9

Digital Innovation in Agriculture

Transforming Value Chains and Finance[1]

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9.1. Introduction

According to a recent report of the World Economic Outlook released by the International Monetary Fund, India has crossed the 4 trillion-dollar mark and has become the 4th largest economy in the world. Agriculture is the backbone of the Indian economy, and approximately 46.1 percent of the Indian population depends on agriculture. However, the contribution of agriculture to the total GDP remains at around 16 percent, and agriculture is expected to grow by 3.8 percent by 2025. The total food grain production is estimated at 3288.52 LMT, which is 211.00 LMT higher than the average food grain production in the last five years. The key drivers contributing to the growth of agriculture are high-value products such as horticulture, livestock, and fisheries (Economic Survey, 2024-25). However, in a country like India, where more than 85 percent of farmers are small and marginal farmers, collectivization and digitalization are the only ways to increase profitability in agriculture. Digitalization refers to the use of digital technology to digitize business processes, services, and business models to increase efficiency and create value in the entire value chain. Recently, several agri-tech organizations have developed innovative models to use digital technologies to solve the prevailing issues in agriculture. The government approved the Digital Agriculture Mission on September 2, 2024, with an outlay of Rs. 2817 Crore. An amount of Rs. 54.972 Crore was allocated for FY 2025-26 (Government of India, 2025).

With a growing population, the demand for food is increasing, and the resources to produce food are decreasing. Several issues, such as weather hazards and climate change, further impact the food production levels. Technology plays a critical role in helping the agriculture sector meet the estimated 70 percent increase in global food production needed to feed 9.1 billion people by 2050 (World Economic Forum, 2024). In this context, this chapter attempts to review successful models of agricultural technology (agritech) supporting the agricultural value chain and compares them in terms of their services, opportunities, and challenges. This chapter provides recommendations for the promotion of sustainable agri value chains.

The chapter is organized as follows. The next section summarizes the current concerns in the agricultural sector. Section 9.3 presents a literature review on the evolution of digitalisation and agricultural technology in India, the digitalisation of agriculture and effect on financial inclusion. Section 9.4 discusses the revenue models in India's agricultural technology in brief. Section 9.5 analyzes business models in agricultural value chains, in detail. Section 9.6 highlights the opportunities in agricultural technology funding for lenders. Section 9.7 concludes, with a few suggestions.

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9.2. Challenges in Agriculture

In recent years, agricultural production in India has shifted from cereal to high-value crops. India has become the leading producer of fruits and vegetables. The demand for a range of food products, such as millet and exotic fruits and vegetables, has increased. A recent report by Kaalaari Capital (2022) stated that India is the world's second largest producer of fruits, vegetables, and staples, and in the year 2021-22 it produced 302 million metric tons of fruits and vegetables and 275 million metric tons of staples. This led to a shift in production patterns. In 2024-25, production increased by 6 percent, reaching a record production of 354 million tons of food grains (Government of India, 2025). The data suggest that horticultural crops contribute 33 percent of the gross value added from agriculture. India is currently producing approximately 353.19 million tons of horticulture. Horticulture produce has surpassed the food grain production with less area, i.e. 28.98 million Ha. Compared with cereals, i.e., 127.6 million Ha. for food grains. Productivity of horticulture crops is much higher (12.49 tons/ha) compared to the productivity of food grains (2.23 tonnes/Ha.) (Government of India, 2024). However, fragmented land, dependency on monsoons, and a lack of proper infrastructure remain some of the pain points in agriculture. Additionally, the volatility of input prices and suboptimal selection of agricultural inputs leads to low production. This can be enhanced using high-quality inputs. The lack of technology has resulted in less efficient cropping and poor yields (NABARD, 2023; NITI Aayog, 2022).

In this context, the role of agritech has improved significantly. Technology can be an enabler of this process. This chapter explores the role of technology in solving various issues across the agricultural value chain.

