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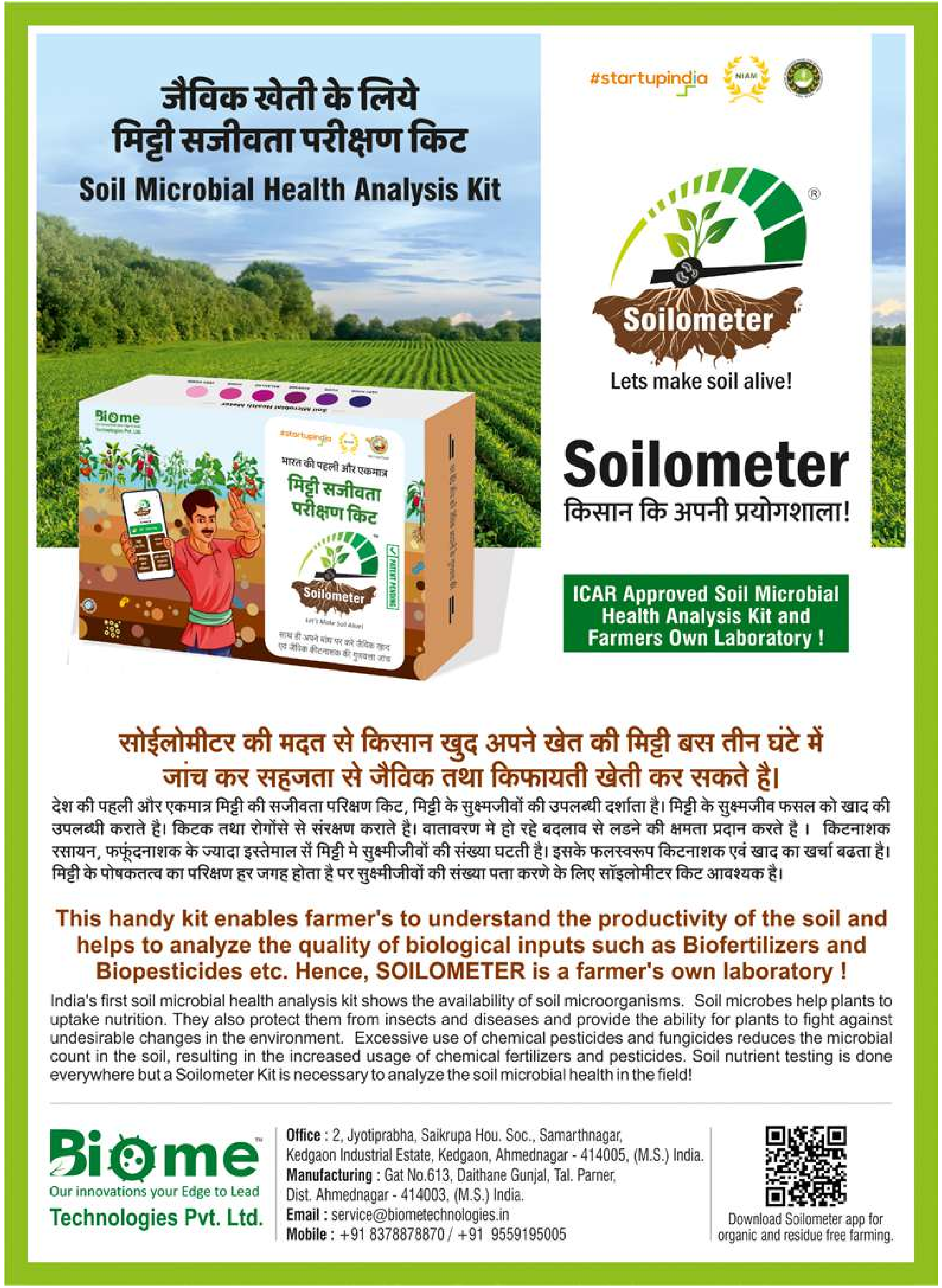
PRECISION AGRICULTURE
... for a smarter tomorrow !!

INDIAN SOCIETY OF AGRICULTURAL ENGINEERS
...Connecting Engineers in Agriculture



From the Editor-in-Chief

Precision Farming... Smart Farming!

Precision Farming refers to the precise application of agricultural inputs with respect to soil,weather and crop need in order to improve productivity, quality, and profitability in agriculture. It is a modern agriculture practice involving the use of technology in agriculture like remote sensing, GPS and GIS for improving productivity and profitability. It enables farmers to use crop inputs more efficiently including pesticides, fertilizers, tillage and irrigation water. More effective utilization of inputs will bring in more crop yield and quality without polluting the environment and will result in sustainable agriculture and sustainable development.

Advantages of precision farming

- Enhance agricultural productivity and prevent soil degradation for sustainability
- Reduce excessive chemical usage in crop production
- Optimization of water consumption
- GPS allows geo-tagging and mapping of agricultural fields, soil characteristics and yield
- Improve quality, quantity and reduced cost of production of crops
- Protect environment by preventing nitrate leaching and groundwater contamination
- Better resource management and hence reduce wastage of resources

How could India benefit from precision farming?

- Refinement and wider application of precision agriculture technologies in India can help in reducing production costs, increasing productivity and better utilization of natural resources.
- It has the ability to revolutionize modern farm management in India through improvement in profitability, productivity, sustainability, crop quality, environmental protection, on-farm quality of life, food safety and rural economic development.
- Site-specific application of irrigation in wheat of Punjab and Haryana, pesticides in cotton and fertilizers applications in oil palm plantation in South India, and coffee and tea garden of eastern India can highly reduce production costs and also reduce environmental loading of chemicals.
- It can increase irrigation efficiency when water resources are low.
- Farmers can use forecast and mitigate problems like water stress, nutrient deficiency, and pests/diseases.
- It also increases opportunities for skilled employment in the agriculture sector

Way Forward

- Low-cost sensors are required to monitor soil nutrients, soil moisture, pests and diseases. Wireless sensors will hold the key to precise nutrient and water applications. Indigenous manufacturing of such sensors needs to be promoted.
- UAVs (Drones) with appropriate sensors be used for a quick survey to identify within field variations in nutrient status, as well as pest infestation for timely action. This is cost-effective and ecofriendly. An appropriate power source for drones, however, needs to be defined.
- Precision Agriculture Service Providers for popularizing and scaling up Precision Farming. The industry, scientists, technologists, academicians, and other stakeholders have to work in unison to develop Decision Support Systems for empowering farmers to take informed decisions in real time.

Happy reading

Manila







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CONTENT

Precision Agriculture – Opportunities & Challenges

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President, ISAE &
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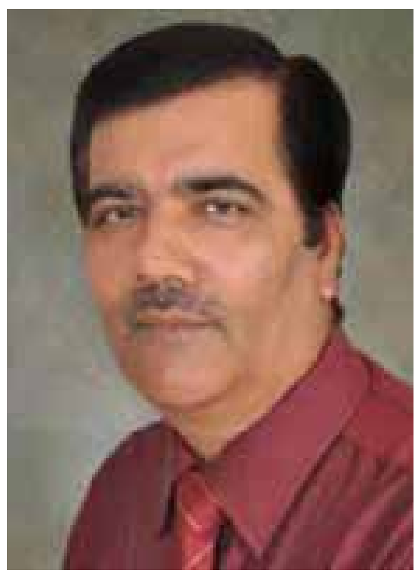
Indian Agriculture is now lesson worthy growth story for the world. It is now feeding the world population not by filling stomach only but also providing nutritional and health securities. Four "Cs" Climate change, Conflict between the nation, and COVID or similar pandemic, and Change in food habits(life styles and willingness of youth for not doing agriculture in the traditional way) are affecting agriculture adversely. Maintaining production and productivity are the challenges. To mitigate these challenges, the advent of precision agriculture occurred about three and half decades ago. It has capacity to increase production, productivity, reduce input costs and increase farmers and all stakeholders' profits substantially. According to study got conducted by the Department of Agriculture and Farmers' Welfare, Govt. of India, mechanization, which is an essential part of precision agriculture,saves 15 – 20 % seeds, fertilizers and 20-30 % time, increases germination by about 25 %, reduces weeds and labour about 20-40 % and enhances cropping intensity by 5-10 % and yield 13 -23 %.



The mechanized agriculture now has turned towards automation and IoT based agriculture and more so in the developed countries under the broad head of precision agriculture. The term precision agriculture is defined in many ways, but the most accepted and appropriate one is that consist of several "R"s of Precision Agriculture. Robert et al. (1994) proposed three "R"s, the Right time, the Right amount and the Right place. Later, the International Plant Nutrition Institute added another "R" to that list, "the Right Source", and more recently, Khosla (2008) proposed an additional "R", the Right manner. For example, in precision nutrient management, "Right manner", refers to the method of placement of nutrient in the soil, (i.e.) broadcast versus banding, dribbling, injecting, etc. The "right manner". The precision agriculture however has become more sophisticated and complex than before because of rapid growth in invention and innovations of new technologies, tools and techniques.

I see great opportunities for both researchers and the precision agricultural techniques adopting communities across the globe. The development and the delivery parts have wide gap in India. Looking the gaps Government of India in last budget announced several schemes such as Kisan drones, Agritech start-ups, centre of excellence of AI in Agriculture etc. These precision practices differ from one place to another place, depending upon the creative mind-set of farmers, practitioners, scientists and consultants local to the area of interest. Several techniques and tools for both pre- and post-production agriculture have been developed (Figs. 1 - 3), however it may require training/calibration and validations for specific work for specific region. Indigenous development of core sensors for such precision tools and machinery are very rare for both pre- and post-production agriculture in the country. Opportunities and requirements of precision agriculture in the country are therefore enormous.

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Precision agriculture holds great promise, yet its uptake is still relatively slow. The adaptation of emergent technology to agricultural practices will allow for optimized farming and budgets to be tightly met with efficient methods of agriculture. However, as this is a new industry there are a number of challenges to be met in the future. For precision farming to meet its potential, these challenges need to be overcome.

Precision Agriculture in our country amongst researchers mostly focuses on five types of techniques: GPS (Global Positioning System), Computers, GIS (Geographic Information System), RS (Remote Sensing) and application control. Besides, the technological innovations available to the modern farmer, they are arial and auto orthomosaic maps,phytogeo morphological approach and prescriptive planting, The Internet of Things, phytobiome, plant phenotyping technological platforms etc. are broadly talked. But all these are hardly having connects with enabling or delivering tools and devices developments. Often digital agriculture, application of IT and statistical tools are misunderstood as precision agriculture, while these may be a small part of developing precision tools and techniques. There are several challenges in developing the precision agriculture tools and their application in our country. Some of them are: 1. Standardizing technologies across platform, 2. Connectivity and compatibility across the tools, devices and machinery. 3. Big and quality data collection, their management and skill of analysis and correct use, 4. Lac of scalability, 5. Lack of trained manpower, 6. Mushrooming precision agriculture apps/digital tools pretending as precision agriculture tool and lack of test their standards and codes, 7. Inadequate indigenous manufacturing, 9. Disjointed efforts between the stakeholders, and 10. Whoever see, all have started talking and working in precision agriculture, that makes real expert in precision agriculture, unnoticed and they hardly get attention. Precision agriculture actually is hard-core engineering job, while others are supportive as per needs. The policy makers and funding agencies should see these aspects before approval for real and accelerated development and adoption of precision agriculture in our country.

Fig. 1. CIAE-Site Specific Chemical sprayer

Fig. 3. Apple harvesting based on maturity using robot in Australia (from website accessed on 9/11/2-23)

Fig. 2. Indigenous hand held mango maturity and ripeness level tester

Pioneering Precision Agriculture

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I. INTRODUCTION

Agriculture is a one of the essential sectors to meet the food, nutritional security of the people and provide livelihood, income in rural areas of India. Issues concerning agriculture have been always hindering the development of the country. The only solution to this problem is precision agriculture by modernizing the current traditional methods of agriculture. Irrigation is a fundamental need for the survival of farmers as it provides water (life blood of crops) to the growing plants and with technologies like drip or sprinkler irrigation farmers can also supply nutrients through water. Plant protection is also possible by adding certain herbicides, fungicides and pesticides through water which can be applied through drip or through sprinkler irrigation methods. India is one of the most water-challenged countries in the world, with 16 percent of the world's population and access to only 4 percent of the world's water resources. With more than 90 percent of the freshwater withdrawals going to agriculture, and following the erratic monsoon and farmer's traditional use of inefficient flood irrigation – including for growing water-hungry crops like paddy, cotton and sugarcane – groundwater levels have fallen

over the years. The water scarcity, decreasing cultivable land, and lower productivity are adding to the woes of the agricultural community in India, and emphasize the need for a change in the sector. Drip irrigation is a technology that delivers to each plant the amount of water and fertilizers that it needs, when it needs and where it needs them. Thus, it enables farmers to double their yields while using only 50% of the water required with traditional irrigation methods and at the same time increases the efficiency of other farm inputs like fertilizers, pesticides, labour etc. India has more than 140 million hectares (Ha) of net cultivated area, and around 45 percent of the area is irrigated. As of now, just about nine million Ha is under micro irrigation, of which drip irrigated area is about four million Ha.

In order to make agriculture smarter, Jain Irrigation Systems Limited is doing extensive research in the area of Precision farming which includes Internet of Things (AgIOT), Remote Sensing, Data Analytics, Machine Learning and Artificial Intelligence.

II. THE OPPORTUNITIES OF PRECISION FARMING

With the global population projected to exceed 9 billion by 2050, it will be critical to optimize agricultural production and food supply chains to more efficiently produce and deliver food, fiber and fuel to meet growing demand. This goal is further complicated by climate change and urbanization. Precision Farming will be an essential component of the second green revolution that will be required to meet these needs.

AgIOT and Machine Learning, which are essential components of precision farming, are already used by many countries and commodity markets for the early detection of disruptions in supply chains for commodity crops such as wheat, rice, corn, and soybean. It further developed with advances in remote sensing data collection, including improved spatial and temporal resolution, spectral resolution, variety of sensor platforms (e.g. satellite, aerial, ground-based), etc. A recent congressional reception also reported that precision agriculture has shown promise in increasing on-farm yields. In addition, there is a potential of increasing farm profits per acre via prescriptive farming that uses predictive modeling to optimize farm management practices ranging from customized seed planting density to fertilizer application based on local soil characteristics and long-range weather forecasts.

Beyond agricultural production, IOT-enabled sensors are being used to track food and generate data of supply chains. Machine learning can also be used to improve supply chain security. For example, spatial data mining techniques (e.g., hotspot detection) can be used with data analytics to identify crops produced in small geographic regions or a set of regions that are vulnerable to climate change and natural disasters. Their supply chain maps can then predict geographic chokepoints of these sensitive crops and animal-based commodities, informing industry and consumers of risks before they hit.

AI can help to generate more business opportunities for ag industries. For example, based on satellite data and weather forecasting or through deep image learning, if there is an alert for specific diseases or pests, or a hotspot is generated, pesticide companies can target that area, deploy their manpower, and make the stock of required chemicals. Which is good for farmers too. He gets assured availability at the right time, he gets better bargaining power. Moreover, he does not need to approach the retailer, he can get this pesticide at his field. This has been tried successfully in Maharashtra where seed material is being supplied to the farmers on their farms. FPO's can play a major role in procurement of such agricultural inputs.

Food processing companies like Jain Irrigation, need to carefully monitor the qualitative and quantitative yields of the agriculture produce they process, Also need to observe the effects of climatological changes on the crop yields. AI is helpful in identification of availability of quality and quantity of produce. It can also help us to monitor the market rate fluctuations. For agri finance companies, it is important to knowthe crop health monitoring, proper information to limit the risk, fast claim settlement on the basis of satellite images.

Similarly, spatial data mining may also help select sustainable sources in a supply-chain. In addition, detailed data on consumer and market behavior can be used to improve food access and nutritional outcomes, and geo-social media can be leveraged for timely detection of food contamination events and control related illnesses.

We envision that Artificial Intelligence will assist decision-making in agriculture at four levels:

Descriptive: For precision agriculture applications, the aim of data collection is to characterize spatial and temporal variability in soil, land cover, crop and weather characteristics and identify stressors, traits, or infectious disease risk factors that need better management.

Prescriptive: Using data collected and associated maps of individual characteristics, traits, or exposures to infectious agents, a prescriptive analysis is conducted to determine necessary farm management interventions.

Predictive: A predictive analysis using historic datasets as well as integrated soil, crop, weather and market models may forecast outcomes such as crop yields and food insecurity. Predictive analytics can also be used to improve decision making to forecast spread and limit the impact of infectious agents on crops and livestock.

Proactive: A proactive level involves observations of crop development and stress on multiple farms over large regions and time scales. Data from these observations are pooled and mined to obtain relationships between site characteristics, weather and crop performance under a range of management conditions. These relationships can be used to customize management practices and seed selection to local conditions.

In all, AI, ML and IOT based precision farming tools will not only be helpful for the farmers to make the right decision at the right time which helps to increase their income but also generates incredible opportunities for ag-companies to sell their product in a better way.

III.INTERVENTIONS IN PRECISION FARMING BY JAIN IRRIGATION

Jain Irrigation stands across the entire value chain in agriculture from farm to fork. We have our presence on the input side, where we supply seeds, tissue culture plants, irrigation systems and pumps. On the farm, where we provide advisory services and on the output side, where we buy back and process fruits, spices, onions and vegetables. Although Precision Farming is a broad concept which includes bringing precision in inputs and agricultural practices for the scope of this article, only few digital agtech solutions are described here.

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Jain Logic - A Decision Support System Platform

Jain Irrigation has developed an advisory platform called 'Jain Logic'. It is an integrated automation solution created to fulfill precise agriculture and irrigation management requirements. It includes monitoring and control devices, software applications, and analytical intelligence for decision support system. Under jain logic we are providing answers to two very important questions in irrigation, when to irrigate? and how much to irrigate?. We provide IOT based soil moisture sensors to users and then using machine learning models we predict the soil moisture movement for the next seven days. User can prescribe the band of soil moisture he wishes to maintain within the effective root zone depth and he gets a proposed irrigation schedule for next seven days.

Resource to Root - A telemetry system for community irrigation projects

We have done several community irrigation projects in which irrigation management at the farm level is managed centrally. We call it the 'Resource to Root' concept. This concept

can help to improve the current average water use efficiency of 35% to 90% by using advanced irrigation techniques like drip irrigation combined with piped distribution networks. 'Water Saving is Water Generation' , this huge saving in water with the help of 'Resource to Root' concept can help the country to bring additional command areas under irrigation. Additional area under agriculture means additional income for the farmers, availability of livelihood within the village itself, which can help to reduce migration.

High quality and quantity yield help to answer the food security issue. These community based irrigation projects are operated through a centralized web based irrigation management system running on IOT and telemetry concept.

IV. CHALLENGES IN ADOPTION OF PRECISION FARMING

While there are opportunities, there are challenges as well.

■ **Accessibility to the Smart Tools:** India is a diversified country. There are linguistic variations, there are multiple agro-climatic zones, soil differs, crop varies hence there can not be one solution that fits all approaches.

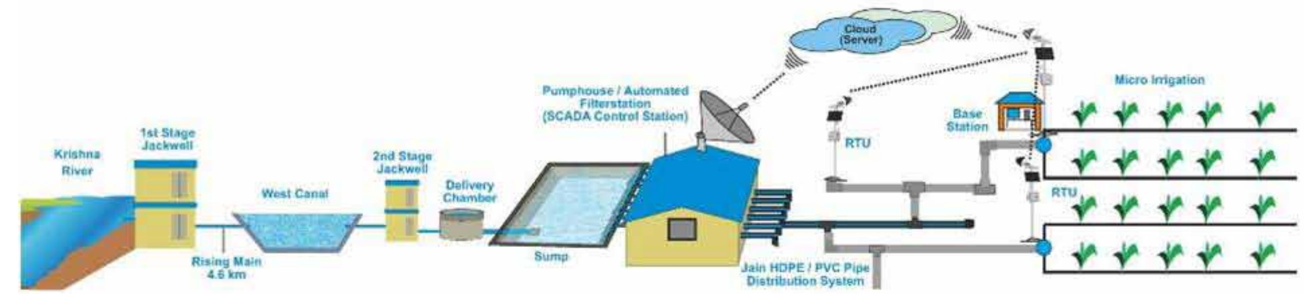
■ **Scalability of the solution -**

This is another issue, in a country where 60 million people are farmers or farm dependents, reaching them is a big challenge. If we wish to penetrate smart agricultural solutions among farmers, the first thing is to gain trust in your solutions. Unfortunately, many solution providers failed to do so, leaving the farmer frustrated and skeptical about these tools.

■ **Liability of the solution -**

Another issue is liability. Is an Agtech entrepreneur ready to take responsibility and liability of his solution on his head? "If your advice doesn't work, what shall I do?" We need to have answers for such basic questions.

Presently there is a wide gap between precision farming tool developers or solution providers and the users or farmers. Even though solutions developed by solution providers are reliable, precise, fitting to the requirements, still sometimes not getting adopted by farmers because of poor understanding of other variables.



For example, if there is advice about the irrigation schedule on the basis of predicted soil moisture, still if the tool has not paid attention for fertigation requirements, farmers may not use it. Or with deep image recognition, the solution provider has given an alert for pest attack but pesticides either are not recommended or not available then such recommendations are of no use.

Solution providers shall consider multiple variables, even some hyperlocal variables to provide the advisory. This requires assistance from a skilled agronomist and farmer himself. Such solutions need time and patience to develop and sometimes become unaffordable. As we talk about accessibility of farmers, in developing countries affordability comes first.

■ **Regulations -**

There is a need for a regulating authority which will scrutinize all agtech solutions before it reaches the farmers. It is observed that sometimes, ag-entrepreneurs or start ups deliver half baked products. It may produce misleading results. We shall not take such risk when such smart solutions to agriculture are at a nascent stage. Farmers in our country work on trust. If this trust is broken, it may leave him frustrated and skeptical.

■ **Communication -**

Communication is a major challenge. For communication, GSM or RF is used. Challenge with GSM is the high recurring cost and poor signal strength in remote field areas.

RF is the better solution but while using RF, in remote areas, sometimes devices are to be placed at distance from the gateway. Green crop coverage, large trees, and undulations are big challenges for using RF. We currently use 865-867 MHz which is delicensed band in India. For agriculture, we need a frequency band which can cover a longer distance. If we want to promote IOT in agriculture, there is a requirement of special delicensed bandwidth reserved for agriculture. It would be better if it is below 450 MHz with at least 1 W power and with an external antenna.

■ **Standardization -**

Each IOT based solution provider has their proprietary communication protocols. If a farmer wants to hook up another sensor with it, it is not possible. We shall think about a common communication protocol which can allow farmers to use any sensor with any gateway. There is an ISO standard ISO 21622 has tried to standardize the protocols. Such standards shall be studied and adopted in India.

■ **Power -**

Power requirement of IOT devices is also a challenge. You have to either use solar power or non-rechargeable battery source.Theft and panel maintenance is an issue with solar panels. With a non rechargeable battery, India does not produce high quality, long life batteries. We are depending mostly on China for this. With the dream of self-reliance India we shall think of manufacturing high quality, long life batteries in India.

