Revolutionizing Indian Agriculture through Innovations in Mechanization & Digitalization

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INTRODUCTION

As the global population continues to grow and the demand for food rises, the agricultural sector faces the challenge of increasing productivity while minimizing resource consumption. In India, a country with a significant agrarian economy, the need to enhance farming practices is of paramount importance. The innovative technologies such as farm mechanization, drones, and robotics has potential to revolutionize farming practices in India. Like other economic sectors, agriculture is increasingly affected by the digital revolution. The use of advanced technologies results in precise matching of agricultural inputs with needs and thus significantly increases profitability. By using technology as a sustainable and scalable resource, agriculture of the country can be taken to new heights, keeping farm to fork in our future. In July, 2021, Honourable Prime Minister addressed chiefs of top 100 technological institutes emphasized that inventions and innovations in agriculture are very important. Agriculture was listed among key

sectors like Defence, Education, Health, climate change and cyber security. He also urged scientists to provide solutions to various issues in agriculture through modern biotechnology, artificial intelligence, block chain technology and drone technology to counter issues like hunger, poverty and malnutrition. Future agriculture will be led by knowledge, technology innovation and skill. In fact, mechanization and automation in agriculture has been one of the top 20 invention of 20th century in the world. Traditional farming practices often rely on manual labor and outdated methods, leading to inefficiencies, resource wastage, and yield variability. The integration of advanced technologies like mechanization, drones, and robotics holds the promise of addressing these challenges and propelling Indian agriculture towards greater productivity and sustainability.

INNOVATIONS IN FARM MECHANIZATION

Agriculture mechanisation is essential for modernising and commercialising the sector since it boosts efficiency and productivity in agricultural operations, supports value addition, lowers cultivation costs, and facilitates adaptation to climate change. In India, agricultural mechanisation is anticipated to expand quickly in light of national driving factors in relation to global driving forces. Therefore, there is no question that mechanisation needs to be improved in order to increase agricultural productivity and stabilise the economy. In light of the existing demand, modern agricultural machinery has enabled farmers to finish seed-to-seed tasks as quickly as possible and even free up equipment

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for special-order hiring by neighbours. However, farm mechanisation in India, at 40-45%, remains low compared to the rest of the world; in the US it is 95%, Brazil 75%, and China 57%. Despite low levels of farm mechanization in India, skills shortages and a lack of awareness among farmers about technology and machinery management pose significant obstacles to progress. A strong focus on integrating science and technology into farm mechanisation would open up new avenues for opportunity and accelerate the development of agricultural mechanisation toward Mechanisation 2.0, which combines automation with the farm mechanisation. The mechanization industry in India has a lot of potential to grow and can play a crucial role in improving the productivity and efficiency of the agriculture sector. The Farm Machinery Industry is an industry sector that produces and supplies a range of machinery, equipment, and tools used in agriculture and farming activities such as ploughing, planting, harvesting, and more. These machines are designed to improve productivity and efficiency in farming operations, and the industry encompasses both small-scale and large-scale farming equipment. However, the industry faces a lot of challenges such as high cost of machinery, lack of awareness, lack of credit facilities, and poor infrastructure. The government, the mechanization industry, and other stakeholders need to work together to overcome these challenges and promote mechanization in agriculture. Following are some of the key interventions for bringing innovations in agricultural mechanization of the country.