9.3. Review of Literature

This section reviews the literature on the evolution of digitalization in agriculture, the status of agritech, and the role and impact of digitalization.

Evolution of Digitalisation

The evolution of digitalization in agriculture is classified into four phases: agriculture 1.0, agriculture 2.0, agriculture 3.0, and Agriculture 4.0 (Aggarwal and Verma 2022). The use of technology in agriculture has shifted from Agriculture 1.0 to Agriculture 4.0. This shift has seen tremendous growth in the use of technology in agriculture, that is, from the use of simple tools to the use of drones and precision farming. Agriculture 1.0, was dominated by simple tools such as handmade implements for agriculture. However, this also simplifies the agricultural operations process and reduces human effort. Agriculture 2.0 was an era of the use of chemical fertilizers, tractors, harvesters, and other advanced technologies. This era is known as the Green Revolution (GR). After the Green Revolution, an era of precision farming and improved crop varieties has emerged. The era of the green revolution was dependent on the use of high-yielding varieties. Technology plays a significant role in the development of high-yielding rice varieties.

Post-liberalization, such as genetics and improved chemicals, was the era of the Bio Revolution. This phase also saw the use of computers and sensors in agriculture. Agriculture 3.0. Agriculture 4.0 is an era of the Internet of Things in agriculture. This era is characterized by the Internet of Things (IoT), Artificial Intelligence (AI), robotics, Blockchain, drone, and big data analytics. Mulla (2013) reported that precision agriculture dates back to the mid-1980s, and precision agriculture dates back to the middle of the 1980s. Remote sensing applications in precision agriculture include the use of sensors for soil organic matter, as well as satellite, aerial, and handheld or tractor-mounted sensors.

To support the digitalization of agriculture, the Government of India has promoted the Digital Mission (2024). The objective of this mission is to enable a robust digital agricultural ecosystem in the country. A total of Rs.2,817 crores have been sanctioned for this project (Ministry of Agriculture and Farmers Welfare, Government of India, 2024). It comprises two foundational pillars.

i. *Agri Stack*: Agri stack works by creating a digital infrastructure backed by the Government. It uses various components of data from farmers and creates unique Farmer IDs, digital Farm IDs, and Crop Certificates. The data were shared with the consent of the farmers. States maintain their data, and organizations working to provide services to farmers, such as credit, insurance, and market access, can use these data. The data collected from the registry were:

   1. Farmers registry
   2. Village land maps registry
   3. Crop sown registry

ii. *Krishi Decision Support System*: The Krishi decision support system integrates various data related to production in agriculture, such as soil, land details, and weather, through satellite imagery. This provides real-time data to farmers and policymakers, facilitating crop production.

   1. Geospatial data
   2. Drought/flood monitoring
   3. Weather/satellite data
   4. Groundwater/water availability data
   5. Modelling for crop yield and insurance

This indicates that the Indian Government is promoting digitalization in agriculture to promote sustainable development. Under the Digital India initiative, a total outlay of Rs.800 crores is allocated to promote technology-led startups and innovation schemes, such as Technology Incubation and Development of Entrepreneurs (TIDE 2.0). This is also helping agritech startups come in a big way and solve some of the critical issues in agriculture.

Status of Agritech in India

Internet penetration in India has increased at a very fast pace. The Government of India reported that 95.15 percent of Indian villages had access to the Internet by March 2024. The total number of Internet subscribers has increased sharply between 2014 and 2025, reaching 974.87 million from 251.59 million, that is, almost four times in a short span of 10 years. Of the total wireless subscriptions in India, there are 533.51 million Rural Internet Subscribers, that is, about 47 percent. The Compounded Annual Growth Rate (CAGR) for Internet subscriptions in India was 14.26 percent. (Ministry of Communications, Government of India, 2024). This has led to an increase in the adoption of digital technologies in rural areas. Hassoun (2025) mentioned that various technologies such as Artificial Intelligence (AI), smart sensors, Internet of Things (IOT), big data analytics, robotics, and blockchain are providing solutions to the issues in agriculture and helping to improve quality, leading to sustainability throughout food supply chains.

