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REVIEW ARTICLE

Nurturing Growth: Agri-Startup Landscape in India and the Challenges Ahead

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Abstract: Agri-startups in India are pivotal drivers of innovation and entrepreneurship, addressing critical chal-lenges related to food security, rural livelihoods, and environmental sustainability. These startups leverage ad-vanced technologies, data analytics, and precision farming techniques to enhance agricultural productivity and reduce post-harvest losses, contributing significantly to achieving Sustainable Development Goals. Government initiatives such as the "Innovation and Agri-Entrepreneurship Development" program, coupled with strategic col-laborations with foreign entities, have provided substantial momentum to the agri-startup ecosystem in India. Through this concerted effort, various stakeholders, including Knowledge Partners and Rashtriya Krishi Vikas Yojana—Agribusiness Incubators, are actively nurturing and scaling innovative agricultural projects. Regions like Maharashtra, Karnataka, Gujarat, and Uttar Pradesh have emerged as hotspots for agri-startup activity, ben-efiting from conducive policy environments and robust agricultural infrastructure. The landscape of agri-tech investments in India has seen significant growth, with a notable surge in 2021, reaching $1.18 billion across 66 transactions. Despite a more cautious approach from investors in 2022, the number of transactions increased, indicating sustained interest. The agri-tech sector demonstrates maturity, with a steady investment pipeline and a notable increase in deals surpassing the $5 million threshold. Agri-startups empower smallholder farmers, con-tributing to SDGs related to food security, poverty alleviation, and environmental sustainability, fostering innova-tion and sustainability in the agricultural sector. Agri-startups encounter several challenges, viz., limited access to capital, regulatory complexities, and technological limitations, hindering their growth. Pricing issues, market penetration constraints, and investor apathy further impede scalability. Despite these challenges, agri-startups promote environmental sustainability through practices like organic farming and water conservation. Collabora-tive research, training programs, and alignment with global sustainability trends empower farmers and position agri-startups to capitalize on emerging opportunities in sustainable agriculture markets worldwide.

Keywords: Agri-startups; Agri-preneurship; Agri-ecosystem; Sustainable development goals; Deal-wise investments; Transactions

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1. Introduction

1.1 Background

Entrepreneurship has made a profound impact on India's economic trajectory, manifesting in the creation of employment opportunities for multitudes, the diversification of the economy, and the cultivation of novel markets that entice foreign investment. As India commemorates its 77th year of independence, the nation acknowledges its formidable contribution to the global entrepreneurial landscape. Evolving from a nascent market, India has solidified its status as the world's third-largest startup ecosystem, boasting over 3.1 million startups among which 0.13 million are recognized by the government of India [1] spanning 806 districts nationwide, inclusive of 107 unicorns, collectively valued at $350 billion [2] a remarkable ascent witnessed over the past decade. Notably, since 2017–2018, the proliferation of unicorns has surged by an astounding 66%, with 42 technology-driven startups joining their ranks in 2021–2022 alone. These startups traverse an expansive array of sectors, from fintech to agri-tech to health tech, capturing the attention of global investors and venture capitalists alike.

The metamorphosis of India into a pivotal startup hub can be chiefly attributed to its swift transition from a stronghold in IT services and business process outsourcing to a formidable R & D center. This evolution has been propelled by shifts in the talent landscape, with a notable emergence of new-age entrepreneurs hailing from non-business backgrounds. Notably, India claims the second position in innovation quality, evidenced by its leading positions in scientific publications' quality and university standards among middle-income economies. During 2015–2024, Indian Startup Ecosystem witnessed exponential growth, marked by a 15-fold surge in total startup investment, a 9-fold increase in the number of investors, and a 7-fold rise in the number of incubators.

The rise of the entrepreneurship culture in India has been predominantly driven by several factors, including the expansion of the Indian economy, the availability of venture capital, the emergence of incubators, and the presence of a vast pool of talented individuals. These elements have collectively catalyzed the growth of entrepreneurship in India, providing ample opportunities for aspiring entrepreneurs to establish their ventures [3]. According to Global Entrepreneurship Monitor 2022–2023 (GEM), India has witnessed a significant increase in entrepreneurial activity with a notable rise from 5.3% in 2020 to 11.5% in 2022–2023. Concurrently, there has been a proportional increase in business ownership, escalating from 5.9% in 2020 to 9% in 2022–2023 [4]. This surge in entrepreneurial activity is due to pent-up demand, emerging opportunities, and a conducive ecosystem, bolstered by institutional and policy support from the government [5].

India has experienced a remarkable surge in its startup ecosystem in recent years, emerging as the third-fastest-growing hub for budding entrepreneurs globally, following the USA and China [6]. According to the Economist Intelligence Unit (EIU) report of April 2023, India ranks tenth in terms of Business Environment Ranking (BER) among 82 countries for the period of 2023–2027. Moreover, in World Bank's Ease of Doing Business Index 2020, India secured the 63rd position among 190 countries [7]. To realize the vision of Atmanirbhar Bharat and achieve a $5 trillion Indian economy by 2024–2025, startups are identified as the next major drivers of development [8]. They have the potential to generate impactful solutions through innovation, thereby serving as vehicles for socioeconomic development and transformation [9].

The Startup India initiative launched in 2016 has witnessed remarkable success through the recognition of 131,211 startups by the Department for Promotion of Industry and Internal Trade (DPIIT) in May 2024, creating employment for 0.89 million individuals. India is also home to 107 Unicorns. The Indian startup ecosystem recorded a 7.5% increase in a number of venture capital deals and raised $27.5 billion across 1,355 deals during 2023 [1]. Among startups from various sectors, Fintech, Edtech, and health tech have emerged as the top categories, witnessing a substantial number of deals. Key among the policy measures is the Startup India Action Plan (2016), designed to simplify regulations, provide funding support, incentivize innovation, and foster industry-academia collaboration and incubation. Additionally, the Fund of Funds for Startups (FFS) Scheme, with a corpus of ₹1,00,000 million, aims to make capital accessible for startups at different growth stages, thereby reducing reliance on foreign capital.

