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FUTURE SMART FARMS
With Mechanization

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CONTENT

THE VISION

M C Dominic
Founder & Editor-in-Chief

Agricultural Prosperity for New India

Agriculture is the backbone of India's economy, supporting over 58% of the rural population and contributing significantly to the country's GDP. As India strives for economic growth and self-sufficiency, achieving agricultural prosperity becomes paramount.

To ensure sustainable agricultural development, it is essential to integrate modern technologies with traditional practices. Advancements in precision farming, biotechnology, and digital tools can enhance productivity and resource efficiency. For instance, the use of drones and IoT devices for monitoring crop health can help farmers make informed decisions, ultimately leading to higher yields and reduced waste.

Improving access to financial support mechanisms, credit and insurance can empower farmers to invest in better seeds, equipment, and practices. Government initiatives like the Pradhan Mantri Kisan Samman Nidhi and the PM Fasal Bima Yojana aim to provide financial security and support to farmers, enabling them to withstand market fluctuations and natural calamities.

Education and training play a crucial role in equipping farmers with the necessary skills and knowledge. Promoting agricultural education and extending outreach programs can help farmers adopt best practices and innovate. Collaboration with agricultural universities and research institutions can also facilitate the dissemination of new techniques and crops that are resilient to climate change.

Market access is another critical component of agricultural prosperity. Establishing direct linkages between farmers and consumers can help eliminate intermediaries, ensuring better prices for farmers and fresher produce for consumers. The promotion of farmer cooperatives can also enhance bargaining power and access to larger markets.

Agricultural prosperity in New India hinges on a multi-faceted approach that embraces technology, education, financial support, and market access. By fostering a more robust agricultural framework, India can secure food security, improve rural livelihoods, and contribute to the nation's overall economic growth.

End of Abridged Preview

FROM THE MD

Mechanization: The Success Mantra for Agriculture

Mechanization has emerged as a pivotal factor in transforming agriculture, driving efficiency and productivity. As the global population continues to grow, the demand for food increases, making it essential for farmers to adopt advanced technologies to meet these challenges.

One of the primary advantages of mechanization is the significant reduction in labour costs and time. Traditional farming methods often rely on manual labour, which can be both inefficient and unsustainable. By integrating machinery, farmers can streamline processes such as planting, harvesting, and processing, allowing them to cover larger areas in less time. For instance, the use of tractors, seed drills, and combine harvesters has revolutionized crop production, increasing yields while minimizing labour-intensive tasks. Additionally, mechanization enhances precision in farming. Modern equipment equipped with GPS and sensors enables farmers to apply fertilizers, pesticides, and water more accurately, reducing waste and environmental impact. This precision farming approach not only boosts productivity but also promotes sustainable agricultural practices, ensuring long-term soil health and resource conservation.

Mechanization can significantly improve the quality of produce. Machines designed for specific tasks often yield better results than manual methods, leading to uniformity and higher market value. As a result, farmers can achieve better returns on their investments.

The transition to mechanization requires addressing certain challenges, including the initial investment costs and the need for training. Government support, such as subsidies and training programs, is vital in helping farmers access modern machinery and learn how to use it effectively.

Mechanization stands as a cornerstone of agricultural success. By embracing technology, farmers can enhance productivity, reduce labor dependence, and contribute to food security. As India and the world face the pressures of increasing food demand, mechanization will be essential in paving the way for a more sustainable and prosperous agricultural future.

Shiny Dominic
Managing Director

EDITOR'S DESK

Future Smart Farms

Indian agriculture is undergoing a transformation with technological revolution, sprawling urbanization, modern cultivation techniques, and climate change. These changes offer unique challenges and opportunities to make agriculture smart, more productive, economically remunerative, socially equitable and environmentally sustainable through adoption of smart mechanization technologies. Smart agricultural machinery has the potential to resolve labor shortages, assist women farmers and the aging farm workforce and also attract youth to agriculture for the establishment of profitable business enterprises.

The future of smart farms with mechanization is poised to revolutionize agriculture, enhancing productivity, sustainability and efficiency. Here are some key aspects:

1. Precision Agriculture

- **Data-Driven Decisions:** Utilizing sensors, drones, and satellite imagery, farmers can monitor soil health, moisture levels, and crop conditions in real-time.
- **Variable Rate Technology:** Machinery can adjust inputs like water, fertilizers, and pesticides based on specific field conditions, reducing waste and costs.

2. Autonomous Machinery

- **Robots and Drones:** Automated systems for planting, harvesting, and monitoring crops can significantly reduce labor costs and increase efficiency.
- **Self-Driving Tractors:** These can operate around the clock, optimizing field work and improving productivity.

3. IoT and Connectivity

- **Smart Sensors:** Internet of Things (IoT) devices can track equipment performance and field conditions, enabling predictive maintenance and timely interventions.
- **Cloud Computing:** Data collected can be analyzed and stored in the cloud, providing farmers with valuable insights and long-term trends.

4. Sustainable Practices

- **Resource Efficiency:** Mechanization can optimize water usage and minimize chemical applications, promoting environmental sustainability.
- **Crop Rotation and Diversity:** Advanced machinery can facilitate diverse planting strategies that enhance soil health and reduce pest pressures.

5. Vertical and Indoor Farming• Controlled Environments: Mechanized systems in vertical farms allow for year-round production with minimal land use, reducing transportation costs and food miles.

- **Hydroponics and Aeroponics:** These methods, supported by automation, use less water and can produce higher yields than traditional farming.

The integration of mechanization in smart farming holds great promise for transforming agriculture into a more efficient and sustainable industry. By leveraging technology, farmers can increase yields, reduce environmental impact, and meet the growing global demand for food. This edition of Agriculture World attempts to brainstorm on Future Smart Farms with Mechanization By 2029 and reaching out to small farmers at the outermost socio-economic periphery.

Mamta Jain
Group Editor & CEO

Envisioning 2047

Agriculture as the Pillar of India's Journey to 'Viksit Bharat'

Mr Harish Chavan

Chief Executive Officer of Swaraj Tractors, Farm Equipment Sector (FES) of Mahindra & Mahindra Ltd. He also serves on the board of Swaraj Engines Ltd & provides oversight to the business. He is also Vice President of Tractor Manufacturers Association (TMA).

Mr Chavan was earlier Chief of International Operations, FES of Mahindra & Mahindra Ltd. & served as President & CEO of M&M's China operations for more than five years. He was awarded the prestigious Lushan Friendship Award by Jiangxi province of China.

Mr Chavan has been conferred with 'Business Leader of the Year 2023' award by Times Group.

> *Achieving the vision of Viksit Bharat by 2047 is possible, but it requires bold actions today. Together, we can transform Indian agriculture into a global powerhouse*

Imagine the year 2047, when India has realized its vision of "Viksit Bharat" – a developed and prosperous nation. Picture rural India, transformed with higher incomes, improved infrastructure, and better living standards. Farmers seamlessly access markets and technology, enhancing their productivity and income. Roads, healthcare, and educational facilities in rural areas are now on par with urban centres.

Agriculture will play a key role in achieving this vision. As a vital contributor to our GDP, it is central to India's economic future. India is already among the top two countries globally in terms of Agri-GDP, surpassing the USA and slightly behind China. To truly make agriculture the bedrock of "Viksit Bharat," we need to shift our focus from mere food sufficiency to becoming the food basket of the world. This shift requires fostering innovation in sustainable agricultural practices, diversifying into high-value crops, and modernizing infrastructure.

Achieving this vision by 2047 requires setting ambitious yet achievable targets. India must enhance food production and close the 30-50% yield gap in key crops like wheat, rice, pulses, and oilseeds, while also expanding the production of high-value commodities such as fruits, vegetables, dairy, and poultry. Promoting sustainable farming practices, including organic agriculture, natural farming, and precision farming, on at least 30% of cultivated land is critical to reducing the environmental impact.

The Focus Areas

Additionally, achieving 100% coverage of efficient irrigation techniques like drip and sprinkler systems will optimize water use. Improving soil health by increasing the organic carbon content to 0.7-1% through balanced fertilization and crop residue management will be essential. To further strengthen agriculture's contribution to the economy, India must boost processed and value-added agricultural exports from 14% to 25% and double farmers' incomes through improved productivity and market access.

While India has made significant progress, from the Green Revolution to the Golden Revolution and advanced mechanization, new challenges have emerged. Two of the most pressing are climate change and the decreasing interest of youth in agriculture. Climate change has increasingly affected agricultural output, with reports of crop damage due to excess rainfall, drought, and heatwaves becoming more frequent. Meanwhile, urbanization and the growth of the manufacturing and service sectors are drawing rural populations away from agriculture.

The Common Solution

Both challenges share a common solution: adoption of innovative technologies to mechanize agriculture. We will have to shift focus towards Sustainable, Climate-smart agriculture, that will lead to efficient water use and soil health restoration. Precision agriculture will drive this transformation, with farmers relying on data analytics, IoT devices, and drones to monitor crop conditions, enabling better resource allocation. Automated irrigation systems based on real-time data will ensure optimal moisture levels, helping address water scarcity.

Enhancing crop management through the adoption of pest-resistant hybrid seeds will lead to higher yields, while integrated pest management (IPM) will minimize environmental impact. Improved market access, supported by digital platforms and strengthened Farmer Producer Organizations (FPOs), will empower farmers to secure better prices, reducing reliance on middlemen.

Technological integration will further enhance productivity, with AI-driven technologies assisting in predicting crop health, optimizing planting schedules, and managing resources efficiently. Sensor networks will provide real-time information on nutrient levels and environmental conditions, allowing farmers to make precise interventions and reduce waste.

The Role Of Mechanization

To achieve these targets, mechanization of the entire crop value chain will be crucial in revolutionizing agriculture. However, the success of this transformation will heavily depend on robust government policies that support and facilitate these advancements.

Restructuring agricultural subsidies will involve aligning them with resource conservation and rewarding outcomes such as total farm productivity and enhanced ecosystem services, rather than focusing solely on yields. Strengthening extension services is crucial to effectively disseminate knowledge on sustainable farming practices, with industry partnerships playing a key role in supporting these efforts. Improving infrastructure and market access is equally important, requiring the development of storage, processing, and marketing facilities for sustainable agricultural produce. Additionally, promoting contract farming and supporting Farmer Producer Organizations (FPOs) will enhance market linkages and improve price realization for farmers.

Supporting evidence generation and monitoring will involve integrating data collection on sustainable agricultural practices into national and state-level agriculture data systems, ensuring these practices are more visible and measurable. Collaboration across the agriculture ecosystem is vital, encouraging partnerships among civil society organizations, research institutions, and the private sector to further promote sustainable agriculture.

Achieving the vision of Viksit Bharat by 2047 is possible, but it requires bold actions today. By uniting policymakers, farmers, and industry leaders, India can prioritize sustainable farming, invest in advanced technologies, and empower the next generation of agricultural entrepreneurs. Together, we can transform Indian agriculture into a global powerhouse.

Emerging Technologies in Farm Mechanization

Dr. Syed Ismail
is an Agricultural Engineering professional working on Electronics & Technology in Agriculture and Industry. He is the Secretary General of 'Asian Association for Agricultural Engineering' and works to bring together the Scientists, Academia and Industry experts in Asian Agriculture in order to achieve common goals

With advancements in ML/AI models, it would be useful to plan a model of 'sharing server' at village level that can use local networks at village level

From the start of green revolution that promoted irrigation pumps, tractors and threshers, India's wheat and rice mechanization has largely improved land preparation, planting and harvest. However, in the next 5 years we expect to modernize our food storage and distribution system that can reduce the current wastages of 24%. Government policies, public private partnership need to be enhanced with inputs from scientific community.

Farm Mechanization instead of Tractorization

'Tractorization' as a measure of 'Agricultural Mechanization in India' is fast changing with India reaching the optimum and sustainable level of one tractor per 10 Ha. In 2022-23, we had a population of 97.3 lakh tractors with 2.8 Kw/Ha farm power availability (which was 0.3Kw/ha in 1961-62). With one tractor per 14 Ha in 2023, we shall reach the saturation limit within next five years considering the affordability of small and marginal farmers as well as the trend towards less tillage and alternate farm transport systems.

Farm mechanization for non-cereal crops like cotton, jute, sugarcane, soyabean, millets, fruits -vegetables, animal -fish- poultry, tea-coffee-spices are yet to see the horizon and initiatives should be laid down during next 5 years.

Collaborative Framework for Agricultural Research

As Indian farmers are exposed to food quality, climate change, soil health and labour availability, the research institutions must form a framework for addressing mechanization of each crop cultivation with sustainable technologies. For example, in sugarcane cultivation we have to work on planting and spacing technologies to make mechanization feasible. In cotton, the spacing and varieties should facilitate machine harvesting – against currently practiced multiple picking.

It is necessary that the research institutes as well the extension agencies stop working in 'silos' and address the farmers needs and challenges collaboratively. Restructuring of these initiatives requires involving middle level Researchers, Industry and NGOs. The academia also needs to interact with Industry and Farmers to frame their syllabus based on Farmers 'pull' needs.

Digital Agriculture

India has started 'Digital Agriculture' mission that aims at a farmer centric digital public infrastructure (DPI) of both central and state governments. 'Agri Stack' that provides an Identification card to each farm is a very useful initiative. The mission also emphasises on soil profile mapping and geo spatial data for weather, crop production estimation, calamities and farm insurance.

Agricultural drones are promoted for more than 5 years. The adaptability by marginal farmers is a challenge even in rental model as the spraying with drones require canopy cover (for pesticides), financial viability and equipment usage. There are other challenges like variable nozzle design, long flying time and higher load capacity that can be addressed by Aviation Engineers, Agronomists, plant pathologists and chemical Industry. Drones are not expected to assist small and marginal farmers effectively/economically during the next five years.

Weeding is a major challenge in agriculture, and we still consider wide spread use of 'herbicides. The advanced technologies in weeding tools and robotics will see a thrust in the research during next five years. Non-chemical interventions in weeding are the most suitable solution and the technology at the doorstep to be implemented.

ML and AI

Modern technologies in Agriculture are the need of the hour. The 'hype' words we hear on Big Data, Machine learning (ML) and Artificial Intelligence (AI) in agriculture depend on the 'dataset' which is the basis. For example, in yield prediction of cereals we need data over period of time on inputs, weather, soil and environment with yield for each crop. For disease detection we need images, videos of infected plants, insects, soil and environmental data.

We know that we have used more than 90% of existing languages words, text, articles and vocabulary in testing the large language models (LLM), that we use in AI applications in search for solutions to topics of interest and translation. Recently more emphasis is given on 'ChatGPT' like transformer models to assist in searching research articles, past experiences and prediction of future trends.

However, similar implementation in classification, recognition, logical regression models in Agriculture need datasets. India having most agricultural land with wide range of crop, soil and environmental conditions besides the largest research and student population has to make a frame work for creating such 'dataset'. There are few agencies that sell such data but lacks in volume and accuracy of data. Indian Government with help of its research institutions and available public awareness in digital communication must create a repository for such 'dataset'. Though it may be argued on proprietary values, the benefits far outweigh the drawbacks. Farmers and students with smart phones are a very important resource for this 'dataset' generation.

The use of ML/AI will be seen in plant health, disease identification, yield estimation, spraying, weeding besides grading and sorting during the next five years. The irrigation models need IOT to be implemented for resource measurement and control of valves. We need to train our scientists and students in the modern technologies with highest priority.

Training existing models in Agricultural applications need to train on basic data collection, cleaning sorting as well logical and predictive intuitions in selecting algorithms. The success of model depends on domain expertise and inference of the outcome. A data scientist alone cannot apply the models effectively without the help of agricultural professionals. Current leadership in Scientific community has to realize the need for this and act soon.

Framework for Farm Communication

For implementing Farm IOT in irrigation/ fertigation control, location systems for precision agriculture, tracking assets and resource level (like well water level), we have to plan a sustainable 'farm communication' system. Village level farm communication system based on multiple technologies like Long Range (LORA), Narrow band IOT (NBIOT) and Non-Territorial Network (NTN) would offer a low-cost solution for Agricultural IOT.

With advancements in ML/AI models, it would be useful to plan a model of 'sharing server' at village level that can use local networks at village level. It would not be economically viable for farmers to use cell phone towers for each device they use in farm. This facility can also introduce weather stations at village level. It is important that the government and research institution heads have vision to look at long term farm needs in communication and take initiatives in the next 2-3 years.

Low hanging Farm Mechanization Possibilities

Modern Storage - logistics for cereals: 3-5 years
Climate controlled short-term storage - logistics for fruits and vegetables: 5-8 years
Restructuring Agricultural research Institutions: 2-4 years
Non cereal crop mechanization: 3-8 years
Improved water - nutrient application (irrigation control, rootzone, AWD): 3-5 years
Precision location systems planters - fertilizer spreaders: 3-5 years
Robot weeders: 3-5 years
Spraying systems with laser/ camera: 3-5 years
IOT in farm Resource information: 3-4 years
Automatic climate control systems for polyhouses: 2-3 years
Machine learning/ AI Application in yield estimation, diseases, sorting/ grading fruits and vegetables, warehouse inventory management : 2-4 years

It is imperative for Agricultural Research Institutes, Administrators, Academia and Industry to collaborate during this critical period 2024-29 to harness emerging technologies in making India the 'Global Food Bowl'.

Agri Mech

Future Smart Farms and Farm Mechanization

> Drone Didi project of GOI is a right step in this direction. The combination of technologies will empower farmers to make data-driven decisions that improve crop yields and reduce environmental impact

Mr Bharatendu Kapoor
has been President- Sales & Marketing of the TAFE Group as for past seven years. An agricultural engineer by profession, has close to 4 decades of experience in rural marketing. He has worked on different projects that involved close interaction with rural customers, farmers and other stakeholders who have presence into rural markets

India, with its vast agricultural landscape, is at a pivotal point in its journey toward modernization & productivity improvement. As the nation grapples with the challenges of feeding a rapidly growing population, the adoption of frugal farming technologies and advanced mechanization affordable for small farms is becoming increasingly critical. By 2029, India's agricultural sector is expected to undergo significant transformations, driven by the integration of technology, data analytics, and sustainable practices. The future of Indian agriculture will likely be characterized by the widespread adoption of smart farms, where precision farming, automation, and advanced mechanization play central roles in enhancing productivity, reducing environmental impact, and ensuring food security.

The Rise of Smart Farms

Smart farming, also known as precision agriculture, leverages technology to optimize agricultural practices, making farming more efficient and sustainable. By 2029, smart farms in India are expected to become prevalent in select pockets where land holding is > 8 acres, supported by advancements in Internet of Things (IoT), Artificial Intelligence (AI), machine learning, and big data analytics. These technologies will enable farmers to monitor and manage their crops and livestock in real time, leading to better decision-making and resource management.

IoT and Sensors: IoT devices and sensors will play a crucial role in smart farms, providing farmers with real-time data on soil health, weather conditions, crop growth, and pest infestations. By analysing this data, farmers can make informed decisions about irrigation, fertilization, and pest control, leading to more efficient use of resources and higher yields. For instance, soil moisture sensors can help farmers optimize water usage, reducing wastage and ensuring that crops receive the right amount of water at the right time.

AI and Machine Learning: We're beginners in this area. While AI and machine learning algorithms will be integral to the future of smart farming in India, this may take another decade. Use of these technologies can analyse vast amounts of data from various sources, such as weather patterns, market trends, and crop performance, to predict outcomes and suggest optimal farming practices. AI-driven tools will certainly help farmers forecast weather conditions, predict pest outbreaks, and determine the best time for planting and harvesting, thereby minimizing risks and maximizing productivity. Extension education driven by pilot projects funded by Govt. of India will be good beginning & we're witnessing some steps from budgetary allocation point of view in this direction.

Drones and Satellite Imaging

Drone Didi project of GOI is a right step in this direction. While at very nascent stage, Drones equipped with high-resolution cameras and sensors will be used for aerial surveys, allowing farmers to monitor crop health and detect issues such as nutrient deficiencies, pest infestations, and water stress. Satellite imaging will complement drone technology by providing broader coverage and enabling farmers to track changes in their fields over time. This combination of technologies will empower farmers to make data-driven decisions that improve crop yields and reduce environmental impact.

Farm Mechanization: The Next Frontier

Farm mechanization refers to the use of machinery and equipment in agricultural operations to reduce labor and enhance efficiency. In India, farm mechanization has traditionally been limited, particularly in small and marginal farms. However, by 2029, the landscape is expected to change dramatically as more farmers embrace mechanization to cope with labor shortages, increase productivity, and reduce drudgery. This will pick pace, as we see consolidation of agricultural lands, wherein many farmers are moving out of agriculture for different reasons & leasing out their land to farmers interested in farming, a trend very much visible.