As per a report released in 2025, Agrifoodtech investment in developing markets reached USD 3.7 billion in 2024. This was a 63 percent increase from the previous year, that is, 2023, and accounted for 23 percent of global investment. This represents a decline of 4 percent from 2023. Globally, investment in agritech is improving and investment has increased in five countries: the United States (+14%), India (+215%), the Netherlands (+118%), Finland (+403%), and Japan (+76%). Among the various Agritech categories, upstream categories remained the top priority for investors compared to downstream categories. The total funding to the upstream category was approximately 51 percent of the total agrifoodtech funding in 2024 through 1,265 deals. By contrast, downstream innovations attracted 38 percent of the total funding, showing an increase in their share compared to 2023. Among Upstream, eGrocery was the top-funded category in 2024 (Agfunder, 2025).

In 2021, the World Economic Forum published a community paper as part of the Artificial Intelligence for Agriculture Innovation (AI4AI) initiative, documenting more than 20 agritech cases. They attempted to classify interventions in various segments and in four categories: intelligent crop planning, smart farming, farmgate-to-fork, and data as an enabler. These four categories represent all stages of crop production, that is, pre-production, production, and post-production stages. They further classified the different activities as follows:

(i) *Pre-production stage*: This stage includes intelligent crop planning (gene editing of the crops, artificial intelligence (AI), soil testing-based, and sowing-window advice for better productivity).

(ii) *Production stage*: This includes smart farming (artificial intelligence and use of augmented reality (AR) for crop advice and field planning, weather predictions, robotics, and yield prediction).

(iii) *Post production*: This included activities of taking produce from farmate-to-fork (traceability, Internet of Things (IoT)-enabled warehousing, smart logistics, and smart packaging).

(iv) *Data as an enabler*: Digital Public Infrastructure (DPI – platform, policy, and protocols) and its implications for farmers.

The Government of India is also supporting data-driven agriculture, precision farming, and digital financial services through its Digital India Mission. (Department of Financial Services, Government of India, 2024).

Digitalisation in Agriculture and its Impact on Financial Inclusion

Digitalization in agriculture will help develop more profitable and sustainable agricultural practices. Klerkx et al. (2019) mentioned that digitalization in agriculture includes technologies such as big data, the Internet of Things, robotics, Sensors, Artificial Intelligence, augmented reality, and blockchains, which contribute to various aspects of the agricultural value chain. A study in China concluded that digital financial services also helped increase the use of agricultural mechanization, which reached a threshold level (Yan et al. 2025). The use of remote sensing to improve production was also discussed. Sishodia et al. (2020) mentioned that spatial, spectral, and temporal satellite images have helped in precision agriculture applications, such as crop monitoring, irrigation management, fertilizer application, disease and pest management, and yield prediction. He also reported that the use of unmanned vehicles helped farmers owing to their cost-effectiveness. Kamilaris et al. (2019) highlighted the role of big data in smart farming. Sharma et al. (2020) highlighted that intelligent irrigation and harvesting techniques reduce human labor and help improve the sustainable productivity and quality of products. Rawat and Kumar (2015) highlighted the role of multi-temporal satellite imagery in understanding changing landscape dynamics. This can further help in planning cropping systems to improve land-use patterns.

A study in China reported that digital capability is an important factor for enhancing digital transformation. They also proposed three categories for digital transformation pathways: technology-driven, technology-organization-driven, and environment-driven (Zheng et al. 2025). Some studies emphasize the advantages of digital technology, whereas others have examined the cost aspect of digital technology (Hunt and Daughtry, 2018). A study by Dong et al. (2025) reported that the advancement of the rural digital economy significantly enhances the net carbon efficiency of agriculture, making it more sustainable. A study in South Africa also reported that ICTs enhanced agricultural productivity and environmental sustainability among farmers (Ngulube, 2025).

