till farming, agroforestry, and cover cropping all help to capture carbon dioxide from the atmosphere and store it in the soil (TAAS, 2021; Choudhari et al., 2024). Soil is a significant carbon sink, and improving its health can help to mitigate climate change. The process of carbon sequestration in soil reduces the amount of carbon dioxide in the atmosphere, thereby helping to counteract the effects of global warming. Furthermore, regenerative farming practices contribute to reducing greenhouse gas emissions by decreasing reliance on synthetic fertilizers and fossil fuels.

3. Enhanced biodiversity

By promoting diverse cropping systems, agroforestry, and the integration of livestock, regenerative agriculture helps to foster rich biodiversity both above and below the soil surface. Diverse ecosystems are more resilient to pests, diseases, and environmental fluctuations (TAAS, 2021). Biodiversity also provides crucial ecosystem services, including pollination, pest control, and nutrient cycling, as these are essential for maintaining healthy ecosystems. By integrating a variety of plants and animals, regenerative farms create healthy habitats for wildlife, beneficial insects, and microorganisms, all of which play important roles in maintaining ecosystem health.

4. Improved water management

Regenerative practices improve the water retention capacity of soils, reducing the need for irrigation. By increasing organic matter, maintaining living roots, and protecting the soil with cover crops, regenerative farming enhances the soil's ability to hold moisture and absorb rainwater. Improved soil structure also leads to better water infiltration and reduced surface runoff, thereby decreasing the risk of flooding and soil erosion. In drought-prone regions, these practices are critical, as they enable farmers to manage their water resources more efficiently.

5. Economic sustainability for farmers

Transitioning to regenerative agriculture can provide farmers with long-term economic benefits by improving soil health, reducing input costs, and increasing resilience to climate stress. While the initial investment in regenerative practices may be higher, these costs are offset by the reduced need for synthetic inputs (such as fertilizers and pesticides) and improved yields over time. Moreover, regenerative agriculture offers farmers the opportunity to participate in carbon markets. By adopting practices that sequester carbon, farmers can earn carbon credits and sell them to corporations and governments seeking to offset their emissions (TAAS, 2021; Choudhari et al., 2024). This additional income stream provides farmers with a financial incentive to adopt sustainable practices.

6. Resilience to climate change

As climate change continues to disrupt agricultural systems, regenerative agriculture offers a pathway to resilient farming. By rebuilding soil health and enhancing biodiversity, regenerative farming systems are better able to withstand extreme weather events, such as droughts, floods, and heatwaves. The practices of regenerative agriculture improve the farm's ability to recover from shocks, making farming more resilient in the face of climate change. In the regions where unpredictable weather patterns have compromised traditional farming, regenerative practices can provide a more reliable and sustainable solution.

Challenges in Implementing Regenerative Agriculture

Despite its apparent benefits, the adoption of regenerative agriculture faces several challenges, particularly for smallholder farmers and those transitioning from conventional farming systems. These include:

1. Initial investment and transition costs

Transitioning from conventional farming to regenerative practices requires an initial investment in new tools, training, and infrastructure. While regenerative practices often reduce input costs over time, the upfront financial commitment can be a barrier for farmers, especially those with limited access to capital.

2. Knowledge and training

Regenerative agriculture requires a deep understanding of soil health, ecosystem dynamics, and ecological processes. Farmers need specialized knowledge on how to implement practices such as crop rotations, no-till farming, and cover cropping effectively. Providing training and support is crucial for successful adoption, especially for farmers who are accustomed to traditional methods.

3. Policy and market access

Government policies and market access play a crucial role in the widespread adoption of regenerative agriculture. Supportive policies, such as subsidies for sustainable practices, incentives for carbon sequestration, and grants for education and training, are vital in making regenerative farming accessible to farmers.

4. Resistance to change

In many regions, traditional farming practices have been deeply ingrained for generations. Changing to regenerative methods requires not only financial investment but also a cultural attitude shift. Overcoming this resistance requires education, outreach, and strong support from both local communities and agricultural organizations.

Real-world Applications and Success Stories

1. Dryland farming in India

In India's dryland regions, covering about 52 per cent of total cultivated land, where water scarcity is a significant challenge, regenerative practices such as conservation tillage, rotation of cereal-legumes in the cropping system, direct-seeded rice, and mulching have demonstrated significant successes. These methods help improve soil water retention, reduce irrigation needs, and increase crop productivity in arid environments.

Unfortunately, CA in drylands in India, having great potential to make these grey areas green, has not been adopted yet on large scale as happened in Latin America, USA, Canada, Australia etc. On the contrary, CA or no till cultivation is adopted in rice-wheat system in the indo- gangetic plain to a level of around 3.5 million hectares. The scope to double it in next 5 years exists but would require a concerted effort.

2. Agroforestry in Africa

In many parts of Africa, agroforestry—the integration of trees with crops and livestock—is helping restore degraded lands, enhance biodiversity, and improve soil fertility. Farmers in countries such as Kenya and Tanzania have seen increased yields and better resilience to droughts by adopting agroforestry systems.

3. Carbon credits in the United States of America

Farmers in the United States have been able to earn carbon credits by adopting regenerative practices, such as no-till farming, crop rotation like corn-soyabean, and agroforestry. These carbon credits provide farmers with an additional revenue stream, incentivizing them to continue sustainable agricultural practices that also benefit the environment.

4. No-till and Broader Conservation Agriculture

The global area under conservation agriculture (CA), , particularly no-till and reduced-till practices,has expanded substantially over the pasttwo decades. A widely cited synthesis of national datasets covering the period 2000 - 2020 estimates that over 205 million hectares of cropland are now managed under conservation/no-till practices — roughly doubling the area recorded a decade earlier.

Growth in the use of conservation agriculture has been rapid especially in the United States, Brazil and Argentina which are the largest single-country holders of no-till area, while other important adopters include Australia, Canada, China and a few selected countries in southern Africa and South Asia.

In the United States, the share of cropland managed under no-till or reduced-till systemscontinues to rise across major field crops such as maize, soybean, and wheat. Similar trends are observed in other major producing regions, where conservation tillage is increasingly recognized for its benefits in soil health, moisture conservation, erosion control, and input efficiency.

Main Benefits Reported

Farmers and researchers have reported several benefits associated with successful implementation of no-till practices. These include: reduced soil erosion, enhanced water infiltration and retention, and lower fuel/labor requirements and costs due to fewer field operations, Additionally, maintaining surface residue improves soil cover , and over time, the system contributes to increased soil organic matter and improved soil structure—particularly when integrated with crop rotations and cover crops.. These benefits are the primary drivers of adoption of no-till systems in the regions facing acute water scarcity or severe erosion challenges.

Conclusion

Regenerative agriculture represents a transformative shift in the way we approach farming, offering a holistic and sustainable alternative to conventional agricultural practices. Regenerative agriculture focuses on rebuilding soil health- the cornerstone of thriving crops, balanced ecosystems, and climate resilience. Through practices such as cover cropping, crop rotation, agroforestry, and holistic grazing, regenerative farming restores vital nutrients, increases carbon sequestration, and improves water retention. These methods not only reverse the degradation caused by industrial agriculture but also enhance the resilience of the soil, making it more resistant to erosion, drought, and extreme weather events—problems that are becoming increasingly common with climate change. One of the most significant benefits of regenerative agriculture is its role in combating climate change. Promoting soil health and increasing carbon sequestration, it serves as a natural carbon sink, drawing down excess carbon dioxide from the atmosphere and helping to mitigate global warming. This stands in stark contrast to conventional farming, which often releases carbon into the atmosphere through practices like tillage and monocropping. Additionally, regenerative agriculture fosters biodiversity by encouraging a wider variety of plants and animals on the farm. This increased biodiversity leads to stronger, more resilient ecosystems, which can help to buffer against the unpredictable impacts of climate change. For farmers, the transition to regenerative agriculture may require some upfront investment in education, equipment, and time to see tangible results. However, the long-term rewards are substantial. Healthier soils lead to higher yields, reduced dependency on synthetic fertilizers and pesticides, and lower input costs. Regenerative practices can also increase farm profitability by diversifying revenue streams through products like livestock, timber, or even carbon credits for sequestration efforts.

The global adoption of regenerative agriculture requires a policy framework that fosters collaboration between farmers, policymakers, businesses, researchers and consumers. Policymakers play a pivotal role in enabling this transition by creating an environment that rewards sustainable land management and long-term environmental stewardship. Knowledge-sharing and access to resources are essential, as farmers need the right tools, support, and incentives to make the transition. Targetted financial incentives, such as subsidies for using sustainable practices or access to markets that value regenerative products, can further encourage the adoption of regenerative agriculture. Moreover, governments play a crucial role in implementing policies that support regenerative agriculture, such as providing tax breaks, funding for research, and creating systems for tracking and rewarding environmental benefits. Ultimately, regenerative agriculture has the potential to reshape our food systems, creating a future where farming is not only productive but also ecologically sustainable and climate-resilient. Through education, effective knowledge sharing and extension systems, easy availability of inputs like biofertilizers, biopesticides, herbicides, growth promoters, soil mulching, easy credit and availability of implements and tools, enabling policy support, and market incentives, we can unlock the full potential of regenerative agriculture and create much healthier, more sustainable agriculture for our future generations

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Renewable Energy

APPLICATION AVENUES

The Global Alliance for the Future of Food (2023) reported that the agriculture and allied sectors accounted for about 2.17% of global energy consumption in 2021. These sectors represented nearly 15% of the total energy use across the global food value chain during the same year. In India, agriculture alone uses about 8.23 lakh terajoules of energy annually (FAO, 2025). Most of this energy comes from fossil fuels and electricity made from non-renewable sources like coal. As reported by FAO (2022), the combined use of fossil fuels and electricity by agriculture and allied sectors worldwide resulted in 0.93 gigatonnes of carbon dioxide (CO_2)-equivalent emissions in 2021. During the same period, energy use in agriculture in India released an estimated 159 megatons of CO_2-equivalent emissions.

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Prospects of renewable energy in agriculture sector

In the days to come, the demand for energy in agriculture is expected to rise steadily due to several structural and technological changes. As farm mechanization expands to compensate for the declining availability of agricultural labour, the reliance on energy-intensive equipment such as tractors, pumps, and processing units will intensify.

The adoption of modern production and post-harvest technologies—including precision farming, controlled-environment agriculture, and cold-chain logistics—will further elevate energy requirements across the agricultural value chain. Additionally, the growing emphasis on value addition, processing, and storage to reduce post-harvest losses will add to the sector's overall energy footprint. Without a transition toward renewable and efficient energy sources, this upward trend could significantly increase carbon emissions, operational expenses, and environmental

pressures, illustrating the importance of sustainable energy interventions in agriculture.

Renewable sources of energy such as solar, wind, biomass, biogas, and small-scale hydropower offer a sustainable pathway to meet this rising energy demand in agriculture. These clean energy alternatives can substantially reduce dependence on fossil fuels by providing decentralized and cost-effective energy solutions for irrigation, mechanization, processing, and storage. For instance, solar-powered irrigation systems can replace diesel pumps, while biogas plants can utilize agricultural residues and livestock waste to generate energy for rural operations. Similarly, wind and biomass-based systems can supplement energy needs for drying, milling, and cold storage. Beyond reducing energy costs, the integration of renewables also plays a pivotal role in lowering greenhouse gas emissions, thereby contributing to climate change mitigation and advancing national commitments toward sustainable and low-carbon agricultural growth.

Avenues for application of renewable energy in agriculture:

Irrigation and Water Management: Renewable energy, particularly solar power, offers a sustainable solution for irrigation and water management in agriculture. Solar-powered pumps reduce dependence on diesel and grid electricity, providing reliable water access even in remote areas. These systems lower operational expenses, enhance irrigation efficiency, and enable timely watering of crops. Integrating solar energy with micro-irrigation systems such as drip or sprinkler irrigation further optimizes water use, promoting resource conservation and climate-resilient farming practices.

Renewable energy technologies can power energy-intensive post-harvest activities like drying, milling, grading, and cold storage. Solar dryers, biomass-based heating systems, and solar-powered cold storage units help reduce post-harvest losses, maintain quality, and extend the shelf life of perishable produce. By ensuring decentralized energy access, these systems support value addition at the farm gate and strengthen rural agro-industries, particularly in areas with unreliable electricity supply.

Livestock and Dairy Operations: Biogas and biomass energy play a crucial role in livestock-based farming systems. Animal waste can be converted into biogas to generate heat, electricity, and cooking fuel, while the slurry serves as a nutrient-rich organic fertilizer. Renewable energy-based chilling systems for milk preservation and solar-powered milking machines enhance the efficiency and hygiene of dairy operations. This circular method cuts down on waste and emissions and supports the long-term health of farms.

On-Farm Mechanization and Power Supply: Solar and biofuel-based energy solutions can power small-scale agricultural machinery such as threshers, sprayers, and rice mills, reducing dependence on fossil fuels. Portable solar charging units can support electric tractors and tools, improving access to mechanization for smallholders. Renewable microgrids and hybrid systems ensure uninterrupted power for farms in off-grid regions, enabling energy self-sufficiency and reducing production costs.

Greenhouses and Controlled Environment Agriculture: Renewable energy can significantly enhance the efficiency of controlled environment agriculture. Solar panels integrated into greenhouse structures can power temperature control, ventilation, and irrigation systems, reducing operational expenses. Geothermal energy can also be used for heating and cooling, ensuring optimal growing conditions year-round. This integration supports high-value crop production, resource-use efficiency, and the expansion of modern horticulture in diverse climatic regions.

Solar Harvesting: Solar harvesting refers to the capture and utilization of solar energy through various technologies to meet the diverse energy needs of agriculture. It extends beyond conventional solar pumping to include solar panels on farm structures, greenhouses, and even crop fields through agrivoltaic systems—where solar panels and crops coexist to produce both energy and food. These systems optimize land use and provide shade that can reduce evapotranspiration Biogas plants in Chhattisgarh are working with more than 80% efficiency, turning farm and animal waste into clean energy and cutting down on methane emissions (Singh et al., 2016). By transforming farms into decentralized power producers, solar harvesting promotes energy security, income diversification, and climate resilience, making it a cornerstone of sustainable agricultural modernization.

Across the globe, numerous case studies demonstrate the transformative economic and environmental impacts of renewable energy adoption in agriculture. In India, for instance, scaling up to five million solar irrigation pumps could save nearly 23 billion kWh of electricity or 10 billion litres of diesel annually, avoiding about 26 million tonnes of CO_2 emissions (International Copper Association India & IIEC, 2022). Agrivoltaic systems in Gujarat have demonstrated that solar power generation can be seamlessly integrated with crop cultivation, achieving annual outputs of over 10,000 kWh per system (Patel et al., 2021). Biomethane could replace fossil-fuel-based power and cut emissions by about 560 g CO_2 eq per kWh. It could also stop the burning of crop residue, which releases an estimated 37–44 Mt CO_2-eq each year (Rana et al., 2022). Additionally, solar pump cooperatives in Gujarat have helped farmers reduce diesel use and sell surplus electricity to the grid, enhancing both incomes and sustainability (CDKN, 2021). Beyond India, in the European Union, utilizing just 1% of agricultural land for agrivoltaic systems could generate nearly 944 GW of solar capacity, surpassing the EU's 2030 photovoltaic targets (Joint Research Centre, 2023). These examples collectively show that renewable energy integration in agriculture enhances energy self-sufficiency and farm profitability while contributing significantly to climate change mitigation and sustainable rural development.

Policy options for promotion of renewable energy

Financial Incentives and Subsidies: Governments should introduce targeted financial incentives such as subsidies, tax rebates, and low-interest loans to encourage farmers to adopt renewable energy technologies. These incentives can lower the upfront costs of installing solar panels, biogas units, and wind turbines, making them more accessible to small- and medium-scale farmers. The renewable energy credit schemes are allowing farmers to sell excess energy back to the grid, providing an additional income stream while promoting sustainable energy generation in rural areas.

Infrastructure Development and Technical Support: To promote renewable energy in agriculture, policymakers should invest in rural energy infrastructure and capacity-building programs. This includes expanding access to reliable grid connections, developing decentralized renewable microgrids, and providing training to farmers and technicians on installation, maintenance, and efficient energy use. Establishing renewable energy service centres at the local level can also ensure technical assistance and spare part availability, thus improving long-term sustainability and adoption rates.

Research, Innovation, and Public-Private Partnerships: Governments should promote research and innovation in renewable energy applications tailored to agricultural needs—such as solar-powered irrigation systems, biomass-based cold storage, and wind-assisted water pumping. Encouraging collaborations between research institutions, the private sector, and farmer cooperatives can help develop cost-effective and locally appropriate technologies. Public-private partnerships can also accelerate commercialization, ensuring that renewable energy solutions are both technically feasible and economically viable for diverse farming systems.

Regulatory Frameworks and Awareness Campaigns: Implementing clear regulatory frameworks and awareness programs is essential for mainstreaming renewable energy in agriculture. Policies should streamline the approval process for renewable energy installations, ensure grid access for decentralized producers, and establish quality standards for equipment and installations. Simultaneously, awareness campaigns need to be organized to educate farmers on the economic and environmental benefits of renewable energy, showcasing successful case studies to foster confidence and community-led adoption.

The transition to renewable energy in agriculture represents a pivotal shift towards sustainability, driven by the establishment of robust regulatory frameworks and targeted awareness campaigns. By implementing clear guidelines and streamlining the approval processes for renewable energy installations, stakeholders can facilitate smoother transitions for farmers looking to adopt these technologies. Ensuring grid access for decentralized producers is essential, as it empowers them to contribute to and benefit from renewable energy production. Furthermore, the establishment of quality standards for equipment not only guarantees safety but also fosters confidence in the adoption of these innovations. By educating farmers on the economic advantages and environmental benefits of renewable energy, we can cultivate a more informed community ready to embrace sustainable practices that enhance both productivity and ecological stewardship. Together, these efforts create a comprehensive approach that not only supports agricultural resilience but also propels us toward a greener future.

Science Must Guide

Policy on Protein Hydrolysate Biostimulants

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India's commitment to sustainable agriculture has historically been anchored on the balance between tradition and science. Recent advances in plant biostimulants, the substances that enhance plant growth, nutrient use efficiency, and resilience to stress have offered promising tools for improving crop productivity under climate challenges. Among these, protein hydrolysate (PH) -based biostimulants have emerged as one of the most significant innovations, providing an environmentally acceptable alternative to regular fertilisers.

However, a recent policy reversal removed animal-origin protein hydrolysates from the Fertiliser (Control) Order (FCO), 1985. This decision risked the years of science-led agricultural reforms like the plant biostimulants, critical in boosting low productivity in the face of climate change. The decision, which was made public on 29 September 2025, through Gazette Notification S.O. 4441 (E) removed all the eleven approved formulations of protein hydrolysates of animal origin from Schedule VI, banning their use as biostimulants.

While government reserves the right to review and revise its policy regulations, but these changes must be based on scientific reasonings drawn out of careful scientific deliberations. ICAR has 114 research institutes and deemed universities, many of which deal exclusively on natural resource management, soil nutrient and soil fertility. Apparently not much academic excellence, research expertise, professional wisdom and resources that might have been available within these public organizations remained unexplored. Neither have any scientific data, safety assessments, or technical justification preceded critical reversal of the regulation. The move appeared influenced more by socio-religious sensitivities rather than the risk-based review. The move raises concern among scientists, industry, and progressive farmers who have invested in biostimulants-based technologies since their formal recognition in 2021.

A Landmark Reform and Its Abrupt Reversal

The inclusion of biostimulants under the FCO through Gazette Notification S.O. 882 (E) in February 2021 was a landmark reform. For the first time, India formally recognized biostimulants as a distinct category of agricultural inputs. These are, substances or microorganisms that, when applied to plants, seeds, or soil, stimulate physiological processes to enhance growth, yield, and stress tolerance. The biostimulants are distinct from biofertilizers and biopesticides, the other two categories of biological inputs that govern plant nutrition and protection from pests. Crucially, the definition explicitly permitted biostimulants derived from plant, microbial, animal, or synthetic sources, provided they met rigorous safety, toxicity, and efficacy criteria.

