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# Harvesting Tomorrow: A Blueprint for Enhancing Agricultural Productivity & Sustainable Agricultural Progress

October 2023

# Message

Agriculture plays a vital role in India's economy, engaging approximately half of the country's workforce and contributing significantly to its GDP. However, traditional farming practices face considerable challenges, such as limited availability of arable land, erratic weather patterns, and inadequate access to resources and technology. The global population is rapidly growing, placing increasing demands on agricultural systems to produce enough food sustainably. To meet these challenges, enhancing agricultural productivity has become a necessity. Integrating improved inputs, technology, and mechanization are vital strategies to boost agricultural productivity. By combining these elements, farmers can optimize their crop yields, improve efficiency, reduce labour requirements, and ultimately contribute to a more sustainable and resilient food production system.

Modern technologies like precision agriculture, remote sensing, drones, and farm management software are revolutionizing Indian agriculture by enabling farmers to make data-driven decisions regarding crop selection, irrigation scheduling, pest control, and fertilizer management. Moreover, innovative startups providing advanced analytics platforms or mobile applications have emerged in recent years to enhance farmers' knowledge of market trends, provide real-time weather updates for better planning, and connect them directly with buyers through e-commerce platforms.

Several initiatives have been put in place by the Indian Government to strengthen the value chain for seed production. Through various programmes, the Government aims to improve the availability of quality seeds and planting materials for farmers nationwide. However, creating awareness about modern agri techniques and their adoption and collaborations between research institutions and corporations are further required to contribute to the growth of this sector, as these initiatives would help optimize resource utilization and improve overall agricultural efficiency while reducing environmental impacts.

Given the significance of the subject, ASSOCHAM, jointly with Nangia Andersen LLP, has come out with this report highlighting the importance of enhancing agri inputs and technological advancements in driving its transformation to increase agricultural productivity and food security. The report also highlights the challenges of agri infrastructure, supply chain, availability of finance and policy perspective to enhance the efficiency and effectiveness of agri practices. We acknowledge the efforts made by the experts in preparing the report being presented at the National Conference on 'Enhancing Agricultural Productivity: Integration of Improved Inputs, Technology and Mechanization'. We hope the report will provide useful information and insights to the stakeholders.

**Deepak Sood**
Secretary General
ASSOCHAM

# Foreword

Agriculture productivity, the key to ensuring food security and economic growth, has evolved into a dynamic realm shaped by innovation, technology, and sustainable practices. As partners in the journey of crafting this comprehensive report, we take great pride in presenting a synthesis of insights, innovations, and strategic perspectives for a holistic view of the agricultural ecosystem.

In the ever-evolving landscape of agriculture, recent advancements have propelled the sector into a new era of productivity and sustainability. Technological innovations, precision farming techniques, and breakthroughs in agrochemicals have reshaped the way we cultivate the land. From the integration of AI and IoT in precision agriculture to the development of climate-resilient crop varieties through biotechnology, the agricultural domain is witnessing a transformative wave. This report navigates through the cutting-edge developments, exploring how these strides in agricultural inputs and productivity are not only enhancing yields but also paving the way for a more resilient, eco-conscious, and productive future for global agriculture.

In these pages, we navigate the intersections of biotechnology, climate resilience, and farmer empowerment, spanning from the meticulous examination of current agricultural landscapes to showcasing global best practices of sustainable practices, offering a roadmap for resilient and environmentally conscious agriculture.

I hope that this report will serve as a guiding compass for policymakers, researchers, and all those invested in a resilient and sustainable future for agriculture.

Together, let us cultivate a world where innovation harmonizes with tradition, where every seed planted holds the promise of a sustainable and abundant tomorrow, and where each harvest symbolizes not just a bounty of crops but a promise for the future of our planet and its people.

Thank you.

**Asgar Naqvi**
Partner
Nangia Andersen LLP

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# 01 Executive Summary

The report commences with an in-depth analysis of the current state of agriculture, examining schemes, seed production systems, agrochemicals, and supply chains. Ongoing projects and research updates offer a dynamic snapshot of the agricultural landscape. Delving into agricultural productivity, it explores advancement in seeds, fertilizers, and pesticides, shedding light on technologies like genetic modification, biofortification, and precision farming. It also explores good farming practices and global benchmarks, in the form of case studies/success stories serving as a practical guide. A critical analysis of doubling farmers' income explores technologies, productivity, and diversification. Efforts to enhance farmer collectives, accessibility to inputs, and the impactful 10,000 FPOs scheme are scrutinized. The report also explores the policy environment, incentives for technology adoption, and a comprehensive database on inputs. Addressing challenges posed by climate change, it emphasizes farmer empowerment, sustainable practices, and the transformative role of technology.

## Highlights from the Report:

### Current Status and Issues pertaining to farm productivity

Agricultural growth is measured by Total Factor Productivity (TFP), which signifies an increase in output—be it crops, livestock, or aquaculture products—without an escalated demand for land, labour, capital, or other resources. TFP rises when producers embrace innovative technologies or more efficient practices, achieving higher output with the same or fewer resources, and a surge in TFP growth indicates a broader adoption of scientifically validated tools, fostering sustainable resource use. From 2011 to 2021, South Asia and China were the global frontrunners in robust TFP growth. In South Asia, India and Pakistan drove significant growth, attributed to technological advancements, including technology adoption, mechanization, labour reallocation, and the integration of ICT for disseminating agricultural information.

### Farm Inputs & Productivity

During the 1960s and 1970s, the most crucial driver of increased agricultural output was input intensification, involving the adoption of improved crop varieties, increased application of fertilizers and crop protection products, and the use of mechanization. However, starting in the 1980s, TFP growth became the predominant contributor to agricultural output growth, a trend continuing to the present day. Additionally, new technologies such as genetic modification, biofortification, and precision farming, coupled with the latest developments in research and development also boost productivity.

### Good Farming Practices and Global Best Practices

The ability of smallholder farmers to modify farming practises and lower risk has improved because of advances in ICT, including GPS, GIS, mediation software, mobile phones, and satellite imaging. In addition, these developments make it possible for governments and development partners to predict the future with more accuracy and monitor farm productivity more effectively.

## Doubling of Farmers' Income - Role of Agri infrastructure and supply chain

### Future Perspectives

i) Integrated Agri Logistics Hubs

The future envisions the establishment of integrated agri logistics hubs strategically located to facilitate seamless connectivity between production centres and consumption zones. These hubs could incorporate warehousing, cold storage, processing units, and efficient transportation networks.

ii) Data-Driven Decision Making

Continued integration of data-driven technologies will be pivotal for informed decision-making across the agri-supply chain. Artificial intelligence and analytics can optimize routes, manage inventory, and predict demand, contributing to overall efficiency.

## Farmer Collectives & Farm Input Accessibility – Recent efforts

A few FPOs have found success in the inputs sector, particularly with regard to fertilisers, pesticides, seeds, and farming equipment, and there are still many gaps in the management of agricultural inputs. Due to its extensive farmer base, the FPO that joins the system can immediately profit through a customer-centric strategy to increase input sales and profits. From these FPO centres, a variety of services including agricultural loans, crop insurance, technological inputs, and marketing assistance can be coordinated. The farming community will benefit when FPOs work with tech firms to pilot essential farming solutions and there exists a specialised national digital platform for inventory management and credit linkages.

## Adopting Technology for improving Agricultural Productivity and information dissemination: farmer's perspective

Leveraging technology for soil and land health faces challenges, hindering its potential against climate change and environmental degradation. Overcoming these requires significant adjustments and investments.

i. Government involvement, especially at the national policy level, promotes awareness and adoption of new technologies.

ii. Ongoing research is crucial for refining and standardizing various soil testing techniques.

iii. Access to information and education on export guidelines and environmental concerns is essential for a modern perspective.

iv. Financial incentives, credit, and insurance plans are needed to encourage technology adoption.

v. Farmer training through extension education, capacity building, and promoting farmer-led enterprises can enhance soil productivity.

vi. Stakeholders must creatively use ICT in local contexts, adapting it to agricultural challenges and macroeconomic needs while considering existing infrastructure.

## Policy Environment

A critical examination of the policy environment unfolds insights into macroeconomic policies, agricultural sector policies, marketing, pricing, trade, and infrastructure. The report also explores incentives for the adoption of innovations and technology, along with the creation of a comprehensive database on inputs. Policy strategies to accelerate productivity:

i. Invest in R&D and Extension Services

ii. Embrace Science & ICT based practices

iii. Improve Infrastructure & Market access

iv. Cultivate Partners for Sustainable Agriculture & improved Nutrition

v. Expand & improve Regional & Global Trade

vi. Reduce Post-Harvest loss & Food wastage

## Emerging Trends in Agriculture Inputs

Agriculture 4.0 is distinguished by a reliance on data-driven management, the adoption of novel tool-based production methods, a commitment to sustainability, a drive towards professionalization, and the endeavour to minimize the environmental impact of farming through the integration of contemporary smart technologies. Notable among these technologies are robot technology, encompassing drones, big data analytics, artificial intelligence, computer vision, 5G connectivity, cloud computing, the Internet of Things, and blockchain. The incorporation of these technologies into agricultural systems imparts greater autonomy and intelligence to the production processes. Fully Automated Decision-Making Systems (ADMS) are designed to monitor multiple chemical or physical parameters of soil and plants while simultaneously regulating them to maintain optimal conditions for each specific plant or soil type.

## Role of Agriculture Biotechnology, Climate Change Resilience, and Sustainable Agriculture Practices

Biotechnology's role in agriculture is pivotal, particularly in precision breeding for climate-resilient crops and genetic modification for pest and disease resistance. The report highlights successes in developing drought-tolerant varieties and reducing reliance on chemical pesticides. Addressing climate change challenges, it explores crop adaptation to shifting climatic patterns and sustainable water management practices, drawing insights from Bangladesh and Israel. Farmer empowerment through training programs and digital platforms is crucial, showcasing positive outcomes in sub-Saharan Africa and India's AgriTech sector. Sustainable agriculture practices, like agroecological approaches and conservation agriculture, are detailed for environmental and climate mitigation. The synthesis emphasizes the dynamic interplay of biotechnology and sustainable practices in securing global food systems and fostering resilience in agriculture.

# 02 | Current Status and issues pertaining to farm productivity

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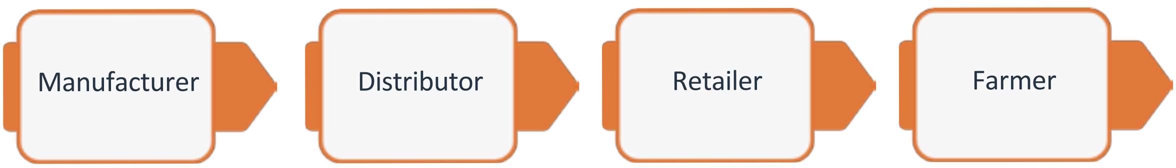
Agricultural intensification and expansion, that started with the Green Revolution, prioritises input-intensive and large-scale uniform production of few crops and livestock, particularly input-intensive and high-yielding varieties (HYV) of grains such as maize, wheat, soy and rice. Agriculture has become resource intensive, and it impacts biodiversity and environment, water resources etc. Agricultural systems are increasingly vulnerable to climate change, uniformity of production systems and degradation of natural resources.[1]

Even with subsidies, incentives and extension support, the overall economic situation of farmers remains precarious owing to many factors such as the high costs of HYV seeds and other inputs, fragmentation of land and low market control. Conditions required for modern agricultural crops are unviable for many small-scale farmers who are left to survive on the meagre margins they make in the complex food systems. Other undesirable socioeconomic consequences include destabilization of food supply patterns, cultural erosion, more vulnerability to price shocks and erosion of the diversity of farms.[2]

*Figure 1. A typical Input Supply Chain*




Cultivated crop varieties, food supply and diets have become more value has raised global malnutrition rates (undernutrition, overnutrition and micronutrient deficiencies). There is evidence that the current global food system is unable to meet consumer demand for certain food groups such as nuts and seeds, fruits and vegetables to ensure healthy diets, let alone guarantee access to these foods.[3]

If the goal of doubling farmers' actual income is to be realised, increasing resource use efficiency is just as crucial, if not more, than increasing the price realization.