Despite their several advantages, these technologies face several challenges. Kamilaris et al. (2019) mentioned that, although the use of blockchain has increased in agriculture, it still faces technical challenges, education, policies, and regulatory frameworks. In addition, the role of affordable and timely financing is emphasized. A study in Africa concluded that FinTech helps agriculture by boosting productivity, ensuring food security, and fostering economic resilience among rural populations (Glavanits and Szabó, 2024). With regard to digital financial inclusion, one study reported that factors such as perceived usefulness, ease of use, and trust had significant and positive impacts on the adoption of mobile banking among the agri-trader community of India (Tikku and Singh, 2023).

This section discusses various aspects of digitalization. This indicates that various studies have attempted to document the use and impact of digitalization in agriculture. However, no study has reviewed the practical experiences of com-

panies that use various technologies to promote sustainable agriculture. In this context, this chapter reviews the various models of agritech companies trying to help farmers through technological interventions.

Some agritech companies choose to provide quality input to farmers to promote quality production. Another important issue in the agri value chain is the huge losses due to the lack of infrastructure and inefficient supply chains. Improving supply chain efficiency will help improve farmers' profitability by reducing waste across the supply chain. Some agritech companies choose to provide technological solutions to the post-harvest supply chain and help improve the efficiency of the supply chain. Uneven quality of produce and lack of large-scale testing. Agri-tech companies, such as Star Agri, promoted Star Lab to ensure that good-quality produce is sourced for further processing and sold to consumers in domestic as well as international markets. The lack of access to credible financial solutions and working capital is another important challenge for farmers. Some fintech companies have opted to provide finance for working capital. Some organizations also provide postharvest warehouse receipt financing, taking the produce as collateral.

9.4. Revenue Models in India's Agritech

Agritech organizations use various methods and models to generate revenue for their businesses. These models can be broadly classified as follows:

(i) *Margin-Based Model*: These organizations take certain margins for the products sold to farmers, such as the supply of agri-input, including credit. They also take a margin to connect buyers and sellers in the market.

(ii) *Subscription-Based Model*: Several apps and software solutions are based on the subscription fees. Some organizations also offer data analytics services on a subscription basis. These services are known as software-as-a-service (SaaS), and are provided via monthly or annual subscriptions.

(iii) *Fee-Based Services*: This type of service includes fees charged according to the services used, such as soil testing, crop advisory, or other specialized expertise. Organizations working in the area of warehouse receipt financing also charge the volume and value of commodities kept in the warehouses.

(iv) *Interest Income from Financial Services*: Most of these organizations also provide financial services to farmers and other stakeholders in the value chain. They charge an interest on financial services. These interest income are among the major sources of revenue for these organizations.

9.5. Business Models in Agri-Value Chain

The agricultural value chain is a complex system comprising of several steps and stakeholders. This section deals with various steps in the agricultural value chain, various agri-tech companies working in that space, and the services they provide.

Upstream

Upstream services are those required for production, such as managing the raw materials for production. These services include the provision of agricultural inputs such as irrigation, pesticides, seeds, and fertilizers. This includes services that help farmers plan intelligent crops. Some organizations choose to provide agricultural equipment to a service fee-based model. Some organizations provide agri-inputs through B2B or B2C platforms that connect farmers with businesses or consumers. This segment is emerging as a major segment, and many companies, such as Ninjacart, Absolute, and Waycool, have raised more than USD 707 million in capital in 2022. One of the criteria for funding such projects is the maturity of these business models, and funding selections are influenced by the maturity of business models. Some organizations choose to provide only finance as credit is one of the critical inputs for the farmers. Some organisations opt to provide credit along with quality inputs for

the productionSome organizations are promoting mechanization in agriculture and their services include providing agriculture machinery on rent. In 2022, Tractor Junction raised more than USD 8 million. Automated Irrigation is another important aspect in which technology plays a significant role.