This reform provided long-awaited regulatory clarity to an emerging sector, to support sustainable and climate-resilient agriculture. The new framework encouraged scientific innovation, research investment, and the entry of validated products into the Indian market. Both plant- and animal-origin protein hydrolysate formulations were approved after thorough evaluation by the Integrated Nutrient Management (INM) Division of the Ministry of Agriculture, based on extensive data covering toxicology, bioefficacy, and quality control. The recognition of biostimulants under the FCO not only brought India in alignment with global agricultural standards but also demonstrated the government's confidence in science-driven policymaking. The 2025 reversal, therefore, marks a concerning deviation from this progressive trajectory.

Understanding Protein Hydrolysates: Chemistry Beyond Source

Protein hydrolysates are mixtures of amino acids, peptides, and other small organic molecules derived from the controlled hydrolysis of natural proteins. These products are known to improve nutrient uptake, chlorophyll synthesis, root growth, and tolerance to abiotic stresses such as drought, heat, and salinity. PHs can be obtained from diverse raw materials—plants (such as soybean or oilseed meals), microbes, or animal by-products (such as collagen, fish waste, or leather trimmings). However, once hydrolysed, the resulting amino acids and peptides are chemically identical, regardless of the source.

An amino acid molecule like glycine or lysine has the same structure, NH_2–CH(R)–COOH, whether derived from a plant or an animal protein. After hydrolysis, no DNA, intact protein, or tissue remains. The final product is a biologically neutral solution, indistinguishable in composition and performance between plant and animal origins. Describing such products as "animal remains" is, therefore, scientifically inaccurate. Toxicological and environmental evaluations worldwide have consistently shown PHs to be non-toxic, biodegradable, and beneficial for soil microbial activity. The European Union, the United States, and Japan all classify protein hydrolysates, irrespective of source, as safe and sustainable agricultural inputs.

The Inconsistency within the Fertiliser (Control) Order

What makes the recent prohibition particularly perplexing is its inconsistency with the FCO's existing provisions. Under the same regulatory framework, several fertilizers of animal origin, such as raw and steamed bone meal, remain officially approved. These are routinely used as organic fertilizers, valued for their phosphorus and calcium content, and are widely accepted in both conventional and organic farming systems. The FCO defines "organic fertilizer" as any material of biological origin, plant or animal, subjected to decomposition or microbiological processes that make nutrients available for plant use. Bone meal, blood meal, fish meal, and other animal-based materials fall squarely within this definition. Their specifications under the FCO include moisture, total phosphate, nitrogen content, and particle size, all designed to ensure safety and quality. In other words, animal-derived fertilizers have been accepted under Indian law for decades, and their continued approval affirms that such materials pose no inherent religious, ethical, or safety risk when processed according to scientific standards.

By contrast, the ban on animal-derived protein hydrolysates, products even more refined and purified than bone meal, introduces a contradiction. It selectively disallows one form of animal-origin input while continuing to permit others under the same law. Such a selective prohibition creates regulatory asymmetry, erodes internal consistency, and weakens the credibility of science-based governance.

Science, Sentiment, and Policy: Striking the Right Balance

India's cultural diversity and spiritual traditions are rightly respected in policymaking. However, agricultural regulation must remain grounded in empirical evidence. Policies driven primarily by perception rather than data risk sending mixed signals to both farmers and researchers. There is a difference between acknowledging public sentiment and allowing sentiment to override science. While faith and ethics have a place in guiding societal values, they cannot serve as the basis for technical standards that determine agricultural inputs. The role of government regulation is precisely to ensure that such decisions are informed by risk assessment, transparency, and evidence. The revocation of animal-origin PHs has the unintended effect of casting doubt on India's regulatory predictability, an essential factor for research investment and innovation. Scientists and companies that complied with the 2021 framework and developed validated formulations are now left uncertain about the continuity of policy. This uncertainty discourages future investments and undermines confidence in India's otherwise progressive agricultural governance.

Why Policy Reconsideration Is Warranted

A science-based reconsideration of the 2025 notification would serve several crucial purposes:

1. Restoring Policy Coherence:

The current FCO allows animal-based organic fertilizers such as bone meal and fish meal. Prohibiting protein hydrolysates derived from similar sources creates inconsistency. Aligning the regulation across categories would ensure internal coherence and prevent arbitrary exclusions.

2. Encouraging Circular Economy:

Protein hydrolysates of animal origin are often produced from collagenous byproducts of meat or leather industries, materials that would otherwise contribute to environmental waste. Their utilization as biostimulants exemplifies circular economy principles, turning waste into value.

3. Strengthening Climate-Resilient Agriculture:

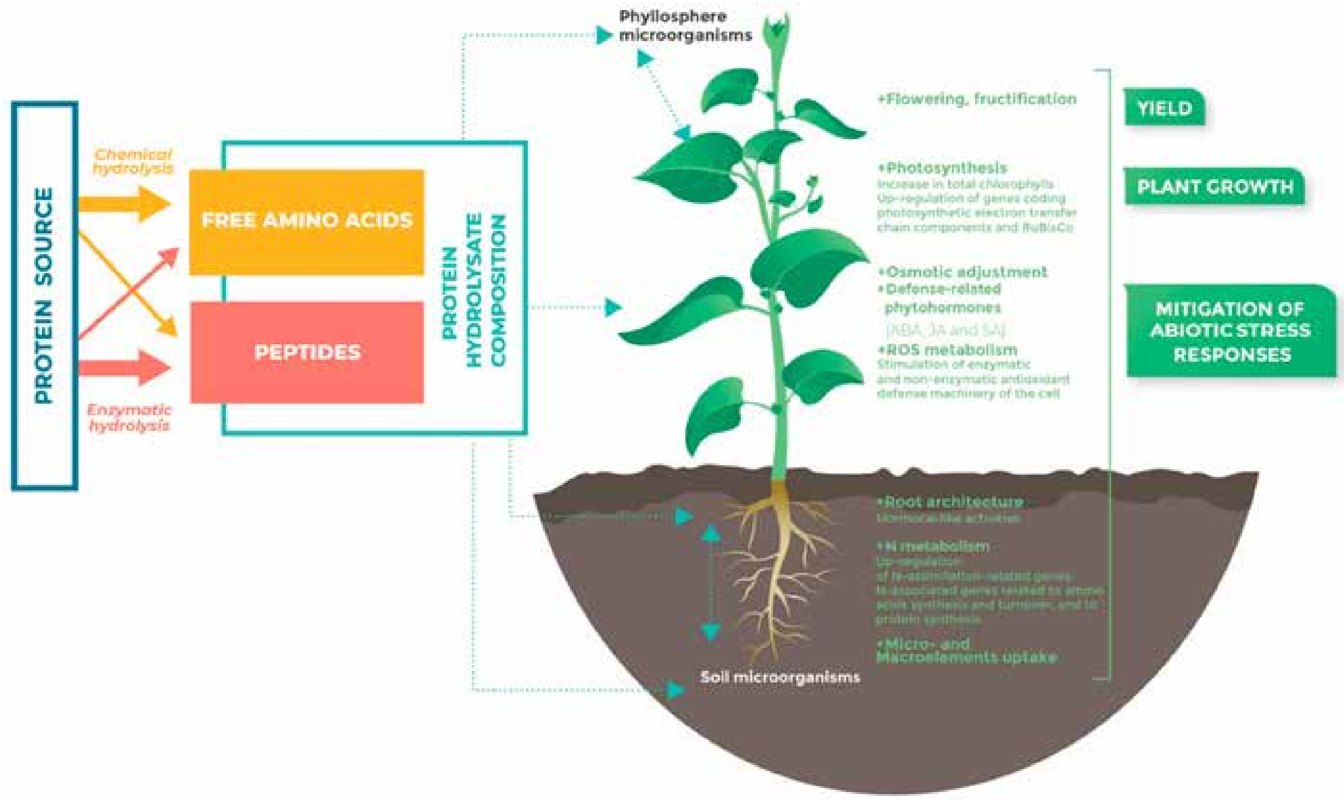
PH-based biostimulants improve nutrient efficiency and crop resilience, thereby reducing dependence on chemical fertilizers. Revoking them without scientific cause risks slowing progress toward the government's sustainability goals under the National Mission on Sustainable Agriculture.

4. Protecting Farmer Interests:

Farmers are the ultimate beneficiaries of science-led reforms. Limiting access to safe, effective biostimulants curtails their ability to manage stress-prone crops efficiently. Ensuring product diversity and choice fosters innovation and economic benefit at the farm level.

5. Safeguarding India's Scientific Integrity:

India's reputation as a science-respecting nation depends on consistent, transparent regulatory decisions. Reversing the recent ban based on evidence would reaffirm that India's policies are guided by reason and not rhetorically.



The Way Forward: A Constructive Path

- A balanced resolution is well within reach. The government could consider the following steps to restore confidence while maintaining public trust:
- Constitute a technical review committee under the INM Division to re-examine the scientific data on protein hydrolysates of animal origin, including toxicology and environmental impact.
- Invite public and scientific representations to ensure transparency and address any ethical or religious concerns through dialogue rather than prohibition.
- Reinstate the approved formulations that had earlier cleared the multi-tier scientific scrutiny under the 2021 framework, pending any new evidence to the contrary.
- Develop clear labelling guidelines to distinguish plant- and animal-derived formulations, allowing informed choice by users without denying access to proven technologies.

Such measures would demonstrate that India's policy system is both responsive and rational. It can accommodate cultural diversity while remaining steadfastly anchored in scientific logic.

Conclusion: Let Science Lead

Protein hydrolysate-based biostimulants, whether derived from plants or animals, represent a class of safe, sustainable, and scientifically validated agricultural technologies. Their prohibition on non-scientific grounds risks undermining India's progress toward sustainable intensification and nutrient efficiency. The issue at hand is not one of faith versus science, but of ensuring that public policy respects both belief and evidence in their rightful domains. India has long shown that science and culture can coexist harmoniously when guided by rational governance. Revisiting the 2025 notification with an open, evidence-based approach would not only correct a policy inconsistency but also reaffirm India's leadership in sustainable agriculture. In doing so, the government would send a message loud and clear, that its decisions concerning farmers welfare, environment safety, and agricultural innovation in India will continue to be guided by science, transparency, and national interest.

MIONP

A Mission to Make India Organic, Natural & Profitable by 2047

A Holistic Roadmap for Accelerated, Scientifically Validated, Farmer-Led Transformation

India stands at a critical crossroads in agriculture. With declining soil fertility, increasing input costs, stagnant yields, and rising consumer demand for safe and nutritious food, the country must urgently shift toward sustainable and profitable farming systems. Prime Minister Narendra Modi has recently emphasized the need to reduce chemical dependency without compromising farmer income or food security. Aligning with this vision, Mission 2047: MIONP (Make India Organic, Natural & Profitable) provides a structured pathway to transition India into a global hub of sustainable agriculture while ensuring profitability from the first crop cycle.

Organized by **Krishi Jagran,** supported by bio-input Industry, and guided by global expertise, MIONP aims to make India a **$1 trillion sustainable agriculture export powerhouse** by 2047.

Why MIONP Is Critical in the Current Situation

1. Soil degradation has reached alarming levels

- Continuous use of chemical fertilizers has reduced organic carbon to 0.3–0.5% in many regions—far below the ideal 5–7%.
- Soil porosity, microbial life, and water-holding capacity have drastically declined, reducing resilience to droughts and floods.

2. Farmer profitability is under pressure

- Chemical input costs have risen 25–40% in five years.
- Returns per acre are stagnating due to soil fatigue and stress-prone crops.
- Farmers need cost-reduced, yield-stable solutions.

3. Water scarcity is now a national challenge

- Over-extraction of groundwater and inefficient farming practices demand immediate adoption of water-efficient, soil-reviving technologies.

4. Global markets are shifting toward organic and residue-free food

- India has the potential to lead but needs scientifically validated, scalable, farmer-friendly protocols.

5. Fragmented efforts are slowing adoption

Fmr. M C Dominic
Krishi Jagaran Group

Dr Ajay Ranka
CMD Zydex Group

Although multiple states and organizations promote natural farming, lack of scientific validation, inconsistency in field results, and absence of standardized protocols restrict widespread adoption.

MIONP aims to directly address these gaps with a unified, validated, farmer-centric model.

With a science based, farmer centric approach with universal adaptability, MIONP will become a gamechanger for Faster, Large-Scale Farmer Adoption.

1. Focus on "One Crop cycle, Profitable Transition"

Instead of long conversion periods, MIONP ensures that farmers see:

- Equal or higher profits in the very first season
- No dependence on "organic premium"
- Reduced input cost and improved soil performance

2. Scientific Validation by ICAR and KVKs

All technologies, inputs, and protocols need to be tested and validated by ICAR Institutions or State Agriculture Universities through KVKs in real farmer fields

This removes uncertainty and builds farmer confidence.

3. A Grand Challenge that brings all solutions to one platform

Eight companies have already joined, with more expected.

Demonstrations across 20 key crops (listed below) and 10 agro-climatic zones will showcase:

- 50% reduction in chemical inputs
- 75% reduction in chemical inputs
- 100% chemical-free protocols

all while maintaining profitability.

- **Field crops:** Paddy, Corn, Groundnut / Soybean, Wheat, Mustard, Tobacco
- **Cash crops / Vegetables:** Sugarcane, Cotton, Banana, Potato, Tomato, Brinjal, Okra, Chilli / Capsicum, Onion / Garlic, Turmeric / Ginger
- **Orchards:** Mango/ Litchi, Orange / Kinnow, Pomegranate, Guava

4. Technology + Tradition = Scalable, practical solutions

All key parameters which will be helpful in large scale adoption by farmers are considered:

- Enhanced FYM quality
- Biofertilizers and biopesticides
- Stress management products
- Traditional seeds
- AI/Digital advisory systems
- Water conservation protocols

These all parameters have the ability of collectively creating a system which farmers can adopt quickly.

A Holistic Roadmap for MIONP: Roles, Validation, and Implementation

To find the best and most suited protocol for profitable transition, there is a need of a holistic approach for Demonstration and Validation of various protocols and practices which will require participation of all stakeholders with a clear mandate/ role. The below action plan is defined for execution.

1. Comparative Evaluation of All Technologies

Every product and protocol—whether from industry, FPOs, NGOs, or farmer innovators—will be:

- Demonstrated in farmer fields
- Compared against existing farmer practice
- Monitored using a uniform scientific matrix
- Validated by ICAR and KVKs

Best-performing, consistent protocols will be selected for national scaling.

Scientific Validation Matrix for All Demonstrations

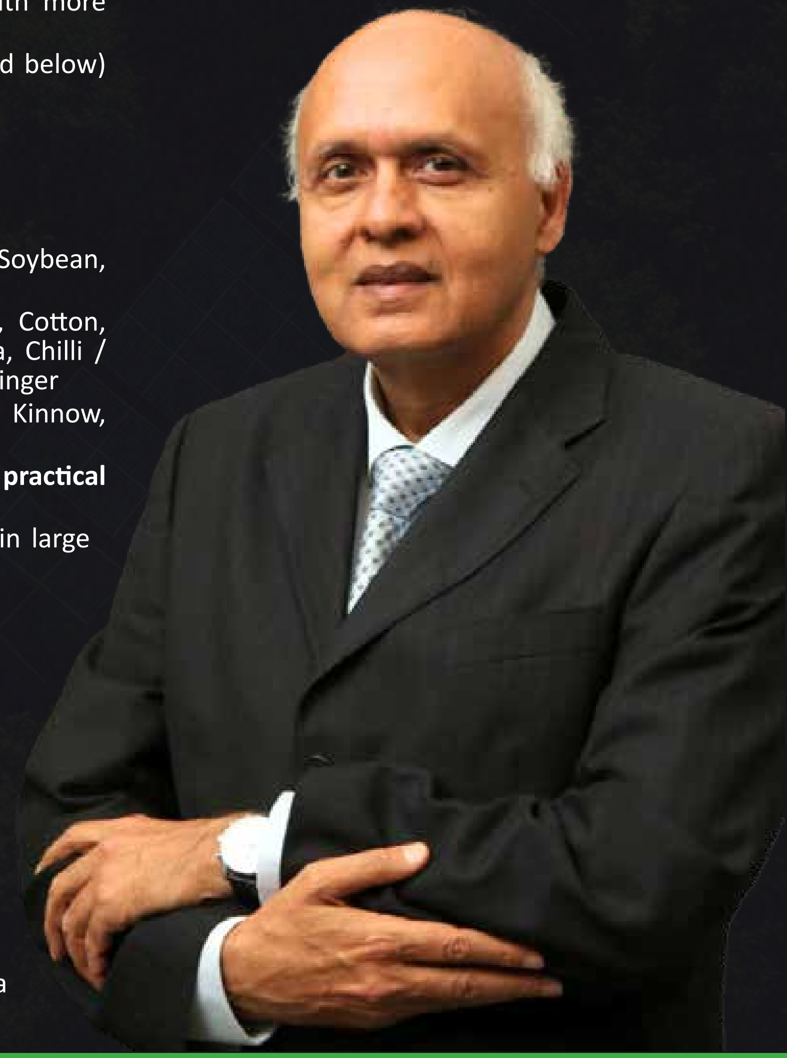
A. Cost of Cultivation

- Full labour cost + Input cost (FYM, biofertilizers, biopesticides, cow-based inputs, stress management products)

B. Water Management

- Water savings achieved (Number of irrigations reduced)

C. Soil Health (Pre & Post)



- Soil Porosity, Softness, Carbon content, Microbial biomass, Gas exchange capacity, EC/ Salinity

D. Crop Productivity

- Germination, Mortality; Height, canopy, biomass; BRIX value; Yield; Nutritional profile - Produce quality (shape, size, colour, taste)

E. Chemical Residue Analysis

- Chemical residue in Soil as well as in Crop (grain/ fruit, straw)

F. Scalability Indicators

- Protocol ease-of-use; Product availability; Suitability for small & large farmers; Compatibility with mechanization

Roadmap: Stakeholder-Wise Expectations for Action Plan

1. Private Companies & Start-ups

(Examples already participating: Zydex, Alga Energy, Biome Technologies, Glow Green Biotech, Varsha Bioscience, Tropical Agro, Ashwathy Green Enterprise, VJ Agrohomeopathy, Sribio)

Action Points:

- Provide 50–100 demonstration plots with farmer-side-by-side comparison.
- Ensure easy-to-use, affordable, scalable products.
- Share all data transparently for ICAR validation.
- Collaborate with farmer organizations for on-ground capacity building.
- Develop crop-wise, region-wise profitable transition protocols.

2. Farmer Producer Organizations (FPOs) & Cooperatives

Action Points:

- Mobilize farmers for village-level demonstrations.
- Collect high-quality data from each plot.
- Facilitate input supply and training.
- Setup aggregation and marketing systems for residue-free/chemical-light produce.
- Work with KVKs to support farmer education through field schools.

3. Farmers & Farmer Groups

Action Points:

- Participate actively in demonstrations.
- Maintain protocols as instructed to ensure valid results.
- Compare outcomes with existing practices.
- Adopt the best-performing, low-risk, profitable models.
- Provide feedback to KVKs and companies for protocol refinement.

4. NGOs, Cooperatives, and Civil Society

Action Points:

- Support awareness creation through local outreach.
- Facilitate smallholder inclusion and women farmer participation.
- Connect farmers to markets, certification bodies, and exporters.
- Help implement agri-tourism models suggested in MIONP.

5. Government of India

Action Points:

- Approve and fund the Grand Challenge as a national program.
- Enable ICAR/KVK-led validation of technologies.
- Create policies supporting profitable transition (input support, training, certification).
- Build organic and natural farming clusters in high-potential regions.
- Facilitate farmer incentives for soil carbon improvement and water conservation.
- Create export pathways for chemical-free produce.

6. ICAR, KVKs & State Agricultural Universities

Action Points:

- Lead scientific evaluation of all protocols submitted under the Grand Challenge.
- Standardize field trial formats across locations and crops.
- Publish transparent performance reports after each season.
- Train FPOs, extension workers, and private partners.
- Maintain demonstration plots in at least 20 focus crops across agro-climatic zones.

7. Global Partners (Denmark, Bhutan, New Zealand etc.)

Action Points:

- Provide technical guidance on large-scale organic transitions.
- Share best practices in biomass management, simplified protocols, labour efficiency.
- Collaborate on carbon credits, sustainability financing, and global marketing.