- Mapping dynamic changes in agri practices and design agri equipment for all operations.
- Manufacturing operator friendly equipment to minimise farmer anxiety (fear of operator skill requirements).
- Assuring quality and durability of equipment to ensure 'Lower Cost of Ownership' in longer run.
- Developing 'Responsible & Accountable' Service Network.
- Ensuring clusters of eco-system for quick availability of genuine spare parts.
- Tractor industry has about 15000 Dealerships across the country. Leveraging this strong network for 'effective penetration' of agri equipment. These Dealerships to be used as 'Knowledge Spring-Boards' to 'Educate & Demonstrate' the advanced agri equipment.
- Agro chemical manufacturers should engage in 'contractual collaboration' with farmers making advanced crop care equipment available at farmer's doorstep to complete all crop care applications without human intervention.
- The government, SAUs, and corporate sectors can conduct awareness campaigns to educate farmers about the benefits of mechanization. This will help in increasing the demand for machinery and will also create a market for the mechanization industry.
- Tractor training centres, KVKs, and industry should be made responsible for training young farmers / owners / operators on how to select, operate and service farm machinery. They should also provide information on developments in mechanisation including the availability of new and better farm equipment for different applications.
- Front-line demonstration of farm machinery should be strengthened and handheld training to users of new generation farm machinery may encourage the extension and adoption of farm power.
- The Agricultural Skills Council of India should work at the district level to address skills shortages on the demand side.
- The collaborative efforts between government institutes, private companies and farmers groups are necessary to boost the agricultural mechanization. The Custom Hiring Centres of farm machinery may be especially useful, and Indian Council of Agricultural Research (ICAR) institutes and SAUs can offer short courses that address skills shortages on the demand side.

CLIMATE SMART AGRICULTURE THROUGH INNOVATIVE WATER AND ENERGY SAVING INTERVENTIONS

Managing sustainable food production with judicious use of water, energy and land has become a matter of global concern due to environmental security under changing climate. Rainfed agriculture is crucial to the country's economy and food security. In 2022-23, of the 141 million hectares of gross sown area in the country, nearly 73 million hectares, or 52%, had irrigation access, up from 41% in 2016, according to updated data from Niti Aayog. Climate-smart agriculture emphasizes the sustainable management of resources to adapt to climate change while enhancing productivity. Innovative water and energy-saving interventions, such as farm ponds, advanced irrigation techniques, and automation, play a crucial role in ensuring climate resilience. Farm ponds serve as on-

farm water reservoirs, reducing dependency on erratic rainfall and supporting irrigation needs during dry periods.

The VNMKV, Parbhani has developed 56 farm implements, both animal and tractor drawn, for different operations. An innovative farming technique like Broad Bed Furrow (BBF) serves the purpose of in-situ moisture conservation as well as drainage channel if excess water is found apart from providing proper aeration in the seedbed and root zone. Mechanization contributes more in conservation agriculture because of timeliness in farm operations. VNMKV developed multipurpose Broad Bed Furrow (BBF) planter for rainfed agriculture accomplishes bed making, sowing and fertilizer application, seed covering and weedicide application in one go. The newly developed five row BBF planter with sprayer and seed covering device can be recommended for cultivation of soybean, red gram, cotton, maize, sorghum under dryland agriculture.

Machinery powered by non-conventional energy sources are now-a–days also gaining importance looking into the excessive use of fossil fuels and their rising cost as well as harmful emissions. Non-conventional energy sources need to supplement the fossil fuels due to their reliability and sustainability. India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. Solar photovoltaic power can effectively be harnessed providing huge scalability in India. Off-grid decentralized and low-temperature applications will be advantageous from a rural application. VNMKV developed multipurpose solar energy

Broad Bed Furrow Planter developed by VNMKV, Parbhani

cart which supplies power to spraying unit, DC pump and lighting system. The spray boom could be oriented either in horizontal or inverted L shape for spraying row crops of different heights as per need. Such innovative technological solutions using alternate sources of energy need a major focus for eco-friendly crop cultivation.

Furthermore, the University's efforts in water conservation have led to the construction of more than 30,000 farm ponds across Maharashtra, as per recommended designed of VNMKV's specification. The VNMKV, Parbhani, has brought more than 2,500 acres of barren land under breeder seed production. Special efforts have been made to mechanize the seed and research farms of the University and adopted seed-to-seed mechanization. Last year, the University doubled its breeder seed production. VNMKV has constructed six large farm ponds with a total capacity of 9 crore litres to provide supplementary and protective irrigation for breeder seed production and has set a target to construct additional farm ponds with a total capacity of up to 26 crore litres on wasteland.

Advanced irrigation techniques like drip and micro-sprinkler systems minimize water wastage while maximizing efficiency. Automation in irrigation scheduling, driven by AI and sensor-based technologies, ensures optimal water application based on real-time crop requirements. These innovations contribute to sustainable agricultural practices, conserving essential resources and mitigating the impact of climate change on farming.