■ **Indigenization of the components -**

Our Honorable prime minister stressed on Self-Reliance for the country, Precision farming solutions sometimes require sensors, electronic gateways, batteries etc. presently most of these components are imported which escalates the cost of the system to such a level to make it unaffordable to the farmers. For example a reliable soil moisture sensor priced in the range of 100 to 400 USD (Rs 8000 to 30000), if a farmer needs to use multiple soil moisture sensors in his farm, it is too expensive for him. We as a country shall promote inhouse manufacturing of these components.

A Strategic View Point of Indian Agriculture

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Agriculture is the most essential and noble occupation and farmers deserve our attention and gratitude with each meal that we eat. Agriculture plays a crucial role in the Indian economy and impacts the livelihoods of about two-thirds of the population, directly or indirectly. The importance of agriculture is underestimated when it is viewed from GDP perspective-a mere 15%. In reality, the balance 85% is meaningless and unachievable without food and nutrition sufficiency, that our farmers provide, to build a healthy and productive India.

Transformation of India's food system from a highly deficient one in the mid-1960s to one that is surplus now is commendable. India is now the world's largest producer of milk, pulses and jute, and ranks as the second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton. It is also one of the leading producers of spices, fish, poultry, livestock and plantation crops.The country still faces several challenges in agricultural development, including small and fragmented landholdings, low productivity, inadequate irrigation facilities, and the effects of climate

change. India needs to continue its efforts to increase production of food, feed and fibre to support the ever-increasing population. This needs collective efforts from all stake holders namely our scientists, policy makers, industries and farmers.

Agriculture is a very complex activity

as it is dependent on interplay of innumerable natural, environmental, scientific, technological, social and human factors. Depleting natural resources and climate change have increased the challenges. Clearly, the focus has to shift to sustainable agriculture growth. We have probably ignored this till now and need a strategic realignment immediately. Let's understand the situation and the challenges through a few examples:

1. As per study on Sustainability Concerns on Sugarcane Production in Maharashtra, India: A Decomposition and Instability Analysis,Abnave Vikas B-ISBN 978-81-7791-297-5 © 2019. It , out of the total sugar mills in Maharashtra state, 40 per cent mills are in drought-prone districts that are

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more suited to growing oilseeds and pulses.A lot of sugarcane cultivation is made possible due to a better support price and other support mechanism for the sugarcane growers where the soil and climatic conditions do not support a sugarcane crop. The state's licensing policy is also in favour of establishing new sugar mills or expanding the existing capacity of mills. These state policies have led to a rapid expansion of sugar mills and encouraged sugarcane production in Maharashtra along with water exploitation in the state (World Bank and GOI, 1998). This situation also causes farmer distress and industrial losses- specially during droughts.

2. According to the NABARD and ICRIER, India's top rice and wheat producers Punjab and Haryana- which contribute almost 15% of India's entire rice production, are also among the world's top water-risk zones for agricultural production. Extensive investments in irrigation and electricity infrastructure and government subsidies on water and power consumption have resulted in stickiness for paddy cultivation and rapid depletion of water table. With the current unsustainable use of groundwater, Punjab and Haryana could again become a desert in 25 years, a draft report of the Central Ground Water Board (North-Western region), has warned.As per a Punjab Agricultural University study regarding groundwater fluctuations over the span of 28 years (1988-2016), there has been an average fall of 51 cm annually. Separate reports by the National Aeronautics and Space Administration (NASA), National Institute of Hydrology, Roorkee, and Indian Institute of technology (IIT) Kharagpur, at different points of time have highlighted the concern over non-

renewable loss in ground water volume. This situation was envisaged long back and huge funds were allocated in 2013 for Crop Diversification in Original Green Revolution States (Crop Diversification Program in Haryana, Punjab & Western Uttar Pradesh -GOI) to divert the area of water guzzling crop i.e. paddy to alternate crops. Not much has happened over a decade. Shifting the major chunk of rice production to India's central and eastern states like Odisha, West Bengal, Chhattisgarh and Jharkhand, while encouraging kharif maize, pulses and cotton cultivation, in kharif season, in the rice-growing regions of Punjab and Haryana, could help prevent an impending water crisis by 2030.

To add to these woes, Punjab farmers are diversifying to spring maize which is adding to further depletion of ground water table. Experts estimate that spring maize was cropped in about one lakh hectares in 2023, which is almost double of last year. State agriculture department and Punjab Agricultural University (PAU) experts strongly favour legislation to ban the water-guzzler 'spring maize' in Punjab.

As per Niti Ayog Working Paper-2023, even with its small share in global exports, India is now the biggest exporter of virtual water, that is, the water embedded in exported agri-food products.

3. Another case in point is the area under millets in Rajasthan where the agroclimatic conditions are suitable for millets. It is notable to note that while the productivity of millets has almost doubled, the area under millets has reduced by almost 63% in last 5 decades. The net production of millets has grown marginally. There was a spike in the area sown with the Indian Government's initiative to celebrate 2023 as International Year of Millets. However, there is continued focus and efforts for growth of millet production and consumption.

Clearly, all agencies need to get together to address this situation. Niti Ayog in its working paper (2023) -From Green Revolution to Amrit Kaal Lessons and Way Forward for Indian Agriculturediscusses many such issues. If one approaches our issues and opportunities from a strategic lens, it will be evident that India has most diverse agro-climatic regions and we erred in not growing crops as per those in many instances. If we start cropping based on these agroclimatic conditions, a lot of our issues will get solved without any technological or costly intervention- and this will be sustainable too. A major policy change will be needed to adopt this strategy. This is a big challenge due to political and social implications. However, there is no choice left if we have to take care of our coming generations. Let's not find solutions to our mistakes, lets undo what we can.

Once we have optimised the cropping pattern, the next step is to improve productivity by recommending and promoting better seeds, fertilisers, machines and agronomic practices. India, with one of the strongest National Agricultural Research Systems in the world, is well placed to take care of such demands. Here again, we need a policy shift from subsidy towards investment in Agri R&D-(Gulati et al. 2018). In FY 2020–21, as per the Union budget, India's expenditure on Agri-R&D (ICAR budget) was a meagre INR 7762 crore (about USD 1.1 billion) (Government of India 2021a). Thus, there lies a huge scope for achieving higher growth momentum, as the marginal returns from expenditures on agricultural research are almost 5 to 10 times higher than through subsidies (Fan et al. 2007). If agricultural growth is to provide food security at a national level, then the expenditure on Agri-R&D needs at least to be doubled immediately (Paroda 2019)

While we have been working on traditional ways of agriculture, new opportunities have arisen in the sphere of science and technology, information

communication technology (ICT) and agri business which have the potential to transform agriculture production. We are a global IT and technology hub and Indian agriculture can gain a lot by harnessing this prowess. Some of the areas that may be addressed through this are:

- Technology can help in providing farmers with real-time information on weather patterns, market prices, and crop health. This can help farmers make informed decisions about crop management and improve their overall productivity.
- Drones and satellite imagery can be used for mapping and surveying farms to help farmers identify problem areas and take corrective action. Similarly, smart irrigation systems can optimize water usage and minimize wastage.
- Technology can help farmers access better market information and connect directly with buyers, eliminating intermediaries and reducing transaction costs.

Realigning our priorities will need involvement and support from each and every stake holder. Agriculture is a State Subject but alleviating hunger is everybody's moral responsibility. A single state may not be able to ensure food security on their own-however, all states together can ensure food security as well as nutrition security for our citizens. A strong political will is essential for such a major change. Our farmers are hard-working, receptive and resilient. Aligning them will be a big piece of this change management. Policy measures to de-risk the farmers from initial losses and uncertainties will be essential for helping adoption. In addition to this, a lot of efforts are needed in extension activities, demo farms, education and hand holding of farmers. While digital penetration has helped in extension, the role of physical efforts can not be undermined. Agricultural Universities and Krishi Vigyan Kendras (KVK) will have to take-up this responsibility. Various public and private industries need to be enrolled and their CSR budgets need to be ploughed back into such efforts. If we are able to manage all this, there are high chances of success and ushering India into the Next Green Revolution. The question is- Do we really have any other option?

Status of Tractor Industry in India 2023

In India, tractor is a dominant power source in farm mechanization since 1991-92. Tractor population has increased sharply from 4.84 million in 2011-12 to 9.75 million in 2022-23 at compound annual growth rate (CAGR) of 6.5%.During 2022-23, the command area per tractor was 14 ha and likely to further come down with increase in population of tractors. India is the largest producer of tractors in the world by volume. The export of tractors has almost doubled from 2011-12 to 2022-23 at CAGR of 5.88%.

Year	Production	Domestic sale	Export	Population*
2011-12	706332	639896	66436	4843000
2012-13	637471	578690	58781	4713402
2013-14	759478	696801	62677	5085384
2014-15	612994	551463	75376	5829511
2015-16	570791	493764	77485	6087673
2016-17	691361	582844	78351	6463265
2017-18	796873	711478	85395	7018130
2018-19	898052	780032	92233	7606529
2019-20	777752	705011	76054	8062463
2020-21	965231	899407	88621	8665790
2021-22	961100	842266	128636	9155688
2022-23	1071310	945311	124542	9755827

Source: Tractor Manufactures Association, TMA;
**Estimated based on historical data*

Precision Farming - For Climate Resilience

Kaushal Jaiswal

Precision agriculture is a crop & site-specific farm management system to ensure crop and the soil receive specific and exact amount of water, nutrition & pest management techniques Or in other words PA is a new advanced method in which farmers provide optimized inputs such as water and fertilizer to improve quality and yield.

Technology has been changing across all industries and mainly driven by climate and environment sustainability and you will observe the similar technological advancement in agriculture also. After ensuring the food security with green revolution, precision agriculture probably will bring the most prominent change in this field and is going to be the future of farming. As technology progresses and becomes more affordable for farmers, we can expect to see the mass adoption in coming years.

But what exactly is precision agriculture? The definition comes from the word itself: It is the use of science and technology in farm management for being precise in all farming practices, from selection of seeds, disease and pest management, fertilizer dosage, irrigation, and all other farm production aspects for maximising production with optimal use of resources.

Let's do the detailed analysis of this technology and understand why it is the future of sustainable agriculture and how big is this opportunity and the challenges associated with this.

The concept of precision farming started in the 1980s in the USA. And lot of new technologies developed over the years and have become the part of it, but basic concept remains unchanged, which is to optimize and improve traditional farming methods through technology. Some of the technologies which are being used now are-

- Remote Sensing
- IOT (Internet of Things)
- Soil Sensors
- Robotics
- Artificial Intelligence.
- Drones

Through these technologies the farmer can get

- Weather forecast.
- Diseases and pests forecast in advance.
- Nutritional requirements.
- Soil and Plant moisture.
- Crop monitoring
- Yield estimation.

With such information farming becomes more predictable and farmers can make better and more precise decisions on farm production. These technologies enable farmers to take a holistic and more informed

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decisions.

MAJOR ADVANTAGES OF PRECISION AGRICULTURE

Cost Reduction

When you use precise amount of water/nutrition and crop protection chemicals then you avoid wastages and at the same time you save on energy cost, labour cost and particularly when you get an advance warning for disease/insect occurrence then you can precautionary measures to safeguard the crops, which always better and cheaper option than the cure.

SUSTAINABILITY & CLIMATE RESILIENCE

Precision agriculture can reduce the use of irrigation water/ chemical fertilizers and other inputs hence helpful preventing ground water pollution which happens due to leaching of these chemicals and it also helps in improving soil health. At the same time it also helps in decarbonization in two ways -

a). You are using less fossil fuel and less energy consumption in farm operations.

b). You are producing lesser chemical fertilizers and crop protection chemicals.

And at the same time, it supports in doing climate resilient agriculture because it's ability to anticipate, prepare, and respond to hazardous events, trends, or disturbances related to climate, hence giving a chance to the farmers to mitigate the risks due to unfavourable climatic conditions like drought or excess rainfall.

INCREASED PRODUCT QUALITY

Precision agriculture helps increase your farm's produce quality by meeting the exact crop requirements.

Therefore, it also helps you meet high-quality marketable produce that would otherwise be difficult with conventional farming methods.

CHALLENGES OF PRECISION AGRICULTURE

Here are some of the challenges of precision farming-

Cost

The main challenge is the cost. Since farmer requires lot of tools and applications for precision agriculture and these modern equipment like drone, IOT devices and sensors are expensive and in current scenario this farming technology is better suited in large-scale rather than small-scale agriculture. I just want to give an example of VRT technology (Variable Rate Technology) which allows farmers to control the application of the number of inputs such as fertilizers, seeds, and chemicals. This is done for specific field and crop depending on a field's characteristics and crop requirement whose data is gathered using different precision farming tools.

The technology requires a computer, controller, software, and a differential global positioning system (DGPS). Further, two approaches are used.

- Map-based VRT. Uses previously generated maps to determine input application.
- Sensor-based VRT. Provides real-time examination of the soil to determine input application.

But cost of adoption is too high for a normal farmer.

LACK OF DOMAIN KNOWLEDGE AND UNAVAILABILITY OF SKILLED WORKFORCE

Due to lack of knowledge and information many farmers are not aware about the efficacy and benefits of precision agriculture. So at this moment they are not very keen to invest in this technology. It may take some time have the mass adoption and this will require lot of technology demonstration and promotion by governments, private entrepreneurs, universities, research institutes and all other stake holders. Most of the farmers don't know how or when to use these new technologies effectively.

There isn't enough skilled work force for either providing services or conducting trainings for the farmers.

There is a lack of eco system for quick adoption.

LACK OF DATA

You require large amount of data to use precision agriculture tools, lack of authentic open source data is one of the big challenges for adoption of Precision Agriculture, it takes years to have a full-cycle data set. This means you will use the initial years for data collection until you can implement the system. Collecting and analysing the data is time consuming and very demanding, especially when you do not have trained work force.

Despite having few challenges Precision Agriculture is the future of sustainable agriculture and which will help farmers to take informed decisions to grow quality food and maximize the yield by optimizing the resources, hence making the earth a better place to live for future generations.

ICAR-CIPHET, Ludhiana

INTRODUCTION

The ICAR – Central Institute of Post-Harvest Engineering and Technology (CIPHET), established in 1989 at Ludhiana, undertakes lead research in the area of the post-harvest engineering and value addition technologies appropriate to agricultural production catchments and agro-processing industries. The institute is also engaged in human resource and entrepreneurship development related to post-harvest operations performed on-farm as well as off-farm in order to minimize the post-harvest losses and empower the rural community with additional income. ICAR-CIPHET has two All India Coordinated Research Projects (AICRP) namely, AICRP on Post-Harvest Engineering & Technology (PHET) and Plastic Engineering in Agricultural Structures and Environment Control (PEASEM) with 31 and 14 cooperating centres, respectively, located all over India. It is also the coordination unit of one Consortium Research Project (CRP) on Secondary Agriculture (SA). ICAR-CIPHET and its schemes are catering to all kinds of farm produce viz. cereals, pulses, oilseeds, fruits, vegetables, specialty crops, fish and animal products.

The Institute has strong multidisciplinary scientific base with sufficient expertise in engineering and allied technology for carrying out research, providing technical services and knowledge services and generating relevant information for national level policies on post-harvest agriculture sector. The Institute at present is operating with five divisions, namely Agricultural Structures & Environment Control, Automation and Sensor Technology,Food Grain & Oilseed Processing Division, Horticulture Crop Processing, and Transfer of Technology. The institute is having a Regional station at Abohar, Punjab working on post-harvest mechanization and processing of horticulture crops.

MANDATE

- Research on post-harvest processing, preservation, storage and value addition of agricultural commodities.
- Human resource and entrepreneurship development in post-harvest engineering and technology.

MISSION

- Post-Harvest loss reduction and value addition to agricultural & livestock produce, residue and process by-products.
- Improvement of agricultural structures and livestock housings for higher system efficiency.
- Quick, reliable and effective knowledge dissemination.

THRUST AREAS

- Application of cutting-edge technologies in post-harvest sector (covering smart bio-degradable packaging and innovative storage solutions for shelf-life enhancement of agricultural produce)
- Modern structures and handling protocols for crops, animals and fishery
- Application of sensors and robotics for automation of post-harvest technologies
- Value addition to agro and agro-processing by-products
- Training and human resource development & knowledge repository

INSTITUTE CAMPUS

Ludhiana Campus - The headquarter of the ICAR-CIPHET is situated at Ludhiana, which houses four Divisions including Agricultural Structure and Environmental Control, Food Grains and Oilseeds Processing, Automation and Sensor Technology and Transfer of Technology Division. The campus is having various facilities like workshop, guest house, residence quarters, pilot plants, etc.

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ABOHAR CAMPUS

The institute's second campus was established on 19 March 1993 at Abohar, Punjab, India which is now Regional Station of ICAR-CIPHET. It has been primarily responsible for conducting research and development activities on fruits, vegetables, and commercial horticultural crops. The mandate has widened after its redesignationas Regional Station to address post-harvest issues of arid regions. This campus also houses the KrishiVigyan Kendra (KVK) of Fazilka District of Punjab which operates under administrative control of ICAR-CIPHET, Ludhiana.

DIVISIONS

- Agricultural Structure and Environment Management (AS&EC)
- Automation and Sensor Technology (AST)
- Food Grains and Oilseeds Processing (FG&OP)
- Horticultural Crop Processing (HCP)
- Transfer of Technology (ToT)

INFRASTRUCTURE/ FACILITIES

The institute has well established and well-equipped laboratories, library, computer hall and the workshop. It also has unique facilities like a Post-Harvest Machinery and Equipment Testing Centre (PHMETC), Agri Business Incubation (ABI) Centre, Agro Processing Centre (APC) and Food Testing Laboratory (FTL).

OUR SERVICES

Research and Development

The institute is doing lead researches in post-harvest mechanization, processing and value addition. Thus, for experimentation the laboratories are equipped with the sophisticated research facilities and equipment, major ones like High Performance Liquid Chromatography (HPLC), Atomic Absorption Spectroscopy (AAS), Raman Spectroscopy, Surface Plasmon Resonance (SPR) System, Texture Analyzer, ZetasizerParticle Size Analyzer, Supercritical Fluid Extraction (SCFE), Gel Permeation Chromatography (GPC), Rapid Visco Analyzer (RVA), Tintometer, Thermocycler, Rheometer and many more.

Few of the concentrated developments are in following areas,

- Agricultural Structures
- Environment Management
- Automation and Sensor Technology
- Drudgery Reduction through Machine and Tool
- Machinery and protocols for primary processing, storage, packaging and product development:
  - Cereals and other Food Grains
  - Oilseed and Pulses
  - Horticultural Product
  - Fisheries Product
  - Livestock Product
- Development of test codes and specifications for variety of food products and agro-processing machineries.

Policy related studies and surveys

- Post-harvest losses
- Handling, procurement and storage protocols
- Quality assurance in agricultural commodities
- Mechanization of post-harvest sector
- Impact and auditing of certain initiatives affecting the post-harvest sector

TESTING AND OTHER SERVICES

Post-Harvest Machinery and Equipment Testing Centre (PHMETC)

PHMETC is a centre, authorized by the Govt. of India, to ensure the supply of quality agricultural post-harvest machinery and equipment to the end-users through rigorous testing and certification. This centre is well equipped with modern precision measuring instruments and equipment for machine and material testing. The manufacturers of processing machineries mandatorily need to get their machineries tested and certified before supplying these to the beneficiaries of government sponsored programmes.

Food Testing Laboratory (FTL)

Food Testing Laboratory is a facility located in the Ludhiana campus

which serves to analyse any food material, raw materials used for food processing, processed foods, food additives, condiments, etc. To provide authentic nutritional information about the concerned material/food. This laboratory helps farmers, students, entrepreneurs and food processors to get their product/material tested at an affordable cost.

Agri-Business Incubation Centre (ABIC)

ABIC, at Ludhiana campus, operates with an objective to promote setting up of agri-business enterprises based on ICAR-CIPHET developed technologies/facilities. This centre extends business incubation support to the interested and potential entrepreneurs/organizations [SHG/ FPO/NGO etc.] for initiating a start-up, entrepreneurship, and business.

Agro Processing Centre (APC)

APC is processing centre located at Ludhiana campus with its primary aim to serve as a model facility for primary and secondary processing of different agricultural produces under single roofthat can be established in rural areas for farmgate processing. This centre has basic agro-processing machineries (primary and secondary processing) for demonstration and promotion of farmgate processing. The facility is frequently used for the practical and live demonstration of basic unit operations in primary and secondary processing of different agricultural commodities during training and skill development programmes for farmers, entrepreneurs, students and government officials and related stakeholders, etc.

HRD

The institute's one more key mandate is skill development in relevant

stakeholders and entrepreneurship development. For which, institute having many innovative methodologies to train the manpower through various online/ offline trainings to farmers, entrepreneurs, students and other aspiring stakeholders. The trainings organized by the institute are appreciated by various community and getting popularity day by day. For instance, during last five years (2018-23) the institute has organized around 120 programmes and trained ~4200 farmers, ~980 students, ~200 officers, and ~750 entrepreneurs including their exposure visits.

Skill Development and Outreach

- Beneficiaries through Transfer of Technology
- Entrepreneurship Development Programme
- Specialized Training on specific technology
- Handholding through providing business incubation facility
- Collaboration with Industries and Institutions through network projects and MoU
- Farmers' First Programme

PILOT PLANTS AND INCUBATION FACILITY

Ludhiana Campus

- o Makhana Processing
- o Groundnut Milk Processing
- o Tomato Processing (500 kg/h)
- o Rice Mill (500 kg/h)
- o Dal Mill (500 kg/h)
- o ChilliPocessing (500 kg/h)
- o Millet Processing

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Makhana processing

Pectin extraction from kinnow peel

Production of protein isolates from de-oiled cakes

Cryogenic grinder

Abohar Campus

- o Amla Processing (100 kg/h)
- o Kinnow Grading and Waxing (500 kg/h)
- o Cotton Ginning (100-200 kg/h)

Grains Cleaning and Grading (500-600 kg/h)

PILOT PLANTS AT ICAR-CIPHET

Significant Achievements

- Conducted two studies to assess the quantitative harvest and post-harvest losses of major crops and commodities in India

Indicator	Till 2023
Technologies developed	99
Technology commercialized	62
No. of licensees	162
Patent filed	64
Patent granted	29

- Recommended norms for safe storage of food grains in FCI and CWC warehouses
- Established automated fumigation chamber for treatment of grapes with SO2 and CO2 at Sahyadri Farmers Producer Company Ltd, Nashik and standardized the treatment protocol for export of grapes to New Zealand and Australia
- Developed National Database on NARES Technologies in post-harvest sector
- Other achievements of ICAR-CIPHET:

Collaborative Partners

- Institute has established linkages with IIP, PAU, TNAU, IMRC, TNFJU, SGAS, GADVASU, IIFPT, C-DAC, FCI, CWC, DBT; DST; SERB; Chhattisgarh State Minor Forest Produce Co-operative Federation; FCI; PM Matsyayojana; DOCA and other SAUs/ Agencies/ Ministries and Departments.

Outside ICAR Funding partners

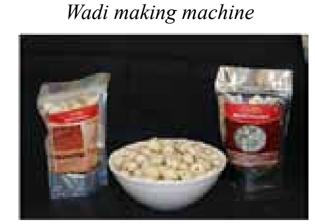
- Contract research - ABI- NAIF, APEDA, FFP, CRP-SA, CWC, DBT, MoCAF& PD, NASF, NICRA, DRDO-LSRB, IMRC, Mumbai and SGAS, Pune
- Consultancy projects – MEITY, C-DAC Kolkata, DOCA, CGMFPF Chhattisgarh, various developers of instruments being used in Food and allied industry.