Tractors and Machinery

The adoption of tractors and other farm machinery is expected to increase significantly by 2029. Technology is available & being piloted by OEM's, however farmers are yet to see benefits. The government's push for farm mechanization, coupled with the availability of affordable and efficient machinery, will encourage more farmers to mechanize their operations. Tractors equipped with GPS and automated systems will enable precision farming, allowing farmers to plant, till, and harvest with greater accuracy and efficiency.

Automation and Robotics: The future of farm mechanization in India will likely see the rise of automation and robotics. This trend will also be visible with increase in consolidation of farming lands. Automated machinery, such as robotic harvesters, planters, and weeders, will reduce the need for manual labor and increase operational efficiency. These machines will be equipped with advanced sensors and AI to navigate fields, perform tasks with precision, and adapt to varying conditions. For example, robotic harvesters can identify ripe crops and harvest them without damaging the plants, ensuring higher quality and reduced wastage.

Custom Hiring Centers: Push for FPO's by Govt. has been there for last few years. To make mechanization accessible to small and marginal farmers, custom hiring centers (CHCs) will become more widespread by 2029. These centers will provide farmers with access to modern machinery and equipment on a rental basis, allowing them to benefit from mechanization without the need for large capital investments. CHCs will play a crucial role in bridging the gap between small-scale farmers and advanced agricultural technology, promoting inclusive growth in the sector. Recent study conducted by TMA shows most FPO's running in losses except few where farmer himself is an entrepreneur & lose ends still need fixing.

Challenges and Solutions

Despite the promising outlook, several challenges need to be addressed to fully realize the potential of smart farms and farm mechanization in India by 2029.

Cost and Affordability: The high cost of smart farming technologies and advanced machinery is a significant barrier for many Indian farmers, particularly small and marginal ones. To overcome this, the government and private sector need to work together to develop affordable solutions and provide subsidies or financial assistance to farmers. Public-private partnerships (PPPs) and innovative financing models, such as microloans and leasing arrangements, can also help make these technologies more accessible. One way formation of policy formation wont yield results & there's a strong need to involve stake holders that's farmers for efficient deployment.

Infrastructure and Connectivity: The success of smart farms depends on reliable infrastructure and connectivity. Many rural areas in India still lack access to high-speed internet and electricity, which are essential for the functioning of IoT devices and automated machinery. Investments in rural infrastructure, such as expanding internet connectivity and improving power supply, will be critical to the adoption of smart farming practices.

Education and Training: Existing infrastructure at KVK's need to be strengthened & there's a need to make KVK officials accountable on deployment of new practices & technology. The transition to smart farms and mechanization requires a skilled workforce that is proficient in using advanced technologies. Training programs and capacity-building initiatives will be essential to equip farmers with the knowledge and skills needed to operate and maintain modern machinery and technologies. KVK's , Extension services and agricultural education institutions will play a key role in disseminating knowledge and best practices to farmers & Private Public Partnership (PPP), in this area need to be worked out with clear time bound outcomes.

Role of Agricultural Universities & Agricultural Engineering Colleges: Govt. of India, need to revisit the course content in Agricultural Engineering Colleges. Graduates coming out of these colleges need to have a very different exposure wrt what they're going thru today. Change in content, pilot deployments within colleges, inter-college competitions on future of farming technology based on real outcomes will enhance the skills.

Poised For Transformation

By 2029, India's agricultural sector is poised to undergo a significant transformation, driven by the adoption of smart farming technologies and advanced mechanization. The future of Indian agriculture will be characterized by greater efficiency, sustainability, and resilience, as farmers leverage technology to overcome challenges and maximize productivity. However, realizing this vision will require concerted efforts from the government, private sector, and farming communities to address the challenges of cost, infrastructure, and education. With the right strategies in place, India can build a robust and sustainable agricultural system that ensures food security and prosperity for its people.

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Research Key to Agricultural Transformation

The Economic Survey 2024 and the subsequent budget speech by the finance minister highlighted the need to increase agricultural research. It is no secret that the key to meeting multiple challenges of Indian agriculture is research. Science and technology provide the answers to the challenges, especially climate change, depletion of natural resources and yield stagnation.

A recently published Policy Paper No.44 by ICAR-National Institute of Agricultural Economics & Policy Research titled "Pay Offs to investment in agricultural research and extension in India" has concluded that every rupee spent in agricultural research pays back Rs. 13.85 and every rupee spent on research into animal science pays back Rs.20.81. This data shows how agricultural research has a major impact on the economy.

The same report shows that we are underinvested in agricultural R &D with only 0.61% of agricultural GDP being invested in research against a global average of 0.93% and 1 to 5% in developed countries. There is an urgent need to step up agricultural research to a minimum of 1% of Agricultural GDP if not more out of which at least 25% should be on animal science research. This means that the total research investment in agriculture should go up to Rs. 45,000 cr compared to the present level of about Rs. 18000 - 20,000 cr per annum (Figure 3.1 of the policy paper). This is a huge jump which cannot be funded by public institutions only.

Setting The Right Agenda For Agricultural Research

Research has to focus on building climate resilience in our agriculture as the highest priority. High temperatures and weather vagaries caused by climate change are the biggest challenge, the humankind is facing which has a potential to reduce yields of crops like wheat by a huge margin as we have seen in recent years. This is the biggest threat to our food and nutrition security, which should not be taken lightly.

Research has to cover seed development, biotechnology, crop protection products, plant nutrition products, agricultural machinery, agronomic practices that can save soil and water, biological products, fighting new pests and diseases and others which can be synergistic with micro irrigation, mechanization, digitization and other modern mega trends that are having an overwhelming influence.

It is important to be at the cutting edge of technology in seeds, crop protection, crop nutrition and mechanization if our farmers have to be competitive in the international markets. Sustainable production is under sharp focus globally and already sustainable production and supply chains are becoming competitive advantages in export markets. The challenge is to produce sustainably and yet economically.

Role of Private Sector

As mentioned by the finance minister in her budget speech recently, private sector has a critical role to play in enhancing the research investments. The above policy paper established that only 8% of agri research investment is from private. This has to increase to 20% in the medium term.

Government policy must recognize private players who are investing in high quality research and incentivize such investments if they are in priority areas. Such priority areas of investment must be discussed thoroughly and published by the government so that the industry has clear directions.

Private investments would improve with a better protection of intellectual property, recognition and encouragement for those who invest, predictable and supportive regulatory policy environment, especially for biotechnology and ease of doing business across states and nations. Globally available technologies with safer crop protection products, modern crop nutrition products, biotechnology traits and others can be brought to India through collaborations by private industry with outside players and institutions. Many Indian companies are interested in enhancing investments in this space. A strategic approach is to be taken in this area by the government.

Role of PPP

Public Private Partnership (PPP) is essential to leverage the strengths of both for the benefit of the farmer. The task that agricultural research faces, as described above, is too huge for one sector to handle. Public and private organizations must come together for this monumental task.

It is important for the two to trust each other. They must collaborate instead of competing. The above-mentioned policy paper says that private investment in research does not crowd out public investments. That means both can work together without fear.

The Role Of Public Institutions

Public institutions have huge strengths like large germplasm base in many crops, infrastructure and manpower. However, their market knowledge and demand driven research are limited because they do not deal with the market. On the other hand, the private sector too has good germplasm in certain crops, very good research infrastructure and highly qualified manpower but their main strength is their market knowledge. If these are brought together in well-structured and clearly laid out contours of collaboration it would produce excellent results. The public institutions will be able to enhance their income through such collaborations.

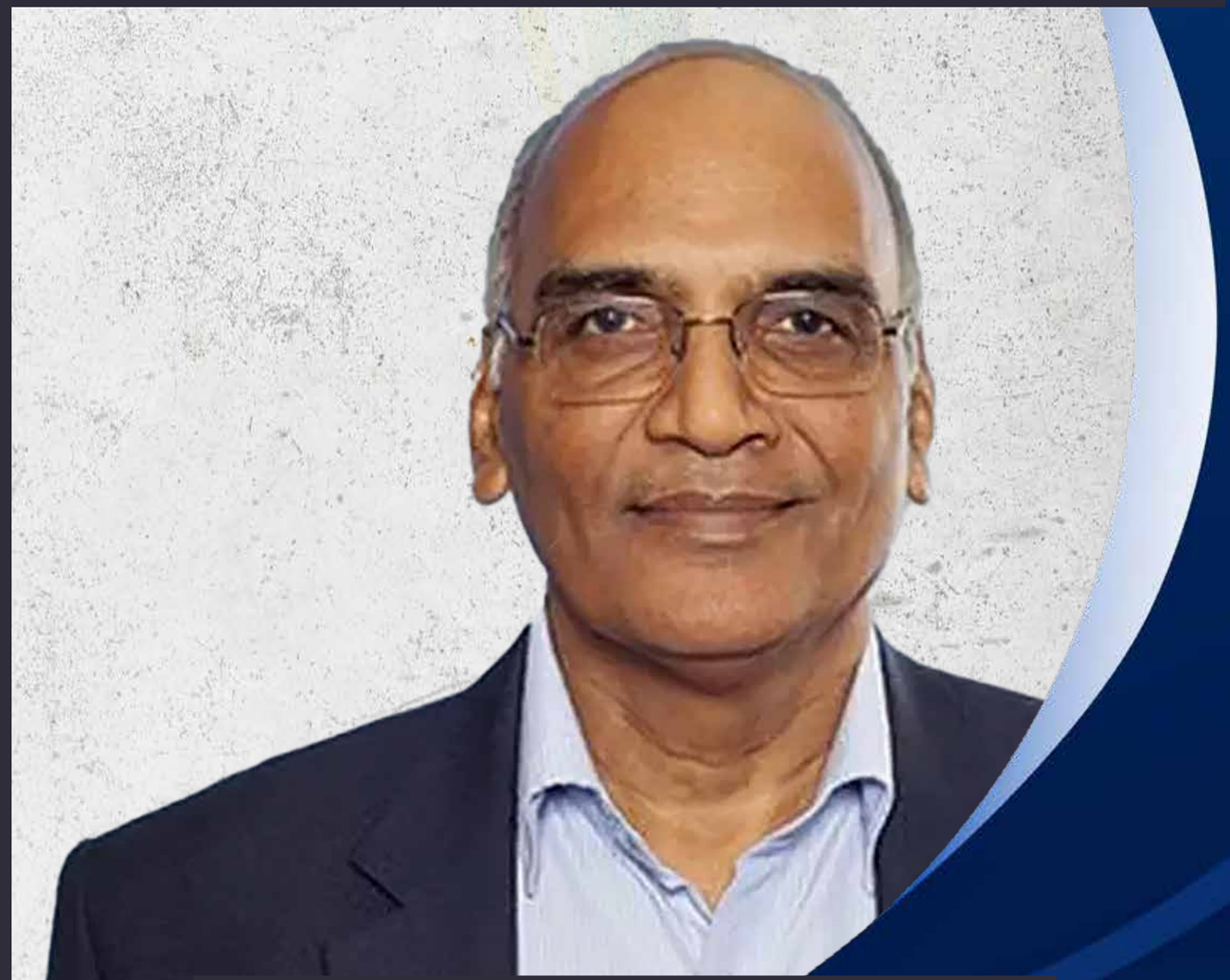
PPP should focus on high priority crops like pulses and oilseeds, agronomic practices like Direct Sown Rice and Minimum Tillage, fighting new pests and diseases like Pink Bollworm and Fall Army Worm and technology projects like biotech-based weed management tools, yield enhancing tools, climate resilient crops, etc.

Need To Strive For Common Objectives

Business as usual will not transform our agriculture. Agri R&D strategy for the country has to be thought through and implemented urgently. Private sector has a huge role to play in this transformation. Public-private collaboration is the key to make this a success. Our common objective is to fight climate change, conserve natural resources, increase yields and make our farmers globally competitive.

Views expressed are personal

"Government policy must recognize private players who are investing in high quality research and incentivize such investments if they are in priority areas



Mr Ram Kaundinya
Adviser to Federation of Seed Industry of India

Highway To Mechanization

Dr C R Mehta
is Director

Dr Bikram Jyoti
Scientist at ICAR-Central Institute of Agricultural Engineering, Bhopal

> Government initiatives like Digital India and agricultural extension services shall play a crucial role in addressing farm challenges

India, as an agrarian economy, faces numerous challenges in ensuring food security, tackling the climate crisis, and improving farmer livelihoods. India is the second-largest agricultural producer globally, but its sector still heavily relies on traditional methods. Traditional farming methods are becoming unsustainable due to the rising demand for food and the pressure of environmental degradation. According to a 2022 report by the Food and Agriculture Organization (FAO), over 50% of India's workforce is engaged in agriculture, contributing around 18% to the national GDP.

However, the sector struggles with inefficient practices, fragmented landholdings, low mechanization levels (only 47% mechanization, compared to over 90% in countries like the U.S.), unpredictable weather conditions, and soil degradation. The Indian government's commitment to doubling farmers' income by 2022 underscored the need for systemic changes in the sector. Mechanization and smart technologies are seen as catalysts in this transformation, aimed at addressing challenges like labour shortages, productivity gaps, and environmental concerns. As of 2023, smart farming remains in its infancy, but the country's agritech ecosystem is evolving rapidly, setting the stage for an agrarian revolution. With the convergence of mechanization, IoT, artificial intelligence (AI), robotics, and big data, the future of Indian farming is poised for a radical transformation by 2029.

Mechanization and Smart Farming Technologies: Key Drivers for Change

By 2029, the Indian agricultural landscape will see the rise of fully integrated smart farms leveraging advanced mechanization. Several key technologies will shape this transformation:

IoT sensors, deployed across large farmlands, will allow for real-time monitoring of soil moisture, nutrient levels, and climatic conditions. These sensors provide critical data, enabling farmers to optimize water usage, fertilization, and pest control measures. The real-time feedback loop will empower farmers with actionable insights, ensuring precision agriculture practices are followed.

In 2023, an estimated 3-5% of Indian farms adopted IoT solutions, but this is expected to grow exponentially by 2029, driven by decreasing cost of IoT devices and government-backed initiatives such as the National Agriculture Market (eNAM) platform.

The ability to monitor farm conditions remotely will reduce the need for manual intervention, which has become a challenge due to labor shortages. In the future, Indian farms will be populated by semi-autonomous robots performing tasks such as planting, weeding, and harvesting. Drones will also become a staple for farm management.

Drone-Assisted Precision Agriculture

By 2029, drone-assisted precision agriculture will be common for crop surveillance, disease monitoring, and pesticide spraying. A 2023 report by FICCI estimated that the Indian agri-drones market could grow to $1 billion by 2025, driven by falling drone prices and regulatory support. Pradhan Mantri Fasal Bima Yojana (PMFBY) has already incorporated drones for crop insurance assessment, and by 2029, drones will perform real-time, large-scale monitoring of fields, boosting productivity.

Agricultural Robots

Agricultural robots, already in early stages of implementation in some developed nations, will be adapted for Indian conditions. Companies like TartanSense and Kheti Buddy are leading the way by developing affordable and scalable robotic solutions for small and marginal farmers.

AI and ML

AI and machine learning will power the decision-making processes on Indian farms. These technologies will help farmers make data-driven decisions regarding crop cycles, pest management, and irrigation schedules. AI-driven predictive analytics will allow farmers to anticipate weather changes, optimize input use, and manage resources efficiently.

By 2029, AI platforms like Plantix and Crofarm will offer integrated solutions that analyse farm data and provide farmers with personalized recommendations, from seed selection to harvest timing. AI will also play a key role in developing climate-resilient crops, an essential requirement given India's vulnerability to climate change. Increased mechanization will address labour shortages and improve productivity. While tractors and plows are already common, the next generation of automated farm equipment will perform tasks with higher efficiency. Automated precision seeding, irrigation systems, and mechanized harvesting equipment will drastically reduce manual labour, leading to higher yields. Farm equipment manufacturers like Mahindra & Mahindra and John Deere are expected to launch affordable and scalable automated solutions that cater to the specific needs of Indian farmers.

Focus On Sustainability

By 2029, smart farms in India will prioritize not only productivity but also sustainability, with various mechanisms ensuring that environmental considerations are integral to agricultural transformation. Water conservation will be a key focus, as agriculture accounts for nearly 70% of India's water consumption, posing a severe challenge in a water-scarce nation.

Smart irrigation systems, leveraging IoT sensors and AI algorithms, will optimize water use by monitoring real-time soil moisture levels. Technologies like drip irrigation, combined with these insights, are expected to reduce water usage by 50-60%, addressing the country's water crisis. Government initiatives, such as the "Per Drop More Crop" scheme under PM-Kisan, have already laid the groundwork for widespread adoption of precision irrigation practices. Climate-resilient farming will also play a critical role, given India's vulnerability to climate change.

Low-Carbon Farming Practices

Additionally, Indian farms will focus on reducing their carbon footprint by adopting low-carbon farming practices. While mechanization can lead to higher greenhouse gas emissions, renewable energy solutions such as solar-powered machinery and biogas plants will help mitigate this. The government's KUSUM scheme, which promotes solar energy in agriculture, is expected to significantly lower the carbon emissions associated with farm operations. Soil health will also be a priority in smart farming.

With over 120 million hectares of land suffering from erosion and nutrient depletion, smart farms will utilize soil health monitoring systems to continuously track key parameters such as soil pH, nutrient content, and organic matter levels. AI-driven insights will guide farmers in applying fertilizers more efficiently, reducing chemical overuse and promoting healthier, more sustainable soil management practices. By integrating these mechanisms, smart farms will enhance both agricultural productivity and environmental sustainability.

Challenges to the Adoption of Smart Farming

While the future of smart farming in India holds great promise, several challenges could impede its widespread adoption. One of the major hurdles is the high initial cost of advanced machinery, IoT devices, and AI platforms. Although these technologies offer substantial long-term savings, the upfront investment can be prohibitive, particularly for smallholder farmers who make up 86% of the farming population. Another significant challenge is the lack of digital literacy among many farmers, especially those in rural areas. This gap in knowledge makes it difficult for them to effectively utilize smart farming technologies.

However, government initiatives like Digital India and agricultural extension services are expected to play a crucial role in addressing this issue by 2029. Infrastructure is another critical factor that must be improved for the success of smart farming. Reliable internet access and a stable power supply are essential, and while the government's push for rural electrification and digital connectivity through the BharatNet initiative is a positive step, more progress is needed to ensure adequate infrastructure across all farming regions. Regulatory hurdles also pose a challenge, as the adoption of new technologies often encounters issues such as drone usage regulations, data privacy concerns, and land use policies. To overcome these obstacles, collaborative efforts between the government, the private sector, and farmer cooperatives will be necessary to create a supportive regulatory environment by 2029.

Addressing Agrarian Challenges

Indian agriculture will experience a profound shift by 2029 toward smart, mechanized farming, driven by the integration of IoT, AI, robotics, and automation. These technologies will not only boost productivity but also promote environmental sustainability, ensuring more efficient use of resources. While challenges such as high costs, infrastructure gaps, and regulatory hurdles remain, government initiatives, public-private partnerships, and continued technological innovation will play crucial roles in overcoming these barriers.

This transformation will enhance food security for India's growing population and significantly improve the livelihoods of millions of farmers. Furthermore, the adoption of smart farming practices will help protect vital natural resources for future generations. India's smart farming revolution will demonstrate how advanced technologies can address the agrarian challenges of the 21st century, creating a more sustainable and prosperous future for agriculture.

Book: Leader as a Coach

"Stop Telling! Start Asking! Put your team in the driving seat of their performance.

"The boss tells, while a leader listens."

In today's rapidly changing world, effective leadership is about more than just authority—it's about empowering your team, nurturing talent, and building a culture of collaboration. This book offers a fresh take on leadership, providing a modern approach to leadership, focusing on how to become an inspirational coach, motivate teams, and drive high performance. Written in an easy-to-read style, it is a perfect leadership guide for everyone. Discover how inclusiveness and participation can drive innovation, transform challenges into opportunities, and craft winning strategies. Discover how to develop essential coaching skills to inspire your team, drive sustainable growth, and ensure long-term success. Whether you're a seasoned professional or new to leadership, this book will guide you in creating a high-performing team and transforming your leadership style for today's challenges. Empower your leadership. Empower your team. **Empower your future.**

The book discusses the importance of leaders adopting a coaching approach in modern workplaces. It highlights the shift from traditional leadership, where leaders provide all the answers, to a style that encourages team members to develop their own solutions. When team members feel ownership of the ideas and solutions, their enthusiasm and execution improve significantly.

