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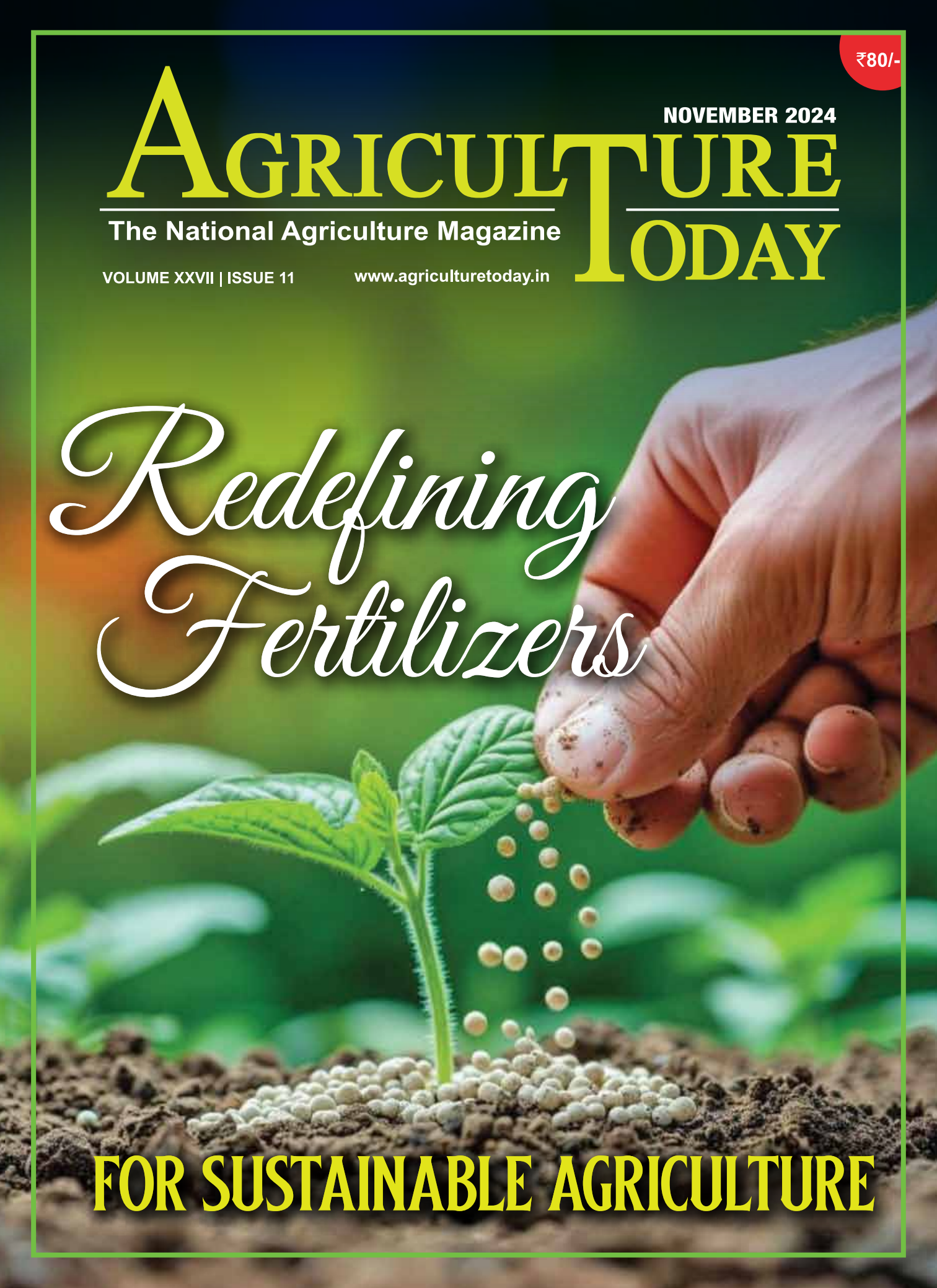

Redefining Fertilizers

FOR SUSTAINABLE AGRICULTURE

भारतीय कृषि एवं खाद्य परिषद्
INDIAN CHAMBER OF FOOD AND AGRICULTURE

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GrainsWorld Conference & Expo 2024

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TO INVESTING IN INNOVATION

Fertilizers hold the cardinal responsibility of supplying nutrients to ensure plant growth and optimal crop performance. However, today their roles have been revised. Apart from nutrient suppliers, the fertilizers today need to be gentle on soil and environment. They have become from being too specific to general, and from being macro to micro in composition and quantity.

Nutrient delivery too has become an important component, and now we have more options than ever before. With the variations in release mechanism, the nutrient availability in the soil is prolonged ensuring efficiency and soil integrity. While we have coated fertilizers, we are also privy to the benefits of nano fertilizers.

Soil health has become a major determinant in the choice of fertilizers. The declining soil organic matter and skewed C:N ratio have brought the focus on organic fertilizers. Natural farming, organic farming and regenerative agriculture are some popular choices these days, which emphasize on organic inputs and soil health, that leverage on enhancing the population of microorganisms in soils. Biofertilizers on the other hand, provide an artificial means to enriching the biotic community of the soil. Besides them, bio stimulants too spur the growth and performance of plants.

Fertilizer development today is not restricted to the plant performance alone. Instead, it is dependent on a myriad of factors such as efficiency, sustainability, performance and economics. Unfortunately, at field level, this finesse has yet to catch up, and the decision is primarily guided by economics and government policies. Farmers use what is easily available and that which is cheaper.

Our government policies are yet to recognize the relevance of novel and innovative products. Rather than incentivizing the fertilizer usage, innovations need to be incentivized. Policies should encourage research and development and promote access of these innovations to farmers. Playing field should be levelled to all players. Regulatory mechanism should not be restrictive but productive.

The key to food security lies in prudence. As the focus of agriculture shifts to sustainable agriculture, we need to choose the inputs wisely. Investing in right fertilizers can meet the perennial human demand of food security and also make our soils rejuvenate and maintain its vigour.

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GrainsWorld Conference & Expo 2024

PIONEERING GLOBAL SOLUTIONS FOR GRAIN TRADE AND FOOD SECURITY

The GrainsWorld Conference 2024, scheduled for November 27-28 in Dubai, UAE, marks a pivotal event in the global agricultural calendar, focusing on the future of the grains industry. The two days B2B conference organized by the Indian Chamber of Food and Agriculture (ICFA), is supported by the Ministry of Commerce, GoI, and the International Grains Council (IGC), World Agriculture Forum (WAF), Wheat Producers and Processors Society (WPPS). This prestigious conference will convene policymakers, agribusiness leaders, and industry experts from around the world, having key institutional partners such as the Global Grains and Pulses Council (GGPC), and the India Global Millets Forum (IGMF), knowledge partner International Agriculture Consulting Group (IACG), marketing partner (HnyB) with GAFTA as the official media partner. The event will provide an influential platform for sharing insights, exploring innovations, and forging strategic partnerships essential to the sustainable growth of the grains sector.

I as the CEO of the Indian Chamber of Food and Agriculture (ICFA), extend invitation to you all to join us in exploring the vital role grains play in ensuring food security worldwide.

Global Grain Production and Access to Food

Humans have been harvesting small, dry seeds known as grains for thousands of years. The world relies heavily on grains as a staple for nutrition and sustenance. With an annual production of approximately 2.2 billion tons, major grains like wheat, rice, and corn are cultivated across diverse regions. The leading producers—the United States, China, and India—play pivotal roles in maintaining global food supply.

However, despite this impressive output, nearly 690 million individuals suffer from chronic hunger, highlighting a significant gap in access to food. The World Food Programme (**WFP**) reports that around 10% of the global population experiences food insecurity, with malnutrition persisting as a critical issue. Furthermore, the international grain trade exceeds 450 million tons annually, primarily driven by major exporters like the United States, Brazil, and Argentina. Yet, many countries in Africa and Asia remain dependent on imports, exacerbating the urgency for equitable access to grains.

About the **AUTHOR**

Ashwani Bakshi
CEO, Indian Chamber of Food and Agriculture (ICFA)

Challenges in Grain Trade and Production

The grain sector faces several challenges that hinder food security and equitable access.

Geopolitical Tensions

Recent conflicts and geopolitical tensions disrupt trade routes, impacting the availability and prices of grains. Export restrictions and sanctions can create ripple effects, making it difficult for countries that rely on imports to meet their food needs. Countries may impose trade barriers to protect their domestic food security, leading to higher prices and global food shortages, whereas the agricultural sector is increasingly vulnerable to climate change, with extreme weather events leading to unpredictable crop yields. Droughts, floods, and shifting weather patterns threaten the stability of grain production, underscoring the need for resilient agricultural practices.

We see the fluctuations in grain prices which can create barriers for both producers and consumers, particularly in developing nations where access to affordable food is essential for survival. Additionally, it can be challenging to

track and verify the quality and origin of grains, and regulatory hurdles can complicate the challenges of grain trade.

In summary, there is a pressing need for significant investments in technology and infrastructure to address the challenges in grain trade.

Relevance of GrainsWorld

GrainsWorld 2024 is a crucial initiative aimed at addressing these pressing challenges within the grain sector, and is catering to comprehensive commodities falling under grains which are rice, millets, pulses, wheat, vegetable oil seeds etc.

This conference seeks to promote fair grain trade practices, ensuring that producers receive equitable compensation for their crops while consumers have access to affordable prices. Key strategies will include advocating for improved trade agreements, enhancing supply chain transparency, and utilizing technology to streamline grain distribution. By doing so, GrainsWorld aims to create a more efficient and fair marketplace. This conference anticipates actionable commitments from stakeholders to support sustainable agricultural practices and initiatives that enhance food security. By fostering collaboration, GrainsWorld aims to establish a cohesive approach to the challenges facing the grain sector.

The World Food Programme (WFP) reports that around 10% of the global population experiences food insecurity, with malnutrition persisting as a critical issue.

Future Outlook of GrainsWorld

Global trade is expected to expand slightly in 2025 as price-sensitive countries, especially in Africa and Asia, increase import demand in response to more available supplies and lower prices. In particular, African countries have shifted to alternate suppliers such as Pakistan but scaled back on total purchases during India's export ban.

Shipments to neighboring Nepal and Bangladesh are also anticipated to rebound.

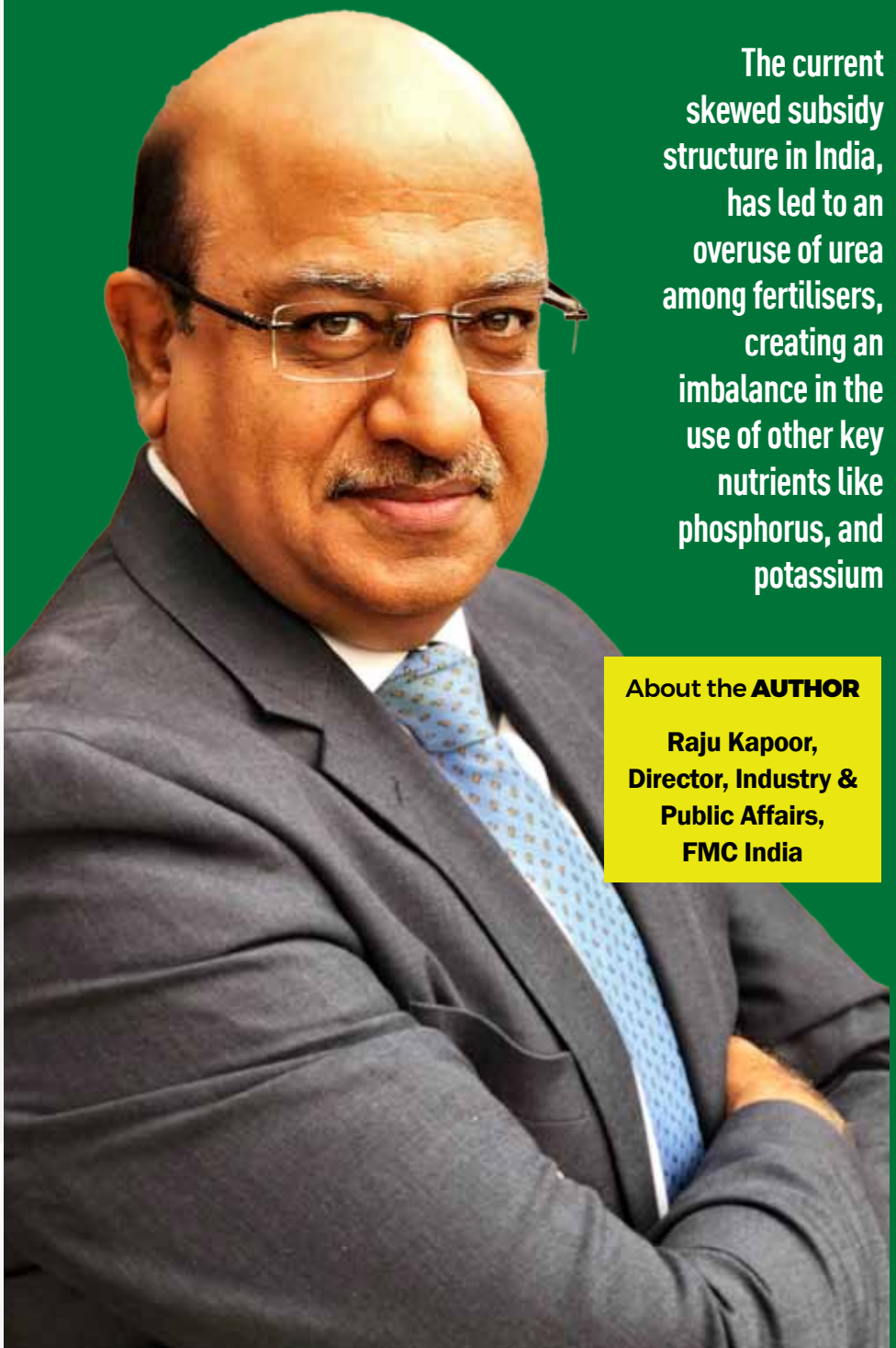
Looking ahead, GrainsWorld is dedicated to shaping a resilient future for the grain sector. Plans include establishing an advisory board to monitor and evaluate progress in promoting fair trade, climate resilience, and innovation in agricultural practices.

GrainsWorld aims to expand its network by collaborating with international organizations, governments, and NGOs. By forging these partnerships, the initiative aspires to foster an inclusive global food system that prioritizes both grain production and equitable access. Future initiatives will focus on empowering local communities by providing resources, training, and support to enhance their agricultural practices, ensuring that food security is prioritized at all levels.

Through these focused efforts, GrainsWorld 2024 stands poised to make significant strides toward enhancing food security and ensuring that grains remain a foundational component of global nutrition. By bringing together industry leaders, policymakers, and agricultural experts, the conference aims to forge actionable solutions that address today's challenges while paving the way for a more secure tomorrow.

RETHINKING FERTILISER USE

A Step Towards Sustainable Farming



The current skewed subsidy structure in India, has led to an overuse of urea among fertilisers, creating an imbalance in the use of other key nutrients like phosphorus, and potassium

About the **AUTHOR**

Raju Kapoor, Director, Industry & Public Affairs, FMC India

The role of fertilisers in modern agriculture is undeniable. They have long been the backbone of increased crop yields and food security. However, as we strive for better outcomes in agriculture, the conversation has shifted toward sustainability, soil health, and the delicate balance between maximising yield and maintaining environmental integrity. While fertilisers have contributed significantly to global food production, their injudicious use has also raised concerns about soil degradation, pollution, and long-term productivity decline. In India the crop yield response to fertilisers has steadily dropped from 12.1 in the period 1960-69 to less than 5 in the period 2010-2017. It's time to rethink how we use fertilisers, with a focus on tailored, sustainable solutions.

The Soil Crisis: Fertility Under Threat

Soil, the foundation of agriculture, is under significant stress due to climate change, improper crop rotation, and excessive & imbalanced use of nitrogen-based fertilisers like urea. This has caused nutrient imbalances, with many Indian soils having an unhealthy NPK (nitrogen, phosphorus, potassium) ratio of 11.8:4.6:1 in 2022-23, instead of the ideal 4:3:1. This imbalance reduces soil productivity, leading to lower yields despite increased fertiliser use, and needless to say pollution.

Though essential for plant health,

The government's Soil Health Card initiative, which aims to provide detailed insights into soil nutrient status, is a step in the right direction, but its findings must be translated into actionable, customised fertiliser packages for farmers.

most soils suffer from micronutrient deficiencies such as sulphur, molybdenum, zinc, copper, and iron etc. apart from that of macro-nutrients. Addressing these issues requires not only adding micronutrients but rethinking their interaction with macronutrients.

Soil degradation is compounded by deforestation, overgrazing, unsustainable farming, and climate change. The Green Revolution's success in boosting food security has now led to sustainability and environmental challenges that need urgent attention.

In response, the government is working to align agriculture with environmental priorities ensuring long-term productivity while safeguarding rural livelihoods and food security. This is more critical as the yields of the major non-horticultural food crops are plateauing. Initiatives like FAO's GEF-6 Green-Ag project in states such as Odisha and Madhya Pradesh focus on sustainable land management and climate change mitigation. Additionally, FAO's GEF-7 Food, Land Use, and Restoration (FOLUR) program promotes sustainable practices in key farming regions like Punjab and Haryana.

Fertiliser Subsidies: A Double-Edged Sword

India's fertiliser subsidy system, aimed at making inputs affordable, costed ₹2.25 lakh crore in FY23, or 0.92% of GDP in FY23, though reduced a bit in FY24 due to the Russia-Ukraine war. While subsidies help farmers by reducing costs and encouraging better seed and machinery use, they also promote over(mis)use of fertilisers, leading to environmental degradation. This has shaped farming behaviour but raises concerns about long-term soil health and sustainability.

The current skewed subsidy structure in India, has led to an overuse of urea among fertilisers, creating an imbalance in the use of other key nutrients like phosphorus, and potassium. This nutrient imbalance harms soil health, reduces fertiliser use efficiency, lowers crop yields, and negatively impacts the environment, as highlighted in the latest Economic Survey.

A more nuanced approach is needed here, one that ties subsidies to customised, crop-specific nutrient management. The existing Nutrient-Based Subsidy (NBS) scheme could be further refined to reflect the specific needs of different crops and soil types. The government's Soil Health Card initiative, which aims to provide detailed insights into soil nutrient status, is a step in the right direction, but its findings must be translated into actionable, customised fertiliser packages for farmers. This alignment between soil health data and nutrient supply is crucial for improving efficiency and productivity.

Organic Content: Restoring the Balance

The other very critical component of sustainable agriculture is soil organic matter, which is currently getting depleted at alarming rates. The predominant and injudicious use of chemical fertilisers has stripped the soil of organic matter, leaving it less fertile and more susceptible to erosion. The solution lies in replenishing the soil with organic matter and humus, which improves soil structure, increases water retention, and enhances nutrient availability.

India's challenge of managing urban and rural waste presents an opportunity here. Initiatives such as Compressed Natural Gas (CNG) production can use organic waste to generate energy and organic manure, providing much-needed organic nourishment for the soil. Establishing waste processing facilities in every district, incentivized by government subsidies, could help solve two problems at once—managing waste and rejuvenating soil health. Increased organic content would enhance the efficiency of chemical fertilisers, reducing the need for excessive application and increasing crop productivity.

Sustainable Solutions: The Role of Technology

India's smallholding farmers face numerous challenges, including erratic weather, pest infestations, declining yields, and significant post-harvest losses, with up to 40% of produce wasted. Many are financially strained, stuck with high-interest loans, and struggling to meet market demands.

Advancements in technology offer promising solutions for sustainable fertiliser use. Precision agriculture, which uses data-driven insights to guide farming decisions, can help farmers apply the right amount of fertiliser at the right time, minimising waste and maximising efficiency.

The World Economic Forum's (WEF) Artificial Intelligence for Agriculture Innovation (AI4AI) is another unique initiative aimed at transforming agriculture through AI-driven solutions. In Telangana's Khammam district, the 'Saagu Baagu' pilot boosted chilli yields by 21%, reduced pesticide use by 9%, fertiliser use by 5%, and improved product quality by 8%. Farmers' incomes increased by INR 66,000 (around 800 USD) per acre per crop cycle according to WEF.

Biological interventions also hold great potential. Phosphorus, for example, is immobile in the soil, often getting "stuck" and becoming inaccessible to plants. Bio-fertilizers and microbial formulations can help mobilise these fixed nutrients, improving their availability to crops. However, regulatory frameworks need to evolve to allow for the import and use of such advanced formulations, which can significantly enhance nutrient uptake and reduce dependency on chemical fertilisers. Same is the case with various bio-stimulants, and bio-fertilisers.