In 2015, **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)** was introduced. The Government of India identified a total of 106 projects, which together would irrigate 6.8 million hectares. Less than half of the projected field channels (32.47%) have been built in 88 projects, according to the command area development and water management (CAD&WM) website.

To ensure risk-free crop production **Pradhan Mantri Fasal Bima Yojana (PMFBY)**, which increases the scope of crop insurance by including more crops under plan coverage and mandates crop insurance for Agri loans, was introduced in the 2016 kharif season. Farmers have to pay just 2% (for kharif crops) and 1.5% (for rabi crops), as premiums, in comparison to the previous scheme. The cap on sum insured was also removed and linked to total cost of cultivation. According to the Government, coverage under the Pradhan Mantri Fasal

[1] Fanzo, J., Hunter, D., Borelli, T., & Mattei, F. (Eds.). 2013. Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health. Routledge. https://www.bioversityinternational.org/e- library/publications/detail/diversifying-food-and-diets/

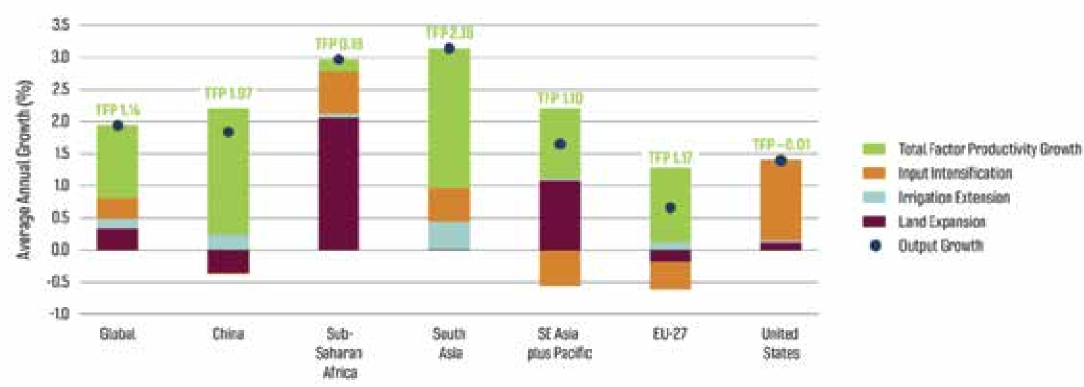
[2] IPES-Food. 2016. From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems. International Panel of Experts on Sustainable Food systems. http://www.ipes-food.org/images/Reports/UniformityToDiversity_FullReport.pdf

[3] FAO. 2016. Influencing food environments for healthy diets. Rome. http://www.fao.org/3/a-i6484e.pdf

Bima Yojana (PMFBY) has increased from 23% of the gross cropped area (GCA) in 2015–16 under the previous schemes to 30% in 2017–18.

Expressed as total factor productivity (TFP), growth in agricultural productivity happens when producers enhance their output of crops, livestock, or aquaculture products without requiring more land, labour, capital, fertilizer, feed, or livestock. To put it differently, TFP increases when producers employ innovative agricultural technologies or more efficient practices to boost output using the same or fewer resources.

An upturn in TFP growth indicates that an increasing number of producers are adopting, at the very least, scientifically validated tools—such as technologies, strategies, and practices—that enhance the sustainable use of limited resources, including non-renewable ones.




Source: USDA Economic Research Service (2023)

Between 2011 and 2021, South Asia and China stood out as the sole global regions experiencing robust TFP growth (as depicted in the figure above). In South Asia, robust TFP growth (2.18 percent) was primarily driven by India and Pakistan (2.47 and 2.41 percent, respectively). Among South Asian nations, only Bangladesh showed a decline in TFP (-1.16 percent annually). The surge in productivity in South Asia is primarily attributed to technological advancements, encompassing technology adoption, mechanization, labour reallocation, and the integration of information and communications technology (ICT) to disseminate agricultural information (Liu et al., 2020a).

**Pradhan Mantri Kisan Samman Nidhi Yojana (PMKISAN)** was introduced in 2019 and is intended for all small and marginal farmers (those who cultivate less than 2 hectares of land) in the nation. The farmer receives an unconditional cash transfer of Rs. 6000 per year, paid in three instalments of Rs. 2000 each. With an annual budget of Rs. 75,000 crore for 2019–20, the farmer can use the money for anything, including purchasing inputs for agriculture and allied activities and meeting domestic needs. The importance of Rs. 6000/year/farmer family, however, will be important in certain locations but insufficient in others since farmers' income and cost of agricultural inputs vary significantly between Indian states.

[4] Radheshyam Jadhav. 2021. Coverage under PM crop insurance scheme has increased: Central Government. Businessline. Pune. https://www.thehindubusinessline.com/economy/agri-businesscoverage-under-pm-crop-insurance-scheme-has-increased-central-government/article30793449.ece

**Rashtriya Krishi Vikas Yojana (RKVY)** is a significant programme that aims to improve infrastructure in agriculture and related fields. A new element under the updated programme **RKVY- RAFTAAR** was introduced in 2018–19 with a goal of fostering an incubation ecosystem and encouraging agricultural entrepreneurship and innovation.

Small land holdings in India poses constraints on farmers' ability to engage in mixed farming or adopt innovative crop-growing techniques. In recent years, the government has been proactive in creating a conducive environment for agriculture, advocating necessary reforms. The nationwide promotion of **Farmer Producer Organizations** stands out as an initiative that has proven beneficial and inspirational for the farming community. However, the prolonged reliance on higher subsidies for chemical fertilizer purchases may potentially hinder farm productivity, leading to adverse long-term effects on soil health. Alternatively, the adoption of newly developed technological tools, such as nationwide **soil testing facilities**, has significantly influenced farmers' decisions regarding crop selection, crop rotation strategies, mechanization levels, and irrigation system choices.

The **digital resources** available to farmers not only facilitate efficient capacity utilization but also have the potential to optimize field operations, resource utilization, and enhance the overall agricultural value chain. Farmers in India encounter significant risks due to small land sizes, limited irrigation facilities, and the burden of expensive informal farm liabilities. Both past and present governments have actively identified and worked to address these challenges. **Farm Mechanisation** initiatives and farmer incentive programmes are being implemented to increase the technological rigour and resilience of farming sector in India. **Applications like Umang and Mkisan** have expedited the dissemination of crucial information to farming communities, enabling farmers to access government benefits, subscribe to seed-fertilizer-credit subsidies, and obtain other vital information. However, achieving an exponential increase in agricultural output requires a comprehensive effort across the entire farming ecosystem, and in this direction, the sector has seen the entry of Agri-entrepreneurs into the agriculture ecosystem.[5]

**Entrepreneur-created service-based models** have empowered farmers to increase production and augment their incomes, bringing about positive socioeconomic changes. The government is cognizant of these disruptive models that are reshaping the ecosystem and has occasionally facilitated changes to agricultural legislation. Startups have influenced every facet of the farming value chain, from providing high-quality seeds to offering farm machinery, logistics support, and access to new markets. They are also at the forefront of offering cutting-edge solutions to increase farm productivity through technologies like **blockchain and AI.**

The ease of obtaining credit and accompanying operational policies that align with the entire value chain are pivotal factors contributing to the success of any sector. There has been a discernible shift in the availability of agricultural loans from non-institutional sources to formal institutions. The categorization of **agricultural loans as a priority sector lending** has induced a transformative shift, impacting the entire lending outreach. Emphasizing new-age financing with targeted actions at the institutional level is poised to further enhance credit access. A more extensive and well-publicized **Kisan credit card** program would substantially improve farmers' access to finance.

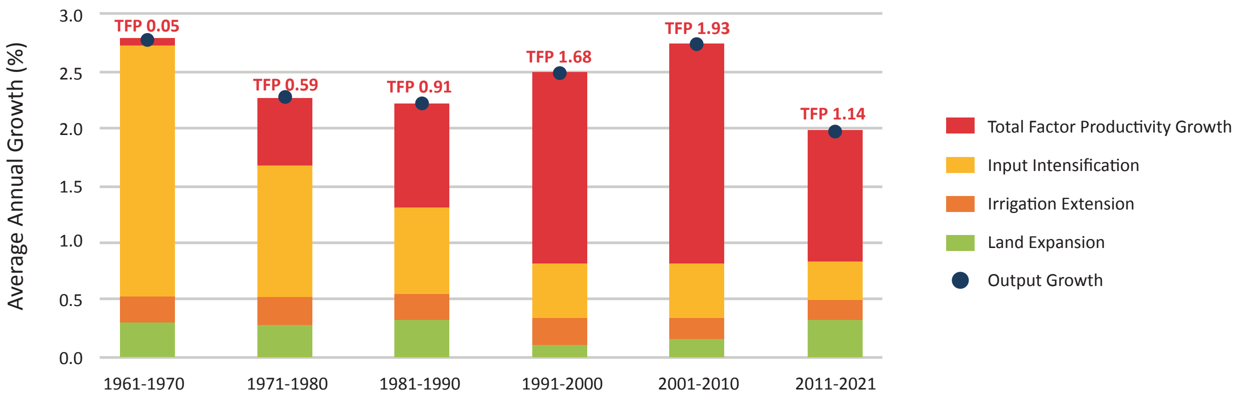
Recent efforts to expand agricultural credit, broaden the scope of crop insurance, and establish a social security system specifically for farmers have positively impacted the farming community. These policy-level measures hold the potential to improve their financial well-being, consequently enhancing the utilization of agricultural inputs for increased Agricultural Productivity.

[5] Manglesh R. Yadav, Shashank Gore. Strengthening the Indian agriculture ecosystem. Niti Aayog. https://www.niti.gov.in/strengthening-indian-agriculture-ecosystem

# 03 | Farm inputs and productivity

# 03 Farm inputs and productivity

The three pillars of modern agriculture—seeds, fertilisers, and pesticides—have played a critical role in expanding the boundaries of agricultural productivity. Introduction of high yielding varieties (HYV) of seeds, along with efficient fertiliser use, and increased irrigation, marked the beginning of the Green Revolution in India.




**Source:** USDA Economic Research Service (2023).

As a result of sluggish TFP growth, it seems difficult to achieve sustainable production of global agricultural needs by 2050, further widening the gap, making it even more difficult to close.6 The widening gap in Total Factor Productivity (TFP) growth carries significant implications, notably the utilization of unsustainable agricultural practices such as the conversion of wild and marginal lands into agricultural production. As a consequence of these practices, a portion of the gap remains unfilled, leading to unacceptably high levels of malnutrition and rural poverty, an accelerated loss of biodiversity, and detrimental system-wide inefficiencies. This gap will disproportionately impact communities that are already resourcepoor.[7]

During the 1960s and 1970s, the most crucial driver of increased agricultural output was input intensification, involving the adoption of improved crop varieties, increased application of fertilizers and crop protection products, and the use of mechanization (as depicted in the figure above). However, starting in the 1980s, TFP growth became the predominant contributor to agricultural output growth, a trend continuing to the present day. In the 1990s, global TFP growth averaged 1.68 percent annually, increasing to an average annual TFP growth of 1.93 percent during the first decade of the 21st century.[8] Regrettably, from 2011 to 2021, average annual global TFP growth fell to 1.14 percent, concluding two decades of robust growth and significantly falling below the global GAP Index target.

The low TFP growth indicates a decline in both the pace of innovation and the adoption of agricultural innovations. This trend is especially alarming given the forthcoming agricultural production challenges. The contraction in TFP growth may worsen already elevated levels of food insecurity and malnutrition, posing a threat to the potential for agriculture-led economic growth in numerous nations.

[6]Global Sources of Agricultural Output Growth, 1961–2021, Global Agricultural Productivity (GAP) Report, 2023
[7] Ibid.
[8] Ibid.

