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Transforming India's Maize Sector

The Critical Role of Technology and Innovations



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Message



Maize is one of the most important cereal crops of the world focusing on food security and sustainability. Sustainable Development Goal (SDG)-II is meant for attaining nutritional security and maize qualifies as the wonder crop among the cereals to cope-up with climate change and achieve crop diversification.

It is the future crop for India which can further enhance the farmers' income by ensuring sustainable use of natural resources in the long-run. India ranks 4th and 6th in terms of global maize acreages and production respectively. It accounts for nearly 10% of the food production in the country and is the fastest growing cereal crop in India.

Maize has a prominent role to play in the Indian economy owing to its diverse usage, not just as food but also for feed, fuel, and other industrial purposes. It has been projected that the demand for maize will continue to increase in near future due to expanding market size of feed and silage industry in the country. India has made significant strides in increasing maize production. However, with rapidly increasing demand, declining farming area availability, and the impact of climate change there needs to be a renewed focus on increasing productivity. Mechanized maize cultivation along with adoption of single cross hybrids has the potential for enhancing productivity and profitability. In current scenario, the need is to focus not only on production and productivity but also on building a competitive maize supply chain.

Driven by structural changes in agriculture and food consumption patterns, maize is bound to hold its share as an important cereal crop in future. Further, the partnership of the Public Institutions and Private Sector is very much important for creating the successful Maize Mission in the country. The study on maize is an effort to bring fore the global and domestic scenario of maize and issues confronting the maize supply chain.

Mr. TR Kesavan
Chairman, FICCI National Agriculture Committee &
Group President, TAFE Ltd.

Message



Given its wider adaptability under varied agro-climatic conditions, Maize is a most versatile crop and plays a prominent role in Indian economy. It is third most important crop in India, after rice and wheat, and is used as food, feed and industrial crop. Not surprisingly, globally maize is also known as "Queen of Cereals".

Besides providing assured raw material supplies for diverse end uses, maize has huge potential to augment farmer's incomes and contribute to Government's vision of doubling farmers' income. Though maize production has improved over the last few years, there is still considerable scope to enhance productivity levels. Given the pressure on land resources and usage, accelerated adoption of new seed technologies, good agricultural practices, agronomic coaching for farmers, and most importantly investments in research and innovation will play a key role in driving Indian yield levels to best in class globally and reaching its full potential.

Empowering farmers with the latest technologies that can increase yield and decrease crop losses due to pest infestation is crucial. Hybrid seeds have time and again demonstrated a lot of promise and advantage over the conventional varieties and can help bridge the yield gap. Bihar and Tamil Nadu are leading the way with 100% production area under corn hybrids. Planting high yielding single-cross hybrids has brought marked improvement in yield, reaching about 8 MT/ha in Bihar – emerging as trusted source for Corn supply in Rabi season. There exists significant opportunity for promotion and adoption of hybrid corn in other states as well to achieve global yield levels.

Pests such as Fall Armyworm (FAW) continue to be widespread concern for Maize farmers. Seed treatment solutions, integrated pest management and good agricultural practices can significantly protect yield and bring down losses from 50% to 25%.

A sustainable roadmap to strengthen maize value chain needs a holistic approach and is need of the hour. Adoption of new seed technologies by farmers will take Indian Maize to next level. Accelerated adoption of better genetics and hybrid seeds, improved agronomic practices, increased farm mechanization, integrated and sustainable pest management framework, knowledge sharing and awareness generation are integral part of the same. This will require a multistakeholder approach with the coming together of policy makers, research institutions and the private sector to develop strong foundation to meet the future demand of Maize.

I congratulate FICCI and YES BANK team for this well-researched knowledge paper. I am confident that this paper would act as a good reference document to understand key trends and technological innovations that will define the Maize sector in the forthcoming period.

Anuja Kadian
APAC Government & Industry Affairs Director
Corteva Agriscience India Pvt. Ltd.

Message



The U.S. Grains Council's (USGC) mission is to develop markets, enable trade, and improve lives, and to fulfill that mission, USGC works closely with local feed manufacturers and other end users to build capacity for more and higher-quality feed and grain demand. The goal of these programs is to accelerate the sustainable growth of local industries using coarse grains and products. In turn, this increases overall demand for grain and meets rising demand from consumers for better food. The Council supports free trade while understanding there are critical constraints and challenges confronting end-user industries.

USGC is pleased to continue partnering with FICCI for the 9th year of the Maize Summit and contribute to the Maize Vision report, which identifies opportunities and challenges within the Indian maize industry and offers recommendations to grow this sector.

In these challenging times, it is critical to develop and implement new approaches and technologies that not only provide a growing global population access to adequate nutritious, safe, and affordable food but also creates value-added products, preserves natural resources, and minimizes negative environmental impacts.

The U.S. is the largest corn producer in the world, with over 90 million acres dedicated to corn production. Although corn (or maize, as it's known throughout much of the world) is grown in nearly all 50 states, production is primarily concentrated in northern and midwestern states—collectively known as the U.S. corn belt. However, corn is much more than just a crop—it represents a source of income for the hundreds of thousands of farmers in the United States. Its diverse uses create value-added products like distillers' dried grains with solubles (DDGS) and ethanol, both of which helped revitalize the U.S. farming industry and economy.

Nearly 50% of U.S. corn is utilized in animal feed (grain and DDGS) and food and beverages. Nearly 20% is exported (primarily for animal feed), and less than 30% is used in fuel. When taking into account domestic and export demand combined, approximately 70% of corn's demand comes from animal feed, food and/or beverages.

Today's seed and precision farming technology has allowed farmers to increase production on each acre of land, and corn productivity is projected to continue to rise. Increased corn productivity enables growers to outpace demand with a higher supply, meeting the demand for food, feed, fuel and exports.

We look forward to growing the U.S.-India trade relationship, and USGC and its partners are ready to support Indian livestock producers and other end user sectors.

Ryan LeGrand
President and CEO
U.S. Grains Council

Foreword



Improvements in agricultural productivity, coupled with enhanced efficiencies in agricultural supply chain, form the bedrock for economic prosperity and social development. Throughout history, technological innovations have had a significant impact on building efficiencies in food supply. While the green revolution led to increase in agricultural production in the past, digital revolution has become a key driver for sustainably achieving food and nutritional security going forward. Adoption of improved technologies has positively impacted the maize supply chain as well, leading to increase in farmers' income, conservation of natural resources and improvement in consumers' access to quality produce.

With a strong vision to positively impact farm production and farmers' access to markets, the Government of India is highly proactive in driving multiple new-age initiatives for modernizing agriculture. For instance, the government has announced the "Digital Agriculture Mission 2021-2025" which aims to support and accelerate projects based on new technologies such as AI, block chain, remote sensing, GIS technology and use of drones among others. The Indian private sector is also complementing these efforts by introducing efficiency building technologies and processes across the maize value chain.

Though multiple technologies and innovations exist, the level of adoption on ground is yet to achieve the intended scale. To ensure faster and wider adoption, a collaborative effort involving multiple public and private sector stakeholders is crucial.

YES BANK is sincerely committed to play a catalytic role in the development of the Indian maize sector, not just by serving as a value-adding banking partner but also by working alongside private sector, government and industry associations for assimilating and propagating knowledge that contributes to sustainable growth of this sector. Towards this, YES BANK is privileged to knowledge partner with FICCI for the 9th edition of India Maize Summit, wherein this knowledge report on "Transforming India's Maize Sector: The Critical Role of Technology and Innovations", is being released.

I sincerely hope that this publication will be a useful reference for shaping strategic interventions oriented towards building a highly efficient, technology enabled maize supply chain.

Prashant Kumar
Managing Director & CEO
YES BANK Ltd.



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Executive Summary



This report provides an outlook of global and Indian maize sector, highlights key technological interventions across the maize supply chain, delves on various government initiatives that promote technology introduction and puts forth select recommendations that could result in creating an enabling environment for introduction and scaling up of innovative technologies that boost productivity at the farm level as well as build efficiencies across the supply chain.

Maize is one of the most widely grown crops in the world. It's resource use efficiency, including its ability to tolerate drought and its relatively low requirement of farm inputs makes it a vital crop in regions where environmental conditions are challenging or resources are limited. In 2021, global maize production touched about 1.21 billion MT generated by farms spanning across 173 countries and covering a cultivated area of 205.87 million hectares. USA was the largest producer of maize contributing to about 32% of global production, followed by China (23%), Brazil (7%), Argentina (5%) and Ukraine (3%)[1]. These five countries contribute nearly 75% of the global maize production.

In 2021, international trade in maize accounted 16% of global maize production, with USA being the largest exporter contributing to 37% of global exports (in value terms) followed by Argentina (17%), Ukraine (11%), Brazil (8%) and France (4%).[2] During this period, India imported roughly about 24 thousand MT of maize worth USD 14.20 million. The country's maize exports amounted to 3.62 million MT valued at about USD 935.61 million, a 2.4X increase in export value over the previous year.[3] This significant rise in exports was driven by surging maize prices across the globe, which made Indian maize more competitive in the international market. In addition, the demand resurgence in the South & Southeast Asian countries (for example: Bangladesh, Vietnam, Malaysia) and lower supply from traditional regions of Argentina, Brazil amid bad weather conditions[4] further boosted maize exports.

[1]FAOSTAT, YES BANK Analysis

[2]FAOSTAT, ITC Trade Map, YES BANK Analysis

[3]ITC Trade Map, YES BANK Analysis

[4]https://agriexchange.apeda.gov.in/news/NewsSearch.aspx?newsid=43653

The year 2020-21 saw India produce 31.65 million MT of Maize. The lion's share of this output came from the top 5 maize-producing states. Karnataka was the leading state contributing 17% of India's maize production, followed by Madhya Pradesh (12%), Maharashtra (11%), Tamil Nadu (8%) and West Bengal (8%)[5]. Collectively, these five states contributed to more than half of India's maize production.

Over the last decade (2011-12 to 2021-22), domestic maize production has increased from 21.8 million MT to more than 33.7 million MT, growing at a CAGR of about 4.5%. Despite this growth, the productivity of maize in India (3.07 MT/Ha) is still far lower than that of other major maize-growing nations such as USA (10.51 MT/Ha) and Argentina (7.86 MT/Ha).[6] It is likely that this productivity gap is due to limited adoption of technological advancements across the maize supply chain. Historically, conservation agriculture practices have been successfully employed in Indian maize-based cropping systems to maintain productivity and profitability. However, to keep up with future demand and remain competitive in the global market, it is essential to implement modern technology-driven practices throughout the entire maize supply chain.

This report highlights the importance of specific technological interventions that can have a significant impact on the maize value chain, leading to increase in production, reduction in wastage and better availability of produce. These interventions encompass use of advance technologies for farm input application, farming and harvesting, adoption of climate smart solutions, storage and post-harvest management as well as modernization of procurement and processing. A snapshot of technologies covered in this report is captured herewith.

FARM INPUTS

- Hybrid seeds
- Seed treatment
- Seed varieties for maize silage
- Genetic enhancement
- Marker assisted technology & genomic selection
- Drone usage
- Remote sensing applications
- Rapid soil testing
- Smart irrigation
- Nanotechnology
- Digital marketplace

FARM MANAGEMENT

- Use of precision farming technologies
- Farm management solutions
- Mechanization of maize farming practices
- Connecting farmers with custom hiring centers
- Digital platforms for extension services

STORAGE & POST-HARVEST MANAGEMENT

- Adoption of mechanized drying of maize
- Use of modern storage techniques and monitoring systems
- Baling technology in silage

[5]As per 4th advance estimates, Ministry of Agriculture & Farmers Welfare, GoI

[6]Agricultural statistics at a glance (2021), Ministry of Agriculture & Farmers Welfare, GoI

PROCUREMENT & PROCESSING

- IoT and blockchain-based traceability solutions
- Aflatoxin reduction through optical sorting
- Real-time online analysis of quality parameters

ACCESS TO CREDIT AND INSURANCE

- Digital opening of accounts linked to aadhar
- AI powered farmer score cards
- Remote sensing and big data analytics for remote monitoring of farm performance
- Modern technology (such as drones) for rapid assessment of crop damage

The Government of India, along with state governments, has taken numerous proactive steps to promote adoption of modern technology and innovations in the agriculture sector. The government has introduced various developmental initiatives and schemes that have a direct bearing on rate of introduction and adoption of innovative technologies in Agriculture. Such initiatives include the National Food Security Mission, the National Livestock Mission, National Project on Soil Health and Fertility, National Agriculture Markets (e-NAM), National e-Governance Plan in Agriculture (NeFP-A), PM-Kusum, promotion of agritech start-ups, promotion of digital extension services and investing on Agri-Stack. In addition to these initiatives, the Government has launched the Digital Agriculture Mission 2021-25 to promote the use of digital technologies in agriculture. The mission aims to cover one million villages across India, providing farmers with real-time market information, enable direct market linkage and facilitate e-commerce platforms for agricultural products.

To ensure that maize technology interventions are being leveraged to their fullest potential, it is necessary for all stakeholders, including policy makers, researchers and private sector to work collaboratively. This report identifies five distinct action areas for identification, adoption and scaling of innovations and technologies. They include:

- Promoting public private partnership to leverage technologies
- Improving adoptability of new technologies
- Devising effective extension programs
- Building necessary connectivity infrastructure
- Developing an enabling regulatory environment for introduction and adoption of new technologies

1

Maize Outlook



Maize is an important crop for global food security and has played a significant role in the development of human civilization. It is grown in around 173 countries[7] in the world and is a significant part of human and animal diet. In addition, it serves as a key ingredient in a plethora of products such as starch, biofuel, protein, oils, beverages, sweeteners, cosmetics, pharmaceuticals, textiles, gums and paper among others. It is a resource-use smart crop having high production potential and lesser water footprint, which underscores its suitability for addressing major challenges of declining water resources, degrading soil health and climate change.

Globally, 1.21 billion MT of maize was produced across 205.87 million Ha in 2021. India ranks 4th and 6th in terms of global maize acreage and production, contributing to about 3.96% and 2.13% respectively.[8] In India, maize is the third most important crop after rice and wheat and is predominantly a kharif crop. It accounts for nearly 10% of the food production in the country (average of the years 2015-16 to 2019-20) and is the fastest growing cereal crop in India. Between 2010-11 and 2020-21, its acreage, production and yield have increased at a CAGR of 1.5%, 3.8% and 2.3% respectively[9].