The Way Forward: A National Movement for a Profitable Jaivik Bharat

MIONP is more than a program—it's a movement to transform Indian agriculture by 2047 through:

- Scientific validation
- Large-scale demonstrations
- Multi-stakeholder collaboration
- Profit-led farmer adoption
- Global leadership in sustainable agriculture

The success of MIONP will depend on **credibility, transparency, consistency, and scale.** With India's agricultural institutions, private innovators, farmer organizations, and global partners working together, India can truly achieve a **"Jaivik, Natural & Profitable Bharat"**—while feeding the world with safe, nutritious, sustainable produce.

Building India's Next-Generation Food System

Dr. Smita Sirohi
ICAR-National Professor,
MS Swaminathan Chair and former JS (G20), DAF&W

India's Reform Wave in Agri-Food System

India's agri-food landscape is undergoing a remarkable transformation. In recent years, there has been a wave of national initiatives—each aimed at improving productivity, sustainability, farmer incomes, and nutritional security. From dietary diversification to digital agriculture, ecological transitions to institutional strengthening, the country is laying down the building blocks of a more modern and resilient food system.

One of the most visible shifts has been the renewed emphasis on nutrition-sensitive crops. The International Year of Millets in 2023 catalysed unprecedented global and domestic attention, with states launching dedicated millet missions, investing in value-chain development, and integrating millets into anganwadi meals, public distribution systems, and school meals. Alongside this, the ongoing national focus on pulses - including MSP support, cluster development, procurement expansion and launch of National Mission on Pulses — marks a significant step toward improving protein security and addressing India's long-standing pulse deficit.

India is also witnessing a quiet but powerful agro-ecological transition. Government schemes like the Bhartiya Prakritik Krishi Paddhati (BPKP), alongside grassroots models such as Andhra Pradesh's community-led natural farming, are gaining ground. These approaches aim to reduce input costs, restore soil health, revive biodiversity, and help farmers adapt to growing climate risks—all while aligning with regenerative principles.

Institutional innovations are reshaping rural economies. The establishment of a dedicated Ministry of Cooperation and efforts to modernise Primary Agricultural Credit Societies (PACS) signal a new emphasis on collective action. From dairy and horticulture to tribal and women-led cooperatives, these structures are being positioned as engines of aggregation, processing, and market access. Complementing this, the government's flagship initiative to promote 10,000 Farmer Producer Organisations (FPOs) is building farmer-led institutions that can access credit, adopt technology, and participate more meaningfully in processing and value addition.

Meanwhile, the digital transformation of Indian agriculture is accelerating at an unprecedented pace. Innovations such as drone-based crop monitoring, AI/ML-powered forecasting, real-time market advisories, and emerging Digital Public Infrastructure (DPI) are rapidly reshaping how farmers plan, irrigate, protect, store, and market their produce. State-level pilots on AgriStack are creating new possibilities for personalised services and data-informed decision-making at scale.

These shifts are further supported by a growing focus on water-use efficiency and climate resilience. Programmes such as the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), expansion of micro-irrigation, solar-powered pump schemes, watershed development, and distribution of soil health cards are gradually making India's agriculture more climate-smart. Investments in resilient seeds, carbon-neutral practices, and ecosystem-based approaches indicate a long-term vision for sustainable food production.

Taken together, these developments represent not just incremental reforms but a meaningful shift in India's approach. India is no longer tinkering at the margins—it is reimagining how food is grown, processed, distributed, and consumed.

II. Why Linkages Matter: The Hidden Power of Convergence

The ongoing initiatives are promising, diverse, and individually impactful. Yet their transformative potential will remain limited unless they are better aligned with one another. The real promise of these efforts lies not in their scale alone, but in their synergy—the ways in which one initiative reinforces another to unlock outcomes far greater than what any single scheme can deliver.

For instance, the success of millets and pulses in enhancing nutritional security and climate resilience depends on much more than increasing production. Without stable market linkages, accessible processing infrastructure, and institutional procurement that drives consumption—through ICDS, PM-POSHAN, or public food systems—their adoption by farmers and uptake by consumers will remain constrained.

At the same time, India's flagship nutrition programmes—like ICDS and school meals—are most effective when closely linked to local agriculture, livestock, horticulture, and food safety systems. When supply chains and production systems are aligned with dietary needs, these programmes can nourish communities while revitalising rural livelihoods.

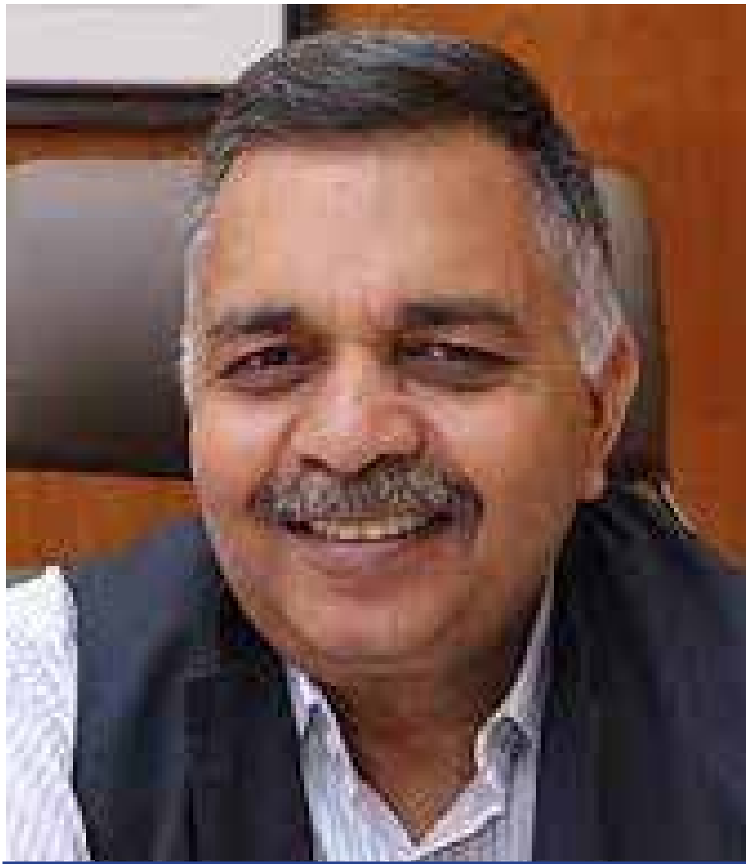
Natural farming offers another compelling example. Its expansion hinges on multiple support systems: water management for ecological balance, timely climate advisories to reduce risks, and downstream value-chain investments to ensure that farmers can command a fair price. Without these connections, natural farming risks becoming an underfunded aspiration.

The momentum around FPOs and cooperatives is similarly contingent on convergence. These institutions can transform the rural economy, but only when backed by complementary interventions—credit flows, digital tools, logistics, branding, and decentralised governance mechanisms that help them scale and sustain operations.

These examples, and many more point to a broader insight: India's food-system outcomes—nutritious diets, climate-resilient production, water stewardship, safe markets, and thriving rural incomes—lie at the intersection of multiple sectors.

III. From Parallel Pathways to Purposeful Integration: The Food Systems Lens

Food systems, by their very nature, span multiple domains—agriculture, nutrition, health, water, environment, logistics, food safety, education, rural development, and markets. Yet, these are managed through distinct ministries, departments, and delivery structures, each operating with separate mandates and priorities. While this sectoral fragmentation is administratively convenient, it can result in five



Pawan Agarwal
CEO
Food Future Foundation and Former CEO FSSAI

predictable governance failures:

- **Contradictory policies:** For example, crop incentives that promote water-intensive staples may conflict with groundwater conservation efforts.
- **Inconsistent implementation:** Programme delivery may vary widely across States and districts, depending on administrative capacity, political priorities, and coordination.
- **Overloaded local institutions:** Panchayats and municipal bodies often receive multiple schemes through separate channels, with little guidance on how to align or prioritise them.
- **Siloed data systems:** Disparate information streams make it difficult to forecast risks, track outcomes, or design integrated solutions that respond to real-world complexity.
- **Limited stakeholder voice:** Farmers, youth, vendors, processors, and civil society rarely have structured opportunities to participate in shaping policy or evaluating what works.

These issues are not simply administrative—they have real-world consequences. A nutrition intervention that doesn't align with local agricultural supply may rely on costly, centralised procurement. A climate-smart farming programme without water coordination can aggravate local scarcity. A food safety initiative launched without market infrastructure support may falter at the first step of implementation.

In short, India's current governance architecture is not designed to deliver coherent, cross-cutting food system outcomes. It excels at managing schemes in silos but struggles to resolve interdependencies and trade-offs. The result is duplication, inefficiency, and missed opportunities.

Recognising and correcting this fragmentation is now the next frontier of India's agri-food transition. The building blocks are in place. The challenge is to organise them into a coherent, resilient, and inclusive architecture.

IV. Riding the Global Wave: India's Moment to Lead

India is not alone in confronting the complexity of food system transformation. In the aftermath of the UN Food Systems Summit (UNFSS) 2021, countries across the world have begun to rethink how they govern food and agriculture-not just as sectoral domains, but as integrated systems that touch health, environment, equity, and economic development.

Since the Summit, at least 17 countries have created or strengthened national food system coordination mechanisms, and 34 now operate with multi-sectoral structures. Countries as diverse as the UAE, Japan, Mexico, Rwanda, Brazil, and members of the European Union have adopted integrated governance approaches to align production, nutrition, environmental sustainability, and market access.

These are not cosmetic changes. They represent a fundamental recognition: that food systems are central to achieving national development goals, climate commitments, and public health outcomes—and that fragmented governance is a structural bottleneck.

India is uniquely placed to build one of the world's most impactful food system coordination models. Its vast federal structure, institutional depth, and ambitious reform agenda offer both scale and experience. More importantly, India is already demonstrating global leadership in areas like millets revival, digital public infrastructure, and climate-smart agriculture.

What is now needed is a governance architecture that ties these innovations together—not just for internal coherence, but also to signal to the world that India is ready to lead by example.

If India moves decisively now, it will not only improve outcomes for its own citizens—it will become a reference point for other nations navigating similar transitions. The moment is ripe. The direction is clear. What remains is the political will to make coordination a national priority.

V. Conclusion: Coherence Is the Next Frontier

India already has what many countries are still striving to build: a robust agricultural foundation, a vibrant rural economy, a growing base of farmer institutions, and a strong reform agenda. However, the outcomes we seek—nutritious diets, sustainable water use, resilient agriculture, rural prosperity—depend on how well the efforts are aligned across the system.

The challenge is no longer about launching more programmes. What India needs now is a systems perspective and governance mechanism that can connect the dots.

By embracing a food systems governance perspective, India has the chance not just to improve outcomes at home, but to become a global leader in sustainable, equitable, and resilient food systems. The moment is right. The world is watching. It is time to lead with clarity, coordination, and conviction.

Renewable Energy
The Changing Paradigm

Col Sandeep Singh (Veteran)
Founder
Saansera Farm2Fuel Solutions Pvt Ltd

Introduction

Agriculture has always been the lifeline of India, feeding the nation, employing millions, and shaping the fabric of our rural economy. Yet, over the years, Indian farmers have continued to struggle with rising input costs, shrinking margins, unreliable energy access, and the growing impact of climate change For centuries, our farmers have relied on nature i.e. the sun, wind, and water – for their livelihood. Ironically, these very natural forces are now reshaping agriculture again, this time through renewable energy.

A quiet transformation, is taking place in our fields. Renewable energy, particularly biomass-based solutions, is emerging as a key enabler of agricultural growth, rural entrepreneurship, and environmental sustainability. It represents a new way of looking at farming, not only as a source of food, but also as a source of clean energy and economic empowerment.

Today, renewable energy is not just about reducing carbon emissions or saving the planet. It has become a powerful catalyst for rural transformation and agricultural growth. Let's look at how this silent revolution is unfolding across our farms and villages.

Powering Farms with the Sun

Solar energy is emerging as a game-changer for farmers. Solar-powered pumps have reduced dependence on erratic electricity and expensive diesel. Farmers can now irrigate their fields when needed, without waiting for power supply schedules.

In many villages, community solar plants are enabling energy farming, where farmers not only grow crops but also generate power to sell to the grid. This dual-income model is slowly turning farmers into energy entrepreneurs.

Biomass – The Hidden Wealth of Our Farms

Every agricultural cycle produces large quantities of residues, paddy straw, sugarcane trash, cotton stalks, maize cobs, mustard husk, and other crop remains. For decades, farmers viewed these residues as a nuisance, quickly clearing them through open burning to prepare fields for the next sowing season.

While expedient, stubble burning has devastating consequences. It degrades soil fertility, destroys vital microorganisms, and releases harmful gases into the atmosphere. The very act that was meant to prepare the land for life ends up polluting the air we breathe.

Yet, this same residue, when managed wisely, holds immense potential. Agricultural waste is rich in energy content and can be transformed into valuable fuel forms such as briquettes, pellets, biogas, and bio-CNG. This clean energy can power industries, generate electricity, and reduce the nation's dependence on fossil fuels.

However, to realize this potential, India must solve one critical challenge, the aggregation of biomass.

The Power of Aggregation

Biomass aggregation is the process of collecting, processing, and transporting dispersed agricultural residues from individual farms into an organized supply chain. Each farmer, on their own, generates only a small quantity of residue. But when the efforts of hundreds of farmers are aggregated through a structured model, the volumes become commercially viable.

Aggregation not only ensures a consistent and quality supply of biomass to energy users but also opens up a new income stream for farmers. It is this principle of organization and scale that is transforming the rural energy landscape today.

One company at the forefront of this transformation is **Saansera Farm2Fuel Solutions Pvt Ltd (SFSPL)**.

Economic and Environmental Impact

The benefits of the aggregation model extend far beyond the immediate financial gains. Farmers can earn ₹3,000–₹10,000 per acre per season by selling residues that were once discarded. This additional income helps offset rising input costs and strengthens rural purchasing power.

On the environmental front, biomass aggregation contributes significantly to reducing carbon emissions and curbing air pollution caused by stubble burning. The controlled removal and reuse of crop residues improve soil fertility, water retention, and microbial activity. Moreover, when biomass replaces coal or diesel in industrial applications, it contributes to India's national clean energy and climate action targets.

The Farm Level Youth (FLY) Model – Empowering Rural India

The FLY model is built on a simple yet powerful idea, rural youth as energy entrepreneurs. Under this initiative, SFSPL identifies and trains young individuals in villages to become local aggregators of biomass.

These trained "FLYs" are equipped with small machinery for shredding, baling, and transporting agricultural residues. They collect the waste directly from farmers' fields, store it, and deliver it to processing units or biomass-based power plants.

This decentralized model creates a seamless connection between the farmer and the energy producer. It generates multiple layers of value:

- **For Farmers:** Additional income through the sale of agri residues, eliminating the need for burning.
- **For FLYs:** Employment, entrepreneurship, and dignity of labour within their own villages.
- **For Industries:** A steady, traceable, and cost-

effective supply of quality biomass.

- **For the Environment:** A dramatic reduction in carbon emissions and rural air pollution.

Through this model, SFSPL has trained and empowered hundreds of rural youths, creating livelihood opportunities while promoting environmental stewardship.

Technology as a Force Multiplier

To manage such a dynamic and complex supply chain, SFSPL employs advanced technologies including Artificial Intelligence (AI), Data Analytics, Geographic Information Systems (GIS), and Remote Sensing.

These tools enable the company to map biomass availability, forecast seasonal variations, assess logistics costs, and monitor ground operations with precision. AI-driven analytics provide actionable insights, ensuring that every stage of the biomass journey , from farm to factory , is efficient and transparent.

By integrating technology with rural entrepreneurship, SFSPL has built a smart, scalable, and sustainable model that can be replicated across geographies.

A Circular Rural Economy

The ripple effect of biomass aggregation extends into multiple sectors. It encourages the establishment of rural-based industries for briquetting, palletisation, and bio-CNG production. It promotes entrepreneurship in logistics, equipment leasing, and warehousing. It engages women's self-help groups, local cooperatives, and small enterprises.

In essence, biomass-based renewable energy is creating a circular rural economy, one where every stakeholder benefits, and every residue has value.

Building Rural Resilience

Renewable energy is empowering rural India in more ways than one. Decentralized energy systems ensure uninterrupted power for cold storage, irrigation, and processing units.

This reduces post-harvest losses, improves market access, and adds value to agricultural produce. Most importantly, it gives farmers independence from unreliable infrastructure and unpredictable costs.

A New Paradigm for Agriculture

The synergy between agriculture and renewable energy marks a fundamental shift in India's development story. Farmers are no longer just consumers of energy; they are becoming its producers. Their fields are not only feeding the nation but also fuelling its clean energy transition.

This shift represents a paradigm change, one that integrates economic growth, environmental stewardship, and social inclusion.

The Road Ahead

The synergy between agriculture and renewable energy offers an exciting opportunity for India. It's time to view energy not as a utility, but as an enabler of growth, innovation, and dignity in farming.

When farmers become active participants in the clean energy transition, rural India will not just feed the nation, it will also fuel its future.

Conclusion

Renewable energy is more than a technology; it is a philosophy of sustainable living. When harnessed effectively, it brings light to rural homes, power to farms, and dignity to those who work the land.

The aggregation of biomass and the empowerment of rural youth are not just solutions to pollution, they are pathways to inclusive growth. As models like SFSPL's continue to expand, India moves closer to a future where agriculture and renewable energy together drive the nation's progress.

In essence, renewable energy is not just about light or power; it's about hope. It's about giving our farmers control over their resources, their incomes, and their destiny.

The paradigm has truly shifted, from agriculture depending on energy, to agriculture driving energy.

Renewable Energy
Integration in Agriculture

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Agriculture is the backbone of India's rural economy, employing nearly 42% of the workforce and accounting for about 85% of freshwater withdrawals. Coverage of irrigation area increased between 2016 and 2021 from 49.3 to 55% of gross cropped area. Irrigation reliability, however, depends on access to affordable and dependable energy. The agricultural sector in India consumes nearly 20% of total electricity and a large share of diesel fuel, primarily for irrigation pumping and this has led to high fiscal stress, inefficient water use, and unsustainable groundwater extraction. For decades, expansion of irrigation relied on canals, diesel pump-sets, and heavily subsidized grid power. As climate variability, groundwater depletion, and energy subsidies strain both ecosystems and state budgets, renewable energy (RE) offers a transformative opportunity to decouple irrigation growth from fossil dependence. The renewable energy transition aligns with India's commitments under the Paris Agreement and the Nationally Determined Contributions targeting 50% of cumulative power capacity from non-fossil sources by 2030. In agriculture, it promises a dual dividend: energy self-sufficiency for irrigation and decarbonization of a high-emission sector. The adoption of RE technologies, especially solar photovoltaic (PV) irrigation pumps, agrivoltaics, canal-top and floating solar, and biomass-based micro-grids—marks a structural shift toward sustainability and circular resource use.

Agricultural power demand in India is approximately 280 TWh/year, with more than 21 million electric and 8 million diesel pumps in operation. The sector contributes about 17% of national CO_2 emissions through diesel use and embedded electricity. Subsidized tariffs result in annual fiscal burdens exceeding ₹1 lakh crore for state utilities. Furthermore, erratic grid supply, often at night, causes over-pumping and inefficient irrigation practices. PM-KUSUM and the State Solar Policy should offer strategic levers to mainstream decentralized RE in irrigation. Research on the water–energy nexus in agriculture highlights both opportunities and risks of renewable integration. This has been reported that solar pumps under Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) increased irrigation reliability and cropping intensity by 20-25% in semi-arid regions. Many researchers emphasized that cheap solar irrigation can empower smallholders but requires groundwater governance to prevent over-extraction. More recent experiments in Gujarat, Rajasthan, and Jharkhand show the techno-economic viability of solar-powered drip irrigation and community-owned micro-grids for tribal farmers.