## Seeds

Three types of institutions manufacture seeds in India: public sector seed-producing corporations, private sector businesses, including multinationals, and research facilities and agricultural colleges. The public sector's percentage of seed production in the nation decreased from 42.72 percent in 2017–18 to 35.54 percent in 2020–21, while the private sector's percentage increased from 57.28 percent to 64.46 percent over the same time period, underscoring the growing importance of private businesses in India's seed industry.

**1960-80s**

- Minimal private sector participation
- R&D in public domain
- Restrictions on germplasm exchange, foreign ownership etc.

**Post - NSP 1988**

- Foreign direct nvestment allowed and encouraged
- Imports of improved varieties and breeding lines liberalised
- Trade regulations liberalised

**Present Status**

- Private Sector account for 80% turnover in seed
- Almost 1/3rd of the companies have a global technology/financial partner
- Private seed companie are spending 10-12% of their turnover in R&D

*Figure 2 Evolution of seed sector in India[10]*

[6] Radheshyam Jadhav. 2021. Seeding growth Private sector's share in India's seed industry expands to 65 per cent. Businessline. Pune. https://www.thehindubusinessline.com/data-stories/data-focus/private-sectors-share-in-indias-seed-industry-expands-to-65- per-cent/arti-cle35101260.ece

[10] J S Chauhan, S Rajendra Prasad, Satinder Pal, P R Choudhury, K Udaya Bhaskar. 2016. Seed production of field crops in India: quality assurance, status, impact and way forward. Indian Council of Agricultural Research. New Delhi

[11] Dashboard. Seednet India Portal. https://seednet.gov.in/GraphReport/SeedGraph.aspx

## Pesticides

With an average world pesticide consumption of 3 Kg/hectare, India still has a long way to go with a consumption of 0.3 Kg/hectare. In comparison, China's consumption stands at 13.06 Kg/hectare, Japan's at 11.8 Kg/hectare, and Brazil's at 4.7 Kg/hectare. New molecules with increased efficacy, reduced toxicity, and with A.I. as low as 4gms/hectare, are a result of remarkable investments in R&D. A few of the Pesticide Industry players are spending as high as 10-15% of their turnover on R&D.

Although, the market for agrochemical pesticides has grown steadily since 2006, in addition to developing and selling agricultural chemicals, major agrochemical companies have focused on genetically modified seeds, which accounts for a considerable proportion of their total sales, growing at a much faster rate, around three times higher than that of the crop protection market.[12] Crop stress management, majority of which is contributed by environmental stress, is an approach with greater potential for improving yield compared to conventional agrochemicals that target biotic stress.

The cost and time required to develop agrochemicals have been increasing each year, and the process involves: discovering a new agrochemical compound; conducting safety studies, biological studies, formulation research in parallel; comprehensively evaluating the results from these studies; and finally applying for and obtaining registration as an agrochemical. The probability of obtaining a new agrochemical is estimated as one in around 160 thousand compounds.

As such, each company developing agrochemicals has to invest 7–10% of its sales in R&D activities every year.[13] Added to it are the field trails, toxic studies and environmental studies cost, which occur at later stage of development of a new product. These harsh conditions are a direct result of growing demand for safer agrochemicals and tightening regulations by national authorities.

[12] P. McDougall: AgriService, Industry Overview—2016 Market (2017).

[13] Ray Nishimoto. 2019: Global trends in the crop protection industry. Pesticide Science Society of Japan. Tokyo

## Fertilisers

Over time, "leakages" started to occur more frequently in India's fertiliser distribution system. According to the Economic Survey of 2015–16, 65% of the fertiliser did not reach the small and marginal farmers, who were supposed to benefit from it.

To promote openness in the fertiliser distribution process, Government launched a number of measures. These include initiatives and technological advancements like the 2007 launch of the Fertilizer Management System (FMS) and the 2008 coating of urea with neem (Azadirachta indica) extract. By including the fertiliser subsidy under the Direct Benefit Transfer system (DBT) in 2016–17, the government carried out further reforms in the way fertiliser subsidies were distributed.

Several difficulties persist despite India's progress in fertilizer distribution. These include - absence of a specific database for fertiliser beneficiaries; no limit on farmers' entitlements to fertiliser, allowing them to purchase whatever amount, regardless of actual need; various degree of subsidies offered to fertiliser manufacturing facilities based on their production costs; excessive application of urea in comparison to potassium (K) or phosphorus (P) nutrients.

India imports over 25% of urea, 95% of phosphates and 100% of potash. India has safeguarded its farmers from price increase despite growing fertiliser costs globally. Further ₹ 1.10 lakh crore is being granted to support the farmers, in addition to the budget's ₹ 1.05 lakh crore fertiliser subsidy.[15]

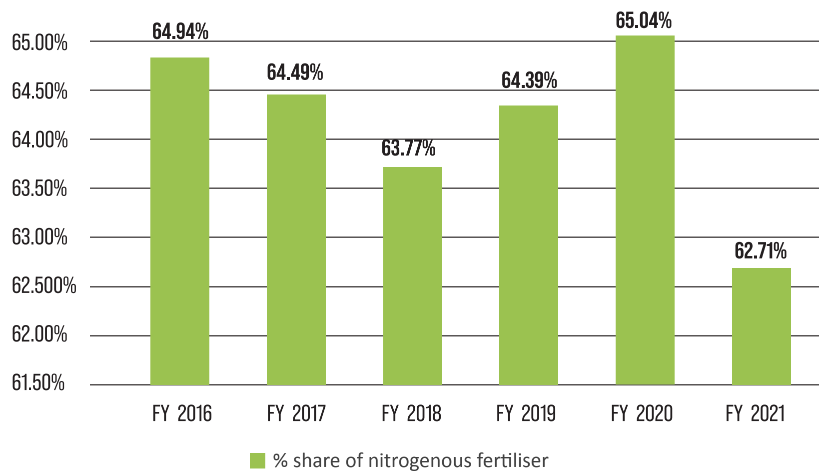



*Figure 4. Share of nitrogenous fertiliser to total fertiliser use in India*[16]

[14] Livemint. 2022. The ripple effects of the global fertiliser crisis on India. https://www.livemint.com/industry/agriculture/can-india-brave-the-global-fertilizer-shock-11650388856854.html

[15] Hindustan Times. 2022. India secures fertiliser supplies from Russia. https://www.hindustantimes.com/india-news/india-secures-fertiliser-supplies-from-russia-101653850554591.html

[16] Statista 2022

# 04 | Good Farming Practices and Global Best Practices

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Farmers must contend with an extremely competitive worldwide market. They work inside a convoluted web of governmental laws and a food chain dominated by a handful of major multinational corporations. Farm production must be cost- and price-driven in order to sustain itself. Therefore, new technology is required to boost production, and to remain competitive, farmers must keep up with these technological advancements.

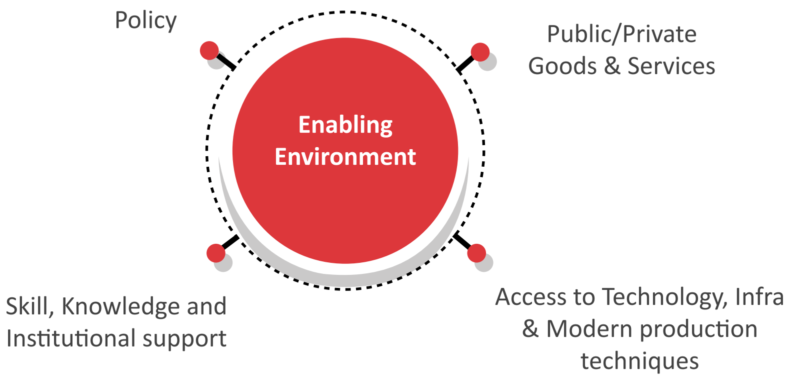



*Figure 5. Productivity Ecosystem*

| External Forces & Shocks | Behavioural Influences |
|---|---|
| Production Shocks | Capabilities(Skills, knowledge, training, support) |
| Conflict | Motivation(Beliefs, prefrences, education, risk, aspirations) |
| Socio- Political Shocks | Access, affordability & enablers/barriers |
| Input Shocks | Farm & Farmer characteristics; production technology |
| Price & Demand Shocks | |

The most significant driver of globalisation and expansion of world agriculture may be technological advancement. The following inferences can be drawn with respect to technological advancements:[17]

- The technology gap between wealthy and developing nations frequently exists.
- Farmer-society relations frequently change because of changes in farming technology
- New technology is frequently at the centre of disputes over international trade.

[17] Gerard Doornbos. 2001. Adopting technologies for sustainable farming systems: the farmer's perspective. OECD. Paris

Even though a farm's potential for production varies, traditional agricultural methods treated all the farms in a region, as homogeneous units. This perception changed, as farmers employed technology to assess the nutrient quality of the soil, crop potential, pasture health, and water-use efficiency.

Digital soil maps, for example, offer comprehensive soil data that can be stored and retrieved online. To evaluate soil and land variations, including understanding the soil characteristics, nitrogen management, and soil carbon sequestration; GPS, satellite imagery, remote sensors, and aerial photographs are used.

The information can also be disseminated swiftly through the Internet and mobile applications. Precision farming can be used to improve crop and livestock management, thanks to the ICT advancements which can improve soil and land productivity in a variety of ways, notably during the pre-planning and pre-planting phases of the production cycle. Some examples include:

- Utilizing sensor technologies for nutrient management.
- Accurate soil assessments, and better agricultural techniques through Digital Soil Mapping.
- Monitoring, measuring, and confirming carbon content and sequestration in agricultural land using satellite imagery and computer-based models.
- Using satellite technologies and wireless sensor networks for precision agriculture.

## Global Production Best Practices: Case Study 1

In Slovenia, the public agricultural advisory service is integrated within the Chamber of Agriculture and Forestry. Field advisors work together with specialist advisors and coordinating advisors to build efficient knowledge flows. The field advisors support farmers across the country. When the field advisors need more in-depth knowledge, they can call on a 'back-office' with specialist advisors who are well-connected to researchers, rural networks, experts from public services and others in the Agricultural Knowledge and Innovation Systems (AKIS) ecosystem. They organise training for the field advisors and prepare educational materials for producers. This cooperation between advisors helps them to cover a broader spectrum with targeted advice, and strengthens their connections with farmers, rural communities and innovative projects.

The ability of smallholder farmers to modify farming practises and lower risk has improved because of advances in ICT, including **GPS, GIS, mediation software, mobile phones, and satellite imaging**. In addition, these developments make it possible for governments and development partners to predict the future with more accuracy and monitor farm productivity more effectively.

To protect crops from pests and diseases, plant protection is crucial. The inability of farmers to recognise or accurately assess plant diseases can impair agricultural productivity and increase expenses, if pesticides are used excessively. Producers may identify, monitor, and safeguard their crops, animals, and livelihoods more accurately, by using a variety of technologies. ICT is increasingly being employed in **Integrated Pest Management Systems** and dissemination of crop protection information. For instance, "crowdsourcing," a concept that leverages mass participation by employing a variety of communication channels, can stop diseases from spreading in the first place. Linking weather data to the evolution of a pest or disease through time is also helpful.

## Global Production Best Practices: Case Study 2

The Africa Soil Information Services (AfSIS) aims to fill a major gap in soil spatial information in Africa. New soil data is collected at over 9000 locations from 60 sentinel sites in Africa and combined with collated and harmonised soil legacy data from over 18000 locations in Africa. The resulting database continues to grow and is the main input to digital soil mapping activities. Digital soil mapping combines information from soil point data with high-resolution, gridded environmental explanatory variables using geostatistical methods.

The raw data that **Wireless Sensor Networks (WSNs) and satellite images** collect, can be processed into knowledge that aid farmers in making the best decisions possible, regarding crop selection (based on water requirements), planting (timing and planting density), input purchases, and fertiliser application. Information about the climate can also help the insurance industry. The **Global Information and Early Warning System on Food and Agriculture (GIEWS) of the FAO** monitors information and patterns pertaining to food security, pricing risks, and natural disasters. The ubiquity of meteorological data made the productivity debate about mediation software very pertinent.

