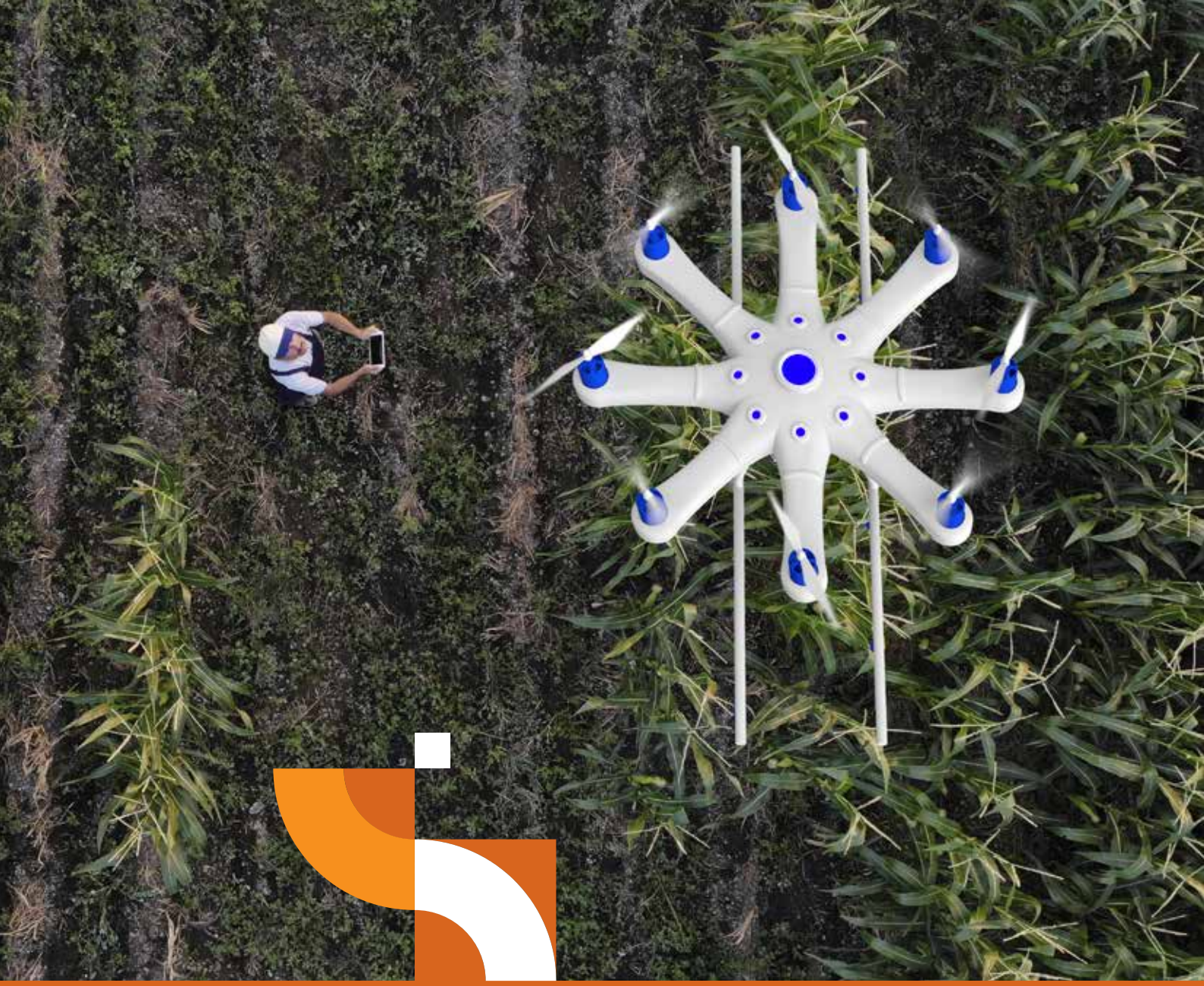

The role of crop-protection industry in driving sustainability in the agriculture sector

October 2024

pwc

FICCI

Foreword

India's emergence as one of the world's top five economies is a remarkable achievement, which inspires not only its Asian neighbours but for emerging economies worldwide. Central to this journey has been agriculture and the continued importance of the agriculture sector for the world's most populous nation cannot be overstated. Smallholder farmers remain the backbone of India's agricultural economy who have achieving the remarkable feat of ensuring the nation's food security while contributing significantly to exports. Supporting these farmers is the crop protection industry, which has played a crucial role in providing modern products and solutions to complex agricultural challenges. India's crop protection industry – the fourth largest globally, has contributed substantially to foreign exchange through its role as a net exporter. As the global demand for sustainable food production grows, the need for this industry to thrive and innovate becomes even more crucial, particularly in the face of increasing pressure to produce more with fewer resources while adopting sustainable and regenerative agricultural practices.

As the Chairman of the FICCI Crop Protection Committee, it is my pleasure to present this insightful report on the vital role of the crop protection industry in driving sustainability within India's agricultural sector, which is pivotal for transforming the country's agrarian landscape.

This report showcases the sustainability initiatives led by Indian crop protection industry players. Sustainability within this sector is multifaceted, extending beyond manufacturing to include packaging, distribution, and, most importantly, engagement with end-users through extensive awareness campaigns which have reached millions of farmers. The approach to using crop protection products must be thoughtful and informed. While the industry has already begun promoting the safe and judicious use of these products, the support of all stakeholders is essential to ensure that these messages reach farmers across the country. It is also vital to recognise the need for modern, safe crop protection solutions which not only enhance yields and increase farmer incomes but also contribute to India's broader economic growth. Equally important is the role of the government in enacting policies and regulations which enable the introduction of new and innovative crop protection solutions to meet the evolving needs of Indian growers.

This report aptly highlights transformative trends within the crop protection sector, signalling a new era of productivity and sustainability. It not only identifies the challenges in achieving sustainable development within the industry but also outlines strategic approaches and interventions which will further support both the industry and the farming community, fostering economic stability and production growth. I hope that the suggestions and recommendations provided in this report will further enhance the narratives on policy discussions and lead to concerted actions toward realising the vision of a modern, sustainable, and inclusive crop protection sector in India.

Simon-Thorsten Wiebusch
Chairman
FICCI Crop Protection Committee and President – South Asia and CEO and Country Divisional Head – India, Bangladesh and Sri Lanka
Bayer CropScience Limited

Message from PwC

The crop-protection industry in India has grown significantly in recent years to become the fourth largest crop-protection chemicals producer in the world. It has the potential to become a global production and innovation hub which caters to domestic as well as export markets. India can achieve its vision of Viksit Bharat by prioritising this sector and develop a strategy for a sustainable food security roadmap.

The Indian agriculture sector has seen tremendous growth over the past few decades but still faces challenges related to low productivity, resource constraints and climate change which threatens the sector's long-term sustainability. At the same time, there is increasing pressure to meet the food requirements of a growing population in an environmental friendly manner. Crop-protection chemicals boost food security by increasing crop yields and protecting them against pests. Judicious use of crop-protection chemicals can significantly improve crop productivity with limited land and water resources, making them a useful tool in driving sustainability in agriculture.

There is a need for targeted interventions to strengthen farmers with the right products, services and educate them about responsible and optimal use of crop-protection chemicals. Promoting sustainable products and solutions like agricultural biologicals, integrated pest management, precision farming techniques and development of sustainable solutions through research and development (R&D) efforts can further reduce the environmental footprint of India's agriculture sector. The crop-protection industry is working towards the goal of sustainability in agriculture through adopting green chemistry principles and focused interventions in their products, operations and at farmer level.

The Government and private sector must work closely with the farming community to disseminate knowledge and facilitate adoption of sustainable practices. Easing regulations while ensuring safety can boost investments and innovation. Public-private partnerships hold promise for taking such measures to scale. With a collaborative approach, the crop-protection industry can effectively enhance productivity, increase profitability and address the environmental sustainability concerns of the Indian agriculture sector. This will play a pivotal role in achieving long-term food and nutrition security in an environmentally responsible manner. This paper discusses the significance of Indian agricultural and food systems, the importance of crop-protection industry and the transition of Indian crop-protection industry towards becoming a sustainable industry.

Shashi Singh
Partner
Agriculture and Food
PwC India

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Executive summary

The agriculture sector has been a driving force of the Indian economy since the country's independence. Accounting for over 18% of the gross domestic product (GDP), the agriculture sector sustains the livelihoods of around 42.3% of the population.[1] Despite technological advancements, challenges like climate change and shrinking landholdings persist, calling for sustainable agricultural practices which resonate with the United Nations' Sustainable Development Goals (SDGs),[2] particularly SDG 1 - No poverty, SDG 2 - Zero hunger, SDG 3 - Good health and well-being, SDG 6 - Clean water and sanitation, and SDG 13 - Climate action.

As the world's fourth-largest crop-protection chemicals producer, the Indian crop-protection industry plays a significant role in the country's economy by boosting agricultural production for both domestic markets as well as for export. The Indian crop-protection industry is one of the largest exporters of crop-protection chemicals. The industry has played a significant role in the growth of the Indian agriculture sector by improving crop yield and reducing crop losses. However, the industry faces many challenges related to the implementation of regulatory frameworks and user awareness about crop-protection chemicals.

Crop-protection chemicals are often perceived in a negative light which can be attributed to the non-judicious use of majority of the chemical products. However, the industry is increasingly incorporating sustainability in their operations, product offerings and adopting sustainable methods like integrated pest management and the development of biopesticides. These approaches are essential for sustainable resource utilisation, meeting regulatory requirements, and catering to a market which is gradually moving towards adopting sustainable products. As a part of the Government's commitment towards adopting sustainable agricultural practices, government bodies are also working proactively towards sustainable development of agriculture and food systems through various initiatives like the promotion of organic farming and technological innovations, and financial support for agri-startups which signifies their commitment towards sustainable agricultural practices which are aligned to the SDGs.

India's crop-protection sector is incorporating sustainability in its manufacturing, supply chain operations and product development processes. These innovations and initiatives are not only crucial for boosting crop yield and health but also for preserving biodiversity and reducing the ecological footprint of farming practices. Agri biologicals are an emerging segment within agriculture. which is gaining acceptability across the globe from farmers and governments owing to their natural origins, targeted action and overall safety. With a push from the regulators towards providing an enabling ecosystem for agri biologicals, the segment will play a crucial role in integrating sustainability in Indian agriculture.

As the crop-protection industry continues to grow and cater to farmers within the country, the government needs to implement measures to provide education and training to farmers on safe and sustainable agriculture practices to promote the use of crop-protection chemicals. The Government also needs to oversee the regulatory frameworks of the sector to ensure the production and circulation of crop-protection chemicals in the Indian market. Adopting a collaborative approach to solve the challenges of the Indian food systems is the need of the hour and both the government and the private sector need to work together to develop a safe, high-yielding and sustainable agriculture sector for the country.