The Credit Guarantee Scheme for Startups (CGSS) is another significant initiative, offering loan guarantees to DPIIT-recognized startups by various financial institutions viz., Scheduled Commercial Banks, Non-Banking Financial Companies, and Venture Debt Funds (VDFs). Furthermore, Government has implemented over 50 regulatory reforms since 2016 to enhance the ease of doing business, facilitate capital raising, and alleviate compliance burdens on the startup ecosystem.

Notably, the agriculture sector remains a pivotal employer in India, offering vast opportunities for innovation and entrepreneurship. Agri-preneurship holds a distinct edge and significance in India in addressing critical issues related to food security, rural livelihoods, and environmental sustainability. With India's growing population and changing dietary preferences, there is a pressing need to increase agricultural output while minimizing environmental impact. Agri-preneurs leverage technology, data analytics, and precision farming techniques to achieve these objectives, thereby contributing to food self-sufficiency. It will enable uplifting rural livelihoods and foster inclusive growth [10]. Through improving access to market linkages, financial services, and technology-enabled solutions, agri-preneurs enable smallholder farmers to improve their income levels, reduce post-harvest losses, and enhance their overall standard of living. Moreover, agri-preneurship generates employment opportunities, thereby stimulating economic development in rural areas. Furthermore, agri-preneurship contributes to environmental sustainability and mitigates greenhouse gas emissions. Through initiatives like organic farming, agroforestry, and water conservation projects, agri-preneurs demonstrate how agricultural activities can coexist harmoniously with the environment, preserving biodiversity and ecosystem services for future generations. In India, agri-preneurship benefits from the country's rich agricultural heritage, diverse agro-climatic zones, and abundant natural resources. Moreover, Government initiatives like the Atmanirbhar Bharat Abhiyan and the National Agricultural Entrepreneurship Development Programme (NAEDP) provide policy support, financial incentives, and infrastructure development to nurture agri-preneurs and promote innovation in agriculture [11].

1.2 Problem Statement

In recent years, India has witnessed a significant surge in its startup ecosystem, emerging as a global hub for entrepreneurial activity across various sectors. However, despite the remarkable growth seen in the startup landscape, the agriculture sector remains an area with vast untapped potential for innovation and entrepreneurship. The emergence of agri-startups presents a unique opportunity to address critical challenges related to food security, rural livelihoods, and environmental sustainability. Nevertheless, the agri-startup landscape in India is characterized by several challenges that hinder its growth and scalability.

In this context, this study aims to shed light on the current status, trends, and potential for growth within this sector. It delves into the promotion of agri-startups and the role of Government support in fostering innovation and entrepreneurship in agriculture. Moreover, the study seeks to identify the obstacles hindering the development and scalability of agricultural ventures, thereby enabling policymakers and stakeholders to formulate targeted interventions. This study holds significant importance in several key areas. Firstly, it sheds light on current status of agri-startups, trends, and potential for growth in India. This study delves into the promotion of agri-startups by initiatives such as the Rashtriya Krishi Vikas Yojana—Remunerative Approaches for Agriculture and Allied sector Rejuvenation (RKVY-RAFTAAR), highlighting the role of government support in fostering innovation and entrepreneurship in agriculture. Understanding the dynamics of the agri-startup sector is crucial for identifying opportunities and addressing challenges effectively.

1.3 Theoretical Framework

The burgeoning landscape of startups globally has been a subject of extensive research, drawing upon various theoretical frameworks to elucidate their dynamics and impact on economic development. Institutional theory, for instance, offers insights into the role of government policies and regulations in shaping the startup ecosystem [12,13]. In the context of India, this theory is particularly relevant as government initiatives like Startup India have played a pivotal role in nurturing entrepreneurship and fostering innovation. The Resource-Based View (RBV) [14,15] provides another lens through which to analyze agri-startups in India, emphasizing the importance of resources, capabilities, and competencies in driving competitive advantage. As Indian agri-startups navigate the complex terrain of the agriculture sector, access to financial resources, technological infrastructure, and market networks becomes crucial for their growth and sustainability.

The Innovation Diffusion Theory sheds light on how agri-startups in India adopt and disseminate innovative technologies and practices within the agriculture sector [16,17]. By examining case studies of successful agri-startups such as AgroStar and Ninjacart, which leverage technology to connect smallholder farmers directly to markets, researchers can gain valuable insights into the factors that facilitate the uptake of innovation and its impact on market penetration and competitiveness.

The Sustainable Entrepreneurship Theory [18–20] offers a framework for understanding how agri-startups

integrate environmental sustainability, social impact, and economic viability into their business models. Through initiatives like organic farming, precision agriculture, and farm-to-fork supply chains, Indian agri-startups are not only addressing pressing environmental and social challenges but also creating value for stakeholders along the agricultural value chain. Additionally, taking an ecosystem approach allows researchers to examine the interconnectedness and interdependencies among various actors within the agro-startup ecosystem in India [21–23]. By studying the interactions between agri-startups, smallholder farmers, government agencies, financial institutions, and other stakeholders, researchers can uncover opportunities for collaboration, knowledge sharing, and resource mobilization. By blending theoretical frameworks with real-world data on Indian agri-startups, researchers can provide a comprehensive understanding of the challenges and opportunities facing this burgeoning sector and offer insights into strategies for nurturing its growth and sustainability in the years to come [1].