1.1 Production

Over the last decade (2011 to 2021), global maize production has experienced a compounded annual growth rate of about 3%, increasing from 923.63 million MT in 2011 to 1,210.24 million MT in 2021. The area under maize cultivation has seen a 2% CAGR, growing from about 176 million Ha in 2011 to 206 million Ha in 2021[10]. Projections estimate that maize production will reach 1,262.36 million MT in 2026 and 1,334.99 million MT in 2031, with a projected growth rate of approximately 1% (refer Exhibit 1).

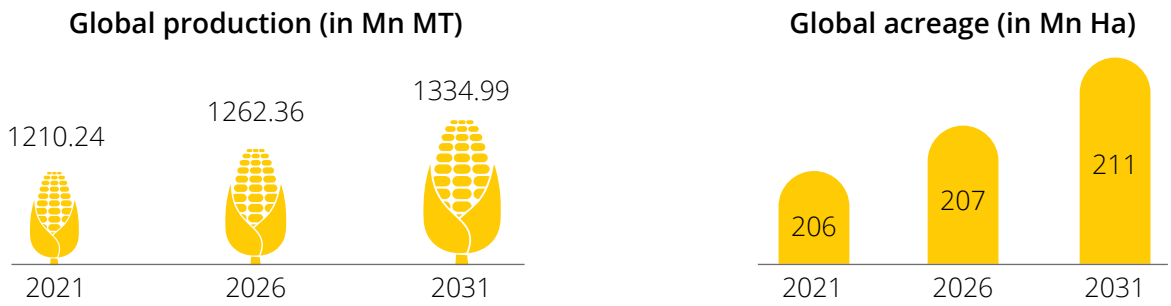
[7]FAOSTAT

[8]FAOSTAT, YES BANK Analysis

[9]Ministry of Agriculture & Farmers Welfare, Govt. of India, YES BANK Analysis

[10]FAOSTAT, YES BANK Analysis

Exhibit 1: Projection of global acreage and production of maize for 2026, 2031



Source: FAOSTAT, OECD-FAO Agricultural Outlook (2022-2031), YES BANK Analysis

USA was the largest producer of maize contributing to about 32% of global production, followed by China (23%), Brazil (7%), Argentina (5%) and Ukraine (3%). Together these countries contribute nearly three quarters of the global maize production[11]. The global production outlook for the 5 key producing countries is detailed in the exhibit 2.

Exhibit 2: Key maize growing countries and their export projection for 2022/23

USA

- USA is the largest producer, consumer and exporter of maize.
- The states of Iowa and Illinois together account for one-third of the US maize crop.
- Total production of the country is expected to be about 349 Mn MT.
- Export is estimated to reach 49 Mn MT which is nearly 14 Mn MT lesser than 2021/22 owing to stiff competition from other exporting nations and lesser planting due to increase in input prices.



China

- China's maize production is pegged at 277 Mn MT
- No significant export due to growing domestic feed usage.
- The resurgence in consumption of maize due to increased feed demand (post African Swine Fever) has propelled the country to be an important producer and importer of maize.



[10]FAOSTAT, YES BANK Analysis

Brazil

- Brazilian maize production has risen significantly during the past year and is expected to touch 125 Mn MT in 2022/23.
- The country is expected to supply 50 Mn MT owing to decrease in domestic use of maize.
- The only other time Brazil exports exceeded USA was during the drought year of 2012-13.



Argentina

- Maize production in Argentina is estimated to reach 47 Mn MT, 5% lower compared to last year (2021/22).
- This decrease is attributed mainly to hot and dry conditions during tasseling and harvest of early planted maize for silage purpose.



Ukraine

- Ukraine has been able to export significant amount of maize under the Black Sea grain initiative, drawing mainly from its accumulated stocks.
- This year the projected production in Ukraine amid continuing war situation is expected to be 27 Mn MT, with an export projection to the tune of 21 to 23 Mn MT. This value is almost 20% lesser than of what was being exported in 2021/22



Others

- South Africa is expected to produce 17 Mn MT.
- Other countries such as Philippines, Vietnam and Uzbekistan are forecasted to have better maize production and are expected to offset the decline in Argentinian maize supply to a certain extent.

The projections are based on aggregate of local marketing years.

Source: WASDE February 2023 edition; https://www.ers.usda.gov/topics/crops/corn-and-other-feed-grains

In India, maize is cultivated throughout the year in all states of the country. Karnataka, Madhya Pradesh, Maharashtra which were earlier non-traditional maize producing states have now become top producers of maize witnessing a significant increase in their acreage and production. In the year 2020-21, maize production stood at 31.65 million MT[12] growing at the rate of about 4% CAGR from 21.72 million MT in 2010-11[13]. Karnataka was the leading maize-producing state contributing 17% of India's maize production, followed by Madhya Pradesh (12%), Maharashtra (11%), Tamil Nadu (8%) and West

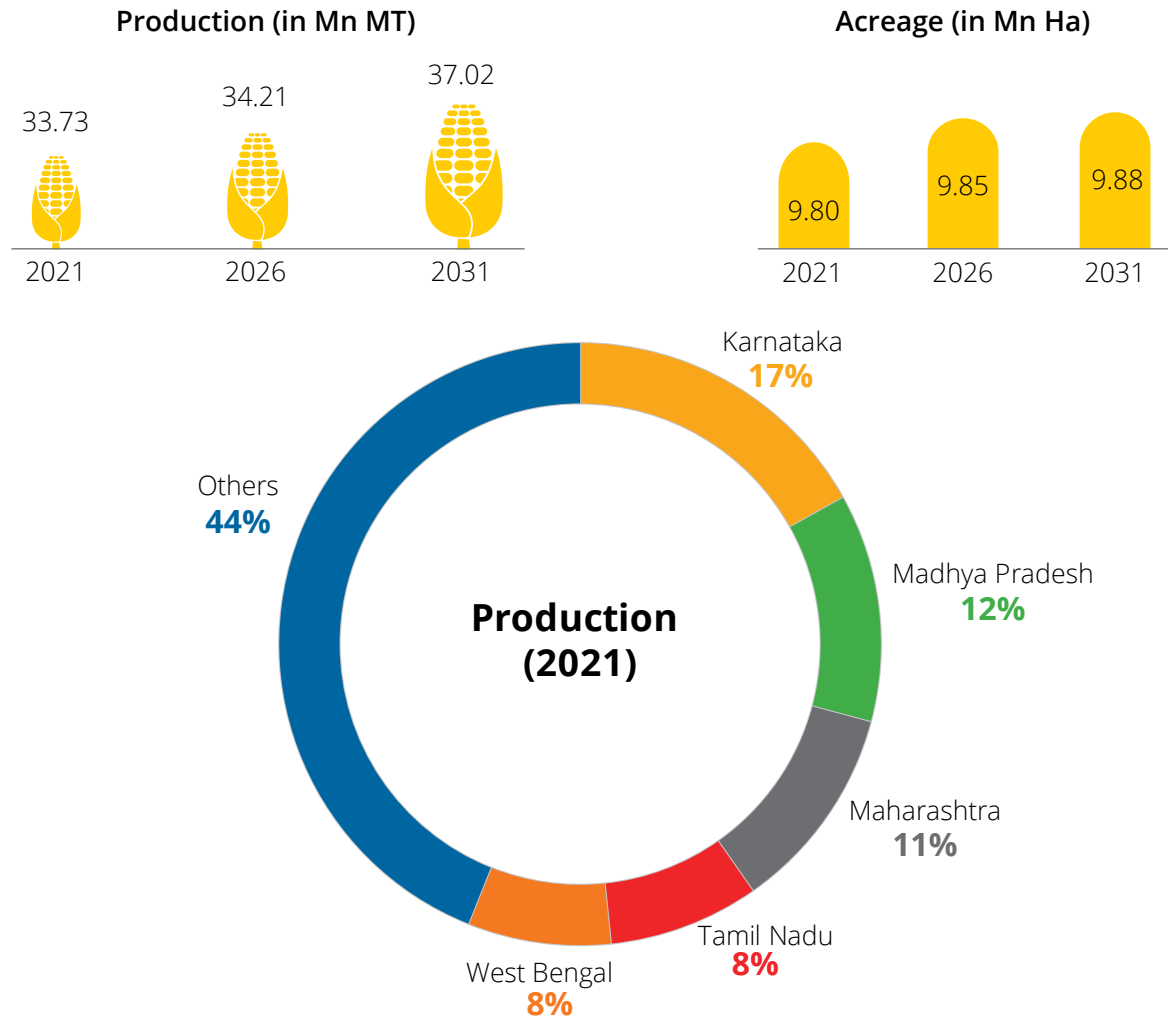
[12]As per 4th advance estimates, Ministry of Agriculture & Farmers Welfare, GoI

[13]Ministry of Agriculture & Farmers Welfare, Govt. of India

Bengal (8%)[14]. Collectively, these five states contributed to more than half of India's maize production (refer Exhibit 3 below).

As per 2nd advance estimates (of February 2023), the production in 2022-23 is pegged at 34.61 million MT against 33.73 million MT for the year 2021-22[15].

Exhibit 3: Outlook of maize production in India



Source:https://www.thehindubusinessline.com/economy/agri-business/kharif-sowing-ends-with-08-drop-in-total-acreage/article65955378.ece; https://indianexpress.com/article/explained/explained-economics/explained-economics-agriculture-and-employment-8480945/; https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1832174;https://agricoop.gov.in/Documents/CropSituation/crops_20012023.pdf; Industry discussions, OECD-FAO Agricultural Outlook (2022-31), Ministry of Agriculture & Farmers Welfare, Govt. of India, YES BANK Analysis

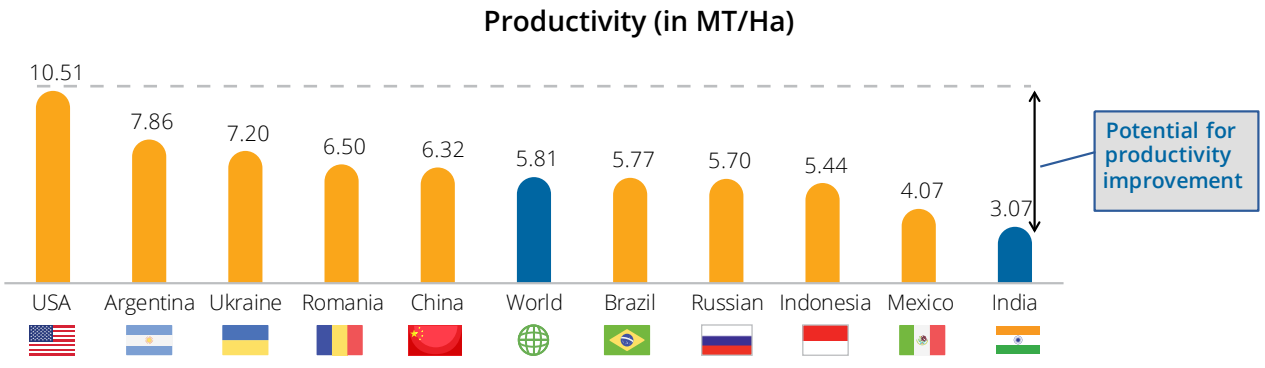
[14]As per 4th advance estimates, Ministry of Agriculture & Farmers Welfare, GoI
[15]Ministry of Agriculture & Farmers Welfare, Govt. of India

- ✓ **Acreage**: Higher acreage expected, driven by higher prevailing prices. For instance, the net area sown under maize in rabi season of 2022-23 grew by 3.35 lakh Ha over 2021-22.
- ✓ **Inputs**:
  - Seeds: Growing preference of hybrid maize over open pollinated varieties
  - Fertilizers: Amid uncertain supply from Russia prices remain on the higher end and are expected to grow
  - Agro-chemicals: Demand remains strong amid pest infestation
  - Labour availability: As per latest PLFS report (2021-22) farm sector's share in country's employed labour force has decreased since 2020-21
  - Amount of rainfall: Less than normal rainfall is expected due to effect of El Nino
- ✓ **Price expectations**: Mandi prices are expected to increase. Feb '22 vs Feb '21 prices recorded a 28% jump
- ✓ **MSP & procurement policies**: Domestic demand is expected to grow by 2% year on year and MSP for kharif maize (2022-23) has been fixed at INR 1,962 per quintal which is about 5% higher than the 2021-22 value.

As a country, India has made significant strides in increasing maize production. However, with rapidly increasing demand, declining farming area availability, and the impact of climate change there needs to be a renewed focus on increasing productivity from available land to satiate domestic needs.

Over the last decade, global average productivity has grown from 5.25 MT/Ha (2011) to 5.96 MT/Ha (2021) at a CAGR of 1.3%[16]. In the year 2021, among the top ten maize producing countries, highest yields were recorded by USA with average productivity of 10.51 MT/Ha followed by Argentina at 7.86 MT/Ha. India's maize productivity reached 3.07 MT/Ha. Exhibit 4 below indicates the untapped productivity potential of maize in India when compared to key producing nations.

Exhibit 4: Average yield of maize across key producing countries



Source: Agricultural statistics at a glance (2021), YES BANK Analysis

[16]OECD-FAO Agricultural Outlook (2022-2031), YES BANK Analysis

GM Maize

In 2019, biotech maize was grown on 61 million Ha globally, representing almost one-third (31%) of the total area under maize (refer Exhibit 5). GM maize has had a significant impact on maize production in many countries such as USA and Brazil, where about 90% of the maize growing area is under GM cultivation. These countries are currently self-sufficient in maize production and are net exporters of the commodity, with the use of GM maize likely being a key contributor to their high productivity. Many developing countries are also increasingly adopting GM maize, recognizing its importance in achieving required production levels and providing economic, environmental and social benefits. Maize farmers in many countries already have access to GM seeds with a diverse range of traits such as herbicide tolerance, multiple insect resistance, drought tolerance, enhanced lysine, modified amylase, and male sterility. Advanced R&D is currently focused on developing other important traits such as next generation of nitrogen use efficiency, low phytate, high oil and biofortification, among others.