It is becoming more crucial for developing nations to create effective water usage laws and well-functioning, well-managed, irrigation systems due to severe water resource limits and climate change. Since agriculture uses 70% of the freshwater withdrawn from watercourses and groundwater, **efficient water management** is essential.

- The use of ICT tools, such as mobile phones, which improve the quality and frequency of producers' contact and engagement, improves the performance of **water-user associations** and their production.
- By providing spatial illustrations of the terrain, such as elevation and property boundaries, digital mapping features, such as digital orthophoto quads (DOQs), which are digital maps that combine the geometric information of a regular map with the detail of an **aerial photograph**, can help delineate irrigation canals and drainage systems.
- Using a laser scanning technology known as **LiDAR**, very accurate digital terrain models can be created for meticulous engineering designs and more extensive land and water management.
- In addition to using **GPS cameras** to monitor and build irrigation systems, satellite data is important for controlling irrigation plans.

## Global Production Best Practices: Case Study 3

The pilot funded by the Korea World Bank Partnership Facility and implemented by the World Bank is the first to show in a large scale on-farm trial that it is feasible for smallholder farmers to apply cutting-edge Internet of Things (IoT) Technology to increase water use efficiency in rice farming. In four rice growing seasons over a period of almost two years, the pilot collaborated with more than 80 smallholder farmers and one farm enterprise cultivating 70 hectares in three different provinces in the Mekong Delta of Vietnam, in Can Tho, Tra Vinh, and An Giang. The pilot applied a rigorous research design to assess the differential benefits of using IoT for applying the alternate wet and dry (AWD) technology in rice cultivation.

The opportunities and difficulties of economic and technological transformation, especially those to increase agricultural productivity and food security, must be met with a swift and effective response. For producers to interact with, and be heard by their peers, local authorities, and institutions, as well as gain access to pertinent knowledge and information, extension and advisory services are crucial. Farm advisory services, through traditional channels like radio, television, video, print media, libraries, and newer choices like text and voice messaging, internet, and mobile services, are still a key source of information for a large number of farmers. There is evidence to suggest that ICT can improve relationships across advising, extension, and research services, in ways that satisfy farmers' needs. But it is only one part of a larger transition, moving away from a traditional, top-down, technology-driven extension system, towards one that is, pluralistic, decentralised, farmer-led, and market-driven.

## Global Production Best Practices: Case Study 4

Egypt's Virtual Extension and Research Communication Network (VERCON) was launched in 2000 to develop and strengthen links among the research and extension components of the national agricultural knowledge and information system. By improving advisory services for Egyptian farmers, especially resource-poor farmers. Another such example is the Grameen Foundation's distributed network of intermediaries, called Community Knowledge Worker or CKW), who used mobile devices to collect and disseminate information to improve the livelihoods of smallholder farmers.

## Global Production Best Practices: Case Study 5

mKISAN, project conceptualized, designed and developed in-house within the Department of Agriculture & Cooperation has widened the outreach of scientists, experts and Government officers posted down to the Block level to disseminate information, give advisories and to provide advisories to farmers through their mobile telephones.

These messages are specific to farmers' specific needs & relevance at a particular point of time and generate heavy inflow of calls in the Kisan Call Centres where people call up to get supplementary information. SMS Portal for Farmers has empowered all Central and State Government Organizations in Agriculture & Allied sectors (including State Agriculture Universities, Krishi Vigyan Kendras, Agromet Forecasts Units of India Meteorological Department, ICAR Institutes, Organization in Animal Husbandry, Dairying & Fisheries etc.) to give information/services/advisories to farmers by SMS in their language, preference of agricultural practices and locations.

USSD (Unstructured Supplementary Service Data), IVRS (Interactive Voice Response System) and Pull SMS are value added services which have enabled farmers and other stakeholders not only to receive broadcast messages but also to get web-based services on their mobile without having internet. Semi-literate and illiterate farmers have also been targeted to be reached through voice messages.

## Global Production Best Practices: Case Study 6

Costa Rica conducted a participatory rural communication appraisal in selected regions to engage farmer organizations in sharing their knowledge. In the Brunca region, for example, livestock production dominates agriculture, and farmers identified livestock diseases as an important concern. One participant, a woman, was famous for her knowledge of how to cure sick cows. The organization decided that the best way to document her knowledge was to film her. The videos could be shown at the local livestock auction and remain available digitally on the national PLATICAR ("talk") Web platform.

# 05 | Doubling of farmers' income - role of Agri infrastructure and supply chain

# 05 Doubling of farmers' income - role of Agri infrastructure and supply chain

According to the Agricultural Census 2015–16, on an average, the size of an Indian farm is 1.08 ha, and it has been getting smaller over time (it was 2.3 ha in 1970–71). There are approximately 146 million landholdings in India, of which 68.5% are marginal holdings or less than 1 hectare, with an average size of 0.38 ha. A further 17.7% of Indian landholdings are classified as small or in the range of 1 to 2 ha, with an average size of 1.41 ha. In other words, 86% of Indian landholdings are smaller than 2 hectares and such farmers fall in the category of small and marginal farmers (SMF). Together, they cover around 47% of the 157 million hectares of operating land in the nation.[18]

To profile the income sources of a typical Indian farmer, the National Sample Survey Office (NSSO) conducted a survey of roughly 35,200 families in 2012–13. It was discovered that the typical Indian farmer earned money from four main sources:

i. Income from farming (including receipts from sales of field crops, plantation/orchard crops etc.)
ii. Income from livestock (including receipts from sales of milk, eggs, live animals, wool, fish, hides, bones, manure, etc.)
iii. Wages and salaries (including income from working on other people's farms; MGNREGA wages etc.)
iv. Income from non-farm work (including receipts from sales of prepared food, refreshments, and beverages, etc.)

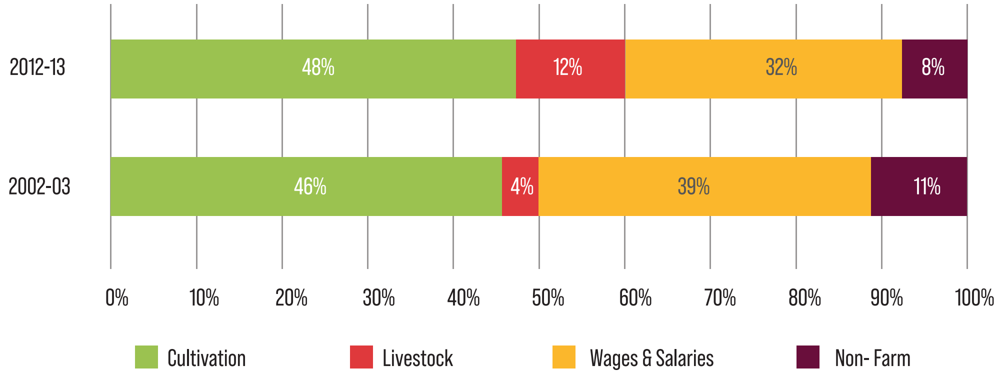



*Figure 6. Average farm income level and composition of farmer's incomes.[19]*

States like Uttar Pradesh, Rajasthan, Maharashtra, Madhya Pradesh, and Bihar, which are home to nearly 50% of Indian farmers, had the lowest incomes nationwide. Any strategic action taken by the Indian government to raise farmer incomes in the nation must have these states as its focus point.[20]

[18] A. Gulati et al. (eds.), Revitalizing Indian Agriculture and Boosting Farmer Incomes, India Studies in Business and Economics, https://doi.org/10.1007/978-981-15-9335-2_10

[19] NSSO 2002-03 and 2012–13 surveys

[20] Ibid.

Some of the areas of focus to double the farmers' income can be as follows:

i. **Improved Agri-Input Technologies:** It is the combination of mineral fertiliser, chemical plant protection, and modern high yield crop varieties, that has the potential to increase production, if used judiciously with ecological considerations. The amount of plant protection products that is necessary to secure the cultivation of crops, particularly from the aspect of economic viability and ecological sustainability, must be worked out. Moreover, investments in Agri-biotechnology, farm management software, mechanisation & equipment like drones, food safety & traceability, novel food and farming systems must match the global investments.

ii. **Improvement in crop productivity:** Achieving high productivity is essential for both, food security and global competitiveness, due to the inelastic nature of the land and the high concentration of farmer households. Committee for doubling farmers' income, set up in April 2016, under the chairmanship of Dr. Ashok Dalwai, suggested a change from the current method of measuring grain per hectare, to one that measures grains + nutrients per hectare. In order to close the yield gap, location-specific causes must be identified, and solutions proposed.

iii. **Resource use efficiency:** Making the soil health card programme more practical and adaptable should be a priority, with specific attention to facilitating soil testing at an affordable cost, creating district-level nutrient maps, enhancing technical proficiency in soil sample collection and testing, etc. Integrated Nutrient Management (INM) and ecosystem-based approaches to plant nutrition, including Organic Farming, should be emphasised in low-income states. Water use efficiency is equally important as nutritional security and access to food, and therefore, water quality monitoring and recording along the lines of the soil health card, wastewater recycling, and micro irrigation should be advocated.

iv. **Diversification and Income form Agri-allied sectors:** It is necessary to raise the productivity of livestock to supplement farmers' income. The key areas of intervention should be quality artificial insemination, genome selection and embryo transfer to sustainably improve breeds, and encouraging feed mills to make compound feed. Off-Farm income can be enhanced through creation of new enterprises around agricultural by-products/primary products, using either traditional or specific skill trainings. By facilitating special category funding and encouraging micro-enterprises run by women, farm-household income can be augmented significantly.

## Agri Infrastructure Challenges

### i. Warehousing and Storage Facilities

A robust warehousing and storage infrastructure is fundamental to preventing post-harvest losses and ensuring a steady supply of agricultural produce. The current status involves a mix of traditional storage methods and emerging technologies like controlled-atmosphere storage. Challenges include the need for widespread modernization, cold storage facilities, and a seamless integration with transportation networks.

### ii. Cold Chain Logistics

The cold chain is critical for preserving the quality and freshness of perishable goods. Currently, there is a growing emphasis on expanding the cold chain infrastructure, including refrigerated transportation and storage facilities. Challenges revolve around the high initial investment, energy efficiency, and maintaining the integrity of the cold chain throughout the supply network.

### iii. Transportation Networks

Efficient transportation networks are the lifeblood of the agri-supply chain. Current networks include a mix of road, rail, and increasingly, technology-driven solutions. However, challenges such as inadequate last-mile connectivity, suboptimal road conditions, and the need for technology integration for real-time tracking persist.

## Logistics and Supply Chain Management Challenges

### i. Digital Integration in Supply Chain

Emerging technologies, including IoT and blockchain, are revolutionizing supply chain management. These technologies enable real-time monitoring, traceability, and transparency, reducing inefficiencies and ensuring the integrity of the supply chain. However, challenges exist in terms of widespread adoption, data security, and industry-wide standardization.

### ii. Farm-to-Fork Traceability

Consumers today are increasingly conscious of the origin and quality of their food. Implementing robust traceability systems from farm to fork is crucial. Current efforts involve leveraging technology to create transparent supply chains, but challenges include the need for universal standards and the integration of small-scale farmers into traceability systems.

### iii. E-commerce in Agriculture

The rise of e-commerce platforms dedicated to agriculture is transforming the way produce reaches consumers. These platforms facilitate direct farmer-to-consumer transactions, offering a potential solution to challenges in traditional supply chains. However, the digital divide, particularly in rural areas, remains a hurdle.

## Future Perspectives

### i. Integrated Agri Logistics Hubs

The future envisions the establishment of integrated agri logistics hubs strategically located to facilitate seamless connectivity between production centers and consumption zones. These hubs could incorporate warehousing, cold storage, processing units, and efficient transportation networks.