1. Press Information Bureau
2. United Nations – Sustainable Development Goals

1. Agriculture sector in India

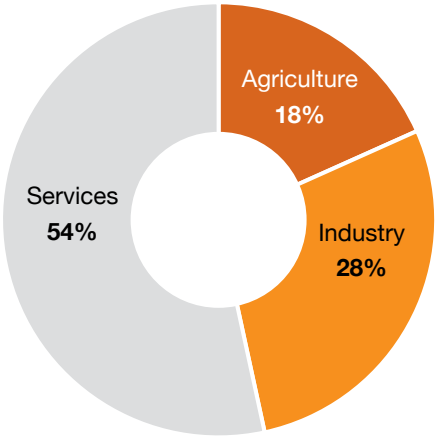
1.1. India's agricultural landscape

India's agriculture sector has gone through significant transformation which has improved the country's food systems with an increase in food grain production from 50 million tonnes in 1951 to 329 million tonnes in 2023.[3,4] The agriculture sector is also a primary source of livelihood for 42% of India's population. Today, India's gross domestic product (GDP) stands as the fifth largest in the world at USD 3.7 trillion and the agriculture sector plays a pivotal role in India's growth story by contributing around 18% to the overall GDP with an annual growth rate of 4.7% during FY 2023.[5]

Indian agriculture sector in numbers

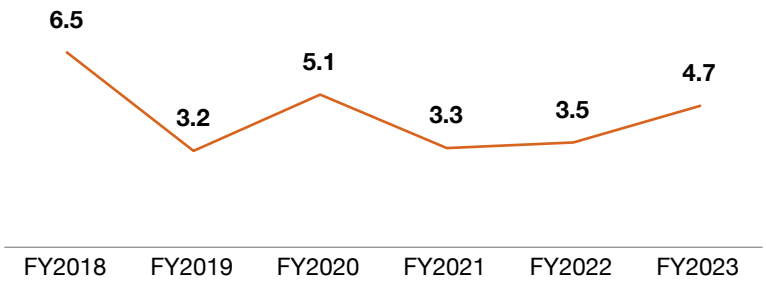
The agriculture and allied sector comprising crops, livestock, fishery, and forestry contributed to 18% of India's GDP (2022–23). The growth rate of GVA (gross value added) in agriculture and allied sectors increased from 2.1% in FY 2019 to 3.96% in FY 2023.[6]

Figure 1: Share of key sectors in GDP (FY 2023)



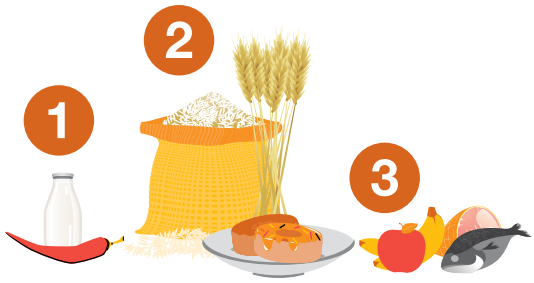
Source: NABARD Annual Report 2022–23

Figure 2: Agriculture and allied sector's GVA growth in 2011-2012 prices (%)



Source: Press Information Bureau

Figure 3: India's rank in key commodities production



India has also emerged as a major producer of key commodities as illustrated below:

1. Milk and spices
2. Food grains, fruits and vegetables, sugar
3. Fish

3. Press Information Bureau
4. Press Information Bureau
5. https://www.livemint.com/economy/bright-spot-in-global-economy-indias-gdp-has-touched-3-75-trillion-mark-in-2023-says-nirmala-sitharaman-11686564064530.html
6. APEDA

According to final estimates of production of major crops for the year 2022–23, the total foodgrain production in the country is estimated at record 329.68 million tonnes which is 14.07 million tonnes higher than the production of foodgrains achieved during 2021–22.

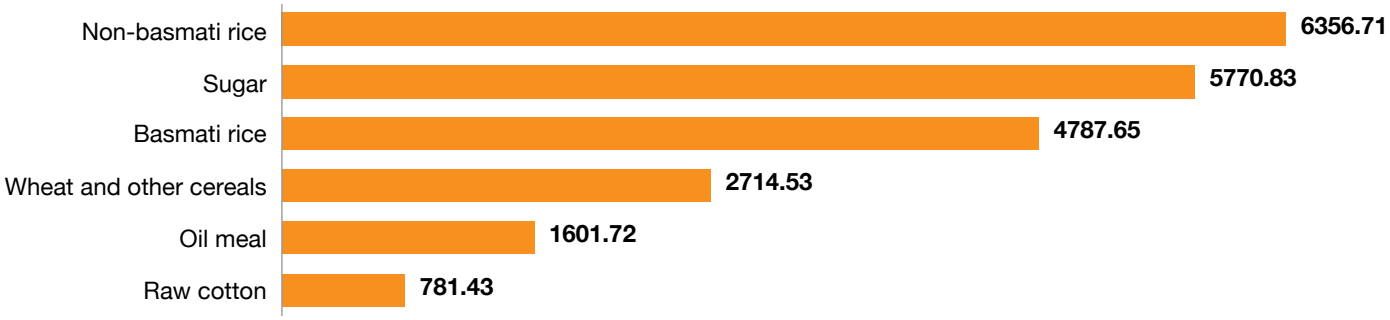
Table 1: Foodgrains and commercial crops production (million tonnes)

Crops	2018–19	2019–20	2020–21	2021–22	2022–23*
Rice	116.48	118.84	124.36	129.47	135.75
Wheat	103.59	107.86	109.58	107.74	110.55
Total cereals	263.39	274.47	285.27	288.31	303.61
Total pulses	22.07	23.02	25.46	27.30	26.05
Total foodgrains	285.21	297.50	310.74	315.61	329.68
Total oilseeds	31.52	33.21	35.94	37.96	41.35
Sugarcane	405.41	370.5	405.39	439.4	490.53
Cotton (million bales of 170 kg each)	28.04	36.06	35.24	31.12	33.66
Jute and mesta (million bales of 180 kg each)	9.82	9.82	9.35	10.15	9.39

Source: Final Estimates of Production of major crops as on 18 Oct 2023

Over the years, the Indian agriculture and food systems have evolved to complement the growing population and rising per capita income. The sector also has a significant scope for export, and agricultural and processed food worth USD 53.1 billion were exported from India in FY 2023.[7]

Figure 4: Exports for agricultural commodities FY 2022-23 (in USD million)



Source: Ministry of Commerce, Govt. of India

7. Press Information Bureau

However, as India's agriculture sector continues to grow, it needs to address the challenges which may hamper the sector's growth. Some of the challenges are discussed in the next section.

1.2. Challenges for the Indian agriculture sector

India has observed a decrease in agriculture landholdings and the average size of operational holdings has shrunk from 2.28 hectares in 1970–71 to 1.08 hectares in 2015–16.[8] Other challenges such as the depletion of natural resources, climate change, Low productivity,reliance on price-led growth, low adoption rate of technology and lack of access to finance are further impeding the growth of the sector. Some of these challenges are described below.

A. Depletion of natural resources

Agricultural practices tend to have a significant impact on land, water and air. In India, more than 40% of land is used for agriculture. The annual ground water extraction is 239.16 billion cubic metre out of which 208.49 billion cubic metre (87%) is used for agriculture activities.[9] The extensive reliance on these resources and lack of awareness about using natural resources judiciously have led to a significant depletion of these resources.

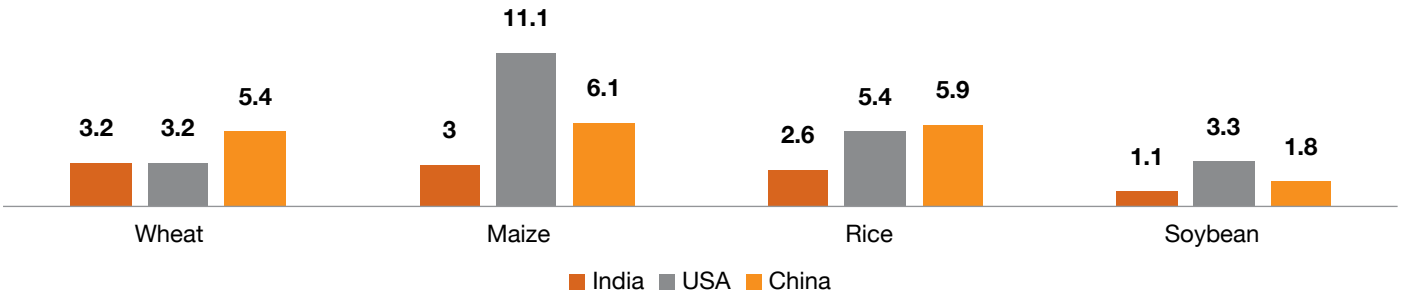
B. Climate change

Since agriculture is highly dependent on consistent climatic conditions, the ever-increasing variability in climate has severe consequences on the sector. Indian farmers are highly dependent on south-west monsoon rains for agriculture. Climate change has already started impacting rainfall patterns leading to erratic rainfall, drought, floods and heatwaves in certain areas. For example, the 2022 heatwave impacted the production of crops such as wheat, soybean and maize and significantly reduced yields, increased pest and disease pressure, and caused soil degradation and droughts. It is also estimated that by 2050 the impact of climate change may lead to significant yield reductions in India for rainfed rice by 20%, irrigated rice by 3.5%, wheat by 19.3%, and kharif maize by 18%.[10]

C. Low productivity

India is one of the top producers of crops such as rice, wheat, pulses, cotton and sugarcane. While the country is the second largest producer of rice, wheat and cotton in the world, the yield of most of the crops is significantly lower than other top-producing countries like the USA, China, and Brazil. One of the reasons for this low productivity could be due to less and inconsistent use of agricultural inputs. For example, the per hectare use of pesticides is significantly lower in India (0.29 kg/ha) compared to countries like China (13.06 kg/ha), Japan (11.85 kg/ha), Brazil (4.57 kg/ha), and other Latin American countries.[11] However, the use of pesticide in states such as Punjab (0.74 kg/ha), Haryana (0.62 kg/ha), Maharashtra (0.57kg/ha), and Kerala (0.41kg/ha) is relatively high compared to other states such Karnataka (0.1 kg/ha), Rajasthan (0.05 kg/ha) and Madhya Pradesh (0.03 kg/ha).[12] Thus, balanced use of pesticides across the states can provide a significant boost to sustainable agricultural productivity in India.

Figure 5: Yield comparison of India with other food grain producing countries FY 2019 (in MT/ha)



Source: Organization for Economic Co-operation and Development

8. Press Information Bureau
9. PIB: Ensuring Optimum Utilization of Water In Agriculture Sector accessed on 16 Jan 2023
10. PIB: Impact of climate change on agriculture accessed on 16 Jan 2023
11. PRS India, https://prsindia.org/policy/analytical-reports/state-agriculture-india
12. ICAR, https://niap.icar.gov.in/pdf/pb43.pdf

D. Reliance on price-led growth

Although India's agriculture sector has seen impressive growth over the years, challenges related to diversification, innovation and excessive reliance on price persist. At present, most of the cropping-related decisions of Indian farmers are driven by price rather than environmental considerations, market linkages, or export markets which may yield higher returns. This has led to practices that are less diverse, sustainable, and viable in nature.