Despite its effectiveness, coaching remains underutilised, as many leaders use the default approach of telling and giving advice. The book aims to equip leaders with coaching skills and advocates for a leadership style that encourages and empowers, leading to sustainable progress. Leaders who generate ownership and engagement and inspire their team to achieve results will not only achieve performance but also set the organisation up for long-term success.

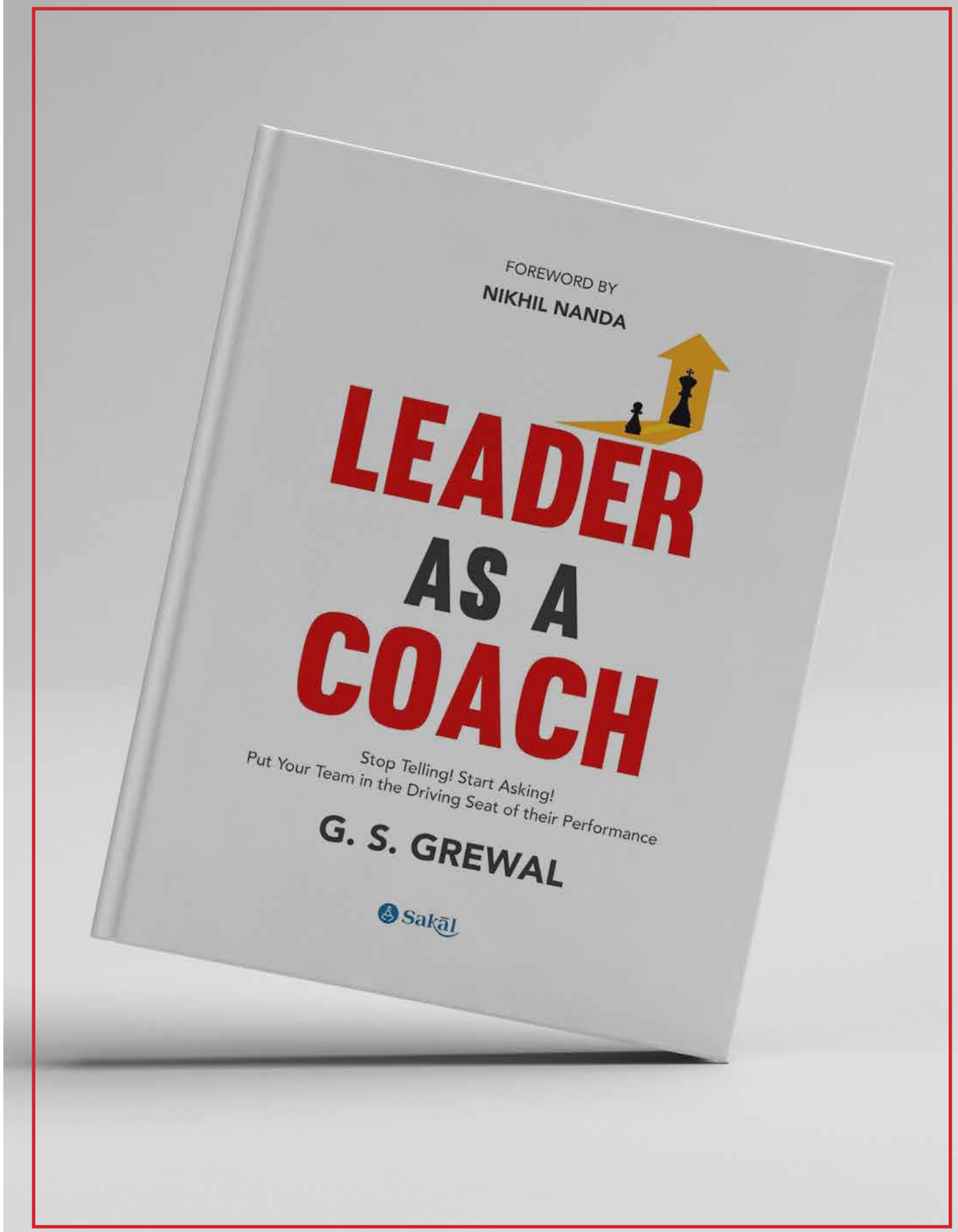
Every word in this book reflects the deep insights of a seasoned leader and coach. It's easy to read, with valuable lessons on every page that are immediately applicable to anyone striving to be an effective leader. Whether you are an aspiring leader, already in a leadership position, or an individual contributor looking to make an impact, this book will guide you. Packed with practical examples, it shows how leaders can inspire their teams to achieve more business results while fostering personal growth and becoming better human beings in the process.

Mr G.S. Grewal

started his career as a young engineer trainee and rose to the position of Managing Director of Kubota Agricultural Machinery India, the subsidiary of Kubota Corporation, Japan. In his 33 years of experience in the industry, he has worked with many Indian and Japanese leaders. He is a strong proponent of coaching leadership style and believes that leaders need to have humility and willingness to learn. He built a culture of mutual respect and trust within the company, bringing together the best of India and Japan. He has been promoting a coaching style of leadership across the organisation. In his new role as CO-Tractor business at Escorts Kubota Limited, he continues to inspire and empower others.

LinkedIn.com/in/gsgrewal2000

The book is available on Amazon.in



Making Agriculture

Future-Ready by 2029

Agriculture in India is at a crossroads, driven by the rapid pace of technological advancements, urbanization, modern farming techniques, and the ever-present challenge of climate change. These dynamics present both challenges and opportunities, demanding a new approach to ensure that agriculture remains productive, economically viable, socially inclusive, and environmentally sustainable. The advent of smart mechanization technologies stands as a beacon of hope, offering the potential to transform Indian agriculture into a future-ready sector by 2029.

The Evolution of Indian Agriculture

Historically, Indian agriculture has been characterized by smallholder farms, traditional cultivation practices, and a heavy reliance on manual labour. While these methods have sustained the nation for centuries, the demands of the 21st century necessitate a shift towards more efficient and technologically advanced practices. Urbanization and industrial growth have led to a significant reduction in the availability of agricultural labour, creating a pressing need for mechanization.

Moreover, climate change poses a significant threat to agricultural productivity, with erratic weather patterns, changing rainfall, and increased frequency of extreme events like droughts and floods. These challenges make it imperative to adopt smart farming technologies that can help farmers adapt to changing conditions while optimizing resource use.

The Role of Smart Mechanization

Smart mechanization technologies, including advanced tractors, precision farming equipment, and automated systems, offer a transformative solution to the challenges facing Indian agriculture. These technologies can address labor shortages by reducing the dependency on manual labor, making farming more efficient and less physically demanding. This is particularly important in the context of an aging farming population and the increasing participation of women in agriculture.

For small farmers, who make up the majority of India's agricultural workforce, smart mechanization can level the playing field. By making advanced machinery affordable and accessible, these farmers can increase their productivity, reduce costs, and improve their overall income. This inclusivity is vital for ensuring that the benefits of technological advancement reach the outermost socio-economic periphery.

Empowering Women and Attracting Youth

One of the most significant social impacts of smart mechanization is its potential to empower women farmers. Traditionally, women have been heavily involved in agricultural work, often performing the most labor-intensive tasks. By introducing mechanization, we can significantly reduce the physical burden on women, enabling them to take on more diverse roles within the agricultural value chain. This not only improves their quality of life but also enhances their economic independence.

Additionally, smart mechanization has the potential to attract the youth to agriculture. With modern technology, farming can be rebranded as a profitable and intellectually stimulating career. Youth, who are often deterred by the perception of agriculture as a low-tech and labour-intensive sector, can find new opportunities in the development, management, and operation of smart agricultural technologies. This can lead to the establishment of profitable agribusiness enterprises, contributing to rural development and economic growth.

Building Smart Farms for the Future

Looking ahead to 2029, the vision for Indian agriculture must be centered on the development of smart farms that are highly mechanized, resource-efficient, and resilient to climate change. To achieve this, several key areas need to be addressed:

1.Research and Development: Investment in R&D is crucial to developing smart mechanization technologies that are tailored to the specific needs of Indian farmers. This includes innovations in precision farming, automation, and sustainable agricultural practices.

2.Infrastructure Development: Building the necessary infrastructure, such as rural roads, storage facilities, and digital connectivity, will ensure that smart mechanization technologies can be effectively deployed across the country, particularly in remote areas.

3.Financial Accessibility: To ensure that small farmers can access smart mechanization technologies, financial solutions such as subsidies, low-interest loans, and cooperative purchasing models must be implemented.

4.Training and Education: Equipping farmers with the knowledge and skills to operate and maintain smart machinery is essential. This can be achieved through targeted training programs, agricultural extension services, and digital platforms that provide real-time support.

5.Policy Support: The government plays a critical role in creating an enabling environment for the adoption of smart mechanization. Policies that promote sustainable farming practices, protect small farmers, and incentivize the adoption of technology will be key to achieving the vision for 2029.

Collective Effort Required

As we look towards the future, the integration of smart mechanization technologies into Indian agriculture holds the promise of transforming the sector into a more productive, sustainable, and inclusive one. By addressing labour shortages, empowering women, and attracting youth, we can build a resilient agricultural system that not only meets the food security needs of a growing population but also contributes to the economic and social development of rural India.

The next decade will be crucial in shaping the future of Indian agriculture. It is an opportunity for all stakeholders—government, private sector, farmers, and civil society—to work together in building smart farms that are equipped to meet the challenges of tomorrow. Through concerted efforts, we can ensure that Indian agriculture thrives in the face of change, creating a prosperous and sustainable future for all.

> *"One of the most significant social impacts of smart mechanization is its potential to empower women farmers*

Mr. Balakrishna
is the Vice president (Sales, After Sales & Marketing) at Same Deutz-Fahr India (P) Ltd, handling India and the SAARC regions. He has more than 30 years of rich technological & commercial experience in tractor business

THE BIG VISION

Future Smart Farms with Mechanization

Mr. Rajesh Movaliya,
MD of Captain Tractors,
has over 30 years of experience. He is a visionary leader, known for his grounded approach in various sectors,inspiring others

Agriculture has long been the backbone of India's economy, and as we move towards 2029, it is evident that the landscape is evolving rapidly. The future of farming will be shaped by the integration of technology, innovation, and mechanization, allowing farmers to increase productivity while minimizing manual labor. Smart farms, which will employ cutting-edge technologies, hold the key to transforming agriculture, especially for small-scale farmers who often work on the outermost socio-economic periphery.

The Role of Mechanization in Small-Scale Farming

Mechanization has always been a cornerstone of agricultural evolution. However, the challenge lies in ensuring that small farms—often constrained by limited financial resources and land size—can benefit from these advancements. Customization of agricultural equipment and mechanization solutions is critical to addressing the needs of small and marginal farmers.

At Captain Tractors, we have always championed the cause of small farmers. As pioneers in the development of compact tractors, we have spent the last 30 years innovating and adapting our machinery to serve the specific needs of these farmers. Our tractors, designed to increase output while reducing manual labor, have already found a place in more than 70 countries and 20 states across India. Looking forward to 2029, we are committed to continuing this legacy of innovation.

Smart Farming: Integrating Technology for Efficiency

Smart farms of the future will heavily rely on precision farming technologies—an integration of sensors, artificial intelligence (AI), and machine learning (ML) to optimize resource use. Small farms stand to benefit immensely from these advancements. Sensors that monitor soil health, water levels, and crop growth, combined with AI-driven insights, will allow farmers to make informed decisions that maximize yields.

For example, a small farm equipped with smart irrigation systems will not only conserve water but will also ensure that crops receive the exact amount of moisture they need. This reduces wastage and ensures higher productivity. Drones and autonomous machines can assist in spraying fertilizers and pesticides, performing tasks faster and more efficiently than manual labor.

In this regard, Captain Tractors envisions developing smart, compact tractors that can seamlessly integrate with modern farming systems. These tractors will not only be robust and fuel-efficient but will also have AI-assisted tools for precision farming, making them indispensable to small farmers.

Customization: Meeting The Unique Needs of Small Farmers

The diversity of Indian agriculture means that no one-size-fits-all solution can work for every farmer. Small farmers, in particular, need customized machinery that suits their specific crop requirements, land sizes, and financial capacities. Mechanization should be scalable, adaptable, and affordable for these farmers.

For Captain Tractors, customization has been a driving force. Our compact tractors are designed to fit small farms, navigate narrow fields, and handle tough terrain. By 2029, we aim to develop even more customized solutions, integrating future technologies like GPS-enabled machinery, smart attachments for various crops, and real-time data collection tools to help farmers make better decisions.

The future of customization will also focus on making tractors easier to maintain and more cost-effective. We are already working on introducing gearless, automated tractors that require minimal manual intervention, ensuring that even farmers with limited technical knowledge can easily operate these machines.

Addressing the Socio-Economic Challenges

One of the key challenges in reaching the outermost socio-economic periphery of farming is affordability and access. Many small farmers lack the financial resources to invest in expensive, high-tech machinery. This is where financial innovations, government support, and affordable machinery solutions must come together.

At Captain Tractors, we believe in making mechanization accessible to every farmer. We are committed to offering financial flexibility, including loan schemes, leasing options and subsidies, so that even the most marginal farmers can own or rent machinery. Partnerships with governmental bodies and agricultural cooperatives will also play a crucial role in bridging the gap, providing small farmers access to modern farming tools.

The Path to Sustainable Mechanization

As the global conversation increasingly shifts towards sustainability, smart farms must also consider the environmental impact of mechanization. We cannot talk about the future of farming without addressing climate change, resource depletion, and ecological balance.

At Captain Tractors, sustainability has always been a priority. Our compact tractors are known for their fuel efficiency, helping reduce the carbon footprint associated with traditional farming practices. As we develop new models for 2029, we plan to incorporate electric and hybrid tractors, reducing dependence on fossil fuels and promoting a greener future for agriculture.

Moving Ahead

The future of smart farming by 2029 is not just about integrating advanced technology but ensuring that these advancements are accessible and affordable to the smallest and most marginalized farmers. With customization, financial accessibility, and sustainable practices at the core of our efforts, Captain Tractors is dedicated to leading the charge in transforming Indian agriculture.

By focusing on small farms and ensuring that mechanization reaches the outermost socio-economic periphery, we are confident that the future of farming will be bright, productive, and sustainable. The road to 2029 may be paved with challenges, but with the right approach, it will lead to a revolution in Indian agriculture.

> "The future of smart farming by 2029 is not just about integrating advanced technology but ensuring that these advancements are accessible and affordable to the smallest and most marginalized farmers

Mechanization and Automation Key Drivers of Agriculture

> Mechanization has been instrumental in increasing the income levels of farmers by improving the timeliness and quality of agricultural operations, thereby enhancing the marketability of produce

Dr. P.K. Sahoo

is Head, Division of Agricultural Engineering of ICAR-Indian Agricultural Research Institute (IARI), New Delhi. He is Fellow of the Indian Society of Agricultural Engineers and Institution of Engineers (India). His specialization is in the area of precision farm machineries, smart farm technologies and energy efficient conservation agriculture equipment.

Dr Nrusingh Charan Pradhan,

Ph.D.Scholar of the Division of Agricultural Engineering, IARI, New Delhi, is presently working as Assistant Agricultural Engineer in Government of Odisha

Agriculture is evolving rapidly, driven by the need to feed a growing global population and address environmental challenges. The United Nations predicts that by 2050, the world population will reach 9.7 billion, necessitating a 60% increase in food production to meet demand. However, traditional farming practices cannot meet these demands efficiently or sustainably. India, a country with a rich agricultural history, is on the cusp of a new revolution—one driven by mechanization and automation.

As the second-largest producer of fruits, vegetables, and grains globally, agriculture remains the backbone of the Indian economy, employing nearly half of the workforce and contributing around 18.2% to the nation's GDP. However, the traditional methods of farming are no longer sufficient to meet the demands of a growing population, changing climate, and increasing pressure on natural resources. Mechanization and automation are emerging as crucial tools to drive the future of Indian agriculture by improving productivity, addressing labour shortages, and promoting sustainability.

Mechanization: The Evolution of Indian Agriculture

The evolution of mechanization in Indian agriculture has been a transformative journey, significantly impacting productivity, labour dynamics, and sustainability. This evolution has been driven by technological advancements, policy interventions, and the need to address challenges such as labour shortages and climate change. Mechanization has not only increased agricultural output but also altered the socio-economic landscape of rural India. The key aspects of the mechanization are:

Technological Advancements and Productivity

Mechanization has played a crucial role in transitioning Indian agriculture from subsistence to commercial farming. The introduction of farm machinery has increased land productivity and allowed for multiple cropping, thereby enhancing the overall agricultural output. The development of Custom Hiring Centres (CHCs) has facilitated access to farm machinery for small and marginal farmers, who constitute a significant portion of the agricultural workforce. These centres have been pivotal in promoting mechanization by providing machinery on a rental basis, thus overcoming the barrier of high ownership costs. The infusion of advanced technologies such as precision agriculture, drones, and IoT has further enhanced the efficiency of farm operations, enabled better management of inputs, and reduced environmental footprints (Cr 2022).

Socio-Economic Impacts

Mechanization has led to a significant reduction in labour demand, particularly affecting women's employment in agriculture. The adoption of machinery for tasks traditionally performed by women, such as weeding, has resulted in a decline in their labour participation without a corresponding increase in non-farm employment opportunities. The increased use of tractors and other machinery has contributed to the consolidation of farms and a shift towards larger-scale operations, which can lead to overproduction and the displacement of small farmers.

Despite these challenges, mechanization has been instrumental in increasing the income levels of farmers by improving the timeliness and quality of agricultural operations, thereby enhancing the marketability of produce.

Policy and Institutional Support

Government initiatives, such as subsidies for farm machinery and the establishment of CHCs, have been critical in promoting mechanization. These policies have aimed to make mechanization more inclusive and accessible to smallholder farmers. The shift from a "not-for-profit" to a "for-profit" approach in agricultural development has encouraged private sector participation, leading to innovations in farm machinery and practices. This transition has implications for competitiveness, inclusiveness, sustainability, and scalability in Indian agriculture.

Automation: The Future of Indian Agriculture

Automation in Indian agriculture represents a transformative opportunity to enhance productivity, sustainability, and economic viability. The integration of advanced technologies such as IoT, machine learning, and robotics is poised to address the challenges faced by the agricultural sector, including labour shortages, inefficiencies, and environmental concerns. This transition, however, is not without its challenges, including economic, social, and technical barriers.

Technological Advancements in Agricultural Automation

- IoT and Precision Agriculture: The use of IoT in agriculture enables precision farming through automated weather forecasting and field monitoring. Their GRU-CNN model achieves high accuracy in predicting weather and monitoring field conditions, which can significantly enhance crop productivity and reduce waste.
- Machine Learning and Deep Learning: Recent developments in machine learning and deep learning have significantly improved agricultural tasks such as plant disease detection, crop classification, and soil parameter prediction. For instance, deep learning models like ResNet-18 and FCN have outperformed traditional machine learning techniques in various agricultural applications, offering higher accuracy and efficiency.
- Computer Vision: Computer vision technology is crucial for automating tasks such as crop monitoring and pest detection. It provides high precision and efficiency, although challenges remain in adapting these technologies to diverse and complex agricultural environments.
- Robots: The integration of robots in agriculture is revolutionizing the industry by enhancing efficiency, reducing labour costs, and promoting sustainability. These robotic systems are being utilized across various agricultural tasks, from precision farming to weeding and harvesting, offering innovative solutions to traditional farming challenges.

Economic and Social Implications

- Economic Impact: Automation in agriculture can lead to increased productivity and sustainability, but it also requires significant investment. The economic feasibility of adopting such technologies is a critical consideration, especially for smallholder farmers in India. The potential for labour displacement is another concern, as automation could reduce the demand for manual labour in agriculture.
- Job Transformation: The introduction of robotics and automation is expected to transform the agricultural job landscape. While some jobs may be displaced, new opportunities will arise that require different skills, emphasizing the need for workforce adaptation and training.

Challenges and Opportunities

- Technical Challenges: Despite the potential benefits, several technical challenges need to be addressed, such as the robustness of automation systems in varying environmental conditions and the integration of large-scale datasets for improved decision-making.
- Sustainability and Resource Management: Automation can contribute to environmental sustainability by optimizing resource use, such as water and fertilizers, through smart irrigation systems and other IoT-based solutions. This is particularly important in the context of India's water scarcity and environmental challenges.