Exhibit 5: Overview of GM maize

In 2019, Biotech maize occupied about 61 Mn Ha globally (32% of the total area under maize)

India

- ✓ In India, GM maize is yet to be approved for cultivation
- ✓ GM maize is already in various stages of regulatory field trials for local data generation
- ✓ Govt approved GM mustard variety for environmental release i.e. cultivation & the hybrid production process for developing new hybrids

GM maize



In other parts of the world

USA

- ✓ Introduced in 1990s
- ✓ Majority of maize grown is GMO

EU

- ✓ Introduced in 1998
- ✓ GM maize is grown mainly in Spain and Portugal

Argentina

- ✓ Introduced in 1998
- ✓ Nearly 6 Mn Ha is under GM maize cultivation

Brazil

- ✓ Introduced in 2007
- ✓ 2nd largest producer of biotech crops after USA
- ✓ Over 90% of the cultivated area

Mexico

- ✓ Introduced in 2008
- ✓ Mexico is in process to ban GM maize for human consumption

Vietnam

- ✓ Introduced in 2015
- ✓ By 2019 one-tenth of the maize is GM

South Africa

- ✓ Introduced in 1997
- ✓ GM white maize is largely grown in S. Africa
- ✓ GM welfare benefits estimated to be USD 695 Mn (from 2001 to 2018)

China

- ✓ Largest grower of maize by area
- ✓ In 2022, the Chinese ministry of agriculture and rural affairs has formulated biosafety certificates which allow domestic cultivation of GM maize

Other countries

- ✓ Philippines was the first Asian country to approve GM maize in 2002
- ✓ Colombia approved GM maize in 2007, area under cultivation in 2021 reached 0.14 Mn Ha
- ✓ Bangladesh is evaluating adoption of GM maize in view of the success of GM brinjal
- ✓ Pakistan has approved field trials of GM maize.
- ✓ Malaysia has allowed imports of GM maize and derived products.

Source: ISAAA, 2019, https://link.springer.com/article/10.1007/s12571-022-01288-7; https://ec.europa.eu; https://www.isaaa.org; https://www.frontiersin.org; https://www.sciencedirect.com; https://phys.org/; https://www.fda.gov/food/agricultural-biotechnology.; https://ec.europa.eu; https://bolsadecereales.com; https://periodicos.ufv.br.;https://enveurope.springeropen.com;http://www.apaari.org/; https://www.bloomberglinea.com/; https://allianceforscience.org; https://www.thehindubusinessline.com; USDA Agricultural Biotechnology Journal 2022 for China, India and Bangladesh; YES BANK Analysis

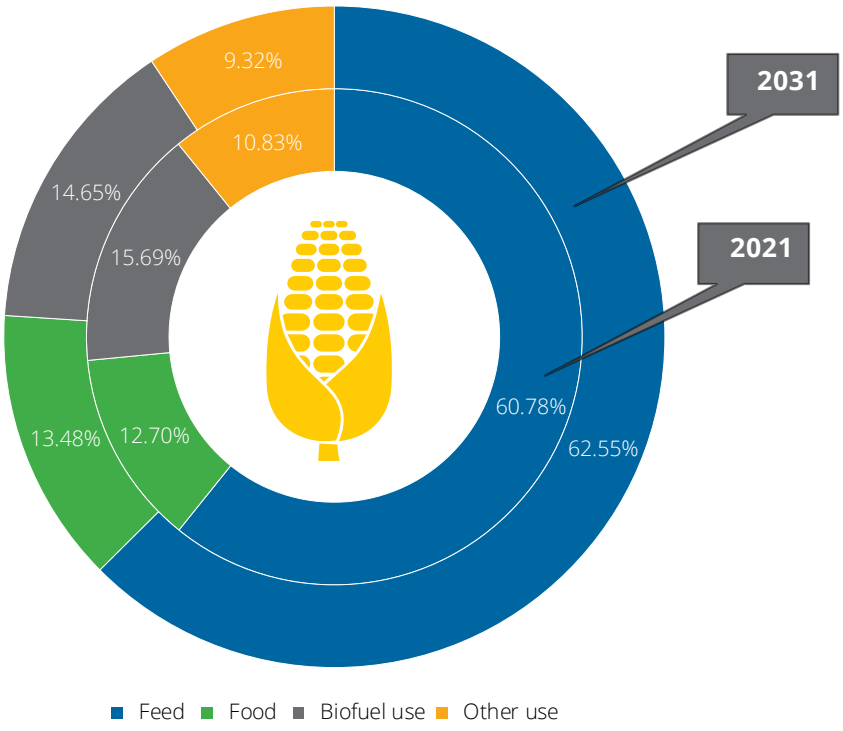
India has not yet permitted the commercial production of GM maize. However, the Government has recently approved the environmental release of DMH-11, a GM mustard variety. This decision was made to address the increasing demand of edible oil in the country and national goal of achieving self-reliance in oilseeds production. If this initiative proves to be successful, it could potentially pave the way for introduction of GM maize in the future.



1.2 Consumption

In the year 2021, global maize consumption reached 1,214.43 million MT. Over the last decade, global maize consumption has increased at the rate of 3% (CAGR) from 899.88 million MT in 2011 to 1,214.43 million MT in 2021. While usage for animal feed accounted for 61% of the total global maize consumption, usage for biofuel accounted for 16%, food usage accounted for 13% and other usage accounted for 11% (refer Exhibit 6 below).

Exhibit 6: World maize consumption outlook



Source: OECD-FAO Agricultural outlook (2022-2031), YES BANK Analysis

The global consumption of maize is anticipated to rise to 1.3 Bn MT by 2031, primarily driven by higher per-capita income leading to increased meat consumption and, in turn, higher demand for animal feed. The proportion of maize used in animal feed is expected to further increase to about 63% (from current 61% in 2021), mainly due to rapid expansion of the livestock sector, particularly poultry, in Southeast Asian countries. It is projected that feed consumption will increase at a CAGR of 1% during the period from 2021 to 2031. Similarly, food consumption is expected to increase by 2% during the same time frame. However, a decrease of 1% CAGR has been projected for "other uses" category, while the biofuel category is anticipated to experience minimal CAGR growth of 0.3%. It is expected that the growth of maize for biofuel production will be limited, as current biofuel related policies focus on other sources of ethanol (both natural and artificial) for blending. The maize consumption outlook for key countries is provided in the exhibit 7.

Exhibit 7: Outlook for Maize in key consuming nations (2022/23)

Key consumers of maize and their outlook for 2022/23

USA

- ✓ Total domestic consumption: 304 Mn MT
- ✓ Domestic feed consumption: 44%
- ✓ Increase expected for biofuel usage

China

- ✓ Total domestic consumption: 297 Mn MT
- ✓ Domestic feed consumption: 73%
- ✓ Increase in feed consumption expected due to revival of pork industry

EU

- ✓ Total domestic consumption: 78 Mn MT
- ✓ Domestic feed consumption: 76%
- ✓ EU imports maize mainly for feed purpose

Brazil

- ✓ Total domestic consumption: 73 Mn MT
- ✓ Domestic feed consumption: 85%
- ✓ Feed consumption is projected to grow by 2 Mn MT y-o-y

SE Asia*

- ✓ Total domestic consumption: 46 Mn MT
- ✓ Domestic feed consumption: 83%

Mexico

- ✓ Total domestic consumption: 44 Mn MT
- ✓ Domestic feed consumption: 59%
- ✓ The country's domestic consumption has been consistent over the past 3 years

S. Africa

- ✓ Total domestic consumption: 13 Mn MT
- ✓ Domestic feed consumption: 54%

Canada

- ✓ Total domestic consumption: 14 Mn MT
- ✓ Domestic feed consumption: 64%
- ✓ Estimated demand for feed projected to be 26% lower than 2021/22 estimates

Argentina

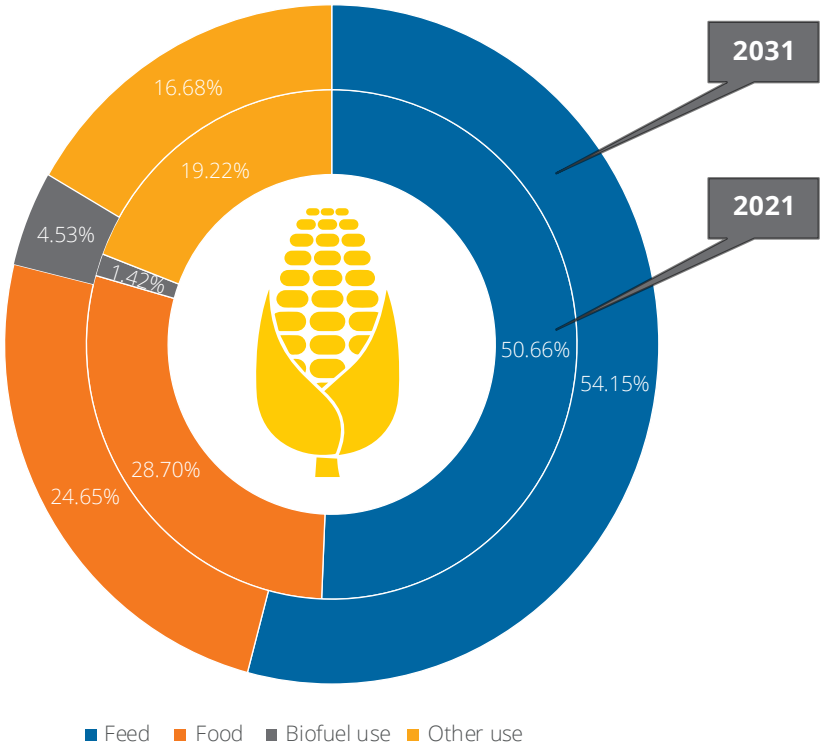
- ✓ Total domestic consumption: 12 Mn MT
- ✓ Domestic feed consumption: 67%
- ✓ The consumption projections have been lowered in line with the production forecasts

**SE Asia includes Indonesia, Malaysia, Philippines, Thailand, and Vietnam*

Source: WASDE February 2023 edition, YES BANK Analysis

Consumption of maize in India reached 29.66 million MT in 2021. Feed industry consumed about 51% of the total maize, while food consumption accounted for 29% (refer exhibit 8). Biofuel production using maize is still in its initial stages, with just about 1% of maize currently being utilized for this purpose. Over the past years, growing economy and expanding middle-income population have been driving the demand for meat/animal protein (poultry and livestock sector). As a result, the demand for maize in India has also increased. By 2031, the share of maize used in animal feed is expected to increase to about 54%. If the Indian Government continues to implement positive policy changes with respect to ethanol blending, the usage of maize for biofuel production could also increase.

Exhibit 8: India maize consumption outlook



Source: OECD-FAO Agricultural Outlook (2022-2031), YES BANK Analysis

1.3 Trade

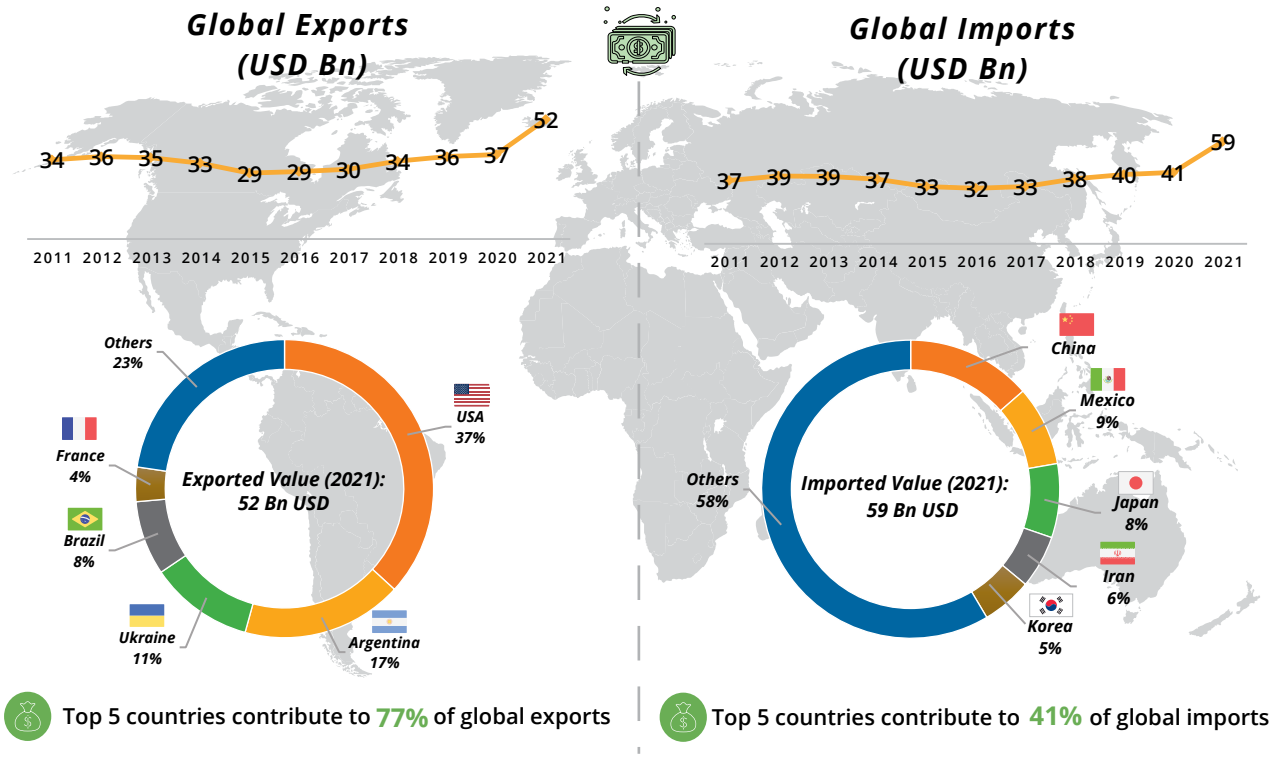
In the year 2021, International trading of maize reached approximately USD 52 billion across 155 countries[17]. Most of the global export value came from the top five maize exporting nations, which accounted for about 77% of total exports. The leading exporters were USA (37%), Argentina (17%), Ukraine (11%), Brazil (8%) and France (4%) as shown in Exhibit 9. Although the USA has consistently been the top exporter, there has been a decline in its maize exports due to increased domestic consumption for bioethanol production, a trend that is projected to continue till 2031[18]. The global exported volume of maize in 2021 was 194.19 million MT. Export volume grew at a CAGR of 6% CAGR over the last decade (from 109.76 million MT in 2011).