Solar Photovoltaic (Solar-PV) powered pumps, micro-grids, and canal-top systems are now mature technologies. Component B of PM-KUSUM targets 1.4 million stand-alone solar pumps, while Component C promotes feeder solarization for daytime supply. Bio-gas and biomass gasifiers can fuel micro-irrigation pumps and farm machinery while utilizing crop residues. Digestate (nutrient-rich by-product of anaerobic digestion) from biogas plants improves soil fertility and reduces synthetic fertilizer dependence. Small-hydro units along canal falls and minor dams can complement solar variability. Pumped-storage or hybrid micro-grids integrating Solar PV and hydro can ensure continuous operation for irrigation cooperatives. Agrivoltaic systems elevate solar panels 3-5 m above the field, allowing simultaneous electricity and crop production. Pilot projects at Coimbatore and in Gujarat show increased water productivity by up to 45%. Soil-moisture sensors and remote pump controllers optimize irrigation schedules; start-ups like Kheyti and Fasal integrate these with solar units. International Water Management Institute pilot project in Bihar and Jharkhand show that solar-irrigation service companies operating cooperative models can ensure equitable access. These innovations show that the next stage of RE growth in agriculture will be data-driven, modular, and digitally connected.

As far as economic and environmental implications are concerned, solar-pump levelized cost of irrigation is ₹1.5–2.0 per m³ of water compared to ₹4–6 for diesel. Even after accounting for capital costs (₹2–3 lakh per pump), payback is under four years with subsidies or feeder solarization. At system level, each MW of decentralized solar offsets ~1,000 t CO_2 per year. Unregulated solar pumping may increase water abstraction. Studies recommend linking pump capacity to groundwater zoning and encouraging solar-power buy-back so that surplus energy, not water, is sold. Combining solar with drip or sprinkler systems can reduce water use by 30-60%, protecting aquifers. Despite all these advantages, the sector suffers from challenges also. Small farmers lack upfront capital even with 60-70% subsidy. Absence of volumetric limits, metering, and aquifer-level planning can negate RE's benefits. Only a few states offer fair tariffs for excess solar power; regulatory uniformity is needed. Accredited local technicians are to be nurtured.

A basin-wise plan aligning renewable-energy deployment with groundwater potential is crucial. There is a need for convergence of PM-KUSUM and Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). Schemes should be implemented jointly, treating solar, microirrigation and soil-moisture sensors as one package. This "per-drop-per-watt" approach could be piloted in rainfed areas. Cluster-based solar irrigation cooperatives financed through NABARD's Micro-Irrigation Fund must be promoted. Public Private Community Partnerships for canal-top projects may be encouraged. CSR funds from mining and power companies earmarked for solar irrigation demonstration units should be planned.

Finally, renewable energy integration into India's agricultural and irrigation systems represents a structural transformation from resource exploitation to resource regeneration. Solar, bio-, and small-hydro technologies can jointly deliver reliable, clean, and affordable power for irrigation while enabling climate-resilient agriculture. The challenge is institutional and not technical. The energy policy, water governance, and agricultural planning must be aligned. RE-based irrigation can drive both productivity and equity. The path forward lies in coupling technology with governance—deploying solar where water is sustainable, enforcing groundwater caps, incentivizing micro-irrigation, and integrating data systems. A state-specific mission linking PM-KUSUM and PMKSY can make RE the cornerstone of rural growth. Ultimately, renewable energy in irrigation is not merely an energy substitution; it is a new paradigm—transforming how water, land, and livelihoods interact in the era of climate change. Renewables are not just a new power source for Indian farms; they are a new operating system for irrigation.

Sunlight to stubble,

Every element of the farm is part of new energy revolution

Green Revolution Reimagined

Agriculture, the backbone of human civilization, is once again at the heart of transformation. As the world grapples with rising energy demands, shrinking resources, and the effects of climate change, a new vision is taking root: farms that not only grow food but also generate clean energy. From sunlit fields to biogas digesters and ethanol refineries, renewable energy is redefining how we cultivate, process, and sustain agriculture in the 21st century.

Energy–Agriculture Connection

Energy drives every facet of farming, powering irrigation pumps, processing machines, cold storages, and transportation networks. Yet, traditional dependence on diesel and coal has left agriculture vulnerable to price shocks and carbon emissions. Globally, agriculture accounts for nearly 30% of total energy consumption and one-fifth of greenhouse gas emissions. The answer lies in shifting to renewable energy, turning farmlands into hubs of both food and power production.

Harvesting the Sun: Solar Power for Smarter Farming

Solar energy has become the face of the clean energy revolution in agriculture. Across India and many developing regions, solar irrigation pumps are freeing farmers from expensive diesel fuels while ensuring reliable water access.

Under schemes like PM-KUSUM, farmers can now sell surplus solar electricity back to the grid turning their fields into "energy farms." In cold desert regions like Ladakh and the Himalayas, solar greenhouses are extending the growing season, enabling year-round vegetable production where frost once limited cultivation.

Wind and Hybrid Systems: Power in Motion

While the sun rests, the wind works. Wind energy, particularly when combined with solar systems, ensures round-the-clock energy supply for rural operations.

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In India's coastal and arid belts, farmers are installing solar–wind hybrid systems to power drip irrigation, grain mills, and dairy units. These hybrid setups are resilient to seasonal changes and require minimal maintenance, fit for decentralized, small-scale farming.

Turning Waste into Wealth: Biogas and Biomass

In rural areas, what was once considered waste is now becoming a valuable energy resource. Biogas plants transform cattle dung, crop residues, and kitchen waste into clean fuel for cooking and electricity.

The leftover slurry serves as an excellent organic fertilizer, enriching soil fertility while reducing chemical dependence. Large dairy farms, for instance, can run entirely on biogas energy, making them carbon-neutral enterprises. Similarly, biomass gasifiers can convert crop residues, rice husk, sugarcane bagasse, or maize stalks, into electricity and heat, providing a clean alternative to open-field burning.

Ethanol: Fuelling the Future from the Farm

Among renewable biofuels, ethanol stands out as a strategic link between agriculture and clean energy. Produced mainly from sugarcane, maize, and damaged food grains, ethanol can replace petrol in transport and reduce carbon emissions significantly.

India's National Biofuel Policy (2018) and Ethanol Blended Petrol (EBP) Programme aim to achieve 20% ethanol blending by 2025, creating a massive opportunity for farmers and agro-industries.

Beyond fuel, ethanol production also generates valuable by-products, distillers' dried grains and press mud, used as livestock feed and organic manure. Modern "second-generation" ethanol plants even utilize crop residues like rice straw, helping curb stubble burning while generating clean energy.

Ethanol thus represents a circular economy model where agriculture powers transportation and industry, and the by-products return to enrich the soil.

Hydropower and Micro-grids: Energy for the High Lands

In hilly and remote terrains, micro-hydropower projects are lighting up villages and powering small agro-industries. When combined with solar micro-grids, they provide reliable power for irrigation, milling, and refrigeration without depending on distant power stations. These systems not only bring energy independence to farmers but also foster community ownership and employment in rural areas.

Smart Farming Meets Clean Energy

Renewable energy and digital agriculture are merging into a powerful duo. Solar-powered IoT sensors now track soil moisture and trigger irrigation only when needed. Drones, powered by lightweight solar batteries, survey crops and apply fertilizers with pinpoint accuracy. From automated greenhouses to renewable-powered cold chains, the next wave of agri-innovation is both energy-smart and climate-resilient.

The Payoffs: Economic, Environmental, and Social

The benefits of renewable energy in agriculture extend far beyond the farm gate:

- **Economic resilience:** Farmers save on fuel costs and earn additional income by producing energy.
- **Environmental gains:** Lower emissions, reduced pollution, and improved soil and water quality.
- **Social empowerment:** Decentralized systems democratize access to energy and create rural jobs.

Challenges and the Road Ahead

Despite its promise, the renewable energy transition faces challenges like high initial investment, limited technical capacity, and policy hurdles. Expanding access to credit, training rural youth, and promoting energy cooperatives can accelerate adoption. Collaboration among research institutions, governments, and local communities will be crucial to scale renewable solutions tailored to regional conditions.

Cultivating the Energy of Tomorrow

Renewable energy isn't just a supplement to agriculture, it's a new paradigm. By weaving solar, wind, biomass, and ethanol into the fabric of farming, we are creating a more resilient and regenerative food system. In the near future, the farms that feed the world will also power it, harvesting not only crops but also the endless energy of nature itself.

A New Paradigm for Growth *in Agriculture*

MV Ashok
Retired CGM
NABARD

Introduction

Energy is the basic necessity for human being to survive. Demand for daily energy requirements creates pressure on finite source of fossil fuel based energy, which is rapidly declining in different parts of the world. Agriculture is one sector, which consumes about 7-8% of total energy consumption of India. Pumping of irrigation water, use of heavy machineries for different farm operations, processing and value addition of farm produces etc. are major activities by which energy is consumed in agriculture sector. With the advancement of food production system from agrarian to a futuristic technology-driven system, there has been rapid increase in energy use in agriculture

Agriculture sector has great scope in meeting this renewable energy target of the country and can be achieved through major two ways viz., the replacement of fossil fuel based farm operations with renewable energy sources and second is the contribution in renewable energy generation from agriculture sector.

Scope for use of Renewable Energy in Agriculture in India

India has an estimated renewable energy potential of about 900 GW from commercially exploitable sources. Among the total renewable potential, wind power potential is about 102 GW at 80 meter mast height, solar power potential of about 750 MW assuming 3% wasteland is made available, bio energy potential of 25 GW and rest is by other renewables.

Modern agriculture is heavily dependent on non-renewable energy sources, especially petroleum. The continued use of these energy sources cannot be sustained indefinitely, yet to abruptly abandon our reliance on them would be economically catastrophic. However, a sudden cutoff in energy supply would be equally disruptive. In sustainable agricultural systems, there is reduced reliance on non-renewable energy sources and a substitution of renewable sources or labour to the extent that is economically feasible.

Most farms machines are driven by fossil fuels, which contribute to greenhouse gas emissions and in turn, accelerate climate change. Such environmental damage can be mitigated by the promotion of renewable energy resources such as solar, wind, biomass, small hydro, and biofuels. These renewable resources have a huge potential for agriculture industry. The concept of sustainable agriculture lies on a delicate balance of maximizing crop productivity and maintaining economic stability, while minimizing the utilization of finite natural resources and detrimental environmental impacts. Sustainable agriculture also depends on replenishing the soil while minimizing the use of non-renewable resources, such as natural gas, which is used in converting atmospheric nitrogen into synthetic fertilizer and mineral ores, e.g phosphate or fossil fuel used in diesel generator for water pumping for irrigation. Hence, there is a need for promoting use of renewable energy systems for sustainable agriculture eg., solar photovoltaic water pumps and electricity, greenhouse technologies, solar dryers for post-harvest processing and solar hot water heaters. In remote agricultural lands, the underground submersible solar photovoltaic water pump is economically viable and also an environmentally friendly option as compared with a diesel generator set.

Uses of Solar energy in agriculture

Solar energy is used in Indian agriculture to power irrigation pumps, reduce costs, and improve efficiency. Other applications include powering greenhouses, cold storage, farm equipment, and electric fences. Initiatives like the PM-KUSUM scheme of Government of India and the concept of agrivoltaics are promoting its use, helping farmers lower energy costs and dependency on fossil fuels, while increasing profitability and sustainability. Solar technologies produce electrical or thermal energy. Livestock and dairy operations often have substantial air and water heating requirements. For example, commercial dairy farms use large amounts of energy to heat water for cleaning equipment. Heating water and cooling milk can account for up to 40 percent of the energy used on a dairy farm. Solar water heating systems may be used to supply all or part of these hot water requirements. Other solar applications include greenhouse heating and solar crop drying besides pumping of water.

Benefits for farmers

- Reduced costs
- Energy independence
- Increased profitability
- Sustainability
- Government support

Agrivoltaics

Agrivoltaics is the simultaneous use of land for both farming and solar power generation, a practice also known as "agrisolar" or "dual-use solar". This approach involves installing solar panels above or between crops to maximize land use efficiency, provide shade to protect crops, and offer a new income source for farmers. It can reduce competition for land, conserve water, and help meet both food and energy needs simultaneously. Agrivoltaics allows for dual-use of land, where panels are installed above crops or livestock to generate electricity while potentially providing shade and reducing water loss for plants.

Benefits of agrivoltaics

- Increased land efficiency
- Enhanced farmer income
- Water conservation
- Reduced land competition
- Environmental advantages

Wind Energy

Wind technologies provide mechanical and electrical energy. Small wind systems can serve agriculture in traditional ways, such as using mechanical energy to pump water or grind grain. Wind energy is used in agriculture for generating electricity via wind turbines to power farm operations or sell back to the grid, and through wind pumps for irrigation and livestock watering. This integration allows for dual land use, as crops can continue to grow and animals can graze around the turbines, while providing farmers with a supplementary income stream from leasing land for turbines.

Applications of wind energy in agriculture

- Electricity generation
- Water pumping

Benefits of integrating wind energy

- Dual land use:
- Additional income:
- Sustainability
- Improved infrastructure

Geothermal Energy

Geothermal technologies produce electrical or thermal energy. Geothermal fluids can be used for such purposes as heating buildings, growing plants in greenhouses, dehydrating onions and garlic, heating water for fish farming, and pasteurizing milk. Geothermal energy has many agricultural applications. Vegetables, flowers, ornamentals, and tree seedlings are raised in 43 greenhouse operations heated by geothermal energy. The drying of onions and garlic is the largest industrial use of geothermal energy.

Advantages of Geothermal Energy

- Renewable
- Reliable
- Clean
- Widely available

Biomass Energy

Biomass energy is a renewable source derived from organic matter like wood, crops, and waste, which can be converted into heat, electricity, or biofuels. It is considered "carbon neutral" because the carbon released when it's burned is roughly equal to the carbon that plants absorbed from the atmosphere during their growth. Key methods for generating energy from biomass include burning it directly to create steam for electricity, co-firing it with fossil fuels, or processing it into liquid fuels like ethanol and biodiesel. Agricultural activities generate large amounts of biomass residues. The main technologies for productive utilization of biomass are :

Biomass based power generation: The technology for generation of electricity from biomass material is similar to the conventional coal-based thermal power generation.

Baggasse-based Cogeneration: Cogeneration is the process of using a single fuel to produce more than one from of energy in sequence which is well fulfilled in the sugar industry.

Biomass Gasification: Biomass gasification is thermo-chemical conversion of solid biomass into a combustion gas mixture through a partial combustion route with air supply restricted to less then that theoretically required for combustion.

Biogas Energy: Biogas represents an alternative source of energy, derived mainly from organic wastes. The estimated potential of household biogas plants based on animal waste in India is 12 million, enough to find use in many energy application s, including power generation.

Sources of biomass

- Forestry and wood residues
- Agricultural residues like straw
- Energy crops grown specifically for fuel
- Organic waste from industry and households
- Animal and human waste

Advantages

- Renewable:
- Carbon neutral:
- Waste reduction
- Reduced fossil fuel reliance

The way Forward

There is significant potential for agricultural involvement in the production and consumption of solar, wind, geothermal, and biomass energy. Renewable resources are abundant and widely distributed throughout the world. are not monetized — they cannot be perceived through price signals. Policies are needed to push or pull these new technologies to full commercial development. Agriculture is one of the main energy users and there are a number of examples of small energy requirements for agricultural end uses such as drying, small scale processing, maize pulping, threshing, milling, preserving (cool rooms), sorting and packaging, plowing, watering/ irrigation, etc. Priority of use of renewable energy in agriculture should go for productive uses. Solar photovoltaic systems could be applied for agriculture such as: cooling, heating and extended lighting of poultry farms, irrigation including drip irrigation, electric fencing for grazing management, pest control, veterinary clinics, cool houses for fruit preservation, cattle watering points, aeration pumps for aquaculture, egg incubators, crop dryers, agro processing, etc. Agriculture plays a double role towards energy: it is a major energy user while it also a major source of renewable - specifically bioenergy. Energy and agriculture are fully connected through the bioenergy linkage and could generate synergy so that the farmer can produce them, agro-industry can contribute to the energy balance such as bagasse in sugar factories, while at the same time bioenergy lacks the diversification of agriculture. Alternative energy sources support rural development by way of providing new opportunities to rural population, creating new infrastructure, backing diversification and attracting new investments in rural locations. Alternative and renewable energy sources also have an impact on sustainability of development initiatives as they affect from the social, economic and environmental points of view. Renewable energy, particularly bioenergy, could greatly contribute to enhancing sustainable development from both perspectives of environmental sustainability and productivity improvement.

RENEWABLE ENERGY

Economic Viability for Smallholders

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Role of Renewable Energy in the Economic Viability of Cereal Crop Farming by India's Smallholders

Introduction

India's agricultural backbone are the smallholder farmers, who possess less than 2 hectares of land, and account for 86% of the landholdings. 65% of these smallholders grow cereal crops like paddy, wheat, and maize. For these crops, irrigation and farm mechanization have significant energy input costs in the form of electricity and diesel consumption. For water-intensive crops like paddy farmers rely on a combination of grid electricity and diesel pumps. Maize farmers rely on diesel-powered dryers post-harvest to dry quickly and reduce losses. Tractors are used for land preparation and also for local transport. At a national level, these farm machinery consume 13% of diesel in retail and direct sales combined (PPAC, 2013). India is among the countries with more than six peak sun hours per day With such a reliable supply of solar (renewable) energy, it is possible to complement and reduce the diesel consumption in agriculture over the next few decades.

Use of Solar Energy

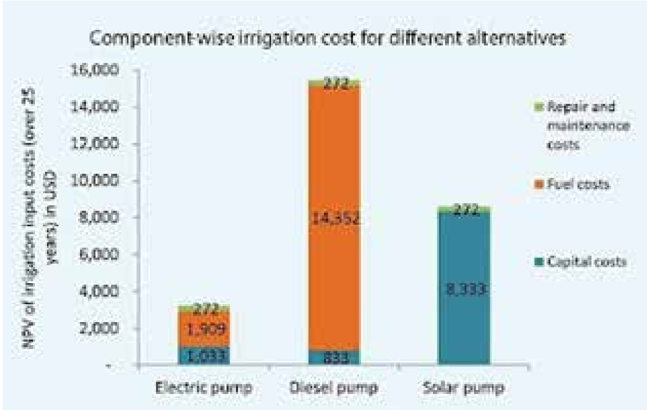
A five horse power solar water pump can save around ₹ 50,000/- of operational expense per year (Rana, 2024). It provides power during the day, and reduces farmers' dependency on night-time grid schedules. To reduce upfront capital expenditure, a smallholder farmer can avail of PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyaan) scheme, to buy stand-alone solar pumps paying only 10% of the cost initially, availing a 60% subsidy from both central and state governments, and applying for a bank loan for the remaining 30%, as a best-case scenario (Source: PIB, Ministry of New and Renewable Energy, 2024)

Solar dryers are an effective method for drying grain to safe moisture levels. There are various models from simple cabinet dryers to solar bubble dryers, developed by International Rice Research Institute (IRRI). They protect the grains from rain, birds, and pests while drying it 2-3 times faster than open-field sun drying (Krishna et al 2023).

Paddy and wheat cultivation generates over 500 million tons of crop residue (stubble) annually. This waste biomass can be converted into methane by a community-level biogas plant, which can run farm equipment, lighting, and small-scale food processing operations. The slurry from the biogas digester is a nutrient-rich organic fertilizer, reducing the farmer's costs on fertilizers (Reddy et al 2025).

However there can be some inertia among smallholders to move to solar energy because existing assets cannot be abandoned if they have not reached end of life. The new assets providing renewable energy require large capital expenditure in comparison to the existing pump-sets (please refer Chart 1 below for component-wise irrigation costs), requiring demand to be aggregated over multiple tracts of landholdings. Also there need to be more successful local models for farmers to learn best practices, and then compare, adjust and implement in their own farms. With this as the starting point, this short paper presents a discussion and the way forward for farmers in our country to find solar power farming remunerative. Other forms of renewable energy and non-cereal crops are outside the scope of this note.

Chart 1: Comparison of Irrigation Cost of Different Pumps (Source: Council On Energy, Environment And Water)



The PM-KUSUM Scheme

As smallholders cannot own every asset, an owner-farmer can set up a solar facility and provide the service to other farmers at a price. Farmer Producer Organizations (FPO) can demonstrate how a small group of farmers can jointly own a solar pump or a community biogas plant and share the resource. Under the PM-KUSUM scheme, government wants to provide energy and water security to farmers, enhance their income, de-dieselize the farm sector, and reduce environmental pollution. Farmers can replace diesel pumps with solar operated pumps in off-grid areas up to 7.5 horse power capacity, with central government providing financial assistance of 30% (or 50% for north-eastern region) for the stand-alone solar agriculture pumps. The same assistance is available for solarising grid-connected agriculture pumps, both at individual and feeder level. As on 30.06.2024, 4,11,222 farmers have benefited in the country through the PM-KUSUM scheme (PIB, 2024). As on 28.02.2025, 9,75,551 pumps have been installed (MNRE, 2025).