E. Low adoption rate of technology and limited research and development (R&D)

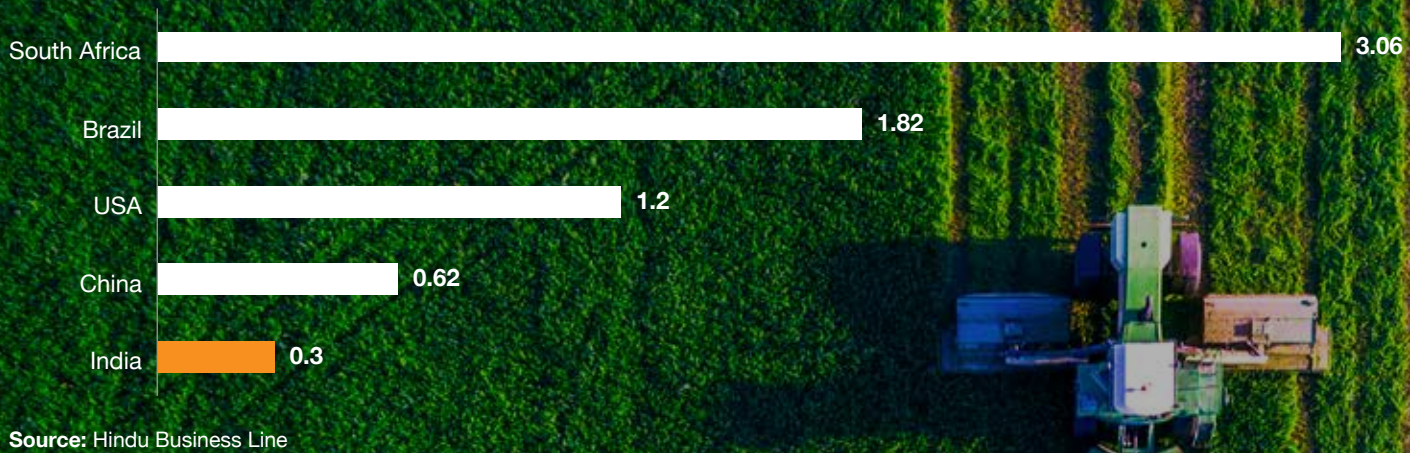
Agricultural research is complex and capital-intensive. Climate change, the contribution of agriculture in global greenhouse gas (GHG) emissions, and other sustainability concerns make agricultural research even more challenging which gives rise to the need for developing a robust R&D system. In recent times, India's agricultural R&D has not kept pace with the major agricultural nations. In FY 2022, the annual average spend on agricultural R&D in India as a percentage of agriculture GDP was a mere 0.3% which is significantly lower than other major countries.[13] This further contributes to the yield gap, lack of adoption of precise and intelligent farming techniques, and the low adoption rate of advanced scientific solutions in agriculture.

F. Lack of access to finance

Access to finance is a major tool in the agricultural value chain in India which impacts resource efficiency and quality. The Government has taken several policy measures to improve the outreach of financial institutions to farming and rural communities. Even though the credit flow to agriculture has increased from INR 4,352 crore in FY 1983 to INR 18,63,363 crore in FY 2022, challenges such as limited awareness among farmers, lack of sufficient customised agricultural finance products, limited capacity for credit repayment and lack of gender inclusion can create major hindrances to equitable access to finance. In addition to this, India also faces regional disparities in credit supply as central, eastern and north-eastern regions get very low agri-credit as percentage of their agri-GDP (20–80% of agri-GDP) as compared to southern regions (100–180% of agri-GDP).[14]

With India's vision of 'Amrit Kaal', i.e. making India a developed and a self-reliant nation by 2047, it is imperative to address these challenges to reform the agriculture sector and enhance the sector's contribution to the national economy. To facilitate this, multiple initiatives have been taken by policy makers in the sector.

Figure 6: Agriculture research spend FY 2021–22 (as % of agri GDP)



Source: Hindu Business Line

13. Hindu Business Line
14. Report of Internal working group to agriculture credit, RBI

1.3. Government initiatives in the agriculture sector

Considering the importance of the agriculture sector in Indian economy and food security, several initiatives and policy measures have been made by the Government to address the challenges discussed above.

A. Government initiatives to promote integrated pest management (IPM) and integrated nutrient management (INM) practices

The Government of India has incorporated integrated pest management (IPM) as a fundamental principle in its comprehensive crop production programme, in response to the detrimental consequences of excessive and indiscriminate use of chemical pesticides in agriculture. These adverse effects include environmental degradation, ecological disruptions, pesticide residues in food and water, pest resurgence, and risks to human and animal health. To mitigate these issues, IPM approach has been adopted, which integrates cultural, mechanical, biological, and judicious chemical control measures to promote eco-friendly practices. The IPM methodology is being promoted through various national and state-level schemes and projects. The Department of Agriculture & Farmers Welfare (DA&FW), under the Union Ministry of Agriculture and Farmers Welfare, is actively promoting the IPM approach through the 'Strengthening and Modernisation of Pest Management' scheme.[15] This initiative is implemented through 36 Central Integrated Pest Management Centres (CIPMCs) located across 28 states and 2 union territories. The primary objectives of these centres include monitoring pests and diseases, producing and releasing bio-control agents, conserving bio-control agents and developing human resources in IPM. To achieve this, the centres provide training to agricultural extension officers and farmers through farmers' field schools (FFS) conducted in farmers' fields, thereby empowering them with the knowledge and skills necessary to adopt IPM practices. The Government of India has also taken several initiatives to promote Integrated Nutrient Management (INM) in agriculture such as Soil Health Card (SHC) scheme, Paramparagat Krishi Vikas Yojana (PKVY) and Mission Organic Value Chain Development in North East Region (MOVCDNER).[16]

B. Government initiatives for agri startups

The Indian agriculture startup environment has seen tremendous growth in recent years. The Government has funded a total of 1,176 agri-startups with financial assistance amounting to INR 75.25 crore under the Innovation and Agri-entrepreneurship Development Programme component of the Rashtriya Krishi Vikas Yojana (RKVY) to foster entrepreneurship and innovation in the field of the internet of things (IoT), artificial intelligence (AI), and blockchain technology in the agriculture sector.[17] The Government has also approved a proposal to set up an accelerator fund of INR 500 crore to encourage young entrepreneurs to set up agriculture-related startups.[18]

C. The use of drones in agriculture

Drones can be utilised in agriculture for a wide variety of tasks such as data collection, irrigation, pest control, surveying and mapping of crops, and application of fertilisers and crop-protection chemicals. Farmers can use these drones to increase crop productivity and reduce the overuse of crop protection chemicals thereby improving soil health. Moreover, using drones for spraying crop protection chemicals ensures safety to humans, animals and minimises damage to the environment by ensuring adequate and even spraying. Application of fertilisers and crop protection chemicals by drones is also much faster than ground application. To promote the manufacturing of drones and drone components in India, the Government of India has launched a production linked incentive (PLI) scheme[19] along with several reforms to make India a global drone hub by 2030. This includes the release of the drone airspace map (2021)[20] which turns nearly 90% of the Indian airspace into a green zone, the notification of the liberalised drone rules (2021),[21] the UAS Traffic Management (UTM) policy framework (2021),[22] the Certification Scheme for Unmanned Aircraft Systems (CSUAS) (2022),[23] the drone import policy (2022)[24] which prohibits the import of drones manufactured outside of India, and the drone (amendment) rules (2022)[25] which

15. Directorate of Plant Protection, Quarantine and Storage
16. Press Information Bureau
17. Press Information Bureau
18. Press Information Bureau
19. https://pib.gov.in/Pressreleaseshare.aspx?PRID=1779782
20. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1757850
21. Press Information Bureau
22. DGCA
23. Press Information Bureau
24. Press Information Bureau
25. Civil Aviation

does away with the need for a drone pilot license in order to operate drones. The Government has also launched a scheme titled NAMO Drone Didi Scheme in November 2023 to empower women members of self-help groups (SHGs) by providing them drones on subsidised price.[26] These drones can be used by the members of women SHGs for rental purpose and can be provided to farmers in which the task of spraying of pesticides or fertilisers in agriculture field will be done with the help of drones.

D. Other government initiatives

In addition to the interventions listed above, several announcements related to agriculture were also made in the Union Budget FY 2023 and FY 2024:

- India will build a digital public infrastructure (DPI) for agriculture (Agri Stack) as an open source, open standard, and interoperable public good[27] to enable inclusive farmer-centric solutions and support the growth of agri-tech industry and startups.

- The Government aims to computerise 63,000 Primary Agricultural Credit Societies (PACS) with an investment of INR 2,516 crore.[28]

- The government plans to incentivise the state and union territories to promote alternative soil enrichment products and reduce the use of chemical fertilisers by the Prime Minister's Programme for Restoration, Awareness, Nourishment and Amelioration of Mother Earth (PM-PRANAM).[29]

- To facilitate the adoption of natural farming practices, the Government plans to set up 10,000 Bhartiya Prakritik Kheti Bio-inputs Resources Centres (BRCs) to provide farmers with easy access to bio-resources such as Jeevaamrit, Ghana Jeevamrit, and Neemastra. These bio-inputs, which rely on cow dung and urine, neem, and bio-culture, play a crucial role in natural farming. Bio-input resource centers will be set up to create a national-level distributed micro-fertiliser and pesticide manufacturing network.[30]

- In the drought prone central region of Karnataka, central assistance of INR 5,300 crore will be given to Upper Bhadra Project to provide sustainable micro irrigation and filling up of surface tanks for drinking water.[31]

- In a significant move to enhance agricultural productivity and mitigate the effects of climate change, Government of India has launched 109 new high-yielding, climate-resilient and bio-fortified crop varieties developed by ICAR-affiliated institutes.[32] These innovative seeds have been approved for cultivation across India's 15 agro-climatic zones, paving the way for a more sustainable and resilient agricultural sector. The seeds, including cereals, rice, maize, wheat, oilseeds, pulses, sugarcane, cotton and various horticulture crops, will be available for large-scale cultivation in 2–3 years. This initiative will address the recent erratic weather impact and support sustainable farming practices.

- In FY 2024-25, the Government unveiled a strategic plan to establish large-scale clusters for vegetable production in close proximity to major consumption centres. This initiative aims to create concentrated hubs of vegetable farming near urban areas, fostering a more efficient and sustainable food supply chain. The Government will work closely with stakeholders, including FPOs, agriculture start-ups, and cooperatives, to implement this initiative.[33]

- Issuance of Jan Samarth based Kisan Credit Cards[34] and Digital crop survey in 400 districts[35] were the other two announcements made by the Government in the Union Budget 2023-24.

26. https://www.indiatoday.in/india/story/namo-drone-didi-pm-narendra-modi-launches-scheme-to-provide-drones-to-women-self-help-groups-2469441-2023-11-30
27. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1927294
28. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1837890
29. Press Information Bureau
30. https://www.cnbctv18.com/economy/budget-2023--centre-to-facilitate-1-crore-farmers-to-adopt-natural-farming-15823881.htm
31. The Hindu Business Line
32. India Business Trade
33. https://www.thehindubusinessline.com/economy/budget/budget-2024-large-scale-clusters-for-vegetable-production-near-major-consumption-centres/article68436321.ece
34. Money Control
35. Hindustan Times

2. Agriculture and sustainability in the Indian context

Though various policies are being implemented to address the challenges related to agricultural food systems, factors such as increasing population, rapid urbanisation, changing consumer trends, globalisation, scarcity of resources and climate change have highlighted the need to adopt sustainable agriculture. Adopting sustainable agricultural practices is the need of the hour to minimise the adverse impact of the agriculture sector on the environment and to implement safer methods of farming for both the farmers as well as the consumers.

2.1 The importance of sustainable development in agriculture

Agriculture and environment have an interdependent relationship. For example, while the increase in climate variability has a negative impact on crop yields, GHG emissions from agriculture practices have a negative impact on the environment. Therefore, it is important to recognise the link between agriculture and climate change to implement an informed approach to agricultural development and policy making. Sustainable agriculture one such approach which integrates environmental health, social equity and economic profitability into agricultural production while moving away from the traditional industrial approach to food production. Sustainable agriculture and food systems also find considerable significance in the United Nations' shared vision of 17 sustainable development goals with 169 targets under the SDGs.