Policy and Practice: The Way Forward

The government's various agricultural schemes have laid the foundation for supporting advanced inputs, but adoption remains slow. Incentives must be aligned with the use of sustainable, crop & nutrient-specific solutions. This is where Farmer Producer Organizations (FPOs) and Women's Self-Help Groups (SHGs) can play a pivotal role, helping to distribute and implement area-specific nutrition packages. Leveraging the Drone Scheme for precise fertiliser application could further improve efficiency and ensure that inputs are delivered exactly where needed.

To achieve long-term sustainability, we must move beyond short-term solutions like fertiliser subsidies and focus on building a more resilient agricultural system. This requires integrating data-driven technologies, promoting organic manures, and supporting biological interventions and allowing newer fertiliser formulations that work with the environment.

The challenge of balancing food security with environmental sustainability is complex but solvable. Fertiliser use must be science-driven, data-informed, and aligned with sustainability principles. By improving soil health, adopting technology, and reforming subsidy structures, we can create an agricultural system that is both productive and eco-friendly.

While companies like FMC are pioneering innovative solutions from having a portfolio of efficient products, small holder farmer initiatives like Project Utkarsh, policymakers, farmers, and consumers must also embrace sustainable practices. Only then can we ensure future generations inherit fertile soils, a healthy environment, and reliable food security.

THE IMPACT OF FERTILIZER USE ON AGRICULTURE:

BALANCING YIELD, SOIL HEALTH, AND SUSTAINABILITY

Fertilizers have been a cornerstone of modern agriculture, significantly influencing crop yields and food production. However, their use comes with a complex array of impacts on soil health, environmental sustainability, and food security. This write-up explores the multifaceted relationships between fertilizer use, crop yield, soil health, sustainable practices, and the pressing need for environmentally considerate methods, including the role of biofertilizers.

The Role of Fertilizers in Enhancing Crop Yield

Fertilizers are essential for replenishing the nutrients that crops extract from the soil. Nitrogen, phosphorus, and potassium (NPK) are the primary macronutrients provided by synthetic fertilizers, which are crucial for plant growth and development. The application of these fertilizers has led to a remarkable increase in crop yields over the past century.

About the **AUTHOR**

Debabrata Sarkar, MD, MicroAlgae Solutions india Pvt Ltd (Subsidiary of AlgaEnergy Spain); Director, AGMA Energy and Vice president -APAC for AE Biologicals

Studies have shown that regions employing fertilizers can achieve yields that are two to three times higher than those relying solely on organic amendments. For instance, the introduction of nitrogen fertilizers has been linked to substantial increases in cereal production, which is vital for feeding the growing global population. In developing countries, where food security is a pressing issue, the use of fertilizers can be particularly transformative, allowing smallholder farmers to produce more food on limited land.

Soil Health: The Double-Edged Sword of Fertilizer Use

While fertilizers can boost crop yield, their overuse and misuse can lead to detrimental effects on soil health. Excessive application can cause nutrient imbalances, leading to soil degradation

and reduced fertility over time. High levels of nitrogen and phosphorus can lead to soil acidification, which affects microbial activity and overall soil quality.

Moreover, the reliance on synthetic fertilizers can diminish organic matter in the soil, reducing its water retention and aeration capabilities. Healthy soil is a living ecosystem that supports diverse microbial communities essential for nutrient cycling. Therefore, integrating organic matter through compost or cover cropping alongside fertilizers can enhance soil structure and fertility, promoting a sustainable agricultural system.

Sustainable Practices and Technologies in Fertilizer Use

To mitigate the adverse effects of fertilizers on soil health, sustainable practices are essential. Integrated Nutrient Management (INM) combines the use of chemical fertilizers with organic amendments, optimizing nutrient availability while maintaining soil health. Crop rotation, intercropping, and cover cropping are also beneficial strategies that help maintain nutrient levels and enhance biodiversity.

Technological advancements, such as precision agriculture, are revolutionizing fertilizer use. By utilizing GPS and remote sensing technologies, farmers can apply fertilizers more efficiently, targeting specific areas of fields that require nutrients. This not only maximizes crop yield but also minimizes environmental impact, reducing the risk of runoff and pollution.

Addressing Food Security through Responsible Fertilizer Use

As the global population continues to rise, food security remains a critical issue. Fertilizers play an essential role in increasing food production to meet the demands of a growing population. However, the challenge lies in using fertilizers responsibly to prevent environmental degradation.

In regions where food insecurity is prevalent, access to fertilizers can significantly improve agricultural productivity. Governments and NGOs are increasingly promoting the use of fertilizers through subsidies and educational programs, empowering farmers with the tools they need to enhance their yields sustainably.

By utilizing GPS and remote sensing technologies, farmers can apply fertilizers more efficiently, targeting specific areas of fields that require nutrients.

Environmental Considerations Linked to Fertilizer Use

Despite their benefits, the environmental consequences of fertilizer use cannot be overlooked. Nitrogen fertilizers can contribute to greenhouse gas emissions, particularly nitrous oxide, a potent climate change agent. Additionally, runoff from fertilized fields can lead to water pollution, causing eutrophication in lakes and rivers, which harms aquatic ecosystems.

To address these challenges, policies promoting sustainable fertilizer practices are crucial. Farmers can adopt various strategies such as buffer strips, constructed wetlands, and controlled-release fertilizers to minimize runoff and protect water quality. Public awareness campaigns on the environmental impacts of fertilizers can also encourage more responsible usage among farmers.

The Importance of Biofertilizers

Biofertilizers are an innovative and sustainable alternative to synthetic fertilizers. Derived from natural sources, biofertilizers contain living microorganisms that enhance nutrient availability and promote plant growth. They can improve soil structure, increase microbial diversity, and facilitate nutrient uptake, making them a powerful tool for sustainable agriculture.

The use of biofertilizers can reduce dependence on chemical fertilizers, thereby lessening their environmental impact. For example, nitrogen-fixing bacteria such as Rhizobium can significantly enhance nitrogen availability in the soil, reducing the need for synthetic nitrogen fertilizers. Similarly, mycorrhizal fungi can improve phosphorus uptake, promoting healthier and more resilient plants.

Moreover, biofertilizers can enhance soil health by improving microbial activity and increasing organic matter content. This, in turn, can lead to improved water retention and soil fertility, creating a more sustainable agricultural ecosystem.

In the recent past we have seen MicroAlgae based Biofertilizers are gaining momentum, because of its unique Nutritional benefit and impactful result in multiple Trials in universities for its capability to optimise conventional inorganic fertilizer with significant increase in Soil organic carbon percentage .

Conclusion

The use of fertilizers in agriculture presents both opportunities and challenges. While they are essential for enhancing crop yield and addressing food security, their impacts on soil health and the environment necessitate responsible use. Sustainable practices, advanced technologies, and the integration of biofertilizers into farming systems are vital for promoting a balanced approach to fertilizer use.

As we move forward, it is crucial to prioritize sustainable agricultural practices that not only aim to increase productivity but also protect our natural resources and ensure a healthy environment for future generations. By embracing a holistic view of fertilizer use—one that considers crop yield, soil health, environmental sustainability, and food security—we can work towards a more resilient and sustainable agricultural future.

DEVELOPMENT OF NEW FERTILIZERS FOR INDIAN AGRICULTURE

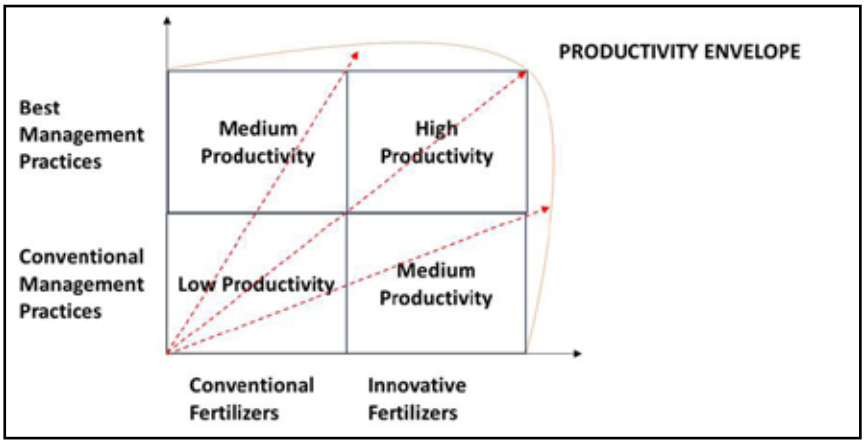
Role of fertilizers in Indian agriculture

India, the most populous country in the world, needs to grow sufficient food to meet the calorific and nutritional needs of the population. Additionally, as the land available for growing food is decreasing due to rapid urbanization, agricultural productivity or food production per hectare must continuously increase to keep pace with the growing needs of the large population. Fertilizers play an important role in improving crop productivity as they provide nutrients to the plants for their growth and development. The other sources of plant nutrients are organic manure, biological nitrogen fixation, and atmospheric deposition; however, bulk of plant nutrients in modern agriculture are supplied by chemical fertilizers.

Nutrient Use Efficiency of fertilizers

Nitrogen, Phosphorus, and Potassium are the primary nutrients required by plants. These are also referred to as N, P, and K. Urea is the main source of N, Di Ammonium Phosphate (DAP) of P, and Muriate of Potash (MOP) of K. Urea is produced from natural gas while P and K fertilizers are derived from mined rock phosphate and potash respectively. Nutrient Use Efficiency (NUE) refers to the percentage of applied nutrients that are taken up by crops. NUE for urea N is low because of losses due to ammonia volatilization and nitrate leaching. NUE for P is also low because of conversion of applied P into unavailable forms in soil. The losses of nutrients to the environment not only cause damage to air, water, and soil, but also lead to lower crop productivity and inefficient use of natural resources. Hence, it is imperative that new and innovative fertilizers must be introduced which offer higher nutrient use efficiency.

Introduction of efficient fertilizers must go hand in hand with adoption of good management practices for ensuring maximum crop productivity.



About the **AUTHOR**

Amit Rastogi,
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Role of nutrient management

Introduction of efficient fertilizers must go hand in hand with adoption of good management practices for ensuring maximum crop productivity. The yield will be sub-optimal if efficient fertilizers are used with conventional practices.

Innovative fertilizers launched in India

In India, number of new fertilizers have been introduced recently to address the need for more efficient delivery of nutrients to crops. Some of them are -

- Neem coated urea
- Sulphur coated urea
- Nano Urea
- Nano DAP
- Liquid fertilizers
- Crop specific grades
- Urea SSP
- Potash from Molasses, Seaweed

Neem Coated Urea and Sulphur Coated Urea offer higher N efficiency by minimizing loss of N to environment thereby ensuring more N is available for

crop uptake. Nano Urea, Nano DAP, and Liquid Fertilizers offer better absorption of N, P, and K nutrients by crops. Crop specific grades and Urea SSP provide more balanced nutrition to crops. Potash derived from organic sources such as molasses and seaweed can become an alternative to mined MOP which is entirely imported by India.

Global developments in fertilizers

Some of the innovative fertilizers which are under development or have been recently launched in other countries are –

- Urea coated with biodegradable polymers
- Organo Mineral Fertilizers
- Mineral fertilizers combined with biostimulants
- Biofertilizers for nitrogen fixation by cereal crops
- Fertilizers from organic waste streams

Urea coated with biodegradable polymer is an environment friendly controlled release fertilizer which matches the release of urea N with the nitrogen demand of crop. Organo Mineral Fertilizers contain organic matter which acts as matrix for holding the nutrients. Mineral fertilizers with biostimulants provide both plant nutrition and stress resistance. Biofertilizers developed through gene editing are now able to fix nitrogen in cereal crops. As part of circular economy, fertilizers are now produced from organic waste streams such as sewage sludge, agricultural residues, etc. Many of the concepts driving the development of new fertilizers globally can be applied in India, especially production of organic fertilizers by recovery of nutrients from waste streams.

New organic fertilizers in India

In parallel to the generation of organic fertilizers through traditional method of composting, the production of fertilizers on industrial scale from certain organic waste streams can be taken up. These waste streams are generated at centralized locations such as sewage/wastewater treatment plants, distilleries etc.

Neem Coated Urea and Sulphur Coated Urea offer higher N efficiency by minimizing loss of N to environment thereby ensuring more N is available for crop uptake.

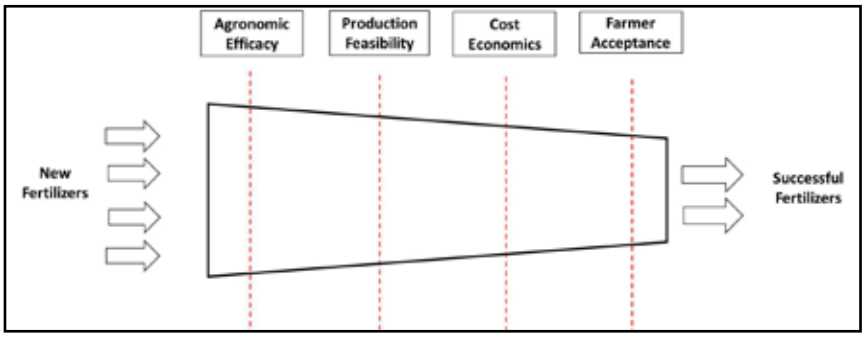
or can be aggregated by organizations such as poultry companies and agricultural processing companies through their linkages with farmers. These industrial plants will complement the decentralized production of organic fertilizers from biomass through composting. The fertilizers produced by industrial processing of organic wastes will reduce the country's dependence on imported fertilizers and the same time reduce the burden of waste disposal.

Key Success Factors for new fertilisers

While many new fertilizers offer high nutrient use efficiency, not all of them are successful in the market. There are four factors which determine the success of a new fertilizer.

- **Efficacy** - How efficient is the new fertilizer with respect to conventional products in terms of performance parameters such as crop growth and vigour, dosage, yield impact etc.
- **Manufacturing** - How easy is it to manufacture these new fertilizers in India considering factors such as investment for new facilities, availability of raw materials, access to manufacturing technology etc.
- **Economics of Usage** - How economical is the new fertilizer with respect to conventional products with respect to unit price, Benefit Cost Ratio, cost of application etc.
- **Farmer Acceptance** - How much effort is required to communicate the benefits of new fertilizers to farmers to convince them to shift from conventional to new products.

The four factors can be considered as four gates through which every new fertiliser must cross to establish its position in the market. This is shown in the figure below.



Conclusion

Efficient fertilizers which minimize losses of nutrients to environment and thereby increase availability for crop uptake are required for Indian agriculture. While number of new fertilizers have recently been introduced in India, there are many more innovative products in the global market which can be considered for Indian agriculture. However, new fertilizers must satisfy four criteria related to efficacy, production, cost, and ease of adoption for achieving success in the Indian market.

ADVANCING SUSTAINABLE AGRICULTURE: PRIORITIES FOR THE FERTILIZER INDUSTRY

Fertilizers play an essential role in improving soil fertility and increasing crop productivity. However, excessive use of fertilizers also poses significant risks, including soil degradation, nutrient runoff into water bodies, increased greenhouse gas (GHG) emissions, soil acidification, and disruption of natural nutrient cycles. For example, nearly 33% of the world's farmland is believed to be moderately to severely degraded, partly due to overuse of traditional fertilizers and pesticides.

There are other reasons why more sustainable agriculture is urgently needed. For instance, despite the decrease in arable land worldwide, the need to double global food production remains critical, driven by the planet's expected population surge to nearly 10 billion by 2050. Meeting this demand with more environmentally friendly farming practices will thus be vital.

Likewise, consumers, particularly from younger demographics, are becoming increasingly mindful of the environmental impact of food production, with a growing demand for sustainably sourced products. A recent global survey found that 60% of Millennials are aware of the implications that their food choices have on the environment. Meanwhile, 73% of Indian consumers say they're willing to pay a premium for products from sustainable brands, according to a Nielsen report.

This shift in consumer sentiment is influencing the agribusiness value chain, driving key industry players to adopt more sustainable practices. Many crop input and agribusiness companies, for instance, aim to enable and promote regenerative agriculture on millions of acres during the next decade. Similarly, packaged food and beverages player such as Pepsi has pledged to sustainably source 100% of its key ingredients and crops by 2030.

The urgency for sustainable agriculture is also reflected in policy initiatives across the globe. The western agrarian economies have defined targets to either bring substantial agricultural land under organic farming or to reduce their agriculture's environmental footprint significantly. Major Asian nations are also embracing this shift, aiming to bring large parcels of land under regenerative agriculture, alongside promoting the adoption of bio-based crop inputs.

As the world shifts to more sustainable agriculture, the fertilizer industry can help lead the charge. In fact, research shows that focusing on three areas in particular can deliver big progress on sustainability: low-carbon ammonia, precision farming, and biofertilizers.

About the **AUTHOR**

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Priority 1: Low-carbon ammonia

The fundamental building block of all mineral fertilizers, ammonia, currently accounts for 2% of annual global carbon emissions. At the same time, 70-80% of the ammonia is currently used in fertilizers globally. To decarbonize the fertilizer industry, adopting low-carbon ammonia is therefore crucial.

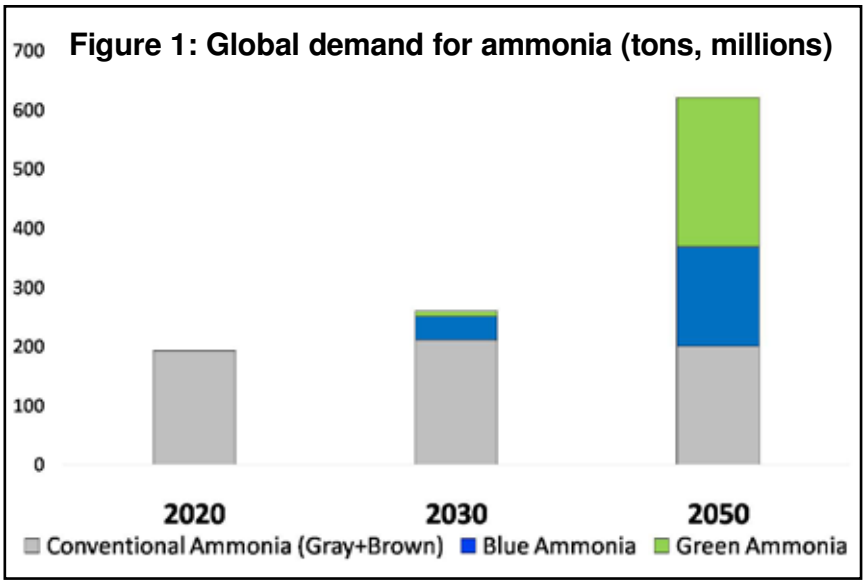
Fortunately, there are several promising options to conventional ("gray and brown") ammonia. Blue ammonia—produced from natural gas, while utilizing carbon capture and sequestration—can reduce carbon emissions by approximately 60% in plants that use steam methane reformation (a widely used industrial process). Green ammonia, which uses renewable energy, offers an even cleaner alternative.

In the short to medium term and with the support of government incentives, blue ammonia can become cost-competitive relative to gray and brown ammonia. Green ammonia, in contrast, represents a better long-term opportunity, with gradual improvement in cost-competitiveness and access to renewable energy.

As the economic viability of blue and green ammonia improves, their use will expand beyond fertilizers to applications such as – low-emission marine fuel, feedstock for power generation, and a hydrogen carrier. Indeed, by 2050, only 30% of ammonia is expected to be used in fertilizers, with the remainder supporting clean energy applications (Figure 1).

Priority 2: Precision farming

Among other benefits, "precision" farm-



Source: S&P Global, IRENA, Accenture Research analysis

ing can optimize crop input use, increase yields, reduce farm emissions, minimize crop loss, lower costs, and otherwise mitigate harmful environmental impact. To achieve these benefits, precision farming makes use of sophisticated technologies, such as sensors, drones, robotics, satellite imaging, variable rate technologies, mobile devices, and AI-driven data analytics.

Precision-farming solutions also allow agri-nutrient companies to offer comprehensive farm-management services, while cultivating deeper relationships with farmers. Precision farming thus presents an attractive opportunity for fertilizer companies to diversify and create new revenue streams.