Downstream

Downstream linkages are required for converting raw materials into final products and postproduction linkages, especially market linkages. This includes processing, packaging, storage, and retail. As product marketing is one of the major challenges for farmers, several organizations have ventured into this space. They provide B2C platforms for input linkages for categories, such as seeds, nutrition, and agrochemicals. In 2022, firms such as AgroStar[2] and BigHaat[3] will attract more than USD 45 million in funding. This includes activities such as agricultural trading, commodity exchange, storage, and postharvest management.

Midstream Agri-techs

Midstream agri-tech provides solutions to the middle of the agri value chain and chooses to provide solutions for food safety and traceability, logistics and transport, and processing. Midstream Agritech companies provide supply chain solutions and help improve the efficiency of the entire agricultural value chain. Companies such as Arya[4] have attracted more than USD 80 million in financing in 2022.

Farm to Fork

Direct-to-consumer brands or platforms that connect farmers to end-consumers have an impact on improving farming practices. In 2022, firms such as Eggoz Nutrition[5] and Akshayakalpa[6] has attracted more than USD 47 million of funding.

End-to-End Ecosystems

Some organizations adopt a holistic approach and choose to provide all types of services, including upstream and downstream services. These platforms operate across the value chain and have a strong presence in various areas such as inputs and outputs. Such businesses, including DeHaat, attracted more than USD 113 million in capital in 2022.

Data-Driven Agriculture Digital Solutions and Precision Agri-tech

These are digital solutions or products that provide farmers with services such as advice, precision farming, and sensor-based solutions. Companies such as Cropin have attracted more than USD 92 million in investments in 2022. According to research by NASSCOM and McKinsey, there is a USD 65 billion to be realized by enhancing 15 agricultural datasets, including soil health records, crop yields, weather, remote sensing, warehousing, land records, agriculture markets, and pest images.

The details of all business models in the agri-value chain are presented in Table 9.1.

9.6. Agritech Funding: An Opportunity for Lenders

Globally, agri-food tech investment has declined post-COVID for the years 2023 and 2024. However, agri-food tech investments have increased in developing markets. The significance of the agri-food tech industry is reported in the Agri-food tech investment report 2025, which states that in the developing market, the agri-foodtech investment reached USD 3.7 billion in 2024, showing a significant growth of 63 percent by 2023. This accounts for 23 percent of the global investment. The investment increase was highest in India, showing an increase of 215percent. Upstream was the topmost funded category with a 51 percent share in total funding, followed by the downstream category, which accounted for 38 percent of the total funding. Midstream received only 11 percent of the total funding. In 2024, the United States acquired the largest share of funding space, followed by India. This shows a positive

2. https://www.corporate.agrostar.in/
3. www.bighaat.com
4. https://www.arya.ag/
5. https://www.eggoz.com/
6. https://akshayakalpa.org/

TABLE 9.1

Comparative Analysis of Different Agritech Categories in India

S. no	*Particulars*	*Upstream*	*Downstream*	*Midstream*	*Farm to Fork*	*End to End*	*Data Driven Agriculture*
1	Organization	Ninjacart	Agrostar	Arya	Star Agri	Dehaat	Cropin
2	Website	https://ninjacart.com/	https://www.corporate.agrostar.in/	https://www.arya.ag/	https://www.staragri.com/	https://agrevolution.in/	https://www.cropin.com/
3	Established	2015	2013	1982	2006	2012	2010
4	Issues addressed	Agri trade	limited access to good-quality agri inputs,	Post-harvest	Post-harvest	Holistic solution	SaaS solutions to agribusinesses globally using deep learning
5	Services provided	Building commerce, finance, and fulfilment solutions	Real-time agronomy advisory and access to farm inputs through AgroStar's omni-channel platform.	Warehousing, Storage, Finance, and Trade	'phygital' platform across the value chain	Agri input, Advisory, Agri output, Farm Intelligence, Finance etc	Purpose-built industry cloud for Agriculture - Cropin Cloud:
6	Different Agritech products	Technology solution through apps like Ninjacart, Ninjamndi, Ninja kisan, Ninja Kirana, Ninja global	Tech-enabled omnichannel platform that enables farmers to access knowledge and buy quality products across channels.	Grain commerce platform, farmgate storage, finance for farmers, FPOs, financial institutions, SME processors, traders, and corporate agribusinesses. Its subsidiary, Aryadhan, provides warehouse receipt financing.	Warehousing, collateral management, financing, export, quality testing, etc.	End-to-end solution including input, advisory through apps	Helps in digitization and predictive intelligence
7	Geographical presence	Bengaluru, Chennai, Hyderabad, Delhi, Gurugram, Mumbai, and Pune.	Across India	5.0 million tonnes of storage capacity across 5,500 warehouses in 21 Indian states.	2,189 professional warehouses in 379 locations across 19 states	DeHaat currently serves more than 1.5 million farmers located across 11 states	The program digitized 16 million acres of farmland, improving the livelihoods of more than 7 million farmers.