SOME PROMINENT TECHNOLOGIES/PRODUCTS

Wadi making machine

Makhana primary roaster and popping machine

Non-destructive quality evaluation of mangoes



Fat free flavoured makhana

Plant based dairy analogues

Makhana kheer mix

IRRIGATION / POLICY

75 lakh ha brought under PMKSY – Per Drop More Crop Micro Irrigation since 2016: Kailash Chaudhary

Since its inception, Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) which aims to enhance water use efficiency at the farm level has covered about 1.5 crore hectares of farmland, the minister informed

Addressing the National Smart Irrigation Summit 2023, organised by FICCI and the Irrigation Association of India, Sh Kailash Chaudhary, Union Minister of State for Agriculture and Farmers Welfare, underscored that a notable 75 lakh hectares brought under micro irrigation since 2016 alone.

Since its inception, Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) aims to enhance water use efficiency at the farm level and has covered about 1.5 crore hectares of farmland. This substantial increase in coverage reflects the Government's commitment to sustainable agriculture and efficient water management, the minister emphasised.

The minister also shed light on the burgeoning role of agritech startups in revolutionising Indian agriculture. Over 3000 startups are currently engaged in introducing innovative technologies and adopting new methodologies to enhance agricultural productivity. Chaudhary emphasised the need for collective action, urging every stakeholder in the agricultural ecosystem to join hands in tackling water scarcity issues.

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Speaking at the occasion, Franklin L. Khobung, Joint Secretary, Union Ministry of Agriculture & Farmers Welfare, stressed that 86 per cent of the country's available water resources are being utilised for agriculture. Further, only 50 per cent of the total net sown area, amounting to 140 million hectares, is irrigated, indicating that half of the irrigated land in India consumes the majority of its water resources, underscoring a pressing need for more efficient water management practices. He pointed out that micro-irrigation can cover an additional 69 million hectares in India. Emphasising the importance of industry collaboration, he noted that micro-irrigation is an industry-driven scheme, reliant on the support and innovation of the private sector.

In this regard, the joint secretary noted that the Ministry of Agriculture has revised operational guidelines to include a special purpose vehicle (SPV) in each state. This initiative has already shown promising results in states like Gujarat and Tamil Nadu. Additionally, special provisions for cluster development have been introduced to further enhance the efficacy of these efforts.

Shrikant Goenka, President, Irrigation Association of India& MD, Premier Irrigation Adritec, underscored the potential of micro-irrigation as a transformative solution. Capable of saving over 50 per cent of water used in agriculture, micro-irrigation enables farmers to achieve significant savings – 30 per cent in fertiliser and 40 per cent in labour costs. Furthermore, the implementation of micro-irrigation has led to substantial increases in farm outputs, often exceeding 50 per cent, he stated.

Kaushal Jaiswal, Co-Chairman, FICCI National Agriculture Committee & Sr. Vice President, Irrigation Association of India & MD, Rivulis Irrigation India, highlighted the critical challenge of water management in agriculture, comparing India's water usage with China. He noted that India uses approximately 560 billion cubic metres (BCM) of water to produce 320 million tonnes of foodgrains, significantly higher than China, which uses 385 BCM and produces 571 million tonnes of foodgrains.

Jaiswal highlighted the critical decrease in India's per capita water availability from over 5,000 cubic metres at independence to just 1,500 today, accentuating the challenges of a growing population and diminishing water tables. He underscored that most of India's irrigation depends on groundwater, the highest globally, underscoring the urgency for effective aquifer recharge. Advocating for micro-irrigation and smart agriculture techniques, Jaiswal emphasised these as transformative solutions for sustainable and efficient farming, crucial for addressing agricultural challenges and achieving sustainability goals.

Only Smart Farming Can Transform Agriculture

Primal Oswal
Managing Director
Harvel Agua India Private Limited.

Agriculture, rather food production worldwide has always been faced with diverse challenges as the sector is heavily reliant on factors like weather, water, climate, soil conditions etc to name only a few and adversity in any of these can lead to disruption/ reduction in production. On the other hand, growing population is outpacing the food production to an extent that increasing regions of the globe are facing food shortages, creating food security issues and its resultant consequences. One of the other major challenges affecting agriculture in very significant manner and leading to reduced production is 'natural disasters' and protracted crises including conflict and violence, which overlap and affect agriculture adversely; a couple of cases in point are the Russia-Ukraine and Israel-Gaza conflicts which have not only affected agriculture in terms of major production losses but have also hugely disrupted food supply chains worldwide.

While the world was slowly coming out of the residual impact of COVID-19 which had created an unprecedented negative situation globally impacting human health, agricultural activities, economy and food security and in the case of India had created seemingly unsurmountable issues of health and livelihood, the above two conflicts have brought fresh challenges for agriculture.

On the world stage, in addition to food shortages caused by low production as well as disruption of supply chains, the global farming as well as allied sectors are also facing many food safety challenges like compromised quality and unpredictable contamination etc. which are being majorly highlighted as people are becoming more concerned about food quality and safety. Paradoxically, on the one hand the world is grappling with food security issues in vast regions on the other hand there is increased demand for greater variety in food choices in many regions since economic growth, rising incomes as well as rapid urbanization is influencing people's eating habits and they are no longer satisfied with subsistence food only. As a result, changes in methods of food production and supply are being initiated to meet the increasing demand quickly of particular types of food items and these supply side issues coupled with new and emerging bacteria, toxins and antibiotic resistance, changes in environment, inclusion of more imported foods is leading to food contamination. These challenges are rendering agricultural production as well as food supply chains more complex.

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As the food supply chains are getting more and more complex, only smart farming solutions can transform the way the entire agri supply chain is managed, of which smart irrigation technology is one of the foremost components, including but not limited to use of weather data or soil moisture data to determine the irrigation need for a particular parcel of land in a specific geographical location in consonance with crop sown. The use of these technologies lead to irrigation efficiency by reducing water waste while maintaining plant health and quality.

One of the other important aspects of smart faming is the increasing use of Data acquired through various sources (historical, geographical and instrumental) in the management of farm activities. An advance technology shall not be fully effective unless the same is backed by relevant and credible Data, necessary to attain actionable insights for managing all the operations on the farm in a cost-effective manner, both pre-and post-harvest. Smart agriculture technologies differentiate themselves by their ability to record Data and make sense of it using tools which ensure that the Data is organized and accessible at all times so that information on all aspects including financial impact can be monitored.

Data centrally stored on a digital platform makes it possible to analyse and identify suitable crop varieties and input requirements for optimization and profitability for varied parcels of the landholding. Early detection of various disruptions and application of inputs only in the affected region saves costs and other valuable resources. Use of satellite imagery techniques to monitor different zones in large farms and use of reliable weather forecasts maximizes resource usage and minimize losses which ultimately leads to good crop growth and higher yields. Automation of entire System increases productivity and cost-efficiency significantly.

Increasingly, Smart farming propelled by IoT driven agriculture is laying the groundwork for a "third green revolution." Combined application of information and communications technologies using devices such as precision equipment, IoT sensors and actuators, geo-positioning systems and robots lead of availability of real time data and effective decision-making and helps in better control of agricultural processes to reduce production risks and enhances the ability to foresee production results, ultimately leading to increased farm incomes.

IoT in agriculture involves sensors, drones, and robots connected through the internet which function automatically and semi automatically performing operations and gathering data aimed at increasing efficiency and predictability. With increasing demands and shortage of labor across the globe, agriculture automation and robots are starting to gain attention among the farming communities worldwide.

To meet the increased demand of quality food, Smart Farming is the need of day. The various challenges associated with agriculture can be minimized by use of these technologies and it will definitely increase the per capita income of farmers, Improve human health status and makes the economy healthier.

Precision Agriculture in India: Seizing Practical Opportunities and Addressing Key Challenges in Micro Irrigation

Shrikant Goenka
Managing Director, Premier Irrigation Adritec

Precision Agriculture, a globally recognized transformative approach, holds immense potential for revolutionizing India's agriculture, particularly when seamlessly integrated with micro-irrigation systems. This article aims to explore the practical opportunities and challenges associated with Precision Agriculture in India's micro-irrigation sector, providing a comprehensive quantitative perspective to inform strategic decision-making.

OPPORTUNITIES:

Precision Agriculture in India, when integrated with micro-irrigation, presents transformative opportunities for the agricultural sector. To begin, it addresses the critical need for Enhanced Resource Efficiency in water-scarce India. Leveraging advanced AI and IoT technologies, such as sensors and drones, can lead to a substantial 20% improvement in irrigation efficiency. This not only minimizes water wastage but also maximizes crop yield, contributing significantly to India's goal of sustainable agriculture.

The potential annual water saving of approximately 140 billion cubic meters underscores the significance of this improvement in the context of India's water challenges.

Next, Customized Farm Management, facilitated by data-driven insights from Precision Agriculture, enables farmers to tailor their approach to crop management. This results in a substantial 22% reduction in operational costs and an impressive 30% increase in profitability. The optimization of inputs based on real-time information directly contributes to the economic well-being of Indian farmers. The potential average annual savings of Rs 15,000 per hectare have the transformative potential to reshape the financial landscape, particularly for small and marginal farmers.

Furthermore, Market Competitiveness and Sustainability are enhanced as Precision Agriculture, when adopted alongside micro-irrigation, improves the quality and quantity of produce. This makes Indian farmers more competitive globally and aligns with India's objective to double farmers' income over the next five years. Furthermore, the adoption of precision practices contributes to a quantifiable 20% reduction in the ecological carbon footprint, aligning with global sustainability goals.

Lastly, Technology Transfer and Skill Development constitute the fourth opportunity. The successful

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integration of Precision Agriculture necessitates collaborations, leading to a substantial increase in farmer empowerment. This empowerment, measured through the acquisition of necessary skills and tools, is crucial for the successful implementation of Precision Agriculture in India. In practical terms, the increase in farmer empowerment translates to enhanced livelihoods for a significant number of farming households, fostering economic growth and rural development. Additionally, the adoption of precision farming technologies is expected to create 2.1 million jobs in India's agricultural sector.

CHALLENGES:

Despite these promising opportunities, Precision Agriculture adoption in India faces challenges that must be addressed. Foremost, Technological Accessibility and Affordability pose hurdles, particularly for small-scale farmers. While the global cost of precision agriculture technologies has decreased, a targeted 25% reduction in technology costs for smallholder farmers is essential. This reduction could potentially extend Precision Agriculture benefits to an additional 25 million smallholder farmer households, democratizing the advantages of modern agricultural practices.

Next, Data Management and Analysis are pivotal for Precision Agriculture success. In India, an intentional boost in investment for infrastructure, training, and robust data governance frameworks is imperative. This increase in investment could potentially result in the creation of a significant number of skilled jobs in the data management and analysis sector, contributing to the advancement of India's digital economy.

Finally, Awareness and Education are critical for successful implementation. In India, the commitment to continuous improvement and innovation in precision agriculture is reflected in expected research and development spending. This indicates a noteworthy investment that, in tangible terms, could lead to a rise in farmer awareness and a substantial improvement in the adoption of Precision Agriculture techniques. This transformative shift in agricultural practices could potentially impact a large number of farmers in India.

CONCLUSION:

The integration of Precision Agriculture into India's micro-irrigation sector presents a promising trajectory for sustainable agricultural development. The practical opportunities identified underscore the transformative potential of Precision Agriculture. Despite challenges, targeted interventions, collaborative efforts, and policy support can pave the way for an inclusive agricultural landscape, enhancing the resilience and competitiveness of Indian farmers. The measurable outcomes in resource efficiency, farm management, market competitiveness, technology transfer, and skill development highlight the tangible benefits awaiting Indian farmers, contributing to a sustainable and prosperous agricultural future. The potential impact of Precision Agriculture, when expressed in numbers, emphasizes its role as a catalyst for economic growth, environmental sustainability, and social development in India.

Improving Micronutrients Diversity in Rice Through Food-to-Food Fortification



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INTRODUCTION

In an era marked by remarkable advancements in science and technology, it is both perplexing and disheartening to acknowledge that a significant portion of the global population still faces a silent, insidious threat known as "hidden hunger". Over 700 million people was facing hunger in the world and around 2.4 billion individuals did not have consistent access to nutritious, safe, and sufficient food in 2022 (World Bank, 2022). Due to increase in the consumption of processed and convenience foods, leading to a spike in overweight and obesity rates across urban, peri-urban, and rural areas. Among worldwide population, child malnutrition is the major affected zone in 2021. Around 22.3% children were stunted (too short for their age), 6.8% were wasted (too thin for their height), and 5.6% were reported overweight throughout the population. Hidden hunger, characterized by chronic micronutrient deficiencies, affects billions of people worldwide, particularly in regions where staple foods form the bulk of daily diets. Among these staples, rice stands out as one of the most consumed and critical sources of sustenance for over half of the world's population. To combat this pervasive issue and address the nutritional gaps that continue to undermine human health

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TABLE 1 MERITS AND DEMERITS OF RICE FORTIFICATION TECHNIQUES

Fortification technique	Conditions	Working	Merits	Demerits
Dusting*	Blended with the powder form fortificants	The vitamin/mineral mix sticks to the grain surface because of electrostatic forces	Simple and cost effective	Nutrients are removed through washing
Coating	Water-resistant edible coatings	The coated kernels are mixed with unfortified rice in a ratio ranging from 1:50 to 1:200	Simple and cost effective	Affects the colour, taste and a loss of micronutrients during washing, as well as during cooking
EXTRUSION				
Cold	30-50°C	The starch is partially cooked by means of extrusion and provide opaque fortified rice kernel	Mimic the normal rice kernel	Not accepted by consumers in terms color, taste and easier to differentiate from unfortified rice kernels.
Warm#	60-80°C	Uses pasta press, but adds a preconditioner with steam, or is equipped with a steam-injection device to produce fortified kernels	Mimic the rice kernel and have similar appearance as regular rice (shine and transparency)	Cannot differentiate in terms of color and taste and assures the consumer acceptability
Hot	80-110°C	Twin extruder in which starch is fully gelatinized	Mimic the rice kernel and have similar appearance as regular rice	-Resulted FRK is puffed in nature beyond 100°C -It is more energy-intensive -It can include a preconditioner, and can rely on a double screw extruder to produce the fortified kernels.

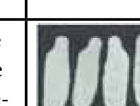
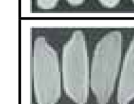
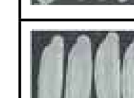
Source: Montgomery et al., 2014
** A remark should be mentioned about "not washing before cooking" on package*
 # Ideally warm extrusion method is mainly use to produce fortified rice kernel in India

and development, a ground breaking approach known as "Rice Fortification" has emerged as a beacon of hope. This innovative strategy holds the potential to usher in a new era in the fight against hidden hunger, offering a simple yet powerful solution that can significantly improve the well-being of millions.

WHY RICE FORTIFICATION

Researchers are mainly focused on eliminating malnutrition by means of cheaper and efficient processing techniques called fortification. Rice is a rich source of macro and micronutrients in its unmilled form. Unpolished rice is a rich source of vitamins B1, B6, E, and niacin (Zahra and Jabeen, 2020). During

TABLE 2 EXTRUSION PROCESS USED IN RICE FORTIFICATION

Techniques		Blending and conditioning	Extrusion	Sifting	FRK	Drying	Blending	
Cold extrusion	Add water or steam in mixture (rice flour, premix*, additives)	Raises moisture content from 12 to 35-40%	30-50°C	To separate FRK on the basis of specific gravity		The drying is carried out 50-70°C to reduce moisture upto 12%	Blending ratio is typically between 0.5% and 2%, depends on the nutrient content of the fortified kernels and the desired level of fortification	Fortified Rice
Warm extrusion			60-80°C					
Hot extrusion			80-110°C					

** includes iron, folic acid and vitamin B12 micronutrients (Source: Montgomery et al., 2014)*

TABLE 3 HEALTH BENEFITS AND LEVEL OF MICRONUTRIENTS IN RICE FORTIFICATION

Micronutrient	Health benefits	Deficiency	Source	Level of fortification
Iron	Transport and storage of oxygen, formation of blood cells,	Anaemia	Ferric pyrophosphate	28-42.5 mg *
			Sodium Iron (III) Ethylene diamine tetra Acetate, Trihydrate (Sodium feredetate-Na Fe EDTA)	14-21.25 mg
Zinc	Increase the femur length, metabolism function, boost immunity, wound healing properties	Weight loss, hair loss, decreased wound healing, skin lesions, growth retardation (stunting)	Zinc oxide	10-15 mg
Vitamin A	Recovered vision and skin related problems, provide immunity	Night blindness, keratomalacia, xerosis	Retinyl Palmitate	500-750 µg RE**
Thiamine (Vitamin B1)	Coenzyme (enhances the action of enzymes), carbohydrate metabolism, normal functioning of brain and heart	Beri-beri, mental depression	Thiamine hydrochloride or Thiamine mononitrate	1-1.5 mg
Riboflavin (Vitamin B2)	Helps thiamine to utilize energy, coenzyme, essential for growth	Dermal lesions, photophobia, chelosis	Riboflavin or Riboflavin 5'-phosphate sodium	1.25-1.75 mg
Niacin (Vitamin B3)	Conversion of tryptophan (precursor of serotonin and melatonin hormones)	Pellagra	Nicotinamide or Nicotinic acid	12.5-20 mg
Pyridoxine (Vitamin B6)	Coenzyme, decarboxylation (removes carboxyl group and releases CO2), deamination (inhibit biogenic amines)	Anaemia, damage to central nervous system	Pyridoxine hydrochloride	1.5-2.5 mg
Folic acid (vitamin B9)	Transmethylation, formation of haemoglobin, normal metabolism	Megaloblastic anaemia, Neural tube defect	Folic acid	75-125 µg
Vitamin B12	Production of blood cells, DNA development	Pernicious anaemia	Cyanocobalamine or Hydroxycobalamine	0.75-1.25 µg

**added at higher level to account for less availability*

polishing, the majority (75-90%) of these vitamins are removed. Only when parboiled does more than 50% of the water-soluble vitamin levels of brown rice remain, and this is due to their migration from the outer layers to the endosperm (Steiger et al., 2014). During rice milling the fat and micronutrient-rich bran layers are removed to produce the commonly consumed starch-rich white rice. White rice is the number one staple food in the rice countries of southeast and northeast Asia, one of the most densely populated regions in the world. Of the world's rice production, 90% is grown and consumed in Asia. On average, 30% of calories come from rice and this can increase to more than 70% in some low-income countries (Bin Rahman and Zhang, 2023). It is an important staple food in several African countries and the Americas.

Rice is therefore a potentially excellent product for delivering micronutrients to a very large number of people and has the potential to significantly alleviate micronutrient deficiencies. However, this will only achieve the desired result as long as the sensory characteristics of the end product are not discernibly changed and people do not object to incorporating fortified rice into their daily diet. In addition, using rice to deliver micronutrients will work only as long as fortified rice is economically accessible to people at the bottom of the income pyramid.

RICE FORTIFICATION TECHNIQUES

The rice fortification process is mainly depending on the type of fortificant used, storage conditions for premix, morphological properties of rice kernel and fortification method.There are several methods of rice fortification, each with its own advantages and considerations as mentioned in Table 1. Among all methods, hot extrusion at the temperature range.

EXTRUSION PROCESS

Extrusion is a compression as well as multifunctional continuous process in which the product is usually mixed, steamed, cooked, shaped and formed top roduce a desired cross-sectional shape. Several cereal based products in the form of snacks, ready to eat and ready to cook products such as pasta, noodles, flakes and water balls have been processed using extrusion technology. Nowadays, rice fortification also uses extrusion process and differ in processing conditions as shown in Table 2.Rice flour, which is typically created by pulverising lower-quality, non-contaminated broken rice, and a premix (Table 3) are combined to create a dough that is then used to extrude fortified kernels. The dough is extruded to create a reinforced kernel that resembles a regular rice grain in appearance. Only a few micronutrient particles remain on the surface of the fortified kernel, which has been evenly distributed with these elements. This lessens environmental exposure and, thus, the degradation of micronutrients. The dried FRK have a water content of 14% or less, which improves storage stability.

RECOMMENDATION

The concept of rice fortification represents a promising and innovative approach in the global battle against hidden hunger. The basics of rice fortification involve enriching rice with essential vitamins and minerals, such as iron, folic acid, and vitamin B12 along with other micronutrients to address these deficiencies. Rice fortification offers several advantages, including its wide acceptance among communities, cost-effectiveness, and scalability. It provides an opportunity to reach a large and diverse population, making it an efficient strategy for improving the nutritional status of millions of individuals, especially in low-income countries.While rice fortification holds immense potential, its successful implementation requires collaboration between government and the private sector. It also demands stringent quality control measures to ensure that fortified rice consistently meets the recommended nutritional standards.

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Precision Agriculture - Opportunities & Challenges

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INTRODUCTION: THE EVOLUTION OF PRECISION AGRICULTURE

Precision agriculture, often referred to as precision farming or smart farming, has emerged as a pivotal force reshaping the landscape of modern agriculture. Its roots can be traced back to the late 20th century when early GPS-based systems marked the dawn of a new era in farming practices.

These pioneering technologies enabled farmers to determine their exact position in the field, laying the foundation for the precise management of resources and the optimization of crop production. Over the years, precision agriculture has evolved from basic GPS-guided systems to sophisticated, data-driven approaches that are revolutionizing the industry.

The adoption of precision agriculture is driven by a convergence of factors that underscore its paramount importance. These key drivers include the ever-increasing global food demand, mounting environmental concerns, and the escalating costs associated with conventional farming methods. Understanding the historical context and these driving forces is essential to appreciate the profound impact of precision agriculture on agriculture's past, present, and future.

EARLY ROOTS: GPS-BASED SYSTEMS

The earliest forms of precision agriculture were primarily centered around GPS technology. Global Positioning System (GPS) technology provided farmers with the ability to pinpoint their exact location in the field, offering an unprecedented level of accuracy in land management. These early GPS-based systems laid the groundwork for precision agriculture by facilitating precise navigation, automated guidance for farm machinery, and the creation of detailed field maps.

RISING TO THE CHALLENGE OF FOOD DEMAND

The first driver behind the adoption of precision agriculture is the ever-increasing global food demand. As the world's population continues to grow, so does the need for sustainable, efficient, and high-yield agricultural practices. Precision agriculture responds to this challenge by offering a suite of technological solutions that empower farmers to maximize crop productivity and meet the surging demand for food.

ADDRESSING ENVIRONMENTAL CONCERNS

Environmental concerns, including soil degradation, water pollution, and the depletion of natural resources, have placed conventional farming practices under scrutiny. Precision agriculture, with its focus on resource efficiency and environmental sustainability, is a response to these concerns. By minimizing the overuse of water, fertilizers, and pesticides, precision agriculture helps mitigate the adverse environmental impact of agriculture.

NAVIGATING ESCALATING COSTS

The rising costs associated with traditional farming methods, including fuel, labor, and inputs, have driven farmers to seek more cost-effective approaches. Precision agriculture provides a solution by optimizing resource utilization. Through precise planting, irrigation, and pest management, it reduces input wastage, thereby lowering operational costs and improving the overall economic viability of farming.