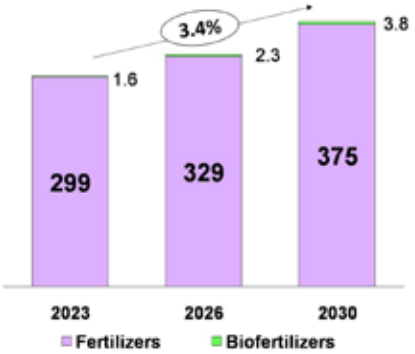
Priority 3: Biofertilizers

The growing emphasis on sustainable agriculture has driven demand for eco-friendly crop inputs like biofertilizers. These microbial-based products enhance nutrient availability for plants, by boosting nitrogen fixation, increasing bioavailable phosphorus, and promoting overall plant growth. While demand for biofertilizers is projected to grow at a CAGR (compound annual growth rate) of about 13% between now and 2030—compared to 3.4% CAGR for the overall fertilizer market—biofertilizers will remain a small segment of the global fertilizer market in the coming years (Figure 2).

A recent survey found that on an average, Indian smallholder farmers are using four to five regenerative farming practices to improve soil health. Their intent to improve soil health is likely to further support the uptake of biofertilizers. [16] Yet limited awareness of the benefits and applications of bio crop inputs, including biofertilizers, poses a significant challenge to their adoption. For instance, one study found that only 11% of Indian farmers are familiar with biofertilizers. [17] To address this challenge, the industry will need support in form of schemes or incentives, to further promote adoption of biofertilizers.

Precision-farming solutions also allow agri-nutrient companies to offer comprehensive farm-management services, while cultivating deeper relationships with farmers.

Figure 2: Global market for fertilizers (USD, billions)



Source: Accenture Research, based on growth consensus estimates and GM Insights

Good for the environment, good for the bottom line

The need for more sustainable agricultural is not only urgent for the planet, but also presents significant opportunities for businesses to innovate and grow their revenues. Crop-input and Agtech firms, for example, are aiding farmers to reduce farm emissions, enabling them to earn premiums from selling certified low-carbon crops. These companies can also provide verified carbon credits to businesses, offering farmers financial incentives to adopt sustainable agricultural practices.

In India, for example, a major crop input player's regenerative agriculture program aims to support over 1 million smallholder farmers in transitioning from transplanted puddled rice to direct-seeded rice (DSR) by 2030. This transition could reduce water use for agriculture in India by 30-40%, as well as cut agriculture-based GHG emissions in the country by up to 45%.

Fertilizer companies in India, and elsewhere, that embrace innovative solutions like low-carbon ammonia, precision farming, and biofertilizers will help make the world greener—and boost their own growth in the process.

**Special thanks to Ashish Kumar Gulgulia and David Kimble for their contributions on this study.*

‘India stands at the forefront of innovation in biologicals’

IPL Biologicals Limited, a subsidiary of M2K Group, with a legacy of 28 years, has been working to improve global food security by regenerating soil, increasing crop productivity, and delivering safe, healthy, and nutritious food to consumers worldwide. Their revolutionary microbial solutions have been helping farmers to achieve sustainable growth from seed to harvest. In an interview with Agriculture Today, Harsh Vardhan Bhagchandka, President, IPL Biologicals discusses the importance of biologicals in sustainable agriculture.

What is the market for biologicals in India?

The Indian Agricultural Biologicals Market size is estimated at Rs. 5000 Cr. in 2024, and is expected to grow at a CAGR of 12-15% till 2029.

As the numbers suggest the agri-biologicals market is experiencing significant growth due to various factors. Government initiatives and policies are the key contributors to the adoption of biologicals, leading to a 25% reduction in chemical inputs. The government of India along with many private stakeholders have been working on the ground towards awareness amongst the farmers on the benefits of organic and sustainable products. Additionally, advancements in biotechnology and research are contributing to the development of innovative and effective biological products. Farmers today are increasingly embracing Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) practices for sustainable and efficient approaches to nutrient and disease management.

Potential areas for growth in the biological market include biofertilizers, biopesticides, and biostimulants. Biofertilizers can enhance soil fertility, promote nutrient uptake, and can improve crop yields by **15%**. Biopesticides can control pests and diseases with-

> “Government initiatives and policies are the key contributors to the adoption of biologicals, leading to a 25% reduction in chemical inputs.

out harming beneficial insects and the environment and can reduce pesticide use by **20%**. Biostimulants can enhance plant growth, stress tolerance, and nutrient efficiency. Overall, the Indian market for biologicals presents a promising opportunity for sustainable and profitable agriculture.

How can biologicals compensate for the ill effects of chemical fertilizers and pesticides?

Excessive chemical use and misguided agricultural techniques have significantly impacted natural resources and the quality of harvests produced by many farmers today, increasing the demand for sustainable agriculture. Microbes serve as a vital natural resource, play an essential role in soil health and help adapt to and mitigate climate change. Microbes can help in increasing the uptake of nutrients, and organic carbon and improving soil texture and overall health. They contribute to crop production through the 3Rs of crop protection: Resistance management, where microbes create biological pesticides that combat pest resistance to chemical pesticides; Residue management, where bacteria convert toxic pesticide residues into harmless compounds, preventing soil accumulation; and Resurgence, where microbes like bacteria and protozoans control pests that resurface in larger numbers after pesticide use. Microbes not only enhance soil health, promote nutrient uptake, and boost crop yields, but also contribute to environmental sustainability by decomposing organic matter and pollutants.

In terms of innovation in biologicals, where does India stand?

India stands at the forefront of innovation in biologicals, with a strong focus on developing sustainable and effective solutions for agriculture. The country has a rich biodiversity and a growing pool of talented researchers and scientists dedicated to harnessing the potential of biologicals. Indian institutions and companies are actively engaged in research and development, leading to the creation of innovative biofertilizers, biopesticides, and biostimulants. These products offer sustainable alternatives to traditional chemical inputs, promoting healthier ecosystems and reducing environmental impact. India's commitment to innovation in biologicals is also evident in its government policies and initiatives, which support research, development, and commercialization of these products. This creates a favourable environment for entrepreneurs and startups to thrive in the biological sector. Overall, India's position in terms of innovation in biologicals is strong and continues to grow.

> **Microbes can help in increasing the uptake of nutrients, and organic carbon and improving soil texture and overall health.**

The country's focus on sustainable agriculture and its rich biodiversity provides a fertile ground for the development of innovative solutions that can benefit both farmers and the environment.

What are the challenges associated with biologicals?

The adoption of biologicals in agriculture is hindered by several challenges. The resistance and skepticism among farmers, rooted in their reliance on traditional chemical-based practices and concerns about potential risks, has hindered the widespread adoption of biologicals. These challenges have been addressed by government and private stakeholders. Yet to fully realize the benefits of biologicals in promoting sustainable agriculture is a work in progress that requires extensive awareness programs with joint efforts from the government and private sector.

What are the future areas where we can see the adoption of biologicals?

As agricultural land remains limited while the global population grows, boosting food production on existing land has become essential. Traditionally, chemical fertilizers were used to enhance soil nutrients, but these have negative environmental impacts, including water pollution and greenhouse gas emissions. A sustainable alternative is the use of biofertilizers—microbial communities that naturally improve nutrient availability, enhancing plant growth and production. Biofertilisers are a key type of microbial biostimulant, with the global biofertiliser market projected to reach USD 5.2 billion by 2028, growing at a CAGR of 10.9%. Additionally, microbial inoculants help maintain soil organic matter (SOM), which is vital for soil quality and crop yield, and play a crucial role in sequestering carbon, contributing to climate change mitigation. Going forward, the adoption of biologicals, especially microbial solutions, will be crucial in enhancing sustainable agriculture.

BACK TO NATURE:

A JOURNEY TO ORGANIC ABUNDANCE

Organic farming has the potential to fulfill the world's food requirements with sustainableresource utilization.. It may be described as a mixture of agriculture, wherein crops and livestockare run through combined technologies depending on resources available at farms or locally.This is practiced by using, wherever possible, agronomic, biological, and mechanical methodsinstead of using synthetic materials to fulfill any precise function within the system. It is an easyway to be in touch with nature.

S.Dalveer Singh is one of those farmers who emphasize organic farming. He is a farmer fromSamrai village in Jalandhar, Punjab, who has followed organic farming for over five years.Before this, he grew conventional crops, like rice, and vegetables relying heavily on chemicalfertilizers and pesticides. Despite their hard work, he saw diminishing returns each year. The soilquality was degrading, water resources became scarcer, and his yields started to drop.

Additionally, the rising cost of chemical inputs pushed him into debt, and he struggled to makeends meet.He began exploring alternatives and shifted towards organic farming and revived the lands by switching to more sustainable farming practices.

Dalveer Singh encourages a sense of communityand cooperation among farmers by openly sharing his knowledge with them.

Motivation for Change

Dalveer Singh started looking into increasing his farm's output without using harmful chemicals. So hebegan attending workshops, and training sessions on organic farming methods organized byPunjab Agriculture University (Ludhiana) and KVKs. He then decided to move to organicfarming because he was motivated by the prospect of employing healthier, more sustainableagricultural practices and was concerned about the long-term health of his crops and soil. Hisstep was to stop using chemical fertilizers and pesticides. After some time, he became a memberof the PAU Kisan club.

The Transition to Organic Farming

The initial transition to organic farming was not easy for Dalveer Singh as he had to give upchemical fertilizers and pesticides. He began adopting various techniques like vermicompost,green manure, compost, etc. He converted his entire farm to organic within three years where heused to grow many organic crops like Sugarcane, wheat, moong, and mustard.

He takes the organic seeds and plant materials for organic farming from

About the **AUTHORS**

Urvashi and Gurshaminder Singh
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PAU (Ludhiana) andKVKs. He used to grow CoJ 85, and Co 05009 varieties of sugarcane. He takes the seeds for thesevarieties from a university seed farm in Ladhowal under Punjab Agriculture University. He alsoadopts crop rotation techniques in sugarcane with wheat, legumes, etc.

Nutrient Management

To boost fertility in his field, he used biofertilizers such as compost, vermicompost, greenmanure, and FYM. He owns approximately 55 cows and 70 buffaloes on his farm. He used tomake high-quality compost from cow manure, agricultural leftovers, and kitchen trash generatedon his farm.

He cultivates crops such as berseem and dhaincha and ploughs his field every four to six weeksto increase soil nutrition and fertility. These biofertilizers include high levels of essentialnutrients like nitrogen, phosphorus, and potassium, all of which are required for plant growth..

Pest and Disease Management

He also began implementing integrated pest management (IPM), which entails using naturalpredators to control pests and planting pest-repellant crops. He employed neem oil, a naturalinsecticide that affects pest life cycles and acts as a fungicide against some ailments.

The Breakthrough

His switch to organic farming was not without its challenges. He had numerous challenges inthe early stages of transitioning to organic farming, such as lower crop yields than inconventional agriculture. This was because the soil needed time to recover from chemical useand adjust to employing organic methods. Organic farming often requires more labor thantraditional farming. Manual weeding, compost preparation, and pest control are time-consumingand labourintensive procedures. The initial expenditure required to switch to organicagriculture, including the expense of organic supplies and certification, was financiallychallenging. One of the most difficult issues was controlling illnesses and pests without the useof chemical pesticides. Natural approaches, when compared to artificial alternatives, may beless rapid and successful in organic farming. Since there were few established channels formarketing organic items, it was initially challenging to find a suitable market for organicproduce.

Dalveer Singh's income has more than doubled in recent years as input costs have decreased and market prices for his organic products have increased.

Current status

Dalveer Singh's hard work began to pay off. Over time, his farm started producing high-qualityorganic crops, including wheat, sugarcane, and vegetables. He produces jaggery fromsugarcane at his home. He also makes other products like Jaggery barfi, Gachak, etc. Theseproducts are completely organic so they are sold within a short period. He also sells his productsthrough stalls in the fairs and gets good profit. Now his produce gained popularity in the localmarket as well.

Benefits

Dalveer Singh's income has more than doubled in recent years as input costs have decreasedand market prices for his organic products have increased. He is no longer reliant on chemicalcorporations for fertilizers and pesticides, which has greatly reduced his farming expenses.

Impact on community

Many nearby farmers have adopted organic practices as a result of his success, sparking amovement towards sustainable agriculture. Dalveer Singh encourages a sense of communityand cooperation among farmers by openly sharing his knowledge with them. He created jobopportunities for residents, providing steady income and reducing the migration of poor peopleto urban areas. Less exposure to harmful chemicals has improved his family's health. Better soil,improved water retention, and higher biodiversity have resulted from less usage of chemicalpesticides and fertilizers.

An Inspiration

Dalveer's story from struggling conventional farmer to successful organic business inspiresfarmers all throughout the country. By adopting organic agricultural methods, he has improvednot just his personal life, but also the health of his community and the environment. His taleserves as a model for farmers everywhere, demonstrating that with passion and perseverance,sustainable farming practices may lead to a bright future.He suggests farmers to start from small efforts when adopting new farming techniques. Nothing is impossible if one has correct knowledge in particular field of work.

NEW ZEALAND AND INDIA FOR DEEPER AND STRONGER ENGAGEMENT IN AGRICULTURE

New Zealand and India have shared a warm relationship and maintained a strong association in both trade and cooperation. In his recent visit to India, New Zealand Minister of Agriculture, Mr. Todd McClay reiterated the New Zealand Government's commitment to further strengthen the relationship and improve the trade and cooperation in agri sector. In his discussion with Dr MJ Khan, President, Agriculture Today Group, he outlined the areas of cooperation between the two countries.

How do you see the current trade relationship between New Zealand and India evolving in the agriculture sector, and what opportunities do you foresee for New Zealand's agricultural products in the Indian market?

India has always been an important partner for New Zealand. We share a warm relationship and have a long association in both trade and cooperation. The New Zealand Government is committed to achieving a step-up in our relationship with India. New Zealand and India are developing deeper and stronger engagement across food and fibre sector – of which New Zealand exports hit $213 million last year. My visit will be an opportunity to discuss our ongoing trade and work through mutual access priorities. Increasing two-way trade in food and fibre products will benefit producers and give consumers in both India and New Zealand greater choice. We produce world-best food and fibre in New Zealand grown in our clean, sustainable, environment, and we are keen to offer Indian consumers the opportunity to experience the benefits of these products. New Zealand can also play a role in providing raw inputs to support the growth of domestic food processing in India.

In India Kiwi is being produced in Himachal Pradesh and some states, but quality and productivity levels are concerns. Can India look forward for any center of excellence with New Zealand's assistance?

If the Indian government is keen on that, it is possible. But in the meantime, an agreement can be signed to start the work to increase the quality and production on the orchards. The main New Zealand company that's responsible for research, production and export of Kiwi, had visited India a number of times, and have seen immense opportunity to help Indian growers with the quality and quantity of the fruit. In fact, part of the reason for my visit to India was to meet the agriculture minister and others to talk about these areas of cooperation. And as with most things, when it's government to government, if you can have a framework agreement to sign between you, then we find that cooperation, research and perhaps, a center of excellence can grow quickly as a result.

With Hon. Indian Minister for Agriculture Shri Shivraj Chouhan

At Azadpur Mandi wholesale market, from where New Zealand fruits such as apples, kiwifruit and avocados are sent off to retailers across India

> Increasing two-way trade in food and fibre products will benefit producers and give consumers in both India and New Zealand greater choice.

Are there any new bilateral agreements or frameworks being discussed that could enhance

trade and cooperation in the agriculture sector?

New Zealand and India have already made good progress in our engagement to date. For example: MPI (Ministry for Primary Industries) has a Food Safety Cooperation Arrangement with the Food Safety and Standards Authority of India. In 2023, MPI funded three Indian officials to participate in a 24-week applied epidemiology virtual course that aims to boost epidemiological capacity of veterinarians in managing animal health and biosecurity. New Zealand has invited a further three Indian officials to attend the course , with another course due to kick off in August. New Zealand has invited two Indian officials to attend a 26-week food safety risk analysis training programme pilot planned for September this year. The MPI hosted India's National Dairy Development Board in New Zealand earlier this year to provide an understanding of our dairying system.

There are also ongoing discussions on many other areas where New Zealand and India can cooperate. These include animal health, horticulture, forestry and 'cooperatives'. To achieve this, we will need to broaden our trade and economic relationship and identifying new opportunities through sectoral cooperation and working at both state and national levels. My visit is an opportunity to discuss and understand where there could be new opportunities for New Zealand and India to work together to deliver on our shared goals.

> **The New Zealand Government is committed to enhancing engagement and cooperation to build a stronger food and fibre sector relationship and support commercial opportunities in both directions**

At the Indo-Kiwi dairy venture Binsar Farms in Haryana

New Zealand is at the forefront of agri-tech innovation. What areas of agri-tech do you see as most promising for New Zealand India partnership?

New Zealand is regarded as having some of the most efficient producers of food and fibre in the world, and that's in large part because of continued innovation and adaption through smart technologies. New Zealand has built a world-class reputation of producing high quality and safe food and fibre products that we export around the world, and this experience and expertise puts us in a very good position to be a world leader in agritech solutions also.

Our agritech sector is made up of over 650 agritech companies developing novel solutions for the agriculture, horticulture, aquaculture, apiculture and fishing sectors to improve yield, efficiency, profitability, resilience, reliability, quality, and to add value. The New Zealand Government believes our smart agritech solutions can also provide benefits for India to help achieve its goals and tackle challenges. Our agritech enables more precise and efficient uses of resources like water, fertilisers, and pesticides, to help minimise environmental degradation and mitigate the negative impacts of farming on the environment while getting a better return on investment. Our farmers are also adopting AI-driven

predictive analytics to optimise irrigation schedules based on weather forecasts and soil moisture levels, to importantly reduce water wastage and improve water efficiency.

Our agritech solutions could have application in India to help boost farmer and grower productivity and profitability. Agritech comes in many forms. For example, New Zealand's most valuable Intellectual Property remains our ability to grow consistently high quality, export grade food.

NDDB Chairman Dr Meenesh Shah and Amul Managing Director Jayen Mehta show Minister Hon. Todd McClay the milk collection process at Anand, Gujarat

What are the key agro commodities in trade between the two countries, and how do you look at broadening or deepening the trade relationship?

India is an important partner for New Zealand. Two-way trade reached $1.6 billion in the year to 31 December 2023, including New Zealand food and fibre exports of $213 million. In the March 2024 quarter, New Zealand's top three agricultural exports to India were fruit and nuts, wool, and dairy products. In that same period, New Zealand's top three agricultural import from India were vegetable, fruit, and nut preparations, fish, and coffee, tea and spices.

New Zealand and India already share a warm relationship and have a long association in both trade and cooperation. Enhancing our trade is just one aspect of a deeper and broader relationship that we are looking to foster with India. We want to develop deeper and stronger engagement with India across all facets of the relationship: politics, business, academia, defence and security, civil society, youth, culture, and sports.

Like India, the food and fibre sector is the backbone of New Zealand's economy, playing a central role in our national identity, economic prosperity and the success of our respective rural communities. A key discussion point during my visit will be exploring areas where we can work together to deliver mutual benefits. My visit is also an opportunity to build rapport with newly appointed, and reappointed, Ministerial counterparts, particularly with India's elections recently concluded, and help set the stage for further bilateral engagement. This could include broadening our trade and economic relationship and identifying new opportunities through sectoral cooperation and working at both state and national levels.

The New Zealand Government is committed to enhancing engagement and cooperation to build a stronger food and fibre sector relationship and support commercial opportunities in both directions. For example, Quality New Zealand set up a plant in India for further processing using New Zealand raw product, which have provided jobs in India.

At the Mother Dairy plant in Patparganj, New Delhi

What are your views on climate change and future food security? It this an area there the the two countries can collaborate?

Our Climate Change Minister is very eager to come and visit India to talk more about this and there are some areas that we can cooperate. New Zealand has invested in some countries to get emissions down. in Southeast Asia, our government is investing in the development of rice varieties to produce more yield with lower emissions, helping them meet climate change obligations.