AGRIPV FOR ENERGY SMART AGRICULTURE

Agri-Photovoltaics (AgriPV) is an innovative approach that integrates solar energy generation with agricultural production, promoting dual land use for sustainability. By strategically placing photovoltaic (PV) panels over farmland, AgriPV enables farmers to harvest solar power while cultivating crops, ensuring efficient resource utilization. This technology not only enhances energy security and reduces carbon emissions but also provides shade, reducing water evaporation and improving crop resilience to extreme weather. As India moves towards sustainable farming practices, AgriPV emerges as a promising solution for balancing food production and renewable energy generation. VNMKV, Parbhani signed

a MoU with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (Germany) for collaborative R & D of Agricultural Photovoltaic (AgriPV) technology. The goal of the research is to devise executable crop cultivation strategies for the selected crops under the different Agrivoltaic structures, that would benefit from the environment created by the solar panels to generate higher yields or higher revenues via shifting the timing of production to off season cycles.

DIGITALIZATION IN AGRICULTURE

Digital Agriculture leverages the smart use of data and generally involves the processes of data creation and analysis, decision making, and implementation through management interventions. These processes are becoming increasingly computational, data-intensive, real-time, and precise. The main Digital Agriculture tools that exist today include cross cutting technologies such as sensors and controllers and computational decision tools. Field-based activities are also enabled by technologies such as geo-locationing, communication (cellular, broadband, and others), geographical information systems (GIS), yield monitors, precision soil sampling, proximal and remote sensing, unmanned aerial vehicles, variable rate technologies and auto-steer, guidance, and robotics. With the country achieving sufficiency in food production, there is an immediate need for the agricultural sector to adopt cutting edge digital and precision agriculture technologies to improve input use efficiency and enhance farmers' profitability by increasing productivity, reducing cost of cultivation and adding value to farm produce. The digital revolution has introduced several emerging technologies that enhance precision and decision-making in agriculture:

- Sensors and IoT: Internet of Things (IoT) devices and sensors monitor soil moisture, temperature, humidity, and crop health, enabling real-time farm management.
- Drones: Agricultural drones assist in precision spraying, crop monitoring, and disease detection, reducing input costs and improving yields.
- Robotics and AI: Robots are used for planting, weeding, and harvesting, while Artificial Intelligence (AI) and Machine Learning (ML) analyze farm data to optimize agricultural practices. The VNMKV has two grafting robots for automated plant grafting. These robots enhance precision and efficiency in grafting operations.
- Machine Learning (ML): Predictive analytics based on ML help farmers in weather forecasting, pest management, and yield prediction.

VNMKV, Parbhani has actively engaged in research and training on digital agriculture, including the use of drones for precision farming

FUTURE FARMING THROUGH DRONE TECHNOLOGY

AgriPV(Agri Photovoltaic) Project for energy smart agriculture

Drone is one such technology that has the potential to revolutionise the farming industry through need-based precise and variable input application leading to input saving, timeliness, reduction in cultivation cost and ensuring farmers' safety from direct exposure to chemicals. Drones have proven to be among the most promising technologies emerging from the fourth industrial revolution. Drones can be used for targeted input application, timely diagnosis of nutrient deficiency, crop health monitoring, rapid assessment of crop yield and crop losses. The drones have capability to fly at low height (1m-3 m) over the crop canopy. This makes them suitable for spraying of crop protection chemicals as well as nutrients and is more adoptable compared to aerial spray. Unlike ground spraying, spraying through drones can be carried out when field conditions prevent movement of wheeled vehicles. It enables the timeliness of spray treatments without inflicting soil compaction.

SCIENCE LED POLICY ON STANDARD OPERATING PROCEDURES (SOPS) FOR DRONE USE IN AGRICULTURE

To promote the use of drone technology in agriculture, the Ministry of Agriculture and Farmers Welfare, Government of India, constituted five national-level committees to develop standard guidelines and Standard Operating Procedures (SOPs) for various agricultural drone applications. The work of the first fifth committees is now complete.