2.2 Sustainable agriculture in India

India's agriculture sector can play a pivotal role in the country's endeavour to achieve many of the UN's SDGs. The relevance of the SDGs in the context of agriculture and key interventions of the Government in achieving these goals are listed in the table given in Table 2.:

Table 2: SDGs and sustainable agriculture in India

SDGs	Relevance to sustainability in agriculture and food systems	Key interventions and achievements
SDG 1: No poverty	SDG 1 aims to eradicate poverty in all its forms by 2030.[36] A significant portion of the Indian population still lives below the poverty line. 65% of the country's population lives in rural areas and 47% of the population is dependent on agriculture for livelihood.[37]	• Initiatives such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and subsidies on fertilisers and seeds to improve the income and living standards of small farmholders and rural labourers. • Over 37 million women, living below poverty line have received liquified petroleum gas (LPG) connections under the Pradhan Mantri Ujjwala Yojana.[38] • Several investments have been made in developing rural infrastructure, such as roads, irrigation and market linkages which are essential for reducing poverty in the country.
SDG 2: Zero hunger	SDG 2 aims to end hunger, achieve food security, improve nutrition and promote sustainable agriculture.[39] Agriculture is at the core of ensuring food security. The Indian agriculture sector has made several contributions to ensure food security by increasing food production, implementing government programmes to address hunger and food security and diversifying crops.	• India's foodgrains production touched a record 315.7 million tonnes in 2021–22.[40] • By adopting diversification of crops, the Indian agriculture sector also cultivates cash crops and produces horticulture-related products. This increase in production and diversification has enabled India to not only address hunger but also improve the dietary diversity and provide better nutrition to the citizens. • Various government schemes and initiatives such as the National Food Security Act, Public Distribution System (PDS) and POSHAN 2.0 have helped India to ensure that food is accessible and available to the vulnerable sections of the population. Furthermore, in response to the unprecedented challenges during the COVID-19 pandemic, the Government has implemented a historic and far-reaching initiative to provide free ration to 800 million citizens.[41]
SDG 3: Good health and well-being	SDG 3 aims to ensure healthy lives and promote well-being for all at all ages.[42] SDG 3's target 3.9[43] aims to substantially reduce the number of deaths and illnesses due air, water and soil pollution and contamination from hazardous chemicals by 2030.	• An extensive extension network of Krishi Vigyan Kendras (KVKs) and advisories have been setup by India and supported by package of practices (PoPs) issued by research organisations such as the Indian Council of Agricultural Research and state agriculture universities who provide recommendations on the appropriate use of pesticides. • The Insecticides Act, 1968, and the more recently proposed Pesticides Management Bill, 2020, aims to regulate all the phases of the pesticides from manufacturing to usage. Additionally, the state agricultural departments also help in enforcing the regulations and provide guidance for safe practices for the farmers.

36. UNDP
37. https://pib.gov.in/PressReleasePage.aspx?PRID=1894901
38. Press Information Bureau
39. UN
40. Press Information Bureau
41. Hindustan Times
42. https://sdgs.un.org/goals/goal3
43. UN

SDGs	Relevance to sustainability in agriculture and food systems	Key interventions and achievements
SDG 6: Clean water and sanitation	SDG 6 aims to ensure the availability and sustainable management of water and sanitation for all.[44] By 2030, target 6.3[45] of SDG 6 aims to improve water quality by reducing pollution, eliminating dumping, and minimising the release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse globally.	• Various missions such as Swachh Bharat Mission-Urban (SBM 2.0),[46] National Mission for Clean Ganga (NMCG)[47] and Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0)[48] have been launched to meet the targets of clean water and sanitation. • In the speech for the 2023 Union Budget, the Finance Minister emphasised India's plans for promoting natural farming with a focus on farmers' land in 5 km-wide corridors along the Ganga. It is proposed that over the next three years, India will facilitate 1 crore farmers to adopt natural farming and has planned to set up 10,000 bio-input resource centres, creating a national-level distributed micro-fertiliser and pesticide manufacturing network across the country.[49]
SDG 13: Climate action	SDG 13 aims to combat climate change and its impacts.[50] The Indian agriculture sector plays an important role in achieving this goal due to the significant environmental implications of agriculture. India has taken significant steps towards SDG 13 by balancing food security with environmental sustainability.	• Schemes such as the National Mission for Sustainable Agriculture (NMSA) have been initiated for the promotion of agroforestry as a practice. • National Mission on Natural Farming (NMNF) has been launched to promote an alternative system of farming among farmers to reduce their dependence on externally purchased inputs and reducing their input costs • Several states in India have encouraged the use of solar pumps and are focusing on renewable energy in agriculture. • To promote sustainable cropping practices, in 2021, the Haryana government announced a direct cash transfer of INR 5,000 per acre to encourage rice cultivation using direct-seeded rice (DSR) technique among farmers. Additionally, a subsidy of INR 40,000 was offered to purchase zero-tillage DSR machines by the government. Continuing their efforts, the Haryana state government allocated INR 810 million for FY 2023 to promote DSR.[51]

It is important to ensure that agricultural practices do not compromise the availability of resources, nutrition and the economic well-being of future generations. However, general practices which lead to an increase in yield may hamper the activities which can help the country achieve its sustainable development goals. The non-judicious use of crop-protection chemicals and resource-intensive agricultural practices can be considered to be some of the key factors which can determine the negative impacts of agriculture on the environment. Therefore, it is important to understand how the agriculture sector can leverage crop-protection chemicals as a tool for sustainable development and counter the challenges associated with its use.

44. UN
45. UN
46. Swachh Bharat Urban
47. NMCG
48. Press Information Bureau
49. Press Information Bureau
50. UN
51. News18

2.3 Crop-protection industry and sustainable development of the agriculture sector

Importance of crop-protection industry in agriculture

According to the Food and Agriculture Organization,[52] it is estimated that every year, up to 40% of the world's crop production is lost due to plant diseases and pests. Additionally, invasive pests are among the primary causes of biodiversity loss and can cost nearly USD 70 billion a year.[53] It is estimated that 30–40% of India's yearly crop yield is lost due to the attack of various agricultural pests.[54] Crop-protection chemicals have a productive role (yield enhancing) and a protective role (against pest attacks) in farming which, in turn, improves the quality of the produce. Since the discovery of DDT in the 1940s, chemical pesticides were largely used in farming practices across the world. During 1960-1970, due to the adoption of Green Revolution in India, apart from the contribution of high-yielding seeds and irrigation, crop-protection chemicals played an important role in increasing crop production and making India self-sufficient in producing food.

Today, the crop-protection sector is constantly evolving to develop innovative ways to manage agricultural pests. While there are several instances where crop-protection chemicals have been replaced by natural and organic inputs and methods of production owing to environmental concerns, a direct substitution of crop-protection chemicals has in-fact, led to a reduction in yield.[55] The food and economic crisis in Sri Lanka caused by the ban on synthetic fertilisers and crop-protection chemicals in 2021[56] is an example which emphasises the need for a cautious approach to address the environmental and health concerns related to the use of crop-protection chemicals, thereby reconfirming that crop-protection chemicals form a critical part of the sustainable production practices. Thus, crop-protection chemicals play an important role in the agriculture sector to manage the losses related to pests and diseases and to address the nutritional requirements of the increasing population of the country.

Crop-protection chemicals industry and sustainable agriculture

Though the use of crop-protection chemicals aims to improve yield, improper use of these chemicals may have an adverse effect on the ecosystem. The indiscriminate use or overuse of these chemicals due to lack of awareness among farmers can result in runoff, leaching and bio-accumulation of chemicals in the ecosystems which can cause serious environmental impacts including contamination of water supplies, creation of hypoxic ocean zones, loss of biodiversity (e.g. disruption of species reproduction, pollinator population reductions), increase in GHG emissions, and soil degradation.

For instance, a study conducted in Uttar Pradesh among a set of farmers identified that the understanding of the farmers for using these pesticides was limited which exposed them to adverse health outcomes.[57] Thus, the use of crop-protection chemicals requires awareness generation amongst farmers to prevent its misuse and prevent the possible negative impacts of these pesticides. Furthermore, by adopting agricultural practices that promote judicious and precise application of crop-protection chemicals, farmers can benefit from natural pest and pathogen control while protecting the environment, thereby preserving soil health and rendering food systems more resilient and stable.

52. FAO
53. Indian farming journal by ICAR, January 2022
54. Indian farming journal by ICAR, January 2022
55. NABARD
56. Wiley
57. NCBI, , Location of study: Uttar Pradesh, India

3. Role of crop-protection industry in the sustainable transformation of the agriculture sector

3.1 Current state of crop-protection industry – India vis-a-vis the world

India is the fourth largest producer of crop-protection chemicals in the world after the USA, Japan and China, accounting for 14% of the global market share.[58] The Indian crop-protection chemicals industry valued at USD 7.9 billion in FY2023, is expected to grow at a CAGR of 9.75% to USD 12.58 billion by 2028.[59] The main growth levers for the industry are increasing population and the subsequent rise in demand for food, adoption of digital technologies, and evolving go-to market (GTM) models such as direct-to-consumer (D2C), e-commerce and direct selling to farmer producer organisations (FPOs).

Crop-protection chemicals can be classified according to different criteria based on their usage, chemistry, mode of action and other factors. Crop-protection chemicals can be broadly classified into insecticides (used for protection against insects), fungicides (used to protect crops from the attack of fungi), herbicides (used for managing unwanted plants), biopesticides (biologically derived pesticides), rodenticides (used for protection against rodents), plant growth regulators (used for improving plant growth and yields) among other categories.

The Indian crop-protection industry comprises multinational companies, domestic players (national and regional), traders, formulators, importers and exporters of crop-protection chemicals. While large crop-protection chemicals players have significantly invested in establishing cutting-edge R&D infrastructure to introduce improved products, newer technologies and process enhancements to the Indian market, smaller players have mainly relied on the manufacturing of off patented and widely consumed generic molecules and formulations.

In 2022, India became the world's second-largest exporter of crop-protection chemicals.[60] The crop-protection chemicals produced by India is regarded to be of high-quality and are used in more than 150 countries.[61] India's prospects as a global manufacturing hub have improved tremendously due to the initiatives undertaken by the Government in prioritising R&D, and the support extended to cater to the rising demand and the need for innovation under the Make in India Mission and Atmanirbhar Abhiyan initiatives. One of the trends which is currently impacting the Indian crop-protection chemicals industry is the redirection of major global companies to decrease the amount of stock in their distribution pipelines across major countries. Additionally, there is a shift towards mitigating risks associated with manufacturing, which is primarily based in China, by exploring other countries, including India, as potential manufacturing locations.