Challenges to Adoption of Mechanization and Automation

Despite the clear benefits, several challenges hinder the widespread adoption of mechanization and automation in Indian agriculture. The high cost of advanced machinery and automation systems is one of the most significant barriers, particularly for smallholder farmers. While government schemes like the Sub-Mission on Agricultural Mechanization (SMAM) provide financial assistance for purchasing equipment, the reach of these programs remains limited, and many farmers still struggle to access credit.

Another challenge is the lack of infrastructure, particularly in rural areas. Automation technologies, such as IoT-enabled irrigation systems and drones, require reliable internet connectivity and electricity, which are often unavailable in remote farming regions. Investing in rural infrastructure will be critical to ensuring that farmers can fully leverage the benefits of automation. There is a need for training and capacity-building programs to help farmers adopt and effectively use new technologies. Many farmers, particularly older generations, are unfamiliar with modern machinery and automation tools. Providing training on how to operate and maintain this equipment will be essential for ensuring the successful integration of these technologies into Indian agriculture.

The Road Ahead

Mechanization and automation are poised to drive the future of Indian agriculture by enhancing productivity, addressing labour shortages, and promoting sustainability. As India faces the challenges of feeding a growing population while managing finite resources, these technologies offer practical solutions that can transform the agricultural landscape. However, for mechanization and automation to reach their full potential, it is essential to address the barriers to adoption, including high costs, infrastructure limitations, and the need for farmer education. With the right support from the government, private sector, and research institutions, mechanization and automation can help build a more resilient and sustainable agricultural sector in India.

Future Smart Farms in India Need For 'Efficient Growth'

India experienced the first green revolution some fifty years ago. The use of high yielding variety (HYV) seeds, mechanised farm tools, irrigation facilities, pesticides and fertilizers has helped in converting us from a food importing country to a food surplus one. However, Indian agriculture is witnessing stagnancy in productivity for the last two decades. The condition is worsening due Continuous land degradation because of intensive cultivation, primitive agricultural practices and overuse of agro-chemicals, fertilisers, pesticides and herbicides. Increasing further productivity with the current practices is a challenge and too costly to be viable.

In addition, new challenges have emerged like:

1.The already serious stress on India's water resources is worsening with each passing year. India uses far more water than many major agricultural countries to produce the same quantity of output.

2.Climate change is resulting into unpredictable weather events that is affecting cropping pattern and increasing risks of crop damage.

There is a need for a shift in strategy from 'growth' to 'efficient growth', so that any increase in productivity is associated with a reduction in the average cost of production. Smart farming technologies offer promising solutions to achieve this. They would enhance the effectiveness of mechanisation by optimising efforts and inputs through timely data gathering and forecasting that would help farmers in taking timely decisions and actions. We are a global IT and space-technology hub and have the capabilities to develop such solutions. Technologies based on data capturing, analysing and Artificial Intelligence (AI) are going to come to India farms in the next 5 years.

There are many smart technologies adopted around the world in the field of agriculture. Not all can be adopted by Indian farms. Key obstacles being the small land holdings of majority of farmers, almost half of the agricultural land lacks irrigation facilities, low-income levels of farmers leading to low purchasing power for machines and technologies, low literacy levels and lack of awareness and knowledge about such technology.

Remote Monitoring of Soil Moisture for Efficient Irrigation

IoT-based soil moisture monitoring systems have been implemented in Indian agriculture to optimize irrigation practices. These systems provide real-time data on soil moisture levels, enabling farmers to schedule irrigation precisely and conserve water resources. The adoption of smart irrigation is expected to be grow in India and can contribute to optimising water use and productivity.

> "IoT-enabled disease prediction models have gained traction in India to combat crop diseases

Predictive Analytics for Disease Outbreak Prevention

IoT-enabled disease prediction models have gained traction in India to combat crop diseases. By studying data from various sources, including weather conditions and historical disease patterns, these models forecast disease outbreaks, allowing farmers to take timely preventive measures. Many private companies/ Agritech startups/ Governments offer these services on subscription basis. India will see growth in their adoption.

Soils and crop health monitoring

Micro and macronutrients in the soil are critical factors for crop health and impacts both the quantity and quality of yield. Traditionally soil quality and crop health are determined by human observation and judgment or with the help of soil testing labs. These methods are less accurate and are not on real time basis.

Satellite imagery/ drones (UAVs) will be used to capture aerial image data that will be used for intelligent monitoring of crop and soil conditions.

Technologies like Visual sensing AI will be used to analyze and interpret this data to:

- Characterize soil texture and soil organic matter
- Track crop health
- Detect crop malnutrition

AI models can inform farmers of specific problem areas so that they can take immediate and specific action. This will reduce rampant use of fertilizers/ pesticides and thus save costs while enhancing productivity.

Predicting the Best Times to Sow and Harvest

The difference between a profitable year and a failed harvest is just the timely information on a simple data point of timing of sowing the seed. To combat this, analytics tool will be used, for analysing weather forecast and soil moisture status and other data points, to arrive at a precise date for sowing the seeds to obtain maximum yield.

Similarly, data from various sources is analysed for accurate yield predictions and suggesting best time to harvest. This is being currently adopted in sugarcane cultivation in some parts of the country. This allows better planning for harvesting (more yield/ha) and also provides better sugar yield to the sugar producing companies. Thus, a win-win for all stakeholders. These solutions will mature over time and will be useful for all key crops in the country.

Climate change is resulting in late rains extending into normal harvesting period. Accurate weather forecast and suitable advisory will help farmers plan the right time for harvesting. Necessary harvesting machines can be arranged on time and thus reduce losses due to such incidents.

Drones (UAV) as Farm Machines

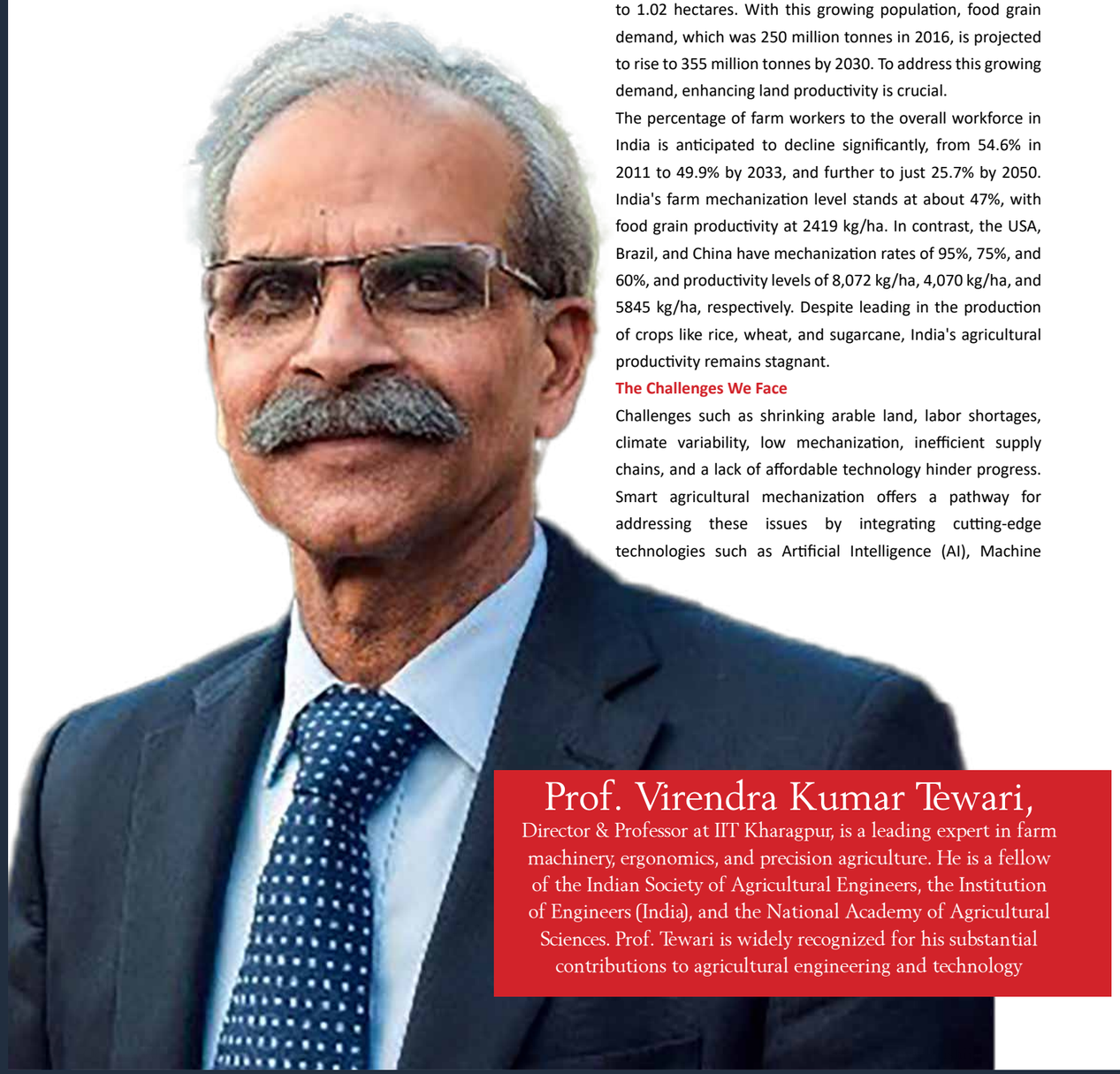
Many of these developments are based on satellite imagery, sensors and other scanning mechanisms are scalable and will provide right information. Machines will be necessary to take necessary action. Improvements will happen by using the existing farm machines at the right time for the right purpose.

Drones will emerge as a necessary farm machine for spraying of fertilisers and pesticides, and monitoring of soil and crop health. Indian government, agri-scientists and private players are working together to make this affordable and effective.

GOI will have to take more initiatives in democratising these AI based technologies and advisory to every farmer in the country. This will also need intense training and extension activities and the necessary support system.

Kumar Bimal
Head of Business Strategy
International Tractors Limited

Smart Agricultural Mechanization Scope and Opportunities



India's agricultural sector plays a vital role in the economy, employing approximately 42.3% of the workforce and contributing 18.2% to the GDP. The population has surged from 55.52 crore in 1970-71 to 132.45 crore in 2015-16, while average land holdings have shrunk from 2.20 hectares to 1.02 hectares. With this growing population, food grain demand, which was 250 million tonnes in 2016, is projected to rise to 355 million tonnes by 2030. To address this growing demand, enhancing land productivity is crucial.

The percentage of farm workers to the overall workforce in India is anticipated to decline significantly, from 54.6% in 2011 to 49.9% by 2033, and further to just 25.7% by 2050. India's farm mechanization level stands at about 47%, with food grain productivity at 2419 kg/ha. In contrast, the USA, Brazil, and China have mechanization rates of 95%, 75%, and 60%, and productivity levels of 8,072 kg/ha, 4,070 kg/ha, and 5845 kg/ha, respectively. Despite leading in the production of crops like rice, wheat, and sugarcane, India's agricultural productivity remains stagnant.

The Challenges We Face

Challenges such as shrinking arable land, labor shortages, climate variability, low mechanization, inefficient supply chains, and a lack of affordable technology hinder progress. Smart agricultural mechanization offers a pathway for addressing these issues by integrating cutting-edge technologies such as Artificial Intelligence (AI), Machine Learning (ML), the Internet of Things (IoT), and robotics. These technologies enhance decision-making processes and improve farm input efficiency, leading to increased productivity.

Prof. Virendra Kumar Tewari, Director & Professor at IIT Kharagpur, is a leading expert in farm machinery, ergonomics, and precision agriculture. He is a fellow of the Indian Society of Agricultural Engineers, the Institution of Engineers (India), and the National Academy of Agricultural Sciences. Prof. Tewari is widely recognized for his substantial contributions to agricultural engineering and technology

Status of Agricultural Mechanization in India

Agricultural mechanization in India stands at about 47%, with notable regional disparities. States like Punjab and Haryana lead in mechanization, while the eastern and north-eastern regions lag behind. Farm power availability has increased from 1.1 kW/ha in 1995-96 to 3.04 kW/ha in 2021-22 and is expected to reach 4 kW/ha by 2030-31. To achieve a mechanization level of 75% by 2047, average farm power must rise to 7.50 kW/ha.

Technological Innovations in Smart Mechanization

Technological innovations in smart mechanization are revolutionizing agriculture by integrating advanced technologies to enhance efficiency and productivity. The adoption of AI and ML in agriculture allows for real-time data analysis and predictive insights, optimizing resource use and crop management. IoT devices collect real-time data on soil conditions, weather, and crop health, enabling farmers to make informed decisions. Drones and aerial imaging technologies facilitate precise monitoring of crops, detecting issues like pest infestations and nutrient deficiencies with high precision. Robotics and automation, such as robotic harvesters and planters, streamline repetitive tasks, increasing operational efficiency. Some of the advanced technologies developed at IIT Kharagpur are tractor-mounted variable rate fertilizer applicator, variable rate herbicides applicator, sugarcane bud planting technology with automatic fungicide applicator, and the ultrasonic sprayer-based orchard sprayer.

Opportunities for Growth in Smart Mechanization

Modern Farming Systems

India is facing a decline in arable land due to rapid urbanization, industrialization, and family fragmentation. Technologies like vertical and rooftop farming can address this challenge by maximizing space and enabling urban crop cultivation. These methods use soil-less techniques such as hydroponics, aquaponics, and aeroponics, allowing for year-round production.

Supply Chain and Storage Solutions

India's agricultural storage capacity of 145 million metric tonnes falls short against an annual production of 329 million tonnes, causing 20-30% post-harvest losses. IoT-enabled cold storage, smart warehouses, and digital logistics platforms can improve crop preservation and transport efficiency. Additionally, blockchain technology can enhance supply chain transparency, reducing intermediaries and ensuring better prices and quality for farmers' produce.

Climate-Resilient Farming Techniques

As climate change affects agriculture, techniques like shed-net cultivation, greenhouses, and protected cropping are becoming vital. They shield crops from extreme weather and ensure optimal growing conditions. Moreover, smart climate-controlled systems can further enhance crop resilience to climatic stress. Additionally, cultivating climate-resilient crops, such as millets and pulses, can effectively mitigate the adverse effects of unpredictable weather patterns.

Export Potential and Value Addition

By leveraging smart technologies in post-harvest processing and packaging, India can ensure its produce meets international quality standards. Data analytics tools can provide insights into global market trends, enabling farmers to align their production with export demands.

Affordability and Accessibility of Technology

The high cost of advanced technology is a significant barrier to widespread adoption among smallholder farmers. Developing indigenous, low-cost tech solutions tailored for small-scale farmers under the 'Make in India' initiative can enhance the affordability and accessibility of smart farming technologies.

Attracting the Younger Generation to Agritech and Agribusiness

Embracing cutting-edge technologies such as AI, ML, IoT, and robotics can make farming more appealing to tech-savvy youth. The Indian agritech market is projected to grow at a CAGR of 50%, potentially reaching $34 billion by 2027, creating lucrative opportunities for young entrepreneurs.

A Forward-Looking Perspective

Smart agricultural mechanization offers a promising path to revolutionize India's agricultural landscape, making it more efficient, resilient, and future-ready. By embracing cutting-edge technologies such as AI, ML, IoT, and robotics, along with advanced farming techniques like vertical farming, hydroponics, and aeroponics, India can address challenges like shrinking land sizes, climate change, and labor shortages.

The way forward lies in making these technologies both affordable and accessible, ensuring that farmers of all scales, from smallholders to large-scale producers, benefit from this agritech revolution. Attracting younger generations to agritech and agribusiness is crucial for sustaining momentum and ensuring the continued growth of Indian agriculture. Furthermore, by improving supply chains, and focusing on value addition, India can foster a modern and sustainable agricultural ecosystem, promoting rural development and increasing farmer incomes. However, this transformation will require coordinated efforts from all stakeholders, including the government, the private sector, and academic institutions, to ensure that smart mechanization becomes a reality for farmers nationwide.

> The high cost of advanced technology is a significant barrier to widespread adoption among small holder farmers

Mechanization Leading The Charge

Agriculture is evolving rapidly, and mechanization is leading the charge toward smarter farms by 2029. As part of this transformation, Shrachi Agrimech is playing a pivotal role, particularly with the introduction of GPS-enabled machines and their full-scale, 100% Indian-made weeder production. These weeders are designed for multi-functionality, capable of performing various tasks such as land preparation, weeding, spraying, and more. They are lightweight, portable, and adaptable to different terrains, whether hilly, flat, or rugged. Additionally, the weeders offer various power options, including gasoline, diesel, and battery-operated models, and feature self-start technology. Notably, the GPS capability helps in tracking and improving farming efficiency.

Shrachi Agrimech's effort to promote domestic manufacturing aligns with the "Make in India" drive, ensuring that high-quality, locally produced machinery is accessible to Indian farmers. This helps reduce reliance on imports while promoting economic growth. The company's commitment to producing advanced agricultural machinery at home reflects its support for farmers and its desire to foster self-reliance in India's agricultural sector.

The integration of GPS technology in these machines is a significant step forward. GPS-enabled farm equipment allows for real-time monitoring, optimized resource allocation, and better land management. By utilizing data-driven insights, farmers can improve efficiency, reduce waste, and enhance crop yields while maintaining sustainability. However, while newer technologies like drones offer potential benefits for monitoring crops and spraying pesticides, their high cost and complexity remain barriers for many farmers. Shrachi Agrimech focuses on providing more accessible, practical, and affordable solutions.

Reshaping The Future Of Agriculture

Mechanization, driven by advances in technology, will reshape the future of agriculture, enabling farmers to manage their land more efficiently while addressing challenges like labour shortages and climate change. Shrachi Agrimech's continued investment in smarter machines reflects the future of farming, where technology-driven solutions will make a profound difference. GPS kits, for example, help farmers reduce input costs and improve productivity, laying the groundwork for what smart farms will look like in the years ahead. As Shrachi Agrimech continues to expand into agri-tech, it is clear that the future of farming will blend traditional practices with cutting-edge innovations.

Mechanization also has a critical role to play in promoting sustainability in agriculture. As farming faces increasing pressure to produce more with less, the integration of smart technology and machines that can operate efficiently and precisely will become vital. Shrachi Agrimech is already pushing forward with technologies that not only mechanize farming processes but also integrate precision agriculture techniques. By 2029, smart farms will likely be a reality, using data to make informed decisions on irrigation, fertilizer use, and crop rotation to ensure sustainable and profitable operations.

Shrachi Agrimech's focus on locally produced machinery that can be seamlessly integrated with technology is helping create a pathway to smarter, more efficient farms. As mechanization continues to evolve, machines like their weeders, capable of performing multiple functions with minimal effort, will become more critical for farmers aiming to enhance productivity while reducing operational costs.

The Transformative Role Of mechanization

In the context of long-term agricultural growth, mechanization will undoubtedly play a transformative role in shaping the future. Smart farms, powered by integrated technology, will not only help address challenges like labor shortages and climate unpredictability but will also enhance the overall productivity and sustainability of farming. With its strong focus on "Make in India" and smart, affordable solutions, Shrachi Agrimech is leading the way in preparing Indian agriculture for the future. As the sector gears up for the challenges of the coming decade, the combination of mechanization and agri-tech solutions will be vital in securing the future of farming.

Mr Ravi Todi,

The Managing Director of Shrachi Group, is a visionary leader in agriculture, engineering, and real estate. A graduate of St. Xavier's College, Kolkata, and the Harvard OPM program, he has led Shrachi Agrimech to become a frontrunner in agri-tech and mechanization. Under his leadership, the company is committed to promoting Make in India by manufacturing innovative, locally produced agricultural machinery. Mr Todi is also active in social entrepreneurship and global ventures, continually pushing for sustainable growth and industry transformation

> "As farming faces increasing pressure to produce more with less, the integration of smart technology and machines that can operate efficiently and precisely will become vital

Use of Artificial Intelligence in Plant Disease Detection

In the agriculture sector, accurately detecting plant diseases is crucial for maintaining crop health, maximizing yields, and reducing economic losses. Traditional methods of disease detection typically rely on visual inspections, which can be both time-intensive and prone to human error. These manual assessments often lack the precision needed to identify diseases at early stages, resulting in delayed interventions and further crop damage.

But with the advancement of Artificial Intelligence (AI) in agriculture, offering innovative solutions to revolutionize the way we detect and manage plant diseases. The role of AI in detecting plant diseases with precision is getting better with AI advancement, empowering farmers and researchers with advanced tools and techniques. By using the power of machine learning, image recognition, and data analytics, AI systems can rapidly study and interpret wide amounts of plant-related data, providing accurate and efficient disease detection capabilities.