[17] *ITC Trade Map, YES BANK Analysis*

[18] *OECD-FAO Agricultural Outlook (2022-2031)*

During 2021, the global import value of maize stood at USD 59.10 billion, with the top 5 maize importers contributing about 41% of total value. The leading importers were China (14%), Mexico (9%), Japan (8%), Iran (6%) and S. Korea (5%) as indicated in Exhibit 9, showing a relatively lower concentration of imports compared to exports. The global import volume of maize touched 167.67 million MT in 2021, growing at a CAGR of 5% over the last decade (from 103.01 million MT in 2011)[19]. The estimated global maize import for the upcoming year is expected to reach 177 million MT[20]. China has emerged as a major maize importer due to increased demand from its domestic feed industry, with imports raising by 152% to 28.35 million MT in 2021 compared to 2020, making China the leading maize importer in the world.

Exhibit 9: Global maize trade scenario



Top 5 countries contribute to **77%** of global exports

Top 5 countries contribute to **41%** of global imports

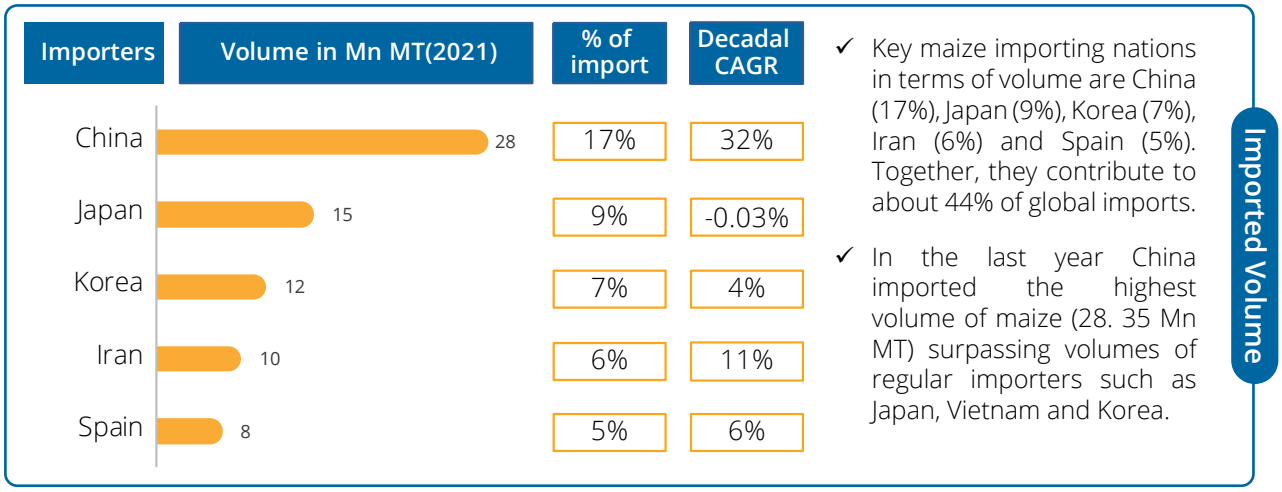
Exported Volume

Exporters	Volume in Mn MT(2021)	% of export	Decadal CAGR
USA	70	36%	4%
Argentina	40	21%	10%
Ukraine	25	13%	12%
Brazil	20	11%	8%
Romania	7	4%	12%

- ✓ Global export volume reached 194.19 Mn MT in 2021, grown at a decadal CAGR of 6%.
- ✓ USA, Argentina and Brazil were the top three exporters of maize.
- ✓ Ukraine is expected to continue export on the back of the Black sea grain initiative.

[19] *ITC Trade Map, YES BANK Analysis*

[20] *WASDE February 2023 edition*



Source: ITC Trade Map (Maize or corn, HS Code:1005), YES BANK Analysis

There is difference between the export & import statistics due to trade systems used, quantity of measurement, time lag in reporting, misallocation, confidentiality issues, re-exports, country's methodology of data compilation and inclusion of transportation and insurance costs in the reported import value but its exclusion from export value.

The ongoing conflict between Russia and Ukraine continues to disrupt normal production and trade of cereals in this region. Despite significant efforts by the UN, such as the Black Sea Grain initiative (refer Exhibit 10), there is still a substantial gap compared to previous supply levels from this region. This is having a particular impact on supply of cereals to East African and NENA (Near East and North African) region which rely heavily on imports from the Black Sea region.

Exhibit 10: Black Sea grain initiative

Black Sea Grain Initiative

- ✓ The 'Black Sea Grain Initiative' is a part of the UN Plan, which allows safe passage of significant volumes of commercial food exports from 3 key Ukrainian ports namely, Odesa, Chornomorsk and Yuzhny.
- ✓ A Joint Coordination Centre is being hosted in Istanbul which is monitoring its implementation and includes representatives from Ukraine, Russia and Türkiye.
- ✓ The other part of the UN Plan focuses on facilitating exports of Russian food and fertilizers.

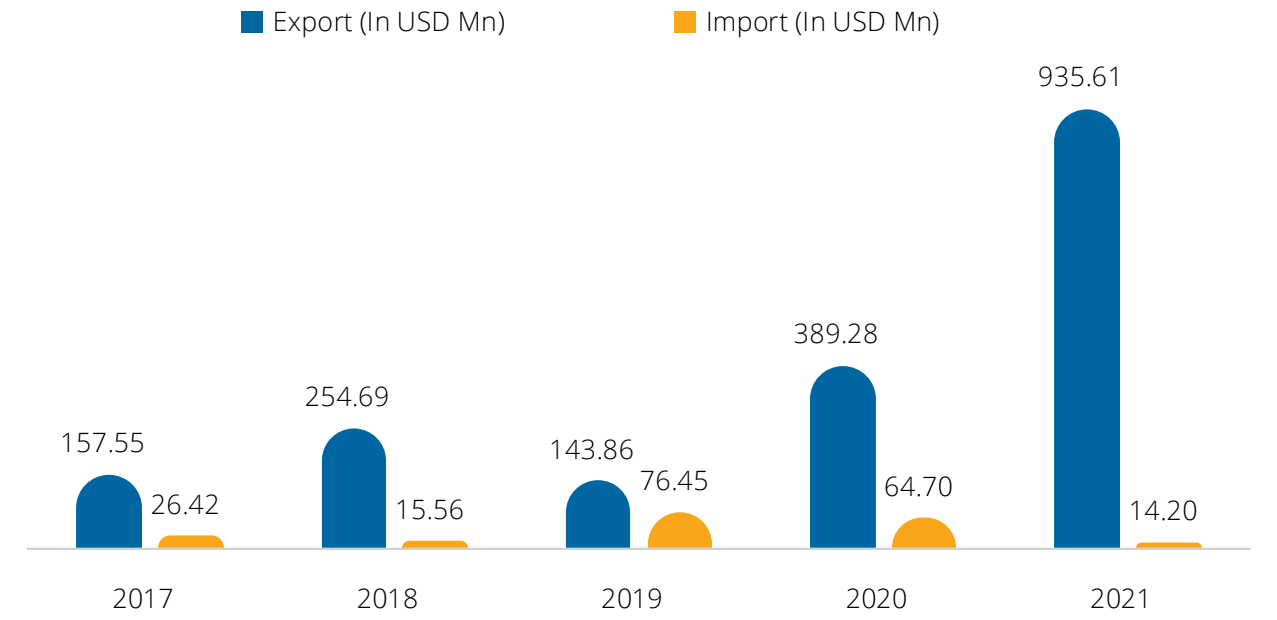
Source: https://www.un.org/en/black-sea-grain-initiative

In the year 2021, India imported roughly about 24 thousand MT of maize worth USD 14.20 million, while the country's maize exports amounted to 3.62 million MT valued at about USD 935.61 million, a 2.4X increase in export value over the previous year[21]. This significant rise in exports was driven by surging maize prices across the globe, which made Indian maize prices more competitive in the international market. In addition, the demand resurgence in the South & Southeast Asian countries (for example: Bangladesh, Vietnam, Malaysia) and lower supply from traditional regions of Argentina and Brazil amid bad weather conditions[22] further boosted maize exports.

[21] *ITC Trade Map, YES BANK Analysis*

[22] *https://agriexchange.apeda.gov.in/news/NewsSearch.aspx?newsid=43653*

Exhibit 11: Overview of India's maize trade (2017-2021)



Source: ITC Trade Map, YES BANK Analysis



The top export destinations for Indian maize were Bangladesh, Vietnam, Nepal and Malaysia. The fluctuation in value of maize exports from India is attributed to factors such as production, international pricing, and domestic demand. As per latest estimates from APEDA, India has already exported about 2.48 million MT of maize (worth approximately USD 814.56 million) during the period April to December 2022[23].

Maize seed trade

Maize seed trade forms a significant part of the global seed trade. Global maize seed export value averaged about USD 3 billion per annum over the last 10 years. In the year 2021, global maize-seed exports were valued at USD 2.96 billion. The top five maize seed exporting nations were France (28%), Hungary (10%), USA (9%), Romania (6%) and Austria (5%) as indicated in Exhibit 12. Currently, India exports USD 53.08 million (2021) worth of maize seeds to Bangladesh, Myanmar, Nepal and Thailand. With the global maize seed industry showing rapid growth, India has a unique opportunity to capitalize on this expansion to boost trade.

[23] *https://agriexchange.apeda.gov.in/news/NewsSearch.aspx?newsid=43653*

Exhibit 12: Key maize seed exporters and importers in 2021 (in terms of value)

Exporters	Value in USD Mn (2021)	% Share	CAGR (2011-2021)
France	821.64	28%	2%
Hungary	285.0	10%	2%
USA	270.3	9%	2%
Romania	165.7	6%	1%
Austria	160.6	5%	7%
India	53.08	2%	12%

Importers	Value in USD Mn (2021)	% Share	CAGR (2011-2021)
Malaysia	495.58	14%	2%
Germany	266.2	8%	-2%
France	194.6	6%	2%
USA	151.0	4%	-6%
Romania	137.3	4%	11%
India	0.74	0.02%	31%

Source: ITC Trade Map, YES BANK Analysis

1.4 Stocks & Prices

The amount of maize stock worldwide typically follows the pattern of production. Given that global production estimates are lower, global maize ending stock is expected to decrease from 316.44 million MT in 2021 to about 310.74 million MT in 2022[24], a decrease of 2%.

The global maize prices experienced an unprecedented price rally during the marketing year 2020/21 due to a combination of factors including Black Sea conflict, increased shipping charges and lesser closing stock. However, the likelihood of a similar event happening again in the near future is low, unless there is a significant production, supply or logistics related issue.

In India, the expected ending stocks of maize for 2022 is projected to be about 4.20 million MT[25], a doubling of the stock from 2012 when it was only 1.96 million MT. This increase is largely attributed to significant improvement in production. Over the past two years, maize prices in the country have experienced considerable growth, rising by 39% from INR 13,822 per MT in February 2021 to INR 19,239 per MT in February 2022[26]. Maize prices have further grown by 14% to touch INR 21,964 per MT in February 2023 (refer Exhibit 13 below). The domestic price movement is influenced by various factors including demand, production, available stocks, weather conditions, input prices and international trade.

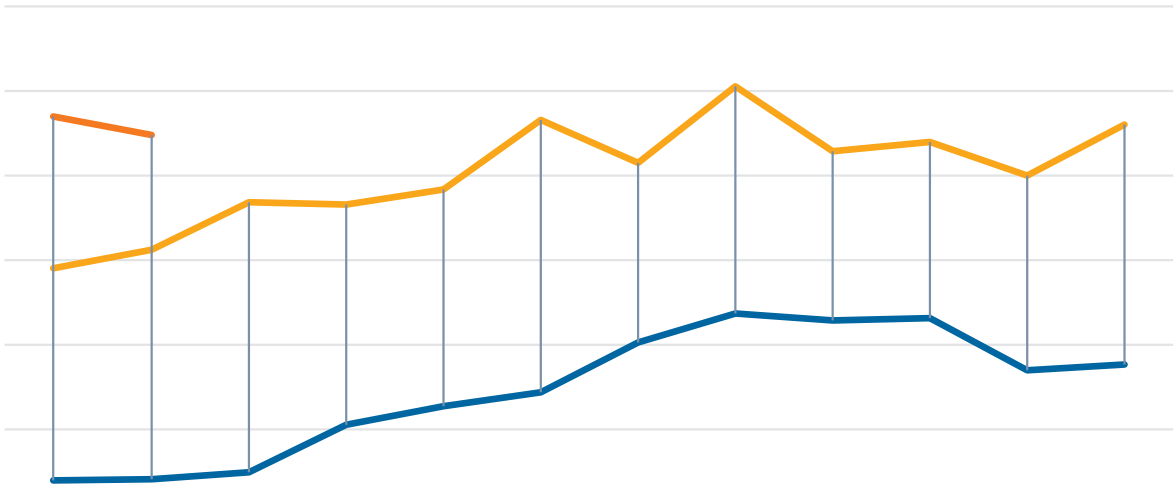


[24] *OECD-FAO Agricultural Outlook (2022-2031), YES BANK Analysis*

[25] *OECD-FAO Agricultural Outlook (2022-2031), YES BANK Analysis*

[26] *Agmarknet, YES BANK Analysis*

Exhibit 13: Overview of maize commodity price movement in India over the last three years (in INR/MT)



	January	February	March	April	May	June	July	August	September	October	November	December
2021	13,780	13,822	13,986	15,097	15,546	15,886	17,050	17,755	17,575	17,633	16,405	16,537
2022	18,804	19,239	20,364	20,306	20,667	22,309	21,300	23,114	21,576	21,804	21,004	22,207
2023	22,399	21,964										

Source: ITC Trade Map, YES BANK Analysis

1.5 Estimate of production & consumption by 2031

Globally, area under maize cultivation is expected to grow at a CAGR of about 0.2% during 2021-2031 and maize productivity is expected to grow at a CAGR of 0.6%. Higher costs of inputs, logistics, fuel prices, production uncertainties (in South American region) and port disruptions will continue to affect the cost of production. Consequently, global maize production is projected to grow at a CAGR of 0.86% during 2021-2031. During this period, global maize consumption is projected to increase at a CAGR of 0.96%[27].

In India, the area under cultivation of maize is projected to grow at a CAGR of 0.1% over the next decade (2021 to 2031) while productivity is estimated to grow at a CAGR of 1.3%. Consequently, maize production is estimated to grow at a CAGR of 1.34% during this period. Maize consumption is estimated to grow at a CAGR of 1.82%[28].