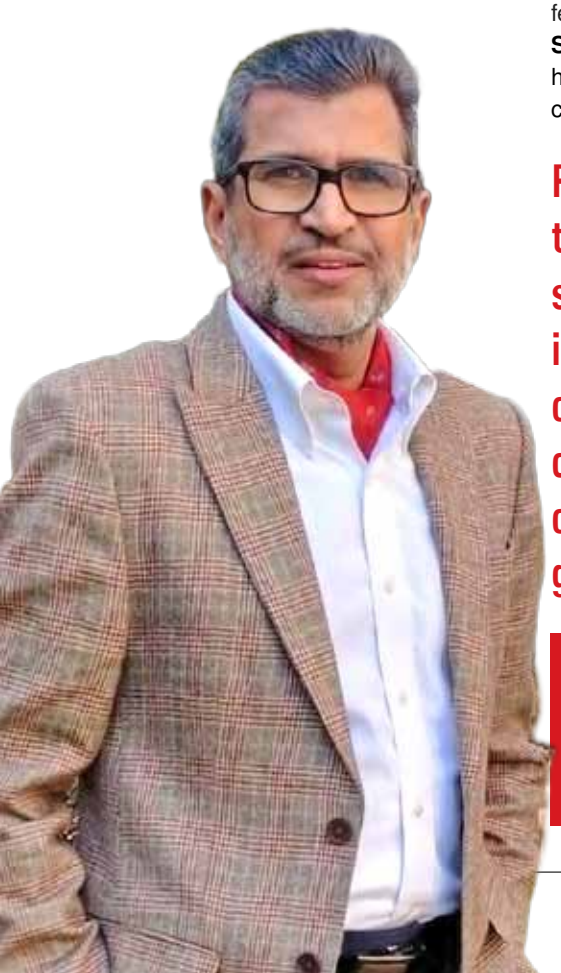
Around animals, there's a lot of work going on in New Zealand. The government, with the private sector, has invested a lot, in R&D for finding ways to allow cows, to produce milk but to reduce the amount of methane. We are a few years away from some of those solutions being commercially available. That means it will be easier for farmers to reduce emissions, helping the country meet its climate reduction obligations but without putting extra cost on the farmers and without compromising production.

I think there are many areas of opportunity in climate change for New Zealand and India to work together.

TRANSFORMING FARMING DECISIONS WITH GIS

The agriculture sector is one of the most important threads in the socio-economic fabric of the Indian economy. The sector's role extends beyond economic contributions, not only ensuring food security and stability for the nation but also posing as the primary source of livelihood for around 55% of India's population. This being acknowledged, it is only wise to strengthen this crucial pillar of support, and the answer lies in using technologies like Geographic Information Systems (GIS) to bring digital transformation in agriculture.

From soil and nutrient analysis to



sustainable farming, GIS has a vital role to play in every facet of agriculture.

Agricultural Mapping

Accurate mapping of geographic and geologic features of farmlands enables scientists and farmers to create more effective and efficient farming techniques. **Suitability analyses,** facilitated by GIS, help the farmers determine the optimal crops for each plot of land, based on its soil, climate, and social conditions and conceptualize the best practices at all stages of the farming season. GIS offers vital insights related to crop health, soil conditions, and weather patterns in real-time. GIS allows the stakeholders to develop a holistic approach to precision farming. It helps in creating maps and dashboards that integrate important variables such as soils, irrigation, yield, production costs, profit, and compliance data.

Recent studies indicate that the global GIS software in the agriculture industry is projected to cater to a market revenue of $2.57 billion in 2024 as compared to $1.44 billion generated in 2018.

About the **AUTHOR**

Agendra Kumar,
Managing Director,
Esri India

Crop Yield Prediction

Accurate yield predictions are vital for food security and financial planning. Using GIS, predictive models can be developed to forecast crop yields based on historical data and current environmental conditions. Machine learning algorithms and statistical techniques are often applied to analyze spatial relationships and make accurate predictions.

Crop Health Monitoring

Instead of manual inspections, GIS enables remote monitoring of crop health using satellite imagery, providing insights about humidity, temperature, and overall growth. This helps identify areas needing attention. GIS allows farmers and agronomists to create detailed maps of fields, depicting variations in crop health indicators such as vegetation indices, chlorophyll content, and thermal imagery. These maps help visualize spatial patterns of crop health across large agricultural areas.

Insect and Pest Control

By monitoring changes in crop health indicators over time, GIS enables early detection of stress factors such as nutrient

deficiencies, water scarcity, diseases, and pest outbreaks. Early identification allows farmers to take timely corrective actions, preventing potential yield losses and reducing the need for extensive interventions later in the season.

Irrigation Control

GIS facilitates the development of irrigation schedules tailored to specific field conditions and crop water needs. By analyzing spatial data on soil moisture, rainfall patterns, and evapotranspiration rates, GIS helps farmers and water managers optimize the timing, duration, and frequency of irrigation events to minimize water waste and maximize crop yields.

Water Quality Management

GIS assists in monitoring water quality parameters such as salinity levels and contamination risks. By analyzing spatial data on soil types, land use practices, and proximity to sources of pollutants, GIS helps in identifying areas vulnerable to water quality degradation and implementing measures to protect irrigation water sources. As much as 70% of good water is used in agriculture, saving on this water use can help in addressing water stress. Wise usage of water can be made possible by adopting precision technology.

By analyzing spatial data on soil types, land use practices, and proximity to sources of pollutants, GIS helps in identifying areas vulnerable to water quality degradation and implementing measures to protect irrigation water sources.

Crop Insurance and Loss Assessment

In periods of catastrophic events like floods, heavy rainfall, drought, etc., GIS can be used to determine exactly how much of a given crop has been damaged and the progress of the remaining crop on the farm. GIS can generate crop condition and distribution analytics, leading to faster loss adjustment and payout to the farmers. In the crop insurance business, high-resolution imagery plays a key role in speeding up the claim process. Using GIS and image processing software like ENVI, farmers and insurance providers can achieve the benefits of faster claim processes and payouts, visibility on in-season crop conditions at different time intervals fostering risk analysis and decision making, crop classification and crop risk analysis, acreage estimation of different crops, identification of inundation area and exposure monitoring, reduced operational and data processing cost, and more.

Conclusion

The list is endless when it comes to the benefits of using GIS in agriculture. As the need to increase food production to meet global demands persists, incorporating GIS in farming is imperative. Recent studies indicate that the global GIS software in the agriculture industry is projected to cater to a market revenue of $2.57 billion in 2024 as compared to $1.44 billion generated in 2018. With advanced mapping, high-resolution imagery, and AI, GIS solutions are set to revolutionize farming practices, helping to feed the world sustainably. Integrating GIS with IoT sensors and drones will provide rapid and improved real-time information. This information combined with historical data, and emerging technologies such as AI will drive informed decision-making to leverage best-in-class farming practices, thereby creating a highly productive environment for both the producers and consumers.

POWER OF TRANSFORMATIVE PARTNERSHIPS

"Corporates play a critical role in advancing rural livelihoods, and at Heifer, we have seen the transformative impact of corporate partnerships," says Ms. Surita Sandosham, President and CEO, Heifer International. In an exclusive interview with Agriculture Today, Ms. Surita discusses in detail the activities of Heifer International and how it has improved the lives and livelihood of Indian farmers.

How was Heifer International's journey so far?

Heifer International was founded in 1944 by an American farmer, Dan West, who outlined a simple yet groundbreaking plan to tackle hunger and poverty around the world. He believed in the philosophy of "not a cup but a cow"—the idea that instead of providing temporary relief to farmers, we partner with them across the range of different livestock and crops, to create unique solutions to local challenges. Together, we build inclusive, resilient economies, so communities can develop effective ways to end global hunger and poverty while caring for the Earth.

Today, Heifer International operates in 19 countries across Asia, Africa, and the Americas, and we've reached over 52 million farming households. Over the years, our approach has evolved. Our current strategy centers on market-based solutions within agricultural multiple value chains, integrating smallholder farmers especially women into food systems. By supporting these farmers, we catalyze income-generating opportunities, build their resilience, and ensure sustainable livelihoods.

Our Values-Based Holistic Community Development (VBHCD) model supports total community transformation and is grounded in societal values or principles. It strengthens social capital and drives personal transformation to build a strong foundation for sustained collective action.

> **We have developed a standout model - the Community Agro-Veterinarian Entrepreneur (CAVE) model, which ensures that farmers have access to sustainable, community-based animal health services.**

What are the key achievements of Heifer in India?

In India, Heifer operates through its local subsidiary, Passing Gifts. To date, we've supported over 136,182 households across three Indian states—Andhra Pradesh, Bihar, and Odisha. Our primary focus has been to provide resources, training and foster strategic partnerships, enabling smallholder farmers to drive inclusive economic growth, adopt sustainable agricultural practices,

and build resilient communities.

One of the pillars of our work in India is gender equity and women empowerment. We have mobilized women farmers in over 10,000 self-help groups and formed 27 cooperatives. Through these women-led groups, they receive training on gender issues and technical services, while also accessing finance and new markets for their goods. These groups serve as an important platform for building self-confidence, social capital and gain experience in decision-making and leadership at different levels.

We have developed a standout model - the Community Agro-Veterinarian Entrepreneur (CAVE) model, which ensures that farmers have access to sustainable, community-based animal health services. This model predominantly trains women to become agro-veterinarian entrepreneurs, empowering them to deliver preventive animal healthcare at minimal cost. To date, we have trained over 453 CAVEs in our project areas.

Additionally, we are integrating regenerative agriculture and climate-smart practices to combat climate change and enhance natural resource management. Our collaboration with organizations such as the International Livestock Research Institute (ILRI) and ICAR-Central Institute for Research on Goats (ICAR-CIRG), as well as central and state government departments, have been instrumental in amplifying our efforts.

On September 27th, at the event in Bihar in partnership with Agriculture Today Group, Animal Husbandry Department Bihar and GIZ India, we launched the goat-based livelihood toolkit and felicitated 10 progressive farmers and CAVE didis.

Just recently, on September 23rd, we presented our **innovative backyard poultry model** (attached) to the Government of India, seeking their support for this initiative aimed at improving poultry farming practices and supporting rural livelihoods. Progressive farmers and CAVE didis (sisters) who had adopted this model were felicitated at the Delhi event.

On September 27th, at the event in Bihar in partnership with Agriculture Today Group, Animal Husbandry Department Bihar and GIZ India we launched the goat-based livelihood toolkit and felicitated 10 progressive farmers and CAVE didis.

The "Toolkit for Goat-Based Livelihood" aims to offer technical inputs for promoting goat-based livelihood in low-income rural households, especially in the context of Enhancing Rural Resilience through Appropriate Development Actions (ERADA) project.

Why is it important to ensure that farmers have better access to agricultural value chains?

Smallholder farmers often lack sufficient knowledge, skills, and networks to actively participate in formal value chains. Without access to these value chains, they remain vulnerable to low and unstable incomes, climate shocks, and economic hardship.

By connecting farmers to value chains, we ensure that they can sell their products at fair prices, bypassing middlemen who tend to reduce their profits. Access to value chains creates new opportunities for growth and resilience, ensuring a more secure future for farmers and for agriculture as a whole. This is the foundation for inclusive development that benefits not just farmers but the entire food system.

How does Heifer help marginal farmers improve their access to formal markets?

Heifer International helps marginal farmers improve their access to formal markets by facilitating the development of their agri-businesses and connecting them to buyers and larger agribusinesses. We provide training in production and business skills, strengthen value chains through infrastructure investments, and ensure access to financial services like microloans and insurance.

Through the formation of Producer Organizations and cooperatives, we enable farmers to improve productivity, negotiate better prices, and access wider markets. Additionally, by introducing modern technologies, such as digital platforms and improved livestock management practices, we enhance their market integration, which leads to increased incomes and sustainable livelihoods.

What are the key takeaways from this trip that stand out for you?

First, I am always amazed by the resilience and determination of the smallholder farmers we work with. When they are provided with the right tools, knowledge, and opportunities, they can make remarkable progress.

Second, the power of transformative partnerships—both within the communities we work with and with external partners like the government, corporates, and civil society—has been evident. These collaborations are critical in scaling up our efforts.

Finally, empowering women continues to stand out as a key driver of transformation. Women are at the heart of our work, and the progress they make, as seen in our self-help groups and cooperatives, directly impacts the well-being and economic growth of entire communities. Besides, it also helps to develop women leadership at grassroot level.

On a policy level, what are your recommendations to improve the income of marginal farmers?

I applaud the Indian government's efforts to enhance farmer incomes through initiatives like promoting organic farming and providing financial support through Kisan Credit Cards and crop insurance. These measures are significant steps forward.

However, further investment in agricultural technology, infrastructure, and training can amplify these benefits. By equipping farmers with modern tools and knowledge, we can drive even greater improvements in productivity and income. Drone Didis (sisters) program by government is another innovative step in the right direction.

At Heifer, we are focused on ensuring that marginal farmers can leverage these government schemes effectively, improving market access and building resilient livelihoods.

Through the formation of Producer Organizations and cooperatives, we enable farmers to improve productivity, negotiate better prices, and access wider markets

How can corporates help in rural livelihood development?

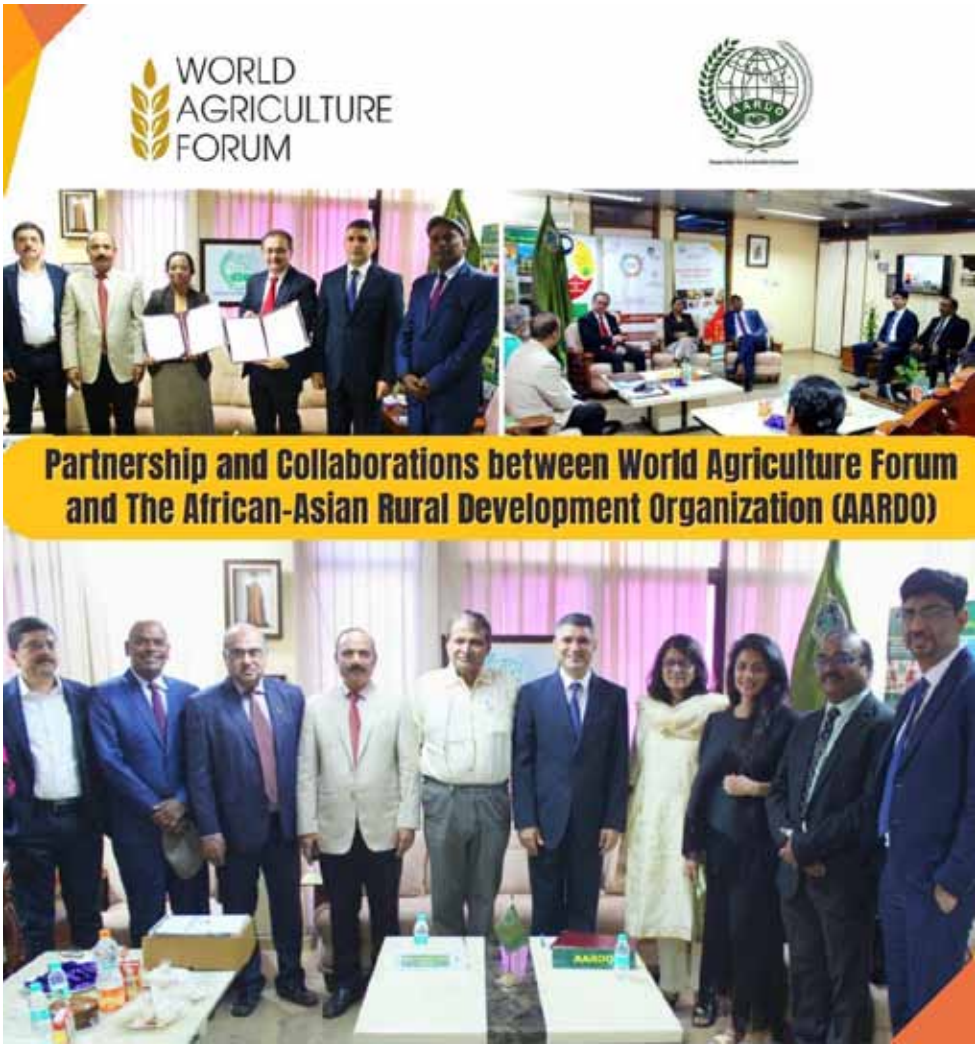
Corporates play a critical role in advancing rural livelihoods, and at Heifer, we have seen the transformative impact of corporate partnerships. One of our flagship initiatives is the Hatching Hope Global Initiative (HHGI), a collaboration between Heifer International and Cargill. In India, we work in Odisha and Andhra Pradesh. The initiative aims to improve the economic livelihoods and nutrition by reaching 100 million people by 2030, with a target of reaching 62 million people in India. Through HHGI, we support women smallholder poultry farmers with training, market access, and improved poultry management practices, enhancing both incomes and community nutrition.

In addition to HHGI, we have partnered with organizations like Mastercard and Walmart to support women through micro-enterprises and cooperatives, boosting their roles in agriculture and food processing. Corporates also help facilitate access to tailored financial products like microloans and insurance, giving rural families the tools they need to thrive. By integrating modern technologies such as solar energy and digital tools, we are building resilient, sustainable livelihoods in rural communities.

WAF AND AARDO SIGNS MOU

PARTNERSHIP TO DRIVE TECHNOLOGICAL INNOVATION, POLICY EXCHANGE, AND KNOWLEDGE SHARING

The World Agriculture Forum and the African-Asian Rural Development Organization (AARDO) signed a Memorandum of Understanding (MoU) in New Delhi to strengthen collaboration on agricultural and rural development initiatives, across Asian and African countries. The MoU was signed by the Secretary General AARDO, H.E. Dr. Manoj Nardeosingh and Ms. Leena Jacob, International Programs Director, WAF, joined by Dr. MJ Khan, WAF India Country Director, and WAF Council Members, Ambassador C Rajasekhar, Dr. Radhika Trikha, CEO-Awadh, IIT Ropar and Mr. Sharad Bhalla, CEO & Director, Indagro, France. From AARDO Mr. Rami Qtaishat, ASG, Dr. SK Behera, Director, Dr. Khushnood Ali and others joined. The ceremony was graced by the august presence of Mr. Suresh Prabhu, former Union Cabinet Minister and the Board Member of WAF from India. This partnership aims to drive technological innovation, policy exchange, and knowledge sharing to enhance agricultural productivity and sustainable development in rural communities across Africa and Asia. Through this collaboration, WAF and AARDO hope to address critical global challenges in food security, poverty alleviation, and environmental sustainability.



This partnership aims to drive technological innovation, policy exchange, and knowledge sharing to enhance agricultural productivity and sustainable development in rural communities across Africa and Asia.

EMPOWERING SMALLHOLDER FARMERS THROUGH GOAT VALUE CHAIN DEVELOPMENT WITH SPECIAL EMPHASIS ON BIHAR

A Report

Goat farming plays a vital role in enhancing the livelihoods of marginal farmers in India. With a goat population **148.88 million (20th Livestock Census 2019)** and contributing approximately 4% to India's agricultural GDP (Source: National Sample Survey Office, 79th Round, 2024), it is a crucial sector for rural economies. Bihar, with its focus on rural and agricultural development, has significant potential for goat farming despite challenges such as poverty and infrastructure gaps.

Realizing the potential of goat farming in enhancing rural livelihood, Agriculture Today, in association with Passing Gifts (A subsidiary of Heifer International) organized a workshop on **27th September 2024 at Bihar Agriculture Management & Extension Training Institute (BAMETI) Patna**, with focus on empowering smallholder farmers through goat value chain development, with special emphasis on Bihar.

Shri Shravan Kumar, Minister of Rural Development and Dr N Vijaya Lakshmi Principal Secretary, Department of Animal Husbandry, Government of Bihar inaugurated the event. The workshop attracted over 300 farmers and key stakeholders from the agricultural and animal husbandry sector. The conference featured esteemed speakers, including Dr MJ Khan, Chairman, Indian chamber of Food &Agriculture and President ATG, Ms. Surita Sandosham, President and CEO, Heifer International; Ms. Neena Joshi, EVP-Asia; Ms. Sonmani Choudhury, Program Director Bihar, Mr Akshaya Biswal, Program Director Odisha ,Ms Rina Soni, Executive Director, Passing Gifts - A Subsidiary of Heifer International; and Dr. Tarun Shridhar, former Secretary of Animal Husbandry, Dairying, and Fisheries Government of India.

Dr MJ Khan-President ATG & Chairman Indian Chamber of Food & Agriculture

In his welcome address, Dr. M.J. Khan emphasized the importance of giving more attention to goat farming, highlighting the need to identify the constraints faced by this sector. He stressed the significance of backyard farming and the development of the value chain, calling for concentrated efforts in these areas. Dr. Khan also urged that a dedicated scheme for goat farming be introduced by the Government of India. He requested the R&D minister to prioritize this matter, emphasizing the role of goat farming in rural livelihoods and economic development.

Ms. Surita Sandosham, President and CEO Heifer International, emphasized Heifer International's commitment to supporting smallholder farmers by improving goat value chains in India, particularly in Bihar, which is one of the country's poorest states.