There is another component of the PM-KUSUM scheme, for farmers who own land near a sub-station (barren or unused) to install solar panels and supply 500 kw to 2 MW of renewable power, to discom grid (electricity distribution company) creating a stable income for as long as 25 years. As of 28.02.2025, we have created 430.98 MW capacity at small solar plants selling power to the grid (MNRE, 2025).

Key Schemes (Beyond Pumps)

While PM-KUSUM is an important scheme for irrigation, a different set of schemes under various umbrellas support other critical renewable energy applications. The Pradhan Mantri Formalization of Micro Food Processing Enterprises (PMFME) Scheme can be availed of by individual entrepreneurs and farmer producer organizations, to receive a 35% credit-linked capital subsidy (up to a maximum of ₹10 lakh) for setting up a micro-food processing unit like a solar dryer for maize or paddy. The Chart 2 below mentions relevant schemes to accelerate use of renewable energy including schemes for collecting and converting stubble.

Chart 2: Key Schemes to accelerate renewable energy consumption & generation

Technology Need	Relevant Scheme	Ministry	How it Works
Solar Dryer (Small)	PMFME Scheme	Food Processing (MoFPI)	35% credit-linked subsidy (up to ₹10L)
Solar Dryer (Finance)	Agri. Infra. Fund (AIF)	Agriculture (MoA&FW)	3% interest subvention on loans
Stubble Machinery	CRM Scheme	Agriculture (MoA&FW)	50-80% subsidy on balers, rakes
Stubble Biogas Plant	National Bioenergy Prog.	New & Renewable (MNRE)	Capital subsidy (CFA) based on plant size
Stubble CBG Plant	SATAT Scheme	Petroleum (MoPNG)	Guaranteed offtake (purchase) of gas

Risk Factors to Adoption

The biggest risk factor to accelerated adoption is that farmers bear most of the risk. They may not be keen to adopt any new stand-alone technology that changes their cultivation practice significantly in relation to the adjacent landholders. A farmer producer organization can ameliorate this risk and guide farmers to solve the systemic issues that come up due to change of practices established over the years, in the following ways:

(1) As there is significant subsidy under PM-KUSUM scheme, the FPO can accelerate adoption by ensuring that bank loan is sanctioned quickly and subsidy reimbursements are disbursed fully. Farmers require the active involvement of FPOs (or a higher local institution) in strengthening, streamlining and accelerating subsidy disbursals and loan sanction process.

(2) The pricing contracts with discoms should be mediated by FPO on behalf of the farmer(s) on the lines of milk cooperatives, where farmers who sell surplus power receive the payment promptly. The incentive to develop and create surplus power comes from a consistent record of accurate and prompt payment to the farmers.

(3) FPOs understand the requirements of their farmers, hence can aggregate and channelize feedback to research institutions and corporates for providing additional engineering solutions that address specific local problems for their members. For example, if the water table is rapidly declining in their vicinity, they should be able to obtain the exact design specifications of the solar pump-sets required.

(4) Insurance is necessary as the solar assets are visibly large and prone to damage. A group insurance policy facilitated by FPO for all their farmer members will have a lower premium per farmer than that of an individual policy. Claim processing can also be enabled through the FPO. As warranties expire, these insurance policies are important in rectifying the damages to solar equipment caused by natural circumstances and not impair the long-term benefits of a solar solution.

A similar risk mitigation framework can be developed for solar dryers, or for manufacturing bio-gas and chemical fertilizers from stubble.

Conclusion

Over 4 lakh farmers have already benefited from the PM-KUSUM scheme, augmenting or overhauling their dependence on grid and diesel supplies, since this scheme has been scaled up in January 2024. This is a significant sample size and data-set to create a playbook for introducing renewable energy into farm machinery and showing the farmers a visible improvement in their cash flow cycle. Farmer Producer Organizations can help in implementation of such schemes by mitigating the risk in their respective farming zones, thereby enabling a speedy transition of the smallholder farmers to benefit from solar or any other form of renewable energy.

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Agriculture mechanization

and end night for diesel?

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Agriculture mechanization and end night for diesel?

Farm mechanization has significantly boosted Indian farmers' efficiency and global competitiveness. Since independence, progress has been considerable, with mechanical and electrical sources now dominating 95% of the total farm power of 3.13 kW/ha, replacing traditional methods. However, the overall farm mechanization level remains at 47%. A heavy reliance on diesel persists, with tractors and engines contributing 76% of mechanical power and the sector consuming about 13% of the nation's diesel. As India aims for 4.0 kW/ha by 2030 to meet food demands, a critical question emerges: is this the end for the diesel engine, and can Indian agriculture shift to electricity? The progress is moving towards a fully electric future.

The future is ELECTRICITY-in FARM

Electricity now contributes 23-27% of India's total farm power, a dramatic rise from just 2.4% in the 1960s, primarily driven by electric pumps for irrigation. The agricultural sector consumes 18-20% of the nation's electricity, a figure projected to grow from 200 Billion Units (BUs) currently to 252 BUs by 2030.

Beyond irrigation, electrical power is gaining popularity for a wide range of allied and post-harvest activities. The modular and robust nature of electric machines makes them particularly suitable for small farmers. A key advantage is their power density; electric engines generate 4.3 kW/kg, which is three times more power per kilogram than diesel engines and 40 times smaller per kW.

While lightweight electric tools are already widespread, the next major game-changer will be the introduction of fully electric tractors and traction machines. This shift is expected to increase electricity's share in farm power from 27% to over 40% within a decade, potentially doubling the sector's electricity demand.

However, this future hinges on a critical question: can India supply this power? The challenge is not overall generation capacity, as India is now a power-surplus nation, but the timing of demand and the financial health of power distribution companies (Discoms). A significant issue is the subsidized nature of agricultural power. The sector, which contributes less than 5% to GDP, consumes a fifth of the electricity, often at low tariffs or for free, causing huge financial losses for Discoms and straining the entire energy chain. Therefore, meeting the growing and versatile demand for reliable, daytime farm electricity requires a major shift in both power production technology and the financial model of electricity supply.

The challenge has TWO pronged:

First, we must ensure farms receives uninterrupted electricity during day time.

Second, we need to prevent the rising demand from agriculture to bleed DISCOM further.

Renewable Energy: The paradigm for agriculture growth

Integrating Renewable Energy (RE) is no longer an alternative but a necessity, forming a new paradigm that decouples agricultural growth from environmental degradation and grid dependency. This shift promises a future of productive, profitable, and climate-resilient farming. This paradigm positions RE not just as a power source, but as an integrated solution that addresses multiple challenges simultaneously. The core components are:

A. Solar Power: The Cornerstone

Solar energy has long been beacon of the Indians energy transition and can provide a greener energy avenue for the agriculture sector. The future power option for the sector may gone through the utilization of solar energy. The technological advancement in the solar PV electricity has to be in three-fold system to cover the entire farm mechanization in near future

1. Solar Water Pumps (SWPs):

Energy-Water Security: Provides daytime, reliable power for irrigation, perfectly aligning with crop water needs. This can help regulate groundwater use and eliminates or drastically reduces diesel and electricity bills. Off-grid pumps remove load from the stressed grid and grid-connected models can even feed surplus power back, turning farmers into "prosumers."

2. Solarising Agricultural Feeders (Feeder Separation):

It is a dedicated solar power plants are built to supply electricity exclusively to agricultural feeders during the day. It ensures quality daytime power for farmers, reduces discoms' subsidy burden by replacing expensive thermal power with cheap solar, and improves grid stability.

3. Agrivoltaics: Synergistic Land Use

Installing solar panels above crops, sharing sunlight between energy generation and agriculture could increase the farmers income due to additional revenue from solar power adds a stable income stream and provides the efficient land use to maximizes output per unit of land.

The Government of India has rightly identified this potential and launched several schemes:

- PM-KUSUM (Pradhan Mantri Kisan Urja **Suraksha evam Utthaan Mahabhiyan):** A flagship scheme with three components aimed at installing:

1. 10,000 MW of decentralized ground/stilt-mounted solar power plants.
2. 20 Lakh standalone Solar Agriculture Pumps.
3. 15 Lakh grid-connected Solar Agriculture Pumps.

- **National Solar Mission:** Includes a strong focus on the agricultural sector.
- **Subsides and Financing:** Capital subsidies and low-interest loans are being provided to make these technologies affordable for farmers.

B. Biomass & Bioenergy: Creating a Circular Rural Economy

- **Agricultural Residue to Power:** Instead of burning crop stubble (a major cause of air pollution in North India), it can be used in biomass gasifiers to generate power for local use or the grid.
- **Bio-CNG and Compost:** Using livestock manure and organic waste in biogas plants produces clean cooking fuel (CBG) and organic manure, reducing fertilizer costs and improving soil health.

C. Small-Scale Wind and Hybrid Systems

In windy coastal and plain regions, small wind turbines or solar-wind hybrids can provide a more consistent power supply.

Adopting this paradigm triggers a virtuous cycle of growth in agriculture could provide

- The economic resilience for farmers by reduced input costs, additional revenue and crop diversification.
- The environmental sustainability through carbon neutrality, improved soil and air quality, sustainable water management.
- The energy security and grid modernization through decentralized power and rural electrification for agro-based entrepreneurship.

Conclusion

Indian agriculture is shifting from diesel to electricity, requiring reliable, clean power for growth. Renewable energy is the definitive paradigm, transforming the sector from a major resource consumer into a solution. By integrating solar and biomass, farming can become a cornerstone of climate and energy security. This productive, profitable future demands a concerted effort from government, institutes, industry, and farmers.

RENEWABLE ENERGY

Trends in Agriculture

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Prologue

Renewable Energy, also called Green Energy, is derived from natural resources that are widely distributed, and naturally and constantly renewed at a rate higher than they are consumed. Renewable Resources which include hydropower, solar, wind, geothermal, tidal and wave energies, and biomass are virtually inexhaustible. These are considered clean and sustainable as they are naturally replenished on human timescale and typically have low or zero carbon footprint, unlike fossil fuels.

Renewable Energy has gained breakthroughs and significant momentums worldwide, driven by the rising consciousness and commitments to reduce carbon emissions, rising energy demands, abundant resources, technological innovations, government incentives, implementation efficiencies, decentralized systems, low costs and market dynamics. The industry is also embracing digital transformation with advanced data analytics and artificial intelligence in optimizing energy production and distribution.

With strong government support and improved economics, the renewable energy sector has become an appealing area for investors.

Renewable Energy - A New Paradigm for Growth

The global energy landscape is undergoing a profound transformation. As nations confront the realities of climate change, dwindling fossil fuel reserves and the need for sustainable economic development, renewable energy has emerged as a cornerstone of progress. This shift represents not just a technological evolution but a new paradigm for growth - one that redefines how societies produce, distribute, and consume energy.

1. From Scarcity to Abundance - The Changing Energy Landscape

Traditional energy systems have long been governed by the limitations of finite fossil fuel reserves, driving competition, geopolitical dependencies and resource depletion. The renewable energy paradigm replaces this with the concept of natural resource abundance. This abundance invites collaboration and democratizes energy by enabling decentralized generation and local empowerment, especially in developing regions.

2. Economic Growth and Social Impact

Renewable energy is no longer a niche sector, it is a driver of economic growth and expansion. Investments in solar, wind, hydro and bioenergies are creating millions of jobs worldwide, stimulating local economies, reducing dependence on imported fuels and improving trade balances besides ascertaining energy security. The shift to renewables in India and the USA has demonstrated measurable impacts on GDP and industrial productivity with varying benefits. The falling cost of renewable technologies has made clean energy more accessible, enabling developing nations to leapfrog traditional energy systems and build resilient, decentralized power networks.

Investments in clean technologies also stimulate innovation, entrepreneurship and rural development.

3. Environmental Sustainability

Renewables substantially lower carbon emissions, reduce environmental degradation, promote cleaner air and water, mitigate global warming and enhance resilience against climate change impacts. They require far less resource extraction compared to fossil fuels and minimize long-term ecological consequences. This cleaner energy trajectory aligns with both national and global climate commitments, offering a pragmatic route to decarbonization and broader ecological well-beings.

4. Innovation and Technological Advancement

The renewable energy revolution is fueled by innovation. Advances in battery storage, smart grids and energy-efficient technologies are enhancing reliability and scalability. Artificial Intelligence and Data Analytics are optimizing energy production and consumption, paving the way for smarter, more adaptive energy systems.

Nations leading in renewable technologies are gaining strategic advantages in the global market, shaping the future of energy economics.

5. Social and Geopolitical Impact

Renewable energy democratizes power generation. Communities can produce their own electricity through rooftop solar or local wind farms, fostering energy independence and resilience. On a global scale, the shift reduces geopolitical tensions tied to fossil fuel trade, promoting stability and cooperation.

6. The Road Ahead and Beyond

Supportive policies, investment in innovation and international collaborations are driving rapid expansions in renewable capacity worldwide. The sector's continued growth relies on technological advancements, effective regulatory frameworks and strong financial support. To fully realize the potential of renewable energy, governments, businesses and individuals must continue to collaborate on policy frameworks, infrastructure investment and education. The transition demands vision and commitment - but the rewards are immense: sustainable growth, environmental preservation and a more equitable energy future.

Strong policy frameworks, subsidies and public-private partnerships are vital for scaling renewables. Global climate accords like the Paris Agreement have accelerated this shift, encouraging countries to invest in green infrastructure and innovation towards resilience and sustainability.

Renewable Energy Trends in India

India is poised to play a central role in the global transition to renewable energy. The country's vast geographical diversity and abundant natural resources offer immense potential for renewable energy generation. In recent years, India has made significant strides in expanding its renewable energy capacity, particularly in solar and wind energy.

India is also exploring the potential of green hydrogen as a key energy source. As part of its broader commitment to decarbonize its economy, India is investing in the production of green hydrogen using renewable energy, which could revolutionize sectors like heavy industry and transportation.

India's renewable energy growth remains among the fastest in the world, driven by multi-pathway expansion.

India remains a magnet for clean energy capital. Renewable tariffs continue to be among the lowest globally, ensuring long-term competitiveness. India continues to be one of the most attractive destinations for investment in clean energy sector, and international interest remains high. Global investors are repositioning towards integrated and storage-backed portfolios. The sector's fundamentals - strong demand growth, policy continuity and cost competitiveness - remain firmly intact.

Epilogue

Renewable energy is not merely an alternative, it is the foundation of a sustainable growth paradigm, and new economic and environmental order. It integrates economic progress with environmental preservation, reshaping industries, empowering societies and ensuring a cleaner and more equitable future. As the world embraces this paradigm, it moves closer to a future defined by innovation, inclusivity and sustainability - a future where growth and responsibility coexist in harmony.

This shift to a renewable energy paradigm marks a foundational change in how societies achieve growth - one that is more inclusive, resilient, and sustainable for future generations.

Biofuels

Transforming Waste into Wealth

Introduction

Agriculture has always been the backbone of the Indian economy, employing nearly half the population and sustaining rural livelihoods. However, conventional agricultural practices are heavily dependent on fossil fuels for irrigation, mechanization, fertilizer production, and transportation. The volatility in fuel prices and the environmental costs associated with fossil energy have exposed vulnerabilities in the agricultural value chain. The transition to renewable energy is, therefore, not just an environmental imperative but also a socio-economic necessity. Renewable energy represents a new paradigm for agricultural growth — enabling energy self-reliance, enhancing productivity, and fostering sustainable rural development.

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The Energy–Agriculture Nexus

Energy and agriculture are interdependent systems. Energy drives modern agriculture — from land preparation and irrigation to post-harvest processing and cold storage. Conversely, agriculture provides biomass and bio-waste that can be converted into valuable forms of energy. This symbiotic relationship is the foundation of a sustainable bioeconomy.

Renewable energy technologies such as solar, wind, biogas, and biofuels are redefining how energy is produced and used in the agricultural sector. They not only reduce greenhouse gas emissions but also lower operational costs and increase energy access in rural areas, where grid connectivity remains inconsistent.

Biofuels: Transforming Waste into Wealth

One of the most promising renewable energy avenues in agriculture is the production of biofuels from agricultural residues and high-value wastes. Platforms such as Buyofuel, for instance, are enabling a circular economy by connecting waste generators, biofuel manufacturers, and fuel consumers through a transparent digital marketplace.

Biofuels derived from used cooking oil, tallow oil, palm fatty acid distillate, and acid oil provide a sustainable alternative to diesel and furnace oil. They not only reduce dependency on imported fossil fuels but also address the challenge of waste disposal. This model turns agricultural and agro-industrial byproducts into profitable energy resources - promoting both energy and resource efficiency.

Moreover, the government's push for blending biofuels with conventional fuels — such as the Ethanol Blending Programme (EBP) and the National Policy on Biofuels — is creating large-scale demand. Farmers can benefit directly by supplying feedstock and indirectly through reduced fuel costs and enhanced environmental resilience.

Solar Power: Energizing the Fields

India's agricultural sector is a significant consumer of electricity, primarily for irrigation. The introduction of solar-powered pumps and decentralized solar microgrids has revolutionized rural energy access. Schemes like PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) encourage farmers to install solar pumps and sell surplus electricity to the grid, generating an additional income stream.

Solar drying systems and cold storage units powered by solar energy also help in reducing post-harvest losses—a persistent challenge in Indian agriculture. For small and marginal farmers, these technologies translate into reduced input costs, increased productivity, and greater resilience to energy supply fluctuations.

Biogas and Biomethane: Closing the Nutrient Loop

Livestock waste, crop residues, and food waste can be converted into biogas or upgraded to biomethane, offering both clean fuel and nutrient-rich slurry as an organic fertilizer. This closes the loop between energy production and soil health.

Community-level biogas plants in rural clusters have demonstrated substantial benefits: lower reliance on LPG and diesel, reduction in open burning of residues, and improvement in farm incomes. Modern biogas systems, integrated with purification and bottling technology, can even supply compressed biogas (CBG) for vehicular use under the SATAT (Sustainable Alternative Towards Affordable Transportation) initiative.

Green Hydrogen: The Next Frontier

As India moves toward achieving Net Zero by 2070, green hydrogen produced through electrolysis using renewable energy is emerging as a game-changer. In the agricultural context, it can serve multiple purposes—from producing green ammonia for fertilizers to powering heavy farm machinery in the long run.

Buyofuel and similar platforms are exploring pathways to integrate green hydrogen and advanced biofuels into rural energy systems, paving the way for cleaner, decentralized, and digitally connected energy ecosystems.

Socio-Economic and Environmental Benefits

The shift toward renewable energy in agriculture yields multidimensional benefits:

Economic Empowerment: Reduces energy costs, generates rural employment, and diversifies farmers' income sources.

Energy Security: Decreases dependence on imported petroleum products.

Environmental Sustainability: Reduces carbon emissions, improves waste management, and mitigates soil and water pollution.

Resilient Rural Infrastructure: Decentralized renewable systems enhance the reliability of energy supply and promote inclusive growth.

By harnessing locally available resources—sun, wind, and biomass—farmers become energy producers as well as consumers, transforming villages into hubs of sustainable energy innovation.

Renewable energy is no longer a peripheral option for agriculture—it is central to its modernization and sustainability. As India's agricultural landscape faces the dual challenge of ensuring food and energy security, the integration of renewables presents a transformative opportunity.

By fostering collaboration among farmers, entrepreneurs, researchers, and policymakers, India can build an agricultural ecosystem that is climate-resilient, economically vibrant, and energy-independent. The synergy between renewable energy and agriculture will not only fuel growth but also redefine the very paradigm of rural prosperity in the 21st century.

Solar Powered Agriculture

Transforming Indian Farms, Empowering Farmers

Manoj K Jain

Director, Cytec Renewables Pvt Ltd

Former Project Director, New & Renewable Energy Dept. Govt of Haryana

Founder: Cytec Foundation

India's agriculture - the backbone of livelihood for nearly half its population - is witnessing a powerful shift. Instead of only relying on grid electricity or diesel for irrigation and farm operations, farmers are increasingly turning to the sun. Solar-based agriculture solutions under the PM-KUSUM scheme are helping make this shift a reality, enabling higher incomes, better productivity and greater resilience.