### ii. Data-Driven Decision Making

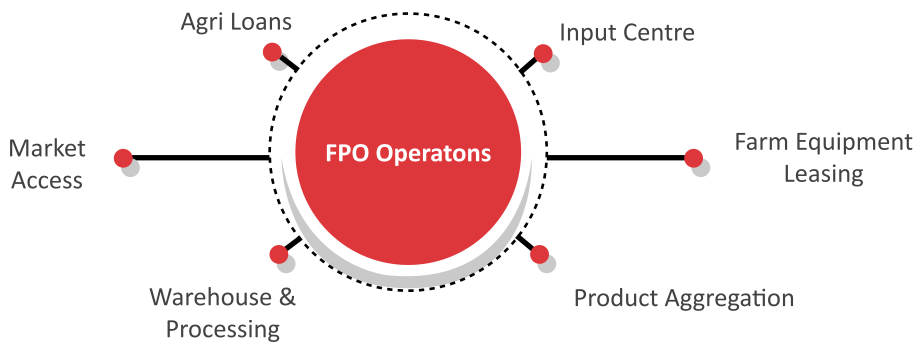
Continued integration of data-driven technologies will be pivotal for informed decision-making across the agri-supply chain. Artificial intelligence and analytics can optimize routes, manage inventory, and predict demand, contributing to overall efficiency.

**Agri infrastructure and logistics form the backbone of a resilient and efficient agricultural supply chain. Addressing current challenges and embracing innovative solutions will be key to ensuring a sustainable and inclusive system that benefits both producers and consumers. The convergence of traditional wisdom with modern technologies holds the promise of transforming the agri-infrastructure landscape, leading to the Doubling of farmers' income.**

# 06 | Farmer Collectives & Farm Input Accessibility – Recent efforts

The goal of FPOs, which are constituted of organised groups of small and marginal farmers, is to assist farmers in increasing their income, through increased market access and collective bargaining power, in both the input and output businesses.

FPOs view input business as one of the most successful ways to engage with farmer members, build business relationships, and guarantee the sale of high-quality goods at reasonable costs, while earning a reasonable profit.




- Share certificates
- Dividends
- Compliances
- Collection and maintenance of member profiles

However, the input business necessitates strategic planning at the FPO level, which includes assessing demand, organising the stock and managing it appropriately, input planning process from procurement to sale to its member farmers, and maintaining the stock register, among other things.

Farmers still buy from local stores because they are already mired in debt cycles, despite the fact that various start-ups and even input manufacturing companies are engaging directly with the farmers. Farmers still place their trust in neighbourhood retailers, who mislead them about the quality of the products they are offering, as it is in their own best interests to promote high margin items and earn large commissions, ultimately leading to the purchase of spurious products, because there is no regulation on them. The capital cycle of these start-ups/input manufacturing firms is negatively impacted by the seasonality of input procurement, and they have a low customer retention, as it takes a substantial amount of time to build lasting customer trust. As the owners and managers of FPOs, the farmer members can play a significant role to develop a long-lasting relationship of trust with the farmers for the purpose of obtaining inputs and farm advisories.

FPOs have significant advantages when running an input business. They can serve as a last-mile entity to advise farmers on the recommended input use, various government programmes, practises, and technologies for better input use. Also, the FPO can directly buy from manufacturers and receive discounts from them, thanks to their vast user base, which would encourage prompt product delivery, better quality, and a fair price for its member farmers.

However, given the current situation, there are problems with the FPO's input business, including lower operating margins, limited stock availability, improper demand estimation, a lack of inventory management expertise, etc. Currently, the FPOs are unable to carry out these tasks and are generally subject to the "bull whip effect," in which retailers overreact to demand and in turn inflate expectations, leading to significant swings in the supply chain. The inability of FPOs to accurately foresee the demand and the amount of produce that will be produced by farmer members to meet that demand, is a major contributing factor to agriculture market discrepancies. This erratic demand causes serious inefficiencies in FPOs' supply chains, including the purchase and storage of excess inventory, loss of income, and price spikes.[21]

Some of the important tasks for effective input planning include the creation of an input committee, baseline surveying, demand estimation and stock indenting, stock/inventory management, and distribution of inputs to FPO members. The primary responsibility of the leaders of the Farmer Interest Groups (FIGs) should be data collection, and BODs chosen by the committee should oversee and compile the results for the final demand estimation. CEO of the FPO should update the BODs on inventory and be the single point of contact for the manufacturers to procure agricultural inputs. Ensuring proper stocks, stock arrangement, stock review, and stock disposal are key elements of inventory management, and FPOs should have categories like seeds, fertiliser, plant protection chemicals and growth regulators, irrigation equipment, and other agricultural technologies that are appropriate for the local conditions.

Increase in the number of FPOs in the nation signifies farmer preference for more modern, effective production techniques. To encourage this, Indian government has also set a target of establishing 10,000 FPOs by 2023, which will enable them to serve a bigger farmer population and geographic area. Cluster Based Business Organizations (CBBOs) established across the nation will further improve these efforts, as they aim to bring technical resources and professional experience closer to the FPO. This would inevitably eliminate needless delays in the farmer's ability to obtain crucial inputs and make decisions.

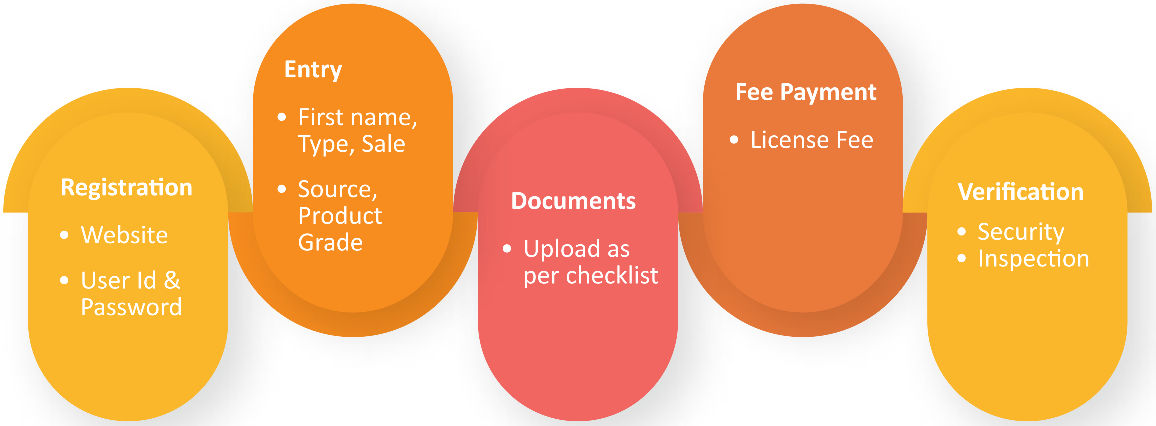



*Figure 7. Input Business license Registration process for FPO*

However, only a few FPOs have found success in the inputs sector, particularly with regard to fertilisers, pesticides, seeds, and farming equipment, and there are still many gaps in the management of agricultural inputs. Due to its extensive farmer base, the FPO that joins the system can immediately profit through a customer-centric strategy to increase input sales and profits. From these FPO centres, a variety of services including agricultural loans, crop insurance, technological inputs, and marketing assistance can be coordinated. The farming community will benefit when FPOs work with tech firms to pilot essential farming solutions and there exists a specialised national digital platform for inventory management and credit linkages. It would be vital if these steps were taken in conjunction with a strong monitoring system that could reduce hazards at various stages of agricultural production and losses in the value chain.

[21] Sustainable Supply Chain of Perishables into Cities (Green Logistics) Project – India. 2020. Guidebook on Input Busnsiness Planning and Management. GIZ. New Delhi.

# 07 Adopting Technology for improving Agricultural Productivity and information dissemination: farmer's perspective

Agricultural productivity increased globally because more land was cultivated, and more intensely, in recent decades. However, due to the rising number of competing uses for land as well as the associated environmental and social costs, adding more land to production is not practical. The desire for more land for farming frequently led to deforestation, decreased biodiversity, and other types of environmental damage. Additionally, it increased greenhouse gas emissions and eliminated options for some communities to earn a living.

Two sets of technologies are crucial in increasing agricultural productivity: yield technologies and ICT and digital tools. ICT and digital tools can support yield technologies, and vice versa, even though they serve different objectives and diverse operating mechanisms. When farmers have access to yield-enhancing technology like biophysical ones, they typically don't know how to employ them to solve their production problems. For instance, they can have fertiliser but not know how much to use. ICT tools like Radio, mobile technology, digital soil maps, and others provide farmers with information so they can employ biophysical technology effectively. Similarly, governments or development partners might be aware that farmers employ new technologies to increase yields but may not be able to comprehend their impact. Most promising ways to connect productivity and ICT, are data-mining tools, decision-support systems, and modelling software that can explain the effects and outputs of yield-enhancing technology.

### Remote Sensing Technologies

- Geographical Information Systems (GIS)
- Global Positioning System (GPS)
- Satellite imagery
- Aerial photography and orthophoto mosaic
- Laser scanning, or Light Detection And Ranging (LiDAR)

**Information Management Technologies**

- Spatial modeling
- Data mining
- Data mediation

**Dissemination Tools**

- Mobile Services/SMS
- Wifi Technologies
- Knowledge Management Systems

The challenge, however, is making sure that smallholders can access and make use of these technologies, which include management of irrigation systems, biotechnologies, pest control and eradication, soil assessment, improved nutrient and land management, improved market access, and innovative storage facilities. Three ways in which ICT could help to raise agricultural productivity are:

- **By improving the effectiveness of traditional farming productivity-boosting techniques:** For instance, to forecast disasters, map agrobiodiversity in multiple-cropping systems, provide timely and appropriate information and agricultural services, and monitor insect thresholds in integrated pest management.

- **Information exchange between farmers and other stakeholders:** For instance, when a hazardous diseases' symptoms occur, farmers can inform the local government or other relevant parties.

- **Optimal use of inputs:** By bettering farmers' knowledge of how to utilise and manage equipment, water, seeds, fertiliser, and pesticides.

To effectively reach the smallholders, technologies like mobile phones are crucial, but extension professionals and farmers themselves must transfer and share knowledge. Accessibility can be increased by integrating ICT into national programmes, fostering an investment-friendly policy climate, and establishing interoperable and uniform digital platforms for information exchange.

## Enabling Farmers to use ICT

### Affordability

Government involvement often raises the visibility and adoption rates for new types of ICT.

### Accessibility

- Technological
- Socio- Economical
- Cultural

### Adaptability

- Use of mobile phones as a platform for exchanging information through SMS and mobile apps.
- Satellites and remote sensors to collect and transmit data.
- Software and GPS services for supply chain and finanical management.

Using technology to enhance soil and land health still faces obstacles, despite its promise to reduce the effects of climate change and environmental degradation. These obstacles can be overcome by making major adjustments and investments in few areas. Firstly, new forms of technology frequently see higher awareness and adoption rates when the government is involved, particularly at the national policy level. Secondly, different soil testing techniques exist and are continuously being developed, further research is required to resolve current issues to make them more reliable and uniform. Thirdly, access to information and education is required, such as country's export guidelines and environmental concerns, to inculcate a modern perspective. Fourthly, access to financial incentives, credit and insurance plans to benefit from adoption of new technology. Fifthly, training and education of farmers with the aid of extension education and campaigns, institutional capacity building and promoting farmer led enterprises to aid in increasing soil and land productivity.

Finally, farmers, communities, government, and other stakeholders must comprehend how ICT might be used innovatively in the local context, to boost agricultural productivity. These stakeholders must learn to adapt ICT solutions to local agricultural obstacles as well as macroeconomic needs, while also examining how existing infrastructure may harness pertinent and appropriate technologies.