[27] *OECD-FAO Agricultural Outlook (2022-2031), YES BANK Analysis*

[28] *OECD-FAO Agricultural Outlook (2022-2031), YES BANK Analysis*

2

Need for Tech Revolution in Maize Ecosystem



Maize is an important staple crop in India, considering its usage in food, animal feed and manufacturing of processed food and non-food materials. Importance of maize in India can be judged by the fact that it is the fastest growing cereal crop in terms of area, production, and productivity. Domestic maize production has tripled from less than 10 million MT in the mid-1990s to more than 34 million MT in 2022-23[29]. However, the current productivity of maize in India is much lower compared to other maize growing nations such as USA, Brazil and Argentina. Low productivity is largely attributed to limited adoption of technological interventions across the maize supply chain. Lack of quality farm inputs and inefficient farming techniques result in lower quantity and inferior quality produce. In addition, maize ecosystem, like other agricultural commodities, is at substantial risk of being impacted by climate change, depleting water resources and widespread land degradation. Increasing demand for maize could lead to a demand-supply mismatch which in turn could lead to shortage of supply in the near future.

Historically, conservation agriculture practices have been successfully employed in Indian maize-based cropping systems to maintain productivity and profitability. However, to keep up with future demand and remain competitive in the global market, it is essential to implement modern technology-driven practices across the entire maize supply chain. Technological innovations in plant nutrition and protection, climate smart solutions (such as precision agriculture and early warning systems), biofortification and modernized harvesting and storage technologies are expected to have a significant impact on production and post-harvest management of maize. In addition, emerging technologies such as gene slicing, nanotechnology, artificial intelligence, data analytics and connected sensors hold promise for boosting yields, enhancing supply chain efficiencies, and fostering sustainability and resilience. Exhibit 14 showcases how technological innovations can provide solutions to current challenges faced by the maize ecosystem.

[29] Ministry of Agriculture & Farmers Welfare, Govt. of India

Exhibit 14: Technology interventions for addressing current challenges of maize ecosystem

Value chain level	Challenges	Technology intervention
Farm inputs	✓ Low crop yield ✓ Pest and disease incidence ✓ Labour unavailability ✓ Deteriorating soil health ✓ Depleting water availability	✓ Hybridization ✓ Purpose specific varieties ✓ Better seed treatment solutions ✓ Genetic enhancement ✓ Mechanization ✓ Drone application ✓ Remote sensing ✓ Precision and smart irrigation systems
Farm Management	✓ Monsoon dependence for cultivation ✓ Fragmented land holdings ✓ Labour unavailability ✓ High input consumption ✓ Lack of timely updates ✓ Low price visibility ✓ Low information dissemination	✓ Precision farming ✓ Mechanization ✓ Digitization of aggregation solutions ✓ Application of AI ✓ Digitization of extension services ✓ AI based solutioning
Storage and post harvest management	✓ High moisture content in grain ✓ Aflatoxin buildup ✓ Improper drying ✓ Unavailability of uniform and quality feed	✓ Mechanized drying ✓ Modern storage structures such as silos ✓ Silage Preparation
Procurement and processing	✓ Lack of traceability ✓ Fluctuating prices ✓ Quality standards	✓ Blockchain ✓ IoT solutions ✓ Cloud based apps for real time updates
Access to credit, insurance and finance	✓ Dependence on informal sources of credit ✓ Unavailability of timely credit ✓ High monsoon dependence	✓ Digitization of transactions ✓ Direct benefit transfer schemes

Source: ITC Trade Map, YES BANK Analysis

3

Key technological interventions across the maize value chain

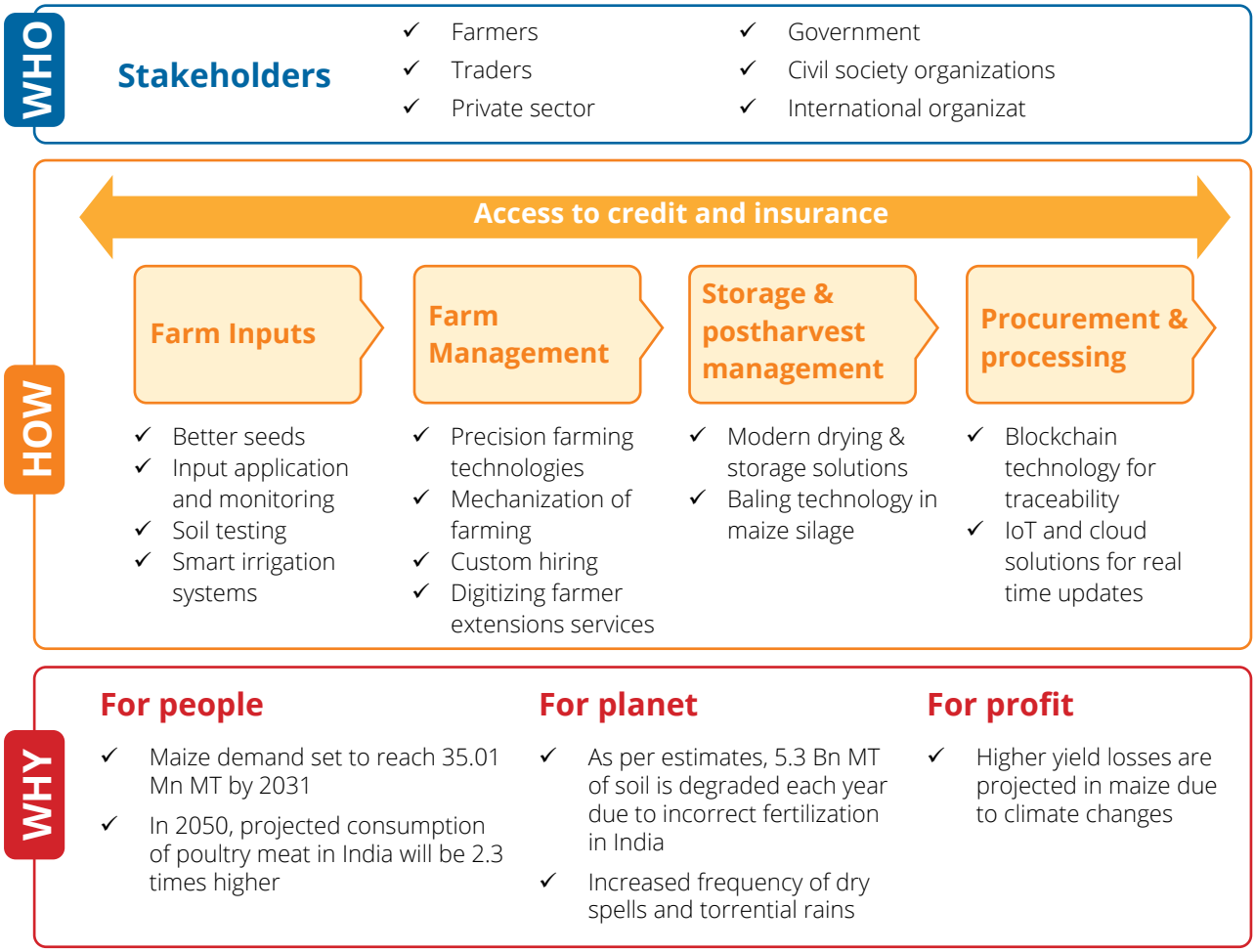


As the demand for maize and maize-based products continue to rise, the traditional methods of production and supply chain management are proving to be inadequate. In response, there is an increasing interest in the adoption of innovations and technological interventions to improve efficiency, sustainability and resilience of the maize value chain. While many of these interventions are still in their early stages, they have the potential to significantly transform both forward and backward linkages across the supply chain. Exhibit 15 illustrates some of these technological interventions and their potential impact on the maize value chain, highlighting the opportunities for innovation and growth in the industry.



[29] Ministry of Agriculture & Farmers Welfare, Govt. of India

Exhibit 15: Key technological trends across maize value chain



Source: Industry Discussions, OECD-FAO Agricultural Outlook (2022-2031), https://nrcmeat.icar.gov.in/docs/Vision-2050.pdf; https://www.thehindu.com/sci-tech/agriculture/India-losing-5334-million-tonnes-of-soil-annually-due-to-erosion-Govt/article15717073.ece, YES BANK Analysis

3.1 Farm Inputs

Seed

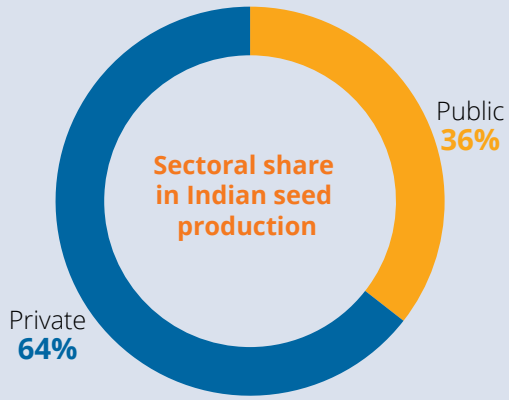
The Indian seed market has experienced significant growth over the years and is currently one of the largest in the world. The seed industry is valued at INR 220 Bn[30]. Maize is one of the top three commercial seed variants in India, generating approximately INR 30 billion in revenue during 2020-21 fiscal year[31]. Maize accounts for 17%[32] of total Indian seed industry, underscoring its importance to the sector as a whole (refer Exhibit 16).

[30] https://fsii.in/wp-content/uploads/2020/08/FSII-Newsletter-July-2020-for-website.pdf

[31] Industry discussions, YES BANK Analysis

Exhibit 16: Contribution of maize to the Indian seed market (2020-21)

- ✓ The Indian seed industry is worth nearly **INR 220 Bn**
- ✓ Nearly 540 private seed companies operate in the country



- ✓ Maize is the 3rd largest category by value in the Indian seed sector
- ✓ Out of the total pie the maize seed industry amounts to **17% (INR 30 Bn)**

- 9 Mn Ha of maize is planted in India
- 6 Mn Ha is under hybrid maize
- Out of which, 65% is single cross hybrid

Source: https://www.thehindubusinessline.com/data-stories/data-focus/private-sectors-share-in-indias-seed-industry-expands-to-65-per-cent/article35101260.ece, Industry discussions, YES BANK Analysis

The Indian seed industry has been driven by hybridization, which has played a key role in increasing the seed replacement rates (SRR). Similar to cotton and vegetables, maize has experienced a significant uptick in hybridization. It is estimated that hybrid seeds account for 67% of the total area under maize cultivation in India[33], highlighting the widespread adoption of this technology in the country.

Key technological interventions in maize seed

High yielding and stress tolerant hybrid seeds– with focus on single cross hybrid

Maize farmers, mostly in non-traditional areas, have rapidly adopted usage of improved hybrid seeds. Since the early 1990s, many private seed companies have been focusing on developing High Yielding Varieties (HYVs), primarily single cross hybrids, that could replace traditional varieties and old hybrids. Hybrid maize, which is mostly feed and industrial grade maize, accounts for around 67% of the planted area in India[34], while food grade maize is produced using traditional cultivars in traditional maize consuming states in the northern parts of India. Hybridization in maize crop in India varies between 23-100% across states, highest in Bihar and Tamil Nadu (100%), while lowest in Madhya Pradesh (23%). As maize varieties have shifted from composites to double cross hybrids to single cross hybrids, there has been marked improvement in productivity, with yields of single cross hybrids reaching about 8 MT/ha in states such as Bihar[35].

[32] Industry discussions, YES BANK Analysis

[33] Industry discussions, YES BANK Analysis

[34] Industry discussion, YES BANK Analysis

[35] https://www.mordorintelligence.com/industry-reports/india-maize-seed-market, Industry discussion

While hybridization has greatly contributed to exponential growth in maize production, there is still significant headroom for further growth, particularly by transitioning from double cross hybrids to single cross hybrids. While area under hybrid maize seeds has increased over years, it is far lower than countries such as USA, Brazil and Argentina where the coverage is over 90%. To combat depletion of natural resources, the Government of India is focusing on introducing high-yielding varieties of maize that can tolerate waterlogging and other biotic and abiotic stresses as a pathway for crop diversification. Exhibit 17 capture the advantages of maize as an option for crop diversification.

Exhibit 17: Advantages of maize as an option for crop diversification

Diversifying crops to include maize, particularly in the rice-wheat cropping systems of India's North-Western states, has the potential to revolutionize the creation of resilient and sustainable ecosystems. This shift can enhance crop yields, profitability and employment opportunities while addressing the pressing challenge of ground water depletion and energy conservation in this region. Furthermore, the integration of maize can help meet the growing demand for this crop, reduce weed growth in the upcoming season, prevent crop residue burning and facilitate timely planting of crops. The government is promoting maize as an alternative crop by providing incentives for crop diversification, such as the 'Mera Jal Meri Virasat Yojana' by Haryana Government and establishing 138 learning sites across 10 districts in Punjab & Haryana.

Introducing maize into the cropping system (especially in NW India) has the potential to increase farmer profitability and boost sustainable production



- ✓ Presently, the domestic demand for maize (Punjab & Haryana together) is:
- ✓ Total: 28 to 31 lakh tonnes
- ✓ Poultry: 22 to 25 lakh tonnes
- ✓ Starch: 6 lakh tonnes
- ✓ Current production needs to be increased to address the needs of these industries

Government of Haryana has implemented the '**Mera Jal Meri Virasat Yojna**' for promotion of rice diversification in which seed, cash incentive (INR 2000 per acre) and assured procurements are given to alternate crops like maize.

Currently, 138 learning sites in 10 districts across Punjab & Haryana have been identified by IIMR (in collaboration with CIMMYT and State Departments of Agriculture) for potential yield demonstration in maize systems

Source: IIMR technical bulletin "Participatory Innovation Platform on Potential Yield Realization of Maize-based Cropping Systems in Punjab and Haryana", YES BANK Analysis

Genetic enhancement of maize

Globally, about 32% (61 million Ha)[36] of area under maize is covered by genetically modifi¬ed crop – primarily in USA, Argentina, Canada, South Africa, Uruguay, Egypt and South America. In India, a host of products are in the pipeline (ranging from BRL 1 trials stage to fi-nal approval stage). Key factors being considered for granting required trial approvals are the role of GM in developing effective & sustainable solutions (for insect control, abiotic stresses (especially drought) and early stage weed losses) and its social & environmental impact.

Genomic selection (GS) has opened up new opportunities towards developing improved hybrids. Herbicide tolerant GM maize has specific potential to reduce production cost particularly during kharif season. CRISPR CAS technique provide new tools to engineer native genes selectively without much disturbance of native genome. These tools have opened-up new horizon of opportunities for maize yield improvement specially to develop new cultivars with resistant to biotic and abiotic stresses.