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OPPORTUNITIES IN PRECISION AGRICULTURE:

Enhanced Productivity and Yield:

Precision agriculture empowers farmers to optimize productivity through several means:

Optimal Planting Densities:

Precision planting equipment allows farmers to adjust planting rates based on field conditions. For instance, in corn farming, precision planting can tailor the seeding rate to specific field areas, ensuring an ideal plant population. This results in higher yields and improved crop uniformity. Research conducted found that precision planting increased corn yields by an average of 8% in their experimental fields.

Precise Input Application:

Precision agriculture enables accurate application of inputs like fertilizers and pesticides. By targeting specific areas of the field where these inputs are needed most, farmers can reduce waste and improve crop health. A study reported a 15% reduction in fertilizer usage while maintaining or even increasing crop yields, demonstrating the potential for yield enhancement.

Effective Crop Stress Management: Precision agriculture technologies provide real-time data on crop health and stress indicators. For example, thermal imaging and multispectral sensors on drones can identify areas of the field under stress due to diseases, pests, or nutrient deficiencies. Farmers can then take immediate action, such as targeted pesticide application or nutrient adjustments, resulting in healthier crops and improved yields.

Resource Efficiency:

Precision agriculture significantly contributes to resource efficiency:

Precision Irrigation: Precision irrigation systems, equipped with soil moisture sensors and weather data, allow farmers to target water application precisely where and when it is needed. This not only conserves water but also prevents over-irrigation, which can lead to waterlogging and leaching. Studies have shown that precision irrigation can reduce water usage by up to 30%, exemplifying the potential for resource savings.

Variable Rate Fertilization: Variable rate fertilization adapts the application of fertilizers based on soil nutrient levels and crop requirements. This technology enables farmers to avoid over-fertilizing certain areas while addressing nutrient deficiencies in others. In places farmers using variable rate fertilization reported up to a 20% reduction in fertilizer expenses.

Data-Driven Decision Making:

Farmers harness various data types for decision-making in precision agriculture:

Soil Moisture Levels: Soil moisture sensors provide real-time data on soil conditions, helping farmers determine optimal irrigation timing and quantity. By avoiding over-irrigation, this data reduces water wastage and minimizes the risk of waterlogging.

Crop Health: Advanced sensors, such as multispectral cameras on drones, capture images that can detect early signs of crop stress or disease. These images assist farmers in identifying areas that require immediate intervention, reducing the need for widespread pesticide application.

Pest Pressure: Data on pest populations and activity can be collected through sensors and remote monitoring. Farmers can then make informed decisions about the timing and location of pesticide application, resulting in both cost savings and reduced environmental impact.

Decision-Making Tools and Platforms: Numerous software and platforms are available to farmers, offering features like data analysis, predictive modeling, and decision support. For instance, DeHaat farmers app provides a comprehensive dashboard where farmers can visualize field data and receive recommendations for action based on real-time information.

REDUCED ENVIRONMENTAL IMPACT:

Precision agriculture is instrumental in mitigating the environmental impact of agriculture:

Precision Irrigation: Precision irrigation minimizes water wastage and runoff, reducing the risk of water pollution. It also aids in conserving water resources, a critical consideration in regions prone to drought.

Variable Rate Fertilization: By applying fertilizers judiciously, variable rate fertilization decreases the chances of nutrient runoff, which can contaminate nearby water bodies. This approach promotes responsible and sustainable fertilizer use.

Improved Farm Management:

Precision agriculture enhances farm management practices through the following means:

Crop Growth Tracking: Farmers can track crop growth using remote sensing technologies. By monitoring plant health and growth, they can adjust management practices as needed, improving overall crop performance.

Identifying Areas Needing Attention: Advanced field monitoring allows farmers to identify areas of the field that may require specific interventions, such as additional irrigation or pest control measures. This targeted approach minimizes resource wastage.

Farm Management Software and Platforms: Various Farm management software offers a centralized hub for monitoring and controlling various aspects of farm operations. It simplifies data management and provides actionable insights to optimize decision-making.

CHALLENGES IN PRECISION AGRICULTURE:

High Initial Costs:

The initial investment required for precision agriculture technology can be a significant hurdle, especially for small-scale and subsistence farmers. High costs associated with purchasing hardware, software, and sensors, as well as the need for training, can be prohibitive. Governments and financial institutions need to provide affordable financing options to make these technologies accessible.

Data Privacy and Security:

As precision agriculture relies heavily on data collection and analysis, concerns about data privacy and security are paramount. Farmers need to trust that their data will not be misused or stolen. The industry must establish clear data privacy regulations and encourage the development of robust cybersecurity measures.

Skill and Knowledge Gap:

Adapting to precision agriculture often requires farmers to learn new skills related to technology and data analysis. Many farmers may lack the necessary education or experience to fully leverage these technologies. Agricultural extension services and training programs are essential to address this knowledge gap and ensure that farmers can make the most of precision agriculture tools.

Integration Challenges:

Precision agriculture technologies come from various manufacturers, and they may not always work seamlessly together. Ensuring that these technologies can integrate with one another and share data effectively is crucial for their success. Standardization efforts and industry collaboration can help overcome these integration challenges.

Connectivity and Infrastructure:

Reliable internet connectivity is essential for real-time data collection and analysis in precision agriculture. In many rural areas, poor or non-existent connectivity can hinder the adoption of these technologies. Governments and private sector stakeholders should invest in improving rural infrastructure, including expanding broadband access, to overcome this challenge.

In conclusion, precision agriculture holds immense promise for the future of farming by offering increased productivity, resource efficiency, data-driven decision-making, reduced environmental impact, and improved farm management. However, addressing the challenges of high costs, data security, knowledge gaps, integration issues, and connectivity limitations is vital to ensure that the benefits of precision agriculture are accessible to all farmers, regardless of their size or location. Agtech startups like DeHaat play a crucial role in bridging these gaps and driving the adoption of precision agriculture practices, ultimately contributing to the sustainable and prosperous future of agriculture.

Precision Agriculture: Opportunities & Challenges

Sanjay Borkar

Precision farming, also known as precision agriculture, stands tall as a beacon of innovation in modern agricultural practices. At its core, it harnesses cutting-edge technology to optimize crop yields, reduce waste, and elevate overall profitability. The transition from conventional farming methodologies to intelligent, sustainable practices is demonstrable, driven by the widespread acceptance and integration of advanced technologies.

The agricultural landscape is undergoing a profound metamorphosis, seamlessly integrating digital technologies into its fabric. Tools like sensors, GPS, drones, robotics, and automated machinery are no longer futuristic dreams; they are now essential instruments dotting fields across the globe. This digital transformation champions a data-driven approach, empowering farmers with real-time information on soil health, weather patterns, and crop conditions. This wealth of data facilitates informed decision-making, pivotal in maximizing agricultural productivity.

The incorporation of technology into precision agriculture translates into a more cost-effective approach. Resources are utilized judiciously, contributing to increased profitability. Precision applications, such as targeted fertilizer deployment based on soil conditions, not only drive cost savings but also align with critical environmental sustainability goals. This careful management minimizes chemical usage, preserving soil health and water quality for a more sustainable future.

Furthermore, the integration of automation and robotics reduces dependency on manual labour, bolstering productivity while lowering labour costs. Precision farming isn't just a practice; it's a comprehensive solution that harmonizes efficiency, cost-effectiveness, and environmental stewardship in the modern agricultural landscape. It's a revolution that transforms the core tenets of farming - Productivity, Predictability, and Profitability.

However, as with any transformative endeavour, precision agriculture is not without its challenges. One of the most significant hurdles lies in the comprehension gap among farmers and agribusinesses regarding the intricacies of precision farming. The concept's complexity demands a comprehensive understanding of various elements, including data collection, sensor technology, remote sensing, and satellite imaging. Mastery of these nuances is imperative, emphasizing the need for comprehensive training programs and robust support systems.

Another notable challenge pertains to the upfront investment required for precision agriculture technologies. Particularly for smaller-scale farmers, these initial financial barriers can be daunting. Beyond financial considerations, concerns surrounding data management and security loom large, demanding robust solutions for widespread adoption.

Despite these challenges, the potential of precision agriculture to enhance efficiency, sustainability, and profitability remains undeniably promising. Overcoming these hurdles necessitates collaborative efforts among farmers, technology developers, policymakers, and various stakeholders to create an ecosystem conducive to the sustainable growth of precision agriculture.

As the agricultural sector continues to evolve, the fusion of technology and agriculture emerges as the cornerstone for a more resilient and productive future, especially for farming communities worldwide. The key lies in navigating challenges with collaborative solutions, paving the way for a transformative and sustainable agricultural landscape.

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Tractor-trailers as a transportation mean: Safety aspects




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INTRODUCTION

Agriculture is one of themain important sector in India, about 50% of the country's population is dependent on this sector, accountingfor 17-18% of the Gross domestic product (GDP).The country's population is increasing rapidly and is expected to reach 1.66 billion people by 2050. This rising population demands huge food and production to feed raising population from the same area of land, i.e., 142 million hectares. The improvement in production and productivity can be achieved with the help of improved crop varieties, cultivation practices and mechanization levels. Tractorizationis one of the important components of farm mechanization because it isthe primary power source for farming (machinery operation) andnon-farming operations (transportation of farm inputs/ produce and people).The farm power availability in the country increased from 0.28 kW.ha-1 in 1960-61 to 2.761 kW.ha-1in2020-21. The tractor is the main power source for increasing the pace of farm mechanizationand plays a vital role in agriculture, serving as the primary and revolutionary machines for various farming tasks. Beyond farming, tractors also find use in transportation and earthmoving activities.However, due todesign constraints, unindented use and lack of safety awareness, a number of accidents happened, causing injuries to workers that may be fatal and non-fatal in nature. Because thetractor-trailer combinations were not originally intended for human transport (live load), a concerning trend of accidents and injuries has emerged.

There are several studies addressing accidents and injuries related to farm machinery and tools, but only a few or limited studies have given attention to tractor-trailer-related studies. Kumar et al. (1998) found that in their study involving 2635 farm workers from Uttar Pradesh and Haryana, 28% of injuries in Phase-1 and 40% in Phase-2 were passengers on tractors or trailers. Among the distribution of victims in Phase-1, 11 (28%) victims were passengers on tractors or trailers, 12 (31%) were occupants of other vehicles and 10 (26%) were working with the tractor. Only 5% of the victims were drivers who were injured while operating the tractor. In Phase-2 there were 15 (41%) victims who were passengers on tractors or trailers. Working with tractors caused 10 (27%) injuries and occupants of other vehicles and drivers were involved in 5 (14%) injuries. However, in case of severity of non-fatality in tractor-tracilers was high, more than 50% are of Abbrivated Injury Scale AIS5 andtractor injuries came out to be very severe, with 21 injuries in both phases being AIS 1 or above. 5% are of AIS6 category compared to agricultural machinery which are of mostly AIS1, AIS2 and AIS3.Tiwari et al. (2002) conducted a study on agricultural injuries survey in Madhya Pradesh from 1995 to 1999 through 10 different leading newspapers. Out of the total fatalities (1,896) due to agricultural incidents reported innewspapers,780 (41.1%) were tractor-related; the causes of tractor–related incidents reported in newspapers are collision of tractors/trailers with other vehicles and overturning of tractors/ trailers constituted 35.7% and 28.8% of the total respectively. Overturning of tractors/ trailers and collision of other vehicles with tractors/trailers caused 70.3% of fatal and 91.6% of non-fatal injuries in tractor-related incidents reported in newspapers. Khadatkar and Kot (2022), in astudy, reported twenty-one incidents in the 360 villages of 9 districts of Madhya Pradesh during 2012-2013. Among 21 incidents, 18 were non-fatal, and 3 were fatal. The three fatal incidents involved a power thresher, tractor-trolley overturning, and bullock cart wheel, respectively. The literature reviewed indicated that tractors had been the most incident-proneused to carry out agricultural operations. Tractor-trailer transportation injuriesseverity had high severity compared to other farm machinery injuries (Kumar et al., 1998). Therefore, it is necessary to study the impact of tractor-trailer accidents and their severity,along with preventive measures suggested to mitigate fatility and non-fatality. Therefore, this study aims to comprehensively assess the implications of the growing population of tractors and trailers and the limitations they pose for rural transport. Moreover, a range of low-cost safety interventionsto mitigateinjuries is suggested,especially for non-farming usage.

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TRACTOR-TRAILER POPULATION IN INDIA

The data on the tractor population from 1960 to 2020 is shown in Fig 1. The total registered number of tractors as of 31st March 2020 are 94.20 lakhs, with a total registered% share of 2.89% among all registered vehicles(Road Transport Year Data Book, 2020), as shown in Fig. 2. These incrementsare significant for farm mechanization but also has a detrimental impact of injuries and health hazards if due attention is not given to safety aspects. The top five states in tractor population in the country are Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharastra and Gujarat, with a percentage share of 16.16, 14.12, 12.99, 8.76 and 8.70respectively. The tractorsarethe most commonly used power source for "on and off" the farms throughout the year for operating different kinds of farm machinery andtransportation means with trailer systems for haulage, carrying and transportation in rural areas.Using tractors in transport accounted for about 60% of the average annual usage(Singh, 2001).

Tractors are mainly hitched with single-axle (unbalanced or semi-trailer) and double-axle (balanced) trailers for transportation in rural areas. An unbalanced or single-axle trailer (two-wheeled trailer attached to the tractor's rear with a single-point hook hitch. A part of its weight is transferred to the tractors rear wheel and rests on its wheels. Such trailers are quite popular throughout the country, requiringspecial skills of tractor drivers for steering and reversing. The load-carrying capacity of the single-axle trailers shall not be more than 5 tonnes (BIS2000). If tractor-trailer combinations are used in road transportation, overload for transportation (more than recommended by BIS) causes accidents due to collisions, sides and overturningsfor various reasons (lack of facilities provided in tractor-trailer combinations).

The total number of registered tractor-trailers (single-axle and double-axle) as of 31st March 2020 is 22.7 lakhs. The share of 'Other vehicles', including tractors,

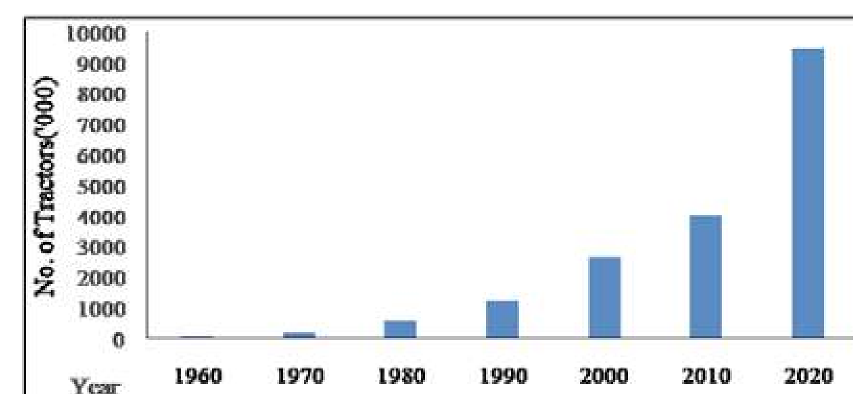

Fig 1. Tractors population from 1960 to 2020. Source (Road Transport Year Book; 2020)

trailers, three-wheelers (passenger)/ Light Motor Vehicles (LMVs) and other miscellaneous vehicles increased from 1.3 percent in 1951 to 6.9 percent in 2020. The trailer population in different states of the country is shown in Figs.3.The top five states with the highest populations of trailers in India areMaharastra with 4.2 lakhs (18.71 %) followed by Gujarat with 3.97 lakhs (17.48%), Karnatakawith 3.2lakhs (14.13 %), Bihar with 2.3 lakhs (10.41%) and Telangana2.1 lakhs (9.29%) respectively followed by other states which may be lacking the proper process of trailer registration.

Theabive fore mentioned paragraphs indicates that there is a continuous increase in tractors and trailers for different usage. From the above facts,an attempt is made to understand how tractor and trailer injuries, including fatalities in different states over the years,occur with the tractor-trailer as a transportation means. The limitations of tractor-trailers as transportation means and possible low-cost mitigation strategiesto prevent accidents are discussed below.

Limitation of tractor-trailers

- Single-point hitch.
- No brakes on the trailers.
- Lacks suspension system.
- No sitting system for passengers can cause higher vibrations, noise and dust exposure.
- Does not have rear visibility or side indicators.

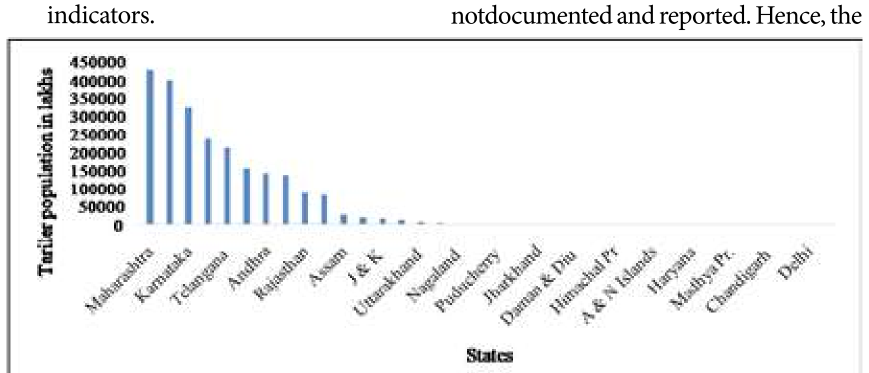

Fig 3. Tractor-trailer population in different states of the country upto 2020

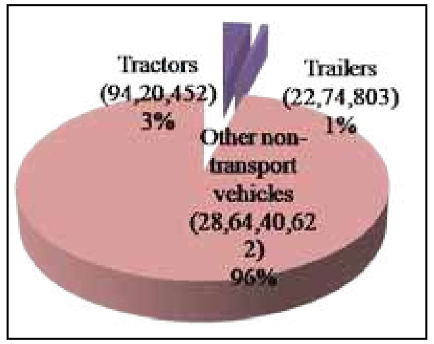

Fig 2. Total number of Registered Non-Transport Vehicles (2019-20)

- Less conspicuous during night rides: lack of rear indicators.
- Trailer is towed by a single-point hitch withthe tractor,leading to the tractor and trailer not moving as a single unit while taking turnsand can causes side overturning.
- During transportation, voluminous material like wheat straw covers a wide area on roads, causing difficulty for other vehicles in visibility and movement.
- Towing two trailers together.
- No safety devices.

Tractor-Trailers associated injuries and fatalities

Mainly, the tractor-trailer is used for transportingfarm inputs, produce, construction materials and people in low-income countries. These are associated with many injuries, and most of them go unreported.There is no centralized agency in India to examine farm injuries at the national level. Therefore, such cases are notdocumented and reported. Hence, the precise extent of occupational injuries is difficult to establish for tractor-trailer accidents. The data was collected from secondary sources on tractor-trailer injuries(Accidental Fatalitysand Suicides in India 2020, National Crime Records Bureau) andreported in the present article. The tractor-trailer accidents in newspaper reports during the transportation of people and haulage are shown in Fig 4.

Tractor-trailer Injuries: Causal factors

The main causes of tractor-trailer injuries are

- Overloaded trailer
- Mismatched trailers
- Poor visibility
- Absence of bright headlights, tail lights and reflectors
- No arrangement either on the tractor (or) trailers for passengers sitting
- Passengers sat on edge with their legs dangling outside, making them vulnerable to injuries
- No ROPS structure with seat belt arrangement

Tractor-trailer injuries: Magnitude

The fatalities and injuriesdue to the tractor-trailer combination from 2014-2020 are shown in Fig5.A total of 72,380 personswere injured and 37746 persons lost life in these accidents. The percentage share of fatality rates due to tractor-trailers among all the other modes of fatality rates is shown in Fig 6.During the Coronavirus years 2020-21, there was a decrease in incidences. Even though the increase intractorization and utilization of trailers can enhance the ease of agricultural activities and ruraltransportationtohelps and enhance production but also causes injuries and disability if proper attention and care are not given. The non-framing activity injuries (road accidents) are recorded only on main roads, whereas most injuries and fatalities are not reported in farming and non-farming conditions in rural areas. The injured victims are

Fig 4. Tractor-trailer accidents: newspaper reports

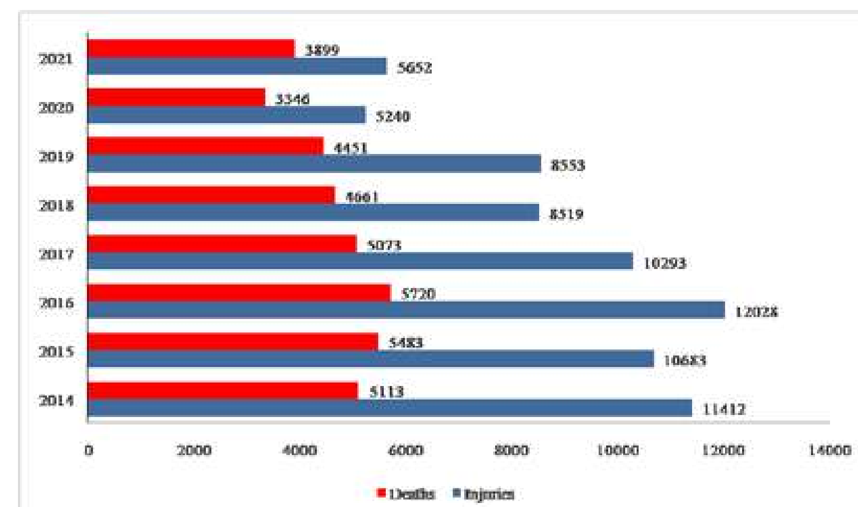

Fig 5. No. of persons injured and died in road accidents due to tractor-trailer from 2014-2021

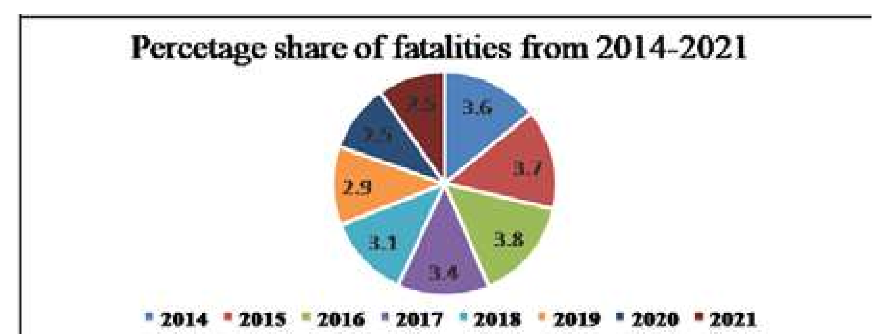

Fig 6. Percentage share of fatality rates due to tractors among all accidents from 2014-2021.

passengers riding on tractors or trailers; passengers fall andget hurt when the trailer hook fails.

Estimation of the magnitude of non-fataland fatal with the tractor-trailer combination

Many public and social events, such as weddings and processions (barats), often witness a significant number of attendees opting for tractor-trailers as their mode of transportation. Similarly, in the construction industry, the transportation of materials requires a substantial labor force, who often accompany the materials riding on tractor-trailers.So, this is a unique situation for many occupants on a tractor-trailer system, unlike personal vehicles. Any incident results in injuries and fatalities to these people traveling on tractor-trailers. These circumstances contribute to a high level of risk and potential severity in accidentscompared to other forms of transportation. The magnitude of the severity of thetractor-trailer is shown in Fig. 7, which indicates the manifold rate of non-fatality and fatalities in the tractor-trailer combination to overall road incidences.