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S. no	*Particulars*	*Upstream*	*Downstream*	*Midstream*	*Farm to Fork*	*End to End*	*Data Driven Agriculture*
8	Total funding	₹2,713.02 Cr	₹885.64 Cr	₹1,369.67 Cr	350 Cr	₹1,712.38 Cr	₹405.81 Cr
9	Revenue (2024)	₹2,081.51 Cr	₹761.51 Cr	₹352.51 Cr	1006.71	₹2,720.31 Cr	₹35.76 Cr
10	No of employees	2808	1639	301	250	1088	236
11	Revenue model	Revenue through directly selling fresh produce to businesses like retailers and restaurants	Through sale of agri input and commission from advisory services	Fees from storage and sale of produce	Multiple sources like trading, storage fees etc.	Agricultural input sales, agricultural produce sales and service fees for advisory services	Subscription fee for its cloud based platforms
12	Important Feature for Success	Reduced waste, Quality assessment	Omnichannel	Scientific storage	Provide a complete marketing solution	End-to-end solution across the value chain	Less competition in the provision of data services

Source: Author compilation from various sources, such as annual reports and company websites.

trend in agritech funding in India. Figure 9.1 shows the trends in global agri-food technology investment. This trend shows that in 2021, the highest investment was made in this segment.

In the current context, where financial inclusion and priority sector lending are the norms of the Government of India and Reserve Bank of India, lending to the agricultural segment is important for bankers. In recent years, the growth of agriteches has provided several important opportunities for bankers. The data suggest that more than 1500 agri-tech startups in India have raised USD 1.6 billion through venture capital. This industry's growth is reflected by the fact that 23 percent of the total capital raised was raised by 2023 alone. This shows a credit gap and a potential opportunity for bankers.

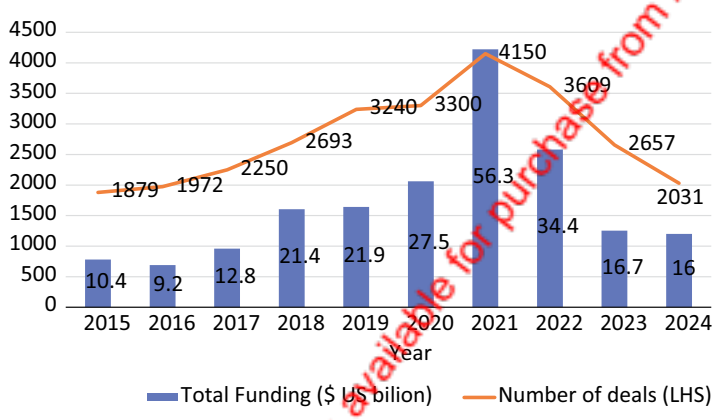
In terms of funding, this sector has seen 9 times increase in institutional funding over the past five years. (Kalari Capital Report, 2021). The data also suggest that, although the number of deals was higher in the seed stage, the total funding in the mature stage of the agritech startup was high. The deal refers to single funding to one organization. This sector is expected to grow at a fast pace, reaching USD 24 billion by 2025 and USD 34 billion by 2027 (Maple Advisors, 2025). The data also suggest that this sector is still in its infancy and has been able to penetrate only 1.5 percent of the total market (Ernst and Young, 2020).