At the heart of AI-driven disease detection is image recognition technology. By training algorithms with vast datasets of labelled images, AI models can learn to identify subtle visual cues and patterns associated with various plant diseases. This allows for the rapid and objective identification of disease symptoms, such as leaf discoloration, lesions, or wilting, across a wide range of crops. Through real-time analysis of plant images captured by drones, cameras, or smartphones, AI can provide farmers with early warnings and actionable insights, enabling them to take timely measures to contain and manage diseases.

Sensor Technologies

AI also shows significant potential in enhancing precision disease detection through the integration of sensor technologies. By utilizing hyperspectral and multispectral sensors, AI can analyze data across a wide range of wavelengths, providing detailed insights into plant health.

These sensors capture subtle variations in reflectance that are often invisible to the human eye, allowing for early identification of disease symptoms and other stress factors that may affect crop health. By combining this spectral data with AI algorithms, it becomes possible to detect subtle changes in plant physiology that may not be visible to the naked eye. These AI-powered systems can effectively identify

The Global Artificial Intelligence in Agriculture Market size is expected to reach $4.9 billion by 2028, rising at a market growth of 24.1% CAGR during the forecast period.

diseases at early stages, enabling farmers to implement targeted control measures and prevent widespread outbreaks.

AI-Driven Disease Detection

AI-driven disease detection is not limited to visual or spectral analysis alone. By integrating environmental and weather data, such as temperature, humidity, and rainfall patterns, with historical disease patterns, AI algorithms can develop predictive models. These models can forecast disease outbreaks, providing farmers with valuable insights for proactive disease management. By anticipating disease risks, farmers can implement preventive measures, optimize resource allocation, and minimize the need for chemical interventions, ultimately promoting sustainable agricultural practices.

The use of AI in detecting plant diseases with precision extends beyond individual farms. AI platforms can facilitate knowledge sharing and collaboration among farmers, researchers, and agricultural experts. By aggregating data from multiple sources, such as remote sensing, field observations, and disease databases, AI systems can analyse patterns, track the spread of diseases, and provide valuable insights for disease control strategies at regional or even global scales.

The precision and efficiency offered by AI-driven disease detection have the potential to transform the agricultural landscape, empowering farmers with actionable information, minimizing crop losses, and promoting sustainable farming practices. As we unlock the full potential of AI, we pave the way for a future where plant diseases can be detected and managed with unparalleled precision, ensuring food security and sustainable agriculture for future generations.

Need of Artificial Intelligence for Plant Disease detection

Artificial intelligence is intelligence produced by a machine, such as a computer system equipped with learning algorithms that can keep improving its ability to make predictions as it gets more information. These tools are so advanced that they can process huge amounts of information within seconds. For crop resiliency, AI can help by making better tools for crop surveillance, designing better robots to deliver pesticides or harvest, and better software to help in breeding for traits like disease resistance and drought tolerance. It has a strong social angle, as it can help farmers and policymakers to make smart decisions.Artificial intelligence (AI) has emerged as a game-changer in the field of plant disease detection, addressing the challenges faced by traditional methods and offering significant advantages for sustainable agriculture. As the global population continues to grow, ensuring crop health and maximizing yields become increasingly critical. AI-driven disease detection not only enhances the accuracy and efficiency of identifying plant diseases but also enables timely intervention and effective control measures. There are various reasons of why AI is a needed for plant disease detection as it can be helpful in early detection, rapid response, accurate and precise disease detection, handling of large-scale data of detection, sustainability, efficient detection of the disease, for knowledge sharing and collaboration with farmers for better surveillance in future.

The need for artificial intelligence in plant disease detection is evident. AI offers advanced capabilities in early detection, accuracy, and data analysis, providing farmers with actionable insights for effective disease management. By leveraging AI-driven technologies, the agricultural industry can enhance crop health, maximize yields, promote sustainability, and contribute to global food security in an increasingly challenging and dynamic environment.

How AI can help in Plant Disease Detection with Precision

When an epidemic first starts to spread in a region, it only affects a small area but later, it will begin to spread rapidly in the field. It may be possible for surveillance to use remote sensing methods like satellite photography and drone technology to locate pathogen-infected

crops in farmlands. But using AI tools, we can easily detect changes in the colours of leaves, flowers, or fruits, as well as in their shapes or sizes, using image analysis. The management of an epidemic can be greatly facilitated by early disease detection and response. In the past, satellite data was quite imprecise, making it impossible to obtain a high enough resolution for disease detection.

For Disease detection through Image Processing, we have to collect and curate thousands of images of healthy and diseased plants in a range of conditions. So, collecting and curating these images takes time and investment. Then algorithms are developed to learn from these images of healthy and diseased plants, to identify signatures of disease. A lot of diseases have distinctive symptoms that can be detected visually. So, if you have a drone for example, that can go and take images in large fields, then those images can be compared and analysed using AI to efficiently diagnose visible crop disease.

AI can also be used with robotic tools for various purposes. Agricultural robotics is a growing field right now. An interesting AI example already in place is segregating healthy fruit from those infected with pathogens or otherwise damaged. Fruit can often be distinguished as diseased or not, based on colour and shape. These AI tools can process those images a lot faster and more consistently so that the discoloured and low-quality fruit which are often infected with pathogens are automatically separated.

How Farmers Incorporated AI Tools Into Farming

Farmers across the world have been gradually incorporating AI tools into their agricultural practices, benefiting from the potential that AI offers to enhance productivity, efficiency, and sustainability. The adoption of AI tools varies depending on factors such as farm size, technological infrastructure, availability of resources, and local agricultural practices.

People have been working on tools for image analysis of diseases so that farmers can take a photo of their plant and then get an assessment using a phone. The images are analysed by AI and support farmers in making informed decisions about crop management. Image analysis for disease diagnosis is generally not 100 percent accurate, but it can provide a level of confidence to help growers diagnose their crop diseases and understand the uncertainty.

It is important to note that the adoption of AI tools varies across regions and farming contexts. Factors such as affordability, accessibility, and technological literacy influence the pace and extent of AI adoption. However, as AI technologies become more accessible and user-friendly, farmers worldwide are increasingly incorporating these tools to optimize their operations, improve crop yields, and contribute to sustainable agriculture practices.

Challenges in development and management of disease detection AI tools

While the incorporation of AI tools in agriculture for plant disease detection offers numerous benefits, there are several challenges that farmers face when adopting these technologies across the world. For one thing, you need a lot of data for the AI system to learn from. To make an image analysis tool for diagnostics, you need to include a representative set of crop varieties, which can have a wide range of shapes and colorations. One big challenge is just getting enough of these images that are labelled correctly to be used for the image analysis tool to learn.

Another big issue is cost. There can be a lot of tools that do what you want them to do, but is the benefit that they bring big enough that it is worth the cost investment? I think there are a lot of AI tools that are already useful, but they might not be profitable for farmers yet. Many current applications are in cases where very high-value materials are processed, such as in postharvest fruit handling and in crop breeding.

Another challenge is training and capacity building so that the use of such tools isn't dependent on one expert but is more broadly used. A challenge for AI, and new technologies in general, is to make sure that the costs and benefits are fairly distributed in society. Connectivity and infrastructure are also a major challenge for incorporation of plant disease detection through AI for the farmers.

In conclusion, the integration of artificial intelligence (AI) in detecting plant diseases with precision has emerged as a transformative force in agriculture. AI tools offer accurate and efficient disease identification, enabling timely intervention and effective control measures. From image recognition and spectral analysis to real-time monitoring and predictive models, AI empowers farmers with actionable insights, minimizing crop losses and optimizing resource allocation. Despite challenges such as cost, technical expertise, and data availability, the pressing need for AI-driven disease detection in sustainable agriculture cannot be ignored. By embracing AI technologies, we can enhance crop health, maximize yields, and contribute to global food security, paving the way for a more resilient and productive agricultural future.

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Prof. R.S. Sengar
is Director Training Placement and Head Dept. of Ag. Biotechnology, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut
Kartikey Sengar is an Engineerand Software Developer at JSS Academy of Technical Education, Noida

NPSS App

AI-Based Pest Identification and Surveillance System for Farmers

India is a vast country with diverse agro-climatic conditions, numerous varieties of crops and cropping systems. Agriculture production is prone to several challenges. One of such challenges is pest attacks which causes losses up to 20% in food production. Expectedly, crops face diverse kind of pest and disease attacks. Thus it is imperative for different central and state agencies to correctly identify, record and monitor the pest population so as to advise the farmers for effective and timely pest mitigation measures.

Regular wide-area pest surveillance/monitoring is the cornerstone of Integrated Pest Management (IPM), through which epidemic situations can be avoided by detecting damage prior to establishing a higher pest population. For effective pest management, farmers need timely access to expert support on pest identification or pest surveillance based expert decisions as advice. However, in the absence of knowledge and expertise, farmers are over dependent on pesticide dealers for pest management decision-support in the country, which results in excessive, injudicious, and irrational use of chemicals for the pest control.

Timely availability of expert support on pest identification and pest surveillance based expert decisions as advice can either result in saving crops worth several cores of rupees or in non-application of pesticides saving cost involved and the environment through regular and systematic pest surveillance, epidemic situations can be avoided by detecting damage before endemic establishment of a pest in any area.

Application of modern technologies such as Artificial Intelligence (AI) and Information and Communication Technology (ICT) can automate and speed up the process of regular and systematic wide-area pest surveillance. Hence, ICAR-NCIPM in collaboration of DPPQ&S (DA&FW), ICAR-IASRI, Plantix and AI-Wadhwani developed National Pest Surveillance System (NPSS) leveraging digital technologies such as Artificial Intelligence (AI), smart phones and web-based tools.

NPSS, an Artificial Intelligence (AI)-based platform aims to connect the farmers with the agricultural researchers to reduce the crop losses and enhance the production and productivity at the farmer's field. This initiative is part of a broader strategy to reduce farmers' reliance on pesticide retailers and promote a scientific approach in the management of Insect-pests.

Aspects Of The System

The system uses AI to correctly identify the pest problem and thus provides pest management information.

The system has functionality for quantitative and qualitative pest surveillance of farmers' fields so as to advice appropriate pest management advice, on the basis of pest situation of the farmers' field.

NPSS comprises three major components: Mobile app and Web portal

Mobile app possess pest identification as well as pest surveillance capability to provide correct pest management advice to the farmers.

Utility For Farmers

The National Pest Surveillance System (NPSS) is a crucial step towards safeguarding crop yields and farmers' incomes through proactive pest management. It is a game-changer for the plant protection in the country. This comprehensive system provides easy and timely access to expert support for pest identification and surveillance-based pest management advice to farmers across the nation.

By offering accurate pest identification and timely management recommendations, the NPSS app greatly enhances productivity and efficiency in the agricultural field. The NPSS system will assist in avoiding pest epidemics and minimizing crop loss due to pests by leveraging real-time data submission from government agencies, resources, and lead farmers. Furthermore, it maintains a repository of the national pest scenario, which is accessible to various public agencies working in the field of plant protection.

This repository helps in identifying pest hotspots and formulating effective plant protection policies. With its intuitive interface and comprehensive features, the NPSS app is beneficial for farmers and agricultural professionals looking to stay ahead in plant protection, ultimately revolutionizing how pests and diseases in major crops are managed.

Presently, NPSS is enabled for providing pest identification for 61 crops and pest surveillance services for selected 15 crops in Hindi and English languages. The NPSS mobile app is available on the Google and Apple play stores for download whereas the web portal is available at https://npss.dac.gov.in.

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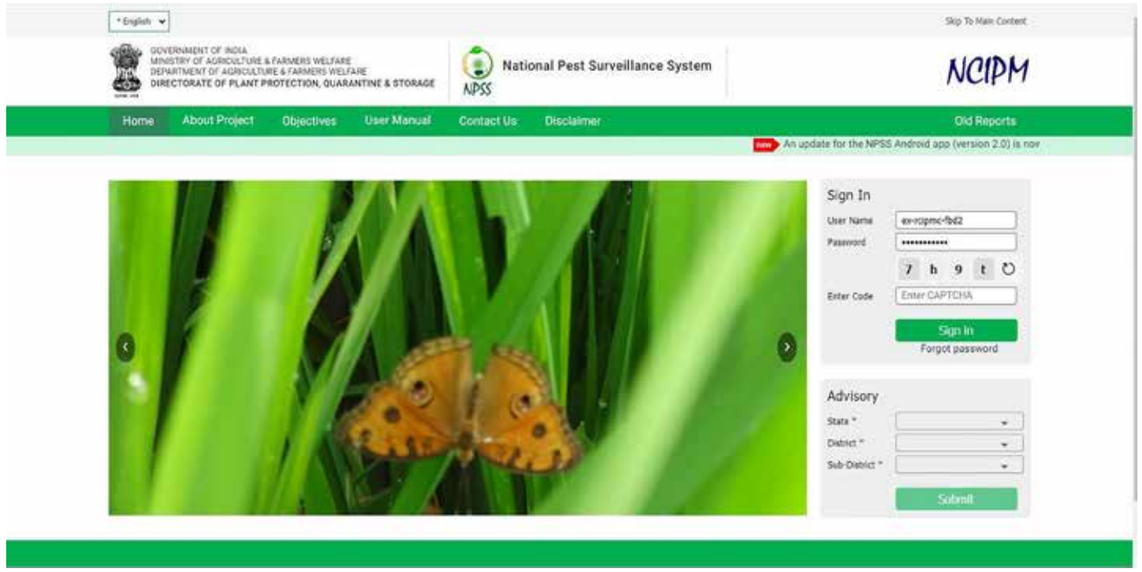
Web portal consists of a dashboard and pest reporting in different formats.



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Dr Meenakshi Malik,
Dr Niranjan Singh,
Dr Anoop Kumar,
Dr M K Khokhar,
Dr Manoj Chaudhary,
Dr P N Meena,
Dr Raghvendra
ICAR-National Research Centre for Integrated Pest Management, Rajpur Khurd, (ICAR-NCIPM), New Delhi

AGRI MECH
THE FUTURE IS NOW

Drones can revolutionize the farming industry through need-based precise and variable input applications leading to input saving, timeliness of operations, reduction in cultivation cost and ensuring farmer's safety from direct exposure to chemicals. Drones are used for targeted input application, timely diagnosis of nutrient deficiency, crop health monitoring, rapid assessment of crop yield and crop losses.

Drone is also helpful for spraying of crop nutrients and pesticides in hilly regions wherein it is difficult for other farm equipment to reach. Many start-ups, industries, SAUs and research institutions have started working on drone to harvest its potential in agriculture including soil and crop nutrient spraying. As the DGCA guidelines are available now, many companies have registered their products on Digital Sky Platform including agriculture drone.

Demonstration on insecticides spraying by drone on farmers fields by VNMKV, Parbhani

SOPs for Drone Use in Agriculture

The Ministry of Agriculture and Farmers Welfare, GOI, formed five national committees to develop Standard Operating Procedures (SOPs) for drone use in agriculture. The first committee, led by Dr. K. Alagusundaram and convened by Dr. Indra Mani, focused on safe pesticide application. The second, chaired by Dr. Indra Mani, created SOPs for drone-based nutrient spraying. The third, headed by Dr. Ravi Prakash, established guidelines for drone-based pesticide application. The fourth committee, led again by Dr. Indra Mani, drafted crop-specific SOPs for applying pesticides on ten selected crops.

These SOPs detail drone parameters (speed, height), sprayer settings, crop stages, and environmental conditions to ensure bio-efficacy and avoid phytotoxicity. Developed for drones with a 10-liter tank capacity, the guidelines emphasize optimal flying height and speed to prevent crop damage while ensuring uniform spray application. Experiments in different agro-climatic zones showed no crop damage when following these SOPs.

AI and Robotics in Farming

AI in agriculture is gaining traction, especially in agricultural robotics, soil and crop monitoring, and predictive analytics. In developed countries, AI is used for seed sowing via drones, soil mapping, and pricing. It reduces operational costs and reliance on manual labor, enabling data-driven farming decisions. In India, AI and robotics are still in early stages and need extensive field trials. Blockchain technology will also play a key role, ensuring real-time supply chain transparency and helping farmers negotiate better prices while boosting consumer trust.

Robots automate repetitive tasks like spraying and weed removal, reducing the need for chemicals and labor. Startups are developing robots for weed detection and removal, as well as fruit and vegetable harvesting, making farming more efficient, healthier, and sustainable. There are startups that are currently working on laser and camera guided robots that not only identify specific types of weeds in a crop but also remove them without any human intervention needed in the process. This whole development could be revolutionary as it could totally eliminate the role of chemicals that were previously being used to get rid of weeds, not only reducing the cost of the whole operation but also making our crops healthier and organic.

Another application that robots find are in vegetable and fruit farms where the monotonous work of fruit picking from the plant needs a lot of time and manpower. More and more companies are coming up with various robotic solutions for this process in order to make it easier, cheaper and faster than it currently is. There are some robots in testing phases that can perform operations as delicate as nut harvesting.

Korean Vegetable Grafting Robots at VNMKV, Parbhani

Initiative at VNMKV, Parbhani for Digital Agriculture

The Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, has taken initiative to promote the digitalization of agriculture. The Centre of excellence for Digital Farming solutions for Enhancing Productivity by Robots, Drones and AGV's (DFSRDA) under Centre for Advanced Agricultural Science and Technology (CAAST) has been established under World Bank sponsored National Agricultural Higher Education Project (NAHEP) of Indian Council of Agricultural Research (ICAR), New Delhi, Government of India, since 2019.

The main objective of the centre is to train PG and Ph.D. students and faculties about advances in digital technologies i.e. new age technologies useful for agriculture sector. Overall, the project aims to establish an advanced basic engineering hardware and software setup such as Mechatronics, CAD/CAM/CAE, 3-D Printers and Instrumentation Laboratories for Agribots, Agri-drones and Agri-AGVs, so that a holistic model can be developed to raise the standard of current agricultural education system that provides more jobs and entrepreneurship development among the youth and on par with the global agriculture education standards.

The centre of excellence creates an advanced Digital Laboratories for students, faculty, and entrepreneurs to obtain a chain of knowledge to get the farming productivity solutions with the help of Agri-bot, Agro-drones, and Agri-AGVs (Automated Guided Vehicles) devices in four portfolio such as Climate based Digital Knowledge Support (CDKS), Centre Seed / Seedling Processing & Nursery (SSPN), Centre Smart Portable Machines (SPM) and Centre Food Processing Automation (FPA) Centre. With the help of these four functional areas, easy and necessary digital equipment for farmers is being developed in NAHEP. Undergraduate, Postgraduate and Ph.D. students as well as researchers are being helped in their research work with the help of this project.

Various activities are being implemented under this project involving students, scientists and farmers with the help of CAD/CAM, advanced instrumentation, modern workshop, robot, drone and mechatronics. More than 30 trainings were conducted to familiarize the students and faculty with digital technology. Scientists and Professors from different countries guided in this training. The MoUs has been signed for collaborative efforts regarding digital agriculture with many reputed national and international institutes including US universities and IIT-Kharagpur, and IIT-Mumbai.