## ICT, Extension & Advisory Services


- Ensure local knowledge capture
- Knowledge Database for extension & advisory services
- Collective Action
- Connecting Farmers & Networks- Access to Information
- Precision Agriculture
- Alternate Livelihoods- Allied Sectors
- Gender Inclusion- Women Empowerment

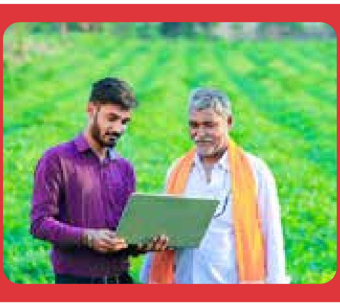
# 08 | Policy Environment

Most of the farmers are still having production and income issues, even after more than seven decades of planning since independence. Significant obstacles to Indian agriculture include:

- According to the Agricultural Census 2015–16, the size of an Indian farm is 1.08 ha on average, as a result, 86% of Indian landholdings are smaller than 2 hectares.
- Farmers' decisions regarding purchase of inputs and sale of produce, are impacted by the limited availability of credit and significant participation of unorganised creditors.
- Less technological utilisation, mechanisation, and low agricultural productivity
- Poor value addition vis-a-vis advanced agricultural nations, and negligible primary processing at farm level.
- Poor support infrastructure, excessive reliance on monsoons, ill developed marketing and supply chain systems.

In recent years, some of the most significant initiatives, policies and schemes for resolving farmer issues have been:

**Schemes**
- Doubling farmers' income
- Pradhan Mantri Krishi Sinchayee Yojana
- Pradhan Mantri Fasal Bima Yojana (PMFBY)
- Paramparagat Krishi Vikas Yojana (PKVY)
- Pradhan Mantri Kisan Samman Nidhi (PM-KISAN)
- Pradhan Mantri Annadata Aay Sanrakshan Abhiyan (PM-AASHA)



**Initiatives**
- Per Drop More Crop
- eNAM
- Formation and Promotion of 10,000 new Farmer Producer Organizations (FPOs)
- Agriculture Infrastructure Fund

**Policy Programmes**
- Agriculture Export Policy, 2018
- Model Land Leasing Act
- Model Contract Farming & Services Act, 2018
- Gramin Agricultural Markets (GrAMs)
- Model Agricultural Produce and Livestock Marketing (Promotion & Facilitation) Act, 2017

Farmers have fared poorly over the past few decades due to declining crop profitability. Their problems and discomfort have only gotten worse as a result of climate change and variability. All options have been considered, from raising MSP to waiving farm loans, but none have been able to alleviate the misery of farmers. Difficulties with the scheme/policy execution have made the farmer issues continue over time.

It is well-known that agriculture is vulnerable to natural disasters including drought, floods, cyclones, storms, landslides, earthquakes, etc. Sale of fake seeds, excessive fertiliser and pesticide use, and price crashes have all contributed to constraints of the farm sector. Crop insurance has lagged due to market inefficiencies like information asymmetry, moral hazard, and adverse selection. Moreover, the pandemic has exacerbated the detrimental impacts on produce and farmer revenue. Early or delayed rainfall, a shorter crop cycle, and a rise in temperatures are all signs of how climate change has negatively impacted farming activity.

To address the major issues facing Indian agriculture, such as small farm holdings, lack of primary and secondary processing, inefficient supply chains, poor support infrastructure, low resource use efficiency, poor marketing, and numerous market intermediaries, a more thorough analysis of the country's agricultural policy landscape is necessary. Work on cost-effective technology for environmental preservation, resource conservation, agricultural marketing reforms stimulating private investment, contract farming, futures trading, etc. is required.

| | |
|---|---|
| **Invest in R&D and Extension Services** | To generate innovation and information that facilitate environmentally sustainable agricultural output growth, improve human health, and support a vibrant agricultural economy. |
| **Embrace Science & ICT based Practices** | To enable producers of all scales to manage environmental and economic risks by improving their sustainability, resilience, and competitiveness. |
| **Improve Infrastructure & Market access** | To support sustainable economic growth, diminish waste and loss, and reduce costs for producers and consumers. |
| **Cultivate Partners for Sustainable Agriculture & improved Nutrition** | To leverage public and private investments in economic development, natural resource management, and human health. |
| **Expand & improve Regional & Global Trade** | Forward-looking trade agreements, including transparent policies and consistently enforced regulations, facilitate the efficient and cost-effective movement of agricultural inputs, services, and products. |
| **Reduce Post-Harvest loss & Food wastage** | Increases the availability and affordability of nutritious food, eases the environmental impact of food and agricultural production, and preserves the value of the land, labor, water, and other inputs used in the production process. |

*Figure 8. Six key strategies to accelerate productivity growth.*[22]

[22] Global Agricultural Productivity (GAP) Report, 2023

Along with this, other factors such as the ICT revolution in India, new agricultural technologies, private investments, particularly in R&D, government initiatives to revive the cooperative movement to address the issues of small holdings and small produce, etc., are altering the face of agriculture in India. Agri-entrepreneur businesses demonstrating the ability to comprehend the enormous potential of investing time and money in this sector, along with the combined influence of technology, will alter how agriculture is practiced. These new-age startups and entrepreneurial ventures have the potential to make significant investments in new ideas, inventions, research and development, and other areas of agriculture. Clubbed with various fiscal incentives provided by the government for inputs, production infrastructure, affordable credit facilities, and marketing and export promotion, the future of agriculture lies in the efforts being made to turn all the problems into opportunities. Policy options aiming at:

- **Infrastructure:** Promoting rural enterprises by creating massive infrastructure - efficient transportation, communications, and financial infrastructures - and affordable and equitable access to markets for agricultural inputs, services, and outputs; plays a significant role in rural income enhancement. Policies focussing on non-farm employment and rural infrastructure, including management of natural resources like land and water, apart from development of post-harvest architecture.
- **Inputs:** Most of the farmers cannot access quality inputs as over 86 per cent of them are small or marginal. Agri-startups, FPOs, and farmer centric policies providing access to affordable crop diagnostics can lead the way.
- **Extension:** Policies to reduce the knowledge gap between field-trial yields and that in farmers' fields, and promoting new technologies including precision farming, decision support systems, drones, Artificial Intelligence, and use of low-cost organic inputs.
- **Market:** Promoting internet-based market intelligence services like AGRISNET, e-Krishi and AGMARKNET, and price discovery/marketing services like e-NAM etc.

# 09 | Emerging Trends in Agriculture Inputs

Agriculture is continually evolving as it embraces technological advancements and sustainable practices. This chapter examines the contemporary landscape of agriculture inputs, exploring the transformative impact of innovations in seeds, fertilizers, plant protection, pesticides, and the integration of modern technologies. Furthermore, it highlights the pivotal role of farm mechanization, agriculture biotechnology, and strategies to counter the challenges posed by climate change.

## Advancements in Agricultural Inputs

### i. Seeds

In recent years, seed technology has undergone a revolution, with a shift towards precision breeding and genetic engineering. Success of drought-resistant maize varieties in Sub-Saharan Africa, increasing maize yields by at least one ton per hectare under moderate drought and with a 20 to 30 percent increase over farmers' current yields, benefiting up to 40 million people in 13 African countries[23], exemplify the positive impact of advanced seed technologies in addressing climate-related challenges. Precision breeding methods have enabled the development of crops with enhanced yield potential, resilience to pests and diseases, and improved nutritional profiles.

### ii. Fertilizers

Advancements in fertilizer formulations aim to enhance nutrient use efficiency while minimizing environmental impact. The adoption of controlled-release fertilizers, as seen in the case of coated urea in Indian agriculture, has shown promise in optimizing nutrient delivery, reducing environmental pollution, and improving crop yields, highlighting the sustainable benefits of advanced fertilizer formulations.

### ii. Plant Protection and Pesticides

Integrated Pest Management (IPM) strategies, combining biological control, cultural practices, and judicious use of chemical pesticides, are gaining prominence. A notable case study from China demonstrates successful IPM implementation in rice and maize fields, resulting in reduced pesticide use and increased crop yields.[24] Key highlights:

- At the end of the two projects in mid-2016, 20 Trichogramma rearing facilities (TRFs) were still producing Trichogramma egg-cards.
- Farmers using egg-cards significantly decreased the amount spent on pesticide by appx 37% and almost halved the numbers of times crops were sprayed.
- During the study, 45% to 100% of maize farmers reported an increase in yields whilst applying Trichogramma egg-cards.

[23] https://www.cimmyt.org/projects/drought-tolerant-maize-for-africa-dtma/

[24] Babendreier D., Wan M., Tang R., Tambo J., Liu Z., Grossrieder M., Kansiime M., Wood A., Zhang F. and Romney D. (2019) Impact of integrated pest management in rice and maize in the Greater Mekong Subregion. CABI Study Brief 32: Impact. DOI: https://dx.doi.org/10.1079/CABICOMM-62-8117

## Role of Modern Technology

In addition to the incremental adjustments in agricultural practices brought about by the preceding three industrial revolutions, the ongoing fourth industrial revolution is actively influencing the current state of agriculture, giving rise to Agriculture 4.0. This emerging paradigm is distinguished by a reliance on data-driven management, the adoption of novel tool-based production methods, a commitment to sustainability, a drive towards professionalization, and the endeavor to minimize the environmental impact of farming through the integration of contemporary smart technologies. Notable among these technologies are robot technology, encompassing drones, big data analytics, artificial intelligence, computer vision, 5G connectivity, cloud computing, the Internet of Things, and blockchain. The incorporation of these technologies into agricultural systems imparts greater autonomy and intelligence to the production processes.[25.]

### i. Precision Agriculture

Precision agriculture, enabled by satellite imaging, drones, and GPS technology, allows farmers to optimize resource use and increase efficiency. Two cases from United States demonstrates the successful implementation of precision agriculture in optimizing irrigation, reducing input wastage, and improving overall farm management.

- Partel et al.[26.] developed a target weed sprayer using deep learning neural network approach for ground-sensor based weed detection that yielded in 71% application accuracy in experimental fields in Florida, USA.

- Optical Trapezoid Model (OPTRAM), analogous to the traditional triangle model, soil moisture in OPTRAM is estimated based on the interpretation of STR-VI space. Using Sentinel-2 and Landsat-8 data, Sadeghi et al.[27.] showed reasonably accurate (<0.04 cm3/cm3) soil moisture estimations with OPTRAM model for grass and cropland dominated watersheds in Arizona and Oklahoma, USA.

### ii. Internet of Things (IoT) and Artificial Intelligence (AI)

The integration of IoT and AI in agriculture facilitates real-time data collection and decision-making. Use of IoT sensors and AI algorithms for predictive analytics in optimizing irrigation schedules, resulting in water savings and improved crop yields is promising.

Fully Automated Decision-Making Systems (ADMS) are designed to monitor multiple chemical or physical parameters of soil and plants while simultaneously regulating them to maintain optimal conditions for each specific plant or soil type. ADMS generally consists of four main sections: the sensing technique, sensor interfaces, the information transmission platform, and the data processing and control unit; using which precision agriculture utilises both historical and real-time data for well-informed decision making.[28.]

[25.] Karunathilake, E.M.B.M.; Le, A.T.; Heo, S.; Chung, Y.S.; Mansoor, S. The Path to Smart Farming: Innovations and Opportunities in Precision Agriculture. Agriculture 2023, 13, 1593. https://doi.org/10.3390/ agriculture13081593

[26.] Partel, V.; Kakarla, S.C.; Ampatzidis, Y. Development and evaluation of a low-cost and smart technology for precision weed management utilizing artificial intelligence. Comput. Electron. Agric. 2019, 157, 339–350.

[27.] Sadeghi, M.; Babaeian, E.; Tuller, M.; Jones, S.B. The optical trapezoid model: A novel approach to remote sensing of soil moisture applied to Sentinel-2 and Landsat-8 observations. Remote Sens. Environ. 2017, 198, 52–68.

[28.] Alahmad, T.; Neményi, M.; Nyéki, A. Applying IoT Sensors and Big Data to Improve Precision Crop Production: A Review. Agronomy 2023, 13, 2603. https://doi.org/ 10.3390/agronomy13102603

### iii. Farm Mechanization for Enhancing Productivity

The mechanization of farming operations, including planting, harvesting, and post-harvest processing, has a profound impact on agricultural productivity.

Case studies from Japan and Brazil exemplify how the adoption of advanced agricultural machinery has streamlined operations, reduced labor requirements, and increased overall farm output.

