Sustainable Agriculture through Innovations in Mechanization, Drones and Robotics

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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. Conquering agricultural challenges need to break through the weakest link of the food chain by using technology, with digitization as a keystone. 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 Traditional farming practices often rely on manual labor and outdated methods, leading to inefficiencies, resource wastage, and yield variability.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 and automation, drones, and robotics holds the promise of addressing these challenges and propelling Indian agriculture towards greater productivity and sustainability.

1. 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 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%. In India, the first tractor was imported in 1914. More tractor were imported later . According to latest data ,India is the largest market in the world . The annual production of tractors in India is over 1.1 million . India started its journey of tractor

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production in 1961 with annual production of 880 tractors. The level of farm mechanization is progressing in India however, skill 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. In fact, world over, mechanization has progressed in three stages; farm operations requiring high energy low skills like tillage get mechanized first. The next those operations which needs medium energy and medium skill like seeding and planting and the third level operation requiring low energy and high skill like cotton picking gets mechanized next. It happened because converting muscle power to mechanical power is easy but skill to automation is very difficult. The mechanization industry in India has a lot of potential to grow and have played 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 spares 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.

2. 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. The challenge is to ensure the economy and social wellbeing of the people particularity those at bottom of pyramid in South Asia and Africa, without violating the planetary resource boundaries. The challenges faced by the world, in general, and India, specifically, in respect of energy, water, and food sectors are increasingly becoming interlinked. Subsequently, strategies for tackling one or the other aspect of this integrated challenge would require consideration of critical aspects of managing supply and demand for energy, water, and food in a manner that ensures security in each of these.

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. Innovative technological solutions using alternate sources of energy need a major focus for eco-friendly crop cultivation.

3. Digital Agriculture : Future Farming Through Drones and Robotics

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. 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. Drone based application in agricultural production system also saves input cost and environment. Due to theses associated advantages, the use of drones in agriculture has increased sharply in recent years worldwide for soil and field analysis, mapping and animal detection, and irrigation, crop spraying and planting. The drone technology has the potential to not only reduce the quantity of the inputs like pesticide, crop nutrients but also save environment and farmers from harmful exposure.It can effectively be used for timely spraying of crop inputs with minimum labour requirements. 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 startups, 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. Lack of standard guidelines for use of drone in agriculture has been a bottleneck in popularizing drone based technologies in India. As the drones are being increasingly used for several agricultural operations, it was essential to develop SOPs that would facilitate application of different types of crop soil and crop nutrients using drones; and harness their potential for successful adoption of soil and crop nutrient spraying. The Standard Operating Procedure (SOP) for use of Drone application for crop protection in agricultural, forestry, non-cropped areas, etc. was released by Ministry of Agriculture and Farmers Welfare (MoA&FW, GoI) in December 2021. The was followed by release of crop specific Standard Operating Procedure (SOP) for the application of pesticides with drones in April, 2023. These SOPs will render guidance to the stakeholders involved in undertaking safe and effective control of pest and diseases by drone-based application.

Not only drone, use of AI in agriculture is also emerging especially in three major categories - agricultural robotics, soil and crop monitoring, and predictive analytics. In many developed countries, farmers are using AI technologies for sowing seeds using drones, soil mapping, and commodity pricing. AI helps bring down the operational costs in farms, by reducing dependence on manual labor and allows agronomic expertise to make data-driven decisions. In India, work on use of AI and robotics for agriculture is at early stage and needs extensive field evaluation for reaping the real benefits of advance technology.

As our population continues to grow, our agricultural methods must grow with it. It is time to take advantage of the technology we have at our disposal to put food on our table and create sigh of relief for our farmers. Youth agripreneurs have a key role to play in the digitalization of the agricultural sector.

There is increased interest in data-enabled farming and related services and many new entrants from the technology industry and start-ups. Vast data collection will drive the use of machine learning and AI and new models will need to be developed to make the data useful.

Conclusion

Innovations in mechanization, drones, and robotics have the potential to revolutionize farming practices in India. By modernizing traditional methods and addressing challenges in agriculture, these technologies can contribute to increased yields, resource efficiency, and sustainability. The journey towards an advanced agricultural sector will require collaboration between policymakers, researchers, and farmers to ensure that these technologies are accessible, affordable, and effectively integrated into India's farming landscape. With the great efforts of research Institutions, vibrant industry and very conducive government policies, agriculture as a whole and mechanization in particular has grown exponentially in the country. Digital tools of mechanization and automation of operations will attract young talented youths, CEOs of startups, professional engaged in NGOs and FPOs towards agriculture which will finally lead to dream agriculture of India 2047.