The fatality rate per lakh of vehicles per year for road accidents is 45.45 and for trailer accidents, it is171.5respectively. In the case of non-fatality rate, it is for road accidents 110.97 and trailer accidents, it is 248.54 per lakh of vehicles per year, respectively. Therefore, these combinations need immediate attention and some preventive measures need to be incorporated to mitigate injuries. The fatality and non-fatality rates may even be higher if the total population of trailers is assumed to be half of the tractor population (94.24 lakhs). The fatility and non-fatility rate with tractor trailer accidents in 2020-21 are shown in Fig 7. Some preventive measures for trctor-trailer accidents are shown in Fig 8.

Fatality and non-fatality rate for on-road vehicles and tractor-trailers:

Total number of registered on-road vehicles (2020)= 33cr

Total no of road accident fatals = 1.46 lakhs

$$Death\ rate = \frac{1,46,100}{3,30,000,000} = \frac{44.27\,\frac{death}{laks}}{year}$$

Total number of registered Trailers = 22,74,803

Total no fatalitysassociated with Trailer (considering accidents with tractor-trailers) = 3900

$$Death\ rate = \frac{3900}{22.74} = 171.5\,\frac{death}{laks}/year$$

Non-fatality rate due to vehicles

$$Injury\ rate = \frac{366232}{330000000} = 110.97\,\frac{Injury}{laks}/year$$

No. of persons injured with tractor-trailer combination =5652

$$Injury\ rate = \frac{5652}{22.74} = 248.54\,\frac{Injury}{laks}/year$$

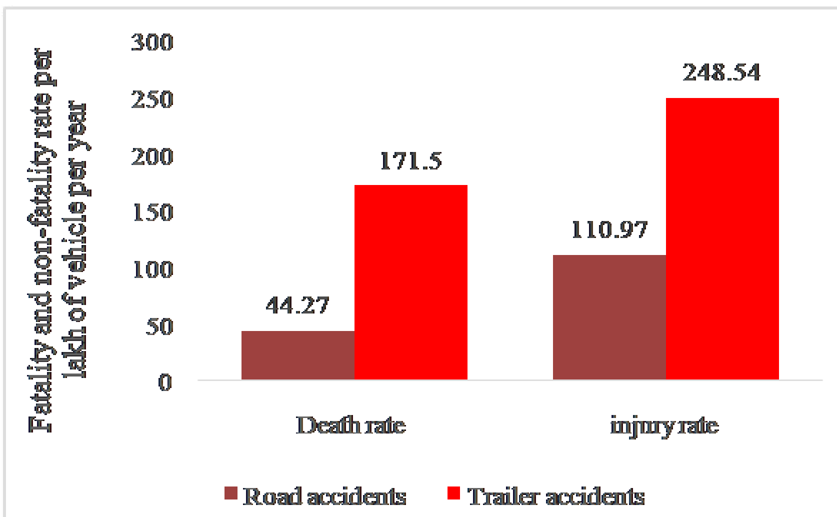

Fig 7. Fatality and non-fatality rate with road and trailer accidents in the 2020-21-year

Preventive measuresto mitigate tractor-trailer accidents during transportation

Following preventive measures can be adopted to make the tractor-trailer system safer

SENSOR-BASED APPROACH

The compromised visibility of a tractor-trailerresulting from overloaded trailers poses a significant challenge to road transportation safety. This visibility hindrance, especially during turns and maneuvers, has been a leading cause of accidents. An infrared (IR) sensor-based system emerges as a practical and cost-effective solution. Thisapproach not only enhances safety but also proves economically viable. By strategically locatingan IR sensor at the rear of the trailer, the system becomes adept at detecting nearby moving vehicles or stationary objects, particularly during turns or maneuvers. Upon detection, the sensor promptly alerts the tractor-trailer operator with an audible and optical signal, effectively mitigating potential collisions and preventing accidents.

REAR VIEW MIRROR (DOWNWARD)

An approach to mitigating tractor-trailer accidents during transportation involves adjusting the mirrors downward for rear viewing by the driver conveniently. This technique proves particularly useful when hauling a fully loaded trailer; this can impede visibility of the rear. By locating the big rearview mirror at the bottom of the tractor and angling up, the tractor-trailer combination can be observedby the driver very clearly. This practical adjustment enhances the overall safety of the haulage operation by compensating for reduced visibility caused by the voluminous load.

SIDE AND REAR UNDERRIDE GUARDS

These designs in tractor-trailer combinations prevent smaller vehicles (such as a car or a motorcycle) from sliding underneath the trailer in the event of a collision. These guards are essential safety features aimed at reducing the severity of accidents and saving lives.

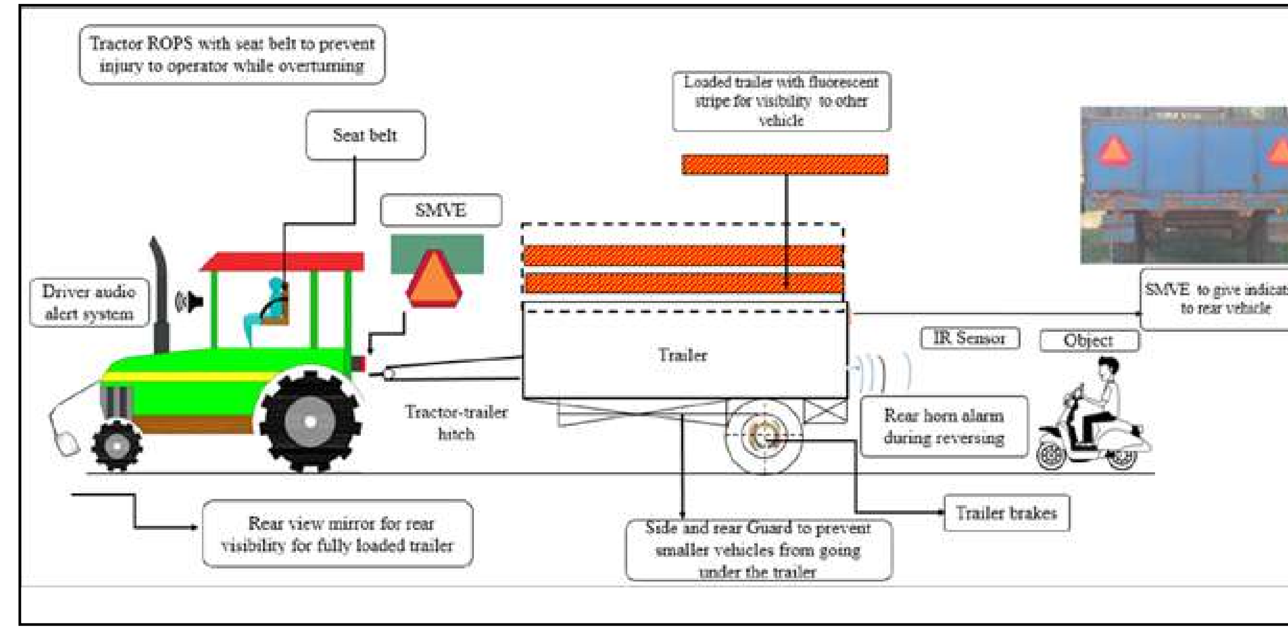

Fig8. Preventive measures for tractor-trailer combination

REAR HORN ALARM

A "backup alarm" or "reverse alarm" is a safety device tractor-trailer combination to provides an audible warning signal when the vehicle is in reverse. It serves several important purposes, warning to the rear invisible side of this combination.

OTHER INTERVENTIONS

- Enhancing the visibility of tractor-trailers by sticking Slow Moving Vehicle Emblem "SMVE" [a triangular shape with truncated corners with a characteristic pattern faced with retro-reflective and fluorescent material] atthe rear.
- Installing low-cost rear camera and display system for the operator.
- Provision of Rear (tail)lights, blinkers and side Indicators.
- Tarpaulin cover with fluorescent stripes/LED strips to make the covered trailer visible.
- Compressing the low-density fodder into blocks for lower volume.
- Careful during driving at sharp slopes, uneven, soft or slippery conditions, alongside ditches or banks, and during turning or reversing.
- When traveling on public roads, keep on the correct side of the road. Use light signals to turn, stop or slow down.
- No overloading of the trailer to prevent tipping backward.
- Removable guards for a trailer when passengers are traveling.
- Use of ROPS with seat belts to prevent tractor driver from non-fatality.
- Training of drivers on safer use of tractor-trailers on roads.

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Precision Agriculture: A Path to Sustainable Food Production!!

Deepak Pareek
Agriculture economist, a serial entrepreneur, investor, and ecosystem builder in the agriculture technology domain

In the face of a burgeoning global population and the pressing need for sustainable food production, precision agriculture (PA) emerges as a beacon of hope, promising to transform the agricultural landscape and usher in an era of enhanced productivity, resource optimization, and environmental stewardship. By harnessing the power of advanced technologies and data analytics, PA empowers farmers to make informed decisions that optimize crop management, irrigation, and nutrient application, paving the way for a more efficient and sustainable agricultural system.

The global PA technology market is poised for significant growth, with projections indicating a value of $23.06 billion by 2030. This growth is anticipated to occur at a Compound Annual Growth Rate (CAGR) of 13.4% from 2021 to 2030. North America currently holds the largest share of this market, followed by Europe and Asia Pacific. While the North American market is considered mature, there remains ample room for expansion as farmers continue to adopt innovative technologies. Europe's market is experiencing rapid growth, driven by government policies that actively

encourage the adoption of precision agriculture technologies. Meanwhile, the Asia Pacific market is expected to witness the fastest growth rate, fuelled by the rising demand for food and the pressing need to enhance agricultural productivity.

THE ALLURE OF PRECISION AGRICULTURE

PA offers a multitude of benefits that address the pressing challenges facing modern agriculture:

Enhanced Productivity and Yield: PA empowers farmers to transcend the limitations of traditional uniform farming practices and cater to the unique needs of individual plants and field segments. This targeted approach, guided by data-driven insights, leads to significant increases in crop yields, ensuring that agricultural production keeps pace with the growing demand for food.

Resource Optimization and Cost Savings: PA fosters a paradigm shift in resource utilization, promoting frugal practices that minimize waste and maximize efficiency. By tailoring fertilizer application to specific soil nutrient levels, PA prevents excessive use that can contaminate waterways and harm ecosystems. Similarly, PA techniques such as variable-rate irrigation ensure that water is applied precisely where it is needed, conserving this precious resource and reducing energy consumption associated with pumping and distribution.

Environmental Stewardship: PA champions sustainable agricultural practices that protect the environment and promote biodiversity. By minimizing the use of pesticides and herbicides, PA reduces the risk of water contamination, soil degradation, and harm to non-target organisms. Additionally, PA techniques such as cover cropping and conservation tillage enhance soil health, improve soil structure, and increase carbon

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sequestration, mitigating the effects of climate change.

Economic Sustainability and Profitability: PA contributes to improved farm profitability by reducing input costs and increasing yields. By optimizing resource utilization and enhancing crop productivity, farmers can generate higher returns on their investments, leading to increased economic viability and improved livelihoods.

NAVIGATING THE CHALLENGES OF PRECISION AGRICULTURE

Despite its transformative potential, PA faces certain challenges that hinder its widespread adoption:

Technological Barriers and Costs: The initial investment in PA technologies, such as sensors, GPS systems, data analytics platforms, and specialized equipment, can be significant, posing a financial hurdle for small-scale farmers. Additionally, the complexity of these technologies may require specialized training and expertise to operate effectively.

Data Management and Complexity: PA generates a vast amount of data, encompassing soil conditions, crop health, environmental factors, and machine performance metrics. Effectively managing, storing, analyzing, and interpreting this data can be challenging, requiring specialized skills, tools, and infrastructure.

Knowledge Gaps and Adoption: The adoption of PA among farmers may be limited due to a lack of awareness about its benefits, potential drawbacks, and the availability of suitable technologies. Educational initiatives, extension programs, and farmer-to-farmer knowledge sharing networks are crucial to bridge this knowledge gap and encourage farmers to embrace PA practices.

Data Privacy Concerns: Farmers may have concerns about the privacy and security of their data, particularly when sharing it with third-party service providers. Clear data privacy policies, transparent data handling practices, and robust data governance frameworks are essential to build trust and encourage wider adoption of PA technologies.

OVERCOMING OBSTACLES, EMBRACING OPPORTUNITIES

To ensure the successful implementation of PA and reap its full benefits, a multifaceted approach is required:

Financial Support and Incentives: Governments and agricultural organizations can provide financial incentives and subsidies to encourage farmers to invest in PA technologies and services. Additionally, low-interest loan programs and cost-sharing initiatives can make PA more accessible to small-scale farmers.

Capacity Building and Training: Comprehensive training programs and extension services are crucial to equip farmers with the knowledge and skills necessary to effectively use PA technologies and interpret data-driven insights. Hands-on training, field demonstrations, and peer-to-peer learning opportunities can foster a more confident and capable PA workforce.

Data Infrastructure and Platforms: Investing in robust data infrastructure, including cloud-based storage solutions and user-friendly data management platforms, can facilitate data collection, organization, and analysis. Additionally, developing open-source data analytics tools and applications can empower farmers to independently interpret and utilize their data.

Research and Development: Continuous research and development efforts are essential to refine existing PA technologies, develop new applications, and address emerging challenges. Collaborations between academia, industry, and government can accelerate innovation and ensure that PA remains at the forefront of agricultural advancements.

CONCLUSION: EMBRACING THE FUTURE OF SUSTAINABLE AGRICULTURE

Precision agriculture holds immense promise for revolutionizing the way we grow food, addressing the challenges of food security, environmental sustainability, and economic viability. By overcoming the existing challenges and fostering wider adoption of PA technologies, we can pave the way for a more sustainable and productive agricultural system that nourishes the world without compromising the planet's health. As we embrace this transformative approach, we stand at the threshold of a new era of agriculture, one that harmonizes technological advancements with ecological principles, ensuring a bountiful future for generations to come.

STARTUPS - In Harmony for a Smart Future

Agam Khare
Founder and Group CEO - Absolute

INTRODUCTION

From inventing agriculture 10,000 years ago, to Theophrastus enquiry into plants, to JC Bose establishing plants have life, to the green revolution, our understanding of mother nature and the process of growing food has been ever evolving. With the global population poised to increase from 8 billion currently to 10 Bn by 2040, the need to grow food with the same resources will become critical. Precision Ag is a beacon of hope for this grand pursuit of human rights.

THE BEGINNINGS

Back in the 80s, American farmers wanted to maximize profits by reducing the expenses incurred on inputs. What seemed like a simple business mindset, held the potential to herald a new era of sustainable farming with Precision Agriculture. The scientific approach to Precision Agriculture details it as a farming management approach that involves the systematic observation, measurement, and response to temporal and spatial variations to enhance sustainability in agricultural production. In simpler terms, it is the use of data-driven technology to optimize farming, from sowing to the application of inputs and finally, the harvest, to optimize yield volumes and curtail input wastage.

The Need for Precision Agriculture

For a significant period in our history of agriculture, we assumed that higher yields required more inputs: a notion that inherently considers the environment as collateral damage in the endeavor to feed humanity. The advent of Precision Agriculture meant not only can we grow more food while using fewer resources, but also control input runoffs into the natural environment, thereby protecting the balance of ecosystems and preventing biodiversity loss. Precision agriculture was also able to contribute to improvement in crop & soil health, reduction in manual labor, remote monitoring of crop health, and farmer livelihood improvement, amongst others. Overall, the premise of Precision Agriculture is a net positive for humankind: improved consumer health, farmer profitability, and environmental sustainability.

This is no longer just a theory: Countries like the US and Canada have been using precision Ag technologies like GPS in agriculture since the 1990s and now, technologies, such as yield monitors, variable rate application equipment, and remote sensing tools have become a new normal to improve crop health and yield. The Netherlands, a country with very limited land resources, has been able to harness Precision Agriculture to become one of the largest exporters of fruits, vegetables, and flowers. Ecuador is using precision agriculture to make daily advances in not only increasing its Banana yield but also actively fighting pests and the disease Sigatoka Negra, which can reduce plantation productivity by up to 50%. Closer to home, China, one of the most populous countries in the world, is deploying drone sprays, unmanned seed transplanters, and IoT devices for land monitoring and data to understand the demand for produce more precisely. Which marvel of Precision Agriculture could unfold next?

OPPORTUNITIES IN PRECISION AGRICULTURE

With a renewed focus of startups, government, and research organizations in agri-tech, a new generation of research and technologies is rapidly bracing the markets. These new technologies coupled with a harmonious synchronicity with learnings from nature: the prospects are unlimited. Below are some key technologies which have immense potential for the future:

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DRONE BASED MAPPING & SPRAYING

Advancements in Drone technology - optimized drone payload management and better aerodynamic engineering, coupled with significant improvement in aerial imaging for precision mapping of fields, drones can be used for spraying pesticides, fertilizers, and other agents based on accurate data, allowing farmers to treat different parts of the same field in unique ways. PIX4Dfields, based out of Switzerland, is one such company, which, in combination with drones and multispectral sensors, helps create and analyze real-time maps of crops to enhance agriculture workflow.

PRECISION DRIP AGRICULTURE

By precise delivery of water to the root zone of plants, Precision Drip Agriculture can help save between 60-80% of water used in traditional irrigation. In operating irrigation systems according to soil moisture and plant sensors, coupled with remote imagery, and plant development algorithms, recent technologies in Precision Drip Irrigation systems are reaching nearly 100% water-use efficiency. With the availability of 50% less water by 2050 being a looming threat, water-efficient farming is a global priority. Netafim, based out of Israel, is one such company providing precision agriculture solutions to grow more with less.

FARMER ADVISORY WITH SATELLITE DATA

Today, Satellite Data can provide invaluable insights into weather conditions, soil health, crop health, and yield estimation. This coupled with data through IoT devices on the ground can generate an even more accurate understanding of soil and crops for every region. Not only does this help farmers monitor crop growth stages and stress levels accurately, enabling them to optimize crop production and reduce costs, but it also opens avenues of risk mitigation and credit optimization, as this data is made available to stakeholders. Companies have now developed proprietary AI/ ML models for remote farm monitoring and advisory, leveraging satellite data and ground truthing through IoT devices transplanted across multiple regions.

SOIL TESTING & HEALTH MANAGEMENT

With sensors to check the soil's physical, chemical, and biological properties, farmers can be enabled to make informed decisions about crop selection, input application, and irrigation management. It also helps in the early detection of nutrient deficiencies in soil which can help mitigate issues with future crops. Furthermore, regular soil testing can also support farmers to track changes in soil health over time, supporting them with insights on carbon content, crop rotation, cover cropping, and soil conservation practices. Insoil, a proprietary health ecosystem from Absolute group, has developed a breakthrough fully autonomous proprietary soil testing machine that can accurately detect 12 critical parameters in soil within 20 minutes.

UNMANNEDFARM ROBOTS

Electronic and Autonomous robots are emerging to be increasingly popular in Precision Agriculture, due to their increased efficiency, reduced need for fossil fuels, low dependence on manual labor, and minimized carbon emissions. Coupled with drone-based mapping and satellite imagery, these can be used to perform precise operations such as planting, spraying, de-weeding, and harvesting, ensuring optimal use of resources and maximizing yield. Blue River Technology, based out of the US, is a leader in the development of farm automation robots.

CROP & YIELD PROFILING EQUIPMENT

We can now use image processing and machine learning algorithms to predict crop quality and yield with high accuracy using precision equipment. This approach can help in grading and quality inspection of produce with ease and reduce the guesswork and extreme manual effort. Fixofarm based out of Austria, is one such company that develops proprietary equipment to track the quality of produce using AI/ ML models.

PRECISION INPUTS

Using biotechnology to develop precision input products for farmers in different regions to reduce input usage, improve crop yields, and improve soil health. Inera, breakthrough biologicals from Absolute, has developed proprietary precision biological inputs to support farmers' journey towards sustainable agriculture. It offers a range of products for farmers to improve soil health, control diseases & pests, and support carbon sequestration.

THE CHALLENGES IN PRECISION AGRICULTURE

An approach as transformative to agriculture presents multifaceted challenges that encompass technological, standardization, connectivity, and policy-related aspects.

POLICY FRAMEWORK

A dual-pronged challenge where on one end stand potential threats to the privacy and autonomy of individual farmers and on the other the absence of evidence-based policymaking to address the challenges and opportunities in precision agriculture. While the private sector has made significant investments in tailoring information technologies for agricultural applications, coming together of public sector, policy makers, private sector, and farmers on one common platform is the need of the hour.

COMMERCIALIZATION-BASED MODEL OF RESEARCH

Most of the companies have to work with a capital-intensive model of research where they have to create an extensive infrastructure and scientific manpower for research, generating significant cash burn in the process. This usually results in shelving multiple research prospects due to a lack of surety on commercialization. So, commercialization-based research models will go a long way in promoting research on these new technologies. Before kick starting any research program, institutions must lay down a very clear framework around IP commercialization, in line with global industry standards.

PEOPLE AND SKILLS

One of the most critical things for developing breakthrough precision ag technologies is getting high caliber people with specialized skill sets. Industry should not view this as a business endeavor, but a moral obligation and they should come forth to invest and train resources. Xenesis fellowship is one such initiative by the research core of Absolute which offers up to $100,000 in grants to promote next gen research.

INTEGRATION OF DIFFERENT TECHNOLOGIES

Since different researchers and companies work on different technologies and operating processes, there are huge gaps in the integration of multiple technologies with each other, due to which adoption of more than one technology is slow and painful. Cross institution collaboration, commercialization oriented inter institution research groups will be key to any country's progress in adopting new technologies.

We may be born in India, but the world is our home, and both its protection and its longevity, are our responsibility. And to this end, the challenges posed by Precision Agriculture need to be addressed, on an immediate basis. The mountain may seem too steep, but scaling is possible when the Government, Private Businesses, and Research Institutions harmonize for a multi-faceted approach, including awareness campaigns, skill development programs, financial incentives, and supportive policies.

With this intent, we launched Absolute: a vision to empower India's small-hold farmers to thrive. With years of research and market study, a tech-driven ecosystem was designed that enables farmers to access the best quality inputs based on data-driven recommendations through our centers, improve yields sustainably through our proprietary agronomy and soil testing services, get access to affordable and sustainable credit through customized products co-developed with financial institutions. Furthermore, farmers can stay protected against weather disruptions through our satellite-based weather prediction. With the last-mile support systems, we also provide access to better markets worldwide to get better prices for their produce.

In collaboration with Pradhan Mantri FasalBima Yojana, the world's largest government-subsidized Agri-insurance scheme, Absolute has provided crop insurance to approximately 5 Mn farmers and is well on the way to insure 20 Mn farmers this year. Absolute today works with 25+ public and private sector institutions worldwide. At Absolute, scientists from institutions worldwide - US, UK, Spain, Germany, Israel, South Korea, Singapore, Australia, and India are creating a new benchmark in agricultural research. Absolute is committed to enriching the lives and livelihoods of small-holder and marginal farmers in India & worldwide.

In fact, in one of my articles in World economic forum earlier this year, I reiterated that "A true breakthrough in agriculture can only come from an unparalleled understanding of why nature and plants behave the way they do, by understanding their choices and preferences and then marrying that science with the latest in technology to build sustainable products and services that impact at scale. Only when the intelligence of nature and artificial intelligence are married together will an exponential shift be seen: substantially increased farmer income, environmental sustainability, and better consumer health".