2. Review of Literature

2.1 Startup Ecosystem at the Global Level

The global startup ecosystem has undergone significant evolution over the past decade, marked by enhanced access to venture capital, technological advancements, and supportive policy frameworks. According to the Global Startup Ecosystem Report (GSER) 2023 by Startup Genome [24], the global startup economy is valued at over $3.8 trillion, surpassing the GDP of most G7 countries. This comprehensive report evaluates 280 ecosystems and 3 million startups using a combination of quantitative and qualitative metrics, including performance, funding, connectedness, talent, experience, and knowledge [25].

Silicon Valley remains the leading startup ecosystem, followed by New York City and London, which are tied for the second position. These top ecosystems are distinguished by their high levels of funding, talent availability, and connectivity. Beijing and Boston complete the top five, demonstrating strong performance in technological innovation and startup support [25,26].

Emerging ecosystems have also shown remarkable growth. The GSER 2021 highlighted the rise of ecosystems such as Tokyo, which advanced six places to rank ninth, largely due to an increase in successful exits contributing to ecosystem value. Additionally, regions like Latin America and the MENA (Middle East and North Africa) have begun producing unicorns, reflecting a growing maturity in their startup ecosystems [24].

Investment trends indicate robust growth across various regions. In 2021, record amounts of venture funding were directed towards Asia ($165 billion), North America ($329.5 billion), and Latin America ($19.5 billion). Australian startup funding tripled to $10 billion, and African startups raised $4.8 billion, showcasing significant year-over-year growth [24,27]. The Indian startup ecosystem is also thriving, aligning with global trends.

2.2 Indian Startup Ecosystem

The landscape of agricultural startups in India is shaped by a multitude of factors, each contributing to the sector's growth and evolution. Reddy et al. (2024) [28] emphasized the critical role of accessible and available finance in fostering the establishment and expansion of startups, highlighting the challenges encountered during the early transaction stage, particularly in securing suitable investors. Aneesha et al. (2023) [29] delved into the intricate challenges faced by Agri-Startups, ranging from governmental incentives to technological scalability and labor availability, accentuating the pressing need for comprehensive support services to navigate these obstacles effectively. Kumar (2023) [30] underscored the historical significance of agriculture in India's economy and the emergence of startups as potential catalysts for revitalizing the sector amid declining contributions to the economy. Srinivasrao and Kumar (2022) [31] provided valuable insights into the funding dynamics within the agri-startup sector, revealing the disruptive impact of the COVID-19 pandemic on funding activities and the sector's resilience in navigating economic uncertainties. Sharma et al. (2021) [32] highlighted the transformative potential of agri-startups in fostering innovation and offering simplified solutions to agricultural challenges, emphasizing the crucial role of government support in nurturing the startup ecosystem. Vikas and Anubhav (2021) [33] outlined the pivotal role of government initiatives in bolstering the agricultural startup ecosystem, providing vital financial assistance and infrastructure to support startup growth. Meena et al. (2019) [34] shed light on the financial obstacles confronting Agri-Tech startups, emphasizing the need for strategic financial planning and innovative solutions to ensure sustainable growth and resilience. Collectively, these studies underscore the multifaceted challenges and opportunities within the agricultural startup landscape, highlighting the need for further research, to explore

solutions and strategies for fostering the growth and sustainability of agri-startups in India.

In the context of past reviews, the importance of this study becomes even more pronounced. Building upon the findings and insights garnered from previous research, this study aims to delve deeper into the intricacies of the agricultural startup ecosystem in India and shed light on the specific challenges hindering its growth and scalability. By expanding on the existing literature, this study can offer a more comprehensive understanding of the dynamics at play within the agri-startup landscape, drawing from a synthesis of past research and new empirical evidence. This holistic approach is crucial for identifying key areas of intervention and developing targeted strategies to address the challenges faced by agri-startups. Furthermore, the relevance of this study lies in its potential to inform policy formulation and decision-making processes at both the governmental and institutional levels. By providing actionable insights into the needs and requirements of agri-startups, policymakers can tailor their initiatives and support programs to better meet the demands of the sector.

3. Materials and Methodology

This study utilizes data from the Government of India's comprehensive portal, Startup India (www.startupindia.gov.in), which supports the startup ecosystem by aggregating data from all registered startups, incubators, accelerators, and other ecosystem partners. The portal also hosts an array of resources, including blogs, e-courses, lists of service providers, policy guidelines, national and international collaborative programs, and the latest sector news. The database maintained on the portal is open access, ensuring the transparency and reliability of the data utilized in this study.

3.1 Data Collection

Data was collected from the Startup India portal, with a focus on registered agri-startups, their geographic distribution, sectoral categorization, funding details, and growth trends. The following steps were undertaken.

(i) Identification of Relevant Startups: All startups categorized under the agriculture sector were identified and extracted.

(ii) Data Tabulation: The data was organized into tables to facilitate analysis. Key variables included the number of startups, funding received, regional distribution, and sectoral focus.

(iii) Validation: The data was cross-verified with other sources such as reports from the Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce and Industry, and publications from relevant industry bodies.

3.2 Data Analysis

The collected data was analyzed using both qualitative and quantitative methods to draw meaningful insights.

(i) Descriptive Statistics: Basic statistical tools were employed to summarize the data.

(ii) Trend Analysis: Historical data from 2016 to 2024 was analyzed to identify trends in startup growth, funding, and sectoral focus.

(iii) Causal Loop Diagram: A causal loop diagram was developed to represent the system's components, processes, and variables, illustrating their relationships and dependencies as derived from the reviewed literature. This visualization facilitated an understanding of the dynamic interactions within the agri-startup ecosystem.