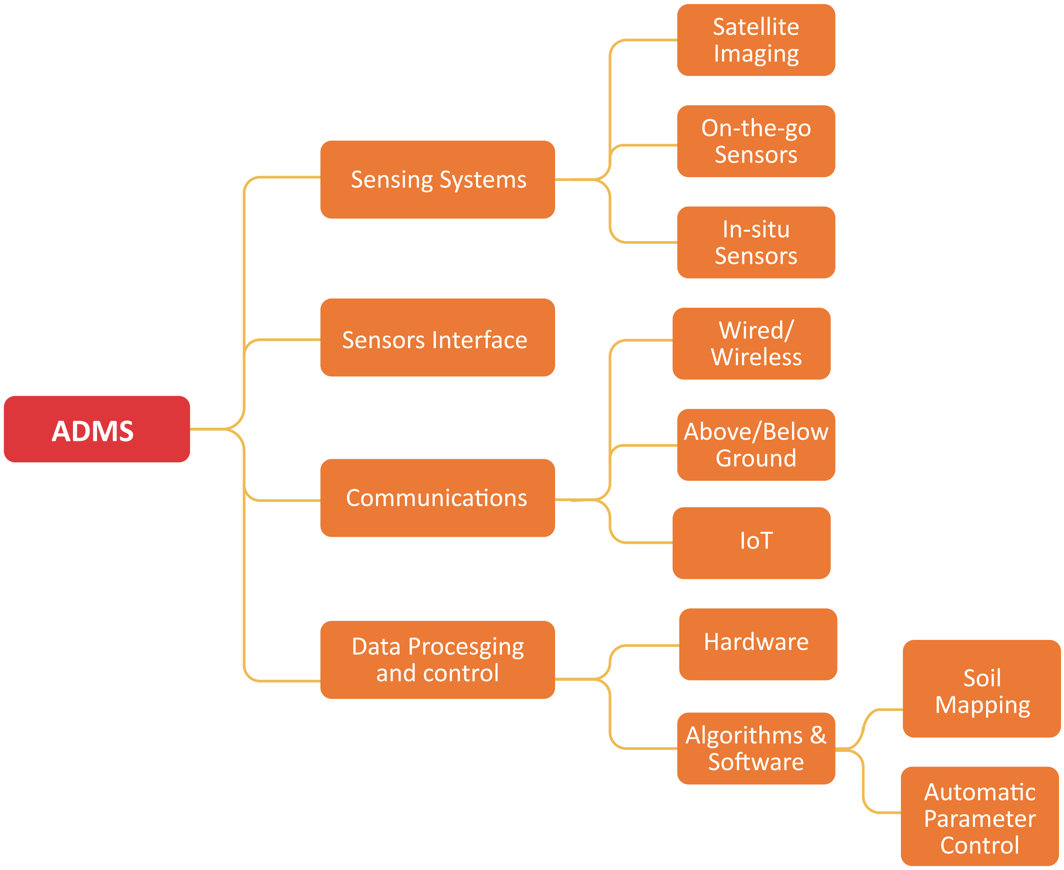



*Figure 9. Structure of a typical Automated Decision Making System (ADMS).*[29]

[29] Marios, S.; Georgiou, J. Precision Agriculture: Challenges in Sensors and Electronics for Real-Time Soil and Plant Monitoring. In Proceedings of the 2017 IEEE Biomedical Circuits and Systems Conference (BioCAS), Torino, Italy, 19–21 October 2017; pp. 1–4. [Google Scholar]

**Brazil** has been at the forefront of innovation, specializing in the creation and provision of technological solutions tailored primarily for tropical crops such as beans, sugar cane, and coffee. While small farms have historically been the focus of bean production, the emergence of robotic harvesting equipment has captured the attention of larger producers, particularly those employing irrigation systems. Manual harvesting is becoming increasingly challenging due to labor shortages and rising costs, prompting the recent development of a diverse array of mechanical coffee harvesting devices and equipment. In the case of sugar cane production, traditionally demanding substantial and labor-intensive efforts, the practice involved burning crop leaves before manual cutting. Currently, mechanical sugar cane harvesting methods are applied to approximately 35% of the planted area.

The agricultural sector in **Japan** boasts a high degree of mechanization, featuring approximately 500 tractors and 250 harvesters per 1,000 hectares. Japanese agriculture is characterized by the utilization of small, refined, and specialized machines. There is a discernible shift toward increased automation in the industry. Additionally, Japan exports its advanced machinery to various regions, including Asia and other parts of the world.

**These emerging trends in agriculture inputs underscore the pivotal role of innovation, sustainability, and technology in shaping the future of global food production. As evidenced by diverse case studies, the integration of advanced agricultural inputs and practices not only improves productivity but also addresses the challenges posed by climate change and resource constraints.**

# 10 Role of Agriculture Biotechnology, Climate Change Resilience, and Sustainable Agriculture Practices

As agriculture confronts the challenges posed by climate change, the integration of biotechnology emerges as a crucial determinant in fortifying global food security. This chapter delves into the multifaceted role of agriculture biotechnology in enhancing productivity while navigating the intricate landscape of climate change resilience. It analyses the challenges posed by shifting climatic patterns, explores strategies for building resilience in agriculture, and underscores the empowerment of farmers through capacity building initiatives and sustainable practices.

Agricultural biotechnology, encompassing genetic modification and gene editing, plays a crucial role in developing crops with desirable traits. The adoption of biotechnologically modified crops, such as insect resistant Bt cotton in India, has demonstrated improved pest control, increased yields, and reduced environmental impact.

## Role of Agriculture Biotechnology in Enhancing Productivity

### i. Precision Breeding for Climate-Resilient Crops

Advancements in agriculture biotechnology, particularly precision breeding techniques, play a pivotal role in developing climate-resilient crops. Case studies, such as the development of drought-tolerant varieties in water-scarce regions, exemplify how biotechnology contributes to improved crop yields in the face of changing climatic conditions. Some examples of conventional breeding programs for drought tolerance are the development of rice, wheat and Indian mustard varieties tolerant to salt and to alkali soils by the Central Soil Salinity Research Institute in Karnal, India; the development of maize hybrids with increased drought tolerance; efforts to incorporate salt tolerance to wheat from wild related species; and the incorporation of drought tolerance as a selection trait in the generation of new maize and wheat germplasm by the International Maize and Wheat Improvement Center.[30]

[30] Pocket K No. 32 Biotechnology for the Development of Drought Tolerant Crops. http://www.isaaa.org/kc

## ii. Genetic Modification for Pest and Disease Resistance

Biotechnological interventions, including genetic modification, have enabled the development of crops with enhanced resistance to pests and diseases. Genetic modification can significantly reduce the need for chemical pesticides, thereby promoting environmentally sustainable farming practices. Success stories with different points of intervention.[31] :

- 3R potato contains three NLRs effective against Phytophthora infestans, which is present as a single mating type in Uganda and Kenya.
- Cell-surface EF-Tu receptor (EFR) provides field level of resistance against the devastating tomato wilt pathogen Ralstonia solanacearum.
- Tomelo, genome-edited tomato has resistance against powdery mildew due to modification of the mlo gene.
- Heterologous expression of hypersensitive response-assisting protein (Hrap) and plant ferredoxin--like protein (Pflp) from sweet pepper provides field level resistance against Xanthomonas wilt disease in banana.
- Overexpression of a virus coat protein in papaya provides commercial control against Papaya ringspot virus in Hawaii.

# Challenges of Climate Change and Strategies for Building Resilience

Climate change poses significant challenges to agriculture, including altered precipitation patterns, increased temperatures, and the intensification of extreme weather events. Strategies for building resilience involve the development and promotion of crop varieties adapted to changing climatic conditions.

## i. Shifting Climatic Patterns and Crop Adaptation

The impacts of climate change, manifested in altered precipitation patterns and temperature extremes, pose substantial challenges to agriculture. The success story of **climate-resilient rice varieties in Bangladesh,** underscores the importance of proactive measures in crop adaptation. These varieties exhibit enhanced tolerance to climatic stresses, ensuring food security in the face of changing environmental conditions. T**he average yield advantages of BRRI dhan56, BRRI dhan71, BRRI dhan51, and BRRI dhan52 were 4.87%, 3.20%, 14.12%, and 10.21%, respectively.**[32] The new varieties were also significantly disseminated and adopted in the subsequent years after their introduction through on-farm trials. This can be credited to the superior performance of the varieties but also indicate how the learnings and awareness have not been limited to only the host farmers who participated in the on-farm trials. The multiple PRA events organized in the same villages affirmed the rapid

[31] van Esse HP, Reuber TL, van der Does D. Genetic modification to improve disease resistance in crops. New Phytol. 2020 Jan;225(1):70-86. doi: 10.1111/nph.15967. Epub 2019 Jul 11. PMID: 31135961; PMCID: PMC6916320.

[32] Nayak, S.; Habib, M.A.; Das, K.; Islam, S.; Hossain, S.M.; Karmakar, B.; Fritsche Neto, R.; Bhosale, S.; Bhardwaj, H.; Singh, S.; et al. Adoption Trend of Climate-Resilient Rice Varieties in Bangladesh. Sustainability 2022, 14, 5156. https://doi.org/10.3390 /su14095156

dissemination of farm-saved seeds through a community network and adoption of the varieties by neighbour farmers. **The adoption rate varied from 15% to 96%, with the average adoption rate of BRRI dhan51, BRRI dhan52, and BRRI dhan71 being 29.13%, 28.83%, and 76%, respectively.**[33]

### ii. Sustainable Water Management Practices

Climate change often exacerbates water scarcity in certain regions, necessitating sustainable water management practices.

Israel's adoption of precision irrigation technologies and sustainable water management plans, illustrate how such practices contribute to efficient water use, improved crop yields, and increased overall agricultural sustainability. About 94% of all wastewater is collected and treated, and 87% is reused, primarily for agriculture. Overall, between 2000 and 2018, agriculture's share of freshwater abstractions decreased from 64% to 35% of total water abstractions.

## Farmers' Empowerment with Capacity Building and Agriculture

### i. Training Programs for Technology Adoption

Empowering farmers with the knowledge and skills required for adopting new agricultural technologies is integral to building resilience. Case studies from extension programs in sub-Saharan Africa highlight the positive impact of training initiatives, resulting in improved agricultural practices, increased productivity, and enhanced livelihoods. **There is indication that countries in sub-Saharan Africa are embracing a variety of climate-smart technologies and practices tailored to their specific contexts.**

**Notably, popular practices, listed in order of prevalence, include enhanced water management, conservation agriculture, agroforestry, and digital agriculture, as reported by the World Bank in 2018.** Additionally, sub-Saharan Africa demonstrates promising outcomes with other climate-smart technologies and practices, such as the cultivation of climate-resilient crop varieties, sustainable intensification methods, and the conservation of natural resources, including rainwater harvesting and soil water conservation.[35] The preference for these practices primarily stems from their capacity to boost crop productivity, enhance soil fertility, and mitigate the risk of crop failure.

### ii. Access to Information and Climate-Responsive Farming

The empowerment of farmers extends to providing them with timely and relevant information for climate-responsive farming. Digital platforms and mobile applications, as observed in the case of AgriTech initiatives in India, facilitate access to weather forecasts, agronomic advice, and market information, thereby enabling farmers to make informed decisions.

[33] Ibid.