The total investment in agri-food technology was USD 940 million. In terms of categories, e-grocery was the top performer, followed by the agricultural marketplace and fintech. Together, these two categories represented 62 percent of the total funding received (India Food Agritech Investment Report 2024). The overall pattern of investment in agrifood technology in India, over the last decade, is shown in Figure 9.2.

The trend in agri-food tech investment suggests huge potential for funding in the agri-food tech sector. Figure 9.3 shows a probable funding opportunity at various stages of crop production.

FIGURE 9.1

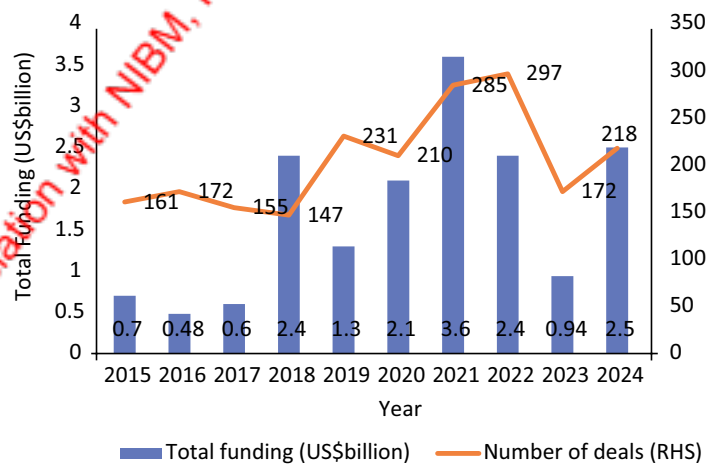
Global Agrifood Tech Funding



Source: Global Agrifood tech investment report 2025.