Marker assisted technology & genomic selection

Genetic markers are short segments of DNA with a known location within the genome and are associated with a trait of interest. By using molecular markers, traits (genes) can be quickly and easily identified early in the plant's development thus making plant breeding significantly more efficient. For example, using molecular markers, fungal resistance can more easily be determined in seedlings. Genomic selection is a further development of the traditional marker technology and leads to even more reliable selection when selecting optimal crossing partners and future varieties.

[36] ISAAA, 2019

Maize genome is one of the most extensively analyzed among the plant genomes. Consequently, maize has been at the forefront in development and evaluation of an array of molecular markers for varied purpose in genetics and breeding. While significant progress has been made in relation to maize improvement in India using traditional breeding strategies, considerable scope exists to further enhance maize productivity. Molecular markers address the limitations of conventional breeding through indirect selection, growth-stage and use of controlled environment[37]. Furthermore, molecular markers-based selection is cost-effective and efficient over phenotypic selection. The introduction of molecular markers in maize breeding added new avenues to the maize improvement, especially for complex traits related to quality, agronomic, abiotic, and biotic stresses. Molecular markers contributed essentially to the germplasm characterization, genetic diversity assessment, heterotic grouping, heterosis prediction, construction of highly dense genetic maps, gene mapping and tagging, and marker-assisted and genomic selections.

Moreover, molecular markers can also serve as useful criteria for Distinctness, Uniformity and Stability (DUS) characterization of new varieties. With the evolving high throughput sequencing platforms, molecular markers are expected play a crucial role in maize productivity improvement.

Seed treatment

Seed treatment has numerous benefits including protection from various soil borne diseases, increased germination, reduced outbreaks of diseases/pests and high-quality crop. Application of seed treatment to maize seed is an important step to ensure that the crop grows to its full potential. Seed treatment has a key role to play in the first two to six weeks after planting, when young seedlings are most at risk from external threats such as insect and disease.

Seed treatment provides highly targeted protection against insect, pests and diseases during the plant establishment period, thus helping maximize seedling emergence, early plant development and crop yield. The use of seed treatment also reduces environmental impact since only minute quantities of chemical active ingredients are used on the seeds. It is typical of companies selling hybrid maize to pre-treat their seeds before they are put on shelves for sale.

Adoption of specific seed varieties for maize silage production

Amongst the non-legume cultivated fodders, maize is the only fodder which produces better nutritional quality along with good quantity of biomass. It is commonly grown as a summer fodder in the northwestern regions of the country particularly Punjab, Haryana, and Western Uttar Pradesh.

Fodder maize varieties play an important role in increasing biomass yield thus making silage profitable. The selection of seeds is very important for silage production as it contributes to 18-20% of the input cost[37] and poor seeds have a drastic effect on the silage yield. Seed companies have introduced silage specific seed varieties in their product portfolio for cultivation of maize suitable for silage.

[37] Report on "Silage as Key Growth Facilitator for Farmers in Punjab", Grant Thornton

Key technological interventions in other farm inputs

Use of drone for input application and crop monitoring

The farming sector in India is expected to undergo a revolution with the adoption of drones, which enable precise application of crop inputs based on specific needs. Use of drones has the potential to boost input use efficiency and enhance farmer safety. In addition, drones reduce the manual workload of farmers by providing an aerial mapping feature for crop monitoring, assessment of soil conditions and detection of pests. The use of drone could also reduce the risk of health and environmental hazards that are typically associated with manual spraying of pesticides and agrochemicals.

Remote sensing applications

Remote sensing applications help in monitoring plant growth, yield loss estimation, irrigation management, identification of crop stress, weed and pest detection, soil mapping, weather forecasting and gathering crop phenological information.

Crop sensors help in applying fertilizers and plant protection chemicals in a very effective manner, maximizing uptake by sensing the exact deficit and reduce the potential leaching and runoff. Crop sensors also enable application equipment such as drones to determine how much fertilizer or pesticide to apply in real time.

Rapid soil testing

Maize farmers can analyze the status of their soil in real-time using rapid soil testing, which recommends the appropriate quantity of fertilizers to be applied, without requiring laboratory testing. This technology utilizes near-infrared spectroscopy to provide immediate soil analysis reports via a mobile application on smartphones. Rapid soil testing device allows for fast and efficient soil testing, making it a convenient and effective tool for farmers.

Smart irrigation

Although, maize in India is primarily a rain-fed crop, in some ecologies, particularly during rabi season, it is irrigated. Flooding or furrow methods are commonly for irrigating maize. However, these methods need precise land leveling and water-guidance channel for uniform water distribution. These conventional irrigation methods have low water use efficiency and are labor-intensive – given the need for construction of irrigation channels and their maintenance.

Drip irrigation does not need leveling, channel formation and channel maintenance. Simultaneous application of water and other inputs such as fertilizer and pesticide through drip lines are also possible resulting in precise, cost-efficient application. Advanced drip irrigation systems with intelligence software have the facility to provide real time monitoring of soil moisture level at farm and give specific area wise recommendation for water requirement through a mobile based app.

Nanotechnology for input application

India has made significant strides in development of nano-fertilizers, nano-pesticides and nanocarriers for agriculture. Nanotechnology has opened a new horizon for improvement of agriculture productivity through efficient delivery of plant growth and protection chemicals. Nanomaterials act as unique carriers of agrochemicals facilitating precise management and control of inputs (fertilizers, pesticides, herbicides).

Nanotechnology has the potential to improve maize output by increasing the efficiency of inputs and minimizing relevant losses through better crop protection.

Digital marketplace for purchase of inputs

Access to digital marketplace through various mobile apps help farmers purchase required inputs at competitive price. They also provide advisory on how to select right inputs for the crop as well as offer credit to farmers for purchase of inputs.

3.2 Farm management

Farm management practices vastly influence the growth in revenue of maize cultivation and technology is an essential core to determine effective maize production strategy. Production techniques used in the cultivation of maize decide the output quality and yield as well. Farmers plan cultivation and harvesting of maize considering factors such as selection of cultivars based on season, sowing time, crop geometry, irrigation techniques, water management, fertigation, integrated nutrient management and integrated pest management.

Key technological interventions for farm management

Use of precision farming technologies

Precision farming leverages advance digital technologies to effectively minimize inputs, labour and time, thus maximizing productivity and profitability. Using precision farming, soil and crop health parameters are determined accurately and these insights are used to make more informed decisions for efficient resource utilization. Precision farming tools include precision irrigation systems, yield mapping & monitoring tools and related information management systems.

Precision farming is continuously evolving with the introduction of new technologies such as sensors, drones, and autonomous vehicles as well as advances in data management and analysis tools. Farmers get guidance on the most ideally suited seed varieties, amount of fertilizer to be used, the precise quantum of water required depending on the moisture in the soil and the right use of pesticides to be applied based on detailed examination of the crop condition.

Digital farm management solutions

Digital farm management solutions enable remote monitoring of maize farms and replace manual intervention with data-driven decisions thus significantly impacting the productivity levels. Farm management systems also provide advisories to farmers to ensure they produce without bringing down soil fertility and soil health, identify specific crop related pests and diseases in time and adhere to the sustainable cultivation practices to minimize crop loss and maximize yield.

Mechanization of maize farming practices

Mechanization of farming practices is becoming an increasingly important technological intervention for enhancing efficient use of farm inputs and reduce cost of cultivation. Adoption of mechanization can result in higher productivity and profitability, as well as provide job opportunities to rural youth. Mechanized cultivation of maize is particularly suitable because the crop is widely spaced and dominated by single cross hybrids with uniform ear placement and maturity. Maize cultivation is completely mechanized in major maize-producing countries such as USA and China. However, maize-farm mechanization in India is progressing at a slow pace, even when compared to crops such as rice and wheat. This could primarily be attributed to lack of awareness regarding the applicability of mechanization for maize cultivation as well as the limited availability of affordable machines for farmers.

However, farm mechanization in maize cultivation has been increasing in all the states, mainly due to the use of tractors for field preparation. In some of the states such as Andhra Pradesh, Bihar, Gujarat, Rajasthan and Tamil Nadu, maize based combined harvesters and maize planters are also being used. Labour shortage is further driving the use of machineries for maize cultivation.

Connecting farmers to Custom Hiring Centres

In India, large number of machineries are available for automation or semi-automation of agricultural operations. However, most heavy machineries are unaffordable for small and marginal farmers who have limited resources. To address this issue, the Indian government is supporting purchase of equipment by individual farmers and is also incentivizing creation of Custom Hiring Centres (CHCs). Agri-preneurs (progressive farmers, rural unemployed youth and agri-graduates) purchase major implements such as tractors and tractor-mounted implements and provide these implements on rental basis to the farmers in need. These farm implements rental services are helping address the problem of labour shortage and improve farm mechanization , ultimately leading to increased crop productivity.

In addition, phygital (physical and digital) farmer-to-farmer platforms are emerging as a popular solution to connect small and marginal farmers with equipment owners who are willing to rent out their tractors and other farm implements. These platforms utilize both physical and digital mediums to create a seamless and cost-efficient rental experience for farmers. Farmers in need of farm equipment can book it through a mobile app, call centre or a field agent, by providing details about the required implement, date, crop, and location. By bridging the gap between equipment owners and those in need of equipment, these innovative platforms have the potential to transform maize cultivation by

improving access to modern equipment, increasing efficiency of farming operations and reducing cost for farmers.

Digitisation of farmer extension

The availability of effective extension service is one of the most crucial factors for the successful adoption of new technologies in agriculture. With the increasing accessibility of digital platforms, providing extension services through these platforms has become a more cost-efficient method to improve farmer's knowledge of current agricultural practices and markets.

Today, farmers can easily access training materials and videos using various apps on their mobile devices, from the comfort of their homes. The government has also taken multiple initiatives to enable farmer extension using digital platforms. For instance, the mKisan Portal was developed for providing timely and need-based information on weather, market, various farm operations, outbreak of pest and disease incidence and their control measures to farming community. Additionally, mobile agro advisories are provided to more than 5 crore farmers by the KVKs using mKisan portal[38].

3.3 Storage and Post-harvest management

Improper handling of maize during the post-harvest period can significantly impact its quality, rendering it unsuitable for human or animal consumption. To prevent this, farmers and other stakeholders need to prioritize the implementation of best post-harvest practices for maize management. Maize needs to be dried immediately after harvest using appropriate drying facility to protect it from contaminants and unpredictable weather. After harvest, maize typically has a high moisture content that needs to be reduced to 13-14% to prevent mold growth. The best post-harvest practices for maize include proper and safe drying using appropriate drying facilities, careful monitoring of moisture content and ensuring proper storage to protect maize from mold growth, pests, and moisture.

Key technological interventions in storage and post-harvest management

Adoption of mechanized drying of maize

At the time of harvest, the moisture content of maize grain is high, typically about 30 to 35%, which can result in farmers receiving lower price for their produce if not dried well. Additionally, storing maize with high moisture content can lead to fungal infection and loss of germination. Therefore, it is essential to appropriately dry maize after harvesting to ensure quality during storage. Traditionally, Indian farmers use sun drying method, which exposes the produce to vagaries of nature and many a times the entire harvest gets damaged. To address this issue, mobile batch dryers can be used for drying maize. These dryers are portable, can dry any type of grain and do not require pre-cleaning of grains. They are also free of the risk of blockages or hot spots and have drying capacity of 2 to 10 MT per hour, depending on maize type and moisture content. Silos with drying facility are also effective in handling large volumes of high-moisture grain received from the farm gate during the harvest period.

[38] https://icar.org.in/hi/content/new-initiatives-division-agricultural-extension

Use of modern storage techniques and monitoring systems

During storage, both biotic factors (insects, pests, and micro-organisms) and abiotic factors (relative humidity, temperature, and time) can lead to grain damage and can trigger mold growth or aflatoxin contamination, making the produce unsafe for human and livestock consumption. Using modernized storage systems can help guard against these stressors and reduce post-harvest losses. Reports by CIPHET and FAO indicate that approximately 5%-7% of maize produced in India is lost due to improper storage, which can be reduced to as low as 0.5% - 1% by using scientific storage methods[39].

There are several storage options available. However, silo storage is the most effective in protecting maize from mold, insects, and other threats to its quality, as these organisms require oxygen and high humidity to thrive. Conventional storage in Jute bags is costly and inefficient as handling them requires lot of manpower. However, silos can be easily mechanized and have a high grain handling speed of up to 700 MT/hour.

Silos have monitoring system for grain condition and moisture along with temperature control mechanism. Advanced silo systems have a carbon dioxide monitoring system — used for very early pest and insect infestation warnings — besides being equipped with a highly effective closed-loop fumigation system.

Silos are advantageous because they require less labour to operate, enable rapid handling and have low overall operating cost. Due to their closed structure, preserving maize in a silo using chilling technique is easier, more efficient, and effective. In sub-tropical countries like India, chilling techniques are increasingly being used for grain preservation over traditional methods that require periodic aeration and fumigation. Further, silos support storage of maize in bulk with grain moisture content up to 14.5% compared to the requirement of 12% for other bulk storage methods. With scientific storage methods, shelf life can be extended by more than 2 years without any significant reduction in quantity and quality, provided that the grain has the appropriate moisture level when it is received for storage.

Few private players have taken the lead for creation of modern bulk silo capacity duly equipped with facilities like dryer and chiller for safe and efficient preservation of maize.

Baling technology for silage

Silage is a technique used to conserve green fodder such as maize, by cutting, chaffing and packing it into airtight containers or packets to prevent the entry of oxygen. The process of silage- making causes the starch to be converted to acids by anaerobic fermentation, creating an acidic environment that kills most microorganisms and preserves the fodder. Maize is considered one of best crops for silage-making due to high sugar as well as starch content and maize silage is widely used in Indian conditions. Silage-making reduces the duration of maize cultivation (85-90 days) as compared to grains and decreases the water consumption[39].

[39] Report on "Silage as Key Growth Facilitator for Farmers in Punjab", Grant Thornton

The advancement of "baling technology' for silage has created new opportunities for maize farmers, balers, and dairy farmers in recent years. The development of bale silage as a value addition to pit silage has provided a way to meet transportation and storage needs. Bales of silage can be transported over long distances to meet the needs of farmers who are unable to grow maize themselves. Popularity of bale silage is driving demand for high biomass yielding maize seeds, fodder harvesters, bale machines, film wraps and additives (inoculants and enzymes).