Automatic Weather Station at VNMKV, Parbhani

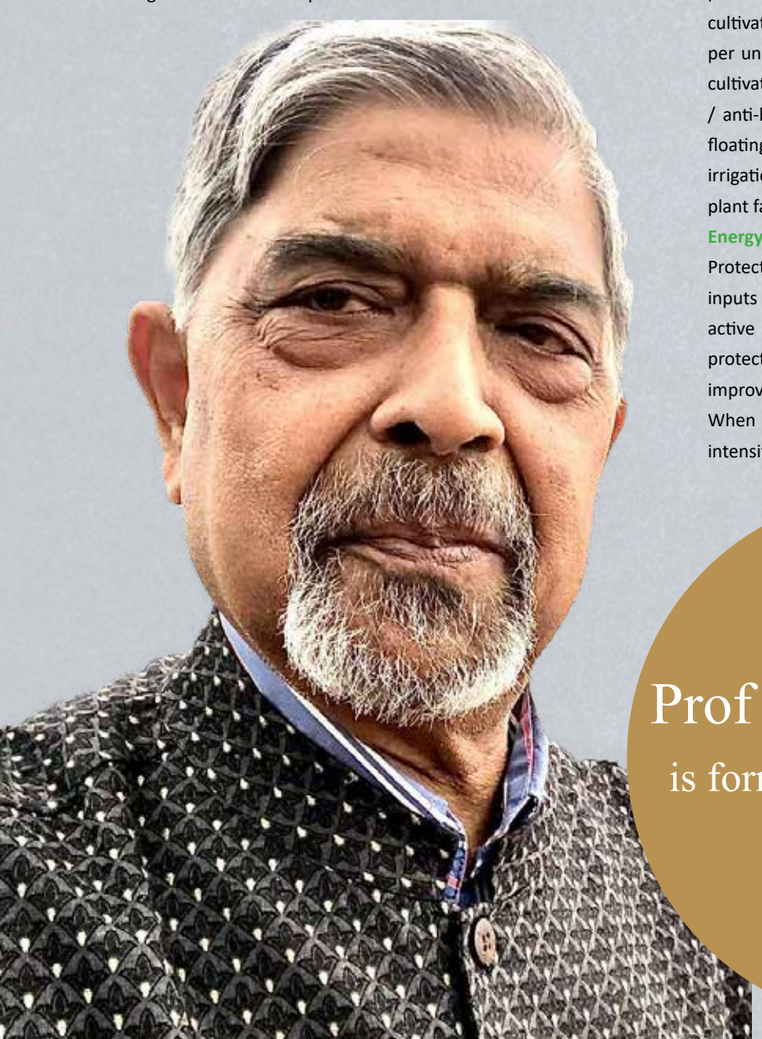
Prof. Indra Mani
is Vice-Chancellor, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra

> "Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani has taken initiative to promote digitalization of agriculture

Protected Farming The Wise Choice

Agriculture mechanization leads to conservation of inputs, timeliness of farm operations, Minimization of drudgery, higher productivity, and higher profitability.

Innovations such as precision agriculture and artificial intelligence; vertical farming; automation and robotics in crop, animal, and fish cultivation, have the potential to attract youth and achieve sustainable production irrespective of climatic aberrations. Farm automation, often associated with "smart farming", is technology that makes farms more efficient and automates the crop and livestock production activities. Integration of these technological developments with the traditional agriculture should lead to more efficient and profitable agricultural and food production in future.



One such innovation is Protected Cultivation that has the potential to overcome most shortcomings of traditional agriculture. Protected cultivation is the application of a wide range of new and emerging Controlled Environment Agriculture (CEA) technologies in agriculture with a view to enhance the production, productivity, and sustained availability of the intended commodity. India began to harness the benefits of protected cultivation in late 1980s.

Multiple Benefits

Protected cultivation allows the raising of plants, unlike open field cultivation, anywhere at any time of the year. Crop productivity is greatly improved in comparison to the open-field cultivation, and it is possible to be maximized per unit area, per unit time, per unit input, and per unit volume. Protected cultivation includes one or more of the windbreak, anti-hail / anti-bird nets, cloches, mulching, row covers/ low tunnels, floating row covers, shade net-houses, drip irrigation, sprinkler irrigation, hydroponics, aeroponics, aquaculture, geoponics, plant factories, agri-cube technologies.

Energy Sustainability

Protected cultivation is energy intensive on account of inputs of plastics, greenhouse structure, and greenhouse active environmental control. This additional energy input in protected cultivation is offset through the savings in inputs and improved productivities.

When the energy crisis of 1970s occurred, efforts were intensified to improve energy conservation through

Prof Pitam Chandra
is former Director, ICAR-CIAE, Bhopal

> "Many challenges faced by farmers can be effectively met through the applications of machinery, protected production systems, smart marketing, and circular agricultural economy

greenhouse design and environmental control strategies. In addition, use of renewable energy for greenhouses began to be investigated. The results have been very significant. A single span single film glazed greenhouse would require 99 litre of heating oil per square metre of greenhouse annually for a location experiencing 5000 degree-days of heating. Energy efficiencies were achieved by switching over to multi-span structures, double layer inflated plastic film glazing, use of insulated night curtains, and floor heating. The result was a nine-fold reduction in the heating requirements. Additional reduction can be achieved by solar collection-retrieval system. There have been further developments and innovations to achieve almost complete independence of greenhouses from fossil fuels.

Water Footprint

Application of hydroponics in conjunction with greenhouse environment pays high dividends in terms of resource use. A tomato crop could be successfully raised with just 9.2 litre water per kilogram of tomatoes whereas 100 litre of water is required under drip irrigated open field crop. Traditional tomato crop with flood irrigation would perhaps need 300 litre / kg. For lettuce, water requirements could be just 4.0-5.5 litre per head in a greenhouse as compared to 600-1800 litre under open field irrigation (without drip irrigation).

Assuming that the lettuce head in the open field cultivation weighs 0.9 kg and 45000 heads are produced per ha (Average 4.5 heads / m2), the lettuce yield is 41 tonne / ha. In a greenhouse 22 plants/ m2 are produced and 24 crops can be taken in a year. Lettuce heads in greenhouses are harvested at the stage of 140-225 g/heads. If each head weighs just 160 g and the space utilization is only 50%, lettuce productivity is 420 tonne /ha for Field. Clearly, less land is required due to 10 – 11 times more production per sqm per year in a greenhouse as compared to open field cultivation. Besides, there is no need for 'quality' land.

Amount of produce per unit of input increases as the level of technology increases. For instance, 43 kg of sweet pepper can be produced with 1000 litre of water in a modern greenhouse, while 13 kg can be produced in a plastic greenhouse and 3 kg in the open field.

Environmental Sustainability

While all protected cultivation practices have the capability to improve the environmental sustainability of agricultural and food production, the following could be emphasized in case of greenhouse cultivation.

> Zero erosion base: soil conservation practices eliminate erosion around greenhouse enclosures/structures; crops are grown within containers

> Zero nutrient runoff: all plant nutrients applied to the crops are contained, recycled or reused

> Zero pesticide: pest control by IPM (Integrated Pest Management) without need for chemical pesticides

> Zero herbicide: weed control by exclusion with no need for chemical weed killers

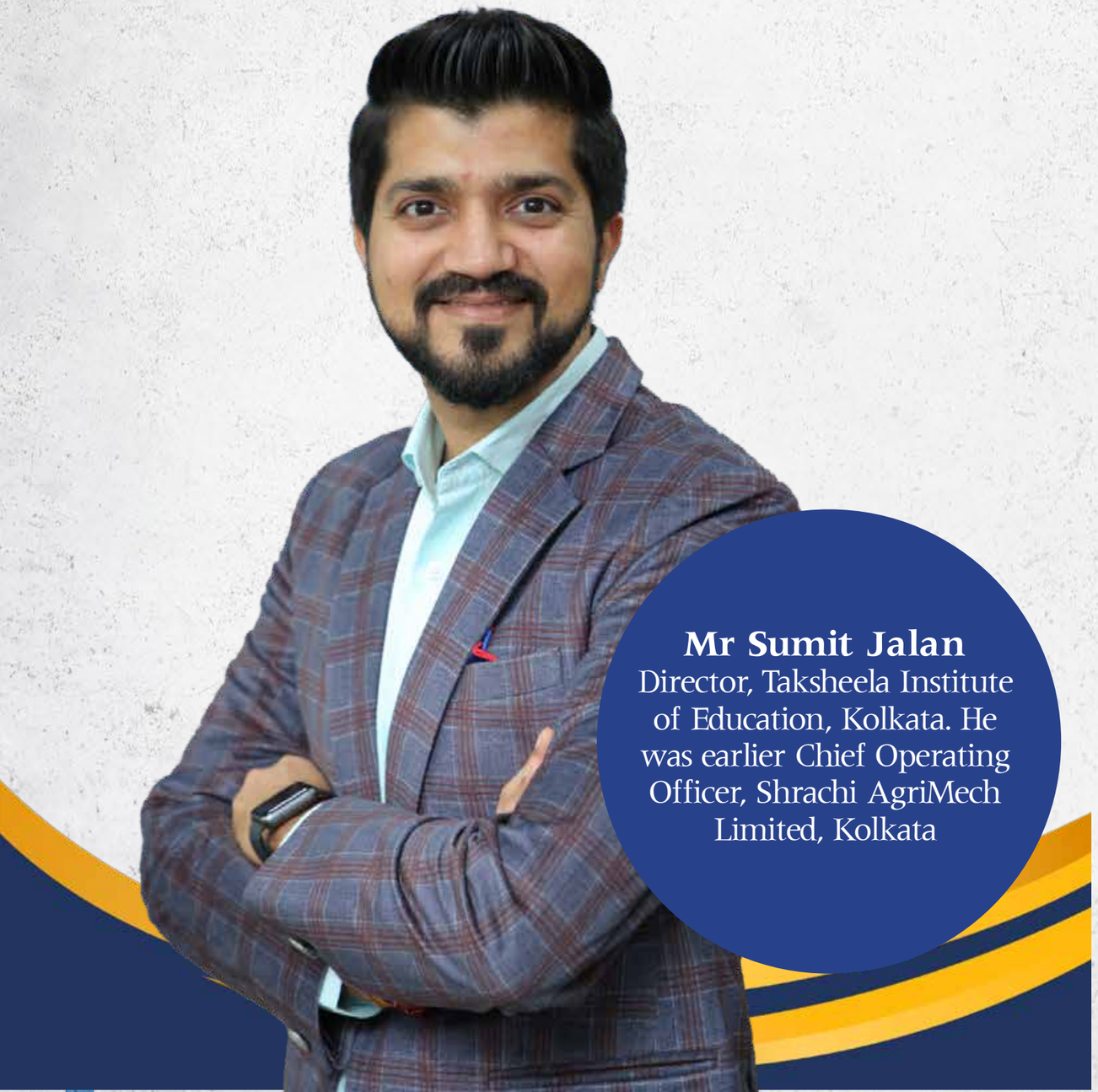
Eliminates soil-borne diseases: disease control by exclusion and by IPM without need for chemical pesticides.

Efforts continue to be made regarding modernization of structures of greenhouse, energy saving technologies using growth and automation devices, as well as renewable energy, and development of Smart farm utilizing ICT. Besides, protected cultivation in integrated mode has the best possibility of assimilation with circular economy. Therefore, protected cultivation continues to be highly relevant. Clearly, protected cultivation enjoys a great future to meet the food requirements of the people in a sustainable way.

The Road Ahead

There are innumerable challenges that agriculture faces today. These challenges could be effectively met through the applications of machinery, protected production systems, smart marketing, and circular agricultural economy. In addition, S&T advancements are on the horizon to completely transform the present-day open field and protected agricultural production practices to industrial manufacturing. Future of farms is indeed exciting.

Smart Mechanisation The Way Ahead



Mr Sumit Jalan
Director, Taksheela Institute of Education, Kolkata. He was earlier Chief Operating Officer, Shrachi AgriMech Limited, Kolkata

Indian agriculture has a deep-rooted connection with traditional farming practices, which are often inefficient and struggle to meet the increasing food demands of the growing population. Smart mechanisation offers transformative solutions, integrating advanced technology to automate food production while enhancing productivity and sustainability. With the adoption of smart machinery, agriculture can not only address labour shortages but also empower women and attract the younger generation, transforming the field into a more profitable and appealing career choice.

The Need for Smart Mechanisation

Smart mechanisation encompasses a wide array of technological tools, including precision agriculture, automated machinery, and data-driven decision-making systems. Precision agriculture, which relies on data analytics and geographic information systems (GIS), optimises the application of water, nutrients, and pest control to improve crop yields. AI-powered machinery, such as drones and robotic harvesters, increases the efficiency of farming operations by reducing dependence on manual labour while boosting productivity. The Internet of Things (IoT) devices offer real-time monitoring of crops, providing valuable insights into crop health and environmental conditions.

These advancements can have a significant impact on small-scale farmers, who often face difficulties in adopting modern practices due to limited resources. By making smart mechanisation more affordable and accessible, we can bridge the gap between small and large farming operations, enabling all farmers to increase productivity and profitability. In addition, smart mechanisation promotes social equity by creating opportunities for women and marginalised groups to participate in agriculture as a sustainable business venture.

The Future of Farming: Smart Farming Solutions

Smart farming solutions integrate technology throughout the entire crop production cycle, enhancing decision-making, reducing waste, and promoting sustainability. Key applications of smart farming in Indian agriculture include:

1. IoT-based Custom Hiring: Custom hiring allows small-scale farmers to rent advanced machinery and equipment without the high costs of ownership. IoT-enabled sensors installed in tractors and harvesters bring transparency to the lending process by providing detailed data on usage, fuel consumption, and operator costs. This transparency can lead to fairer lending rates for small and marginal farmers, reducing their operational costs in the preparation and harvesting stages of crop production. Companies like Carnot, Trringo, RoboFarm, AgroStar, and Intello Labs are leading the way in IoT-based custom hiring solutions.

2. Agri-Drones: Drones have become an essential tool in modern agriculture, performing tasks like seed broadcasting, irrigation, and pesticide spraying. Equipped with 3D cameras, thermal imaging, and multispectral sensors, drones assess crop health, monitor plant density, and detect diseases. These drones can provide critical insights into fertiliser application, water mapping, and pest control, making them invaluable for efficient crop management. Some notable agri-drone manufacturers in India include General Aeronautics, IdeaForge, IoTech World, Kisan Drones, and Asteria Aerospace.

3. Big Data: Big data is revolutionising farming by enabling farmers to make data-driven decisions. By gathering vast amounts of information through IoT sensors, drones, and satellite imagery, farmers can gain a deeper understanding of soil health, crop conditions, and environmental factors. Predictive analytics help forecast yields, optimise resource use, and provide early warnings of pest or disease outbreaks. Companies like Fasal, Ninjacart, CropIn Technology Solutions, Earth Analytics, and Aibono are harnessing the power of big data to drive precision farming in India.

4. Blockchain: Blockchain technology enhances precision farming by providing transparency and traceability throughout the agricultural supply chain. It enables real-time tracking of products from farm to consumer, improving food safety and quality. Smart contracts automate transactions, ensuring timely payments and reducing administrative burdens. Blockchain also allows secure data sharing among stakeholders, fostering collaboration and improving decision-making. Companies like AgriDigital, Intello Labs, FarmLink, and CropIn are leveraging blockchain to create a more efficient and resilient farming ecosystem.

Challenges and Solutions for Precision Farming in India

The integration of precision farming technologies across India faces several challenges, which can be mitigated through targeted policies, technological innovation, and education:

1. Awareness and Education: Precision farming is still relatively new to many Indian farmers. To increase adoption, regular workshops should be held in rural areas to introduce these technologies and demonstrate their benefits. Using local media outlets, including radio and television, to share success stories can also raise awareness.

2. Affordability: The high upfront cost of precision farming equipment is a major barrier for small farmers. Government subsidies, low-interest loans through agricultural funds, and the promotion of equipment rental services can help make these technologies more affordable.

3. Data Management and Interpretation: Farmers need user-friendly software that turns complex data into actionable insights. Mobile platforms offering localised advice based on real-time farm data can empower farmers to make informed decisions.

4. Cultural Resistance: Many farmers are hesitant to adopt new technologies. Engaging respected local leaders and encouraging successful early adopters to share their experiences can help overcome this resistance.

5. Public-Private Partnerships: Collaboration between government bodies, private companies, and research institutions is key to driving innovation in precision agriculture. Investment in research and development, along with grant opportunities, can accelerate the advancement of smart farming technologies.

Conclusion

The future of Indian agriculture lies in embracing smart mechanisation and precision farming. By leveraging IoT, AI, big data, and blockchain, Indian farmers can overcome the challenges of labour shortages, low productivity, and resource inefficiency. These innovations hold the potential to make farming more profitable, sustainable, and inclusive, ensuring that India's agricultural sector thrives in the coming decades.

> Smart farming solutions integrate technology throughout the entire crop production cycle, enhancing decision-making, reducing waste, and promoting sustainability

Farm mechanization Catalyst For Growth

The Indian agricultural machinery market is estimated at US$16.73 billion in 2024 and projected to reach US$25.15 billion by 2029. Major growth drivers include favorable government policies, rising farm incomes, and the imperative role of mechanization.

Anticipated trends include rising global food demand, increased mechanization and automation, adoption of smart farming solutions, sustainable agriculture initiatives, and precision agriculture, making the sector more investment friendly. Key trends in the forecast period involve collaboration, labor scarcity and efficiency, customization, climate change adaptation, and IoT sensor adoption.

Rise of Mechanization in Agriculture

Mechanization in agriculture is not a novel concept. Since the advent of the Industrial Revolution, machinery has played a crucial role in enhancing productivity and efficiency. However, the next decade promises unprecedented advancements in agricultural mechanization, driven by AI, robotics, and IoT.

- **Financial Support and Incentives:** Offering targeted subsidies or financial incentives to farmers, particularly small and marginal ones, for purchasing machinery. Encouraging financial institutions to provide affordable credit facilities for acquiring farm equipment.
- **Indigenous Solutions and Innovation:** Focusing on research and development to create machinery suited to Indian conditions, crops, and farm sizes. Enhancing the 'Make in India' initiative to develop cost-effective, durable, and locally relevant farm machinery.
- **Infrastructure Development:** Improving rural roads and connectivity to ensure the smooth transportation of machinery. Expanding reliable electricity access in rural areas to support electric-powered machinery, and promoting solar-powered solutions to address energy challenges.
- **Collaboration with the Private Sector:** Partnering with private companies and start-ups focused on mechanization and precision farming technologies like GPS-guided tractors, drones, and sensor-based systems. Supporting the development of affordable technology tailored to small plots and exploring cooperative models for machinery sharing.
- **Policy Reforms:** Revising trade policies to prevent the import of low-quality machinery while promoting domestic manufacturing. Providing tax incentives and grants for companies investing in research and development for farm equipment.
- **Promotion of Agri-Entrepreneurship:** Encouraging youth to enter the agri-mechanization sector as service providers. Establishing skill development institutes focused on training technicians in the repair and maintenance of farm machinery.
- **Monitoring and Evaluation:** Regularly assessing the impact of mechanization programs to identify gaps and refine strategies. Using data analytics to track adoption rates, challenges, and successes to inform policy decisions.

Sustainability Through Smart Farming

As concerns about climate change and environmental degradation grow, sustainable farming practices will become imperative. Smart farms, equipped with advanced mechanization, will play a pivotal role in promoting sustainability.

1. Water Conservation: Water scarcity is a pressing issue in many parts of the world. Smart irrigation systems will use IoT sensors to monitor soil moisture and weather conditions, applying water only when necessary. This precision watering will minimize water usage, reduce runoff, and enhance crop health.

2. Reduced Chemical Use: Smart farms will employ targeted pest management strategies. Drones and ground-based robots will apply pesticides and fertilizers only where needed, based on real-time data. This approach will reduce the overall use of chemicals, mitigating their impact on the environment and human health.

3. Renewable Energy: By 2029, many smart farms will harness renewable energy sources such as solar and wind power to operate machinery and power IoT devices. This shift towards clean energy will reduce the carbon footprint of farming operations and contribute to the fight against climate change.

Economic and Social Impact

The mechanization of smart farms will have far-reaching economic and social implications. While the initial investment in advanced machinery and technology may be substantial, the long-term benefits will outweigh the costs.

1. Increased Productivity: Adoption of mechanization and precision agriculture will lead to higher crop yields and more efficient use of resources. This increase in productivity will help meet the growing global food demand, ensuring food security for the burgeoning population.

2. Job Transformation: The rise of smart farms will shift the agricultural labour market. While some traditional farming jobs may decline, new opportunities will emerge in the fields of agronomy, data analysis, and agricultural technology. Farmers will need to acquire new skills to manage and maintain advanced machinery and interpret complex data.

3.Rural Development: Smart farming can drive economic development in rural areas. By increasing productivity and creating new job opportunities, smart farms can boost local economies and improve the quality of life for rural communities.

Challenges and the Path Forward

Despite the promising prospects, the transition to smart farming with advanced mechanization by 2029 will face several challenges.

1. High Initial Costs: The cost of acquiring and implementing advanced machinery and technology may be prohibitive for small-scale farmers. Governments and organizations will need to provide financial support and incentives to facilitate this transition.