Ms Sandosham highlighted how Heifer's initiatives, which focus on building sustainable livelihoods, are designed to empower marginalized farmers, especially women, by integrating them into vi-

able agricultural value chains. "The goat value chain project is seen as a transformative effort to enhance economic opportunities for small-scale farmers by improving productivity, ensuring market access, and fostering resilience through community-based approaches. This project aligns with Heifer International's broader mission to end hunger and poverty while promoting economic inclusion for rural populations. It builds on Heifer's successful models in other countries, focusing on creating sustainable systems that help communities thrive independently," She said.

She observed that the event also underlined the potential impact of collaborative efforts between Heifer, local governments, and communities to develop scalable solutions for poverty reduction and food security through agribusiness interventions. **Mr. Rajiv Ahuja, GIZ Representative,** highlighted the global presence of Heifer International and its 65-year partnership with the Indian government in various agricultural initiatives. Speaking at the launch of the "Bakri Adharit Ajivika" toolkit in Bihar, he discussed the significance of the Irada project, aimed at improving the livelihoods of over 40,000 farmers and women across four states, including Bihar. Supported by the German Ministry of Economic Cooperation and Development and GIZ, the project focuses on sustainable agriculture, especially goat farming, as a critical income source. Ahuja stressed the need for multi-stakeholder collaboration, including government departments and private sectors, to strengthen the goat value chain and improve rural economies. The toolkit, designed with contributions from research institutions, offers practical guidance to empower marginalized communities, especially women, ensuring sustainable livelihoods through goat-based initiatives. He concluded by underscoring the toolkit's role in fostering economic resilience and rural empowerment

Launch of Goat Value Chain Study Report Training Manual and Farmers' Handbook with GIZ and Passing Gifts- A subsidiary of Heifer International.

Ms. Sonmani Choudhary, **Project Director of Passing Gifts (a subsidiary of Heifer International),** highlighted key recommendations from the toolkit for goat-based livelihoods. The toolkit included a development guide, training manual, and farmer handbook. Major recommendations included leveraging the MGNREGA scheme to enhance livestock production by improving feed, fodder, water, and infrastructure, and strengthening rural roads for better market access. The report also emphasized the need for capacity building of rural and MGNREGA functionaries in livestock development, cost-effective goat shelter construction, and improving goat nutrition through the plantation of fodder trees like Moringa and Guava. Additional suggestions included using wastelands for pasture development, marking common lands for group goat ownership, and conducting community sensitization workshops to manage grazing and protect plantations.

Dr Tarun Shridhar, former Secretary, AHD GOI expressed his gratitude to the organizers and participants of the event, highlighting the importance of animal husbandry in empowering smallholder farmers. He emphasized that India holds a significant position in global animal husbandry, being a leading producer of milk, fish, fruits, vegetables, and goat meat. However, he noted that while India excels in production, productivity remains low. Dr. Shridhar stressed the need to enhance productivity to improve farmers' returns and advocated for combining traditional knowledge with modern science to achieve better outcomes. He concluded by calling for practical solutions that economically empower farmers through increased productivity and effective livestock management.

Facilitation of 10 CAVE/Goat Entrepreneurs (Lakhpati Didis)

A highlight of the event was the recognition of ten outstanding women farmers who have excelled in goat farming. Their achievements serve as an inspiration for others in the community, showcasing the impact of dedicated agricultural practices.

Principal Secretary AFRD Dr. N Vijayalaksmi, **AHD, Govt. of Bihar**, emphasized the importance of goat farming, goat value chain management, and empowering goat farmers. She highlighted that agriculture and allied sectors go hand in hand and noted that Bihar has completed three Agri Road Maps, a unique initiative where 12 departments

collaborate to improve agricultural productivity. She stressed the importance of the livestock sector, particularly goat farming, in boosting the Indian economy. The state of Bihar is actively running missions to enhance goat farming, recognizing its potential for growth. Dr. Lakshmi also referred to the NITI Aayog Report 2023, where Bihar was ranked first in reducing multidimensional poverty. She underscored the need for genetics and breed improvement programs, increased investment in the sector, and effective management strategies such as feed and fodder management. Additionally, she spoke about the Bali breed and the Mobile Veterinary Unit Project, both of which are crucial for the development of goat farming in Bihar.

In his inaugural address**, Shri. Sharavan Kumar, Minister Rural Development,Govt.of Bihar** emphasized the vital role of goat rearing in driving the economic development of rural communities. He commended the organizers for bringing together stakeholders dedicated to uplifting smallholder farmers through innovation and collaboration. Through the Ministry of Rural Development, in partnership with the Government of Bihar, initiatives like MNREGA and JEEVIKA have focused on empowering women farmers and enhancing livelihood opportunities for marginalized families. The goat farming mission has already benefitted 62,000 of the targeted 2 lakh families, highlighting its success. Various other projects are underway to create jobs, boost incomes, and improve the well-being of farmers, promoting sustainable farming practices and economically empowering rural women.

Ms Rina Soni Presented the vote of Thanks.

Goat farming is playing a crucial role in improving the livelihoods of marginal farmers in Bihar, offering them a viable source of income and economic stability. However, several challenges within the goat value chain were identified, including limited access to markets, inadequate veterinary services, and poor infrastructure. Despite these obstacles, opportunities emerged to enhance productivity and value addition. Efforts were made to promote networking and information exchange among stakeholders, facilitating the sharing of knowledge and best practices. Actionable strategies were developed to foster sustainability throughout the value chain, ensuring long-term benefits. Additionally, stakeholders converged to create and strengthen enabling environments for further improving the goat value chain across the country.

PANEL DISCUSSION 1: DIVERSIFYING INCOME OF SMALLHOLDER FARMERS THROUGH SMALL RUMINANT AND LIVESTOCK DEVELOPMENT THROUGH CONVERGENCE (11:30 AM – 12:30 PM)

Panelist

- Dr. Rakesh Kumar Singh State Project Manager-Livestock
- Dr Santosh Kumar, State Goat Nodal Officer, Bihar,
- Dr. Bibhudatta Nayak (Deputy General Manager, NABARD Bihar Regional Office)
- Dr Ganikant ,SBI Patna ,
- Sh.Vivek, Anand-Rural Development Advisor cum State Coordinator-Bihar,
- Sh. Bidya Shankar KVK,Nalanda ,
- Sh. Anish Ranjan Rao, MGNAREGA Representative
- Ms Sonmani Choudhary, Project Director - Passing Gifts- A subsidiary of Heifer International

The discussion on diversifying the income of smallholder farmers through small ruminant and livestock development highlighted the critical need to recognize that smallholders not only have limited landholdings, but also face constraints in practicing animal husbandry. Diversification was emphasized as essential for their growth, with various stakeholders playing key roles. SBI representative outlined three important schemes supporting smallholders: the MUDRA Scheme, Agri Enterprise Loan, and the National Livestock Mission, all designed to provide financial backing for growth in agriculture and livestock. The role of JEEViKA in maintaining socio-economic balance by empowering farmers and building resilience was also underscored. NABARD's efforts in helping diversify farmers' income streams were discussed, along with the proactive con-

tributions of the Bihar Animal Husbandry Department (AHD) and government programs in uplifting the rural economy and enhancing farmers' livelihoods.

ROLE OF PRIVATE SECTOR IN THE LIVESTOCK AND AGRI VALUE CHAIN DEVELOPMENT (12:30 AM – 01:30 PM)

Panelists

- Mr Amit Vatsyayan, EY-Moderator
- Mr Amit Gaurav-4S India
- Dr Surya Yadav Animal Health Expert, Godrej Agrovet
- Mr Bipin JHA-Progressive Goat Farmer (Swastic Foundation)
- Mr Rajeev Ranjan Senior Manager, Canara Bank
- Sh. Bhibhakar Jha,Lead District Manager, PNB, Patna

The role of the private sector in livestock and agri value chain development is crucial for driving innovation, improving productivity, and fostering sustainable growth. Private enterprises contribute by introducing advanced technologies, improving market access, and enhancing efficiency across the value chain. In the livestock sector, advancements in animal health and nutrition, supported by private companies, help increase productivity and profitability for farmers. Additionally, the private sector plays a key role in empowering smallholder farmers by providing access to better resources, training, and modern farming practices. Financial institutions also play an important part, offering tailored credit schemes and financial products that support farmers in scaling their operations. The collaboration between the private sector, farmers, and financial institutions is essential for creating a robust, resilient, and profitable agricultural and livestock ecosystem.

CONCLUSION AND WAY FORWARD

The dignitaries on the dais included Dr Tarun Shridhar, former Secretary, AHD GOI and Ms Neena Joshi, Senior Vice President of Asia Programs.

The event on *Empowering Smallholder Farmers Through Goat Value Chain Development in India*, with a special focus on Bihar, has shed light on the immense potential of goat farming as a sustainable and profitable livelihood option for smallholder farmers. Through insightful discussions and diverse stakeholder engagement, key takeaways have emerged to enhance the goat value chain, particularly for marginalized communities in Bihar.

Significant Takeaways

- A multi-stakeholder approach that integrates government policies, private sector innovations, and financial support to strengthen the goat value chain.
- Capacity-building initiatives, such as training farmers in best practices
- Providing access to credit
- Convergence of existing schemes like MNREGA with livestock programs
- Scaling up successful models
- Fostering collaborations between public and private sectors
- Addressing challenges such as feed availability, goat health management, and market linkages
- Leveraging the combined efforts of government agencies, financial institutions, NGOs, and the private sector, the goat value chain can be transformed into a powerful driver of rural economic growth
- Genetics and breed improvement programs
- Increased investment in the sector,
- Effective management strategies such as feed and fodder management.
- Mobile Veterinary Unit Project

RETHINKING CATTLE NUTRITION

THE KEY TO REDUCING METHANE EMISSIONS IN INDIA

India, home to one of the largest livestock populations in the world, relies heavily on its dairy and meat sectors for economic growth and food security. However, the country faces a significant environmental challenge: methane emissions from cattle, which contribute to climate change. With livestock responsible for approximately 18-20% of India's greenhouse gas emissions, methane is a major concern due to its heat-trapping capacity, which is over 25 times more potent than carbon dioxide. Fortunately, eco-friendly cattle feed offers a sustainable solution to reduce methane emissions while supporting livestock productivity.

The Challenge of Enteric Fermentation

Methane emissions in cattle primarily result from enteric fermentation, a natural digestive process in the stomach of ruminants like cows and buffaloes. During this process, microbes in the rumen break down food and produce methane as a byproduct, which is then released into the atmosphere through burping. This process contributes significantly to agricultural methane emissions, making livestock a focal point in discussions on climate change mitigation.

In India, with a cattle population of over 300 million, managing methane emissions is vital not only for environmental sustainability but also for meeting the country's climate goals under the Paris Agreement. Reducing these emissions can have a considerable impact on global efforts to limit temperature rise and promote sustainable development.

About the **AUTHOR**

Dr. Ramanuj Panda,
Founder and CEO,
GoCarin Industries Pvt Ltd.

Eco-Friendly Cattle Feed: A Game-Changer

One of the most promising solutions to reduce methane emissions from live-

stock is the development of eco-friendly cattle feed. These innovative feed formulations are designed to modify the microbial activity in the rumen, leading to a reduction in methane production. By incorporating natural additives, such as plant-based oils, fats, and tannin-rich fodder, these feeds can help lower methane emissions by up to 20-30%.

Seaweed, for example, is an emerging feed additive that has shown promising results in reducing methane production. Seaweed contains bioactive compounds that inhibit the activity of methane-producing microbes in the rumen, thereby cutting emissions without affecting the health or productivity of livestock. In trials conducted across various regions, such eco-friendly feed formulations have demonstrated improvements in both livestock health and reduced emissions, making them a viable option for India's dairy and meat sectors.

Government Initiatives and Indigenous Solutions

India's government has taken proactive steps to address the issue of methane emissions from livestock through various initiatives and policies. The National Livestock Mission, for instance, promotes sustainable feeding practices to reduce the environmental impact of livestock farming. This includes encouraging the use of methane-reducing feed technologies and improving feed quality to ensure that livestock receive optimal nutrition while minimizing their methane output.

Indigenous innovation is playing a crucial role in these efforts. By integrating traditional knowledge with modern science, researchers and farmers are developing cost-effective and sustainable feeding solutions that cater to local conditions. Improved feed formulations not only reduce methane emissions but also enhance livestock productivity, leading to a more efficient and sustainable livestock sector.

A Holistic Approach to Livestock Sustainability

By improving access to high-quality feed year-round, farmers can optimize their resources and contribute to a more resilient and climate-friendly agricultural sector.

Improving cattle feed to reduce methane emissions is just one part of a broader effort to make India's livestock industry more sustainable. Healthier and better-nourished animals are more productive, requiring less feed and resources while producing more milk and meat. This not only reduces the environmental impact per unit of production but also benefits smallholder farmers, who make up a large portion of India's livestock sector.

Additionally, sustainable livestock management practices help address other challenges, such as fodder shortages and unstructured dairy supply chains. By improving access to high-quality feed year-round, farmers can optimize their resources and contribute to a more resilient and climate-friendly agricultural sector.

A Greener Future for India's Livestock Industry

Reducing methane emissions from cattle is a critical component of India's efforts to combat climate change. Eco-friendly cattle feed, developed through a combination of scientific innovation and traditional practices, offers a practical and sustainable solution to this pressing issue. By adopting these feeding practices, India can mitigate the environmental impact of its livestock industry while enhancing productivity and supporting its farmers.

As the nation continues to work towards its climate commitments, sustainable livestock management will play a pivotal role in balancing the need for food security with the responsibility of protecting the environment. Through continued innovation and government support, India's livestock sector can become a model of sustainability, contributing to a greener and more prosperous future for all.

WINTER IS COMING IS STUBBLE BURNING, TOO?

Since winter is around the corner, people in North India, especially Delhi NCR have started worrying about air pollution. As the harvest season ends in Punjab and Haryana, the thick, suffocating smoke from stubble burning blankets the region. During this period, Delhi's air quality plunges, with PM2.5 levels at times reaching 80 times higher than the WHO permissible limits. Not many people realize that the farmers themselves face the brunt of stubble burning emissions, and yet they continue to do it.

Stubble burning is a significant source of gaseous pollutants such as, carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx), and methane (CH4) as well as particulate matters (PM10 and PM2.5) causing serious damage to human health and the environment.

Haryana's recent initiatives, offering financial incentives for non-burning practices and rewarding panchayats that achieve "zero burning," have shown encouraging results.

Scientific estimates suggest that crop residue burning contributes about 15 per cent to India's PM 2.5 emission load annually. The stubble burning in north-western states contribute about 20-30 per cent to Delhi's PM 2.5-pollution load during the peak burning period.

Why Do Farmers Burn Stubble?

So, why do the farmers of Punjab and Haryana burn stubble despite the well-known harmful effects? This is because farmers have a short window - usually about two to three weeks between harvesting paddy and planting wheat. They need to quickly dispose the stubble before moving onto the next crop cycle.

About the **AUTHOR**

M Ramakrishnan, Managing Director, Primus Partners

What can Farmers do with Stubble?

The answer to stubble burning lies in associating economic value with it. The 27.62 million tonnes of stubble produced annually by Punjab and Haryana could be transformed into valuable products that generate income for farmers and create jobs.

One promising avenue is **biofuel** production. The Indian government has a target of 20% ethanol blending with gasoline by 2025. Farmers can direct paddy straw towards producing second-generation biofuels. India has the potential to produce 45 billion litres of bio-ethanol per year, much of it from agricultural waste like stubble. Current ethanol blending in India stands at around 15%, and experts believe this can easily reach ~25%.

Another key sector is **biomass power**. India has a 10 GW installed capacity for biomass power, but agricultural residue could contribute up to 18 GW of additional power. Biomass power plants not only reduce stubble burning but also provide reliable, decentralized energy to rural areas. Punjab currently has 11 biomass power plants with an installed capacity of 97.5 MW, using 0.88 million MT of paddy straw, and two more being commissioned, along with several biogas projects that utilize paddy straw. Farmers can explore where the nearest biomass power stations are and supply their stubble there.

Sustainable packaging is another growing industry which could benefit from stubble. With India's ban on single-use plastics, there is increasing demand for eco-friendly packaging. Consumer

awareness around climate change and their increasing spending power have led to significant demand for climate-friendly products. Farmers can sell their crop residue to sustainable brands, or paper and packaging industries. Thus, the crop residue can be processed into biodegradable packaging materials. Start-ups like Dharaksha are experimenting with this, and this sector could scale up rapidly.

What can the Government do?

However, realizing the full potential of stubble as an economic resource would require a supportive ecosystem. High initial costs for setting up stubble-based businesses remain a barrier. Also, the big killer, with limited buying units for these stubbles, is the logistics cost. The landed cost of crop residue from far away farms makes it unviable for businesses.

To mitigate this, the government should offer subsidies, incentives, or interest subvention to encourage private investment. In the EV (Electric Vehicle) space, we see significant progress thanks to incentives laid down by the government and the infrastructure (i.e. charging stations) investments. Similarly, for addressing crop stubble, the Government (both at Centre and State levels) should offer financial support to set up bioethanol production and biomass power plants across the Punjab / Haryana farming belts.

The stubble burning in north-western states contribute about 20-30 per cent to Delhi's PM 2.5-pollution load during the peak burning period.

To cut down the logistics cost, we probably need a large number of small-capacity-plants, spread across the clusters. Decentralized storage and processing units, supported by government initiatives and private investment, could be a major driver for change.

PPP (Public-private-partnerships) could play a crucial role in scaling up infrastructure. The government can also look at supporting FPOs to take up this activity and increase their income.

Similarly, Government should provide incentives to small businesses or traders (Arhatiyas) to procure stubble directly from farmers, making it economically attractive.

Farmer education is another critical component. Government-backed awareness campaigns, combined with assured procurement programs, almost like a MSP – minimum support price – program can be a huge help. Haryana's recent initiatives, offering financial incentives for non-burning practices and rewarding panchayats that achieve "zero burning," have shown encouraging results. Expanding such programs across northern India could drive wider adoption of sustainable practices.

An Economic and Environmental Imperative

Stubble burning is not just an urgent environmental crisis, but also an overlooked economic opportunity. By incentivizing the private sector and FPOs to invest in stubble-based businesses, India can not only reduce its air pollution but also create new industries, jobs, and income for farmers.

REDUCING CLIMATE FOOTPRINT AND INCREASING RESILIENCE: FOR SUSTAINABLE AGRICULTURE IN INDIA

India's agricultural sector has been the backbone of our economy for generations. It's a way of life that engages over 148 million people every year, providing livelihood to more than half of our working population. But as we look back, it's clear that things have changed significantly over the decades. Back in 1990-91, agriculture made up 35% of our total Gross Value Added (GVA). Fast forward to 2022-23, and that number has dropped to 15%. Now, while this might seem concerning at first glance, it's actually a sign of progress. This shift indicates that our economy is evolving, with more people finding opportunities in other sectors like manufacturing and services. Essentially, it means we're using our land and resources more efficiently, allowing our human capital to be better utilized in a variety of industries.

Today, Indian agriculture is at a crossroads. On one hand, we're seeing incredible advancements in farm mechanization and the adoption of modern practices. On the other, there's an increasing need to ensure that our agricultural methods are sustainable. India's diverse geography makes us particularly vulnerable to climate change, with over 80% of our population living in districts at risk of climate-induced disasters. In such a scenario, sustainability in agriculture isn't just a buzzword—it's a necessity. From the seeds we plant to the way we protect our crops, harvest them, and store them, every step needs to be thought through with the environment in mind. And with India's agricultural exports surpassing USD 50 billion in FY2023, the spotlight on sustainability isn't just local; it's global. People around the world care about the quality of our food and the practices we use to grow it.

Given the challenges posed by climate change and the growing emphasis on sustainability, it's clear that we need to reduce agriculture's carbon footprint and boost its resilience.

Stoking Innovations

Given the challenges posed by climate change and the growing emphasis on sustainability, it's clear that we need to reduce agriculture's carbon footprint and boost its resilience. This is where the agrochemical industry plays a pivotal role. Our agrochemical sector is growing rapidly—at a 9% CAGR—and is expected to reach US$ 14 billion by FY2028. But

About the **AUTHOR**

Vimal Kumar, Managing Director, Best Agrolife Ltd

with this growth comes responsibility. Globally, around 4 billion tons of pesticides and 12 billion kg of agricultural plastics are used each year. As the second-largest exporter of agrochemicals, India must lead by example in developing sustainable solutions for our farmers. For our agricultural sector to thrive, farmers need access to crop protection solutions that are not only effective but also environmentally friendly. While natural solutions are often seen as better for the ecosystem, they're not always readily available, making it difficult for them to fully replace chemicals. The reality is that moving away from chemicals isn't practical either. Instead, the path forward lies in innovation—creating products that are effective but don't harm the environment. It's heartening to see that our government, along with countries like Ecuador, Uruguay, and Vietnam, has launched a $379 million initiative to tackle the pollution caused by pesticides and plastics in agriculture. Thanks to supportive policies that encourage research and innovation, India is rapidly developing unique insecticide formulations that are not only broad-spectrum but also flexible in application and quick to act. These new formulations are designed to be long-acting, reducing the need for frequent applications and offering extended protection. In essence, they are helping us move towards more sustainable farming practices.