4. Results and Discussion

4.1 Agri-Startup Ecosystem in India

The agri-ecosystem is poised for significant growth and innovation, driven by the recognition of the agriculture sector's crucial role in supporting livelihoods and achieving Sustainable Development Goals (SDGs). The agriculture sector contributes approximately 16.5% of India's Gross Domestic Product. In 2022, the total value of agricultural production was valued at US$ 435.9 billion and is growing at a growth rate of 4.9% in the past 5 years. Smallholder farmers are crucial agents in achieving the SDGs, particularly the aims of eradicating poverty and hunger by 2030 [35,36]. However, the agriculture sector faces multifaceted challenges such as production constraints, market linkages, supply chain inefficiencies, and climate-related risks, leading to substantial losses for smallholders [37,38]. In addressing these challenges, several innovative agri-startup solutions, encompassing a wide range of innovations and business models [39] aimed at improving efficiency, productivity, and sustainability in agriculture, have emerged in India, aimed at building a scalable ecosystem and enhancing smallholder productivity to meet SDG targets. Significant support and investment are imperative to realize the full potential of these solutions.

Agri-tech startups, in particular, enjoy the potential to develop innovative solutions to overcome existing agricultural challenges [40–42]. The burgeoning agri-tech sector in India presents vast opportunities for expansion, bolstered by initiatives such as 'Make in India' and 'Digital India' [43–47].

Table 1 portrays the distribution of recognized startups across different industries within various regions of India in 2023 [1]. North region enjoys the highest total number of startups (37,500), with significant representation in IT Services, Construction, Professional & Commercial Services, and Healthcare & Lifesciences. With 33,200 startups, the South region shows a diverse distribution across various industries, including Agriculture, IT Services, and Healthcare & Lifesciences. Agri-startups hold a 13% share, reflecting the region's agrarian economy and emphasis on technology-driven solutions in agriculture. Despite having a smaller total number of startups (1,400), the North-East region demonstrates a significant presence in agri-startups, accounting for 21% of the total. This highlights the region's reliance on agriculture as a primary livelihood source and thus, promotion of agri-preneurship. With 30,800 startups, the West region exhibits strengths in IT Services, Construction, and Non-Renewable Energy. The shares of Agriculture (16%) and Food & Beverages (15%) startups in this region highlight agricultural heritage and the prominence of food-related industries in meeting local consumption needs. Additionally, favourable climatic conditions and natural resources conducive to agriculture may encourage entrepreneurs to invest in these sectors. Government policies and initiatives aimed at promoting agricultural innovation and food processing industries have contributed towards the distribution of startups [48]. Furthermore, the presence of agricultural research institutions, universities, and supportive ecosystems for agri-businesses may contribute to the relative shares of both agriculture and food & beverages startups in the region. The East region too, with 9,200 startups, shows a significant presence of agri-startups, accounting for 16% of the total. With 4,900 startups, the Central region has the highest share of agri-startups at 22%. This suggests a strong emphasis on agriculture-driven entrepreneurship in the region, possibly due to factors such as abundant arable land, agricultural diversity, and government policies aimed at promoting agricultural development and rural entrepreneurship. The Islands region, with 55 startups, shows a notable share of agri-startups at 12%. This reflects the region's reliance on agriculture as a primary economic activity and the potential for agricultural innovation and entrepreneurship to drive economic growth and sustainability. This distribution of agri-startups across different regions of India underscores the importance of agriculture as a key sector and the need to promote agri-preneurship to address challenges such as food security, rural livelihoods, and environmental sustainability. Factors such as favorable climate conditions and Government initiatives to promote agricultural innovation contribute to the share of agri-startups in these regions [31,49].

4.2 Sector-wise Breakup of Agri-startups in India

As of July 2023, India has a remarkable count of 5,577 agri-startups officially recognized by DPIIT. Figure 1 presents a breakdown of startups in the agriculture sector across different categories, revealing insights into the diverse entrepreneurial landscape within agriculture. Agri-tech emerges as the dominant category, constituting 46.76% of total startups, indicative of a strong focus on technological innovation to enhance agricultural practices [31]. Following closely, organic agriculture and food processing startups represent significant proportions at 15.44% and 15.92% respectively, reflecting the rise in demand for organic products and value-added food items. Startups in animal husbandry and dairy farming, horticulture, and fisheries contribute to the sector's diversity, albeit in smaller percentages. While animal husbandry and dairy farming (5.74%) cater to protein-rich food demands, horticulture (3.14%) and fisheries (1.36%) underscore efforts in crop cultivation and seafood production. The remaining category, 'Others' encapsulates startups with miscellaneous agricultural ventures. Overall, the distribution reflects a dynamic entrepreneurial ecosystem driven by factors like technology adoption, sustainability concerns, and evolving consumer preferences in the agriculture industry [50].

Of the total startups recognized by DPIIT in India, which stands at 99,380, the agriculture, food, and beverages sector comprises a notable 11 percent. This significant presence underscores the growing importance of entrepreneurship in addressing challenges and opportunities within the agricultural and food industries. Within this segment, approximately 27.16 percent of startups are dedicated to creating value-added products, indicating a strategic focus on reducing post-harvest losses and enhancing the quality of agricultural goods, thus contributing to the export market. Geographically, the concentration of these agri-startups is noteworthy, with around 60 percent located in just four states: Maharashtra (1,104), Karnataka (516),

Table 1. Top-performing industries with recognized startups across different regions in India (2023).