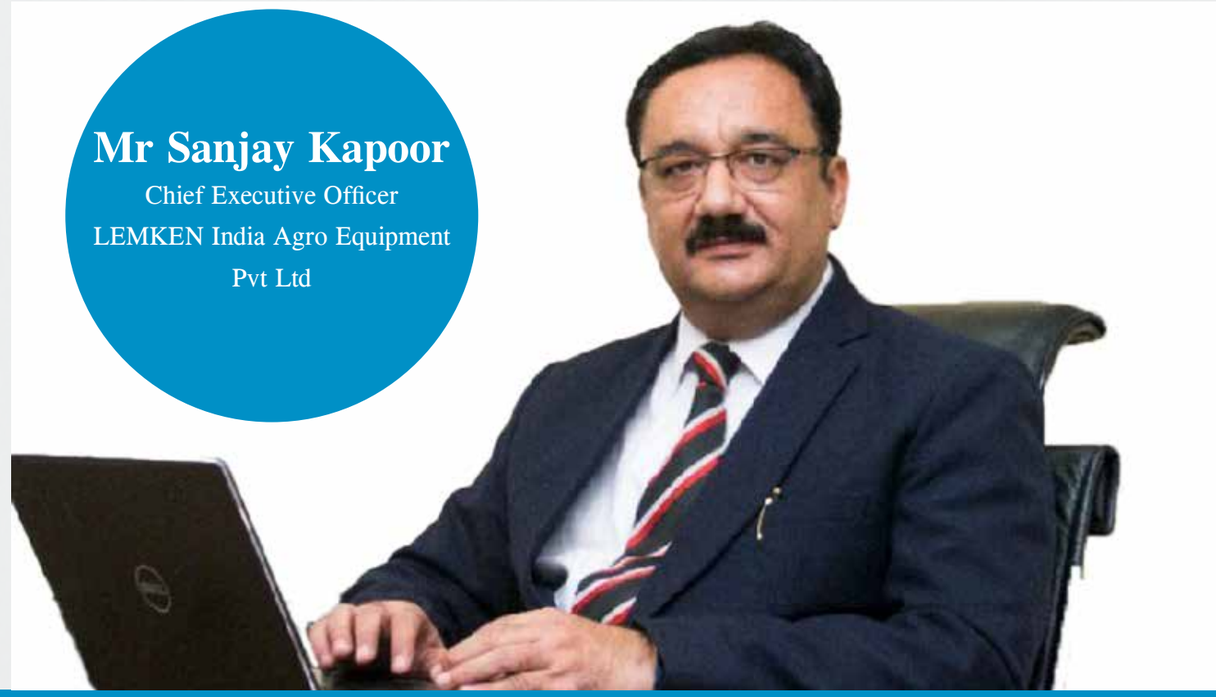
2. Technological Barriers: The successful implementation of smart farming requires robust internet connectivity and technological infrastructure, which may be lacking in remote rural areas. Investments in digital infrastructure will be crucial to ensure the widespread adoption of smart farming practices.

3. Knowledge and Training: Farmers will need to be educated and trained to use new technologies effectively. Extension services, agricultural institutions, and technology providers must collaborate to offer training programs and support to farmers.

Embracing technological innovation in agriculture is essential for a sustainable and prosperous future.

"The integration of mechanization, AI, and IoT will revolutionize agriculture, giving rise to smart farms that are highly efficient, sustainable, and productive

Mr Sanjay Kapoor
Chief Executive Officer
LEMKEN India Agro Equipment Pvt Ltd



Get Prosperity and Progress with STIHL's Agricultural Equipment During Festivals

India is an agrarian country where farmers require the right and quality agricultural tools for every activity related to farming, in addition to crop production. With changing times, farmers are adopting new technologies and equipment to increase productivity and earn better profits. Especially when important festivals like Dussehra and Diwali are approaching, farmers look for new agricultural equipment to ensure the prosperity and growth of their land. During these festivals, when we hope for renewed growth and prosperity, STIHL emerges as a reliable partner for farmers, offering tools built with quality and reliability.

STIHL: A Trusted Partner for Every Farmer

STIHL India, a symbol of German quality and innovation, provides advanced agricultural tools for farmers. These tools are specifically designed to meet the needs of farmers, helping them perform every farming task with ease and efficiency. Whether it's soil preparation, weeding, harvesting crops, or irrigation, STIHL's equipment supports farmers in every task.

Reliable Agricultural Equipment for Progress in Farming During Festivals

Dussehra and Diwali represent the time for new beginnings. This is when farmers aim to increase their land's yield and hope for economic prosperity. STIHL's reliable agricultural tools provide farmers with an opportunity for growth and prosperity in farming during these festivals. The company's equipment is known for its high quality, sturdy construction, and durability. These include power tillers, power weeders, brush cutters, mist blowers, blowers, and water pumps, which make various farming tasks easier and more productive.

Power Tiller: A Reliable Solution for the Proper Care of Soil

STIHL's power tiller, designed specifically for Indian soil structure, is an excellent option for preparing soil in fields. Its lightweight and robust construction make it easy for farmers to use. With the power tiller, farmers can effortlessly prepare land for sowing, applying

fertilizers, and irrigation. This tool offers low fuel consumption and high efficiency, allowing farmers to benefit from better production at a lower cost.

Brush Cutter: An Effective Solution for Harvesting Paddy, Wheat, and Weeds

STIHL's brush cutter is an excellent choice for farmers, enabling them

to easily harvest paddy, wheat, or weeds without any hassle. Its design and lightweight make it highly convenient for working in the fields. Additionally, this machine saves fuel and provides long-term service, allowing farmers to benefit from it in every season.

Water Pump: A Better Option for Transporting Water from Water Sources

STIHL India has launched a new range of petrol-driven water pumps

for farmers, commercial producers, and private users. These pumps are ideal for transporting water from rivers, lakes, wells, and other sources, especially for large-scale irrigation. The range includes three key models:

- WP 300: A 2-inch pump with a 212 cm³ engine, 4.4 kW (6 hp) power, a flow capacity of 37 m³/h, capable of pumping water up to 33 meters.
- WP 600: A 3-inch pump with a flow capacity of 63 m³/h, pumping up to 31 meters, suitable for large irrigation tasks.
- WP 900: A 4-inch pump with a 252 cm³ engine, 5.2 kW (7 hp) power, a flow capacity of 94 m³/h, ideal for large water transport needs.

These pumps are powerful, built to last, and easy to transport. They come with a 2-year warranty, ensuring their long-term reliability.

Petrol-Driven Mist Blowers

STIHL has launched a new range of petrol-driven mist blowers for farmers and large-scale cultivators to improve crop protection,

including the SR 420, SR 450, and SR 5600 models. These mist blowers are particularly useful for fruit, vegetable, and grape crops, offering a horizontal spray range of 11 to 12 meters and a vertical spray range of 10 to 11 meters. The SR 420 model has a 56.5 cm³ engine and a 13-liter container, suitable for pesticide spraying from 30 minutes

to 5 hours, making it easy to cover large areas. The SR 450 is more powerful, with a 63.3 cm³ engine, while the SR 5600 is a lightweight option, with a 56.5 cm³ engine and a weight of 11.2 kilograms, making it easy to use for extended periods.

They are equipped with a comfortable backpack harness, making them easy to carry from one place to another. These blowers produce minimal vibration and require less maintenance. The mist blowers spray with 50-micron-sized droplets, ensuring pesticides stay on the leaves for longer and do not fall to the ground. These are an ideal solution for large areas, featuring ergonomic designs that reduce fatigue and provide long-term use convenience. All models come with a 1-year warranty and can easily switch between spray or dusting modes.

Easy Maintenance and Service Support

STIHL not only sells products but also provides essential accessories like spare parts for their maintenance. The company offers training to farmers on how to use the equipment correctly and provides tips

for proper use. In case of any malfunction in the equipment, the company's service team is always ready to fix it. STIHL dealers and service centers, spread across India, are always available to serve farmers.

Path to Prosperity and Progress

The festivals of Dussehra and Diwali not only bring new opportunities for farmers but also raise their hopes for prosperity and success. STIHL's high-quality agricultural equipment helps farmers not only progress in farming but also reduces their effort. This festive season, embrace STIHL's reliable agricultural tools to bring prosperity and progress to your farming and take it to new heights.

Story of Kalanamak The Best Rice of the World

1.Historical Background

The history of Kalanamak rice is deeply intertwined with the local myths and cultural practices of the region. According to legend, Lord Gautam Buddha, after he received enlightenment, was returning from Bodha Gaya to his father's kingdom in Kapilvastu, he was requested by the villagers of Bajaha jungle (now Bajaha and Mathala villages) to bless them. He then took out a fist of paddy seeds from his bag and asked them to grow these in the lowland. The fragrance of the rice will remind them of Him and the nutritive value as His blessing. This story has not only persisted but has also become a part of the local folklore, enhancing the cultural significance of Kalanamak rice (Chaudhary, 2003,, 2023).

2.Decline of Kalanamak to near extinction

The decline of Kalanamak rice cultivation can be attributed to several socio-economic and technical factors. Basically, there were four major reasons for the decline of the Kalanamak area. First was the advent of High Yielding Varieties (HYV) of rice in 1965, which yielded double Kalanamak. The second reason was the absence of any improved variety of Kalanamak which had become a Land Race and admixture. The third reason was the neglect of Kalanamak by the research and academic institutions. The fourth reason was the loss of aroma and grain quality due to unscientific seed production. The sum of all the factors reduced the Kalanamak area (Table 1).

3.Organized Research on Kalanamak rice

Organized efforts to improve Kalanamak did not start until 1974, though the Department of Agriculture did try to test some Kalanamak germplasm at their research centres. The first organized efforts started at G. B. Pant University of Agriculture and Technology, Pantnagar with the start of Mutation Breeding. Not much could be achieved except getting some mutants of academic interest in Kalanamak. Later Pantnagar did try testing some germplasm of Kalanamak but nothing

Fig,1.Paddy, polished rice of Kalanamak

of use could come out.

3.1.Germplasm Collection and Evaluation of Kalanamak

Before the germplasm collection of Kalanamak was formally started, some preliminary work on inducing mutation in Kalanamak rice was done at G. B. Pant University of Agriculture and Technology, Pantnagar. Funded by UPCAR, germplasm was collected (Chaudhary, 2023).

3.2 Breeding of Kalanamak KN 3

As per procedure, any crop variety to be released for general cultivation in Uttar Pradesh must be tested by the Department of Agriculture at their Regional Agricultural in Testing and Demonstration Stations (RATDS) for three years. Pureline selection of Kalanamak (KN3-27-3 -3) was tested from 2004 to 2007. Based on its superior performance it was released by U. P. State Variety Recommendation Committee in 2007 as Kalanamak KN3. However, it was notified by the Central Sub Committee on Varietal Release and Notification in 2010. KN 3 was the first Kalanamak rice variety developed through Pureline selection and set a historic platform with original aroma and grain quality KN 3 became popular with farmers and will remain popular in the low-lying areas where water stagnates for more than half a meter.

Farmers and consumers realized that the aroma and grain quality of Kalanamak have returned back in KN 3. Since the variety Kalanamak KN3 was released and notified on the proposal of PRDF Gorakhpur, we retain the exclusive right to produce Nucleus Seed and Breeder Seed. Other organizations like National Seeds Corporation, U. P. Beej Vikas Nigam, and others produce Certified Seed of it. A package of practices for the cultivation of Kalanamak was standardized and publicity was done by All India Radio, Door Darshan, in Indian Farming, Kheti, Rice India, and other popular magazines.

3.3 Breeding of Bauna Kalanamak 102

A proposal for the release of Bauna Kalanamak 102 was put up once the U. P. State Variety Release Committee released it in 2017. Bauna Kalanamak 102 was a definite improvement on the grain characters of Bauna Kalanamak 101. That is how it became more popular with the farmers and consumers.

3.4 Breeding of Kalanamak Kiran

Kalanamak Kiran was derived from a cross of KN 3 and Swarna Sub1. The segregating generations were handled by the Pedigree method of breeding and selection. The breeding line was purified as PRDF-2-14-10-1-1 and tested as PRDF-2-14-10 and the pedigree line PRDF-2-14-10 was tested at RATDS of the Department of Agriculture during 2013 – 2016. It stood at first rank with an average yield of 32.95 quintal/ha. It out-yielded the check variety Kalanamak KN3 by 26.58 %. On average PRDF-2-14-10 out-yielded the check variety Kalanamak KN3 by 26.58%. Over the second check variety Lalmati, it out-yielded by 25.23 %. In AICRIP trials as the IET No. 27453 in AICRIP trials, it out-yielded the check variety Kalanamak KN3 by 33.35% across the country. It is semi-dwarf, lodging resistant, and suitable for harvesting by combine harvester. On the date of the planting trial, it was established that a seed sown in the -mid-June and transplanted in -mid-July is the best for its performance and yield as it is a highly photoperiod sensitive variety, and inherited from its Kalanamak parent. The resistance to pests and disease is acceptable, as compared to the other varieties of the group.

The grain quality was tested in the Regional Food Analysis and Research Centre (R-FRAC) at Lucknow, and in the Asia Pacific Lab in Singapore. PRDF-2-14-10 has the same black husk, white and aromatic rice grain with excellent cooking quality, as the original Kalanamak KN3. Its aroma content was confirmed by the Indian Institute of Chemical Technology (IICT), Hyderabad through sophisticated tests. Its aroma content was confirmed by the Indian Institute of Chemical Technology (IICT), Hyderabad confirmed its aroma equal to KN3. Kalanamak Kiran has the same level of Iron and Zinc as its original parent Kalanamak KN3.

Compared to its 200 cm tall parent KN3, PRDF-2-14-10 (Kalanamak Kiran) is semi-dwarf (height 95 cm (Fig. 2), highly resistant to lodging and shattering, and is suitable for harvesting by combine harvester. PRDF-2-14-10 (Kalanamak Kiran) matures earlier than Kalanamak KN3 by about 10 days. This early maturity enables planting of the following Rabi crop earlier, by 10 days. Therefore, PRDF-2-14-10 was found superior to the checks in all these tests and was recommended for release as Kalanamak Kiran by the U. P. State Variety Release Sub-Committee in its 56th meeting held on 19th May 2017 at Lucknow. Based on the above superior features of PRDF-2-14-10, the U. P. State Variety Release Sub-Committee proposes that PRDF-2-14-10 should be released and notified as Kalanamak Kiran (Table 3) for eastern Uttar Pradesh. It was notified by the Government of India Gazette of India under Gazette No. 3220 (Part II (3) dated 06 08.2019.

4.Key Features of Kalanamak Rice

4.1 Unique grain Quality attributes and pleasant Aroma

Kalanamak rice is distinguished by its unique black husk and white rice (Fig. 3), and greenish kernel if unpolished (Fig.4). With extraordinary fragrance, the name "Kalanamak" is derived from two words: "Kala" meaning black and "Namak" meaning salt. "Kala" referring to the black husk, and "Namak" referring to marshy soils that contain salt. Its palatability is excellent when cultivated in this particular soil. The aromatic quality of Kalanamak rice is one of its most celebrated features. This fragrance is attributed to the presence of a compound called 2-acetyl-1-pyrroline, which is also found in other aromatic rice varieties like Basmati and Jasmine. However, the concentration

Fig. 2. Unpolished Kalanamak rice

of this compound is higher in Kalanamak, making its aroma more pronounced.

The grain size of Kalanamak rice varies from short to medium, and it has a high elongation ratio when cooked. This means that the rice grains expand significantly upon cooking, resulting in a fluffy and soft texture. The combination of its unique fragrance, texture, and mouth feel is the unique quality of Kalanamak. Kalanamak rice is a gourmet product, often sought after by connoisseurs of fine foods. The rice's aroma is so distinctive that it has been described in historical texts and local folklore as capable of attracting herds of deer from the jungle. This legend is not only a testament to its fragrance but also highlights the cultural importance of Kalanamak rice in the region.

4.2Nutritional Properties

Kalanamak rice is not only prized for its aromatic qualities but also for its nutritional benefits. Studies have shown that Kalanamak rice is rich in micronutrients such as iron and zinc, which are essential for human health. The iron content in Kalanamak rice is significantly higher compared to other rice varieties, making it beneficial for preventing anaemia and other iron-deficiency disorders. The zinc content is also noteworthy, contributing to the rice's role in boosting the immune system and supporting metabolic functions (Table 4).

In addition to its micronutrient content, Kalanamak rice has a higher protein content than many common rice varieties. It contains about 11% protein, which is nearly double that of Basmati. This makes it a valuable food source, particularly in regions where protein intake might be limited. The rice also has a low glycemic index (GI), ranging between 49% and 52%, making it suitable for people with diabetes as it does not cause a rapid spike in blood sugar levels.

The rice is also rich in antioxidants, which help in combating oxidative stress in the body. These antioxidants are crucial for preventing chronic diseases and promoting overall health. The presence of beta-carotene in Kalanamak rice, which is not found in many other rice varieties, adds to its nutritional profile by providing Vitamin A, important for

Fig. 3.Kalanamak KN 3 (2m tall)

vision and immune function (Chaudhary, 2022, 2023). The nutritional benefits of Kalanamak rice, highlight its superiority and value as a heritage crop variety (Table 3, 4, 5).

4.3Comparison with Other Rice Varieties

When compared to other popular rice varieties, such as Basmati, Kalanamak rice holds its own due to its unique qualities. Basmati rice, known for its long grains and distinctive aroma, is often used in Indian and Middle Eastern cuisines. Jasmine rice, another aromatic variety, is popular in Southeast Asia. While both these varieties are highly regarded for their flavour and texture, Kalanamak rice surpasses them. Firstly, the fragrance of Kalanamak rice is stronger and more lingering than that of Basmati or Jasmine. The higher concentration of 2-acetyl-1-pyrroline in Kalanamak rice gives it a more robust aroma. Secondly, the nutritional content of Kalanamak rice, particularly its higher levels of iron and zinc, provides health benefits that are not as prominent

in Basmati or Jasmine rice. Besides Kalanamak has a good amount of Vitamin A in the form of Beta Carotene. The quantity is more than that of Golden rice (Chaudhary, 2023).

In terms of texture, Kalanamak rice is softer and fluffier when cooked, compared to the slightly firmer texture of Basmati. This makes it suitable for a variety of dishes, from simple boiled rice to more elaborate preparations. The elongation ratio of Kalanamak rice, although significant, is not as high as that of Basmati, which makes it less prone to breaking during cooking, thus retaining its shape and integrity better.

Economic factors also played a role in the decline. The lack of market support and the absence of premium pricing for Kalanamak rice made it less attractive for farmers. Over time, the focus shifted to more commercially viable varieties, leading to the near extinction of Kalanamak rice by the 1990s.

4.4 Geographic Indication (GI) Tag

In recognition of its unique qualities and historical significance, Kalanamak rice was awarded the Geographic Indication (GI) tag in 2013. This GI tag has been given for its association with 11 districts - Siddharthnagar, Kushinagar, Maharajganj, Gorakhpur, Bahraich, Balrampur, Basti, Deoria, Gonda, Sant Kabir Nagar, and Shrawasti (Fig. 5). This tag is crucial as it helps in preserving the authenticity of the Kalanamak rice and protecting it from counterfeit products. The GI tag identifies Kalanamak rice with the specific region of Siddharth Nagar and its adjacent districts, thereby ensuring that only rice grown in this area can be marketed under the name 'Kalanamak'.

The GI tag (Fig. 5) awarded to Kalanamak rice in 2010, and valid until 2030 (Fig.6), has also played a crucial role in its revival. The GI tag

Fig. 4. Kalanamak Kiran (0.9m tall)

protects the authenticity of the rice and serves as an inspiration for other regions and products (Chaudhary, 2006, 2016, 2022, 2023).

5.Prosperity of Kalanamak Farmers

Due to poor yield, poor quality, and lesser income as compared to HYV rice, the area under Kalanamak had declined (Table 1). However, now with the availability of a better quality variety of Kalanamak KN3 and high-yielding ones like Bauna Kalanamak 101, 102, and Kalanamak Kiran, those negatives have been annulled. The government announces a Minimum Support Price (MSP) for fine rice of around Rs. 2,020/ per quintal. However, most farmers can't get that rate due to various reasons and are compelled to sell their paddy at lower prices, around Rs. 1,500 per quintal. Compared to that, Kalanamak paddy sells between Rs. 3,500 to Rs. 4,500 /- per quintal. Thus, now Kalanamak farmers are tripling their income. Protocol for producing Organic Kalanamak has been developed that fetches 20 percent higher price. Common rice with an average yield of 40 qtl/ha can give a net profit of Rs.35,500. KN3 and Bauna Kalanamak can give an average yield of 25 and 55 quintals per ha respectively. This amounts to a net profit of Rs. 56,875 for KN3 and for Bauna Kalanamak varieties Rs. 88,750. The net profit thus will be double to triple (Table 6). This should bring prosperity to the farmers of eastern U.P., where Basmati cannot be grown legally due to GI restriction. Production of Organic Kalanamak further benefits organic farmers by as much as Rs. 1,10,000/- per ha, which amounts to tripling the Kalanamak farmers' income (Table 6).