The first committee, chaired by Dr. K. Alagusundaram, Deputy Director General (Agricultural Engineering) at ICAR, and convened by Dr. Indra Mani, Head of the Division of Agricultural Engineering at the Indian Agricultural Research Institute (IARI), this committee developed comprehensive guidelines for the safe, efficient, and environmentally friendly use of drones for pesticide application.

The second committee, chaired by Dr. Indra Mani, focused on drafting SOPs for spraying soil and crop nutrients using drones. It covered aspects such as dosage, application methods, and safety protocols to optimize nutrient management with drones. The Ministry released the Generic SOP for crop spraying with pesticides and nutrients in 2022.

The third committee, chaired by Dr. Ravi Prakash, Plant Protection Adviser at the Central Insecticides Board & Registration Committee (CIB&RC) in Faridabad, developed SOPs for applying crop protection products using drones. This committee developed detailed procedures for drone operation, pesticide application techniques, and safety measures to ensure effective and safe crop protection.

The fourth committee, chaired by Dr. Indra Mani, developed Standard Operating Procedures (SOPs) for the application of pesticides using drones for ten selected crops: rice, maize, cotton, groundnut, pigeon pea, safflower, sesame, soybean, sugarcane, and wheat. These crop-specific SOPs, released by the Ministry in 2023, aim to tailor pesticide application processes to the specific needs of different crops, thereby enhancing pest management's effectiveness and efficiency.

The fifth committee, chaired by Dr. Indra Mani, on the Use of Drones in Various Agricultural Activities Other than Spraying Pesticides and Liquid Fertilizers recently submitted its final report to the Ministry of Agriculture and Farmers Welfare, Government of India.

The crop-specific SOPs were formulated for the application of various pesticides and fungicides via drones, focusing on several key parameters: drone parameters (such as flying speed and height above the crop canopy), sprayer parameters (including nozzle and swath characteristics), crop parameters (such as canopy volume, growth stages, water volume per hectare, pesticide concentration and dosage, and optimal spraying times), and weather conditions (temperature, humidity, and wind speed) tailored to specific locations and climatic zones. Emphasis was placed on achieving optimal bio-efficacy and avoiding

phytotoxicity.

VNMKV INITIATIVE FOR PROMOTION OF DRONE TECHNOLOGY

The University has taken a leading role in promoting the use of digital technology in agriculture, focusing on innovation such as drones, robots, and sensor technology. The VNMKV, Parbhani has singed MoUs with national and international reputed institutes and companies for agricultural research and capacity building regarding advance mechanization viz., Kansas State University, University of Florida, Washington State University, MoU with Rajiv Gandhi Science & Technology Commission, TAFE, CNH (India) Industrial Pvt Ltd, ISRO-SAC, Ahemadabad, CIPHET, Ludhiana, IISR, Lucknow etc.

A six month professional Agri Drone Course has been started by the University, specifically designed to foster skills and entrepreneurship among agricultural graduates, farmers and rural youth. In addition, the university has established a Custom Hiring Centre to provide drone services for insecticide spraying to farmers at a reasonable price. Furthermore, it has collaborated with the drone industry to set up Remote Pilot Training Organization (RPTO) Centre, offering training and drone pilot license facility. A Centre of Excellence (CoE) in Digital and Sustainable Agriculture has been sanctioned from the Dept of Science and Technology, Govt. of India.

CONCLUSION

Innovations in mechanization, drones, and robotics are set to revolutionize Indian agriculture by transforming traditional farming practices into a modern, efficient, and sustainable system. These technologies enhance productivity, resource efficiency, and climate resilience, addressing key challenges faced by farmers. The rapid advancements in digital tools, automation, and precision farming will not only improve agricultural outputs but also attract young professionals, startups, NGOs, and FPOs to the sector, fostering an environment of entrepreneurship and innovation. The integration of advance engineering and technology in agriculture is crucial for achieving sustainability, food security, and economic growth. With strong collaboration among policymakers, researchers, and industry stakeholders, India is making significant strides in agricultural modernization. Coupled with vibrant industry participation and supportive government policies, mechanization and automation are poised to drive India towards the vision of Viksit Bharat @ 2047, ensuring a resilient, productive, and technologically empowered agricultural sector.