Precision agriculture is poised and pregnant with a potential to make a tectonic shift in how we engage in agriculture today. It now rests on us as a society on what we can achieve together.

Boost Crop Yield With Agri-Intelligence

Mr Mohit Pande - Chief Business Officer, Cropin
Rajesh Jalan - CTO and Head of Engineering, Cropin

The global population is growing at an alarming rate, and the agricultural sector must undergo significant changes to cater to the increasing demand for food in line with the population explosion. Smallholder farmers are among the key players that can help to achieve global food security. As per the World Economic Forum, globally 600 million smallholder farmers work on less than two hectares of land and are estimated to contribute 28%-31% to total crop production and 30%-34% to food supply on 24% of gross agricultural area.

However, these marginal farmers are often the neglected, vulnerable group and account for most of the poor and hungry in developing and underdeveloped countries. Most of these farmers are trapped in a vicious cycle of low-intensity farming, poor yields, limited access to agricultural technology and markets, and inadequate profits. The negative effect of climate change only adds to the agricultural production challenges.

The progressive decline of arable land due to growing urbanization is a major hurdle to smallholder farmers and the Agri-industry. Accompanying challenges include feeding a growing population, providing livelihoods to farmers, and protecting the

environment.

To support marginal farmers, enhance food security, reduce poverty, and tackle climate change, we must understand the dynamics involved in agricultural production. Agriculture is influenced by numerous factors – some being technological, such as data-driven agricultural practices, management, and decision-making; others being biological such as diseases, insects, pests, and weeds; and environmental, like topography, soil fertility, water quality, and climatic conditions.

MAJOR OPERATIONAL EFFICIENCY ISSUES PLAGUING AGRICULTURE

1. Agricultural holdings are mostly individual businesses predominantly managed by smallholder farmers
2. Lack of technological access to smallholder farmers
3. Feeding a growing population while adhering to Climate Smart Agriculture (CSA) norms
4. Ensure predictable yield and good quality of produce, to provide a stable and secure livelihood for farmers
5. Volatility of food prices mandates improved crop resilience and yield protection
6. Protecting the environment
7. Coping with climate change
8. Trans-boundary pests and diseases
9. Rise in demand for quantity and quality of food
10. The need to curtail food wastage
11. Lack of data sources on/off the field
12. Need for optimum use of agrochemicals

Technology is a key enabler to solve these predominant operational efficiency issues plaguing the agricultural industry. Accelerated digital transformation drives farmer engagement that enables knowledge sharing, increasing efficiency, productivity and quality of produce, and adoption of sustainable agricultural practices. The intelligent insights derived using agriculture cloud platform accurately predicts yield and supports dynamic real-time decision-making that mitigates risks, protects yield, and ensures adherence to precision farming practices. The

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agricultural transformation brought about by intelligent agriculture cloud can enhance resilience among smallholder farmers, enable affordable food production, and ensure farm-to-fork traceability.

HOW TO INCREASE CROP YIELD WITH AGRI-INTELLIGENCE

Agriculture, one of the oldest industries, has been shaped by various technological innovations over the last few years. We are constantly innovating to increase crop yield to meet the demand of a growing population. Quality seeds, irrigation facilities, fertilizers, and pesticides have helped farmers increase crop yield.

Today, climate change, increasing population, growing demand for food, diminishing arable land and freshwater resources, etc., have made it imperative to leverage technology to transform the agri-food system. Modern technology can be used in several aspects of agriculture such as the application of herbicides, pesticides, fertilizers, and improved seed production. Thanks to technology, farmers can grow crops in areas that were earlier considered impossible for cultivation and make every process more efficient to improve production.

FACTORS INFLUENCING CROP YIELD

Crop yield that indicates a farmer's agricultural output at a given period measures produce harvested per unit of land area. Farmers are always considering ways to increase crop yield. Numerous factors, including technology, play a significant role in increasing crop yield. Here are the five factors influencing crop yield, and technology is helping achieve that.

SEED QUALITY

Good quality certified seeds are essential to maximizing crop yield. To increase yield, plant breeding companies must select the right hybrid seed, for which historical analysis of various environmental factors, along with the variable weather and pests and the greatest asset soil must be done. Using artificial intelligence models, farmers are assisted in choosing the ideal seed variety for their farms. On the other hand, to produce excellent quality seeds, seed companies face challenges such as grading seed varieties, ensuring data accuracy before the seed multiplication stage, on-ground fleet management, harvesting at the right time, loss due to fake hybrid seeds and counterfeit products, etc. Leveraging intelligent agriculture cloud, seed companies can reduce time spent on R&D while meeting standards for seed certification, implement traceability systems to eliminate counterfeiting, engage with farmers to optimize yield, and enjoy accurate demand forecasting that ensures timely availability of seeds.

FIELD PRODUCTIVITY

To improve field productivity, analysis of various factors like enhancing soil fertility, decreasing pests, diseases, and weather predictions from sowing to harvest is done by integrating agri-data from a wide variety of data types,

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including location, images/videos, spatiotemporal feeds, and satellite monitoring of crops. Knowledge sharing with farmers in the form of Package of Practices (PoP) specific to seed variety and region, alerts, details on agri-input availability, timely advisories, remote monitoring of in-field activities, etc., helps to increase crop yield. Data collated from AI/ML models provide actionable intelligence that allows farmers to reduce operational costs. Pest and disease alerts help thwart the issue at an early stage and arrest losses.

WEATHER PREDICTION

Along with climate change, erratic weather conditions can cause havoc to crop and impact the harvest. Although it is impossible to avert the effects of severe weather conditions, farmers can manage them by preparing in advance. Crop and environmental monitoring machine learning models use weather and satellite data to arrive at predictive agri-intelligence. Agriculture technology provides advisories on the quantum and time to apply various agri-input resources depending on the weather.

OPTIMUM USE OF AGRI-INPUT RESOURCES

By protecting crops from pests and diseases or adding necessary fertilizers and pesticides, agri-input companies play a critical role in increasing crop productivity. However, the proper usage of chemicals would depend on an appropriate understanding of which areas would benefit most from what kind of input. An intelligent agriculture cloud leverages data collated by various methods and provides data-driven insights to farmers on the quantum of agri-input resource usage. This is specific even to particular patches within a farm and has the dual benefit

of improving yield and optimizing operational costs for the farmers.

SEAMLESS COMMUNICATION BETWEEN STAKEHOLDERS

Communication between various stakeholders – farmers, seed companies, agri-input companies, food processing companies, and others – is important for maximizing per-acre value. Digitalization in agriculture offers a platform for seamless communication among various stakeholders and improves the visibility of farmers. Such an engagement helps with remote monitoring, sends early warning alerts and advisory for risk mitigation, ensures farmers' enablement with precise information on the availability of agri-input resources and market advisories, details on farm equipment and new loan schemes, etc.

INTELLIGENT AGRICULTURE CLOUD PLATFORM CONNECTS FARMERS AND BUSINESSES

To ensure the above factors are implemented successfully to increase agricultural productivity, nurturing a healthy relationship with farmers and other stakeholders becomes vital. Pioneers in the field like Cropin, leverage Internet of Things (IoT), Artificial Intelligence (AI), robots, drones for remote sensing, apps and devices, satellite farming, etc., for the digital transformation of agriculture and to connect farmers with various stakeholders seamlessly. This empowers farmers to become better decision-makers and maximize their crop yield.

Precision Farming - The Modern Approach

Ananda Verma
Founder and CEO, Fasal
Heading - Grow More, Grow Better

Precision agriculture, also known as precision farming or smart farming, is a modern approach that utilizes technology to optimize various aspects of farming practices. In a country like India, where agriculture plays a crucial role in the economy and sustenance of a vast population, adopting precision agriculture can lead to significant advancements. This article delves into the opportunities and challenges associated with the implementation of precision agriculture in India.
Opportunities:

INCREASED PRODUCTIVITY:
Precision agriculture employs cutting-edge technologies such as IoT, sensors, and data analytics to monitor and manage crop fields. This leads to better-informed decisions on irrigation, fertilization, and pest control, ultimately enhancing crop yields and quality.

RESOURCE EFFICIENCY:
With the precise application of water, fertilizers, and pesticides, farmers can minimize wastage and ensure that resources are used optimally. This not only reduces input costs but also addresses concerns related to water scarcity and environmental impact.

DATA-DRIVEN DECISION MAKING:
Precision agriculture relies heavily on data collected from various sources. Advanced analytics and artificial intelligence enable farmers to analyze this data and make informed decisions, leading to improved crop management and overall farm efficiency.

COST REDUCTION:
By optimizing resource use and minimizing waste, precision agriculture helps in reducing overall operational costs. This is particularly beneficial for small and marginal farmers who often face financial constraints.

REMOTE MONITORING:
Precision agriculture allows farmers to monitor their fields remotely, saving time and effort. This is especially valuable in a country like India, where many farmers still rely on traditional, labor-intensive methods.

MARKET ACCESS AND TRACEABILITY:
Adopting precision agriculture practices enhances the quality and traceability of produce. This can open up new markets and increase farmers' bargaining power in the supply chain.

CHALLENGES:
High Initial Investment:
One of the primary challenges faced by farmers in adopting precision agriculture is the high upfront cost of technology and equipment. Many small-scale farmers may find it difficult to invest in the required infrastructure.

Limited Digital Literacy:
A significant portion of the Indian farming community lacks digital literacy, making it challenging for them to understand and operate advanced

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technologies. Training programs and awareness initiatives are crucial to overcoming this hurdle.

Infrastructure Challenges:
In many rural areas, there is inadequate infrastructure, including a lack of reliable power supply and internet connectivity. Precision agriculture heavily relies on these infrastructural elements, posing a challenge to its widespread adoption.

Data Security and Privacy Concerns:
Precision agriculture involves the collection and analysis of sensitive data. Farmers may be concerned about the security and privacy of their data, especially in a scenario where it is being shared with various stakeholders in the agricultural ecosystem.

ADAPTATION TO REGIONAL VARIATIONS:
India is diverse in terms of climate, soil types, and crops. Precision agriculture solutions need to be adaptable to regional variations to be effective across the country. Customization is crucial to addressing the unique needs of different farming communities.

POLICY AND REGULATORY FRAMEWORK:
A robust policy framework is essential to support the adoption of precision agriculture. The government needs to provide incentives, subsidies, and a conducive regulatory environment to encourage farmers to embrace these technologies.

ACCESS TO CREDIT:
Small and marginal farmers often face challenges in accessing credit for investing in precision agriculture technologies. Financial institutions need to design specialized loan programs to support farmers in adopting these innovations.

CONCLUSION:
Precision agriculture presents a transformative opportunity for Indian agriculture, offering the potential to increase productivity, optimize resource use, and improve the livelihoods of farmers. However, addressing the challenges associated with technology adoption, digital literacy, infrastructure, and policy support is crucial for the widespread success of precision agriculture in India. By fostering collaboration between the government, technology providers, and the farming community, India can pave the way for a sustainable and technology-driven agricultural future.

AI-Powered Localization: Revolutionizing the Way We Communicate

Miss Amrit Warshini

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Artificial intelligence (AI) is transforming the way we communicate, and localization technologies are no exception. AI-powered localization tools are helping to make products and services more accessible to people around the world, regardless of their native language.

One of the most significant impacts of AI on localization is the development of machine translation (MT) systems that are capable of producing high-quality translations in real time. These MT systems are trained on massive datasets of text and code, and they are constantly learning and improving. As a result, AI-powered MT systems are now able to translate text into hundreds of languages with a high degree of accuracy.

Another key area where AI is impacting localization is in the development of natural language processing (NLP) tools. NLP tools are able to understand the meaning of language, and they can be used to perform a variety of tasks, such as text summarization, sentiment analysis, and entity extraction. These NLP tools are being used to develop new localization solutions, such as tools that can translate and localize multimedia content, such as videos and images.

AI is also having a major impact on the way that localization is managed. AI-powered localization management systems (TMS) can automate many of the tasks involved in the localization process, such as project management, asset management, and quality assurance. This frees up localization teams to focus on more strategic tasks, such as developing and implementing localization strategies.

Overall, AI is revolutionizing the way that we localize products and services. AI-powered localization tools are helping to make products and services more accessible to people around the world, and they are also helping to streamline the localization process.

Here are some specific examples of how AI is being used to revolutionize localization:

Google Translate: Google Translate is one of the most popular AI-powered MT systems in the world. It can translate text into over 100 languages, and it is constantly learning and improving. Google Translate is used by businesses and individuals around the world to translate websites, documents, and other types of content.

Amazon Translate: Amazon Translate is another AI-powered MT system that is gaining popularity. Amazon Translate can translate text into over 200 languages, and it is available as a cloud service. Amazon Translate is used by businesses of all sizes to translate their products and services into multiple languages.

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Microsoft Translator: Microsoft Translator is another AI-powered MT system that is widely used. Microsoft Translator can translate text into over 70 languages, and it is available as a cloud service. Microsoft Translator is used by businesses and individuals around the world to translate websites, documents, and other types of content.

Memsource: Memsource is another AI-powered localization platform that helps businesses to translate their products and services into multiple languages. Memsource combines AI-powered MT with human post-editing to ensure the highest quality translations. Memsource is used by businesses of all sizes, including Fortune 500 companies.

These are just a few examples of the many AI-powered localization tools that are available today. AI is rapidly changing the way that we localize products and services, and it is making it easier than ever for businesses to reach global audiences.

THE BENEFITS OF AI-POWERED LOCALIZATION:

There are many benefits to using AI-powered localization tools. Some of the key benefits include:

Improved accuracy: AI-powered localization tools are becoming increasingly accurate, and they can now produce high-quality translations for a wide range of content types.

Reduced costs: AI-powered localization tools can help to reduce the costs of localization by automating many of the tasks involved in the process.

Faster time to market: AI-powered localization tools can help businesses to launch their products and services into new markets faster by reducing the time it takes to translate content.

Improved customer satisfaction: AI-powered localization tools can help businesses to improve customer satisfaction by providing them with products and services in their native language.

THE FUTURE OF AI-POWERED LOCALIZATION:

The future of AI-powered localization is very bright. AI technology is constantly evolving.

AI translation is changing the way we work with local languages. It's empowering us in ways we never thought possible. For example, Microsoft Translator can translate your PowerPoint presentations into multiple local languages in seconds. Google Indic Keyboard lets you type in Hindi, Bangla, Tamil, and other Indian languages on your Android device. And Google Translate can translate text from English to Hindi, Bangla, Tamil, Urdu, and many other languages.

AI-powered localization is making products and services more accessible to people around the world, regardless of their native language. It is also helping businesses to streamline the localization process and reduce costs.

IMPORTANCE OF AI FOR INDIAN AGRICULTURE

AI-powered localization is the use of artificial intelligence to translate and adapt content to different languages and cultures in a way that is natural and engaging. This is particularly important for agriculture in India, where there is a high degree of diversity in terms of languages, cultures, and farming practices.

Here are some of the ways that AI-powered localization can revolutionize the way we communicate about agriculture in India:

Improved access to information: AI-powered localization can help to make agricultural information and resources accessible to a wider range of farmers, including those who speak minority languages or have low literacy levels. This can lead to better decision-making and improved farming practices.

More effective communication: AI-powered localization can help to tailor agricultural communication to the specific needs and interests of different audiences. This can make communication more effective and engaging, and lead to better outcomes for farmers and other stakeholders in the agricultural sector.

Increased collaboration: AI-powered localization can help to facilitate collaboration between farmers, researchers, and other stakeholders from different language and cultural backgrounds. This can lead to new innovations and improved agricultural practices.

Here are some specific examples of how AI-powered localization is being used to improve communication about agriculture in India:

Google AI is working on a project to develop a new language model that can understand and translate Indian languages, including Hindi, Urdu, and Bengali. This model will be used to develop new tools and services that can help to make agricultural information and resources more accessible to farmers in India.

The Indian government is using AI-powered localization to develop new agricultural extension programs that can be delivered in multiple languages. These programs will provide farmers with access to timely and accurate information about new farming practices, weather forecasts, and market prices.

AI is also being used to develop new financial products and services for farmers. For example, some companies are using AI to develop crop insurance products that can help farmers to mitigate the risks of crop failure.

Several Indian startups are developing AI-powered apps that canhelp farmers to identify pests and diseases, monitor crop health, and get advice on best farming practices. These apps are available in multiple languages and are designed to be easy to use for farmers with all levels of education.

Overall, AI-powered localization has the potential to revolutionize the way we communicate about agriculture in India. By making agricultural information and resources more accessible and engaging, AI-powered localization can help to improve decision-making and farming practices, facilitate collaboration between stakeholders, and lead to better outcomes for farmers and the agricultural sector as a whole.

Artificial intelligence (AI) has the potential to revolutionize Indian agriculture by helping to address these challenges and improve the productivity and profitability of the sector. Here are some of the ways that AI is being used to transform Indian agriculture:

Crop monitoring and yield prediction: AI can be used to monitor crops in real time and predict yields with high accuracy. This information can help farmers to make better decisions about irrigation, fertilization, and pest control, leading to increased yields and reduced costs.

Precision farming: AI-powered precision farming techniques allow farmers to apply inputs, such as water and fertilizer, to their crops with greater precision. This can help to reduce waste and environmental impact, while also improving yields and profitability.

Disease and pest detection: AI can be used to develop early detection systems for diseases and pests. This can help farmers to take timely action to prevent the spread of disease and protect their crops.

Market intelligence: AI can provide farmers with real-time information about market prices and demand. This information can help farmers to make better decisions about when and where to sell their crops, maximizing their profits.

Access to information and finance: AI-powered platforms can provide farmers with access to information and financial services that were previously unavailable to them. This can help them to improve their farming practices and increase their income.

The adoption of AI in Indian agriculture is still in its early stages, but it is growing rapidly. As AI technology continues to develop and become more affordable, it is poised to have a major impact on the sector.

Food Safety Management Systems – a brief overview

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A management system refers to a structured and organized approach that an organization uses to achieve its goals and objectives efficiently and effectively. It provides a framework for planning, implementing, monitoring, and improving various processes within the organization. Food Safety Management Systems (FSMS) are a set of practices and procedures designed to ensure that food products are safe for consumption. They are implemented by food businesses and organizations to identify, prevent, and manage potential hazards related to food safety throughout the entire food supply chain, from production to consumption. These systems are crucial for protecting public health and maintaining consumer confidence in the food industry.

KEY COMPONENTS OF A FOOD SAFETY MANAGEMENT SYSTEM

i **Hazard Analysis:** It's a systematic preventive approach that identifies, evaluates, and helps in controlling hazards that are significant to food safety.

ii. **Critical Control Points (CCP's):** These are the points in the supply chain, which if not controlled can lead to serious food safety issues. Determining critical control points, establishing critical limits, monitoring procedures, corrective actions, verification, and record-keeping, are essential in food safety.

iii. **Good Manufacturing Practices (GMP):** GMPs are a set of guidelines and standards that cover areas such as facility cleanliness, personal hygiene of workers, equipment maintenance, and storage conditions.

iv. **Standard Operating Procedures (SOPs):** SOPs are detailed written instructions that describe step-by-step procedures for specific tasks or processes within a food business. These procedures help maintain consistency, efficiency, and safety in various operations.

v. **Traceability and Recall Systems:** These systems enable food businesses to track the flow of food products through the supply chain and identify the source of contamination or quality issues quickly. In case of any food safety issues, an effective recall system helps to remove affected products from the market promptly.

vi. **Training and Education:** Proper training and education are essential to ensure that employees and stakeholders understand the importance of food safety.

vii. **Auditing and Verification:** Regular internal and external audits help to verify that the food safety management system is functioning correctly and meeting established standards. External audits may be

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performed by regulatory authorities or third-party certification bodies.

viii. **Legal Compliance:** Implementing an FSMS helps organizations stay compliant and avoid legal issues.

FOOD SAFETY MANAGEMENT SYSTEM STANDARDS

There are several Food Safety Management System (FSMS) standards that have been developed by different organizations and regulatory bodies to help food businesses implement effective food safety practices. The choice of a specific system depends on the type of food business, size of the organization, and regional or international regulations that apply. Some of the most widely recognized FSMS standards include:

ISO 22000: Developed by the International Organization for Standardization (ISO), it provides a framework for food safety management systems and covers all organizations in the food chain, from farm to fork. ISO 22000 incorporates the principles of HACCP and includes requirements for communication, management commitment, and continual improvement.

HACCP (Hazard Analysis and Critical Control Points): While not a standard per se, HACCP is a systematic preventive approach to food safety that has been widely adopted as a prerequisite program for many food safety standards. It involves seven principles, including conducting hazard analysis, determining critical control points, establishing critical limits, monitoring procedures, corrective actions, verification, and record-keeping.

FSSC 22000: The Food Safety System

Certification (FSSC) 22000 is a Global Food Safety Initiative (GFSI) recognized standard. It combines ISO 22000 with additional requirements, such as prerequisite programs, food safety management system requirements, and an annual certification process.

BRCGS (British Retail Consortium Global Standard for Food Safety): Developed by the British Retail Consortium, this standard is designed for suppliers to retailers. It sets out requirements for food safety, quality, and operational criteria, helping suppliers demonstrate their ability to produce safe products.

SQF (Safe Quality Food): The SQF standard, also recognized by GFSI, provides a comprehensive approach to food safety management.

IFS (International Featured Standards): The IFS Food standard is used to audit food manufacturers' processes and products. It emphasizes food safety, quality, and compliance with customer specifications.

GMP (Good Manufacturing Practices): GMP is not a single standard but a set of guidelines and principles that are followed to ensure the quality and safety of food products during production. Various countries and regions have their own GMP regulations.

In addition to the above, some specific standards are available for certification in food industry. Some of these standards are Kosher Certification (Jewish religious based certification); Halal Certification (for products permissible under Islamic law); Organic Certification; Gluten Free Certification Programme (GFCP); Non-GMO Certification etc.

MANDATORY IMPLEMENTATION OF FOOD SAFETY MANAGEMENT SYSTEMS IN INDIA

The FSSAI has introduced a certification system known as the Food Safety Management System Certification Scheme (FSMS-CS). Under this scheme, food businesses are required to implement FSMS based on the principles of Hazard Analysis and Critical Control Points (HACCP) or other internationally recognized food safety management standards. It is mandatory for certain food businesses

in India to implement Food Safety Management Systems (FSMS). The food businesses falling under the scope of mandatory FSMS implementation include:

1. Food businesses involved in the production, processing, storage, distribution, and transportation of milk and milk products that handle over 50,000 liters of milk per day or more than 2500 metric tons of milk solids per annum.
2. Food businesses engaged in slaughterhouses, meat processing, and poultry processing handling over 500 kg of meat per day or 150 metric tons of meat per annum.
3. Food businesses involved in processing, manufacturing, packaging, and storage of oils and fats (excluding solvent extraction units) handling more than 1000 kg of oils and fats per day or over 250 metric tons per annum.

CERTIFYING AGENCIES FOR FOOD SAFETY MANAGEMENT SYSTEMS

In India, food safety management systems are regulated and certified by various organizations and authorities to ensure the safety and quality of food products. Some of the prominent certifying agencies for food safety management systems in India are:

1. **British Standards Institution (BSI):** BSI is a global organization that offers certification services for various standards, including food safety management systems like ISO 22000. They provide assessments and certifications for businesses looking to demonstrate their compliance with food safety standards.