Region	Total Startups (Number)	% Share in total								
		Agriculture	Food and Beverages	IT Services	Construction	Professional & Commercial Services	Education	Healthcare & Lifesciences	Non-Renewable Energy	Travel & Tourism
North Region (Ladakh, Jammu & Kashmir, Himachal Pradesh, Punjab, Chandigarh, Uttarakhand, Haryana, Delhi, Uttar Pradesh, Rajasthan)	37500	-	-	29	14	15	18	24	-	-
South Region (Andhra Pradesh, Karnataka, Kerala, Puducherry, Tamil Nadu, Telangana)	33200	13	12	36	-	-	16	23	-	-
North-East Region (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura)	1400	21	-	17	26	-	18	18	-	-
West Region (Dadra and Nagar Haveli and Daman and Diu, Goa, Gujarat, Maharashtra)	30800	16	15	27	-	14	-	28	-	-
East Region (Bihar, Jharkhand, Odisha, West Bengal)	9200	16	-	26	21	-	16	21	-	-
Central Region (Madhya Pradesh, Chhattisgarh)	4900	22	-	26	16	-	16	20	-	-
Islands (Andaman and Nicobar Islands, Lakshadweep)	55	12	-	24	21	-	-	-	15	28

Source: www.startupindia.gov.in

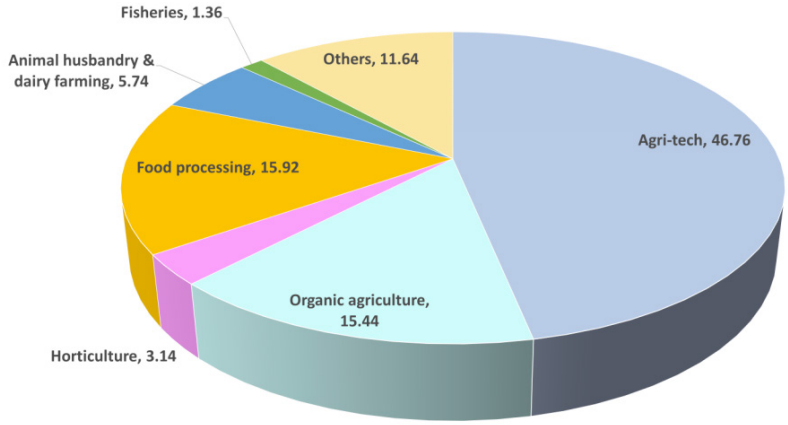

Figure 1. Sector-wise break up of agri-startups in India.

Source: Startupindia, 2024.

Gujarat (474), and Uttar Pradesh (465). This regional distribution reflects the influence of factors such as favorable agricultural ecosystems, access to markets, supportive policies, and the presence of research and innovation hubs. Maharashtra, with its diverse agro-climatic zones and robust infrastructure, leads the pack, followed closely by Karnataka, Gujarat, and Uttar Pradesh, all of which offer conducive environments for agricultural innovation and entrepreneurship. These statistics underscore the multifaceted contributions of agri-startups towards agricultural development, technology adoption, and economic growth, while also highlighting the varying regional dynamics shaping their distribution across the country.

4.3 Promotion of Agri-Startups by RKVY

While DPIIT focuses on the overall promotion of industry and startups across sectors, including agriculture, the Ministry of Agriculture and Farmers Welfare specifically caters to the unique needs and challenges of the agricultural sector [51], providing targeted support and resources to agri-startups to foster innovation, entrepreneurship, and sustainable growth in agriculture. The MoA & FW has been spearheading the "Innovation and Agri-Entrepreneurship Development" program under the RKVY-RAFTAAR since 2018–2019, aimed at fostering innovation and nurturing the agri-entrepreneurship ecosystem across the nation. This initiative is designed to offer both financial and technical support to startups, facilitating their growth and development. To this end, five Knowledge Partners (KPs) and twenty-four RKVY-RAFTAAR Agribusiness Incubators (R-ABIs) have been appointed to provide incubation services and oversee the implementation of the program. Startups undergo training and incubation under the guidance of these KPs and R-ABIs, thus enabling them to progress from the conceptual stage to scaling and eventual growth.

The Government of India organizes a series of national-level events, including agri-startup conclaves, agricultural fairs and exhibitions, webinars, and workshops, creating platforms for startups to connect with various stakeholders and fostering their promotion and collaboration. Agri-startups supported through this program operate across a spectrum of agricultural and allied sectors, including precision agriculture, farm mechanization, agri-logistics & supply chain, agro-processing & food technology, waste to wealth, organic farming, animal husbandry, dairy & fisheries, among others. Leveraging emerging technologies, these startups offer affordable and innovative solutions to challenges encountered in agriculture and allied sectors.

India witnessed remarkable growth in its agri-startup landscape, with the number of startups increasing from 58 in 2019–2020 to around 350 by 2023–2024 (Table 2). This growth trajectory is fuelled by increasing farmer awareness, expanding internet connectivity in rural areas, and growing demand for agricultural efficiency. Moreover, India's regulatory framework continues to evolve, facilitating the adoption and dissemination of digital agricultural technologies [47]. Over this period, a total financial support of Rs. 1062.50 million has been disbursed to 1524 agri-startups, facilitating their journey towards sustainability and success in the agricultural landscape. Out of these 1524 agri-startups, around 450 are agri-tech startups in operation in 2022, witnessing a 25% year-on-year increase, The agri-tech sector presents a significant opportunity, valued at US$

24 billion, but with a market penetration of less than 1%. This substantial gap between potential and actual value realization underscores the immense potential for both new and existing agri-tech startups to capitalize on this burgeoning sector and further contribute to its development and growth [52].

Table 2. Number of agri-startups supported in India under 'Innovation and Agri-Entrepreneurship Development' programme under RKVY-RAFTAAR.