FIGURE 9.2

Investment in Agrifood Tech in India



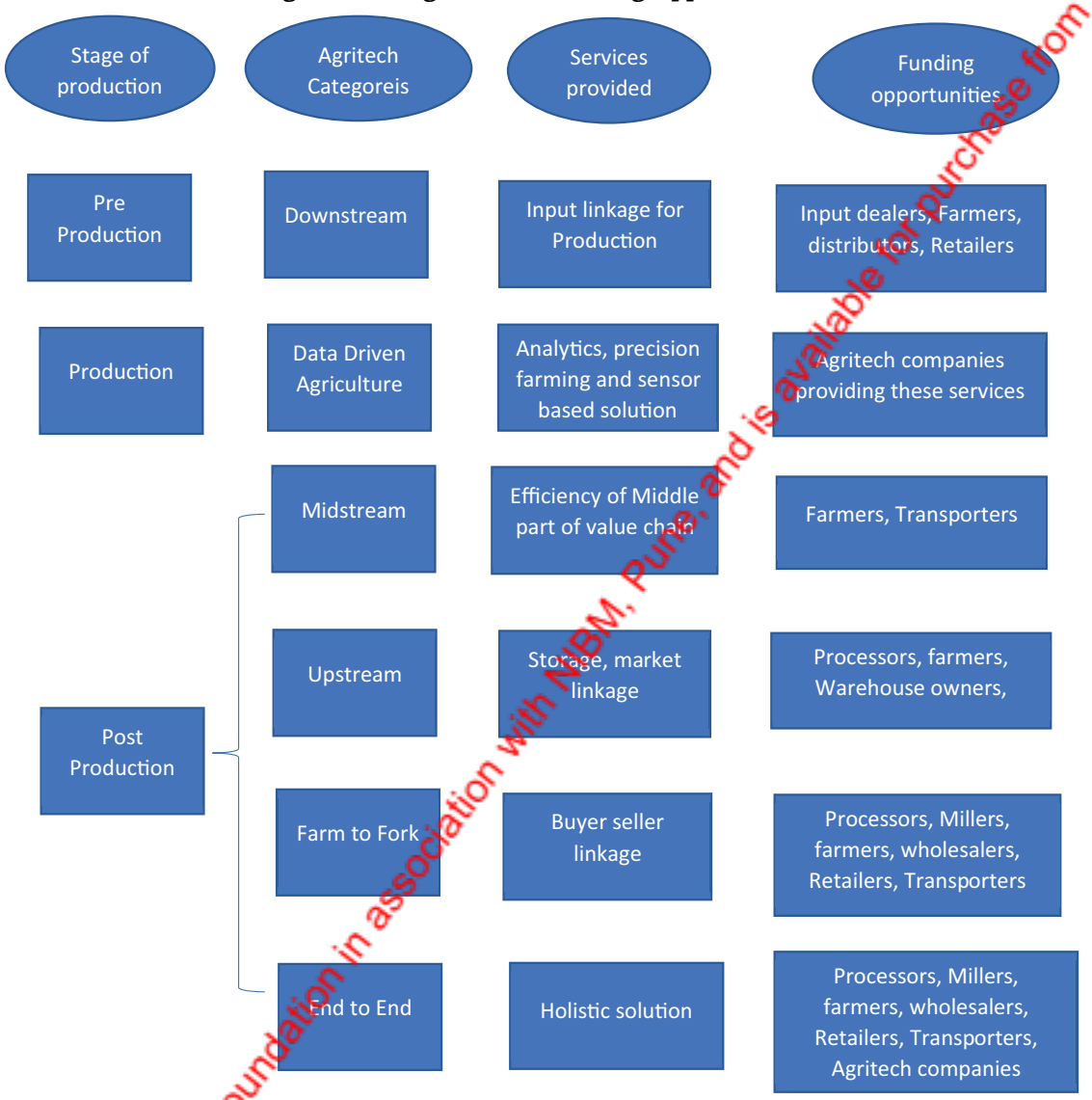
Source: Global Agrifood tech investment report 2025.

9.7. Recommendations and Conclusions

The digitalization of the agricultural value chain has increased significantly in recent years. This has led to the emergence of several agritech start-ups in this domain. This chapter concludes that there are various categories of organizations working at various stages of the value chain. At each stage, organizations try to use technology in such a way that it provides a sustainable solution to agricultural issues. Another important issue is that technology can help deal with labor shortages in agriculture (Ryan 2023). These organizations need fund-

FIGURE 9.3

Agritech Categories and Funding Opportunities



Source: Author's construction.

ing at every stage, that is, the seed, growth, and maturity stages. The seed stage refers to the stage in which the entrepreneur wants to test his ideas. The growth stage reflects the stage in which the entrepreneur has started their business, but needs funding for the expansion of their business. The maturity stage refers to the stage in which the entrepreneur is already established, but needs funding to run their business (e.g., a working capital fund).

The chapter also concludes that these organizations can generate substantial funding from investors. Most of these funds have been in the downstream segment, that is, to link farmers to the market and e-grocery, followed by end-to-end solutions. These two segments also have high revenue. This clearly shows the direct relationship between the funding and revenue of the company. This highlights the importance of funding in this sector. However, it is important to note that other value chain interventions are equally crucial and can do well if provided with adequate financial support. The data also revealed that most funding came during the growth and maturity stages. We suggest that the seed stage is also important to encourage

entrepreneurs to test their ideas in the market. Financial institutions should consider these aspects when supporting startups. As most start-ups support small and marginal farmers, this presents a huge opportunity for financial institutions to tap this potential to meet their priority sector lending targets. We recommend that financial institutions carefully evaluate the performance of agritech startups and support them in meeting their financial needs. Such financial support will help develop sustainable agriculture.

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