58. Times of India
59. The Hindu Business Line
60. The Economic Times
61. The Economic Times

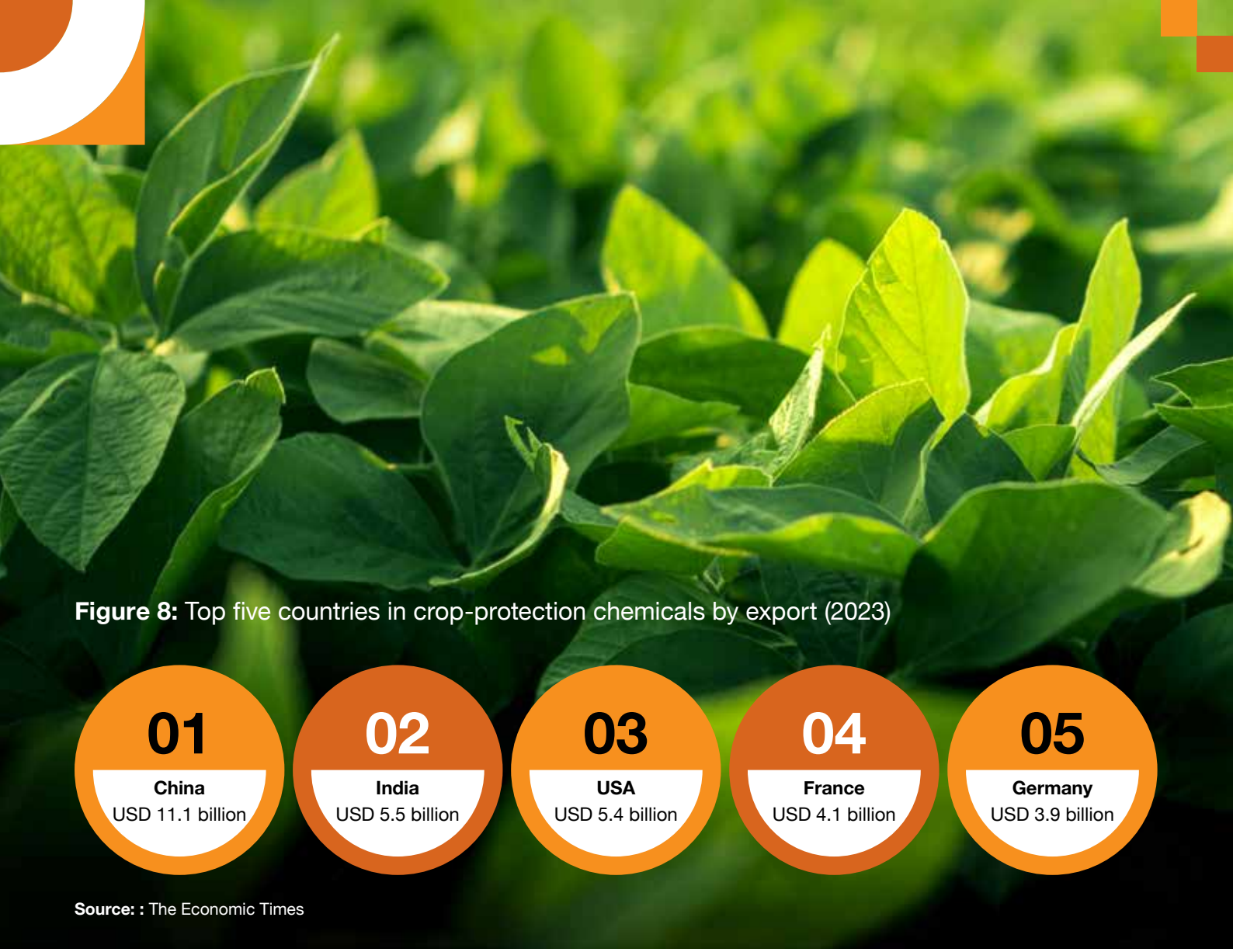
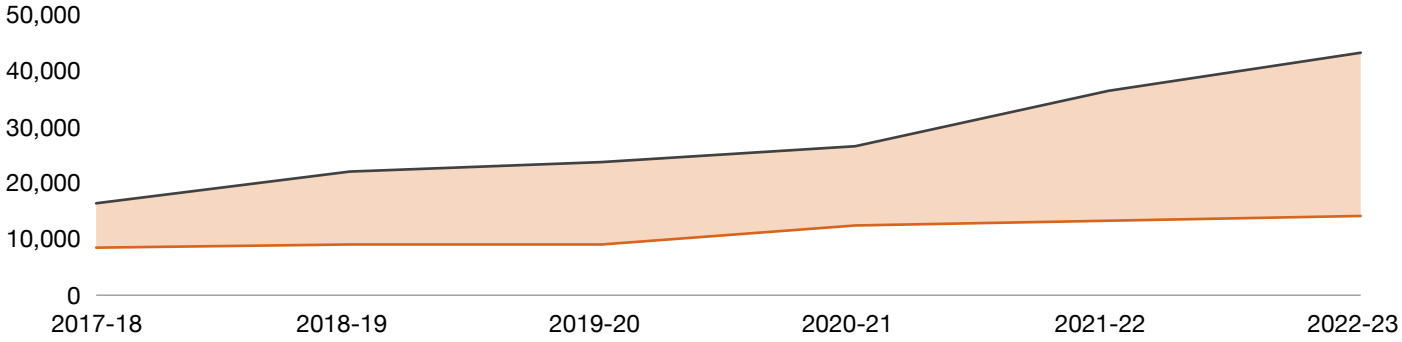


Figure 8: Top five countries in crop-protection chemicals by export (2023)

Source: : The Economic Times

To address the nutritional requirements of the country's population, India's demand for food is expected to rise significantly in the coming years. Therefore, the crop-protection chemicals industry has a key role to play in increasing production efficiency and meet the growing demand of the agriculture sector. With the Government of India's supportive policies and India's rapid rise to prominence as a preferred global hub for sourcing post-patent crop-protection chemicals, the industry exports are likely to double over the next three years. The crop-protection chemicals industry contributes tremendously to India's trade surplus every year.

Figure 9: India's crop-protection industry – export and import



Source: : The Economic Times

3.2 Key trends in the Indian crop-protection industry

Climate change, technological advancements and the regulatory landscape influence the Indian crop-protection industry. The section below provides a brief description of these trends.

A. Increasing concerns due to climate and environmental changes

Climate change has a significant impact on the Indian agriculture sector. There is growing concern about the use of crop-protection chemicals, which has become a major factor which links agriculture and environmental issues. The impact of climate change leads to an increase in the use of pesticides to maintain production, thereby creating a vicious cycle between the dependency on these chemicals and its subsequent impact on the environment. Inappropriate usage of crop-protection chemicals can result in decreased effectiveness, and with climate change impacting the environment, there is an increase in intensity of pests' attacks, leading to greater use of synthetic pesticides in agriculture. This can result in greater resistance to herbicides and insecticides, and have an adverse impact on humans, animals, and the environment..

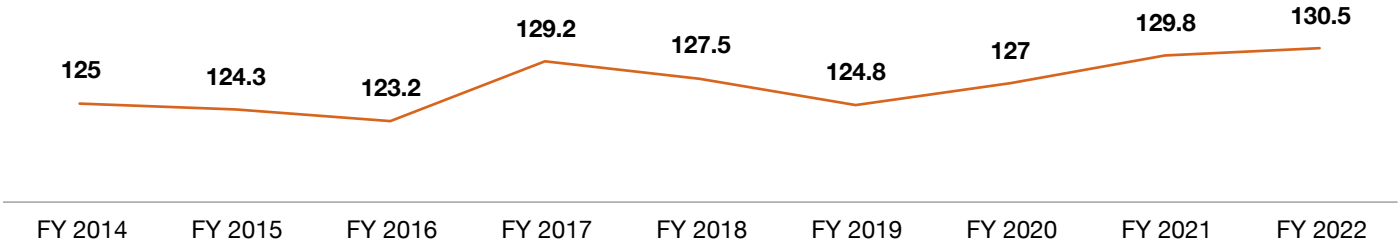
In order to mitigate these challenges, the Government promotes integrated pest management (IPM) practices through training programmes, subsidies for biopesticides and research support. IPM is an effective and environmentally sensitive approach to managing pests that combines biological, cultural, physical, and chemical tools in such a way that minimises health, economic, and environmental risks. IPM offers a balanced and sustainable approach to pest management, reducing the negative impacts of pesticides while maintaining agricultural productivity. Its adoption in India is crucial for promoting healthier crops, protecting the environment, and ensuring economic benefits for farmers.

B. Growing demand for food

The demand for food in India is expected to increase to up to ~400 million tonnes (MT) by 2050.[62] However, the total cultivated area for food grains across India has remained almost steady from FY 2014 to FY 2022.[63]

62. Vision 2050, Indian Agricultural Research Institute
63. Press Information Bureau

Figure 10: Total area under cultivation of food grains across India for FY 2014 to FY 2022 (in million hectares)



Source: Statista

A major challenge which the nation is currently facing is the decline in the number of agricultural workforce which puts more pressure on farmers to increase their productivity in order to feed the expanding population. Crop-protection chemicals play an important role in enhancing the yield and sustaining the growing demand for food.

C. Need for evolving regulatory landscape

India passed the Insecticides Act, 1968, and Insecticides Rules, 1971, to regulate the import, registration process, manufacture, sale, transport, distribution, and use of insecticides (pesticides) across India. However, there is scope to upgrade the regulatory framework to stay competitive in the global market. For instance, the registration of a new crop-protection product takes a fixed amount of time in other countries while the registration time varies in India which highlights the need for streamlining the processes and aligning them with global standards.

D. Growing pesticide resistance

The evolving pesticide resistance can be detrimental for agriculture as it can disrupt pest control and threaten food security. Resistance of insects, pathogens and weeds mainly happens if the same insecticide/fungicide/herbicide or the same mode of action is used year after year on the same crop in the same area. This, in turn, can increase the risk of selection for resistance. Similar cropping patterns repeated over the years due to the commercialisation of farming can further worsen the problem of pesticide resistance. These trends have led to an increase in the adoption of IPM and integrated resistance management (IRM)

E. Increasing technological advancements and innovations

Digital technologies such as data science, artificial intelligence (AI), blockchain, phenomics, genomics and mobile-app-based advisory are transforming the crop-protection chemicals industry in India with improved decision-making through analytics and traceability across the value chain. Evolving go-to market (GTM) models like direct selling to farmer producer organisations (FPO) and direct-to-consumer (D2C) e-commerce enabled by digital ecosystems like Open Network for Digital Commerce (ONDC) and Agri Stack are enabling better market access to the farmers. A few crop-protection chemicals manufacturing companies have begun to transition from traditional agriculture input providers to more advanced integrators of product and solutions, utilising digital technologies and information and communication technology (ICT). Considering the advantages of drone technologies in agriculture, the Ministry of Agriculture and Farmers' Welfare (MoA&FW) has taken several initiatives for its adoption.[64] Other players in the crop-protection chemicals industry are also working to use digital technologies effectively and assist farmers in their day-to-day activities.

3.3 Drivers of sustainable development in the crop-protection industry

The agriculture sector in India needs to adopt sustainable agricultural practices while ensuring an increase in productivity to meet the growing demand for food. There has been an increasing focus on sustainable practices in agriculture such as IPM, biologicals and genetic engineering. Given below are some of the key drivers that can help in promoting the adoption and scaling-up of sustainable agricultural practices.

64. Press Information Bureau

A. Economic benefits of efficient resource utilisation

Some of the economic advantages of sustainable farming beyond their ecological benefits are:

- **Income source diversification:** While traditional agriculture often only relies on growing a single crop leaving farmers susceptible to market fluctuations and weather-related risks, sustainable farming promotes diversification by encouraging cultivation of various crops and implementing different agroecological practices. Thus, by diversifying their production, farmers will be able to mitigate market risks and create multiple income streams.
- **Employment opportunities:** Due to the labour-intensive nature of sustainable farming, additional employment opportunities can be created for rural communities. Various agricultural practices such as organic farming and soil conservation, which are essential for sustainable agriculture can pave the way for the younger workforce to acquire new skills, secure employment and explore social entrepreneurship opportunities.
- **Market access and premium prices:** There is a growing demand for organic products for health-conscious consumers who are willing to pay a premium price for healthier food options and farmers can leverage the growing need for organic and sustainably produced food. Organic certifications and sustainable farming techniques will enable farmers to gain access to these premium markets which will not only boost their income but also benefit the rural economy.
- **Promote local and indigenous food:** Sustainable farming practices can also promote farmer's markets which provide fresh produce and facilitate social interactions between the producers (farmers) and consumers. Sustainable practices also focus on dietary and nutrition diversity (e.g. backyard nutrition gardens) thus reducing the dependency on distant food sources and enhancing local food security.

B. Market demand for sustainable products

Recent consumer trends suggest an increasing interest in greener alternatives to food with some consumers are even willing to pay higher prices to buy them. As a result of the shift in consumer patterns, the agriculture sector is also being driven to adopt sustainable farming practices. There is a growing popularity of organic foods which subsequently encourages farmers to use biopesticides as well as bio-fertilisers, bio-stimulants and soil ameliorators. From a consumer perspective, the key segments which will drive the growth of sustainable products are demand for organic foods, plant-based proteins, sustainable seafood and locally sourced, sustainably produced food.