S. No.	Financial Year	Number of agri-startups supported	Total fund released (in instalments) (₹ Million)
1	2019–2020	58	31.30
2	2020–2021	588	274.30
3	2021–2022	277	203.40
4	2022–2023	253	243.50
5	2023–2024	348	310.00
Total		1524	1062.50

Source: www.startupindia.gov.in

4.4 Trends in Agri-Tech Investments and Transactions

Figure 2 highlights the steady increase in both investments raised and the number of transactions in agri-startups in India from 2016 to H1-2022 (i.e.., Jan to June 2022), with a notable surge in 2021. This surge aligns with the broader trend of India's burgeoning startup ecosystem, marked by the emergence of unicorns and significant fundraising activities. In 2021, India witnessed unprecedented growth in investment raised by agri-startups, reaching $1.18 billion across 66 transactions. This surge can be attributed to various factors, including increased investor confidence in the agriculture sector, heightened awareness of food security issues during the COVID-19 pandemic, and the acceleration of digitalization in agriculture. This underscores the resilience and adaptability of the agriculture sector, as well as the strategic importance of digital solutions in addressing emerging challenges. However, the investment landscape in 2022 has seen a more cautious approach from investors, with investment values dipping by 15% compared to 2021. While indicating investor scepticism, this also offers agri-startups an opportunity to prioritize the development of sustainable and scalable business models. Despite this, the number of transactions has increased slightly, indicating continued investor interest in backing a broad base of agri-startups. These trends depict a dynamic and evolving investment landscape for agri-startups in India, characterized by both opportunities and challenges. Moving forward, it will be essential for stakeholders to continue fostering an enabling ecosystem that supports the growth and success of agri-startups, driving innovation, sustainability, and inclusive development in the agriculture sector [53–55].

4.5 Deal Activity of Agri-Tech Investments

The deal activity in agri-tech sector during 2021 and the first half of 2022 portrays a relatively steady investment pipeline, rather than a funnelling effect commonly seen in other sectors (Figure 3). Over the span of 18 months, approximately 100 deals were executed,

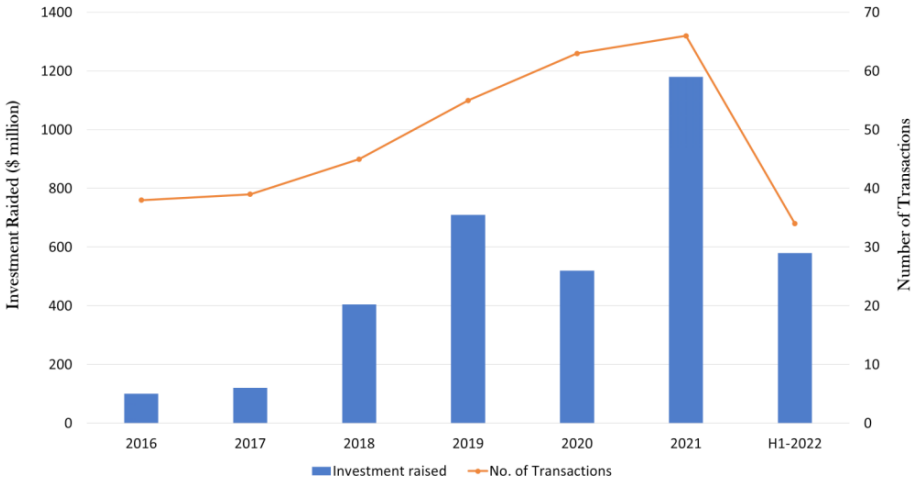

Figure2. Investment in Agri-Tech in India during 2016 to 2022.

Source: Startupindia, 2024.

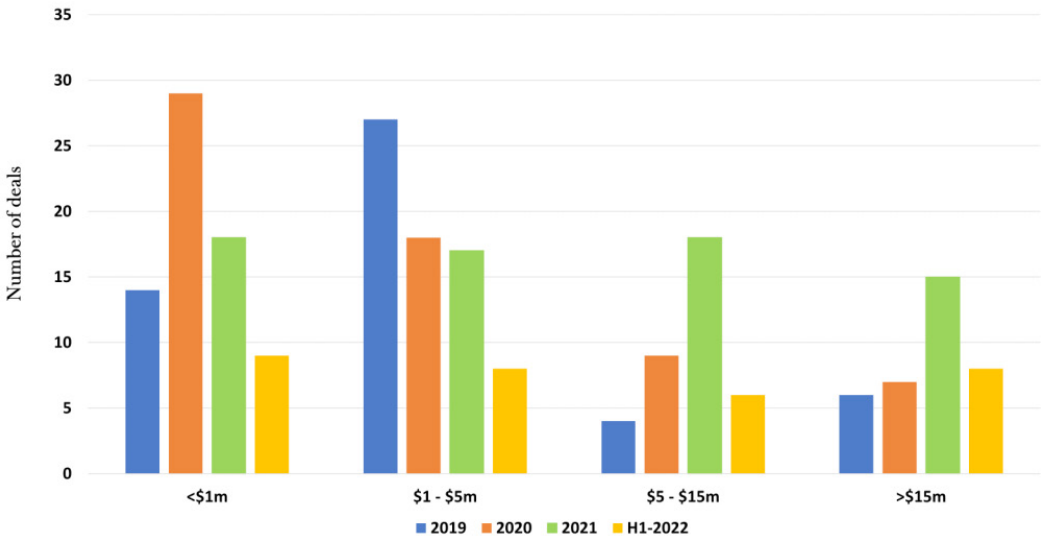

Figure 3. Investments in Agri-Startups based on value of deal.