2. **Det Norske Veritas Germanischer Lloyd (DNV GL):** DNV GL is a certification body that offers services related to quality, safety, and sustainability, including food safety management system certifications.

They provide certifications for various food safety standards.

3. **TÜV SÜD:** TÜV SÜD is a German certification, inspection, and testing company that offers services in food safety management system certifications, such as ISO 22000. They assess and certify organizations for compliance with food safety standards.

4. **Intertek:** Intertek is a multinational inspection, product testing, and certification company. They offer food safety management system certifications, helping organizations demonstrate their commitment to food safety and quality.

5. **SGS India:** SGS is a global leader in inspection, verification, testing, and certification. They provide certification services for food safety management systems, aiding businesses in meeting international standards.

6. **QCI - Quality Council of India:** QCI is a government body that offers accreditation and certification services. They are involved in accrediting certification bodies that assess and certify organizations for compliance with various standards, including food safety management systems.

When seeking certification for food safety management systems in India, it's essential to ensure that the chosen certifying agency is reputable, accredited, and recognized by relevant authorities. Different agencies may offer certifications for various standards such as ISO 22000, FSSC 22000, HACCP, etc. Organizations should select the certification that best suits their needs and aligns with their industry requirements. It is always recommended to verify the latest information as certifications and accrediting bodies can change over time.

CONCLUSIONS

In summary, Food Safety Management Systems are essential for safeguarding consumer health, ensuring regulatory compliance, maintaining brand reputation, and achieving operational excellence in the food industry. They play a pivotal role in preventing foodborne illnesses, protecting businesses from legal issues, and fostering consumer confidence in the products they consume. Implementation of FSMS is not mandatory for all the businesses in food supply chain, in India; however, its implementation benefits the food business.

Precision Agriculture: Nurturing Growth in the Digital Era

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In the heart of every seed planted and every crop harvested lies the promise of sustenance for our growing global population. The mission at the forefront is to revolutionize the agricultural landscape by harnessing the power of precision agriculture to digitize the quality of produce. In this article, we will explore the vast opportunities and inherent challenges that come with embracing precision agriculture.

OPPORTUNITIES: CULTIVATING SUCCESS THROUGH PRECISION AGRICULTURE

Increased Productivity:
Precision agriculture leverages cutting-edge technologies such as GPS, sensors, drones, and machine learning to optimize various aspects of farming. This leads to increased efficiency in resource allocation, resulting in higher yields per acre.

Resource Optimization:
By utilizing data-driven insights, farmers can make informed decisions about irrigation, fertilization, and pesticide application. This not only minimizes waste but also reduces the environmental impact of agricultural practices.

Cost Savings:
Precision agriculture allows farmers

to precisely target their interventions, minimizing the use of inputs such as water, fertilizers, and pesticides. This, in turn, reduces operational costs and enhances overall profitability.

Quality Assurance:
The integration of technology in agriculture ensures that every step of the farming process is monitored and controlled. This level of precision guarantees a higher quality of produce, meeting stringent standards and consumer expectations.

Data-Driven Decision-Making:
Collecting and analyzing data from various sources provides valuable insights that empower farmers to make strategic decisions. This includes predicting crop yields, identifying potential risks, and adjusting farming practices accordingly.

CHALLENGES: NAVIGATING THE PATH TO DIGITAL AGRICULTURE

Initial Investment:
The adoption of precision agriculture technologies requires a significant upfront investment. Many farmers, particularly those with smaller operations, may find it challenging to procure the necessary equipment and tools.

Technological Literacy:
Implementing digital solutions necessitates a certain level of technological literacy. Farmers must be trained to use and interpret data from advanced technologies, creating a potential barrier for those unfamiliar with digital tools.

Data Security and Privacy Concerns:
The collection and storage of vast amounts of data raise concerns about security and privacy. Safeguarding sensitive information, such as crop yield data and farming practices, is crucial to maintaining the trust of farmers and stakeholders.

Infrastructure Limitations:
In many regions, especially in

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developing countries, inadequate infrastructure, such as limited access to the internet and electricity, poses a significant obstacle to the widespread adoption of precision agriculture technologies.

Integration Challenges:
Coordinating the integration of various technologies into a seamless system can be complex. Compatibility issues, interoperability, and the need for standardized protocols are challenges that must be addressed for a holistic precision agriculture approach.

As we navigate the evolving landscape of precision agriculture, the commitment is to bridge the gap between these challenges and the transformative opportunities that lie ahead. By fostering innovation, providing education, and developing user-friendly solutions, we can empower farmers to embrace the digital revolution and cultivate a sustainable future for agriculture. Together, let us sow the seeds of change and harvest a bountiful, digitized crop that nourishes our world.

EMPOWERING FARMERS FOR A DIGITAL TOMORROW: A CALL TO ACTION

Precision agriculture holds the key to a more sustainable and efficient future for global agriculture. The opportunities it presents, from increased productivity to cost savings and enhanced data-driven decision-making, are undeniable. However, as we embark on this transformative journey, it is crucial to acknowledge and address the challenges that may hinder widespread adoption.

Investing in the Future:
To overcome the initial investment hurdle, governments, NGOs, and

private entities should collaborate to provide financial assistance, subsidies, or low-interest loans to farmers. This support can empower them to acquire the necessary technologies without compromising their financial stability.

Promoting Technological Literacy:
Efforts to enhance technological literacy among farmers are imperative. Training programs, workshops, and accessible educational resources can equip farmers with the skills needed to navigate and leverage digital tools effectively. Partnerships with educational institutions and technology companies can facilitate the dissemination of knowledge.

Securing Data and Privacy:
The concerns surrounding data security and privacy require comprehensive solutions. Industry-wide standards, regulations, and certifications can establish a framework for responsible data management. Additionally, providing farmers with control over their data and transparent policies can foster trust and encourage participation.

Addressing Infrastructure Gaps:
Governments and organizations should prioritize infrastructure development in rural areas. This includes improving internet connectivity, ensuring reliable power sources, and facilitating the availability of necessary hardware. Bridging these gaps will create an environment conducive to the seamless integration of precision agriculture technologies.

Facilitating Integration:
Stakeholders in the precision agriculture ecosystem must collaborate to address integration challenges. Standardizing protocols, promoting interoperability, and fostering an open-source approach to technology development can streamline the integration process. This collaborative effort will ensure that farmers can easily adopt and adapt to the evolving digital landscape.

In conclusion, the journey toward a digitized, precise agriculture future is both promising and challenging. The commitment to overcoming obstacles and unlocking the potential of precision agriculture requires a collective effort from governments, organizations, and the agricultural community. By investing in the future, promoting literacy, securing data, addressing infrastructure gaps, and facilitating integration, we can empower farmers to embrace the opportunities that lie ahead and cultivate a sustainable and nourishing future for agriculture on a global scale.

BUNDELKHAND - Vertical Farming for Escalated Farm Revenue

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Vertical farming refers to the growing of crops, mostly vegetables and herbs on stacks of shelves indoors using artificial light and nutrient solutions, negating the need for sunshine and soil. It is often incorporates controlled-environment agriculture ruling out adverse effects of climate change, it focuses on optimizing plant growth conditions employing soilless farming techniques. If comparison with the conventional/horizontal farming by identifying the needs, constraints, implementation opportunities, possible alternative approaches and highlight the potential of vertical farming technology as possible option for food and nutritional security in India. It is an entirely new approach evolved generally ensuing indoor farming in a way employing cutting-edge technologies.

In India, vertical farming is still in nascent stage but has a potential to be speciality agriculture by growing foods such as micro greens, leafy greens and high value food crops. It

Tomato with coloured cauliflower curd

is not going to replace mainstream arable agriculture but can make its place as an innovative form of growing foods. Vertical farming can become more main stream and remunerative option of growing food. A lot of new and advanced technologies will drive the vertical farming industry and with adoption of high-value crops combined with reducing capital investment, it will become more remunerative. It helps in intensive production of crops under full or partially controlled conditions.

In India the states such as Karnataka, Madhya Pradesh and Andhra Pradesh are the main states for production of tomato under protected condition. India is the second largest producer of tomato after China. It is grown easier than the others vegetable crops and it can be grown successfully round the year in poly-houses. It has very important pigment lycopene associated with good number of vitamins of the most important for processing industry. Protected cultivation technology has great potential if implemented in a planned manner. It is well established fact that the harsh and challenged climatic conditions (extreme heat and cold waves) ultimately reduce the potential production and productivity of crops. During summer and winter season in north India in general and Bundelkhand in particular, it is extremely difficult to grow vegetables in open field conditions.

Bundelkhand with its wide variability of climate and soil type is favourable for

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growing a large number of vegetables crops. The economy of Bundelkhand is primarily and largely dependent on agriculture and its allied sectors owing to its predominantly rural inhabitants. Regional inhabitants' livelihood is mainly based on subsistence, rain-fed, and single/mixed farming system. The university has formed 8 different protected structures such as natural ventilated polyhouse, insect proof net, green shade net and mist chamber with hardening chamber the project "Centre of Excellence on Dry land Agriculture" for cultivation of high value vegetable crop. Simultaneously, BUAT Banda organizes trainings, conducts field day on low cost protected cultivation, and makes awareness among the farmers to adopt low cost protected cultivation technology at their fields and gradually progressive farmers of the Banda District have been showing their interest and started creating low cost protected infrastructure at their field for commercial cultivation and large dissemination. With this limited effort, some of the farmers are ensuring better yields, greater price and are saving their input resources year after year that helped them to uplift their socio-economic livelihood in the region.

BRIEF CULTIVATION PRACTICES

Indeterminate tomato growth habit is suitable for greenhouse cultivation. The maximum yield with vertical growth of the plant increases the yield, quality and colour. Tomato hybrids are grown up to a height of 5-6 meter, utilizing the vertical space in greenhouse. For vertical farming tomato production nursery sown in July-August and transplanting done in August-September (hybrid variety NS-4266) it will harvested up to March-April. The nursery of cauliflower (Bishop-RZ) cabbage (Marcello-RZ, KPS 99 champ and Improved Bahar), broccoli, (Tahoe-RZ) and coloured cauliflowers (Carotena & Valentena) were sown in October and transplanted between two tomato plants in the month of October-November. Beds of 90-100 cm width and 15-20 cm height are prepared leaving 45-50 cm footpath between the beds.

The two inline drip lateral 16 mm at 50 cm dipper distance on laid on each bed at 50 cm of spacing having a discharge of 2 LPH is placed at each planting row on the bed prior to planting. Plastic mulching may be done on transplanting beds it provides several advantages such as 20-30 % yield increased, fruit earliness, weed controls and soil moisture retention. Black/silver polyethylene mulch film 100 micron (400 gauges) thickness having 1.2 m width is used to cover the planting beds and securing the edges of the sheet by burying in the soil. 25-30 days old, vigorous and uniform in size 15-20 cm in height seedlings are selected for transplanting. Seedlings are transplanted at planting distance of 50 cm x 50 cm on drip irrigation system for efficient use of water and fertilizers. The beds are drenched with copper oxy chloride (@ 3 g/lit) if seedling mortality due to damping off is observed.

The fertigation of nutrients and fertilizers started after transplanting to first flowering through N: P: K: (19:19:19) 250g/500 square meter, flowering to fruit set N: P: K: (19:19:19) (100g), 46: 0: 0 (175 g) and 0: 0: 50 (275 g) should apply. The water soluble fertilizers such as N: P: K: (19:19:19) (100g), 46: 0: 0 (250 g) and 0: 0: 50 (275 g) should be given at fruit set to up to peak harvesting. The doze of N: P: K: (19:19:19) (50g), 46: 0: 0 (125 g) and 0: 0: 50 (150 g) should be given at crop end. The plants are fertigated twice a week, starting from 25 days after transplanting. Retain single stem and sides' shoots or suckers that develop between leaf petiole and the side branches have to be pruned. Pruning operation starts 20 to 30 days after transplanting at weekly interval. The main stem of tomato plants branches into two after the first flower cluster. Plant are supported by separate plastic twine hanging from an overhead GI wire trellis support system 3m above the ground level.

Demonstration on vertical/mixed farming with tomato, coloured cauliflower, broccoli, white cauliflower and cabbage transplanted on side bed/hockey area in Natural Ventilated Poly house (NVPH)
The tomato hybrid (NS-4266), transplanted on dated 15/08/2021 and white cauliflower (Bishop-RZ), coloured cauliflower (Carotena & Valentena), brocolli (Tahoe-RZ), and cabbage (Marcello-RZ, KPS 99 champ and Improved Bahar) transplanted on dated 17/11/2021 under the umbrella of indeterminate tomato. It is observed that the single plant of tomato gave 7.5 kg fruit whereas, under the tomato umbrella the white cauliflower hybrid Bishop-RZ noted compact curd and weight (0.900 kg). The coloured cauliflower such as Valentina and Carotena recorded (0.800 kg) and (0.950 kg), respectively. Regarding Broccolli hybrid Tahoe-RZ showed (0.750 kg) of compact curd. The cabbage hybrids i.e. Marcello-RZ, KPS-99 champ and Improved Bahar recorded (1.05 kg), (0.900 kg) and (0.850 kg), respectively.

Demonstration on vertical farming with indeterminate tomato and garlic sown between two rows of for green leaves in Insect proof net house
The tomato hybrid (NS-4266), transplanted on dated 25/08/2021 and garlic variety Yamuna Safed-3 (G-282) sown between indeterminate tomato on dated 31/10/2021. It is observed that the single plant of tomato gave 7.0 kg fruit whereas, under the tomato umbrella the good green quality of garlic plant uprooted and make a bunch of 10-15 plants and sale in the market @ 15/bunch.

Protected Cultivation Of Off-Season Vegetables

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India is the second largest producer of vegetables in the world next only to China. During 2021-22 the total vegetable production of India has already touched a level of 209.143 m tonnes (https://agricoop.nic.in/en/StatHortEst, MOA&FW, GOI) is to be raised to 250 m tonnes by 2024-2025 (Singh, 1998), but the productivity and quality of most of the vegetable crops is very poor due to several biotic and abiotic stresses during the field cultivation. The off season vegetable cultivation is the thrust area of hill agriculture in India. Vegetable crops grown under protected cultivation are generally destined for specific markets 'off season', at a time when the same crop(s) grown in open fields are not available. Alternatively use of protective cover allows crops to be grown in zones where climatic conditions would not normally allow production in the open. A diverse range of horticultural crops are grown under glass or plastic covers, with the main ones being tomatoes, capsicums, cucumbers, beans, several types of gourds, strawberries and lettuce.

Protected cultivation of vegetables provides the best way to increase the productivity and quality of vegetables especially during off-season, which also fetches better market price. The yield of some off the vegetables like tomato, capsicum and cucurbits can be increased manifold compared to their open field cultivation. Normally the economics of protected cultivation directly depends upon the initial cost of fabrication of the protected structure, its running cost and the available market for high quality produce. Therefore, low-cost protected structures, which can generally be fabricated with les investment / unit area; and the running cost of such structures is also very low, just like naturally ventilated greenhouses, walk-in-tunnels and plastic low tunnels. These are highly suitable for off-season cultivation and also for year-round cultivation of vegetables such as tomato, capsicum and cucumber. Walk-in-tunnels are suitable for off-season cultivation of melons. Plastic low tunnels are highly suitable and profitable for off-season cultivation of cucurbits like summer squash, bottle gourd, bitter gourd, muskmelon, watermelon, round melon and long melon in peri-urban areas of northern plains of India. Keeping in view the importance of protected cultivation for increased yield and quality vegetable production with minimum resource use, in the present paper efforts are made to discuss issues of protected cultivation with special reference to off-season cultivation of vegetables under poly-greenhouses.

PROTECTED CULTIVATION

Protected cultivation practices can be defined as a cropping technique wherein the micro climate surrounding the plant body is controlled partially/fully as per the requirement of the plant species grown during their period of growth. With the advancement in agriculture various types of protected cultivation practices suitable for a specific type of agro-climatic zone have emerged. Among these protective cultivation practices, green house/poly house cum rain shelter is useful for the hill zones. The green house is generally covered by transparent or translucent material such as glass or plastic. The green house covered with simple plastic sheet is termed as poly house. The green house generally reflects back 43% of the net solar radiation incident upon it allowing the transmittance of the "photosynthetically active solar radiation" in the range of 400-700 Nm wave length. The sunlight admitted to the green house is absorbed by the crops, floor, and other objects. These objects in turn emit long wave thermal radiation in the infra red region for which the glazing material has lower transparency. As a result the solar energy remains trapped in the green house, thus raising its temperature. This phenomenon is called the "Green house Effect". This condition of natural rise in green house air temperature is utilized in the cold regions to grow crops successfully. However in the summer season due to the above stated phenomenon ventilation and cooling is required to maintain the temperature inside the structure well below 350C. The ventilation system can be natural or a forced one. In the forced system fans are used which draw out 7- 9m 3 of air / sec / unit of power consumed and are able to provide 2 air changes / minute.

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Fig 1. Quality capsicum production under micro irrigation

BENEFIT ASSOCIATED WITH PROTECTED CULTIVATION

■ The vegetables / any other produce harvested from the protected cultivation have better quality in terms of the fruit size, per fruit weight, TSS, colour , texture and other quality parameters.

■ The productivity of the crop under protected cultivation increases f manifold (3-10 times) as compared to conventional system.

■ Off-season cultivation of the vegetables is the most important aspect of protected cultivation. The winter season vegetable crops such as cauliflower, coriander, spinach etc can be grown during rainy season. Similarly, summer season vegetable crops are successfully grown during winter and the winter season leafy vegetable can be grown during summer.

■ Under protected environment the incidence of insect and disease are minimized due to its isolation from open field. Use of micro irrigation and off-season cultivation also minimizes the disease and insect incidence.

■ Less infestation of insects and disease offer reduced use of pesticides.

■ The protected cultivation offers efficient use of two most precious resources land and water. Other inputs such as fertilizers, chemicals and labour are also efficiently utilized under such environment.

■ The year round cultivation of single / multiple crops with high quality produce and high productivity. The off-season cultivation of vegetable offers high income and better employment generation round year for the small and marginal farmers in hills and peri-urban areas.

PROTECTED CULTIVATION TECHNOLOGIES

Micro irrigation, raised bed , trellising and staking, mulching, : plastic covered and insect screen covered tunnels, shade nets and insect-proof nets and greenhouses (polyhouses, poly carbonate houses and FRP sheet houses) are the important protected cultivation technologies, wherein the soil and plant micro climatic conditions are modified for better plant growth and high production and quality produce during main/off-season.

Micro irrigation systems: Frequent application of water onto the soil at very low rates on or below the soil surface from a system of small diameter plastic pipes fitted with outlets called emitters. Water is applied directly into the plant root zone in quantity that approaches consumptive use of the plants. Soil moisture is maintained near the field capacity of the soil and nutrient is also applied as per plant need. It could be of High pressure system where quantum and scheduling of irrigation

Fig. 2. Raised bed cultivation under rain-shelter type green house and under drip irrigation

and fertigation is automated; and low pressure under which quantum and scheduling of irrigation and fertigation is manual. The high pressure system is suitable for medium to high land holding wherein low pressure system is appropriate for small holdings and greenhouses. A typical capacity and requirements of low pressure micro irrigation system is presented in Fig.1.

Raised bed technology : Raised bed farming (Fig.2) is the practice of using complex terraces of elevated earth to grow vegetables, it is done simply by forming a bed of topsoil that lies about 15 to 25 cm above the rest of the ground. Generally this bed is 80-100cm wide and having length of 2.5 -3.0 m under surface method and up to 50m in micro irrigation. Higher application efficiency of water and fertilizer along with improved aeration in root zone are the main advantages of raised bed cultivation. The raised bed cultivation also advanced the crop by 15-30 days which fetches better market price as compared to crops under conventional system of cultivation.

Trellising of vegetable crops: Trellising is used for training the vegetable crop vertically for better management enhanced yield and quality produce Trellising represents most efficient ways to utilize space in vegetable garden. People who have small piece of land will want to grow as many crops as possible, and vegetable growers who plenty of space will still need to lend physical supports to some of their vegetables, such as peas, beans,

Trellising or staking of greenhouse crops: Trellising in greenhouse crops is necessary to use more of vertical space and allow maximum light to reach canopy.

Trellising in open field vegetable crops: Good management of crop and Higher quality and productivity of crop can be achieved

Fig.3. Trellising of crops under greenhouse and in open filed (PFDC Pantnagar)

Fig.4. Different coloured mulches has specific purpose

cucumbers, melons and tomatoes. Trellising can be constructed from either wood or metal material such as GI wire. Peas and bean like smaller mesh poultry wire while cucumber prefer larger aperture of stock wire. Some vegetables like tomatoes, squash, and melons require tying of plants gently to support or carefully weave them through the trellises as they grow. Trellising of crops under greenhouse and in open filed is presented in Fig.3.

Mulching: Under adverse climatic conditions like high and low temperature regimes, mulching has favourable effect on growth and productivity of vegetables. Shallow tillage practices like racking of soil, simple scraping, hoeing, light digging etc. provide mulching effect, termed as mechanical mulching. It conserves soil moisture and increases soil aeration, microbial activities, nitrification process and also regulate soil temperature. In heavy soils, increased aeration by frequent cultivation increased nitrification process. In soil with limited moisture, it helps to conserve soil moisture by disturbing or stopping upward capillary movement of water. In cold regions it increases the soil temperature which facilitates longer duration for plant growth and development ultimately advances the crop.

Mulching is usually done with organic materials like straw, green leaves, dry leaves or by using plastic sheets. Different colour and thickness of poly mulches (Fig.4) are used for specific purposes. Mulching with black polyethylene sheet is very effective in suppressing weed growth in cultivation of vegetables. Yellow plastic mulch attracts white-flies and acts as a control measure of LCV.

Plastic low tunnels for growing vegetables ahead of normal season in the winters: In low tunnels (Fig 5) plastic covers (200-300 gauges thick) are supported above the crop by wire hoops. A simple way to make hoops already in a hoop confirmation is to buy a coil of wire and use bolt cutters to snip the hoops at the desired length. The ends of the hoops are inserted 15-20 cm into the soil on each side of the row so that the width of the hoop at the base is 60 to 100 cm and the height at the apex of the hoop is 40 to 60 cm. The hoops are spaced about 1.2m apart in the row. There are many variations of these dimensions, depending on

Fig.5. Off-season summer squash cultivation under low tunnel at GBPUA&T Pantnagar

crop size. Hoops made from a coil of wire are installed by hand; but for machine-installed hoops, the wire has to be straight to properly feed into the machine. For most crops grown with hoop-supported covers, black plastic mulch is used for weed control as well as for improved crop growth. Depending on the crop and the environmental conditions; the covers are left in place for 3 to 4 weeks and then removed. For crops requiring bee pollination, the covers are removed about the time of the appearance of the first female flowers. For wind pollinated crops (tomato, pepper etc), time of removal is somewhat temperature dependent since temperatures should not exceed 900 F at the late bud to open flower stage for more than a few hours.

Nets in protected agriculture: Shade nets are useful in cutting excessive solar radiation falling on crop canopy(Fig. 6). They help in moderating the micro-climate of plants besides saving them from wind, birds and hails. The crop season is extended and higher yields are achievable. The nets are available in different colours and shading percentages:

- ■ Shade nets with shading intensity : 20%, 30%, 40%, 50%, 75% and Colours - white, black, green
- ■ Insect-proof nets with porosity : 25, 40, 50, 60 mesh
- • Nets provide protection against animals, birds, insects, excessive radiation, wind and hails

COMMON TYPES OF GREENHOUSES BEING USED IN INDIA

Walk-in tunnels: These greenhouses are good for raising nursery and growing off-season vegetables. With proper technical guidance, these can be built with the help of local artisans, thus minimizing the cost of construction. Utility of walk-in tunnels can be enhanced by using a combination of plastic and insect-proof net as the covering materials. The construction cost ranges from Rs. 500 to 800 / m2.