C. Sustainability claims, value for sustainability-oriented investors and brand reputation

Regenerative farming practices can enable the integration of agricultural systems with biological processes which can lead to greater yields, improve drought and flood resistance, and increase soil regeneration. Organic farming currently accounts for only a fraction of the total agricultural land globally representing an untapped resource for improved efficiency and sustainability to feed the global population. Today, many investors invest in socially and environmentally conscious companies, thereby necessitating the need for organisations to start focusing their business strategy on sustainable practices. The Dow Jones Sustainability World and Emerging Markets Indices (DJSI)[65], and NIFTY 100 ESG[66] are examples of financial market indices that are based on long term environmental, social, and governance criteria.

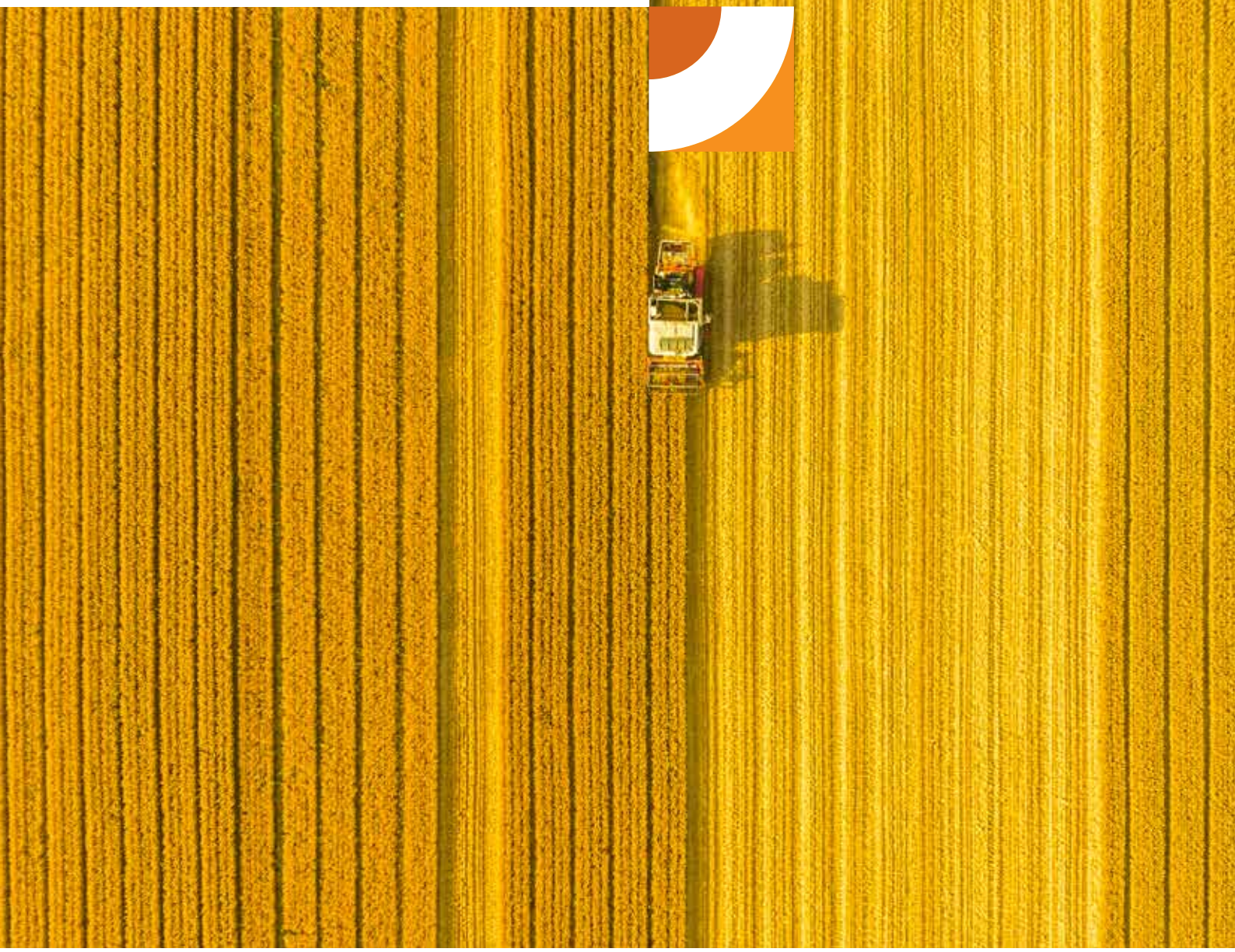
D. Carbon markets[67]

The rising demand for food due to the world's expanding population has increased the carbon footprint from agricultural activities. In 2018, global emissions due to agriculture accounted for 9.3 billion tonnes of CO2 equivalent. Similarly, methane and nitrous oxide emissions due to crop and livestock activities contributed 5.3 billion tonnes CO2 equivalent.[68] Farmers, business leaders and government agencies are becoming more interested in the emerging carbon markets designed specifically for farming and related activities. Globally, a large number of farmers have begun sequestering carbon through sustainable soil, crops, livestock, and agroforestry practices. By enabling farmers to sell their carbon credits, carbon farming offers a way to financially reward farmers for adopting sustainable farming.

65. S&P Global
66. NSE India
67. UNDP
68. SEBI

E. Improve compliance with regulations

The crop-protection chemicals sector's increasing challenges pertaining to environmental, social and governance (ESG) parameters require the businesses to adhere to the reporting and regulatory norms. With the introduction of the Business Responsibility and Sustainability Reporting (BRSR) by the Securities Exchange Board of India (SEBI) in 2021, the Government has mandated top 1,000 listed companies (by market capital) to report under the BRSR framework from FY 2023. Furthermore, on July 2023, SEBI has introduced the BRSR Core[69] for assurance by specific listed entities.



69. SEBI

4. Integrating sustainability in India's crop-protection chemicals industry

4.1 Sustainable practices and technology in the industry

Due to global challenges of climate change and food security, there is a growing focus on sustainable practices and technology in the crop-protection chemicals industry. Companies in this industry are increasingly transforming their operations and using data and targets to demonstrate their commitment to sustainability. Additionally, sustainability concerns are connected to financial risks. To minimise such risks, businesses are producing sustainability reports which detail their practices towards being more sustainable. Keeping with this trend and encouraged by Government initiatives to establish sustainable value chains, numerous crop protection companies have embraced the triple bottom line approach of profit, people and planet – making sustainability the central focus of their operations. In alignment with the SDGs, these companies are chalking out plans to improve the skills of farmers, implement more eco-friendly chemical practices, promote a circular economy, empower marginalised communities and women, and upgrade technology to reduce carbon emissions. Moreover, they've adopted sustainable practices across various levels – including product development and manufacturing levels, and at the farmer level.

Product development

Product development plays a pivotal role in ensuring sustainable agricultural practices and enhancing crop yields. It enables companies to develop products that are effective, sustainable, profitable and safe. This process involves a series of stages and each stage is crucial for delivering effective and environmentally responsible solutions. The invention-to-market stage can take a long time and incur heavy costs to develop a new product in many instances, depending on whether regulatory requirements are met by the companies. The process starts with research and invention for potential molecules and formulations, which address pertinent and emerging issues in agriculture. Further steps include testing under laboratory conditions, greenhouse and field trials to generate data related to efficacy and other important aspects. Exhaustive data on safety has to be generated by conducting studies on acute, sub-acute and chronic toxicity. The generated data is then submitted to regulatory authorities for scrutinisation and obtaining registration for manufacturing and sale.

In recent years, the crop-protection chemicals industry has increasingly recognised the need to shift towards sustainable practices, particularly at the product development stage. This shift has profound implications at environmental, social and economic levels and is not only profitable for the industry but also benefits the environment and the society. Some of the sustainable practices that are adopted in the product development stage are given in Figure 11.

Figure 11: Product development stages for crop protection chemicals

Using bioinformatics and computational modelling to reduce the need for experimental testing and minimising animal testing

Designing products with low toxicity and a lower environmental impact

Developing biodegradable and biocompatible active and ingredients and formulations

Sourcing of raw materials from sustainable and certified sources, such as Roundtable on Sustainable Palm Oil (RSPO) or Marine Stewardship Council (MSC)

Using recycled materials and implementing waste-reduction strategies

Implementing traceability systems to ensure responsible sourcing

Source: PwC analysis

Manufacturing/supply chain

The adoption of sustainable practices in the manufacturing stage of crop-protection chemicals products marks a transformative journey with far-reaching implications. Beyond environmental stewardship, this shift carries economic advantages, enhances corporate responsibility and positions companies to better navigate a rapidly changing global landscape. Some of the implications of adopting sustainable practices at the manufacturing stage are given in Figure 12.

Figure 12: Benefits of adopting sustainable manufacturing practices

Environmental impact reduction

From energy-efficient processes to waste reduction initiatives, companies are minimising resource consumption and environmental pollution. This reduction in negative impact aligns with the global efforts to address climate change and biodiversity loss.

Operational efficiency and cost savings

Efficient resource utilisation, streamlined processes and waste reduction contribute to operational efficiency, leading to cost savings. This economic benefit positions companies for long-term success in a competitive industry.

Corporate social resposibility (CSR) and stakeholder relations

Engaging in sustainable production practices demonstrates social responsibility, fostering positive relationships with stakeholders. This includes communities surrounding production facilities, consumers and investors who increasingly prioritise ethical business practices.

Regulatory compliance and risk mitigation

Embracing sustainable production practices ensures compliance with evolving standards, reducing the risk of legal issues and penalties. Proactive risk mitigation becomes a crucial aspect of long-term business strategy.

Innovation and market leadership

Companies investing in eco-friendly production methods can gain a competitive edge by offering novel, environmentally conscious products.

Resilience to supply chain challenges

Crop-protection chemical production is intricately tied to complex global supply chains. Sustainable practices enhance resilience by promoting local sourcing, reducing dependence on scarce resources and adapting to disruptions caused by factors such as climate events or geopolitical conflicts.

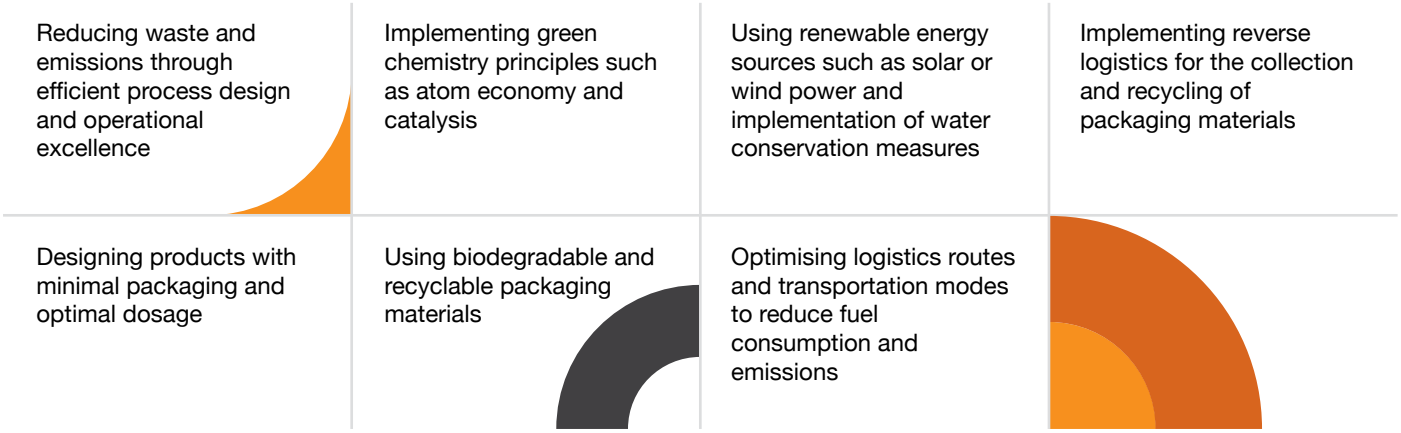
Long-term industry viability

As societies demand more environmentally friendly solutions, companies that prioritise sustainability not only secure their future market relevance but also contribute towards a more sustainable and resilient global agricultural sector.