Source: Startupindia, 2024.

with a nearly even distribution across different funding brackets delineated in the analysis. This distribution marks a notable increase in deals surpassing the $5 million threshold compared to previous years, indicating a heightened level of maturity attained by agri-tech models and the ecosystem overall. In 2021, out of the 56 follow-on deals observed, a significant portion of agri-tech startups secured funding either slightly less than their previous round or experienced moderate growth ranging from 2 to 10 times the previous fundraise. Moreover, a remarkable 15% of these companies managed to secure investments exceeding ten times their previous funding amount. However, the trend observed in 2022 differs, with only half of the deals surpassing the funding amount of the previous round [56]. This shift may be attributed to a more cautious investment environment prevalent in the current year, possibly influenced by the significant funding sizes witnessed in 2021. The observed fluctuation in deal sizes and follow-on investments suggests a nuanced investor sentiment, reflective of both market dynamics and individual company performances. While the agri-tech sector has demonstrated considerable promise and potential for growth, investors seem to be adopting a more discerning approach, likely influenced by factors such as market saturation, regulatory uncertainties, and the perceived scalability of individual business models. Additionally, the notable variance in follow-on investment outcomes underscores the importance of robust business strategies and execution capabilities for agri-tech startups seeking sustained financial backing in an increasingly competitive landscape [53,57].

4.6 Agri-Tech Investments Across Categories

Figure 4 depicts that in 2021, there was a notable shift in the distribution of Ag-Tech deals across categories, indicating a maturing Ag-Tech ecosystem. Although Downstream Ag-Tech solutions continued to attract the majority of capital, there was a decline in their proportion from 52% in 2020 to 35% in 2021. On the contrary, Upstream Ag-Tech and Precision Ag-Tech segments witnessed significant growth in fundraising, attracting larger transactions across more deals compared to previous years. This trend suggests that innovations in these segments are gaining traction, and their business models are evolving and maturing. The diversification of investment continued into the first half of 2022, with Downstream Ag-Tech solutions resuming their dominance, accounting for nearly half of all deals. However, Upstream Ag-Tech and Precision Ag-Tech maintained their fundraising pace, indicating sustained investor interest in these segments. The Ag-Automation category also saw growth, driven by the emergence of startups developing hydroponic farming technology. Agri-Tech startups across various categories have been adding adjacent services to their offerings and moving towards vertically integrated solutions. This trend is reflected in their exploration of opportunities for inorganic expansion through acquisitions. Additionally, there has been a notable emergence of value chain-specific platform solutions, particularly in dairy and fishery sectors, indicating a deeper integration of technology into specific agricultural value chains. Thus, the shift in investor focus towards seg-

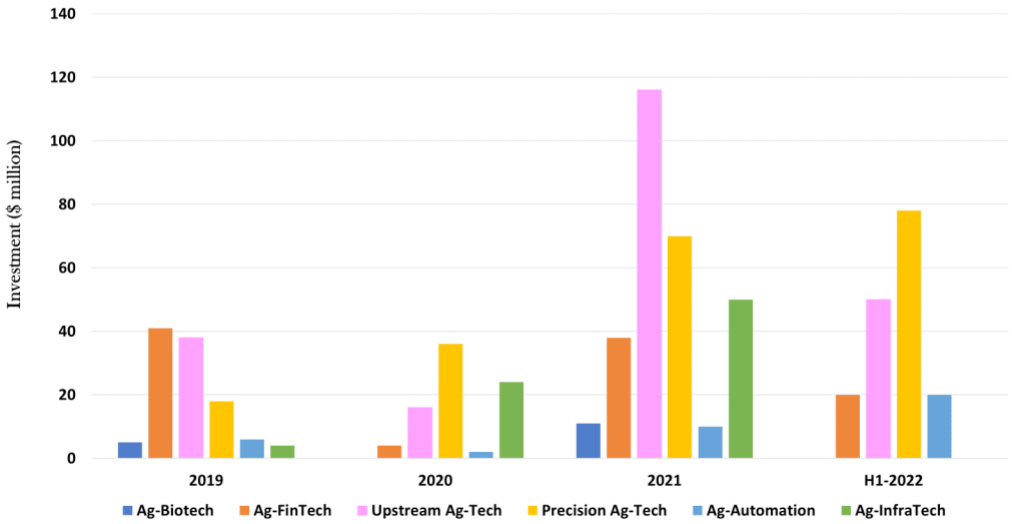

Figure 4. Investments in agri-startups based on category.

Source: Startupindia, 2024.

ments like Upstream Ag-Tech and Precision Ag-Tech underscores the growing recognition of their potential and the need for innovative solutions to address challenges in agriculture. This trend also highlights the adaptability and agility of Agri-Tech startups in responding to market demands and evolving their business models to capture new opportunities [58,59].

4.7 Dynamics of Agri-startup Sector

A causal loop diagram (Figure 5) highlights a visual depiction of complex interactions among variables viz., Government policies, collaborations, technological interventions, market dynamics, and environmental protection. The MoA & FW, through its "Innovation and Agri-Entrepreneurship Development" program, has strategically collaborated with five KPs and 24 R-ABIs to spearhead various agricultural initiatives. These initiatives encompass training, incubation, and the execution of innovative projects aimed at driving growth and sustainability within the agriculture sector. In parallel, the Ministry of Commerce and Industry, specifically the DPIIT, has initiated strategic partnerships with foreign entities to introduce cutting-edge technological interventions in agriculture. This collaborative effort seeks to provide agri-startups with access to increased investments, advanced technologies, robust research funding, and global partnerships, thereby catalysing their development and growth trajectory [60]. Consequently, international projects were launched to optimize resource utilization and foster sustainable growth in the agriculture sector. These initiatives hold significant transformative potential, enabling the evolution of nascent agri-startups into resilient and sustainable entities.

By nurturing an environment of dynamic market competition and addressing environmental concerns, these efforts contribute to economic growth, livelihood improvement, and revenue diversification within the agri-startup ecosystem. Furthermore, these initiatives attract additional foreign investments and collaborations, further propelling the virtuous cycle of growth and innovation within the agri-startup landscape [61]. Ultimately, they reinforce the overarching framework of economic growth while promoting sustainability and resilience in the agriculture sector.