3.4 Procurement & Processing

IoT and blockchain-based traceability solutions

The use of Internet of Things (IoT) and blockchain-based traceability solutions allow for creation of a transparent and secure supply chain that can be tracked from farm to fork. IoT sensors can be used to monitor crop growth, harvest times and storage conditions, while blockchain technology can ensure the authenticity of data and prevent tampering. Traceability ensures accurate tracking at all stages, resulting in better quality control, better inventory management and reduced post-harvest losses.

Digital marketing platforms enable farmers to get a fair price for their produce and provide real time updates on procurement prices, quality and status of produce in transit. Combining these technologies to facilitate better linking of farmers to markets has the potential to provide a trusted, sustainable and transparent supply chain solution for all stakeholders involved.

Aflatoxin reduction through optical sorting

Mycotoxins are toxins produced by molds during metabolism that can have harmful effects on humans and animals, even at low concentrations. Aflatoxin is the most common mycotoxin found in maize. Due to improper drying and storage methods, maize is particularly vulnerable to mycotoxin contamination. Timely identification and removal of mold-infested grains is necessary for effective mycotoxin reduction. While laboratory analysis can determine mycotoxin content, it is costly and time-consuming process. An efficient solution is using technology and automation to identify mold infested grains based on their gravity or optical properties.

Fully integrated solutions are available for efficient mycotoxin reduction. For instance, sample collectors and separator-classifiers help accurately assess mycotoxin content in incoming deliveries and remove low-density impurities through efficient pre-cleaning. High-capacity grain cleaners remove matter likely to be contaminated by mycotoxins, such as light, broken, and shriveled kernels, while optical sorter identify and separate grains with visual mold signatures using hyperspectral cameras and an LED-based UV lighting system. Use of such integrated and automated solutions ensure preservation of produce quality during storage and transit.

Real-time online analysis of quality parameters

Continuous real-time online analysis of quality parameters including those of raw material, intermediary products and final products during maize processing allows timely adjustments of processes and optimization of quality. Online quality measurement also reduces the need for traditional lab testing that is costly and time taking.

Online analyzers can analyze raw material and finished products across various parameters in real-time during the production processes. Sensors are positioned after pre-cleaning section to measure moisture, crude fat, fiber, starch and protein content of raw material. At the other end of the process, sensors measure the required parameters of the finished product (flaking grits, maize flour etc.). Calibrations can also be provided to measure protein, crude fiber and starch content in the final maize product. Online particle size analyzer optically measures granulation.

Providing real-time quality data allow for continuous adjustments in the processing operations leading to optimized quality and increased throughput. They also allow for greater consistency and better resources-use efficiency.

3.5 Access to credit and insurance

Availability of timely, cost-effective, and adequate credit to the farmers is one of the most crucial factors for the adoption of modern technologies in maize cultivation. Although credit is not a direct agricultural input, it facilitates farmers to meet expenses required in adopting improved agricultural technologies. Access to timely credit enable farmers to purchase good quality seeds, farm equipment, and manage operational costs until the sale of harvested produce.

Several innovative digital banking products and fintech solutions are being piloted for enhancing farmers' access to credit. Initiatives such as digitization of documentation for KCC verification and AI-powered platforms to establish the credit score of farmers have significant potential to improve efficiencies in the process of underwriting, leading to better access to credit for farmers. Innovations and advancements in image processing and big data analytics are facilitating financial institutions remotely monitor farm performances – to develop tailormade products for specific crops and regions. Deployment of modern technology such as drones and remote sensing for rapid assessment of damage to crops has the potential to improve efficiencies and reach of crop insurance products as well.

Key technological interventions in credit and insurance

Digital record keeping of farmer information

Banks face challenges in accessing the agri-data of smallholder farmers. In addition, farmers applying for loan often do not have the necessary documentation thus making it difficult for banks to validate the provided details. Technology could help banks/other financial institutions by providing accurate data of individual farmers pertaining to income, identity proofs, current debt and liabilities that could be used to appraise loan applications. This will make credit availability more accessible and convenient for small and medium farmers.

Potential risk forecasting using AI

Statistical models built using satellite image processing and machine learning will enable lenders to forecast the farmer's yield and the potential risks involved, along with examining the various risk mitigation options for both the bank and the farmer. AI and ML will also help in establishing the agri creditworthiness score of farmers based on a combination of historical production data and the potential that exists in the region. Image processing and big data analytics will also facilitate financial institutions to remotely monitor farm's performance and crop's health in real-time thus allowing them to take possible risk mitigation measures in case of potential crop failure or damage.



4

Government support for promoting technology interventions



With a strong focus on doubling farmers' income while conserving natural resources by promoting sustainable agriculture, Government of India has rolled out several policy initiatives, schemes and programmes that benefit the entire agrultural ecosystem. Some of the key government initiatives which are boosting adoption of new technologies across the agricultural supply chain are captured in exhibit 18.

Exhibit 18: Key Government initiatives and support policies related to maize

For improving crop productivity and farmer income

- ✓ Initiatives by IIMR for crop improvement, protection, management
- ✓ Sub mission on feed and fodder development under NLM
- ✓ Sub mission on agriculture mechanization
- ✓ National project on soil health and fertility

For infrastructure development and credit facilitation

- ✓ National Agriculture Market (e-NAM)
- ✓ Agriculture Infrastructure Fund
- ✓ National e-Governance Plan in Agriculture (NeGP-A)
- ✓ PM-Kusum

For processing of maize

- ✓ Pradhan Mantri Kisan Sampada Yojana (PMKSY) under MoFPI
- ✓ Promoting Maize dryers
- ✓ MoFPI's Formulation of Micro Enterprises scheme
- ✓ Animal Husbandry Infrastructure Development Fund

For extension

- ✓ Promotion of agritech start-ups
- ✓ Promotion of digital extension services and apps
  - National Interactive Digital Platform
  - Kisan Suvidha mobile application
  - Krishi Yantra

Source: Annual Report 2021, IIMR, https://pib.gov.in/PressReleasePage.aspx?PRID=1777684, Ministry of Food Processing & Industries, YES BANK Analysis

Initiatives by Indian Institute of Maize Research (IIMR)

IIMR carries out basic, strategic, and applied research aimed at enhancing production, productivity and sustainability of maize in India. Technologies developed by IIMR focus on three major thematic areas namely, crop improvement, crop protection and crop management. New technologies are validated through All India Coordinated Research Project (AICRP) on maize and are then transferred from lab to land through extension and outreach programs. Key initiatives of the institute across maize supply chain are provided in the Exhibit 19.



Exhibit 19: Key initiatives by IIMR across maize supply chain

Area	Key Initiatives
Crop Improvement	The crop improvement program is focused on introduction and characterization of germplasm, improving productivity of the hybrids and parental lines, germplasm enhancement for resistance to biotic/abiotic stresses and quality traits. This program plays an important role in development of high quality, high yielding, and stress tolerant genotypes.
Crop Protection	Crop protection research is carried out in the disciplines of Entomology and Pathology to manage pests and diseases of maize. Identification of sources of resistance and management of biotic stresses by integrating cultural, biological, and chemical means is explored to prevent economic loss to the maize crop.
Crop Management	The crop management program focusses on tillage, nutrient and cropping system management. Recent initiatives under the program involved development of precision conservation agriculture practices in the cereal-based systems in Indo-Gangetic Plains and sensor guided nitrogen management in maize-based cropping system.
Extension Programs	This program focuses on reach out to farmers and other stakeholders through frontline demonstrations, learning platforms and agribusiness incubation center. The institute also imparts technical trainings on scientific maize cultivation to various stakeholders. Under Mera Gaon Mera Gaurav Program, 7 teams of ICAR-IIMR scientists adopted 23 villages across Punjab, Haryana, Bihar and Telangana. Scientists were in regular touch with farmers of these villages through visits and ICT tools, and organized interface meetings/kisan gosthies, distributed quality farm inputs and facilitated linkage with other agencies benefitting more than 800 farmers.

Source: Annual Report 2021, Indian Institute of Maize Research

Sub-Mission on Feed and Fodder Development

This sub-mission on Feed and Fodder Development (SMFFD) is a government initiative launched in 2014 under the National Livestock Mission (NLM). SMFFD aims increase fodder production and improve quality of feed, which can help enhance milk and meat productivity and improve livelihood of livestock farmers. SMFFD seeks to achieve this by promoting scientific interventions in fodder production, improving feed and fodder management practices, improving availability of certified fodder seeds, and encouraging entrepreneurs for establishment of fodder blocks, hay bailing units and silage making units. A snapshot of incentives provided under this sub-mission is captured herewith.

Assistance for Quality Fodder Seed Production	Towards multiplication of seeds of high yielding fodder varieties which has been developed through research and innovations. 100% incentive is provided for production of certified quality fodder seed i.e. breeder, foundation.
Entrepreneurial Activities in Feed and Fodder Entrepreneurial Activities in Feed and Fodder	Eligible entities will be incentivized for infrastructure development related to Hay/Silage/Total Mixed Ration (TMR) and Fodder Block. 50% capital subsidy up to INR 50 lakh will be provided towards project cost for procuring machinery like bailers, block making machines, TMR machine, forage harvester and heavy duty power operated chaff cutters.

Source: https://nlm.udyamimitra.in/Home/SubmissionOnFeed

Sub Mission on Agricultural Mechanization (SMAM)

This sub-mission was launched under the larger umbrella of National Food Security Mission (NFSM). The aim of SMAM is to increase farm productivity and reduce drudgery of manual labour in the agricultural sector by promoting the adoption of modern farm machinery and equipment. Key initiatives under SMAM include:

- ✓ Promoting Custom Hiring Centers
- ✓ Creating hubs for hi-tech and high value farm equipment
- ✓ Distribution of various agricultural equipment
- ✓ Creating awareness among stakeholders through demonstration and capacity building activities
- ✓ Ensuring performance testing and certification at designated testing centers located all over the country.

To make provisions of subsidy for farm machinery more transparent, the Government has developed Direct Benefit Transfer (DBT) portal, Centralized Farm Machinery Performance Testing Portal and FARMS Mobile App.

Soil Health Card Scheme

Under this scheme, soil health cards are issued to farmers for providing status of soil with respect to various parameters including N,P,K (Macro-nutrients); Zn, Fe, Cu, Mn, Bo (Micro nutrients). Based on the assessment, soil health card also indicates fertilizer recommendation and soil amendment required to realize optimal yields. A farm will get the soil health card once in every 3 years. Soil Health Card Portal is also available where farmers can track soil samples.

National Agriculture Market (e-NAM)

Digitization of the agri-value chain has been a key focus area for the central government. One of the key initiatives that could have a significant impact on farmers' price discovery and markets is the e-NAM initiative – an electronic trading portal which intends to integrate all APMCs across the country through a common online marketing platform – to facilitate a transparent online auction process. Industry discussions reveal that this initiative, if implemented widely and efficiently along with the promotion of e-kisan mandis, could transform the way maize is traded in India.

Agriculture Infrastructure Fund (AIF)

AIF aims to mobilize medium to long term debt finances facility for investment in viable projects for post-harvest management infrastructure and community farming assets. Financial assistance is provided digitally in the form of interest subvention and credit guarantee to eligible beneficiaries for setting up post-harvest management infrastructure. Investment in digital connectivity and optic fiber infrastructure is also an eligible activity for the projects covered under the scheme.

National e-Governance Plan in Agriculture (NeGP-A)

Under NeGP-A, funds are released to the State(s)/UT(s) for project involving use of modern technologies such as Artificial Intelligence (AI), Machine Learning (ML), Robotics, Drones, Data Analytics and Block Chain.

Pradhan Mantri Kisan Sampada Yojana (PMKSY) under MoFPI

PMKSY is a comprehensive package of incentives which is expected to result in creation of modern infrastructure with efficient supply chain management from farm gate to retail outlet for the food processing sector. Various schemes under PMKSY relevant for maize sector are listed in Exhibit 20 below:

Exhibit 20: Incentives under Pradhan Mantri Kisan Sampada Yojana for Maize

Scheme	Components Covered	Grant-in-aid
Creation/ Expansion of Food Processing/ Preservation Capacities	Creation of processing and preservation capacities and modernisation/ expansion of existing food processing units including starch, food (popcorn, nachos, tortillas, boiled/frozen corn)	✓ @ 35% of eligible project cost in General areas & 50% of eligible project cost in difficult areas# ✓ Max grant limit per project -INR 5 Cr

Scheme	Components Covered	Grant-in-aid
Infrastructure for Agro processing Clusters	Development of modern infrastructure and common facilities to encourage group of entrepreneurs to set up food processing units based on cluster approach	✓ @ 35% of eligible project cost in General areas & 50% of eligible project cost in difficult areas ✓ Max grant limit per project-INR 10 Cr

Source: Ministry of Food Processing Industries

Difficult areas include - North East States, Himalayan States, ITDP Areas & Islands

Promotion of agritech startups

Agritech start-ups are playing a key role in addressing deep rooted challenges across the agri-value chain by identifying and introducing innovative technologies, business models and digital solutions such as artificial intelligence, internet of things and big data analytics. These solutions are transforming the way agricultural produce is cultivated, sourced, traded, marketed, and consumed. Through the "Start-Up India" initiative, Government of India has put in significant effort to facilitate growth of Agri-Tech startups. The government is facilitating an enabling eco-system for start-ups as setting up incubators, building innovation centers, providing funding support, tax exemptions and creating a start-up India hub for sharing of knowledge. In the agriculture sector, DPIIT in collaboration with Ministry of Agriculture and Farmers Welfare has launched an Agriculture Grand Challenge inviting solutions on 12 problem statements. Winners of the challenge have received mentorship, free of cost incubation for a period of 3 months, opportunities to conduct pilot programs and funding support in the form of grants. In May 2019, NABARD announced an investment of INR 7 billion venture capital fund for equity investment in agriculture and rural-focused start-ups. This strong focus on promoting agri-tech start-ups is expected facilitate introduction of innovative technologies that increase productivity as well as build efficiencies across the maize value chain.

Promotion of digital extension services and apps

- ✓ **National Interactive Digital Platform** - MoA&FW has signed an MoU with Digital Green under PPP framework for developing a National Interactive Digital Platform to strengthen extension system. The platform will host a digital library of curated multi-format multi-lingual content, help extension workers access and deliver curated content to farmers on time and upskill the vast network of extension workers for agriculture, horticulture, fisheries, livestock and rural livelihood missions through certified online courses.
- ✓ ***Kisan Suvidha mobile application*** – has been launched to facilitate dissemination of information to farmers on the critical parameters such as weather; market prices; plant protection; input dealers (seed, pesticide, fertilizer); farm machinery; soil health card; cold storages & godowns, veterinary centers and diagnostic labs.