A New Dawn in Indian Farming

The government's PM-KUSUM scheme (launched 2019) is aimed at enabling farmers to harness solar energy for irrigation and power generation on their farms. It has three main components:

- **Component A:** Decentralized grid-connected solar or other renewable plants.
- **Component B:** Installation of standalone off-grid solar agriculture water pumps.
- **Component C:** Solarization of existing grid-connected agricultural pumps, including feeder-level solarization.

The targets are ambitious: 10,000 MW under Component A; 14 lakh standalone pumps under B; 35 lakh existing pumps solarized under C.

Progress & Scale

Recent verified data shows encouraging progress, though there remains a gap to full targets. Rapid progress over FY 2024–25, with major contributions from Maharashtra, Rajasthan, Haryana, Gujarat, and Madhya Pradesh

"As of September 2025, approximately 8.5–9.0 lakh standalone solar pumps have been installed under PM-KUSUM Component-B across India. This marks a sharp rise from earlier years and reflects the momentum of the solar-agriculture revolution, though it remains short of the 14-lakh target set for this component."

From Diesel Drains to Solar Gains

Traditionally, irrigation pumps in India ran on diesel or grid supply, which meant variable cost, fuel logistics and unreliable power. Diesel pumps, especially, incur heavy operational cost — roughly ₹ 50-60 per hour, wear & tear cost of engine sometimes much more depending on region in addition to environmental factors.

By contrast, a solar pump once installed has almost zero "fuel" cost over its lifetime (aside from maintenance), offering savings of ₹ 60,000 -80,000 or more annually for a 5 HP pump irrigating 2–3 ha (varies regionally). These savings translate into stronger purchasing power for seeds, fertilizers, livestock or even children's education. Importantly, solar-pumps reduce dependence on erratic grid supply or diesel tankers. They provide dignity, autonomy and planning ability to farmers.

Solarization and the Green Economy

Under PM-KUSUM, many farmers have now become "solar entrepreneurs" — generating irrigation power for themselves and in some cases selling surplus electricity back to the grid. Beyond income, there is a strong environmental benefit: each solar pump can avoid around 4-5 tonnes of CO_2 emissions per year (compared to diesel). Over time and scale, this becomes a meaningful contribution to India's climate goals.

The Impact on Lives of Farmers

Solar adoption has reduced irrigation costs, boosted farm profits and enabled timely, reliable irrigation that improves yields and lowers crop losses. It also diversifies income through surplus energy sales, reducing dependence on single-crop earnings. Beyond economics, solar energy empowers farmers with self-reliance, strengthens rural resilience, and promotes cleaner air, lower emissions, and better health across farming communities.

In Haryana's districts like Sirsa, Bhiwani, Hisar and more, where majority of systems have been installed so far, the farmers who adopted solar pumps under the scheme reported noticeable improvement in net income and reduced dependence on diesel. In some drought-prone states community-shared solar irrigation models under PM-KUSUM have enabled groups of farmers to share a pump system, saving groundwater and costs. It's like Solar Pump as a Service (S-PaaS)

Policy Support & Key Additional Points

The success of PM-KUSUM is driven by robust policy support, including shared central–state subsidies that lower farmers' costs to just 10–40%, expanding domestic manufacturing that strengthens the "Make in India" initiative, and seamless integration with other agricultural programs such as crop insurance and drip irrigation to build a holistic, sustainable farming ecosystem.

As installations increase, strengthening the maintenance ecosystem and ensuring easy access to spares are crucial. Solar pumps, when integrated with smart controls, can support sustainable groundwater management, while post-harvest solar applications like dryers and cold storage boost farmer income and reduce waste. Equally important is continuous farmer training on system operation, financial planning, and long-term benefits to ensure sustained adoption.

Challenges & The Way Forward

Despite strong progress, challenges persist - installation rates still fall short of targets (around 60% for standalone pumps as of Sept 2025), and adoption remains uneven across states due to low awareness, high upfront costs, and logistical hurdles. Technological mismatches and early-stage feeder solarization add complexity, while inadequate maintenance networks and limited monitoring systems risk reducing long-term performance.

To accelerate progress, India must simplify financing through pay-as-you-save or rental models, link solar irrigation with soil health and crop diversification schemes, strengthen local service networks and manufacturing, leverage digital platforms for performance monitoring and subsidy tracking, and enhance farmer awareness through field demonstrations and peer-led success stories.

Agrivoltaics - The Future of Solar-Powered Farming

As India advances in solar irrigation, a new frontier called Agrivoltaics is emerging - where solar panels and crops share the same land, creating a powerful synergy between energy and food production. Instead of competing for space, solar modules are elevated or strategically arranged to allow sunlight to nourish both plants and photovoltaic cells.

This dual-use model has immense potential for India, where land is precious and agricultural livelihoods dominate rural life. Pilot projects in Gujarat, Maharashtra, and Tamil Nadu show that crops like leafy vegetables, pulses, and spices can thrive under semi-shaded solar panels while farmers simultaneously earn from energy generation. Early studies indicate up to 30% improvement in total land productivity when energy and crops are co-produced.

Looking ahead, agrivoltaics could become the next wave of India's solar-agriculture revolution, integrating PM-KUSUM with sustainable land use and precision farming. By combining AI-driven irrigation, real-time data analytics, and climate-smart crop planning, this model can help India achieve food security, water efficiency, and renewable energy targets together - truly making the farmer the "prosumer" of tomorrow's green economy.

The Sun as a Partner in Prosperity

Renewable energy in agriculture is more than replacing diesel or grid pumps - it's about reshaping India's rural future. The sun that once symbolized hope for a good harvest is now powering the pump that brings water to that harvest.

As India moves towards its goal of doubling farmers' income and meeting climate commitments, solar-based agriculture plays a pivotal role. Each solar pump installed is more than technology - it's a beacon of cleaner, smarter and self-reliant farming.

Having an experience of more than 38 years of ground level experience in implementation of various Renewable Energy Programmes like Rooftop Solar, Solar Water Pumping, Distributed Renewable Energy, Energy Efficiency, Conservation, Rural livelihood, Rural Sanitation & Waste Management.

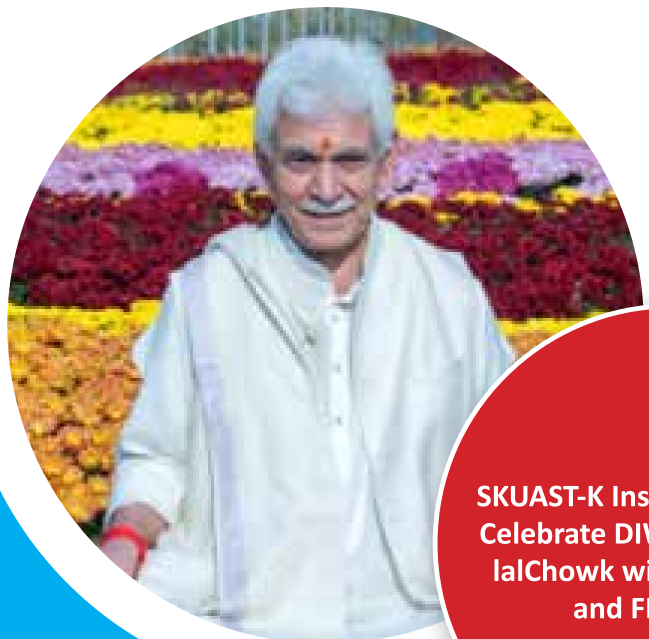
From Guli Lala to Guli Dawood
SKUAST-K's Chrysanthemum Festival
Redefines Autumn Tourism in Kashmir

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) has once again brought innovation and life to the Valley's cultural and tourism landscape — this time through a spectacular Chrysanthemum Show that turned the historic Lal Chowk into a vibrant, flower-decked plaza.

Under the visionary leadership of Vice Chancellor, Prof. Nazir Ahmad Ganai, SKUAST-K has worked for the past three years to introduce and popularize Chrysanthemums as the "Colors of Autumn", bridging the tourism gap that traditionally follows the spring tulip season.

This year's initiative saw the installation of over 3,000 chrysanthemum pots of diverse varieties at the city centre LalChowk, meticulously nurtured by Dr I T Nazki and his team of faculty and students. Overnight, the business hub of Lal Chowk — long known for its political and commercial significance — was transformed into a European-style floral plaza. Commuters and shopkeepers woke up to an entirely new look: streets bursting with color, fragrance, and freshness.

This event, on October 18, was witnessed by administration especially Divisional Commissioner, Kashmir Shri Anshul Garg (IAS) and Commissioner, Srinagar Municipal Corporation, Shri Haseeb and thousands of the people from different walks of life, who lauded SKUAST-K's efforts for blending science, art, and civic aesthetics. The initiative, they noted, not only beautifies the city but also demonstrates how universities can play a transformative role in public life, environment, and tourism-based economy. As part of the celebrations, SKUAST-K organized a musical evening that drew large crowds and created an atmosphere of joy, optimism, and community spirit. The event continued with a heartwarming Diwali celebration at Lal Chowk, where SKUAST-K students lit hundreds of diyas, symbolizing peace, harmony, and a new dawn for Kashmir. The spontaneous participation of citizens made the square come alive with light, laughter, and music — a true reflection of Kashmir's return to peace and progress.



SKUAST-K Inspired people to Celebrate DIWALI at historic lalChowk with the DIYAAS and FLOWERS

The festivities continued with a grand floral show at the main campus of university at Shalimar, where thousands of visitors, tourists, and dignitaries admired the rich diversity of chrysanthemum blooms. Lt Governor Shri Manoj Sinha, while visiting the garden, highly appreciated the efforts of the university in extending the tourism to the autumn and winter months, and desired that the other departments must take it further to beautify other gardens and parks and the city center

Speaking on the occasion, Vice Chancellor Dr. Nazir Ahmad Ganai said:

"Our vision is to make flowers not just a symbol of beauty, but of livelihood, peace, and prosperity. Through these initiatives, we are turning Kashmir into a year-round floral destination — a place where science meets culture, and nature inspires harmony."

With this initiative, SKUAST-K has once again demonstrated how agricultural science can extend beyond laboratories and farms to touch people's lives, foster sustainable tourism, and project Kashmir as a region of peace, creativity, and cultural resurgence.

The credit goes to SKUAST-Kashmir and its Vice Chancellor for extending the tourism season through the lean autumn months. He has demonstrated exemplary leadership on all fronts — from excellence in education, research, innovation, and outreach — securing SKUAST-K a place among the elite institutions in the country. Under his stewardship, the university has evolved into one of India's most socially relevant organizations, ideating and scripting a new roadmap for agriculture with the vision to make Jammu and Kashmir a Model Bioeconomy State, powered by the ₹5,000 crore Holistic Agriculture Development Program (HADP).

His efforts have also made SKUAST-K India's most culturally diverse agricultural university, hosting students from across all states and international backgrounds, thus setting a powerful example of communal harmony and inclusive growth.

About SKUAST-K

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir is a leading State Agricultural University recognized nationally for its excellence in research, innovation, and outreach. The university's initiatives in climate-resilient agriculture, agribusiness incubation, and community-based innovation have placed it among India's top three State Agricultural Universities in NIRF 2025.

Celebrating Innovation-Led Growth: SKUAST-K Completes a Century of Patents

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) has achieved a landmark milestone by securing its 100th patent, marking a historic moment in the university's journey toward innovation-led growth and academic excellence.

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) has achieved a landmark milestone by securing its **100th patent,** marking a historic moment in the university's journey toward innovation-led growth and academic excellence.

Launched in 2020 under the **World Bank-funded National Agricultural Higher Education Project (NAHEP),** SKUAST-K initiated a comprehensive transformation of its academic and research framework, positioning innovation at the heart of its educational reforms. It became the **first State Agricultural University (SAU)** in India to introduce an **Innovation and Startup Policy (SISP)** and establish a dedicated **SKUAST-K Innovation, Incubation and Entrepreneurship Centre (SKIIE)** to nurture entrepreneurial culture and technology-driven solutions.

Over just four years, the SKIIE Centre has evolved into one of the country's leading incubation ecosystems, propelling a new wave of **student - and faculty-led startups.** The university today boasts **over 89 startups** and **100 patents,** with an impressive **43 filed in the first ten months of 2025 alone.**

The university's innovation ecosystem is strengthened through multiple national-level programs - including a **DST-funded i-TBI Centre,** a **NABARD-supported Rural Business Incubation Centre,** a **BIRAC E-Yuva Centre,** the **JKCIP Incubation and Startup Component,** and a **MEITY-supported Startup and Commercialization Project** - creating a robust and inclusive platform for innovation, incubation, and entrepreneurship.

Reflecting on this milestone, **Prof. Nazir Ahmad Ganai, Vice Chancellor of SKUAST-K,** stated:

"SKUAST-K has made a paradigm shift — from Education for Innovation to Innovation for Education - to realize our vision of becoming an Innovation-Led University. We have transformed our research focus from publication-oriented to problem-solving and product-driven outcomes that directly serve society."

Under this renewed vision, the university has fostered **translational research** to develop science-based products, processes, and solutions for challenges in agriculture, environment, health, climate change, and food systems. With only five patents in its first forty years, SKUAST-K's remarkable leap to **95 new patents in less than five years** underscores its rapid innovation trajectory and strong institutional will.

The university's emphasis on its motto **"Patents to Products"** has enabled the successful **commercialization of several patented technologies,** linking innovation directly to market and societal needs. Through **faculty-led, student-driven startups,** SKUAST-K has bridged the gap between laboratories and industries, ensuring that research translates into tangible benefits for farmers, entrepreneurs, and consumers.

> "Our startups - proudly branded as SKUAST-K BabyCorns - symbolize the birth of a new innovation culture in the university. This milestone reflects the collective effort of our faculty, researchers, students, and innovation teams. It is a tribute to our commitment to build Viksit Jammu & Kashmir by harnessing the bioeconomy through technology-enabled solutions,
>
> Prof. Ganai added.

> "This is not the culmination but the beginning of a new era - where every research idea at SKUAST-K has the potential to become a product, a policy input, or a startup,
>
> Prof. Ganai emphasized.

The Vice Chancellor also commended the **IP & Technology Management Cell,** the **SKIIE Centre team,** and all university faculties for their unwavering dedication to promoting innovation. He urged the academic community to continue pursuing research with commercial, societal, and environmental value.

SKUAST-K's century of patents stands as a testament to its innovation-led growth model, placing it among the leading State Agricultural Universities in India and reinforcing its role as **a catalyst for bioeconomic transformation, entrepreneurship, and sustainable development** in Jammu and Kashmir and beyond.

About SKUAST-K

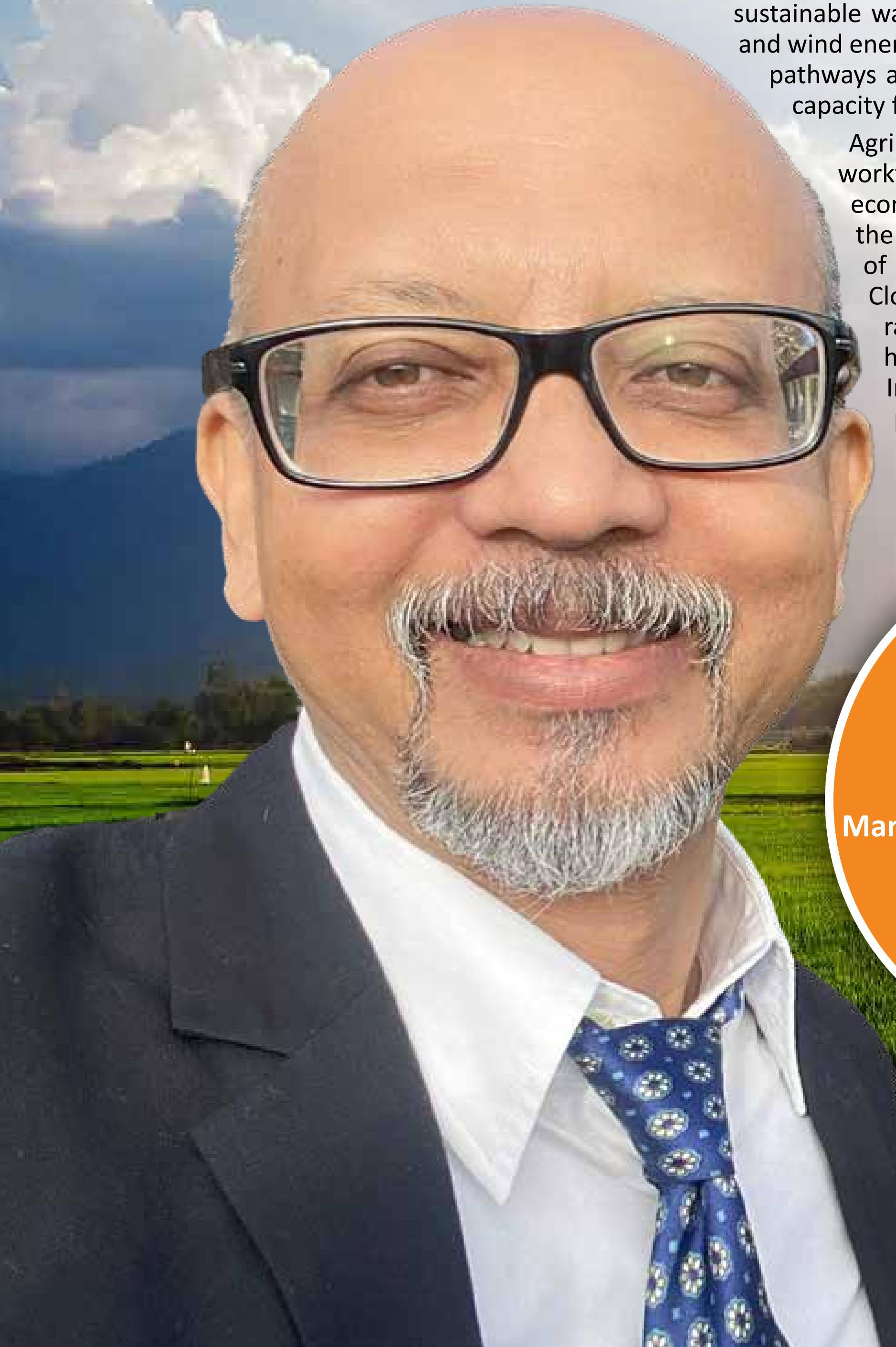
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) is a leading institution in agricultural education, research, and innovation in India. With a vision to become an Innovation-Led, Inclusive, and Globally Engaged University, SKUAST-K has redefined the higher education landscape by integrating outcome-based learning, translational research, and entrepreneurship. The university's focus on sustainability, digital transformation, and bioeconomy-driven growth has positioned it among the **top three State Agricultural Universities in India (NIRF 2025)** and as a national model for agricultural innovation and rural transformation.

Towards

Agricultural Independence

With the largest population of 1.45 billion in the world, India is a lower-middle income country with GNI per capita of USD 2650 . It is also the fastest growing economies in the world with a growth rate of 6.5% in 2024 and aspires to be a developed by 2047. However, India chooses to grow in a clean, sustainable way aimed to be net zero by 2070. Solar and wind energy plays a major role in decarbonization pathways and has a target of 500 GW of installed capacity from non-fossil fuel sources by 2030.

Agri sector in India employs over 43% workforce and contributes 16.4% to the economy is in FY 2024 . That signifies how the agricultural sector is the backbone of rural livelihoods and food security. Close to 60% of the agriculture in India is rainfed. However, the rainfall patterns have changed due to climate change. In this background, renewable energy, particularly the solar energy is emerging as a welcome change offering clean, decentralized and affordable energy for the farmers. Yet, it has both pross and cons. Let us first discuss the advantages first.



Pranab Nath

Managing Consultant at GSES India

Energy Access and Irrigation Independence

Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM) Scheme of Government of India has a target of installing 35,00,000 agricultural pumps, one of the largest in the world. India has already installed 9,03,444 solar pumps by September 2025 . Solar pumps works when it gets the sunlight in the morning and stops in the afternoon. A solar pump can typically deliver 25,000 liters per day to 1,00,000 liters per day depending on its capacity and location of installation. It has several advantages over a diesel operated pumps:

- Increased control over irrigation timing improving crop yields.
- Solar replaces costly diesel thus reduce fuel costs, making farming more economical.
- Solar pumps have no carbon emissions and contribute to cleaner air.