Source: PwC analysis

Some of the common sustainable practices adopted at the manufacturing stage in the crop-protection chemicals industry are outlined in Figure 13.

Figure 13: Sustainable manufacturing practices adopted by crop-protection chemicals industry



Source: PwC analysis

Many crop-protection chemicals companies in India have adopted sustainable practices in their product manufacturing stage to reduce their environmental impact and promote sustainable agriculture. Some key initiatives include using renewable energy sources to power manufacturing processes and using rainwater harvesting and wastewater treatment facilities to reduce water usage. Moreover, sophisticated, environmentally friendly, and regulatory-compliant ways of water disposal are being practiced at a larger level.

Sowing sustainability: Post-sales practices in the crop-protection chemicals industry

Recognising the pivotal role of growers in the broader agricultural ecosystem, the crop-protection chemicals industry is increasingly focusing on sustainable practices at the farmer level, i.e., beyond production and distribution. With regard to this, the Government is taking multiple initiatives to promote sustainable, responsible, and safe agricultural practices, and crop-protection chemicals usage. Some of the major initiatives being undertaken are:

- **Education and training:** The crop-protection chemicals industry is investing in educational programmes and training sessions for farmers, empowering them with information on good agricultural practices. Some major areas covered under these programmes include integrated pest and nutrient management, regenerative agricultural practices, minimum tillage, careful selection and usage of crop-protection chemicals, soil health management, and crop rotation.
- **Precision agriculture technologies:** The industry is increasingly developing and promoting precision agriculture tools by making use of new technologies. Precision agriculture contributes to resource efficiency and aligns with the industry's commitment to environmentally conscious farming. While the feasibility of using such technologies varies across the agricultural landscape, specific applications on larger landholdings and high-value agriculture can be commercially viable and profitable in the longer term.
- **Responsible disposal and recycling programmes:** Initiatives for the responsible disposal of containers and leftover products are being undertaken by crop-protection chemicals industry players. Recycling programmes ensure that packaging materials are managed in an environment friendly manner, thus reducing waste and minimising the overall ecological footprint of the industry. Moreover, promotion of triple rinsing method will significantly reduce product residue in used containers and packets and help in minimising environmental hazards.

- **Financial incentives for sustainable practices:** Recognising the economic limitations of farmers, some crop-protection chemicals companies have considered the inclusion of financial incentives or rebate programmes for the farmers who are adopting sustainable practices. These initiatives encourage a positive feedback loop, where sustainable farming practices benefit both the environment as well as the economic well-being of farmers.

4.2 Role of agriculture biologicals in sustainability

One of the measures to alleviate the challenges of resource degradation and contribute to sustainable practices is the use of biological crop protection. Agri biologicals, by definition, are beneficial crop production and protection tools that are derived from naturally occurring sources and not synthetically modified. Agri biologicals are typically categorised in the segments given in Table 3.

Table 3: Comparison between different agri-biological segments:

Biopesticides	Bio-stimulants	Bio-fertilisers
These are agriculture biologicals that are derived from natural organisms such as bacteria, fungi, viruses or plant-produced substances that target specific pests and diseases. They help in minimising the impact on non-target species and maintain the ecological balance. For example, Bacillus thuringiensis (Bt) is used for insect control, and the Trichoderma species are effective against fungal diseases.	These are microbial inoculants, enzymes, seaweed extracts and humic substances etc. that help in boosting plant growth and resilience. They enhance the capacity of the plant for more efficient nutrient uptake, increase tolerance to abiotic stress, and improve crop quality and yield.	Biofertilisers comprise living micro-organisms like bacteria, algae and fungi that help in enriching soil fertility. They improve nutrient availability and uptake, support root growth, and enhance soil structure and biological activity. Nitrogen-fixing bacteria (e.g. Rhizobium in legumes), Azotobacter, Nitrobacter and phosphate-solubilising bacteria are some examples of biofertilisers.

Source: PwC analysis

In India, biofertilisers and bio-stimulants are regulated under the Fertiliser Control Order (FCO), while biopesticides, botanicals such as neem, Pyrethrum., plant growth regulators (PGRs) and pheromones are regulated under the Insecticides Act 1968.

With farmers being the backbone of Indian agriculture, Government of India aims to secure a brighter future for them and is continuously making efforts to enhance productivity, improve framers' income and livelihood. Since farmers success becomes a major factor for country's development, it is important to give sustainable and innovative technologies to them and enabling them to increase their productivity and growth.

One such complementary, sustainably advanced, climate adaptive solutions for farmers is agricultural biologicals, which play a crucial role in offering sustainable solutions to them for enhancing productivity while minimising environmental impact. Some of these benefits are illustrated in Figure 14.

Figure 14: Key benefits of Agri-Biologicals

Key benefits of agri biologicals

01

Improve soil health

- Enhance soil fertility by promoting the growth of beneficial microorganisms and improving nutrient cycling.

02

Sustainable agriculture

- Sustainable solutions for farmers to enhance productivity while minimizing environmental impact
- Improvement in nitrogen use efficiency
- Agricultural biologicals(usually microbes) break down immunity of soil pathogens, thus achieving higher impact with much lower spray costs.

03

Reduced chemical residue

- Agricultural biologicals target specific pests or diseases, sparing beneficial organisms and maintaining ecological balance. Biofertilizers and soil amendment products improve soil health by enhancing structure, nutrient availability, and biodiversity.
- Bio-stimulants can boost plant growth and resilience, optimising nutrient uptake and increasing tolerance to abiotic stresses, leading to improved yields and crop quality. This is increasingly important under the challenges posed by climate change.
- Natural decomposition of agricultural biologicals can result in minimal residue on produce, aligning with consumer preferences for authentic food and meeting stringent residue standards.

04

Enhance environmental safety

- Strong enabler of integated pest managment
- Manage pests with minimal chemical residue on crops, addressing concerns related to food safety and residue buildup.
- Lower MRLs means access to higher value export market.
- Novel microbes allow plants to synthesise N, P and K. Thus, introduction of these novel microbes can help reduce urea application , which can further help reduce the subsidy impact of key fertilisers too.

05

Increase Crop Yield

- Aid in increasing crop yields by promoting root development, nutrient absorption, stress tolerance, and aiding plant metabolism.
- Biopesticides and biostimulants aid pest control (rotation partner) and help plant recover from pest/disease damage

Source: PwC analysis

Aligning India's agri-biologicals to UN's SDGs

Agri biologicals market is evolving rapidly across the globe. The global agri-biologicals market was valued at USD 11.73 billion in 2022 and is projected to grow at a CAGR of 14.14% from USD 13.35 billion in 2023 to USD 33.69 by 2030.[70] There is growing adoption of biologicals in the market as tools for sustainable agriculture of the future. Moreover, a megatrend towards regenerative agriculture – which emphasises protection of beneficial organisms and healthier soils with the potential to improve food security, mitigate the impact of climate change and preserve biological diversity – has been fuelled by agri-biologicals.

The MoA&FW aims to provide farmers with a diverse set of tools which can significantly enhance their agricultural productivity and sustainability. The Government has launched several initiatives under the National Mission for Sustainable Agriculture (NMSA)[71] to facilitate sustainable agriculture practices across India such as Rainfed Area Development (RAD),[72] Sub Mission on Agroforestry (SMAF),[73] National Bamboo Mission (NBM),[74] Soil Health Management (SHM)[75] and Paramparagat Krishi Vikas Yojana (PKVY).[76] The agri-biologicals segment can complement the Government and the farmers in achieving the objectives under these initiatives. The step taken by the Government of India to bring bio-stimulants under the Fertiliser Control Order is a welcome move. Moreover, the publication of draft guidelines by the Government of India shows its willingness to bring in new products and technologies to help crop management.

Figure 15: Benefits of using agri-biologicals

SDG 2: Zero Hunger

- Enhance crop yield.
- Improve food security
- Integrated pest management
- Development of resilient and productive agriculture systems

SDG 3: Good Health and Well being

- Requires fewer applications, and it allows fewer applications of other agricultural inputs
- Thus promotes the overall well-being of farming communities

SDG 12: Responsible Consumption and Production

- Aligns with the goal of ensuring more responsible consumption and production patterns, minimising the environmental impact of agriculture.
- supports the achievement of Circular Economy

SDG 13: Climate Action

- Contribute to development of climate-resilient agricultural practices, mitigating the impact of climate change on food production.

SDG 15: Life on Land

- Fosters biodiversity and soil health.
- Support sustainable land management practices

SDG 17: Partnerships for the Goals

- Biologicals requires collaboration between farmers, researchers, policymakers, and the industry. Partnerships are essential for widespread adoption of these sustainable tools.

Source: PwC analysis

70. Fortune Business Insights
71. NMSA
72. NMSA
73. NMSA
74. NMSA
75. NMSA
76. DARPG

The industry, research bodies and governments across the globe have been working collaboratively to include agricultural biologicals in mainstream and targeted approaches towards solving challenges in agriculture in a sustainable manner. Table 4 discussed two examples from Brazil and ASEAN member states which discuss the role of agricultural biologicals in solving key challenges as follows:

Table 4: Examples of using agriculture biologicals in solving agricultural challenges

1. Brazil: A government-led approach towards bio-based agricultural inputs

About	The Ministry of Agriculture, Livestock and Food Supply (MAPA) in Brazil has introduced National Programme for Bio-based Agricultural Inputs or the Bio-input Programme. The programme aims to reduce the dependence on imported agricultural inputs and improve supply of input raw materials by exploring the country's biodiversity potential.
Outcome	Focused research efforts have been carried out by Brazil Agricultural Research Corporation (Embrapa) to develop bio-inputs to tackle the pressing crop pest and disease issues in the country have been taken up by the research bodies. More than 14,000 strains of nutrient fixing microorganisms and 10,000 strains of biocontrol organisms have been included in a germplasm bank. As a result, there are over 265 biological pest control products registered in Brazil and the efforts to introduce a wider bio-input basket to farmers continue.
Learning	A focused effort from the Government towards research for biological products and a conducive regulatory environment resulted in availability of a wider and effective range of bio-inputs to Brazilian farmers

Source: Ministry of Agriculture, Livestock and Food Supply, Government of Brazil

2. Southeast Asia: Adoption of sustainable agricultural practices among Association of Southeast Asian Nations (ASEAN) member states

About	Agriculture is a way of life in ASEAN with 8 out of 10 countries in ASEAN dependent on agriculture and its production. In Myanmar and Lao PDR, this sector accounts for more than 40% of the GDP. The region is a major producer and exporter of palm oil, crude rubber, rice, sugar, seafood and fruits.
Outcome	The sustainability of the sector – and plates of millions of Southeast Asians is currently at a threat due to climate change, overfishing, unsustainable farming methods, food wastage and other problems in which effort is required to ensure the regions agriculture sector, as a key source of food and income continue with the wise stewardship of earth's resources.
Challenges (if any)	Challenges (if any) To address these challenges in ASEAN food systems, the ASEAN Ministers of Agriculture and Forestry (AMAF) adopted the ASEAN Regional Guidelines for Sustainable Agriculture at the forty-fourth AMAF Meeting in October 2022. The Guidelines outlines the importance and relevance of new sustainable and circular agricultural policies and encourages the development of sustainable agricultural industry practices, including the development and adoption of biological control agents, such as bacteria, fungi and nematodes.
Learning	Since the adoption of these Guidelines, AMAF as a group has been working on the development of implementation programmes to translate the Guidelines into practical actionable plans. As the Chair of ASEAN this year, Laos PDR is expected to pass the Implementation Plan for Sustainable ASEAN Agriculture as one of its key deliverables. Across ASEAN, governments are now looking for alternatives to agricultural chemicals, including biological products for crop protection. The Philippines' Department of Agriculture led the way by revising its administrative circular on importation of agricultural inputs to also include biological products in 2022. Although other countries are yet to follow the Philippines' lead to clarify biological product registration process, the intention is clearly there among ASEAN nations to adopt more biological products in the future for a sustainable agricultural sector in Southeast Asia.