- ✓ **Krishi Yantra** - Central Institute of Agricultural Engineering, Bhopal (ICAR-CIAE) under Indian Council of Agricultural Research (ICAR) has developed a "Krishi Yantra" app to augment research, operations and technology dissemination process in the field of agricultural engineering. In addition, a web portal has been made available by ICAR-CIAE on their website where option of interaction between user and specialists is available to ensure that appropriate mechanization technology is selected by the entrepreneurs.
- ✓ Government is also providing advisories services on various crop related matter to the registered farmers through SMSs.

Other select government initiatives promoting adoption of technology in maize ecosystem

- ✓ Pradhan Mantri Krishi Sinchai Yojana for development of irrigation sources in drought prone areas & Micro Irrigation Fund Scheme.
- ✓ PM-Kusum: to install the Renewable energy capacity, to power agriculture pumps.
- ✓ Pradhan Mantri Fasal Bima Yojana (PMFBY) for crop insurance & KCC for access to credit and putting up a common data infrastructure for farmers in the country.
- ✓ Promoting Maize dryers at APMCs for improving quality
- ✓ MOFPI's Formulation of Micro Enterprises scheme – supports FPOs for development of infrastructure and primary processing
- ✓ Animal Husbandry Infrastructure Development Fund (AHIDF) incentives investment in animal feed processing facilities

Digital Agriculture Mission 2021-25

The Digital Agriculture Mission 2021-25 was launched by the Government of India to promote the use of digital technologies in agriculture. The mission aims to cover 1 million villages across India and benefit about 20 million farmers.

Under this mission, various initiatives will be undertaken, such as creation of digital infrastructure for agriculture, the establishment of digital extension services, the development of farmer centric mobile applications, promotion of sensor-based technologies for crop and soil health monitoring and the integration of artificial intelligence and machine learning in agriculture. The mission also aims to provide farmers with real-time market information, enable direct market linkage and facilitate e-commerce platforms for agricultural products.

In addition, the mission seeks to promote collaboration and knowledge sharing among stakeholders in the agricultural ecosystem, including farmers, agronomists, researchers, agribusinesses, and policy makers. By fostering partnerships and creating digital platforms for knowledge exchange, the mission aims to accelerate innovations and drive the adoption of new technologies that can transform agriculture.

5

Recommendations for creating an enabling environment to leverage technology for maize ecosystem



Emerging technologies present a growing range of opportunities to transform India's maize ecosystem. To harness these opportunities, there is a need to foster a collaborative approach between policymakers, researchers, private players, extension workers, technology providers and farmers to identify and scale those technological innovations which hold the most transformative potential for sustainable growth and development of maize.

Maize growers and buyers encounter specific challenges such as inefficiencies in maize quality management, low availability of maize during rabi season, high involvement of intermediaries and high volatility in maize commodity prices. Addressing these issues through promising technologies in maize value chain, as discussed in the previous chapter, can bring about a transformation in the Indian maize industry. However, harnessing the potential of emerging technologies requires investments in research and development, human capital, infrastructure, and knowledge sharing. To identify, adopt and scale up the use of newer technologies in maize ecosystem, five action areas have been identified as captured herewith.

- Promoting public private partnership to leverage technologies
- Improving adoptability of new technologies
- Building necessary connectivity infrastructure
- Devising effective extension programs
- Developing an enabling regulatory environment for introduction and adoption of new technologies

Promoting public private partnership to leverage technologies

Promotion of public private partnership (PPP) is vital to harness scientific expertise, skills, resources, and technological innovations in both backward and forward maize value chain. Combining public investments, in the form of various central and state government initiatives along with the private sector investment will be a force multiplier for the maize sector. Under PPP models, private players can drive emerging technology innovations and new business models while universities and research institution can bring in domain level expertise and help in validating solutions for large scale deployments. In addition, FPOs and non-governmental organizations could play a critical role by building farmer capacity and extending innovative products and services to farmers.

PPP in maize can be driven with the primary objective of enhancing the income of small farmers by creating additional value through provisioning of quality inputs, technology extension, market linkages, and value addition. PPP initiatives should lead to modernizing farming practices, promoting research in high yielding maize varieties, developing robust farm level infrastructure for maize drying/storage, and connecting farmers to new technology as well as innovative business models.

Over the years, the government has taken numerous proactive steps to incentivize PPP initiatives in the agriculture sector that improve yields, reduce losses, and enhance farmer incomes. With the advent of innovative technologies such as drones, satellite mapping, IoT and blockchain, PPP in the sector is becoming increasingly important to ensure adoption of these technologies at farm level. PPP initiatives will facilitate private investment in maize sector, leverage public investment and align all stakeholders in a shared vision of dynamic and value-added growth of the sector. An illustrative PPP model framework that could be adopted in maize ecosystem is provided in Exhibit 21.

Exhibit 21: PPP model framework in maize ecosystem

Farmer/ FPOs	✓ Pooling resources (inputs, farm machinery, storage, processing, marketing) ✓ Capacity building ✓ Implementation on farm
Private industry	✓ Setting up of infrastructure (maize silos, maize dryers, machinery banks) ✓ Introduction of new technology and products (smart irrigation, bio-inputs, hybrid seeds, farm management solutions, innovative maize food products) ✓ Online distribution platforms ✓ Digital marketplace
Start-ups	✓ Digital and high-tech services (satellite mapping, monitoring, rapid testing devices) ✓ Innovative business models

Academia & research institution	✓ Research capabilities ✓ Domain expertise ✓ Validation of new technologies ✓ Startup incubators
Government	✓ Access of data ✓ Field resources ✓ Enabling policy and governance ✓ Support through subsidies/interest incentives

Source: https://www.weforum.org/agenda/2022/03/unlock-the-power-of-agricultural-technology-through-private-public-partnerships, YES BANK Analysis

Improving adoptability of new technologies

Significant efforts have been put in by the government and private sector to promote large scale adoption of innovative and modern technologies, that have the potential to increase yields and farmer income. However, large scale adoption of these technologies is yet to fructify. Large scale adoption of new technologies among farmers is a major challenge owing to land fragmentation, limited trust around data sharing, high costs and lower returns. To drive large scale adoption of new technologies in maize ecosystem following measures could be taken.

- ✓ **Identify specialized maize clusters and develop of "Maize FPOs"** to increase accessibility and to achieve better unit cost economics of available technologies.
- ✓ **Explore and popularize innovative portable equipment's for assessment of quality at farm level, drying and storage of maize** to enable farmers adopt new equipment/ technology even if they are working on a leased land parcel.
- ✓ **Promote use of digital platforms that offer equipment renting and sharing services (such as Krishi Yantra).** This will enable small and marginal farmers who are not able to purchase equipment to adopt mechanization despite constrained financial resources and small farm plots.
- ✓ **Elevate end user interface for ease in use of technology by farmers.** Streamlining customer support operation through digital interface (support videos, web messaging, AI assisted chatbots) and traditional person-to-person technical support will help in driving adoption. Development of farmer friendly, easy to use interface of various apps in regional language could facilitate its usage on a large scale.
- ✓ **Build farmers' trust to enable voluntary sharing of data.** Technology providers can build trust among farmers through streamlining the process of data collection and gathering only that information which is essential for delivery of superior products and solutions to farmers.

Building necessary connectivity infrastructure

Implementation and usage of digital technologies at farm level relies heavily on connectivity infrastructure. Digital devices and sensors, such as satellite remote sensing, UAV imaging systems, Internet of Things (IoT) sensing systems and ground-based robotic systems, are required for collecting high-resolution temporal and spatial big data of crops, environment, and farm equipment. To successfully adopt and implement these advancements, wireless connectivity is an enabling technology. Data analysis becomes more efficient via artificial intelligence systems after being placed on cloud-based servers. Key recommendations for building required connectivity infrastructure are given below.

- ✓ **Develop Information technology (IT) infrastructure and networks in rural areas** to provide better connectivity at affordable price.
- ✓ **Provide support through incentives to deploy remote/in-situ sensors, purchase of drones and setting up of automatic weather stations.**
- ✓ **Promote frontier technologies i**ncluding high band 5G and LEO constellation to ensure full usage of digital applications and analytics.
- ✓ **Modernize existing cellular infrastructure** in rural areas

Devising effective extension programs

To promote largescale adoption of new technologies at farm level, it is crucial to create pathways that enhance awareness among farmers. Although on-field demonstrations, farmer fi¬eld days and promotional activities have traditionally been effective methods for promoting new products and technologies, it is also important to acknowledge the significance of digital platforms in reaching farmers. The government and private sector have both developed farmer friendly apps that can be used to disseminate information about new products and provide training on new technologies via mobile devices. With increased use of mobile phones and internet in rural areas of India, actively reaching out to farmers through digital channels with relevant information and training videos can greatly aid in rapid adoption of new technologies. Therefore, a well-designed extension program needs to incorporate both traditional and digital methods to ensure effective dissemination of information and successful adoption of new technologies.

Developing an enabling regulatory environment for introduction and adoption of new technologies

A conducive regulatory environment is crucial in ensuring the development and adoption of new technologies. The policies and regulations in place determine the extent to which innovative technologies, including digital tools, are available to farmers and other stakeholders thereby affecting the speed of introduction and adoption of technologies. Policy interventions are required to incentivize private sector investment in research and development of new technologies, facilitate procurement of material required for innovation, promote accountable data sharing, establish development and

deployment frameworks for AI systems, and promote research and innovation along with cross-border collaborations to catalyze the exchange and adoption of frontier technologies. Recommendations to provide a regulatory environment conducive for adoption of new technologies are mentioned below.

- ✓ **Create an enabling policy environment for research, development and introduction of high yielding, climate resilient maize varieties**. Towards this, while private seed companies could play a critical role in introducing globally best varieties at a price affordable to Indian small-holder farmers, government need to create an enabling environment for introduction of new hybrids as well as for protecting IPRs. Specific enabling policy interventions include – reviewing the repetitive procedures (such as the need for a three-year confirmatory trial for any hybrid seed being introduced into the state, in spite of it having been tested and approved elsewhere in the country); setting up common and standard procedures/guidelines across states for faster approvals and enforcing a predictable Intellectual Property Rights (IPR) regime & The Plant Variety Protection Act (PVP&FRA) landscape to assure and incentivize private companies to further invest in research and development of more resilient and efficient seed varieties. Measures could include offering tax breaks on private sector R&D investments.

- ✓ **Ensure access to farm level data held by government agencies and departments** to enable users to access best available data for development of algorithms and artificial intelligence

- ✓ Use of automation and AI requires hi-tech hardware devices and machinery, which are generally imported and are capital intensive. **Policy support and collaboration with exporting countries are needed to facilitate easy procurement of IoT devices and other technologies.**

- ✓ **Promote investment in maize focused bulk storage and logistics infrastructure**- A dedicated Kisan Rail for maize and developing large scale integrated bulk handling projects for maize in PPP mode similar to those developed for wheat.

- ✓ **Create conducive policies to promote startup ecosystem in maize**- Agritech startups are transforming the world of agriculture by introducing innovative approaches and technologies to solve specific problems. Handholding and promoting the start-up ecosystem could yield significant returns towards introducing new technologies and innovations specifically focused on the maize value chain. With a view to catalyze start-up interest in the maize value chain, following actions are suggested:
  - Establish a maize specific start-up accelerator – in a PPP mode, with significant private sector participation
  - Launch a maize supply chain grand challenge and cohort
  - Develop a maize innovations sandbox

Technology offers the opportunity to make Indi's maize ecosystem more resilient, sustainable, and profitable. In the past, choice of technologies and their adoption was primarily driven by production, productivity, and farm incomes. However, in recent years, trade, R&D, technological innovations, education, training, and digitization have been strong influences on the choice of technology adopted in maize cultivation as well as maize farmers' access to markets. As sustainable farming gains more attention, it is crucial for all parties involved to determine how to effectively implement the most appropriate technologies in the maize ecosystem so as to achieve maximum production and profitability while minimizing any potential risks to both people and the environment.

6 Abbreviations

Abbreviation	Extension
AHIDF	Animal Husbandry Infrastructure Development Fund
AI	Artificial Intelligence
AICRP	All India Coordinated Research Project
APEDA	Agricultural and Processed Food Products Export Development Authority
APMC	Agricultural Produce Market Committee
Bn	Billion
BRL	Biosafety Research Level
CAGR	Compound Annual Growth Rate
CAS	CRISPR-associated
CHC	Custom Hiring Centre
CIPHET	Central Institute of Post-Harvest Engineering and Technology
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
DBT	Direct Benefit Transfer
DPIIT	Department for Promotion of Industry and Internal Trade
EU	European Union
FAO	Food and Agriculture Organization
FCI	Food Corporation of India
FPO	Farmer Producer Organization
GAP	Good Agricultural Practices
GM	Genetically Modified
GMO	Genetically Modified Organisms
Ha	Hectares
HYVs	High Yielding Varieties
ICAR	Indian Council of Agricultural Research
IIMR	Indian Institute of Maize Research

Abbreviation	Extension
IoT	Internet of Things
IPM	Integrated Pest Management
INR	Indian Rupee
ISAAA	International Service for the Acquisition of Agri-biotech Applications
KCC	Kisan Credit Card
LEO	Lower Earth Orbit
ML	Machine Learning
Mn	Million
MoA&FW	Ministry of Agriculture and Farmer Welfare
MoFPI	Ministry of Food Processing Industries
MoU	Memorandum of Understanding
MSP	Minimum Support Price
MT	Metric Tonnes
MY	Marketing Year
NABARD	National Bank for Agriculture and Rural Development
NENA	Near East and North African regions
OECD	Organization for Economic Cooperation and Development
PDS	Public Distribution System
PLFS	Periodic Labour Force Survey
PMFBY	Pradhan Mantri Fasal Bima Yojana
PMKSY	Pradhan Mantri Kisan Sampada Yojana
PPP	Public Private Partnership
PPV&FR	Protection of Plant Varieties and Farmers' Rights Act
R&D	Research & Development
SRR	Seed Replacement Rate
UAV	Unmanned Aerial Vehicle
UN	United Nations
USD	US Dollars

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