Saw-tooth, multi-span: These types of greenhouses provide effective natural ventilation through side and roof vents. These can be used in mildly hot climate for commercial production of flowers, vegetables and medicinal plants. Cost of construction ranges from Rs.1150 to Rs 1425 / m2 for naturally ventilated poly-houses and Rs.1500 to Rs.2000 for environmental controlled poly-houses. Saw-tooth, tubular structural designs with 4 m gutter height are popular for floriculture and vegetables production. There are several manufacturers of these designs in India.

OFF-SEASON PRODUCTION OF VEGETABLES UNDER POLY GREEN HOUSES

Fig.6. Quality tomato production under shade-net during summer at PFDC, Pantnagar

Crops for growing in greenhouses should be selected carefully keeping in view the quality aspects and market price. Off-seasonality should be the main criteria to fetch higher profits. Tomato, capsicum and cucumbers are most suitable crops under polyhouses. Tomato and cucumber production can be successfully grown under zero energy naturally ventilated saw tooth type greenhouse. Indeterminate varieties of tomatoes are grown in greenhouses which give one crop per year, which fetches two off-season (December – February and June-August) in Pantnagar Tarai condition of Uttarakhand. Production levels up to 250-300 tons/ha is achievable in zero energy naturally ventilated greenhouses with the intervention of drip-fertigation. The production technology developed at PFDC, GBPUA&T, Pantnagar, is presented in Fig.7. Similarly, capsicum can also be grown successfully under naturally ventilated poly houses with single crop per year (PFDC Annual Report, 2007-08). The production level to the tune of 196 - 250 ton/ha can be achieved with suitable varieties in combination with suitable package and practices under drip-fertigation .Exotic varieties of cucumber can be grown round the year with 3 crops-cycles (Fig.8). Each crop can yield about 40-45 tons/ha. Crop production in greenhouses requires suitable varieties and management skills. Value- addition through on-farm grading and packaging gets higher profits High quality, long duration crop inside a climate-controlled greenhouse. High cost of structure and energy to operate results in high production cost needs premium markets for good returns. Off-season production of vegetables in naturally ventilated tunnel type greenhouse is highly profitable and risk-free for small growers.

Fig.7. Production of quality tomato under zero energy naturally ventilated poly house at PFDC Pantnagar

EMPLOYMENT GENERATION THROUGH PROTECTED CULTIVATION

Greenhouse production system offers great scope of employment for providing service support to the greenhouse growers. It has been observed that big manufacturers of greenhouses are often not prompt in giving support services, like, replacement of plastic, nets, repair of structural members etc., which adversely affect the production schedules of these enterprises. These types of services including micro-irrigation can be undertaken by local entrepreneurs by developing suitable skills and facilities. On an average, this would provide regular employment to 3 persons per hectare area under greenhouses / micro irrigation. Protected cultivation technology offers high quality fresh products with minimum toxic residues. It also provides scope of agro-enterprise on small land holdings.

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The Evolution of Cotton Harvesting: A Critical Review of Contemporary Technologies



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1.1 INTRODUCTION:

Cotton, a soft and white fibrous material, envelops the seeds of the cotton plant and is processed into textile fibers and threads, widely used in sewing.It can be also defined as a crop plant with white hairs. In the world, China and India are the largest producers of cotton. Cotton is an important commercial crop in India. In India, the state of Gujarat, Maharashtra, Karnataka, Andhra Pradesh and Madhya Pradesh are leading cotton producing states (Gupta et al, 2017).

Cotton holds a pivotal role in shaping both the social and economic landscape of Indian society. As a significant contributor to the global cotton industry, India ranks as the world's largest cotton producer, the second-largest exporter, and also the second-largest consumer. In the 2017-18 period, India's cotton production reached an impressive 362 lakh bales, each weighing 170 kg. Among the states, Gujarat led the production with 105 lakh bales, while Karnataka ranked seventh, contributing 18 lakh bales. During the same year, India's cotton exports amounted to 60 lakh bales. The domestic utilization of cotton spanned across various sectors, including mill consumption, small scale industry units, and other non-mill applications, as reported by the Cotton Association of India in 2018.

1.2. HISTORY OF COTTON HARVESTING

In the early 1920s cotton was still picked by hand and caused a lot of manual labour, people would go day by day picking the flowers from the plants placing them in bags this is how it had been for very many years (Evolution of the Cotton Picker 2013).In the late 1930s the first one row cotton picker was developed and sold but John Rust but was not commercially sold, the picker also proved not to be very durable and so the inventor was reluctant to sell many.In the early 1940s the cotton picker became commercially made and sold. The barbed spindles would pick the cotton on the plants and would drop it to the ground this did potentially degrade the cotton but it was mechanical and this meant less labour.In the 1950s the original spindle for the cotton picker was redesigned into a more durable and stronger metal, it could pick multiple rows and had a basket to catch the cotton instead of dropping it on the ground.

From the 1960's to 1980's, various modifications were made in the cotton pickers as shown in Fig.2, keeping the basic concept same. In the 70's the first picker with a driver's cabin was introduced. This ensured the driver's safety and comfort making working on fields a pleasant experience.

The 4-row cotton picker, as shown in Fig.3, was introduced by John Deere in 1980 which increased operator's productivity by 85-95%. This increased the efficiency of cotton picking to a large extent and was welcomed by the farming community.

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In the late 90's, as shown in Fig.4, the six-row cotton picker had been introduced with a large basket on the back this new picker made cotton picking much faster and easier as the cotton was just tipped into a module builder where it was pressed.

In 2009 John Deer released the first-round baler which picks the cotton, rolls it, places it in a tarp and drops it to the ground. Therefore, less manual labour was needed again and the module builders were no longer needed to press the cotton as shown in fig.5.

1.3. TYPES OF COTTON HARVESTERS

1. Portable hand held cotton picker
2. Portable pneumatic cotton picker
3. Pneumatic cotton picker
4. Cotton strippers
5. Spindle cotton picker
6. Self propelled walk behind finger type cotton stripper
7. Cotton picking with electrostatically charged spindles
8. Cotton harvester with two bale chambers
9. Robot for picking of cotton

1.PORTABLE HAND HELD COTTON PICKER

The illustrated portable cotton picker in Figure 6 features a specialized mechanical design enabling efficient picking of cotton from each boll. This manually operated device incorporates a dual chain system with sharp, small teeth and sprockets, all powered by a lightweight 12V battery. The cotton fibers are caught by the chain and then funneled into a collection bag. Additionally, the machine contains two internal rollers adorned with blades on their peripheries, enhancing its functionality. The design prioritizes ease of use and affordability for field operators.

However, a comparative analysis revealed several disadvantages. Parameters like average heart rate, oxygen consumption, workload, and energy expenditure were significantly higher when using this manual cotton picker compared to traditional hand picking, across all three varieties of cotton tested. Specifically, oxygen consumption ranged between 0.81 to 0.97 liters per minute, workload from 36.32 to 46.16 Watts, and energy expenditure from 16.83 to 20.33 kJ per meter for both subjects in machine picking scenarios. Additionally, operators reported maximum discomfort in various body parts such as the right wrist, palm, forearm, upper and lower back, left shoulder, lower legs, and feet while using the manual cotton picker.(Maneset. al. 2012).

2.PORTABLE PNEUMATIC COTTON PICKER

It works on principle of generating vacuum and sucking cotton from each cotton ball. It consists of a suction tube whichcan be moved by operator from one boll to other as shown in Fig.7. Vacuum is generated in the pipe which helps insucking cotton from the boll and taking it to the storage bag which can be carried by operator on his back. Wholeassembly can be carried by field operator which makes the device easy to operate. The main limitation of pneumaticmultiple cotton picker is vacuum can take leaves and other trash of the plant with it. If trash gets trapped in cotton then itis very difficult to separate trash from cotton, cotton being a very fibrous material. Time required for cotton picking by pneumatic cotton picker is more as cotton from boll cannot be picked at a time. Weight of the machine also increases dueto use of compressor or blower for generating vacuum. Operator has to be skilled before using machine to pick the cottonefficiently. Due to all these constraints pneumatic cotton picker is not used worldwide (Ravinder, R. and Majumdar, G., 2013).

3.PNEUMATIC COTTON PICKER

The pneumatic cotton harvesting apparatus as shown in Fig. 8 includes a plurality of harvesting heads arranged inadjacent spaced relation side by side with each having a side panel opposing a side panel on an adjacent opposingharvesting head. An air intake manifold within each side panel has a plurality of extraction units with air intake ports forharvesting of seed cotton. The extraction units are each arranged in a staircase configuration to extract cotton into a passthrough chamber housed within the harvesting head. The cotton is transferred through the air plenum transfer chamberattached to the harvesting heads to a cotton storage container. Air supply nozzles arranged before the extraction units aidthe extraction of cotton by blowing air on the cotton plant before entering the extraction units to loosen the cotton. Horizontal ledges above and below the air intake ports and raised deflectors forward and rearward of the of the air intakeports deflect the cotton plants away from the air intake ports and support the vacuum mechanism for extraction of thecotton seed through the extraction (J.A. Bell, 2010).

4. COTTON STRIPPERS

Cotton strippers as shown in Fig.9,a type of harvesting machinery employed for one-time harvest. These machines are particularly useful in regions where climatic conditions don't permit multiple harvests. Cotton strippers work by either plucking entire bolls, irrespective of their ripeness, or by cutting the stalk near ground level, thus collecting the whole stalk along with the cotton bolls. Subsequently, another machine is utilized to separate the burrs and plant debris. Historically, early versions of these machines included a wooden sled, which was pulled by a horse or mule. This sled was ingeniously designed to harvest cotton. It achieved this by guiding the plants through a conical gap that was wide enough to allow the stalks through while narrow enough to capture both open and unopened bolls. Typically, these sleds were designed to harvest a single row of cotton per pass, although there were models capable of handling multiple rows. Post-harvest, farmers would often gather the cotton on the edge of the field, allowing any green bolls that hadn't yet opened to do so prior to the ginning process (Wanjura 2010).

5.SPINDLE COTTON PICKER

The spindle picking arrangement is shown in Fig.10.The plants would pass over a series of spindles that were turning atfairly high speed. When the spindle encountered an open boll, the cotton fibers would wrap around the spindle. Thespindle would then move around to a doffer where the spindles would rotate in the opposite direction and the dofferwould doff the fibers off the spindles further the spindles pass through the moisturizing units which easily pick the cottonand holds it on to the spindle accelerating the picking efficiency (Willcutt, 2010).

6.SELF PROPELLED WALK BEHIND FINGER TYPE COTTON STRIPPER

A novel self-propelled, walk-behind, finger-type cotton stripper was engineered by integrating a specially designed cotton stripper header onto a self-propelled power tiller, powered by a 3.6 kW engine. The cotton stripper header was meticulously developed, taking into account optimal specifications for the stripping fingers, kicker/paddle mechanism, belt-pulley arrangement, and a material collecting tank.In this innovative model, the 70 cm long stripping fingers were strategically welded to the front part of the engine frame, positioned at a 21° angle. The header itself measured 64 cm in width. It featured a dynamically rotating paddle/kicker, operating at a speed range of 120 – 250 m-1, effectively guiding the stripped materials—including open and closed cotton bolls, along with sticks and burs—into a collecting drum. This drum, with a capacity of 15-20 kg, was affixed behind the header for efficient collection of the harvested cotton(Sharma et al. 2014).

The operational principle of this cotton stripper is straightforward yet effective: as the machine moves through the cotton field, its forward motion and the incline of the fingers facilitate the stripping of cotton bolls, including green bolls, sticks, and leaves, while leaving the rest of the plant undisturbed in the field.

7. COTTON PICKING WITH ELECTROSTATICALLY CHARGED SPINDLES

Spindle picker machines rely on the direct contact of rotating spindles with mature cotton fibers, adhering the fibers to the spindles for effective picking. However, due to the sheer number of bolls and limited spindle contact, many bolls are often missed, leaving cotton unpicked in the fields. The traditional method of wetting spindles with water to enhance picking efficiency introduces mechanical complications and demands specialized maintenance. Additionally, the water can cause discoloration and staining of the cotton, and in cold weather, there's a risk of the moistening system freezing.

An innovative solution to these challenges involves applying an electrostatic charge to the picking spindles and, inductively, to the cotton itself. This method effectively creates a magnetic-like attraction, drawing the cotton towards the spindles, thereby ensuring contact with bolls that would otherwise remain untouched.

The electrostatic forces not only attract the fibers to the spindles but also aid in their adherence, reducing the loss of cotton during the wrapping process. Furthermore, this invention includes the pre-treatment of the cotton within the open bolls using an induced electrostatic force, encouraging the individual fibers to stand upright and actively reach towards the rotating spindles in the picking zone (Beach, R. and Hare, N., 1954).

8.COTTON HARVESTER WITH TWO BALE CHAMBERS

An on-board cotton harvester baling System includes firstand Second balers mounted Side-by-side on the frame of a cotton harvester adjacent a single accumulator that extendsgenerally the width of the balers. One of two sets of metering rollers located at the bottom of the accumulator is selectively activated to feed cotton to the first baler. A reversible augerextending the width of the accumulator moves cotton within the accumulator towards the activated Set of metering rolls to assure a continued Supply of material for the operating baler. When the first bale is fully formed, the oppositeSet of metering rolls and the Second baler are activated, andthe auger is reversed. The completed bale can be easilyunloaded while the Second baler operates so that cotton harvester operation

9. ROBOT FOR PICKING OF COTTON

The aims at achieving a prominent solution with the use of Machine vision together with Image Processing and Microcontrollers foridentification, recognition, and processing of the cotton image assuch and picking the cotton with robotic arms to yield maximumproduction in a day per hectare. Research and development inperceptual system for robots enabled the agricultural sector tocatch hold of the technology in reducing the overall cost. Theseintelligent robots use variety of visual sensors to detect objectswith respect to their identity, position, color, orientation in 3Dpattern at the fields. Based on the input signal from DSP processor, theelectrical control system with feedback employed moves therobotic arm which consists of six degree of freedom (6-DOF)movement i.e., at waist, shoulder, elbow, wrist, thumb, and the signal given by the DSP chip must be analyzedby the controller used and should give a correct signal to theservo mechanism to operate these six axis movementsaccording to the cotton location, distance, 3D position (Rao, USN., 2013).

CONCLUSION

Machine picking of cotton demonstrates significant savings in terms of cost, time, and energy when compared to traditional manual methods.Advanced cotton harvesters are a common sight in developed countries, streamlining the harvesting process with their technological sophistication.However, in India, the scenario differs. Given the prevalence of small-sized landholdings and the practice of conducting multiple picking rounds, advanced cotton harvesting technologies are less utilized and Indian cotton varieties are not suitable to developed heavy machines.

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Farm Robots: A New Reality for Indian Agriculture

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INTRODUCTION

Robots has been catching the imagination of masses in almost all the field including medicine, automobiles, shopping malls, offices, news reading, household works etc. Though agriculture sector has been lagging in adopting robots for field activities, a no. of standalone application has been already performed by the farm robots. The farm robots are mostly fully autonomous or semi-autonomous types. Farmers with thousands of acres of land in developed countries as well as a farmer in a developing country with only a few acres of land could use the robots for field operation. Even automation has always been a big part of agriculture, from the traditional land preparation to modern combine harvesters and IOTs. So, the automated robots, should have sound motors which will be a key component to perform their tasks, driving their robotic arms enabling them to move, grip & pick to undertake precision tasks. The supporting data acquisition sensors should match to requirement of the robots for quick interpretation. The automatic guidance of vehicle,

Different components of agricultural robots are

- Vision system
- Control system
- Mechanical actuators
- Mobile platforms

VISION SYSTEM

This is the eye of the robot. It captured the images of the surrounding objects through mounted sensors such as panchromatic, visible, NIR or thermal camera (operating at different wavelength). Panchromatic sensors give a binary image of black or white color. The visible sensors replicate the actual color of the object. The NIR cameras generally more sensitive towards vegetation. The thermal cameras could be used for measuring variation in temperature, also help in identifying hidden objects.The vision or acquisition system also includes touch sensors, proximity sensor, inertial sensor (accelerometer, gyroscope etc.), sound sensors and environmental sensors etc.

CONTROL SYSTEM

The controlsystem works as brain of a robot. It recordsthe information from the vision system and analyses, and prepares the response accordingly. These control units may be CPU or GPU type. The GPU is generally expert in analysing graphical information and designed for parallel computing operation.

MECHANICAL ACTUATORS

As per the directions given by the control system, the actuators perform the duty of its movement, positioning and specialized activity. The actuators can be of electrical type, small hydraulic system, piezoelectric type or pneumatic type. The actuators should be reliable and durable, as their performancesare closed observed. This may affect the standing crop if not monitored properly.

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Figure 1: Different systems of agricultural robots (Katzschmann et al., 2018; Raj et al., 2019)

MOBILE PLATFORM

It helps the robot to navigate, take turns, avoid obstacles and ensure smooth movement of the system around the working environment. The movement is generally laser guided by carrying out continuous scan of the surroundings. The mobile platforms required very special attention as the robots need to move through farm lands, undulated terrain under open sky condition.The broad use of fully autonomous agricultural robots reduces labor costs and greatly increases the efficiency of farming work. Meanwhile, semi-autonomous robots are also an indispensable element of agricultural robots considering variable condition of agricultural fields.

SCOPE OF AGRICULTURAL ROBOTS

Various agricultural operations have been carried out through robots as standalone applications. Integration of these activities may be required for developing robot based automated agriculture systems.

Tillage operation: It is a major operation in agriculture to initiate the farming activity for preparing the land surface for sowingseed or transplanting the seedlings. Through mechanization, the primary and secondary tillage mostly carried out through tractor or power tiller mounted implements. Initial involvement of robot for tillage operation was through operating driverless tractors. These tractors are mounted with different navigation system to move around the field following a loaded route map. The big size farm lands in the developed countries may not be problem for driverless tractor operation with minimum risk of hitting a plot boundary or obstacles. Recently, John Deere rolled out an electric robot tractor called Sesam 2, which can produce 300 kW (400 hp) of power and play a key role in both tilling and harvesting. Moreover, it is able to achieve synergy with several other robots (Heidrich et al. 2022).

Sowing/transplanting robots: Sowing or transplanting is generally carried out after a level surface is prepared through ploughing or puddling operations. Row sowing can be easily carried out by small size robots with minimum attention from the operators. Transplanting has been a labour intensive job with least time available to complete the job. Flying robots (Drone) may be used for transplanting of seedlings, as monitoring movement of robots through puddle soil may require intensive research work. However, driverless self-propelled transplanters could be tried in future to carry out transplanting work.

Inter-culture operations: The spraying of weedcides, pesticides etc. has been immensely taken over by the drones. Through the projects of Government of India (2022) drones have been provided to State agricultural universities and various research institute. The drone system is somewhat expensive, which may be supported through Custom Hiring Centres or cooperatives to the farmers. However, spraying drone has very high field capacity, which can cover large area in short time. This system is very effective for small size farm plots engaged in growing a single crop (for instance rice crop or jute crop) covering a large area.Even driverless tractor mounted spraying system can also be used for large size farm lands. Somewhat inspection is required as spraying is affected by wind and surrounding conditions. Now-a-days, variable rate spraying is also encouraged for optimizing the crop input use and reducing the ill impact of over spraying through modern technology.Direct removal of weeds may be a great challenge for robots for field crops for broadcasted seeding. However, the weeds within two rows of a row-crop can be easily remove by the robots.

Irrigation/fertilizer application: Irrigation reduces crop stress and ensures proper vegetation growth. Based on the input from the field sensors measuring soil moisture, temperature, humidity etc., irrigation scheduling can have been automated with least inspection. The operation of the irrigation pumps power through electricity or solar panels can put on/off through fully automated mode or by a remotely monitored system.Fertilizers are generally available in the form of big granules, small granules or liquid form. It may be applied

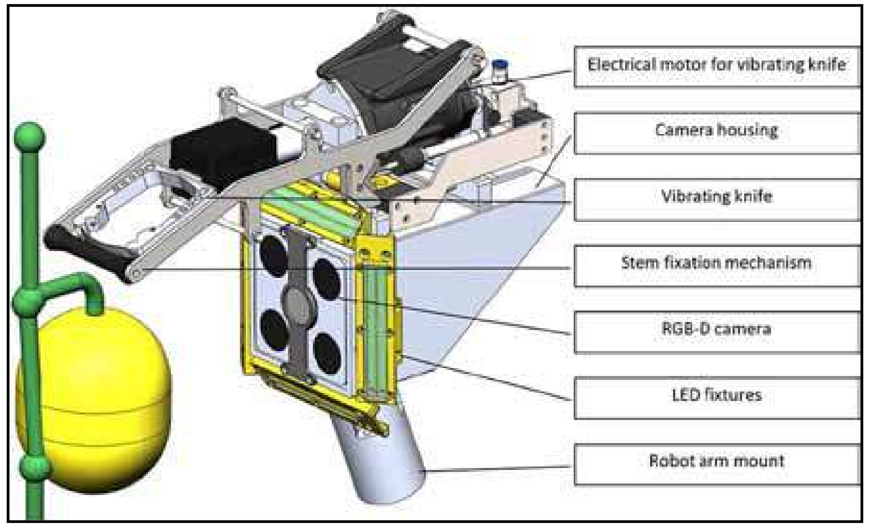

Figure 2: Schematic diagram of a sweet pepper harvesting robot (Arad et al., 2020)

in terms of top dressing, besides the plant or the soil with systematic approach. Based on the type fertilizer and application technique, robots may be designed for field applications. Even liquid or soluble fertilizer may be applied through drones.

Harvesting and threshing operation: Harvesting of greenhouse crops has been initiated for quite sometimes ago. Sweeper robot is used for sweet pepper harvesting in greenhouse(Arad et al., 2020). There is huge scope for designing robots for harvesting operation with the development of machine learning techniques and mobile platforms. Particular row crops, and vegetables and fruits can be easily harvested by robots.

Robots in allied agriculture sectors: Robots have been used for milking of cows since last two decades in developed countries like Denmark etc. (Filho et al., 2020). Animal feeding can also be carried out through robots.

BENEFITS OF ROBOTS IN AGRICULTURE

Robotics in agriculture will ensure

- Better productivity
- Waste reduction
- Precision and timeliness of operation
- Long term cost effectiveness

DRAWBACKS

As agriculture operations are complicated more research work required to enhance the efficiency of farm robots. Cost has been a major drawback in implementing robots along with lack of user friendly technology for wider adoption. A long way need to cover in terms of implementing robots for agricultural application.

CONCLUSION

Robots are the promising technology to reduce labour demand, ensure food security and take agriculture to next level.Driverless tractors mounted with implements can be controlled from remote place to carryout various field operations. Flying robots (drone) is going to play big role in automation of various agricultural operations. Robotic agriculture may require some investment by the farmers, which will give handful return in future. Additionally,there is an emerging global interest in cooperative robotics in agriculture, which will open path for adopting robots.

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