[34] https://www.oecd.org/climate-action/ipac/practices/israel-s-sustainable-water-management-plans-d81db5f5/

[35] Tesfaye, K., Kassie, M., Cairns, J.E., Michael, M., Stirling, C., Abate, T., et al., 2017. Potential for scaling up climate smart agricultural practices: examples from subSaharan Africa. In: Leal Filho, W., Belay, S., Kalangu, J., Menas, W., Munishi, P., Musiyiwa, K. (Eds.), Climate Change Adaptation in Africa. Climate Change Management. Springer, Cham, pp. 185–203. https://doi.org/10.1007/978-3-319- 49520-0_12.

| Segments | Description |
|---|---|
| **Downstream agtechs** | B2B or B2C platforms or brands that connect farmers with businesses or consumers. **Eg. Ninjacart, Absolute, and Waycool** |
| **End-to-end ecosystems** | Platforms that operate across the value chain and have a strong presence in a variety of areas, such as inputs and outputs. **Eg. DeHaat** |
| **Digital solutions and precision agtech** | These are digital solutions or products that give farmers with services such as advising, precision farming, and sensor-based solutions. **Eg. Cropin** |
| **Midstream agtechs** | Companies that assist in the provision of supply chain solutions that improve efficiencies in areas such as logistics and warehousing. **Eg. Arya** |
| **Agribiotech** | Agtechs that use biotechnology to generate green and sustainable new products or ingredients such as food additives. **Eg. String Bio** |
| **Farm to fork** | Direct-to-customer brands or platforms that connect farmers to end consumers and have an impact on improving farming practises. **Eg. Eggoz Nutrition, Akshayakalpa** |
| **Upstream agtechs** | B2C platforms for input linkages, for categories like seeds, nutrition, agrochemicals, etc. **Eg. AgroStar and BigHaat** |
| **Agriculture mechanization/automation** | Solutions that supply various automation technology or certain types of machines as a service for use on farms. **Eg. Tractor Junction** |
| **Agric.ulture fintech** | Developing long-term finance possibilities for rural agriculture stakeholders. **Eg. firms like Support Farming.** |

*Table 1 AgriTech Industry in India.*[36]

36. https://www.ibef.org/blogs/agritech-ecosystem-in-india

## Sustainable Agriculture Practices

Sustainable agriculture practices encompass a holistic approach to farming that promotes environmental stewardship, economic viability, and social equity.

### i. Agroecological Approaches for Environmental Sustainability

The **adoption of agroecological principles,** as illustrated by the case of **Adoption and Diffusion of Agroecological Practices in the Horticulture of Catalonia,**[37] showcases the potential of sustainable practices in conserving biodiversity, improving soil health, and delivering high-quality produce. **Below are some excerpts from the study shedding light on farmer perception and behaviour with respect to agroecological and sustainable agricultural practices:**

" *Farmers understood by agroecological practices those agricultural practices which are ecological and meet the daily demands of exploitation while enhancing the natural processes of crops' defense. They are environmentally friendly practices which maximize ecosystem services. It is also a symbiosis between profitability and sustainability. Producing agroecologically is producing with care and respect, living together in harmony with the environment and its natural surroundings.* "

" *Farmers had a good level of knowledge about all aspects of agroecological practices. The aspects best known by farmers were the "cost of adopting agroecological practices", "Crop rotation", "crop diversification" and the general concept of "agroecological practices.* "

" *The benefits most perceived by farmers are "Agroecology reinforces the health and well-being of the soil, environment, producer and consumer", "Agroecology allows to protect and/or conserve ecosystems", "Agroecology reduces environmental deterioration" and "Agroecology incorporates ancestral values and knowledge of an avant-garde character.* "

" *The agroecological practices most adopted by farmers so far are "Organic fertilization", the "Reduction of the use of inputs harmful to the environment", "Conservation agriculture", "Biological control of pests", "Drip irrigation", "Split fertilization" and "Choice of crops and rotations.* "

[37] Polonio Punzano, A.; Rahmani, D.; Cabello Delgado, M.d.M. Adoption and Diffusion of Agroecological Practices in the Horticulture of Catalonia. Agronomy 2021, 11, 1959. https://doi.org/ 10.3390/agronomy11101959

> *In the short term, the most adopted practices will be: "Reduction of the use of inputs harmful to the environment", "Drip irrigation of crops", "Effective management of nutrients and biomass", and "Conservation Agriculture". In the medium term they will be the "Elimination of synthetic chemical pesticides", the "Choice of crops and rotations", the "Reduction of the use of inputs harmful to the environment" and "Tillage 0"; and, in the long term, the "Use of the soil's own organisms", the "Use of crops resistant to any stress", the "Use clean and efficient technologies", among others and will never be: "Agroforestry", "Tillage 0", "Divided fertilization", etc.*

## ii. Conservation Agriculture for Climate Mitigation

Conservation agriculture practices, such as minimum tillage and cover cropping, contribute to climate mitigation by enhancing soil carbon sequestration. Conservation agriculture principles are universally applicable in all agroecological conditions and landscapes with necessary adaptation to the specific local and practical conditions.

**Advantages, in comparison with Conventional agriculture (Christensen and Johnston, 1997; Hobbs, 2008; Busari et al., 2015; Joseph and Issahaku, 2015), can be roughly divided as:**

| Short-Term Advantages | Long-Term Advantages |
|---|---|
| increased water infiltration and improved soil structure, lower trafficability and compaction, reduced erosion by wind and water, reduced soil water evaporation, lower water saturation/drought stress, lower fuel, mechanization and labour costs. | increased soil organic matter content resulted in better soil structure, Cation Exchange Capacity (CEC), higher water holding and storage capacity, improved crop nutrition, higher and stable yields, lower costs, increased biological activity, lower weediness. |

**The intertwining dynamics of agriculture biotechnology and climate change resilience underscore the need for strategic and innovative approaches in securing global food systems. As demonstrated by diverse case studies above, the judicious adoption of biotechnological interventions and sustainable agricultural practices is instrumental in navigating the challenges posed by climate change, empowering farmers, and ensuring a resilient and sustainable future for agriculture.**

# 11 | Conclusion and Way Forward

The ratio of farm output to farm input is called productivity. Fertility is not the same as productivity. High production does not always imply high fertility. For instance, productivity in India is substantially lower than in China and South Korea despite having more fertile agricultural area overall.

Three factors significantly control agricultural productivity, environment, socio-economic interactions, and inputs. Climate and soil are the primary influences of environment. In advanced nations, the land is well-managed, but in developing countries, land is passed down through families, making land management a social issue, as a result, agricultural growth is limited. A crucial role is played by inputs in agriculture, such as Irrigation facilities, HYV, Chemical fertilizer, Modern agricultural implements, Pesticides etc.

The international community supports national agricultural development plans that should have the backing of multi-lateral, regional, and bilateral donors, the corporate sector, other partners in development, and civil society. Several nations have already adopted this multi-stakeholder strategy for country-owned agriculture development projects. Even though there have been regional and intra-regional variances in agricultural production, emerging countries are increasingly making efforts to increase agricultural productivity, mostly by employing agricultural inputs. The rise in production that has been observed in some nations makes this clear. Examples of commercial grain farming include those practised in the United States, Canada, France, Norway, Sweden, Australia, and New Zealand. Wheat, maize, and rice yields in the USA and the potato and wheat yields in Western European nations are excellent. Several lessons could be drawn for the way forward:

## i. Sustainability

Conservation agriculture practices, such as minimum tillage and cover cropping, contribute to climate mitigation by enhancing soil carbon sequestration. Conservation agriculture principles are universally applicable in all agroecological conditions and landscapes with necessary adaptation to the specific local and practical conditions.

### ii. Multistakeholder Engagement:

Government, Agri-entrepreneurs, investors, development partners, farmers, and civil society need to come together as committed partners to attain common objectives through realistic working arrangements.

### iii. Setting Strategic Priorities:

Parative advantage, and market-based opportunities should be used to define the priorities for improving agricultural productivity. A national level productivity enhancement plan that identifies specific focal areas (regions or value chains) around which stakeholder activities can be defined, aligned to their mutual advantages.

### iv. Innovation, Investment and Entrepreneurship:

Market stimulus to promote Agri-entrepreneurship around strategic priorities. Public and private investments to boost innovation, with maximum potential for commercial and development returns, utilising value chain analysis, enhanced input use efficiency, and multi-sector engagement.

### v. Service Delivery & effective Scheme Implementation:

Designing, implementing, and overseeing schemes and initiatives to promote change on a large scale, through multi-stakeholder collaboration, community leadership and public-private coordination.

### vi. Hard & Soft Infrastructure:

Physical infrastructure, policy and regulations, human and institutional capacity building are key enablers for the agri-ecosystem transformation.

### vii. Agri-Finance & Risk Mitigation:

Mechanisms to finance and reduce risks to ensure productivity transformation's long-term success. This could involve raising fresh catalytic money or releasing restrained funds through policy changes or risk-reduction measures.

Future strategies should focus on fostering innovation and efficiency, embracing modern technologies and research updates to enhance the overall efficacy. To propel agricultural productivity, the adoption of advanced technologies in seeds, fertilizers, and pesticides should be at the forefront of future strategies. Exploring and implementing cutting-edge technologies such as genetically modified organisms (GMOs), biofortification, and precision farming can pave the way for sustainable and high-yield farming.

The future agenda should involve not only introducing but scaling up Good Farming Practices (GAP) globally. Strategies should emphasize comprehensive soil testing, the promotion of quality seeds and seed treatment, the integration of weather station and remote sensing services, and the adoption of integrated pest and nutrient management practices. Global best practices should serve as benchmarks for achieving excellence in farming methodologies.

To realize the goal of doubling farmers' incomes, policies should adopt a holistic approach. This involves leveraging improved agri-input technologies, enhancing crop productivity, optimizing resource use efficiency, and promoting diversification in agricultural practices. Continued efforts in strengthening farmer collectives, such as the 10,000 Farmer Producer Organizations (FPOs) scheme, should be a key aspect of future strategies. Schemes should address incentives for adopting innovations and technology while emphasizing the importance of a comprehensive database on inputs to achieve policy objectives.

A forward-looking approach involves harnessing technology to its full potential. This includes the adoption of innovative agricultural productivity and yield technologies, the expansion of extension and advisory services, and the promotion of appropriate technologies for sustainable agricultural systems. Ensuring farmer awareness and facilitating collaboration with independent research institutes will be instrumental in this endeavour.

Strategies should centre on sustainable agriculture practices, the integration of precision agriculture, IoT, AI, and farm mechanization to enhance overall productivity and resilience. Leveraging biotechnology for enhanced productivity while developing robust strategies to address the challenges posed by climate change is important. Farmer empowerment through capacity building and the promotion of sustainable practices form integral components of this approach.

The way forward demands a concerted effort from stakeholders across the agricultural spectrum. Collaboration between governments, research institutions, farmers, and technology providers is paramount. Embracing technological advancements, implementing sustainable practices, and fostering an environment conducive to innovation will pave the way for a resilient and productive agricultural future.

# Notes

# Notes

ASSOCHAM

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## About Assocham

### The Knowledge Architect of Corporate India

The Associated Chambers of Commerce & Industry of India (ASSOCHAM) is the country's oldest apex chamber. It brings in actionable insights to strengthen the Indian ecosystem, leveraging its network of more than 4,50,000 members, of which MSMEs represent a large segment. With a strong presence in states, and key cities globally, ASSOCHAM also has more than 400 associations, federations, and regional chambers in its fold.

Aligned with the vision of creating a New India, ASSOCHAM works as a conduit between the industry and the Government. The Chamber is an agile and forward-looking institution, leading various initiatives to enhance the global competitiveness of the Indian industry, while strengthening the domestic ecosystem.

With more than 100 national and regional sector councils, ASSOCHAM is an impactful representative of the Indian industry. These Councils are led by well-known industry leaders, academicians, economists, and independent professionals. The Chamber focuses on aligning critical needs and interests of the industry with the growth aspirations of the nation.

ASSOCHAM is driving four strategic priorities – Sustainability, Empowerment, Entrepreneurship and Digitisation. The Chamber believes that affirmative action in these areas would help drive an inclusive and sustainable socio-economic growth for the country.

ASSOCHAM is working hand in hand with the government, regulators, and national and international think tanks to contribute to the policy making process and share vital feedback on implementation of decisions of far-reaching consequences. In line with its focus on being future-ready, the Chamber is building a strong network of knowledge architects. Thus, ASSOCHAM is all set to redefine the dynamics of growth and development in the technology-driven 'Knowledge-Based Economy. The Chamber aims to empower stakeholders in the Indian economy by inculcating knowledge that will be the catalyst of growth in the dynamic global environment.

The Chamber also supports civil society through citizenship programmes, to drive inclusive development. ASSOCHAM's member network leads initiatives in various segments such as empowerment, healthcare, education and skilling, hygiene, affirmative action, road safety, livelihood, life skills, sustainability, to name a few.

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