Technology Development

Let's talk about technology for a moment. It's truly transforming agriculture in ways we couldn't have imagined a few decades ago. Advanced technologies like AI, machine learning, and blockchain are giving farmers tools that make a real difference. For instance, AI-driven predictive analytics are helping farmers make smarter decisions about crop management, which not only reduces waste but also boosts productivity. Agri-tech startups are leading the charge, developing innovative solutions like soil health monitoring systems and climate-resilient seeds. These technologies have the potential to significantly reduce the carbon footprint of farming activities.

Of course, sustainability isn't just about agrochemicals or technology—it's about adopting the best practices across the board. Precision agriculture, for example, is a game-changer. Using tools like satellite imagery, drones, and soil sensors, farmers can optimize resource use and boost productivity. Water management is another critical area—drip irrigation, rainwater harvesting, and drought-resistant crops are all essential in addressing the growing challenge of water scarcity. Crop diversity and rotation are also vital, as they help reduce the risk of pests and diseases, improving soil health and yield stability. And let's not forget about sustainable practices like agroforestry, conservation tillage, and organic farming. These methods not only lower the carbon footprint but also enhance the resilience of our agricultural systems.

Government initiatives are key to driving the adoption of sustainable practices. Programs like the Pradhan Mantri Fasal Bima Yojana (PMFBY) offer crop insurance, giving farmers the confidence to try new techniques without the fear of financial loss. The introduction of subsidies for sustainable inputs and funding for agri-tech research are also crucial steps in fostering innovation in the sector. And there's more that can be done—policymakers might consider tax incentives for sustainable farming practices and enforce stricter regulations on non-sustainable practices to further encourage this shift.

By practicing carbon sequestration and embracing methods like cover cropping and reduced tillage, we can play a significant role in mitigating climate change.

Knowledge Transfer

Healthy soil is at the heart of sustainable agriculture. By practicing carbon sequestration and embracing methods like cover cropping and reduced tillage, we can play a significant role in mitigating climate change. Knowledge is power, and that's why disseminating information through extension services, training programs, and digital platforms is so important. Farmers need access to the latest research and technologies to stay ahead. And from a policy perspective, supporting farmer education, offering financial incentives, and improving market access can drive the large-scale adoption of sustainable practices. Investing in agricultural R&D for climate-resilient crop varieties and sustainable farming technologies is essential. By integrating these strategies, we can reduce agriculture's climate footprint, enhance resilience, and secure a sustainable future—one that balances environmental responsibility with economic opportunity.

Our journey towards sustainable agriculture in India requires all of us to come together. Farmers, agribusinesses, policymakers, and consumers—we all have a role to play in reducing agriculture's climate footprint and increasing its resilience. The future of Indian agriculture lies in our ability to innovate, adapt, and embrace sustainable practices. By doing so, we can ensure not only the well-being of our environment but also the prosperity of our farmers and our nation as a whole. Let's envision a future where Indian agriculture leads the world in sustainability, providing high-quality, nutritious food while safeguarding our planet for generations to come.

INTEGRATING SUSTAINABILITY INTO TRADE

IDH - The Sustainable Trade Initiative - works to transform markets and enable businesses to create value for people and the planet. IDH, in collaboration with Sattva Consulting, recently organized its flagship event, The Sustainable Trade Summit 2024, themed "Accelerating Responsible Sourcing in Indian Markets". Daan Wensing, CEO, IDH, and Jagjeet Singh Kandal, Country Director, India – IDH interacted with Agriculture Today and discussed on sustainability and responsible sourcing. Excerpts from the Interview.

Daan Wensing

Jagjeet Singh Kandal

Why was IDH formed? How far has it been able to achieve its objectives?

Daan Wensing : IDH - The Sustainable Trade Initiative - was formed 16 years ago by the Dutch government that was looking for a partner to bring the private sector to deliver the the millennium goals (which are now the sustainable development goals). It wanted to leverage the private sector for its innovation, delivery and investment potential. It is still the core mandate of IDH. Since its inception, we have become an independent organization and not an entity of any government. We are an international organization with offices in over 15 different countries and with over 55 different nationalities in our workforce.

We have also helped in certification of forestry around the world in more than 10 million hectares.

We have helped millions of farmers to certify in crops like cotton, palm oil, spices and many other crops. We have also helped in certification of forestry around the world in more than 10 million hectares. Apart from this we have also helped in sector governance. We have brokered deals in tea, coffee, palm oil sector not only with independent companies but full markets like European markets, and even global sectors have committed to stand by sustainability targets. Through that we have reached way more farmers and crop lands. We have been able to broker pre competitive collaboration on shared agenda of sustainability between companies that normally

are competitors.

On the thematic front, IDH was able to create a visible impact. For instance, the case of living wage. We have been working on it for more than 10 years. Apart from the moral imperative, there is also a business imperative to pay people better because they become more productive, healthy and retention is also higher. We have partnered with ILO and with individual companies who have embraced the concept of living wage and mainstream it. The entire banana sector has embraced the concept of living wage.

Jagjeet Singh Kandal – A great example of the work that we have done in India is the Trustea Programme. This pre competitive programme was curated by IDH, Unilever, Tata and today it is run by Unilever, Tata and Wagh Bakri- the largest three packeteers of tea. They have certified almost 80% of the India tea produced. It is a great example of the industry working towards sustainability.

Can you elaborate on responsible sourcing?

Daan Wensing - It is quite a recent topic in the industry. In the past sustainability agenda was mostly focused on farm and the farmer. And the farm practices. But this is only a part of solution. It is also important to focus on procurement, for example the inputs. Instead of buying on spot market, long term contracts will help create and relationship and sustainable trade realtions. It will help to share the risk with the value chain as we can buffer the risk with other actors.

What are the strategies that India can develop to ensure responsible sourcing, and how it can improve India's standing in global trade?

Jagjeet Singh Kandal - It is important to create a demand from the market side for sustainably sourced products. Many Indian companies are stepping up to it. A few years ago, sustainability and procurement teams were two different entities. Those are merging now. Procurement teams earlier were focused on

It is important to create a demand from the market side for sustainably sourced products.

buying at the cheaper price, but now it is to buy at a sustainable price.

What are the challenges faced by the small holder farmers?

Jagjeet Singh Kandal – Small farmer doesn't have a leverage. The only thing can we do is collectivization of farmers. The government has already 10000 FPO collectives programme. But half of them do not function because there is no professional management of the collective.

What is your view on multistakeholder collaboration in supporting smallholder farmers and enhancing sustainability?

Daan Wensing - We believe in the power of collaboration. They can all work in a different way and prevent dominance. IDH does not have a financial stake and that allows us to carve out a common agenda, keeping the farmers at the centre.

What were the key take away points from the Sustainable Trade Summit 2024, themed "Accelerating Responsible Sourcing in Indian Markets," on October 17-18, 2024?

Jagjeet Singh Kandal – The conference talked about the collaboration and the significance of small holder farmers. There were also discussions on regenerative agriculture and how it is supporting sustainable agriculture. Living wage was also the centre of the discussion. This will be important to create an equitable value chain. Safety of the workers and their rights formed a crucial point of discussion.

What is the future of Sustainable Agriculture?

Daan Wensing – There will be no future without sustainable agriculture. Climate change is affecting agricultural yields around the world. In coffee, global yields are 40% less than what it used to be. Cocoa yields are less than 20-30%, and so is palm oil yields. Climate change is real and is disrupting the value chain. Farmers are in more vulnerable position who are perennially stuck in poverty so much so that their younger generation is reluctant to pursue farming as a profession. Factoring in climate change, stakeholders across the value chain have realized the importance of sustainable agriculture.

What would be your recommendations to Indian government to enhance sustainability?

Jagjeet Singh Kandal - The government has already taken many initiatives on sustainability reporting. We need to have sector specific guidelines. In the recently concluded Sustainable trade Summit, six of the companies have signed manifestoes on sustainable palm oil production. We have to take up discussions with the government on the sustainability measure in palm oil sector especially when there is a palm oil mission to increase production. Government will be a huge enabler in these discussions. Code of wages is a fantastic initiative. The states have already completed the foundation work.

Daan Wensing – Sustainability is entering a new era. More collective action is happening around the world. It is the future.

3PL PLAYERS

ADDRESSING RISING FOOD WASTE

Every year, nearly ***one-third*** *of all food produced for human consumption is wasted.* While food waste is often seen as a result of excess production, its roots run deeper. The industrialization of agriculture, rapid advancements in transportation, and the rise of global food trade have allowed food to reach consumers like never before. Yet, this progress has come at a cost—escalating food wastage. In India, where agriculture is a cornerstone of the economy, the problem is acute. Poor infrastructure, erratic weather, and fractured supply chains lead to staggering post-harvest losses. Tackling this requires collaboration across all stakeholders, but one solution stands out: third-party logistics (3PL). With the right cold-chain infrastructure, these players can dramatically reduce food waste, ensuring that more of what's produced actually reaches consumers in good condition.

Cold storage and refrigerated transportation are vital for preserving perishable items like fruits, vegetables, dairy, and meat, preventing spoilage during storage and transit.

The Scale of the Food Waste Problem

Food waste is a growing concern worldwide, and the scale of the issue is enormous. According to the UNEP Food Waste Index Report 2021, India alone contributes 68.8 million kilograms of wasted food annually, accounting for 7% of the global total. These numbers highlight the urgent need for action to curb waste and improve the overall efficiency of the supply chain.

A significant portion of this wastage occurs at the farm level, where food losses often go unnoticed or unaddressed. For example, a study conducted by the World Resources Institute (WRI) on the tomato supply chain in Madhya Pradesh, a key growing region for this crop, reveals that 15% of tomatoes are lost at the farm level. Another 12% of tomatoes are wasted at the retail level due to inadequate handling, storage, and cosmetic standards. This adds up to a staggering total of 27% of the crop being lost before it even reaches the consumer.

While these statistics highlight the food wastage problem in India, it's important to note that the issue is not just about the volume of food lost. The larger problem is the resource inefficiencies that accompany it. The water, labor, energy, and raw materials used to produce the food are also wasted, which impacts not only the economy but also the environment. Addressing food waste requires a multifaceted approach, and 3PL players, particularly those specializing in cold-chain logistics, can make a substantial difference.

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The Role of Cold-Chain Logistics in Reducing Food Waste

Efficient cold-chain logistics is one of the most effective ways to combat food waste. Cold storage and refrigerated transportation are vital for preserving perishable items like fruits, vegetables, dairy, and meat, preventing spoilage during storage and transit. The third-party sector, especially those specializing in cold-chain logistics, plays a

crucial role in reducing food waste. By enhancing infrastructure, optimizing systems, and leveraging technology, these players help minimize losses and ensure fresh produce reaches markets, even in remote areas.

How 3PL Players Help Combat Food Wastage

Efficient Storage Facilities

One of the major contributors to food waste is inadequate storage capacity. In India, the National Centre for Cold Chain Development (NCCD) estimates that the country's cold storage capacity stands at 37 million metric tons, while the annual production of perishable commodities is over 104 million metric tons. This gap leaves a significant portion of produce unprotected and susceptible to spoilage. 3PL players with access to state-of-the-art cold storage facilities are crucial in addressing this gap. By managing vast networks of cold storage, these companies can ensure that food is stored at optimal temperatures, reducing spoilage, and extending shelf life. For example, products like tomatoes, which have a high risk of spoilage, can be stored for several weeks in cold storage, as opposed to just a few days at room temperature. This minimizes waste at both the farm and retail levels.

Refrigerated Transport

Transport is another area where cold-chain logistics plays a vital role in minimizing food waste. Poor road infrastructure, coupled with delays in transit, can lead to food spoilage during transportation. Refrigerated transport ensures that perishable goods maintain their temperature and quality during transit, regardless of the distance or weather conditions. This is especially important for commodities like dairy, meat, and certain fruits and vegetables, which are highly sensitive to temperature changes. With more advanced technologies in refrigerated transport, 3PL players can optimize their fleets, ensuring faster and more efficient delivery of perishable goods, thereby reducing the time food spends in transit and minimizing the potential for spoilage.

Handling and Processing Expertise

Cold-chain logistics companies also excel in managing food handling and processing. Many post-harvest losses are attributed to poor handling at various stages of the supply chain. From the farm to the consumer, improper handling, such as exposure to excessive heat, incorrect stacking, or inadequate packaging, can cause significant food waste. 3PL players bring expertise in handling perishable goods. By implementing industry best practices and providing proper training to staff, these logistics providers can ensure that food is handled with care and kept under optimal conditions throughout the supply chain. This reduces food damage, wastage, and the potential for spoilage.

Technological Integration

Technology is revolutionizing cold-chain logistics, with IoT, blockchain, and AI driving efficiency and reducing waste. IoT devices enable real-time monitoring of temperature and humidity, ensuring perishable goods remain in optimal conditions throughout the supply chain. Blockchain provides transparency and traceability, preventing mishandling and ensuring food quality. AI plays a key role in predicting market demand, optimizing supply chain operations, and forecasting product shelf life, which helps reduce overproduction and waste. By integrating these technologies, 3PL players are enhancing cold-chain operations, ensuring food reaches markets fresh and with minimal loss.

Market Efficiency and Price Stabilization

Cold storage and efficient transportation also contribute to market efficiency and price stabilization. By reducing food waste, more produce is available for consumers, reducing the volatility in prices that often accompanies seasonal gluts or shortages. This helps both farmers and consumers by stabilizing prices and ensuring a steady supply of fresh produce throughout the year. For example, during peak harvest periods, farmers can store their produce in cold storage and release it gradually into the market, thereby avoiding price crashes caused by oversupply. This not only helps farmers get better prices for their crops but also ensures that consumers can access affordable, fresh produce year-round.

Government Policies and the Role of Public-Private Partnerships

In recognition of the critical role cold-chain logistics plays in reducing food waste, the Indian government has launched several initiatives to improve food storage and distribution. The Pradhan *'Mantri Kisan SAMPADA Yojana'* (PMKSY) and the *'Integrated Cold Chain'* and *'Value Addition Infrastructure'* are two such schemes aimed at creating robust cold chain infrastructure in India.

Public-private partnerships (PPPs) have also emerged as an effective way to bring in the necessary capital and expertise to develop and manage cold storage and logistics facilities. Logistics players are well-positioned to partner with the government to expand cold chain infrastructure, create a more efficient supply chain, and reduce food waste on a large scale.

Conclusion

Food wastage is a critical challenge in India, impacting food security, economic stability, and sustainability. While various stakeholders are working to tackle the issue, third-party logistics players, particularly in cold-chain logistics, play a pivotal role. Their expertise in storage, refrigerated transportation, and technological integration helps reduce waste, stabilize prices, and boost agricultural productivity. As India advances toward becoming a $7.3 trillion economy by 2030, empowering logistics players to lead in preserving and efficiently transporting food will be essential in building a more sustainable food system, driving both economic and environmental benefits.

TECHNOLOGY FOR ENHANCED AGRICULTURAL LOAN MANAGEMENT

A GAME-CHANGER FOR FINANCIAL INSTITUTIONS

India's agricultural prowess is not just a matter of tradition—it's a vital cornerstone of its economy, fuelled by the country's rich agro-ecological diversity. Agriculture supports the livelihoods of around 42.3% of the population and contributes a significant 18.2% to India's GDP, despite the country's growing focus on business and services. Over the past five years, this sector has shown impressive resilience, with an average annual growth rate of 4.18%. With a US$ 24 billion agritech opportunity on the horizon, the potential for innovation in this space is immense. Yet, despite this promise, only 1.5% of the market has been tapped. As agritech continues to evolve, one thing is clear: the future of agriculture in India will be shaped by technology, particularly in how financial services are delivered to rural areas.

Benefits of Technology in Agricultural Loan Management

The need for robust financial support in agriculture has never been more crucial. As agricultural activities expand, so does the demand for quick and reliable financial services. Financial institutions (FIs) are increasingly turning to technological solutions to streamline agricultural loan management. Leveraging AI and digitized land records is becoming pivotal in increasing efficiency, transparency, and security in the agricultural lending process.

Advanced technology solutions, such as AI, allow financial institutions to monitor and manage the entire loan life-

AI-powered platforms can automate the verification of critical data, reducing manual errors and speeding up the loan approval process.

cycle more effectively. AI-powered platforms can automate the verification of critical data, reducing manual errors and speeding up the loan approval process. By employing AI to assess risks and opportunities, banks can offer faster, more accurate loans, improving financial inclusion for farmers across the country. These tools also help banks maintain more accurate, real-time records, enhancing decision-making and reducing the risk of human error.

The Role of Digitized Land Records in Enhancing Transparency and Trust

One of the most significant advancements in collateral-based lending is the digitization of land records. Digitized land records enable banks to verify collateral more efficiently, standardizing data and improving transparency. This increased transparency reduces the risk of errors and discrepancies in documentation, which can cause tension and mistrust between lenders and borrowers.

With digitized land records, banks can quickly access and validate property information, ensuring that the land pledged as collateral is legitimate and accurately valued. This process not only minimizes the risk of fraud but also enhances trust between farmers and financial institutions. Additionally, digitized records are especially valuable in a country like India, where multiple languages and regional distinctions complicate loan

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processing. Advanced transliteration accuracy helps lenders process loans even in linguistically diverse regions, increasing the reach and inclusivity of agricultural financing.

Challenges in Collateral-Based Lending

Collateral-based lending, though advantageous, comes with its own set of challenges. One of the most persistent issues is data verification. In many cases, land records are outdated, incomplete, or fragmented, leading to delays in loan processing and increased fraud risk. Farmers often lack proper documentation to prove property ownership, making it difficult for financial institutions to secure loans against these assets.

Furthermore, the complexity of managing agricultural loans increases due to the diversity of land ownership patterns across the country. In many rural areas, farmers may hold land under multiple forms of tenure, further complicating the process of collateral verification. These challenges can result in significant delays, preventing farmers from receiving timely financial support, especially during critical farming seasons.

Reducing Loan Fraud and Mitigating NPA Risks with Technology

According to recent data from the RBI, public sector banks have seen a surge in fraud cases, particularly in loan portfolios. In FY 2023-24, a staggering 36,075 fraud cases were reported—a dramatic increase of nearly 166% from the previous year. Despite the rise in fraud cases, the amount involved in these activities decreased by 46.7%, highlighting the need for more effective risk mitigation strategies in lending.

Advanced technologies, particularly Generative AI, are proving to be a game-changer in the fight against loan fraud. GenAI helps financial institutions detect potential risks at an early stage by automating the analysis of collateral data and implementing robust monitoring systems. AI-driven platforms now enable banks to standardize property records, often fragmented and stored in various formats. This ensures accurate verification and legal compliance while identifying anomalies early in the process. By improving the efficiency of loan assessments, these technologies play a crucial role in reducing Non-Performing Assets (NPAs) and safeguarding the overall health of financial portfolios.

The Impact of Accurate and Fast Loan Processing on Farmers and the Agricultural Sector

The speed and accuracy of agricultural loan processing have a direct impact on farmers and their productivity. In India, timely access to credit can make the difference between a successful harvest and a financial crisis. Faster loan processing ensures that funds reach farmers during critical periods, such as planting or harvesting seasons, enabling them to invest in seeds, fertilizers, and equipment. This availability of funds significantly boosts productivity and yields.

Faster loan processing ensures that funds reach farmers during critical periods, such as planting or harvesting seasons, enabling them to invest in seeds, fertilizers, and equipment.

Improved loan processing also supports rural economic growth. Faster approvals promote timely investments in the agricultural supply chain, which increases farmers' incomes and encourages a sustainable agricultural ecosystem. Moreover, integrating technology into agricultural finance helps bridge the gap between rural and urban financial services. Digital platforms now allow farmers to access loans through their smartphones, ensuring financial inclusion even in remote areas with limited banking infrastructure.