The solar panels, the costliest part of the solar pumping system have a live of 25 to 30 years depending on the quality and upkeep.

Income Diversification through Agrivoltaics

Agrivoltaics is growing crops under or along the solar panels and that has gained traction in India. Several successful agrivoltaics farms are operating in India now and research and development is ongoing. This model allows farmers to generate power and crop cultivation on the same land that gives opportunity for dual income. Pilot projects in Maharashtra and Punjab show that crops like tomatoes, spinach, and beans can thrive under solar arrays. Farmers earn from electricity sales to the grid, creating a new revenue stream. Also, the panels provide shade, reducing heat stress on crops and conserving soil moisture.

Post-Harvest and Cold Storage Solutions

Farmers are generally not getting the price they deserve. Farming is seasonal and all the farm produces are some are perishable. Many a times, farmers need to sell at a through away price or distress selling.

Solar energy can powers cold storage units in a remote village, helping reduce post-harvest losses—especially like fruits and vegetables. Solar dryers allow value addition by drying of agricultural produces like chillies, ginger, turmeric, medicinal plants to fishes at the farm level. This can support rural entrepreneurship, women-led microenterprises, market access and price realization.

Through there are several bright spots of using solar energy, there are few issues that may limit the penetration of solar energy or resulting strain – both in economic, social and environmental front.

Land Use Conflicts

Solar power plants typically need 3 to 4 acres of land with the current crystalline silicon technology. India has already installed 116.25 GW of solar by June 2025 as per the Ministry of New and Renewable Energy, Government of India. With a population density of 475.7 people per square kilometer as of 2021 (world average is only 58 people/sq km), the pressure on land is already high. With the increasing demand for land for setting up of solar plant, land acquisition and conversion from mostly agricultural land to industrial land created tension between power developers and the local community. It is also raising concerns about inclusive growth and a just transition by putting the great majority of farmers and vulnerable communities at risk of losing their means of subsistence.

Technical and Operational Challenges

Solar pumps require regular maintenance, which is often unavailable in remote areas. Agrivoltaics systems have safety concerns as the systems are working in high voltage and current. It must me protected from farm machineries, human and animals. Dust accumulation on solar panels, inverter faults, and battery degradation can reduce efficiency. Farmers need training and capacity building to manage systems safely and effectively.

Equity and Inclusion Concerns

Without targeted interventions, solar adoption may benefit larger landholders and commercial farms, widening inequalities. Women farmers and tenant cultivators often lack access to schemes and ownership rights. Community-based models and inclusive financing are essential to bridge this gap.

Conclusion

Solar energy already showed its potential to revolutionize Indian agriculture—making it more productive, resilient, and sustainable. From powering irrigation, cold chains and drying to enabling income diversification and climate adaptation, the benefits are compelling. Yet, realizing this potential requires addressing land use conflicts, financing barriers, and equity concerns. With the balanced enabling policies, partnerships, and innovations, renewable energy can bring even better greener and more inclusive growth in agricultural sector.

Cultivating a New Green Revolution

How Four Farm Scientists Envision to Transform Agricultural Education for India's Future

Four eminent agricultural scientists have jointly argued that India now needs bold, practical reforms in agricultural education policy to drive a truly sustainable "Agricultural Revolution 4.0." They emphasize that without overhauling how future professionals are trained, the country cannot address emerging challenges of technology-driven farming, climate stress, and farmer distress.

The Green Revolution deserves unqualified praise for rescuing India from the brink of famine and transforming it from a food-deficit nation to a food-surplus country in just a few decades. However, its implementation was often injudicious, overconcentrating benefits in a few irrigated regions and large-holding farmers, while leaving rainfed areas and smallholders behind. It also promoted excessive and unbalanced use of chemical fertilizers, pesticides, groundwater, and monocropping, which resulted in environmental degradation and erosion of biodiversity. Today, India needs a "real" Green Revolution that is inclusive, sustainable, and nutrition-sensitive, covering not only rice and wheat but also millets, pulses, oilseeds, fruits, vegetables and spices and plantations. Achieving these requires a call for a fundamental reorientation of agricultural education policies so that universities produce technology-savvy, field-oriented, socially conscious professionals who can lead this transformation.

Dr. BV Ramana Rao

Dr. Chittaranjan Kole

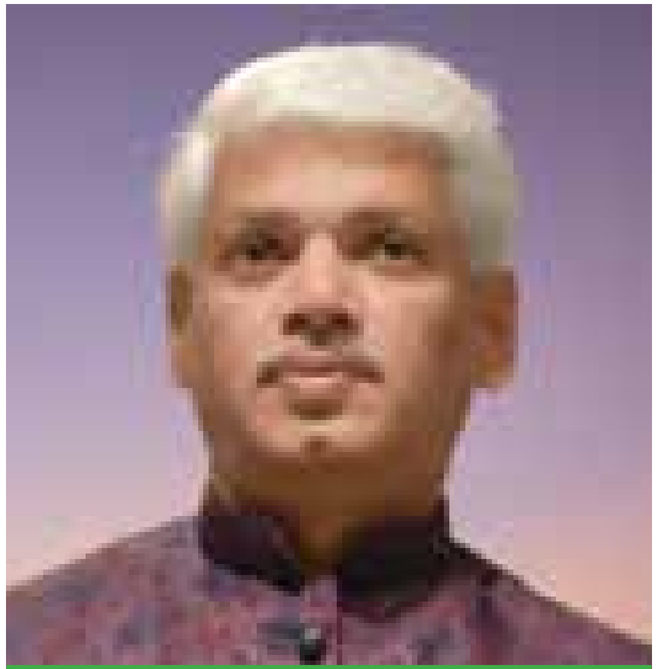
In the November 2025 issue of Just Agriculture magazine, the four authors presented a comprehensive agenda for such change under the theme "Leadership for the Agricultural Revolution 4.0: Evergreen & Evergrowing." In that article, they dissected current shortcomings - obsolete curricula, weak industry linkages, poor rural connect, inadequate entrepreneurship training, language barriers, and non-professional leadership - and set out practical, time-bound measures to correct course and place those proposals before a wider public and policy audience.

Prof. Chittaranjan Kole, with his global expertise in crop genomics and climate-resilient agriculture, calls for aligning India's agricultural education with cutting-edge science while keeping farmers at the center. Dr. B. V. Ramana Rao, with his long association with agrometeorology and national coordinated projects, stresses the need for climate-smart training that prepares graduates to manage weather and climate risks on farmers' fields. Dr. Surender Singh, a senior professor of agricultural meteorology, highlights how data, models, and decision-support tools can be integrated into the curriculum so that students learn to convert information into actionable advisories. Prof. N. Manikanda Boopathi, an academic trailblazer in plant biotechnology, underscores the urgency of embedding genomics, 'omics' tools, and innovation-driven thinking into teaching and field training so that students can drive the next wave of technological breakthroughs.

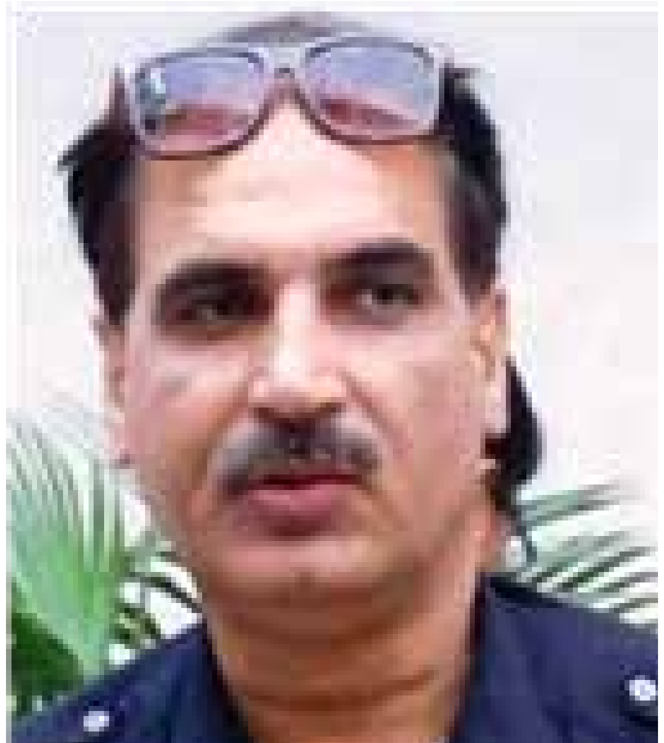
A central and pathbreaking proposal in their article is a one-year mandatory rural internship for all agricultural students, carefully designed to balance academic rigor with deep practical exposure. The aim is not to impose an additional burden but to create a structured bridge between classroom learning and real-world farming systems, thereby changing both student mindset and farmer perceptions about agricultural professionals.

The proposed strategic outline for this one-year rural internship can be visualized in four phases. In the initial orientation phase (about 1–2 months), students would receive preparatory modules on rural sociology, participatory methods, ethics, and basic extension skills, along with refresher inputs in key disciplines such as agronomy, plant protection, soil health, and agrometeorology. This would ensure that when they enter villages, they carry not only technical knowledge but also the interpersonal and communication skills needed to work respectfully with farmers and local institutions.

In the core field immersion phase (6–8 months), students would be placed in carefully selected clusters of villages, preferably in collaboration with Krishi Vigyan Kendras, state agriculture departments, farmer producer organizations, and credible NGOs. Each student (or small student team) would be assigned a set of households or farmer groups for which they would maintain detailed farm and family profiles, document cropping systems, input use, and constraints, and co-design low-cost, locally suited innovations in areas such as crop planning, water management, integrated nutrient and pest management, and digital advisory tools. During this period, students would be required to conduct on-farm demonstrations, organize farmer meetings, and help link farmers to schemes, markets, and services.



Dr. N Manikanda Boopathi



Dr. Surender Singh

The academic integration phase would run concurrently through structured assignments, periodic contact classes (online or short contact sessions at the university), and joint evaluation by university faculty and field mentors. Credits would be attached to well-defined deliverables: village situation analysis reports, technology demonstration records, farmer feedback documentation, and reflective diaries on what worked, what failed, and why. In this way, the internship becomes an academic spine rather than an informal attachment, with clear learning outcomes in problem-solving, systems thinking, and leadership.

Finally, in the synthesis and leadership phase (1–2 months), students would return to the campus to present village-wise or thematic case studies, policy notes, and innovation proposals based on their field experience. Over time, such an internship program would help build a cadre of professionals who understand rural realities first-hand, speak the language of farmers, and at the same time are able to deploy advanced tools of data science, biotechnology, agrometeorology, and agribusiness management.

If these reforms including mandatory rural internships, tech-driven curricula, stronger industry-farmer ties, entrepreneurship training, multilingual content, and professional leadership are embraced in earnest, they hold the potential to profoundly transform India's agricultural future. Policymakers are earnestly urged to thoughtfully review these practical recommendations and consider their progressive implementation in the broader interest of national agriculture.

RENEWABLE ENERGY

A New Paradigm for Growth in Agriculture

In the 21st century, agriculture stands at the crossroads of transformation—driven not just by the need for higher productivity but by the urgency to make farming sustainable, low-carbon, and energy-efficient. The confluence of renewable energy and agriculture is now emerging as the next big paradigm shift for rural Bharat, promising to reshape the way we cultivate, process, and sustain our natural resources.

For a long time, agriculture has been seen as a passive consumer of energy—dependent on fossil fuels for irrigation, mechanization, fertilizers, and logistics. Today, it is rapidly evolving into a producer of clean energy and a steward of the planet's carbon balance. Renewable energy technologies—especially biomass-based solutions—are proving that the farm can not only feed the world but also power it sustainably.

The Energy-Agriculture Nexus

Agriculture consumes nearly 18% of India's total energy, primarily through diesel and grid electricity used for pumps, cold storage, and post-harvest operations. Meanwhile, over 500 million tonnes of agricultural residues, invasive weeds, and forest wastes lie untapped every year—posing fire hazards and releasing millions of tonnes of CO_2 when burnt in the open. Converting this biomass into usable energy or carbon-negative products represents one of the most powerful opportunities for circular rural economies.

The Government of India's push toward "Energy Transition for Atmanirbhar Bharat" recognizes this synergy. Decentralized biomass energy, biogas, solar, and biochar-based carbon capture systems can together unlock a self-reliant rural economy, reduce energy import dependence, and generate green jobs across India's hinterlands.

Sajeevan Life: Turning Waste into Wealth and Energy

At the forefront of this transformation is Sajeevan Life Pvt. Ltd., an agritech enterprise pioneering alternative green energy solutions through biomass valorisation. Based in Gujarat, Sajeevan Life works with farming communities and local administrations to convert invasive species like Prosopis juliflora and Lantana camara—often seen as ecological nuisances—into high-value energy products such as biochar and syngas.

The company's innovation-driven approach rests on a "Full-Stack Carbon Removal" model—linking waste biomass management, renewable energy generation, soil health improvement, and carbon credit monetization into one integrated system.

1. Biomass to Syngas Machines – Through its partnership with its R&D partner, Sajeevan installs modular syngas machines that convert woody biomass into clean synthesis gas used for industrial and thermal applications. Each 10 MTPD unit replaces fossil fuel consumption worth ₹30–35 lakh annually, offering industries a renewable, carbon-neutral energy source.

2. Biochar for Carbon Capture and Soil Regeneration – The co-product, biochar, is a stable form of carbon with immense benefits for soil fertility and climate resilience. It locks atmospheric carbon for centuries, improves soil organic carbon, and enhances water and nutrient retention in farmlands. Sajeevan's biochar units are now producing artisanal-grade biochar for agriculture and horticulture use, and are being recognized among India's most credible carbon removal solutions.

Sandeep Sabharwal

Co-Founder

Sajeevan Life Pvt Ltd.

3. Biochar-based Biofertilisers – Moving a step ahead, biochar-based biofertilizers are possible (as experimented by Sajeevan Life) using local agricultural residues, dung slurry, and organic inputs. This organic alternative to chemical fertilizers not only enhances soil microbial activity but also reduces farmers' dependency on synthetic fertilizers—thereby saving the significant energy that goes into fertilizer manufacturing and transportation.

Together, these innovations demonstrate that renewable energy in agriculture is not just about producing power—it is about creating regenerative ecosystems.

From Local Solutions to National Replication

India's drylands and wastelands are home to millions of hectares infested with Prosopis juliflora and Lantana camara. These invasive species choke native biodiversity and deplete groundwater, yet their biomass holds tremendous energy potential. Sajeevan Life's pilot projects in Gujarat, supported by Panchayati Raj institutions and cooperative frameworks, have proven that community-led biomass clearing can:

- Reclaim degraded lands for productive use,
- Generate rural employment and income,
- Supply renewable feedstock for decentralized energy systems, and
- Produce biochar that regenerates local soils.

The model is now ready for replication at scale in other states such as Madhya Pradesh, Rajasthan, Haryana, Chhattisgarh, and Jharkhand—where invasive species are abundant, rural energy needs are high, and sustainable livelihoods are essential. With the right policy incentives under India's National Bioenergy and Carbon Farming missions, such decentralized renewable energy clusters can become engines of rural transformation.

Indirect Energy Savings through Regenerative Agriculture

Beyond direct energy generation, Sajeevan Life's initiatives have an equally profound impact on energy savings in farming. Conventional agriculture's dependence on chemical fertilizers and irrigation-intensive crops consumes vast amounts of fossil energy. By promoting biochar-based soil amendments, organic inputs, and natural farming practices, Sajeevan Life reduces farmers' need for synthetic fertilizers, which account for nearly 2% of global energy use.

Each tonne of biochar applied to soil not only sequesters carbon but also enhances nutrient efficiency, reducing fertilizer and irrigation demand by up to 30%. This translates to indirect but substantial energy conservation and greenhouse gas reduction at the national scale. In effect, biochar makes the soil itself a renewable energy storage system.

The Road Ahead: Green Energy for a Resilient Bharat

The synergy between renewable energy and agriculture offers an unprecedented opportunity to achieve energy security, climate action, and rural prosperity simultaneously. The transition calls for a policy ecosystem that encourages:

- Decentralized biomass energy clusters linked with Farmer Producer Companies (FPCs),
- Carbon credit frameworks rewarding smallholders for biochar use,
- Public-private partnerships for waste biomass collection and processing, and
- Research and skilling programs to build green rural entrepreneurship.

Sajeevan Life's pioneering work stands as a blueprint for this vision—a proof that renewable energy can emerge not just from solar panels and wind farms, but from the very roots of India's farmlands. By transforming agricultural residues and invasive weeds into clean energy, soil wealth, and carbon credits, it is redefining how Bharat can grow sustainably—from the soil up to the sky.

In this new paradigm, every acre becomes a potential energy source, every farmer an energy entrepreneur, and every rural community a node of India's green revolution 2.0—powered by renewable energy, grounded in agriculture, and sustained by nature.

Strengthening Indonesia and India
Collaboration for a Sustainable Edible Oil Future

India stands at the heart of the global edible oil ecosystem. As one of the world's largest consumers and importers, its policies and partnerships influence food security far beyond its borders. With consumption rising steadily, India's ability to maintain affordable, reliable access to edible oils, especially palm oil will play a defining role in ensuring household nutrition, price stability, and rural economic resilience.

Today, over half of India's edible oil requirements are met through imports, with palm oil accounting for the majority share. Much of this comes from Indonesia, which remains the world's largest producer and a longstanding, trusted partner in meeting India's needs. This interdependence highlights the need for stable, predictable trade policies that can protect consumers from global volatility and foster long-term industry investment.

Building Predictable and Sustainable Trade Relations

In recent years, global edible oil markets have faced repeated disruptions from weather-linked supply shocks to sudden export curbs and shifting import duties. Each change reverberates through India's refining, processing, and retail ecosystem. The lesson is clear: short-term interventions may stabilize prices temporarily, but only long-term policy predictability can anchor lasting food security.

A multi-year, transparent trade framework built on trust and collaboration would allow refiners, importers, and producers to plan confidently. For India, this means stable access to affordable oils and smoother price transmission for consumers. For Indonesia, it ensures a reliable export market that supports smallholders and industry livelihoods. A predictable tariff structure and continuous government-to-government dialogue can help prevent price spikes, encourage private-sector investment in storage and logistics, and build resilience across both economies.

Palm Oil's Role in India's Food Security

Edible oils remain outside India's core food subsidy systems, yet they are a vital calorie source for millions. Price swings in cooking oil can therefore have an outsized impact on household budgets, especially in lower-income segments. Stable palm oil flows help cushion these consumers while sustaining India's thriving food processing sector, an industry that employs millions and contributes significantly to manufacturing GDP. For Indonesia, this partnership is equally strategic. Palm oil exports to India not only support foreign exchange earnings but also demonstrate how trade cooperation can advance shared goals of food security and sustainable development.

Collaborating for a Sustainable Future

As both countries deepen their trade relationship, sustainability must remain central. Indonesia's palm oil industry has made tangible progress through replanting programs that improve yields, stricter land-use regulations, and the adoption of internationally recognized certification systems. Nearly one-fifth of global palm oil production a share steadily rising as major exporters expand certification now meets recognized sustainability standards, reflecting the industry's growing commitment to responsible growth.

The Indonesian Palm Oil Association (IPOA) continues to champion this progress by promoting traceability, smallholder inclusion, and best-practice standards. Collaboration with Indian refiners, policymakers, and research institutions can further strengthen transparency and technology exchange, ensuring that the palm oil trade supports both environmental goals and supply security.

Towards a Shared Policy Vision

A future-ready edible oil framework requires coordination across three fronts:

1. Predictable trade policies that provide long-term visibility for both importers and exporters.
2. Joint sustainability standards that align with global benchmarks while promoting local livelihoods.
3. Investment in downstream value chains, including refining, packaging, and bio-innovation, to generate employment and diversify revenue streams.

India's National Mission on Edible Oils - Oil Palm (NMEO-OP) represents a promising step toward building domestic capacity. Indonesia stands ready to share its technical expertise to help India balance productivity with ecological safeguards. Responsible expansion, not rapid monoculture can ensure that India's self-reliance ambitions complement global sustainability efforts.

Conclusion

India and Indonesia share more than trade; they share responsibility for the future of food security in Asia. The strength of this partnership lies in its ability to balance affordability with sustainability, commerce with community, and growth with environmental stewardship.