The development of dwarf varieties like Bauna Kalanamak 101, Buna Kalanamak 102, and Kalanamak Kiran has been particularly instrumental in this increase. These varieties are more resistant to lodging and pests, offer higher yields, and are better suited to modern farming techniques. The introduction of these varieties, along with training and support provided by government and non-governmental organizations, has encouraged more farmers to switch to Kalanamak rice cultivation.

The increase in production has also been supported by improved government policies, infrastructure and market access. The establishment of processing and packaging centres, often managed by FPOs, has ensured that the rice is processed and packaged efficiently, maintaining its quality and appeal. Enhanced market access through both traditional and e-commerce platforms has provided farmers with broader markets, ensuring better returns on their produce (Chaudhary, 2003, 2009, 2016, 2022, 20023). Sufficient quantity of Foundation and Breeder Seeds of these varieties are available from PRDF Seeds, D-41, Industrial Area, Khalilabad, Sant Kabir Nagar, Mob. 9415173984.

6.Challenges for Future

6.1 Legal Protection to Kalanamak

The Protection of Plant Varieties and Farmers Rights Act (PPV & FRA) came into being in 2001. The scope and importance of the act is amply clear from its name. This gives the right to farmers to own, retain, sow, re-sow, and sell the seed of their varieties. Accordingly, we at PRDF helped the farmers of Siddharthnagar to get the registration of Kalanamak done under PPV & FRA on 8th April 2009. The registration assures that no individual or organization can steal the rights of the farmers of Kalanamak KN3 rice. It is protected until 30th August 2025. PRDF also helped Kalanamak to get a Geographical Indication (GI) in 2010 covering 11 districts of eastern U. P. (Fig. 4). It expired in 2020 and once again, PRDF helped get the GI protection extended (Fig. 5) until 2030. Geographical Indication of Goods (GI) as the name implies, is an indication, in the form of a name or sign, used on the goods that have a specific geographical origin and possess qualities or a reputation that are due to the place of its origin. This was signed into an Act on 30th December 1999 by the President of India and enacted on 15th September 2003. GI protects the consumer and also safeguards the interests of the producers. The GI is perceived as both an origin and quality indicator because of which the consumer willingly pays a premium price, and producers make a bigger profit that leads to the growth of the regional economy. The importance and benefits of GI have been described will in the publications emanating from PRDF. Looking into all the benefits it would bring to Kalanamak as a commodity and Agro-climatic Zone No. 7 of Uttar Pradesh, its impact can well be imagined. GI for Kalanamak covers 11 districts namely Bahraich, Balrampur, Basti, Deoria, Gonda, Gorakhpur, Kushinagar, Maharajganj, Sant Kabir Nagar, Siddharth Nagar, and Shrawasti, located between Nepal border in the north to Ghaghra river in the south, Bahraich in the west to Deoria in the east (Figs. 4, 5). GI was registered for Kalanamak in August 2010 and published in the GI Journal of the Government of India, is now validated until 2030

6.2 Counterfeit and Adulterated Products

Despite the successful branding and commercialization efforts, Kalanamak rice faces significant challenges related to counterfeit and adulterated products. The high demand and premium pricing of Kalanamak rice have led to the proliferation of fake products in the market. Unscrupulous traders often mix Kalanamak rice with lower-quality varieties, or entirely counterfeit the product, misleading consumers and undermining the brand's reputation. The problem stems from the lack of any regulation to control it.

Efforts to combat counterfeit and adulterated products include the use of advanced technologies such as blockchain and QR code-based traceability systems. These technologies enable consumers to verify the authenticity of Kalanamak rice by scanning codes on the packaging, which provide detailed information about the product's origin, processing, and distribution. Such measures are essential to protect the integrity of the brand and ensure that consumers receive genuine Kalanamak rice.

6.3 Ensuring Authenticity and Quality Control

One of the most significant challenges facing Kalanamak rice is ensuring its authenticity and quality control. The high market value and growing demand for Kalanamak rice have led to an increase in counterfeit and adulterated products. These fake products undermine consumer trust and can severely damage the reputation of this heritage rice.

To combat this, advanced technologies such as blockchain and QR code-based traceability systems can be employed. Blockchain technology can provide a secure and immutable ledger of the entire supply chain, from farm to fork. By using blockchain, every transaction involving Kalanamak rice can be recorded, ensuring transparency and traceability. Consumers can scan QR codes on the packaging to verify the authenticity of the rice, and obtain detailed information about its origin, cultivation practices, and supply chain journey.

In addition to technological solutions, strengthening regulatory frameworks is crucial. Governments and regulatory bodies need to enforce stringent quality control standards and conduct regular inspections to ensure compliance. Certification schemes, such as the GI tag, must be rigorously implemented and monitored to prevent misuse. Public awareness campaigns can educate consumers about the importance of purchasing authentic Kalanamak rice and recognizing counterfeit products. To handle all these issues, the establishment of the Kalanamak Promotion Board has been mooted to the government in 2022. Their decision is long awaited.

Collaboration between stakeholders, including farmers, government agencies, researchers, and businesses, is essential to develop and implement these measures effectively. Creating a robust system of checks and balances will help maintain the integrity of Kalanamak rice and protect it from fraudulent practices.

6.4 Expanding Market Reach

Expanding the market reach of Kalanamak rice involves both domestic and international efforts. While the rebranding as 'Buddha Rice' has been successful in attracting attention, continuous marketing and outreach are necessary to maintain and grow its consumer base. Targeted marketing campaigns that emphasize the unique qualities and historical significance of Kalanamak rice can help attract new customers. Participating in international food exhibitions and trade fairs can also showcase Kalanamak rice to a global audience.

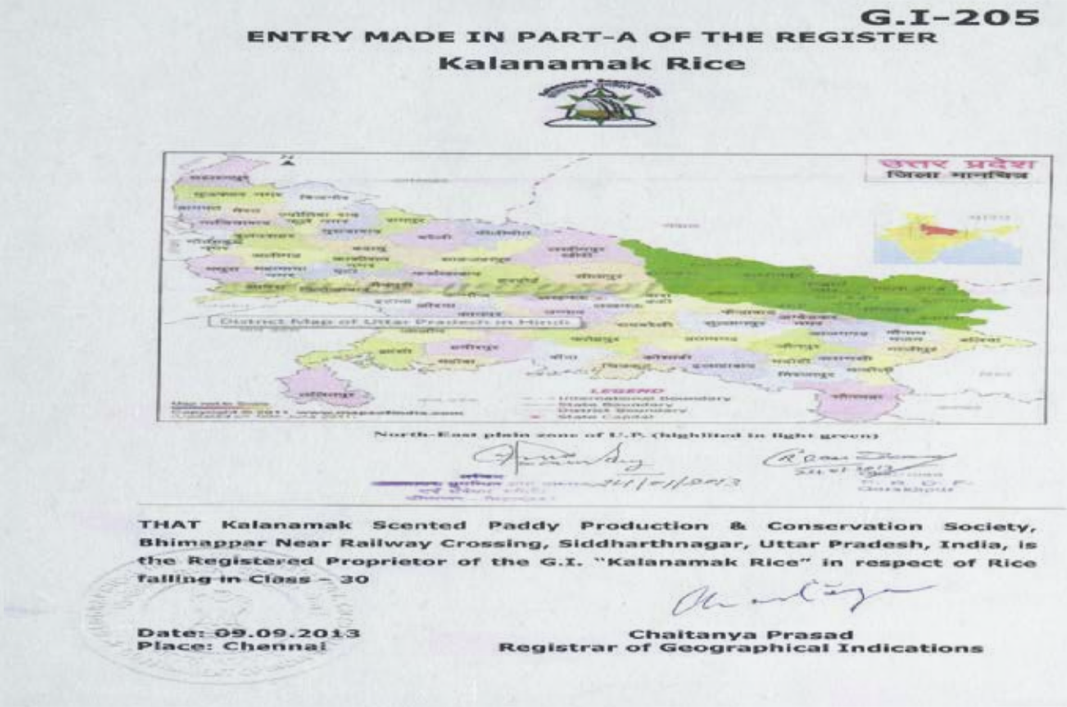
In the domestic market, promoting Kalanamak rice through local and regional festivals, culinary events, and organic food markets can enhance its visibility and appeal. Collaborations with renowned chefs and food bloggers can create a buzz and highlight the rice's exceptional culinary qualities. Developing partnerships with retail chains and specialty stores can ensure that Kalanamak rice is available in premium outlets, catering to health-conscious and gourmet consumers.

7.Summary of the Journey from Extinction to Distinction

Kalanamak rice, often referred to as the 'Buddha rice,' boasts a fascinating journey that intertwines legend, history, and modern agricultural science. This aromatic rice variety, native to the Tarai region of Uttar Pradesh, India, has a storied past linked to Gautam Buddha, who is believed to have bestowed the rice upon the region's farmers. The legend says that Buddha, during his travels, gifted the villagers seeds of Kalanamak rice, blessing them with the promise that the rice would carry a fragrance that would remind them of him. The historical cultivation of Kalanamak rice flourished for centuries, known for its distinct aroma, taste, and health benefits. However, the advent of the Green Revolution in the mid-20th century brought high-yielding, modern rice varieties that overshadowed traditional types like Kalanamak. Farmers began to abandon Kalanamak rice due to its lower yield and the intensive labour required for its cultivation, leading to a drastic decline in its acreage.

The revival of Kalanamak rice began in the late 20th century, spearheaded by dedicated agricultural scientists and supported by government initiatives. Efforts focused on enhancing the rice's agronomic traits while preserving its unique qualities. Dr. Ram Chet Chaudhary's pioneering work in developing improved varieties such as KN3 and dwarf versions like Bauna Kalanamak 101, Bauna Kalanamak102, and Kalanamak Kiran played a crucial role in this revival. These varieties addressed issues of low yield and lodging, making Kalanamak rice more viable for modern agriculture. The Geographical Indication (GI) tag awarded to Kalanamak rice in 2013 marked a significant milestone, protecting its authenticity and boosting its market appeal. Branding initiatives, particularly the rebranding as 'Buddha Rice,' and export efforts under schemes like the One District One Product (ODOP) have expanded its reach to international markets. Farmer Producer Organizations (FPOs) and e-commerce platforms have further facilitated the commercialization and distribution of Kalanamak rice, ensuring better returns for farmers and contributing to the regional economy.

In conclusion, the journey of Kalanamak rice from near extinction to distinction is a powerful example of how traditional knowledge and modern science can come together to create sustainable solutions. By preserving the heritage of Kalanamak rice and promoting innovation, this unique rice variety continues to thrive and contribute to the well-being of farmers, consumers, and the environment. President of India, Mrs. Droupadi Murmu awarded me the second most prestigious award "Padma Shri" in April 2024 for this work.



G.I–205

ENTRY MADE IN PART-A OF THE REGISTER

Kalanamak Rice

North-East plain zone of U.P. (highlited in light green)

THAT Kalanamak Scented Paddy Production & Conservation Society, Bhimappar Near Railway Crossing, Siddharthnagar, Uttar Pradesh, India, is the Registered Proprietor of the G.I. "Kalanamak Rice" in respect of Rice falling in Class – 30

Date: 09.09.2013
Place: Chennai

Chaitanya Prasad
Registrar of Geographical Indications

Fig. 5 Geogrpahical Indication area of Kalanamak rice indicating 11 districts of U.P.

Geographical Indications Registry

Geographical Indications

INTELLECTUAL PROPERTY INDIA

Application Details

Application Number	205
Geographical Indications	Kalanamak Rice
Status	Registered
Applicant Name	Kalanamak Scented Paddy Production & Conservation Society
Applicant Address	Bhimappar Near Railway Crossing, Siddharthnagar, Uttar Pradesh, India
Date of Filing	25-03-2010
Class	30
Goods	Agriculture
Geographical Area	Uttar Pradesh
Priority Country	India
Journal Number	50
Availability Date	07-05-2013
Certificate Number	194
Certificate Date	09-09-2013
Registration Valid Upto	24-03-2030

GI-Logo

Kalanamak Scented Rice
कालानमक सुगंधित धान
Kalanamak Rice

Participatory Rural Development Foundation
Gorakhpur

Fig. 6 Geographical Indication of Kalanamak submitted in 2010 valid till March 2030

Table 1. Area under Kalanamak rice

S.N.	Year	Kalanamak area (ha) estimate	Remark on technology and support
1	1960	50,000	The traditional area under Kalanamak
2	1970	40,000	The traditional area under Kalanamak
3	1980	10,000	Spread of HYV rice
4	1990	2,000	Spread of HYV rice
5	2000	2,000	Spread of HYV rice
6	2010	3,000	Release & Notification of Kalanamak KN3
7	2015	10,000	Release & Demonstration of Kalanamak KN3
8	2016	20,000	Release & Notification of Bauna Kalanamak 101
9	2017	25,000	Release & Notification of Bauna Kalanamak 102
10	2018	35,000	Release & Notification of Bauna Kalanamak 102
11	2019	40,000	Release & Notification of Kalanamak Kiran
12	2020	45,000	Release & Notification of Kalanamak Kiran
13	2021	50,000	Notification of Kalanamak Kiran, Govt. support as FPO, CFC, Mahotsav, exhibitions
14	2022	70,000	Govt. support, inspiration from the President Smt. Droupadi Murmu, PM Sri Narendra Modi and CM Sri Yogi Adityanath, MSME, Dept. Agric. U. P.
15	2023	80,000	Govt. support, inspiration from the President Smt. Droupadi Murmu, PM Sri Narendra Modi and CM Sri Yogi Adityanath, MSME, Dept. Agric. U. P.
16	2024	82,000	Government and strong consumer support

1 R. C. Chaudhary and 2 Pushker Chauhary

1 Chairman, Participatory Rural Development Foundation,
59 Nahar Road, Gorakhpur 273014, U. P., India,
Mob. +919450966091,
Email: ram.chaudhary@gmail.com,
2 CEO, PRDF Seeds, Mob. 9415173984

Table 2. Morpho-agronomic and grain quality characters of Kalanamak Kiran

Morpho-agronomic traits	Description	Grain Traits	Description
Basal leaf sheath colour	Green	Kernel length	5.76 mm
Tillering ability	Medium (20 tiller/hill)	Medium (20 tiller/hill)	2.18 mm
Days to 50% flowering	110 days (Photosensitive)	L/B Ratio	2.64 mm
Days to maturity	135 days (Photosensitive)	Grain type	Medium Slender
Culm angle	Slightly Open (450)	Kernel colour	White
Leaf length	59 cm	1,000-grain weight	15 grams
Leaf width	1.4 cm	Hulling	80 %
Panicle length	31 cm	Milling	75 %
No. of grains/panicles	400	Head rice	70 %
Plant height	95 cm	Alkali value	6 - 7
Aroma in plant	Highly scented	Volume Expansion	4.5 times
Apiculus colour	Brown (tawny)	Gel consistency	80 mm
Awning	Absent	Amylose content	20 %
Lemma, Palea colour	Green – Purple Black	Aroma in grain	Strong
Stigma colour	White	White	Soft, aromatic

Table 3. Grain quality characters of Kalanamak varieties

S. N	Traits	Description of the variety			
		Kalanamak KN3	Bauna Kalanamak 101	Bauna Kalanamak 102	Kalanamak Kiran
1	Method of Breeding	Germplasm / Pureline selection	Hybridization and selection	Hybridization and selection	Hybridization and selection
2	Year of release/ notification	2007 / 2010	2015 / 2016	2016 / 2017	2019 / 2019
3	Published in the Govt. Gazette	No. 1816, (1), August 31, 2010	No. 2771, (23), November 24, 2016	No. 2458, (12), August 29, 2017	No. 2948, (8), September 6, 2019
4	Kernel length	5.76 mm	5.76 mm	5.76 mm	5.76 mm
5	Kernel width	2.18 mm	2.18 mm	2.18 mm	2.18 mm
6	L/B Ratio	2.64 mm	2.64 mm	2.64 mm	2.64 mm
7	Grain type	Medium slender	Medium slender	Medium slender	Medium slender
8	Kernel colour	White	White	White	White
9	1,000-grain weight	15 grams	15 grams	15 grams	15 grams
10	Hulling	80 %	80 %	80 %	80 %
11	Milling	75 %	75 %	75 %	75 %
12	Head rice	70 %	70 %	70 %	70 %
13	Alkali value	6 - 7	6 - 7	6 - 7	6 - 7
14	Volume Expansion Ratio	4.5	4.5	4.5	4.5
15	Gel consistency	80 mm	80 mm	80 mm	80 mm
16	Amylose content	21 %	22 %	22 %	21 %
17	Aroma	Highly aromatic	Aromatic	Highly aromatic	Highly aromatic
18	Iron (ppm) *	4.82	4.35	4.55	4.81
19	Zinc (ppm)*	16.97	14.35	14.55	16.37
20	Protein	10.64 %	10.50 %	10.64 %	10.64 %
21	Beta Carotene**	0.52 mg/100g	0.50 mg/100g	0.52 mg/100g	0.53 mg/100g

All India average of 15 locations from AICRIP trials
*** Analysis done at R-FRAC, Dept. of Horticulture, Govt. of U. P., Lucknow*

Table 4. The nutritional benefits of Kalanamak rice (Source: IRRI – ISAEC, Varanasi)

Nutrients	Quantity per 100g	Health Benefits
Protein	11%	Essential for muscle growth, tissue repair, and enzyme/hormone production.
Iron	3.9 mg (too high conc.)	Vital for the formation of haemoglobin and prevention of anaemia.
Zinc	16.97 ppm	Supports immune function, DNA synthesis, and cell division.
Carbohydrates	68%	Provides a primary source of energy.
Dietary Fibber	3.50%	Aids in digestion and helps maintain bowel health.
Fat	0.50%	Essential for absorbing fat-soluble vitamins and providing energy.
Beta-carotene (brown rice)	0.53 mg (claiming more than golden rice)	Converted to Vitamin A in the body, important for vision and immune function.
Glycemic Index	49-52	A low glycemic index helps in maintaining stable blood sugar levels, making it suitable for diabetics.
Magnesium	25 mg	Important for muscle and nerve function, blood sugar control, and bone health.
Phosphorus	95 mg	Crucial for the formation of bones and teeth, as well as the body's use of carbohydrates and fats.
Vitamin B1 (Thiamine)	0.1 mg	Necessary for glucose metabolism and plays a key role in nerve, muscle, and heart function.
Vitamin B2 (Riboflavin)	0.03 mg	Important for growth, energy production, and the breakdown of fats, drugs, and steroid hormones.
Vitamin B3 (Niacin)	1.6 mg	Helps convert food into energy and is essential for healthy skin, nerves, and digestion.
Vitamin B6 (Pyridoxine)	0.5 mg	Involved in the creation of neurotransmitters and red blood cells, and helps maintain normal brain development and immune system function.

Table 5. Comparative grain quality characters of Kalanamak rice and Basmati rice. (Analysed at R-FRAC, Dept. of Horticulture, Government of U. P., Lucknow)

S.N.	Parameter	Kalanamak	Basmati	Test method
1	Fat %	0.51	0.50	IS12711: 1989 RA2005
2	Protein %	10.6	5.8	IS 7219: 1973 RA
3	Total Ash %	0.32	0.32	FSSAI Manual 2016
4	Iron mg / 100 g	3.0	1.0	FSSAI Manual 2016
5	Zinc mg / 100 g	16.37	4.23	FSSAI Manual 2016
6	Amylose %	18.86	24.50	ICAR – IIRR Hyderabad
7	Glycemic Index	49 – 52 %	80 – 85 %	ICAR – IIRR Hyderabad
8	Vitamin A (ß Carotene)	0.53	0.0	R-FRAC, Lucknow
9	Cooked rice softness	Soft	Hard	

Table 6. Comparative profitability of KN3, Bauna Kalanamak and Common rice, 2022-23

Item	Common rice	Kalanamak KN3	Bauna Kalanamak*	Organic Kalanamak*
Rice area (ha)	9,24,976	5,000	63,000	2,000
Average Yield (qtl/ha)	40	25	35	35
Selling price of paddy (Rs./qtl)	2,020	3,500	3,500	4,000
Gross Profit	80,000	87,500	1,22,500	1,40,000
Cost of Cultivation (Rs./ ha)	44,500	30,625	33,750	30,000
Net profit (Rs./ha)	35,500	56,875	88,750	1,10,000
Incremental income in (Rs/ha)	0	21,375	53,250	74,750

Bauna Kalanamak 101, Bauna Kalanamak 102, Kalanamak Kiran

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