Adapting to a Digital Future

India's agricultural sector is evolving, and financial institutions must innovate to meet the rising demand for agricultural credit. With a growing population and increased agricultural activity, adopting digital solutions like AI, digitized land records, and automated risk management is essential for staying competitive. These technologies improve transparency, efficiency, and security in agricultural lending, reducing fraud and NPAs while ensuring farmers get timely access to crucial funds. As India advances in agritech and financial inclusion, technology will be key to driving rural economic growth, empowering farmers, and securing a brighter, more sustainable agricultural future for generations to come.

HIGH-VALUE LOANS: A CATALYST FOR POST-HARVEST TRANSFORMATION IN INDIAN AGRICULTURE

India, a global leader in agricultural production, faces a paradox: staggering post-harvest losses of 10-30%. The Ministry of Food Processing Industries reports an annual loss of approximately USD 14 billion(A Report on Resilient Food Systems February 2024 by ASSOCHAM) in agricultural produce in India due to insufficient post-harvest infrastructure. Insufficient storage and transportation facilities contribute to a staggering 30% loss of the country's total agricultural output each year. This translates to substantial economic hardship for farmers, diminished food security, and missed opportunities for value addition. Traditional lending models, focused on pre-harvest financing with limited loan sizes, fall short in addressing these critical post-harvest challenges. Securing high-value loans for post-harvest advancements remains difficult for farmers. Limited loan sizes, lender risk perception, lack of collateral, and complex applications are major hurdles. Repayment challenges due to long production cycles and limited market access further complicate matters. Equipping farmers with technical knowledge and market linkages alongside tailored loans is vital for successful post-harvest transformation.

Thus high-value loans in agriculture play a very crucial role in addressing these post-harvest challenges by providing farmers with substantial capital to invest in advanced infrastructure and processing capabilities. High-value loans, exceeding the scope of microfinance, emerge as a game-changer, empowering farmers to bridge the gap between farm and market. By strategically allocating larger loan amounts, this innovative approach equips farmers and farmer collectives with the tools and infrastructure needed to minimize losses, enhance product value, and unlock new income streams.

Investing In Various Post Harvest Activities Including Infrastructure Development and Maximizing Value

High-value loans act as a springboard for advancements in key areas of post-harvest management:

- **Advanced Cold Chain Infrastructure:** High Value Loans can be used to establish or upgrade sophisticated cold storage facilities equipped with controlled atmosphere (CA) storage capabilities. This technology plays a critical role in preserving the freshness and quality of high value produce like fruits, vegetables, and flowers. Extended shelf life allows farmers to access premium markets, fetching higher prices and reducing spoilage.
- **Large-Scale Processing Units:** High Value loans specifically designed, can supportthe creation of state-of-the-art processing units involved in various post harvest activities like sorting, grading, and value addition capabilities transforming agricultural produce into high-value products . For example production of frozen fruitsand vegetables, juices, jams, or dehydrated products. This empowers farmers to not only reduce spoilage but also create new revenue streams, diversifying their income sources and becoming less vulnerable to price fluctuations in commodity markets.
- **Integrated Logistics and Transportation Systems:** High- value loans can finance investments in comprehensive logistics and transportation infrastructure. This could include dedicated refrigerated warehouses strategically located near production areas, along with fleets of refrigerated trucks. Efficient and timely movement of perishable produce from farm to market minimizes spoilage during transportation, a significant contributor to post-harvest losses .
- **Financing against eNWR receipts :** It can be a powerful tool to prevent future losses. By offering easier access to credit by financing against eNWR receipts based on the value of stored produce (represented by eNWR), farmers can afford better storage facilities, reducing spoilage and also can avert the financial crunch due to holding up of stocks in godowns or cold storages. Additionally, eNWR flexibility allows selling produce when prices are higher, minimizing distress sales due to immediate financial needs. This combined

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approach helps mitigate future losses and improve overall financial security for farmers

4. Tailoring High-Value Loans for Success:

The success of this model hinges on carefully structured loans that meet the specific needs of borrowers:

- **Loan Size:** Unlike traditional microfinance models, loan amounts are tailored to the specific project requirements. Factors like the scale of infrastructure needed, processing capacity, and projected cash flow from value-added products are considered. This ensures sufficient capital to invest in advanced post-harvest infrastructure and processing units, crucial for maximizing the impact of the loan.
- **Risk Mitigation Strategies:** Larger loans necessitate robust risk mitigation strategies. Loan guarantees from government agencies, agricultural insurance products tailored to post- harvest losses, or partnerships with established food processing companies or large retailers offering offtake guarantees can beexplored. These strategies create a safety net for both lenders and borrowers, fostering a more risk-tolerant lending environment.
- **Long-Term Repayment Schedules:** Recognizing the extended production cycles associated with agriculture, repayment terms need to be extended beyond single harvest cycles. Ideally, these terms should span several years and be linked to projected market returns on processed products. This allows for efficient cash flow management and ensures loan sustainability for farmers.
- **Project Management and Capacity Building:** High-value loans alone are insufficient. Comprehensive project management support is necessary. This encompasses infrastructure development, processing technology selection, market analysis, and training programs on operating and maintaining the facilities. Additionally, capacity building for farmers on financial management and cooperative governance becomes crucial, especially for Farmer Producer Organizations(FPOs) seeking larger loans. Equipping farmers with the necessary skills fosters long-term project success and financialsustainability.

5. Connecting Farmers to Premium Markets:

High-value loans, when coupled with market access initiatives, create a powerful combination:

- **Establishing Direct Market Linkages:** Loans can support the formation and scaling up of FPOs with the capacity to invest in shared, large-scale post-harvest infrastructure and processing units. FPOs, with their increased bargaining power and larger production volumes, can bypass middlemen and negotiate directly with large retailers and food processing companies.This empowers them to access premium markets for their value- added products, capturing a larger share of the profits and gaining greater control over the value chain. Farmers become not just producers of raw commodities but entrepreneurs managing and marketing their value-added products.
- **Contract Farming with Guaranteed Buyback:** Loan programs can facilitate contract farming arrangements with established food processing companies or large retailers. Such arrangements provide farmers with guaranteed buyback of their produce at pre-determined prices. This not only mitigates market risks and ensures a predictable income stream but can also incentivize the adoption of specific quality standards and cultivation practices. This, in turn, benefits processing companies with a consistent supply of high-quality produce, creating a win-win situation for all stakeholders.

The Road Ahead: A Collaborative Effort for Transformation

High-value loans hold immense potential to transform the Indian agricultural sector. By empowering farmers and FPOs to invest in advanced post-harvest management infrastructure and processing capabilities, this approach offers a roadmap to a more resilient and profitable future:

- **Reduced Post-Harvest Losses:** By minimizing spoilage through efficient storage, processing, and transportation, high- value loans can significantly reduce post-harvest losses. This translates to increased income for farmers, improved food security for the nation, and a more sustainable food supply chain.
- **Enhanced Value Addition:** Processing agricultural produce into high-value products creates new revenue streams for farmers. This not only reduces dependence on volatile commodity markets but also unlocks new market opportunities. Imagine Indian farmers supplying a wider range of processed food products, from frozen mangoes to dehydrated vegetables,to domestic and international markets.
- **Improved Market Access:** High-value loans empower farmers to bypass middlemen and establish direct linkages with premium markets. This allows them to capture a larger share of the profits and gain greater control over the value chain. Farmers become not just producers of raw commodities but entrepreneurs managing and marketing their value-added products.
- **Increased Investment and Job Creation:** This model can attract significant private sector investment in post-harvest infrastructure and processing units. This surge in investment not only strengthens the agricultural sector but also stimulates rural economic development by creating new job opportunitiesin areas like logistics, processing, and quality control.

MICROBIAL DEGRADATION OF PESTICIDES: A SUSTAINABLE APPROACH IN MANAGING PESTICIDE HAZARDS

Modern agriculture has experienced remarkable growth over the past few decades, driven by technological advancements, improved farming practices, and the development of high-yielding crop varieties. Innovations in irrigation, mechanization, and the use of synthetic fertilizers have significantly boosted food production to meet the demands of the growing global population. This agricultural revolution has increased crop yields and enhanced food security. However, the widespread use of pesticides has been a key factor in this growth.

While pesticides have played a crucial role in protecting crops and maximizing yields, their excessive and improper use has led to serious environmental and health challenges. Many pesticides are persistent in nature, leading to their accumulation in soils, water bodies, and living organisms, which poses serious risks to both ecosystems and human health. Traditional methods of pesticide removal, such as chemical and physical treatments, are often inefficient and expensive. In response to these challenges, microbial degradation has emerged as a sustainable and environmentally friendly alternative. This process involves microorganisms breaking down toxic pesticide compounds into less harmful or non-toxic by-products, contributing to the detoxification of contaminated environments. It also restores soil fertility through the re-establishment of microbial balance. Microbial degradation is not only effective in managing pesticide hazards but it is also economically viable and ecologically sustainable.

While pesticides have played a crucial role in protecting crops and maximizing yields, their excessive and improper use has led to serious environmental and health challenges.

Pesticide consumption ratio

In order to meet the growing demand for crop production in modern agriculture, there is widespread use of pesticides. Pesticides have a market worth of billion dollars as their economic importance is huge. 84.5 billion of revenue was generated in 2019 and a mark of 130.7 billion dollars is expected to be achieved by 2023 (The Business Research Company, 2020). Pesticide consumption in the year 2021, stood at 3.53 million metric tons. The global consumption of agricultural pesticides has increased

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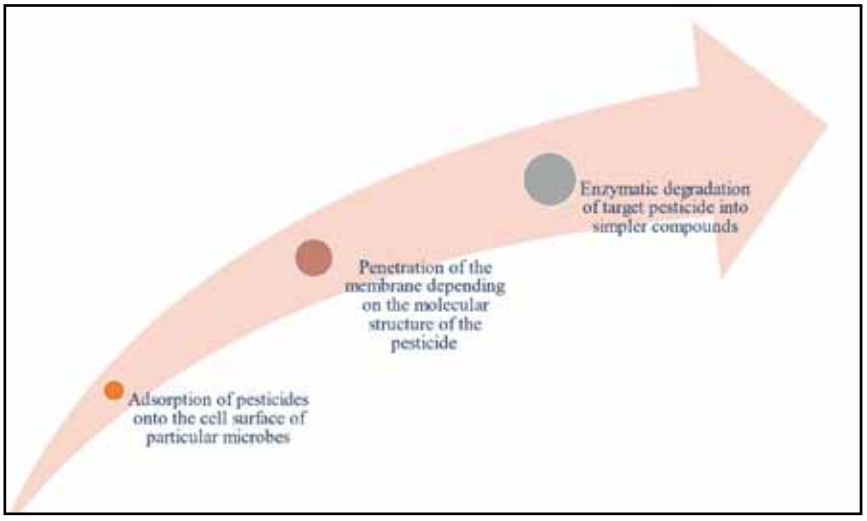
by 96 percent (Statista Research Department, Sep 20, 2023). According to the ranking of global purveyors of agrochemicals, India ranks fourth after USA, Japan and China. In India, the pesticide industry is the biggest in Asia and ranks 12th globally. With a consumption rate of 0.29 kg/ha, India stances second among the Asian continents (Devi et. al., 2017). To reduce crop loss, there is an excessive dependence on pesticides which is leading to an intense escalation in pesticidal hazards in India.

Microbial Degradation

In this threat of pesticide hazards, microbial degradation is a light for future generations. Several microorganisms like bacteria, actinomycetes, and fungi can degrade the chemical toxic compounds into less toxic compounds with their metabolic functions. This process of degradation with the help of microorganisms is called biodegradation (Sun et al., 2020). Microbes interact with the target compound both chemically and physically, leading to its transformation into a non-toxic substance, complete degradation, or the removal of specific toxic properties (Ortiz-Hernández et al., 2013). Biodegradation is usually referred as microbial degradation as the role of microorganisms is greatest (You and Liu, 2004). Different types of biodegradation are illustrated in Table 1. The microorganisms derive their nutrients or energy from the degradation process of the synthetic or xenobiotic compounds and convert them into inorganic compounds like water and carbon dioxide (Ortiz-Hernández et al., 2013; Huang et al., 2018). Hence, this method is a sustainable, environmentally friendly and economic method (Aresta et al., 2015).



Mechanisms and process

The degradation of pesticide residues by microorganisms happens through a series of complex steps. Various biochemical processes play a role in breaking down these compounds, including reactions such as oxidation, reduction, hydrolysis, and others like dehydrogenation, dehalogenation, and decarboxylation. Additionally, transformations like molecular rearrangements, conjugation, and isomerization contribute to this degradation process (Hugo et al., 2016). Various types of oxidation, reduction, and hydrolysis reactions occur, facilitating the breakdown of complex pesticide molecules into simpler inorganic compounds. The primary enzymes involved in the biotransformation of these pesticide molecules can be categorized into four main classes: hydrolases, translocases, oxidoreductases, and transferases (Fernandez-Lopez et al. 2017). These enzymes play crucial roles in driving the degradation process.

Conclusion

Microbial degradation of pesticides represents a promising and environmentally friendly approach to mitigate the harmful effects of pesticide pollution. By leveraging the natural metabolic abilities of microorganisms, we can break down toxic pesticides into less harmful or inert compounds, reducing their persistence in soil and water ecosystems. However, challenges such as incomplete degradation, formation of toxic by-products, and variability in degradation efficiency must be addressed through continued research. Advancements in biotechnology, particularly in microbial engineering and metagenomics, offer potential solutions to enhance the degradation process, making it a vital tool for sustainable agriculture and environmental protection.

IPM & ICT STRATEGIES TOREVITALIZE STRAWBERRY CULTIVATION IN NOAOTLA-III VILLAGE

A remote village nestled amidst the lush green hills, Noaotla-III was once grappling with a persistent threat to its strawberry crops. However, thanks to the innovative intervention of the Krishi Vigyan Kendra (KVK) and the power of technology, the village has witnessed a remarkable transformation in its agricultural practices.

Farmers in Noaotla-III village, Mizoram, have increased their strawberry production by using ICT to manage pests. Farmers are in direct contact with agricultural experts through WhatsApp and are taking care of their crops based on their advice. In this way, farmers are also being trained about expert systems, DSS, databases, Mobile Apps and other modern technologies so that they can more efficiently manage their crops at the difficult situations.More than 50% of the farmers cultivating strawberry in Noaotla-III village now have access to smart phone. Thus, reports on the performance of their crops could be directly updated to KVK through WhatsApp Group. Mobile Advisory Services have also reached the farmers in this village which is very useful for them in being able to take proper pest and disease management practices in appropriate time by getting direct advice from concerned Scientists from different fields.

A study was conducted in Noaotla-III village, Mizoram and the study highlights the successful implementation of Integrated Pest Management (IPM) techniques in Noaotla-III village, Mizoram, to combat insect pests affecting strawberry crops.

Farmers in Noaotla-III village, Mizoram, have increased their strawberry production by using ICT to manage pests.

KVK-Siaha introduced strawberry cultivation in 2010, and the positive results encouraged local farmers to adopt the practice. However, in 2017, a mass destruction of strawberry crops occurred due to root weevils and other minor pests. But the researchers at the KVK developed different modules to address the Pest problem. Through IPM and expert guidance, farmers have been able to manage pests effectively and sustain strawberry production in the region

Demonstration

Method Demonstration on soil treatment, seedling treatment and foliar application at Farmers' Fields started endend of July to beginning of August.2017. In most cases, 90% of the strawberry crop were already infested and damaged by root weevils. The average pest incidence of white grub was 15nos. white grubs per 10plants and 7nos. of root weevil per 10 plants. The average infestation percent of white grub was 68% and average in-

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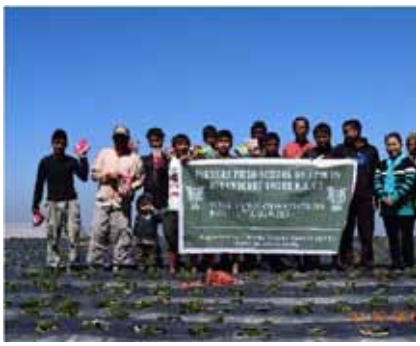

The modern, large-fruited strawberry emerged in Europe during the 18th century. Since then, various countries have developed their own cultivars tailored to specific climatic conditions, day lengths, altitudes, and production needs. Strawberries are cultivated for both fresh consumption and processing into frozen, canned, preserved, or juiced products. Due to their perishable nature and the challenges of mechanical harvesting, strawberry production is typically concentrated near consumption or processing centres with adequate labor. Hand-picking remains the primary method for harvesting strawberries.

festation percent of root weevil was 64%.

Whatever was left of the planting materials were collected and treated with Copper Oxychloride as seedling treatment @ 500g/200 litres of water per acre and soil treatment was done by Carbofuran 3G or Phorate 10 G @ 1.5kg a.i/ha. Later on, seedling treatment was again done by Mancozeb 75% WP @ 200-250g/100 litres of water. These treated planting materials were cultivated on a small scale for mother block in a new plot of land.

Crops like cabbage, green peas and onion were cultivated in these strawberry fields as crop rotation in the year 2019 – 2020. Mass cultivation of strawberry in the old fields started from June, 2021 onwards and is showing good results. Meanwhile, cultivation of strawberry still continues in new plot of land where pest infestation through soil is not heavy with proper IPM modules being conducted.

Mobile Advisory Services have also reached the farmers in this village which is very useful for them in being able to take proper pest and disease management practices in appropriate time by getting direct advice from concerned Scientists from different fields.

After a severe pest outbreak in 2017, KVK Siaha implemented IPM strategies to revitalize strawberry cultivation in Noaotla-III village. These strategies included soil and seedling treatments, as well as crop rotation to reduce pest populations. While the 2017-2018 season was used for soil solarisation and alternative crops, strawberry cultivation resumed in 2021 with promising results. By following IPM guidelines, farmers have successfully managed pests and maintained a consistent supply of strawberries.

The efforts of KVK Siaha and ICAR-NCIM have yieldedimpressive results. The strawberry crops in Noaotla-III have recovered from the pest infestation and are now thriving. Farmers are reaping the benefits of increased yields and higher incomes. The successful implementation of IPM technologies and the effective use of ICT have transformed this remote village into a model of sustainable agriculture.The KVK's initiative has not only saved the strawberry crop but has also paved the way for a brighter future for the village's farmers.

Technologies Demonstrated and Results:

Technology demonstrated	Demonstration Yield	Yield of Local Check	% of increase in yield	Gross cost (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	BC ratio
1. Soil treatment using Carbofuran 3G or Phorate 10 G @ 1.5kg a.i/ha)	60	51	17.64%	2,20,000	6,00,000	3,80,000	2.72
2. Treatment of planting materials with Copper Oxychloride as seedling treatment @ 500g/200 litres of water.							
3. Plant treatment by Mancozeb 75% WP @ 200-250g/100 litres of water							
Farmer's Practice (No IPM)				2,10,000	5,10,000	3,00,000	2.42

BIOE3 POLICY: 'THE BIOTECHNOLOGICAL ECONOMY AHEAD'

The union cabinet under the chairmanship of Prime Minister Narendra Modi approved the Biotechnology for Economy, Environment, and Employment Policy (BioE3) aimed towards 'Building High Performance Biomanufacturing' through with National mission of the Government of India including 'Net Zero' carbon economy and Mission LiFE (Lifestyle for environment). The policy was officially launched by S&T Minister Dr Jitendra Singh, while addressing the media he also said "BioE3 policy will be a landmark not only for bio economy but a disruptor for Viksit Bharat @2047".

BioE3 Policy

BioE3 (Biotechnology for Economy, Environment, and Employment) Policy is an initiative with an objective to lead biomanufacturing and biotechnology industry in the country of India. BioE3 policy is a step up from India's current biotechnology plan, aimed to capitalize on India's strengths in scientific human capital, biological resources, and growing economic prowess for a key global biotechnology player. This policy package aims at solving many national challenges at once: economic development, environmental protection, the food security challenge, the health challenge, and the challenge of employment.

It is expected that BioE3 policy will bring about revolutionary changes in food, energy and health sectors. Hence six themes have been identified and are provided as an overview of the policy, namely which are Bio-based chemicals and enzymes, Functional foods and Smart proteins, Precision biotherapeutics, Climate resilient agriculture, Carbon capture and its utilization and Futuristic marine and space research.

Sector wise Impacts

In the agriculture sector the policy aims at established genetically modified crop varieties that is resistant to climate change and that have high yields. This covers biotech crops that exhibit traits such as; drought resistance, pest resistance, and improved diet quality. As the means of decreasing chemical input in the agricultural system, the policy also extends the sale and utilization of biofertilizers and biopesticides. Precision agriculture is another important field due to the latest biotechnology-based sensors and diagnostics for soil and crops' health assessment in terms of diseases.