As both nations navigate evolving global dynamics, a predictable, transparent, and sustainability-driven palm oil trade will not only secure edible oil access for millions of Indian households but also contribute to a more stable and equitable global food system. Together, we can ensure that the bond between Indonesia and India continues to nourish both economies and the generations that depend on them.

By Eddy Martono
Chairman,
Indonesian Palm Oil Association (IPOA)

MORINGA
The Tree of Health and Wealth

Introduction:

Moringa oleifera, known as the "miracle tree", grows well in tropical and subtropical regions and is believed to have originated in India, Pakistan, Bangladesh, and Afghanistan. It's a fast-growing tropical deciduous plant of the Moringaceae family, has tuberous roots, light green leaves, abundant flowers, and pendulous fruits with seeds. It belongs to a family of 13 species, but M. oleifera is the most well-known for its nutritional, medicinal, and agricultural uses. It grows well in dry areas and can survive in different types of soil, especially well-drained sandy or loamy soil with a pH between 5 and 9. This plant is often called the "Miracle Tree" because almost every part like leaves, roots, seeds, bark can be used for food, medicine, or household products. This drought-tolerant tree is one of the most affordable sources of essential nutrients and plays a crucial role in combating malnutrition, particularly among infants and lactating mothers.

Moringa is rich in nutrition owing to the presence of a variety of essential phytochemicals present in its leaves, pods and seeds. In fact, moringa is said to provide 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 9 times more protein than yoghurt, 15 times more potassium than bananas and 25 times more iron than spinach. Due to its low cost, high nutritional value, and resilience to harsh climates, Moringa oleifera is considered a valuable resource for addressing malnutrition, especially in rural areas, and improving food security, health, and environmental sustainability.

Almost every part of the Moringa tree has practical uses. The leaves are rich in beta-carotene, calcium, and potassium, and are commonly used in health drinks like Zija. Dried leaves contain about 70% oleic acid, making them valuable in the production of moisturizers. The bark is traditionally used to treat ulcers, toothache, and high blood pressure. Roots are used for managing toothache, parasitic worms, and paralysis. The flowers are known to help with ulcers and spleen-related issues and are also used as a natural aphrodisiac. In Ayurveda, it is used to treat asthma, epilepsy, eye and skin diseases, fever, and hemorrhoids.

Moringa is not just a nutritious plant for household use—it also has great industrial and commercial potential. Different parts of the Moringa tree (leaves, seeds, pods, bark, and roots) can be processed into value-added products for food, health, cosmetics, agriculture, and industry.

Nutritional Composition of Moringa oleifera (Drumstick Tree)

1. Moringa Leaves

- Fresh leaves are rich in protein, vitamins (especially A and C), calcium, iron, and antioxidants.
- Dried leaves and leaf powder are more concentrated, offering higher amounts of protein (up to 30%), calcium (over 2000 mg), and iron (up to 28 mg).
- Leaves provide all essential amino acids and contain healthy unsaturated fatty acids like omega-3 and omega-6.
- The calorific value is low, making moringa leaves suitable for weight-conscious diets.
- They also contain important phytochemicals (e.g., flavonoids, phenolics, isothiocyanates) that support immune and anti-cancer functions.

2. Moringa Pods (Drumsticks)

- Commonly used as a vegetable.
- Rich in dietary fiber, helping in digestion and preventing colon-related diseases.
- Immature pods contain up to 46% fiber and 20% protein.
- High in vitamin C, moderate in potassium and phosphorus.
- Contains beneficial fatty acids and minor amounts of essential minerals.

3. Moringa Seeds

- Seeds are a rich source of edible oil (up to 40%), primarily made of oleic acid (a heart-healthy monounsaturated fat).
- High in protein (up to 36%) and contain good amounts of calcium, magnesium, and iron.
- Also used for water purification due to natural coagulant properties.
- Seeds contain antioxidants and natural compounds with potential medicinal uses.

4. Moringa Flowers

- Less commonly consumed, but rich in essential amino acids, healthy fatty acids, and antioxidants.
- Contain linoleic, linolenic, and oleic acids—important for heart and brain health.
- Flowers have potential for use in functional foods, herbal teas, and traditional remedies.

Nutritional Benefits

- Leaves are the most nutrient-dense part, especially rich in protein, calcium, iron, and vitamins A, C, and E. Pods are excellent for fibre and vitamin C, ideal for digestive health. Seeds provide healthy fats and protein, and have unique roles in both nutrition and water purification. Flowers offer a balanced mix of amino acids and plant-based fats, with antioxidant benefits. Low in Calories: Especially leaves and pods, beneficial for weight control.
- Phytochemical-Rich: Contains antioxidants, flavonoids, tannins, alkaloids, and anti-cancer agents like glucosinolates and isothiocyanates.
- Safe Anti-nutrients: Small amounts of phytates and oxalates are present but not harmful when consumed in normal quantities. Processing (like drying or cooking) reduces them further.

Health Benefits of Moringa oleifera:

Moringa oleifera, known as the "Miracle Tree", is rich in antioxidants, vitamins, minerals, and medicinal compounds. It supports prevention and management of many diseases.

1. Diabetes Management

- Helps control both Type 1 and Type 2 diabetes.
- Lowers blood sugar and improves insulin activity.
- Protects pancreatic cells and prevents diabetic complications.

2. Cancer Prevention

- Contains isothiocyanates and niazimicin with anti-cancer properties.
- Slows tumor growth and promotes natural death of harmful cells.
- Protects normal cells while targeting cancer cells.

3. Other Health Benefits

Condition	Benefit
Brain health	Improves memory and protects against stroke and dementia
Kidney health	Reduces urea/creatinine; prevents kidney damage
Stomach ulcers	Reduces acidity and promotes healing
Arthritis	Relieves joint pain and inflammation
Infections	Fights bacteria and fungi; natural antibiotic
Immunity (HIV/AIDS)	May help boost immune strength (research ongoing)

4. Medicinal Uses by Plant Part

Plant Part	Uses
Leaves	Anti-diabetic, anti-cancer, antimicrobial, antioxidant, brain-protective
Seeds	Treats arthritis, infections, epilepsy, and inflammation
Roots	Ulcer relief, heart stimulant, muscle relaxant
Flowers	Supports cholesterol control, joint and urinary health
Pods	Aids digestion, liver function, and joint pain relief

Value-Added Products from Moringa oleifera:

Moringa oleifera is used to develop a wide range of nutritional, medicinal, and commercial products from its different parts-leaves, seeds, pods, flowers, and roots.

1. From Moringa Leaves

Product Type	Description/Use
Leaf Powder	Used as a dietary supplement for vitamins and protein
Herbal Tea	Made from dried leaves; rich in antioxidants
Capsules/Tablets	Health supplements for boosting immunity and energy
Moringa Juice	Nutrient-rich drink with medicinal benefits
Animal Feed	High-protein additive for livestock and poultry

2. From Moringa Seeds

Product Type	Description/Use
Moringa Oil (Ben Oil)	Edible oil rich in oleic acid; used in cooking and cosmetics
Water Purifier	Crushed seeds used as a natural coagulant in water treatment
Seed Cake	Fertilizer and animal feed after oil extraction

3. From Moringa Pods

Product Type	Description/Use
Vegetable Products	Used in soups, curries, pickles, and frozen mixes
Ready-to-Cook Mixes	Dried pod-based food products for quick preparation

4.From Moringa Flowers

Product Type	Description/Use
Edible Delicacies	Used in traditional dishes and herbal recipes
Medicinal Tinctures	Used for anti-inflammatory and urinary health

5. From Moringa Roots & Bark

Product Type	Description/Use
Herbal Extracts	Used in traditional medicine for digestive and cardiac benefits

6. Cosmetic and Personal Care Products

Product Type	Description/Use
Face Creams & Lotions	For skin hydration and antioxidant protection
Hair Oils & Shampoos	Promote hair growth and scalp health
Soaps	Herbal cleansing with antibacterial properties

Industrial Uses of Moringa oleifera :

Moringa oleifera is not only valuable for nutrition and medicine but also plays a significant role in various industries due to its unique bioactive compounds and functional properties.

1. Pharmaceutical Industry

- **Herbal Medicines:** Leaves, seeds, and roots are used to make capsules, tablets, and syrups.
- **Natural Antioxidants:** Extracts are used in formulations for anti-aging, immunity, and diabetes control.
- **Cancer Research:** Compounds like niazimicin and isothiocyanates are studied for anti-cancer potential.

2. Nutraceutical Industry

- Dietary Supplements: Leaf powder and extract are used in protein powders, health drinks, and energy bars.
- Functional Foods: Fortified flours, soups, snacks, and beverages enriched with moringa.

3. Cosmetic & Personal Care Industry

- **Skincare Products:** Moringa oil is used in creams, lotions, soaps, and anti-aging serums.
- **Hair Care:** Shampoos, conditioners, and oils contain moringa for scalp health and hair strengthening.
- **Soap Manufacturing:** Due to its antimicrobial and moisturizing properties.

4. Food Processing Industry

- Natural Preservative: Leaf and seed extracts are used for their antioxidant and antimicrobial effects.
- Flavor Enhancer: Dried leaf powder adds nutritional and sensory value to food products.
- **Edible Oil:** Moringa seed oil (Ben oil) is stable, odorless, and used in high-quality cooking oil blends.

5. Water Purification Industry

- **Natural Coagulant:** Crushed moringa seeds are used to clarify turbid water by settling impurities.
- **Eco-Friendly Alternative:** Offers a biodegradable, low-cost replacement for alum and other chemicals.

6. Agriculture and Animal Feed

- **Green Manure and Biofertilizer:** Seed cake (after oil extraction) is rich in nutrients.
- **Plant Growth Promoter:** Moringa leaf extract acts as a natural biostimulant.
- **Animal Feed Supplement:** High-protein leaf and pod meals enhance livestock health and productivity.

7. Textile and Dyeing Industry

- Natural Dye Source: Bark and roots are used in traditional dyeing.
- **Fabric Finishing:** Moringa seed extract may be used for antibacterial finishing in fabrics.

8. Biofuel and Lubricant Industry

- **Biofuel Potential:** Moringa seed oil can be converted into biodiesel.
- **Industrial Lubricants:** Due to its high oleic acid content, moringa oil can be used in machines and precision instruments.

Moringa in Animal and Fish Sector:

Moringa oleifera is increasingly used in livestock and aquaculture due to its high nutritional value, medicinal properties, and growth-promoting effects.

1. Animal Feed Supplement

Moringa oleifera is gaining widespread attention in the livestock and aquaculture sectors because of its rich nutritional profile, medicinal properties, and ability to promote growth and productivity. As an animal feed supplement, moringa leaves and pods are excellent sources of protein, vitamins A, B, and C, as well as calcium and iron. Their inclusion in the diets of cattle, poultry, goats, and pigs has been shown to improve weight gain, increase milk yield, and enhance egg production. Additionally, moringa acts as a natural dewormer and immune booster in livestock. For example, dairy cows fed with moringa leaf meal have demonstrated increased milk yield and higher butterfat content, while poultry diets supplemented with moringa have led to better egg production and improved egg quality.

2. Fodder and Silage

Moringa leaves also serve as a valuable source of fodder and silage, either in fresh form or as preserved feed. Their high digestibility and palatability make them ideal for ruminants such as cows, goats, and sheep. When combined with conventional fodder crops, moringa enhances the overall nutritional content of livestock diets.

3. Moringa Seed Cake

Furthermore, the seed cake, which remains after oil extraction, is rich in protein and can be used as a supplemental livestock feed. This by-product also serves as an effective natural fertilizer, adding value to both animal husbandry and crop cultivation systems.

4. Moringa in Aquaculture (Fish Farming)

In the field of aquaculture, moringa leaf meal is increasingly being used as a feed additive for fish and shrimp. Its incorporation in aquatic diets has shown to boost growth rates, improve survival, and enhance feed conversion efficiency. In addition, moringa strengthens disease resistance and immunity in farmed fish, helping to reduce dependence on synthetic antibiotics and growth hormones. Common fish species benefiting from moringa-enriched diets include tilapia, catla, rohu, and common carp.

5. Health and Medicinal Benefits

It acts as a natural antibiotic and antioxidant, helping to lower stress levels and disease incidence. Bioactive compounds in moringa support gut health, reduce inflammation, and enhance metabolic functions, contributing to the overall well-being of farm animals and aquatic species.

6. Environmental Benefits

Moreover, moringa has notable environmental benefits in the livestock sector. When used as a feed additive in ruminants, it helps to reduce methane emissions, thereby lowering the environmental impact of animal farming. Its ability to grow in dry, degraded lands also makes moringa cultivation a sustainable option for year-round fodder production in climate-stressed areas.

Agricultural Uses of Moringa oleifera

Moringa oleifera has multiple applications in agriculture due to its antifungal, growth-promoting, and stress-reducing properties:

Natural Fungicide:

- Extracts from Moringa leaves, roots, seed oil, and pods showed antifungal activity against pathogens like Fusarium, Alternaria, Rhizoctonia, Sclerotium, and Macrophomina, reducing spore germination and growth.
- Moringa seed oil and leaf extract effectively controlled early blight (Alternaria solani) in potatoes and improved tuber yield.

Crop Growth Enhancer:

- **Apples:** Foliar spray (6%) improved growth, fruit set, yield, and resistance to climate stress in 'Anna' apples.
- **Plums:** Spraying enhanced yield, fruit weight, quality, and antioxidant levels in "Hollywood" plums.
- **Lettuce:** Seed drenching (5%) and foliar spray (10%) improved growth under salt stress, increased chlorophyll and nutrient levels (N, P, K), and reduced nitrate content.
- **Potatoes and Lettuce:** Moringa leaf extract and seed cake increased vegetative growth, chlorophyll content, and overall plant health.

Soil and Microbial Health:

- Moringa application increased soil microbial activity, leaf nutrient content, fruit quality, and yield across different crops.

Soil Amendment:

- Mixing Moringa seed cake with vermicompost (50:50) improved apple tree growth and productivity.

Moringa as a Climate-Resilient Crop:

Moringa (Moringa oleifera) is recognized as a climate-resilient crop due to its ability to thrive in challenging environments, making it ideal for sustainable farming in drought-prone and resource-limited regions.

1. Drought Tolerant

Moringa (Moringa oleifera) is widely recognized as a climate-resilient crop because of its remarkable ability to grow in difficult environments, making it highly suitable for sustainable agriculture in drought-prone and resource-poor regions. One of its key strengths is its drought tolerance—once established, it requires very little water and can thrive in semi-arid and arid climates with as little as 250 to 300 mm of annual rainfall. It is capable of surviving long dry spells without the need for irrigation.

2. Heat Resistant

Moringa is also highly heat resistant, growing well in temperatures ranging from 25°C to 48°C while continuing to produce leaves and pods even under intense heat and sunlight. Its adaptability extends to poor soil conditions as well.

3. Grows in Poor Soils

The plant can grow in marginal, sandy, or rocky soils with low fertility and is tolerant of both slightly acidic and slightly alkaline soils. It can produce well with little or no fertilizer input.

4. Fast Growing and Perennial

As a fast-growing and perennial tree, moringa can reach heights of 3 to 5 meters in its first year alone. It allows for multiple harvests of leaves and pods throughout the year and can be coppiced and regenerated easily, ensuring year-round availability of food and fodder.

5. Low Input, High Output

It is a low-input, high-output crop, requiring minimal agrochemical use and is easy to manage, especially for small and marginal farmers. Its compatibility with agroforestry and mixed cropping systems makes it even more valuable in sustainable agriculture.

6. Soil and Environmental Benefits

Moringa also offers important soil and environmental benefits. Its deep root system helps prevent soil erosion and improves soil structure. Additionally, it contributes to carbon sequestration, playing a role in mitigating climate change. The tree is frequently used in reforestation and wasteland reclamation efforts.

7. Livelihood Support under Climate Stress

Most importantly, moringa serves as a source of livelihood support under climate stress. It provides nutritious food, animal fodder, and a potential source of income during periods of drought, acting as a reliable safety-net crop in the face of increasing climate uncertainties.

Impact Story

Value Addition in Moringa – A Successful Enterprise Model

Case Study :1

Moringa Entrepreneur: Mrs. Ponnarasi, Dindigul District

Mrs. Ponnarasi, a progressive farm woman from Gujiliamparai block in Dindigul district, cultivates around 20 acres of moringa. Despite achieving good yields, frequent market price fluctuations drastically affected her income, making it difficult to sustain her family and support her children's education. Seeking a sustainable livelihood solution, she approached KVK, Dindigul, Tamil Nadu which guided her to transition from selling raw moringa to value-added product processing for better income stability and profitability.

She attended a four-day training programme at KVK, Dindigul on preparing moringa leaf and fruit powder, instant soup mix, nutri mix, seed oil, and moringa soap. Equipped with these skills, she established a home-based enterprise, secured FSSAI certification, and received technical support from IIFPT, Thanjavur for product testing and improvement. With KVK's support in branding and marketing under the label "Arasi Moringa" and active participation in agricultural exhibitions and fairs, she effectively transformed her farm produce into profitable, high-value products, establishing herself as a successful moringa entrepreneur.

Achievements

She now produces and markets a range of value-added moringa products under her brand "Arasi Moringa."

She now produces and markets:

- Moringa Leaf Powder – ₹400/kg
- Moringa Seed Oil – ₹300/100 ml
- Moringa Soap – ₹45/piece
- Moringa Soup Powder – ₹500/kg

Outcome and Impact

- Earns an annual income of ₹7.0 lakh through her moringa-based enterprise.
- She has trained 214 farm women and SHG members in moringa value addition and rural entrepreneurship, fostering livelihood opportunities and women empowerment.
- Inspired neighbouring farmers for starting moringa enterprises.
- FPO formation initiated for collective marketing and export.
- Created livelihood opportunities and strengthened women entrepreneurship in the region.
- As model woman entrepreneur promoting nutrition, income, and empowerment in rural Tamil Nadu

Exhibiting Moringa products at exhibition

Case Study-2

Moringa Entrepreneur: Mr. V. Kannaiyan, Karur District, Tamil Nadu

Moringa is a major crop in Aravakurichi block of Karur district, covering over 2,100 ha. During the peak harvest season, farmers face sharp price drops due to oversupply. To overcome this and enhance income, ICAR–KVK, Karur promoted value addition in moringa as a sustainable solution to minimize post-harvest losses and improve profitability.

KVK, Karur developed and demonstrated simple, low-cost processing techniques for converting moringa pods, leaves, and flowers into high-value food products such as moringa milk, soup mix, and health powders. The interventions included standardization of dehydration and blending techniques, product testing, branding, labeling, and FSSAI certification support.

Achievements

Mr. V. Kannaiyan, a moringa grower from Karungalpatti village, applied these technologies and established a small-scale processing unit under the brand "Yugas Naturals." Utilizing raw materials from his 30-acre moringa farm, he diversified into multiple products such as:

- Moringa soup mix (nine variants including jamun seed and Aavarampoo)
- Moringa milk and milk powder
- Moringa-enriched millet balls, cookies, and nutrimixes

Outcome and Impact:

- Established a sustainable value chain for moringa, ensuring year-round income and reduced wastage.
- Generates an average monthly income of ₹45,000 from diversified moringa-based products.
- Provides regular employment and skill-based livelihood to four rural women, fostering inclusive growth.
- Promotes local marketing and consumer awareness through sales outlets and a bakery located on National Highway–44 near Karur.
- Achieved a 50–60% increase in farmer income through systematic value addition.

Conclusion

The Moringa tree, renowned globally as the "miracle tree", represents nature's ideal combination of health, wealth, and sustainability. Each part of the tree possesses extraordinary value—its leaves and pods are rich in nutraceuticals and food, while its seeds and extracts serve various purposes in agriculture, veterinary medicine, and fisheries. Beyond being merely a crop, Moringa is a climate-smart option for farmers. It protects soil and water, enhances ecosystems, and simultaneously increases farm income through fresh produce and value-added products that create opportunities for new businesses and livelihoods. So, it is a natural gift of resilience and abundance, a true companion for a healthier life, stronger farms, and a greener Earth.

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RNI No. DELENG/2015/ 65174 Postal Reg. No DL-SW-1/4191
Published on 25th & Posted on 27-28 at NDPSO in Advance Month