Source: ASEAN Regional Guidelines for Sustainable Agriculture in ASEA, Republic of the Philippines, Department of Agriculture

Challenges in the adoption and scaling up of agriculture biologicals in India

Despite their benefits, the adoption of agriculture biologicals in India is at a nascent stage and faces the following challenges:

- **Expensive production and commercialisation:** The production of biologicals is complex process which drives up production and commercialisation costs. Many global players have developed certain products (e.g. specific microbial strains) which can be imported to India but are facing challenges due to import restrictions on the same. While domestic multiplication of these products would align with the 'Atmanirbhar Bharat' vision, establishing multiplication facilities for all products would require significant investments. Furthermore, the cost of commercialisation of these products will also be high – including regulatory compliances, field trials and marketing costs.
- **Handling requirement and shorter shelf life:** One of the biggest challenges of certain agri biologicals is their short shelf life which affects their widespread adoption. Improper storage and handling of certain biological products, especially predators and beneficial organisms, can lead to significant degradation in their efficacy. These challenges are further exacerbated by moderately complex supply chains, distribution mechanisms and minimum infrastructure at grassroot levels, which exist along with seasonality of product sale and usage.
- **Narrow target range:** Biopesticides generally have a narrow target range, i.e. they are effective against certain insects/pathogens only; and also, are effective only on certain stages of the life cycle. Hence, there has to be advance information to farmers on pest/disease occurrence in a particular rea. This limits the utility and application of agricultural biologicals during the cropping season at a large scale.
- **Knowledge gap among farmers:** Due to limited awareness about agri biologicals among Indian farmers, there exists a resistance towards its efficacy and benefits. Moreover, to ensure greater effectiveness, farmers need to use multiple products in combination with agri biologicals for comprehensive pest control, thus hindering the widespread adoption of these products.

Key suggestive measures to enhance adoption of agriculture-biologicals

- **Regulation for import:** While industries such as pharmaceuticals and animal nutrition can import and offer biological products in India due to certain relaxations in import regulations, biopesticides formulations (based on microorganisms namely beneficial fungi and bacteria) developed in other countries that could be useful to Indian agriculture are restricted to be imported in India. Policymakers may, therefore, consider outlining similar regulations for the import of biopesticides and biofertilisers to benefit the sector.
- **The need for a robust regulatory system for agricultural biologicals**
  - **Regulatory framework:** The current process for the registration of bio-stimulants and biofertilisers is the same as that for chemical pesticides and fertilisers in India. In order to facilitate the industry to develop newer products and enable farmers' access to newer technologies, the Government may consider introducing a more streamlined mechanism with a predictable registration timeline. Also, an increased focus towards protection of intellectual property rights (IPR) and regulatory data protections (RDP) shall further encourage and enable the development of novel and innovative products in the Indian market.
  - **Harmonised data requirement for registration:** There is limited availability of information regarding the quantum and parameters of the data required for the registration of biofertilisers. For example, bio-stimulant manufacturers in India face difficulties in registering certain categories of products due to the unavailability of data packages required for registration. The FCO had already considered provision of data waivers for certain type of bio-stimulants alleviating such problems and consortium products of biopesticides are now allowed by Central Insecticide Board and Registration Committee (CIBRC).

- **Strict measures for counterfeit and spurious products:** Regulating the production and supply of agricultural biofertilisers is crucial as such products have severe consequences on a farmer's income, agricultural productivity and the health of the consumers. This can be done by:
  - Enforcing strict regulations at state level for production and distribution of counterfeit inputs is essential. Stringent measures for promoting regulatory compliance are the need of the hour. By implementing strict measures to issue licenses for agricultural biologicals, governments can ensure the responsible development, marketing, and use of these products while safeguarding environmental integrity and sustainable agriculture.
  - It is important to educate farmers about buying high quality agricultural biological products from reliable sources. Implementing technology solutions and conducting awareness campaigns to educate farmers about the risks associated with counterfeit inputs is equally important.
  - Government should define standards and generate key capabilities to detect and prevent counterfeit products. This requires strong collaboration and regulatory compliance measures along with technological advancements which can ensure clear and accurate labelling in products about ingredients, sources, and processes to promote transparency and empower farmers to make informed choices.
- **Need for farmer stewardship in agricultural biologicals:** The government may focus on enabling farmers with proper training to maximise the use of biofertilisers. Some of the steps that can be taken in this regard are:
  - provide farmers with comprehensive education and training on the proper use, application dosage, application guidelines, and benefits of agricultural biologicals
  - encourage farmers to adopt agricultural biologicals as part of integrated pest management strategy.

4.3 Challenges in the sustainable development of the crop-protection industry

The current trends and initiatives in the crop-protection chemicals industry highlight a significant shift towards adopting and promoting sustainable practices in India that help reduce the environmental impact of agricultural practices, while also ensuring the long-term viability of the industry. In this regard, the Government of India has also taken several steps to promote sustainability in agriculture through focused interventions and budget allocations. These initiatives aim to reduce the use of chemical pesticides and fertilisers, promote organic farming practices, and encourage the use of biofertilisers, biopesticides and bio-stimulants as well as integrated pest-management techniques. Despite these positive trends, several challenges remain to be addressed. Some of these have been outlined below:

- **Regulatory challenges:** The crop-protection chemicals industry helps to introduce and promote safer and sustainable crop-protection chemicals products to Indian farmers. However, the process for registering new products takes up to 4–5 years at present, which can hamper the development and production of such products. Since high costs are involved in R&D, testing and data generation of each product, the long timeline can impact the working capital, time-to-market, profitability and innovation pipeline. To address this, the Government had already created a single window system of registration, with CIBRC being the only authority which has taken the effort to register around 300 molecules in India and organises monthly registration committee meetings to speed up the process.[77] Small and medium players are already encouraged in with speedy registrations, which are granted within 4 months' time versus new 9(3) registration taking 5-6 years. However, the Government may consider making additional reforms to enable the registration committee to speed up the registration process by deploying required manpower particularly experts and enable a smoother regulatory landscape which will further encourage small and medium players to be an active part of the industry's sustainability journey.

77. https://ppqs.gov.in/sites/default/files/65th_cib_meeting.pdf

- **Farmer-level challenges:** Due to the limited awareness among farmers about sustainable agricultural practices and the benefits of eco-friendly alternatives, the adoption rates of green crop-protection chemicals products are low. Reservations related to tangible impact and farming economics-related perceptions of farmers towards new products and practices also impact the adoption of sustainable inputs and practices. Moreover, use of sustainable methods can be perceived to have higher upfront costs since many products and practices follow a preventive approach of crop health management.
- **Agri input ecosystem:** The dominance of conventional crop-protection chemicals in the market poses a challenge for sustainable alternatives to gain traction at a rapid pace. Furthermore, the limited infrastructure for R&D as well as the distribution of sustainable crop-protection chemicals can impact the industry's transition towards sustainable approaches.

4.4 Key policy measures to support sustainability in the crop-protection chemicals industry

Adopting and promoting sustainable practices in this industry requires concerted efforts from the Government, industry stakeholders and research institutions. By focusing on education, regulatory support and infrastructure development, India can pave the way for a more sustainable and environmentally conscious crop-protection chemicals sector.

- **Some of the steps which these organisations can consider are: Increasing awareness and adoption of sustainable practices through education and training programmes:** Education and outreach programmes are crucial in order to promote awareness and adoption among farmers and help them make informed decisions. Though such initiatives are being taken by the industry, efforts to increase awareness about maximum residue levels (MRLs), application techniques, container disposal, safety measures, market dynamics, weather forecasts and pest advisory may be undertaken. The companies can also explore a multistakeholder collaborative approach to address the current waste disposal practices for used crop-protection chemicals containers, through initiatives like a reverse supply chain to recycle used containers safely or educating farmers on safe and responsible disposal of used containers can also reduce health and safety hazards.
- **Providing farmer-centric solutions:** A comprehensive approach which considers crop diversity, sustainability and economic viability can provide farmers with better solutions. The industry may consider moving towards service packages for end-to-end crop health management, keeping sustainable practices at the centre. Such solutions will be able to address farmer-level challenges concerning productivity, economics and income.
- **Developing technology-based solutions:** The crop-protection chemicals industry may leverage technology to establish a traceable supply chain to gain greater trust amongst stakeholders, enhance product safety and reduce environmental and health risks. This can be implemented by using blockchain technology, radio frequency identification (RFID) sensors, and the internet of things (IoT) sensors to establish a trusted and transparent system ensuring that genuine products reach the farmers.
- **Investments in R&D:** The industry may consider investing in R&D to improve sustainable agriculture practices. Investing in collaborative initiatives that boost farm-level carbon sequestration and mitigate carbon emissions can also be considered.

Some of the steps which the Government can consider are:

- **Incentivising farmers:** Government incentives could play a pivotal role in easing the economic burden of farmers. This may require collaborations among the industry stakeholders, Government and financial institutions in order to provide feasible incentives to farmers such as subsidies, loans and grants to farmers who adopt sustainable practices.
- **Reviewing the registration process and timelines:** The Government may consider reviewing the registration procedure and timelines for crop-protection chemicals and aligning them with international standards. Also, prioritising the registration of novel molecules under section 9(3) to introduce the product at a faster pace in the market can be considered by the government.[78]
- **Supporting import of innovative products:** As most of the crop protection products are developed outside India, interim relaxations in import regulations can support companies in commercialising new products and moving towards the local production of largely consumed products.
- **Encouraging public-private partnerships:** The Government may consider promoting public-private partnerships in order to help develop and promote sustainable crop protection technologies. Supportive funding may be provided to startups that are involved in the development of innovative

78. Directorate of Plant Protection, Quarantine and Storage

crop protection solutions. Further, there is a need to develop a common platform to collaborate and co-create interventions between like-minded private players as well as between the private sector and the Government.

- **Promoting efficient and safe use of agriculture inputs:** The crop protection sector is associated with a lot of misinformation and misconceptions, which need to be addressed through extensive awareness aimed at all levels of stakeholders – from farmers to final consumers. This would involve collaborative efforts from the Government, industry stakeholders and research institutions.

Conclusion

India's crop-protection chemicals industry plays a vital role in advancing sustainable agriculture, which is crucial for a nation heavily reliant on farming for economic stability and population support. Facing the dual challenge of ensuring food security and managing resources sustainably amidst issues like climate change and low crop productivity – the Indian agriculture sector needs to undergo significant transformation. Currently, the crop-protection chemicals sector faces major challenges such as misuse of chemicals, environmental harm and health risks.

It is important for the country to adopt sustainable agricultural practices and consider environmental, social and economic aspects while designing policies for the agriculture sector. Many government initiatives are promoting organic farming and technological advancements in order to guide farmers towards implementing sustainable farming. The industry is also focusing on precision farming, integrated pest management and incorporating digital technologies into farming practices. These improvements aim to increase the efficiency while reducing the negative environmental impact of farming. In addition, the crop-protection chemicals sector is developing sustainable products, promoting responsible farming practices and improving manufacturing efficiency.

The Indian crop-protection chemicals industry has the potential to implement sustainable farming and thrive by adopting eco-friendly solutions which are backed by sound policies and collaborative endeavours. This can be done by focusing on R&D and building partnerships to ensure a sustainable future for Indian agriculture. Collaborative approaches amongst the industry players and public-private partnerships to improve product offerings, promote adoption of better practices at farmer level and facilitate technology solutions at farm level are some of the most important drivers of this transformation.

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