For healthcare, BioE3 emphasizes the development of affordable diagnostics and therapeutics, particularly for diseases prevalent in India. This would involve promoting the biosimilars to reduce healthcare costs, generation of new vaccines and exploration of traditional medicine through modern biotechnology. The policy also encourages

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genomics and proteomics research with a view to applying precision medicine, based on the genetic differences of the Indian population.

The policy in the industrial biotechnology sector fosters the use of bio-products as substitutes for products derived from petroleum. This comprises of bioplastics, bio-lubricants and the construction-based bio materials. Another thematic focus area is enzyme technology with its application in textile and Leather processing and food processing sectors. The policy also supports the application of biotechnology in waste and emission management, bioremediation, contaminated sites, as well as commercialization of biofuel processes.

One of the major areas defined by the BioE3 policy as a focus area of research is marine biotechnology which would involve programmes to prospect the extensive Indian coastline and marine species for new biologically active molecules of drug interest. The policy also seeks to develop the sustainable aquaculture and the new generation of mariculture products such as nutraceuticals.

Policy Particulars

In order to achieve such lofty objectives, more focused investments in infrastructure are planned and spelled out in the policy. This includes the setting up of one stop biotechnology park with necessary infrastructure for research and development and Pilot scale production. Biotechnology incubation centers are intended to promote biotechnology startups by offering them resources and mentorship. The policy also calls for establishment of regional biotechnology clusters, so as to facilitate biotechnology collaboration between universities, industry and the government.

Education and skill development are critical key drivers in the BioE3 strategy.

In the policy, special emphasis is placed on the issue of the regulation. It proposes streamlining approval processes for biotech products while ensuring safety and ethical considerations. This includes updating regulations to keep pace with emerging technologies like gene editing and establishing specialized committees for fast-track approvals of critical products. The policy also addresses the need for a robust intellectual property rights (IPR) regime, proposing measures to enhance patent filing from Indian institutions and companies.

BioE3 (Biotechnology for Economy, Environment, and Employment) Policy is an initiative with an objective to lead biomanufacturing and biotechnology industry in the country of India.

A significant aspect of the BioE3 policy is funding. It proposes more government support for biotechnology-related basic and applied research, with an emphasis on high-priority fields that are in line with domestic need. In order to encourage private investment in biotech R&D, the policy also suggests establishing venture capital firms with a biotechnology concentration and offering tax breaks. It also offers strategies for public-private cooperation to close the knowledge gap between laboratory research and finished goods.

The emphasis is on international cooperation as a way to boost India's biotech industry. The policy suggests bilateral and multilateral agreements for cooperative research initiatives, especially in fields in which India is not an expert. It also recommends strong involvement in international biotechnology projects and conferences, as well as student and researcher exchange programs with top biotech nations.

Vision

The BioE3 policy outlines a vision and challenging goals for the growth of India's bioeconomy. These are measurable outcomes that include more specific goals as to the intended contribution of the biotech sector to GDP, wider targets for biotech exports, and objectives for the generation of a set number of biotechnology start-ups and SMEs within a particular number of years. The policy also avows to align these goals with UN Sustainable Development Goals basically in the areas of food, health, energy and environment standards.

Public awareness and participation are yet another essential element of the policy. It suggests initiatives to raise public awareness of biotechnology and address genetically modified organism (GMO)-related issues by engaging stakeholders and maintaining open lines of communication. The strategy additionally endeavors to foster bio-entrepreneurship among young people by means of contests, mentorship initiatives, and early biotechnology exposure in educational settings.

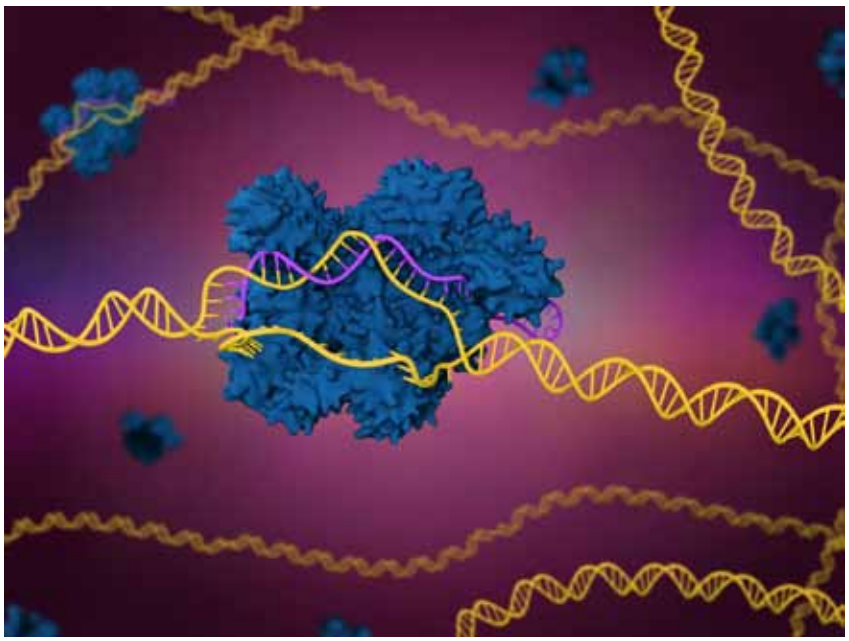
The BioE3 policy gives special consideration to rural development. It suggests creating biotechnology-specific solutions to address issues in rural areas, like affordable water purification systems, biogas plants to meet energy needs in rural areas, and cottage industries centered around biotechnology. Additionally, the policy highlights the use of biotechnology to enhance health and sanitation in rural areas, including the creation of point-of-care diagnostic instruments for rural health centres.

A concerted effort involving many government agencies, academic institutions, and business associations is suggested to implement the BioE3 policy. The policy recommends setting up a high-level steering group to supervise its execution, with periodic evaluations and modifications made in response to advancements and new developments in the field of biotechnology worldwide.

To sum up, the BioE3 policy is a thorough and ambitious plan to use biotechnology to further India's growth. Its success will rely on how well it is implemented, how long it is funded, and how well it can change with the quickly changing global biotechnology scene. Like any long-term program, its full effects might not become apparent for years, thus continuing evaluation and modification will be essential to achieving its objectives.

UNLEASHING THE POWER OF CRISPR/CAS9: THE GENE EDITING TOOL SHAPING OUR FUTURE

CRISPR-Cas9 technology is a highly effective gene-editing tool that has revolutionized the field of genome editing. This system originates from a bacterial immune mechanism and consists of two key components: clustered regularly interspaced short palindromic repeats (CRISPR) and the CRISPR-associated protein 9 (Cas9) nuclease. The CRISPR element contains short, repetitive DNA sequences interspersed with unique spacer sequences, which function as a record of previous viral infections. Cas9, an enzyme, acts like molecular scissors capable of cutting DNA strands. Together, CRISPR and Cas9 work in tandem to accurately target and alter specific DNA sequences (Richardson et al. 2023). The specificity of CRISPR-Cas9 technology is driven by the single guide RNA (sgRNA), which is designed to complement the target DNA sequence. The sgRNA guides Cas9 to the exact spot in the genome that requires editing. Once Cas9 reaches this location, it creates a double-stranded break in the DNA (Mingarro, and lídel Olmo, 2023). Besides CRISPR/Cas9



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GENESIS

CRISPR, which stands for clustered regularly interspaced short palindromic repeats, was first identified in the DNA sequences of Escherichia coli bacteria. This discovery was made by Ishino et al. in 1987 from Osaka University (Japan). CRISPR sequences were subsequently found in various bacteria and archaea, leading to hypotheses about their potential roles in DNA repair or gene regulation. A major breakthrough occurred in 2005 when it was observed that many spacer sequences in CRISPRs originate from plasmids and viruses. Additionally, researchers discovered that CRISPR loci are transcribed, and that cas (CRISPR-associated) genes encode proteins with presumed nuclease and helicase functions. This led to the proposal that the CRISPR-Cas system acts as an adaptive defense mechanism, using antisense RNAs as memory signatures of previous invasions. In 2010, the type II CRISPR-Cas system was shown to cut target DNA, and by 2011, it was discovered that type II CRISPR-Cas includes tracrRNA. Later in the same year, it was found that Cas9 is the only cas gene required for the type II defense function. Finally, in 2012, the CRISPR-Cas9 system was demonstrated to act as an RNA-guided DNA endonuclease (Doudna and Charpentier, 2014)The ability to accurately edit genomic sequences has vast applications in fields such as basic research, biotechnology, agriculture, and medicine. While various DNA-editing techniques were explored as early as the 1960s, it wasn't until 2012 that dependable, versatile, and efficient genome-editing technologies emerged. That year, Emmanuelle Charpentier and Jennifer Doudna published a groundbreaking paper on the CRISPR–Cas9 system. Highlighting the significance of their work, these groundbreaking discoveries earned them the 2020 Nobel Prize in Chemistry.

technology, there are other genome editing tools such as transcription activator-like effector nucleases (TALENs), zinc-finger nucleases (ZFNs), base editors (which modify single DNA bases without making double-strand breaks, allowing precise edits, such as changing A to G), and prime editing (a versatile tool that combines CRISPR and reverse transcriptase to precisely edit the genome without requiring double-strand breaks) (Gaj et al.2016).

Why Cas9?

Cas9 is a specific protein from the Type II CRISPR system in bacteria. It is named Cas9 because it was the ninth protein discovered in this family, specifically in *Streptococcus pyogenes*. There are many other Cas proteins, such as Cas1, Cas2, Cas3, Cas12, and Cas13, each with different roles in the CRISPR system. Cas9 is special because it is an RNA-guided endonuclease, a type of molecular "scissors" that cuts DNA at specific locations, making it a key tool for gene editing.

Application of CRISPR/Cas9 in various domains-

CRISPR-Cas9 technology in agriculture

CRISPR-Cas9 technology is widely used in agriculture to improve crops by enhancing traits like disease resistance, yield, and stress tolerance. It has been applied to rice to increase resistance against bacterial blight and holds promise for addressing food security challenges by creating crops resistant to pests and environmental stresses. Additionally, CRISPR-Cas9 offers the potential to produce nutritionally fortified crops, which could help fight malnutrition and promote better health.

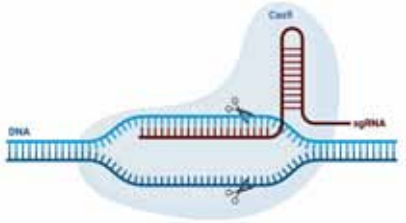


Figure 1: Components of the CRISPR-Cas9 system.

CRISPR-Cas9 technology is widely used in agriculture to improve crops by enhancing traits like disease resistance, yield, and stress tolerance

CRISPR-Cas9 technologies in healthcare

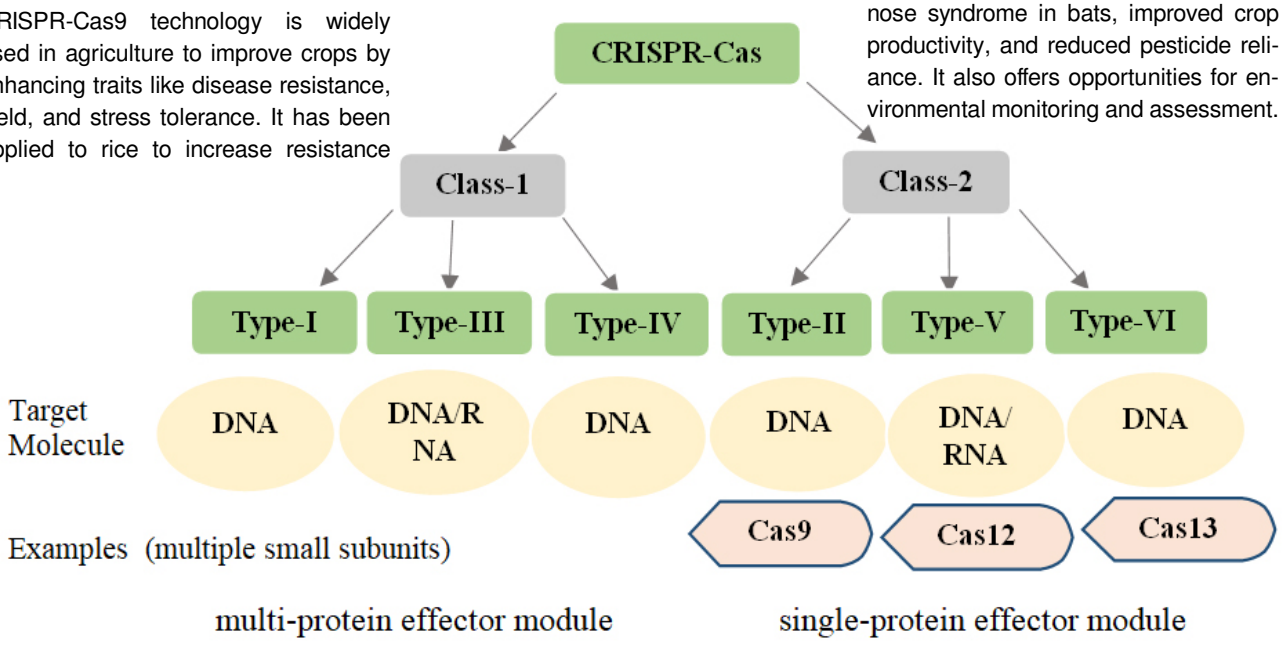
CRISPR-Cas9 technology is a valuable tool in medicine for studying gene function and disease mechanisms. It selectively modifies genes in human cells or model organisms, providing insights into genetic diseases. This technology also holds promise for gene therapies, allowing targeted disruption of genes or specific modifications to sensitize cancer cells to existing treatments.

CRISPR-Cas9 technologies in the medical sciences

CRISPR-Cas9 technology is being utilized in clinical sciences for therapeutic interventions and precision medicine, targeting genes like PCSK9 to lower cholesterol levels, treating genetic diseases, and editing CCR5 genes to confer HIV resistance. Researchers are also exploring CRISPR-based cancer therapies for selective cell elimination.

CRISPR-Cas9 technology in environmental sciences

CRISPR-Cas9 technology is being utilized in environmental sciences to tackle environmental issues and promote sustainable practices. It has successfully introduced genetic resistance to white-nose syndrome in bats, improved crop productivity, and reduced pesticide reliance. It also offers opportunities for environmental monitoring and assessment.



CRISPR-Cas9 in biotechnological

CRISPR-Cas9 has transformed biotechnology by enabling precise genome editing, gene regulation, and advancements in synthetic biology. It accelerates the development of GMOs with improved traits, allows detailed study of gene functions, and enhances the engineering of biological systems. CRISPR tools also improve crop quality by increasing stress tolerance and have streamlined the creation of animal models to study human diseases, aiding in disease research and therapy development.

Nanotechnology CRISPR-Cas9 system

CRISPR-Cas9 technology can be integrated with nanotechnology for targeted delivery, imaging, and sensing applications. This enhances genome editing efficiency, provides real-time imaging insights, and modulates gene expression, offering new avenues for disease treatment and fundamental biological research.

CRISPR-Cas9 technology in fisheries

CRISPR-Cas9 technology has the potential to improve aquaculture by enhancing fish health and introducing traits like disease resistance, faster growth, and stress tolerance in commercially important species. It can also help develop disease-resistant strains by targeting genes linked to infections.

CRISPR-Cas9 technology in machine learning and bioinformatics

The integration of CRISPR-Cas9 technology with bioinformatics and machine learning has enhanced genomic research by providing deeper insights into genome structure and function. Machine learning algorithms help predict off-target effects, improving the specificity and accuracy of gene modifications. This combination offers great potential for advancing genomic biology and personalized medicine.

The CRISPR-Cas9 technology's future directions

CRISPR-Cas9 has significantly impacted fields like agriculture, medicine, and biotechnology. Future research aims to improve precision and reduce off-target effects, while researchers are also developing RNA-targeting CRISPR systems for precise RNA editing, which could open new avenues for treating diseases. The technology shows great promise for therapeutic applications, including in genetic disorders and cancers. However, ethical and regulatory considerations are crucial, with frameworks being established to ensure its safe and responsible use.

In conclusion, CRISPR-Cas9 technology has transformed the landscape of genome editing, offering a highly effective method for precise gene modifications. Originating from a bacterial immune system, it employs the unique pairing of CRISPR and the Cas9 nuclease, guided by single guide RNA (sgRNA) to target specific DNA sequences. This innovative tool stands out among other genome editing methods, such as TALENs and ZFNs, due to its accuracy and versatility. With the potential to enhance various fields, including agriculture, medicine, and biotechnology, CRISPR-Cas9 and its associated systems represent a groundbreaking advancement in genetic research and application. Further exploration of its capabilities will pave the way for significant advancements in genomic biology and personalized medicine.

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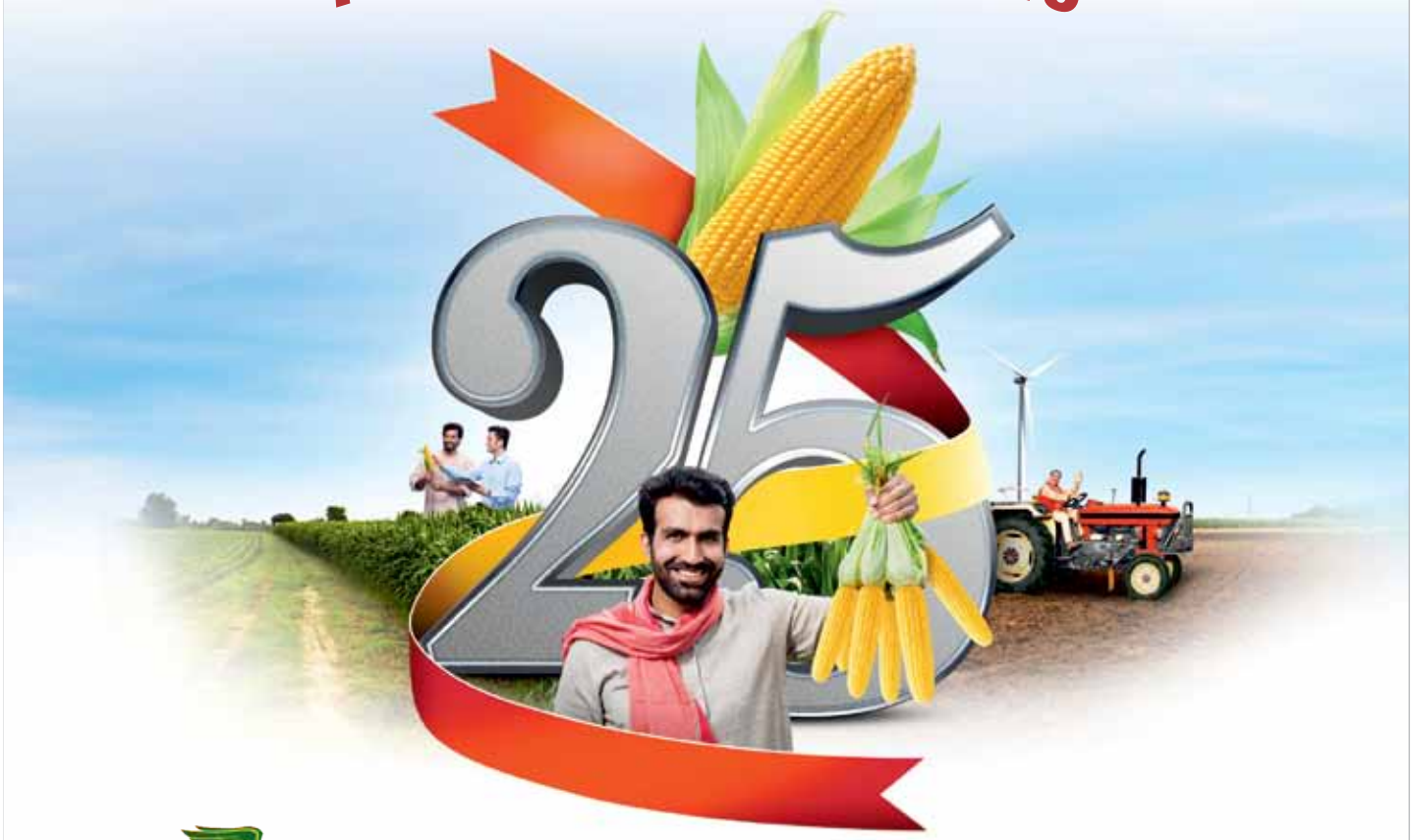

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