The gain feedback loop (R1) delineates a pivotal process within India's agri-startup ecosystem, whereby access to modern technology, research funding, and strategic partnerships propels startups into international projects aimed at optimizing resource utilization and promoting sustainable practices. This catalytic cycle, in turn, stimulates heightened competition, compelling startups to innovate and enhance operational efficiency. Consequently, this virtuous cycle yields improved livelihoods for farmers and rural communities, underscoring the imperative for sustained investment in cutting-edge technology, research funding, and collaborative alliances. These endeavours contribute for sustainable development and foster economic growth within India's dynamic agri-startup landscape.

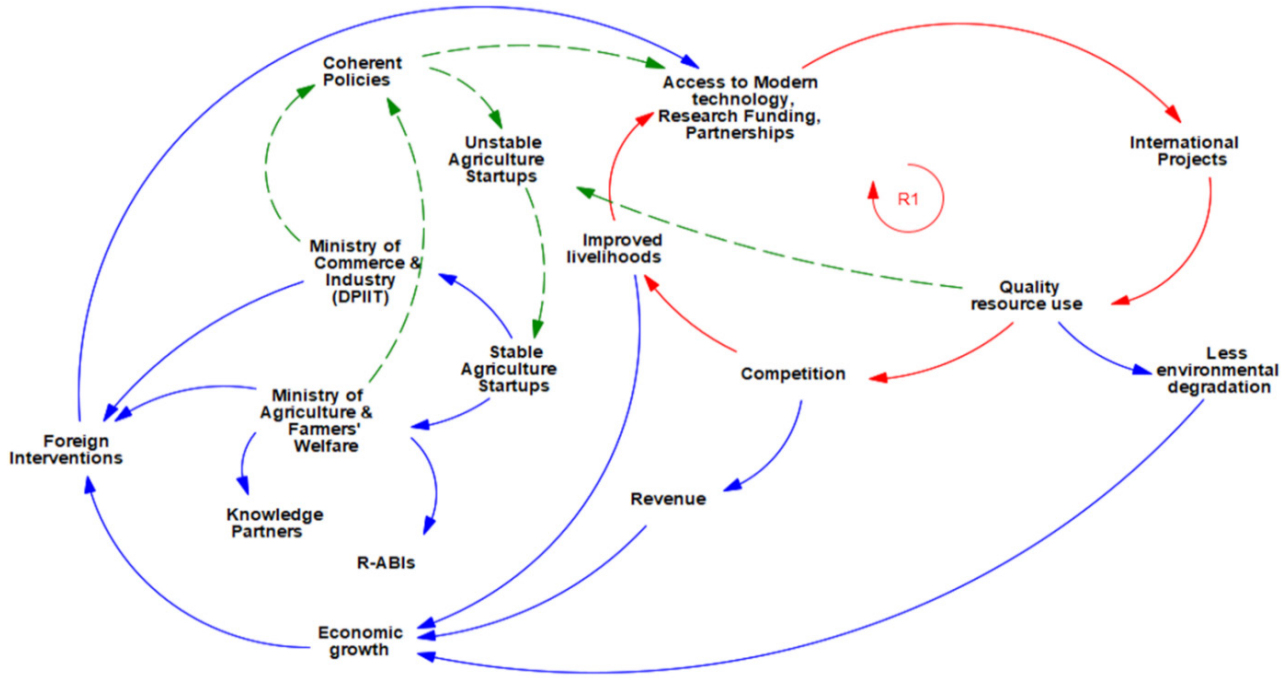

Figure 5. Interaction of components in India's agri-startups ecosystem.

4.8 Deterrents to Growth in Agri-Startups

The causal loop diagram (Figure 6) provides a clear visualization of the constraints encountered by agri-startup entrepreneurs within the agricultural ecosystem. Mapping out the interconnected relationships among different factors, effectively illustrates the intricate web of challenges that impact the growth and sustainability of agri-startups. The diagram emphasizes that constraints faced by agri-startup entrepreneurs stem from a myriad of interconnected challenges, primarily centred around inadequate capital, regulatory hurdles, technological limitations, and organizational deficiencies. The insufficient availability of capital to scale up operations is a critical issue, often exacerbated by the complex regulatory and legal frameworks governing the agricultural sector. These challenges hinder startups from accessing the necessary funds to expand their operations and innovate, thereby impeding their ability to compete effectively in the market.

The lack of focus on core issues, poor teamwork, and the development of rigid startup models contribute to the vulnerability of agri-startups [62]. Without a clear vision and effective commercial guidance, startups may struggle to identify and address key market needs, leading to mistimed product launches and eventual obsolescence. Additionally, the absence of competent incubators and mentorship further exacerbates these challenges, depriving entrepreneurs of crucial support and guidance needed to navigate the complexities of agricultural landscape.

The fluctuating profits in agribusiness, coupled with customer reluctance to pay high prices for startup services, create pricing issues and limit market channels for agri-startups. This results in stagnant growth and an inability to achieve sustainable profitability, further exacerbating the challenges faced by entrepreneurs. Additionally, the lack of market penetration and competitive advantage diminishes the growth potential of startups, leading to uncertain returns on investment. Investor apathy towards high-scale investments in agri-startups perpetuates this vicious cycle, as the perceived risks outweigh the potential rewards. Without adequate financial backing and investor confidence, startups struggle to innovate, expand, and compete effectively in the market, perpetuating a cycle of stagnation and decline in the agricultural startup ecosystem. So, the constraints in the agri-startup ecosystem encompass a wide range of interconnected challenges, including inadequate capital, regulatory hurdles, technological limitations, organizational deficiencies, pricing issues, and investor apathy [28].

The feedback loops (R2), (R3), and (R4) elucidate critical dynamics within the agri-startup landscape, each contributing to distinct challenges faced by emerging ventures. (R2) delineates a feedback loop wherein startups, ensnared by rigid operational models, grapple with adapting to evolving market dynam-

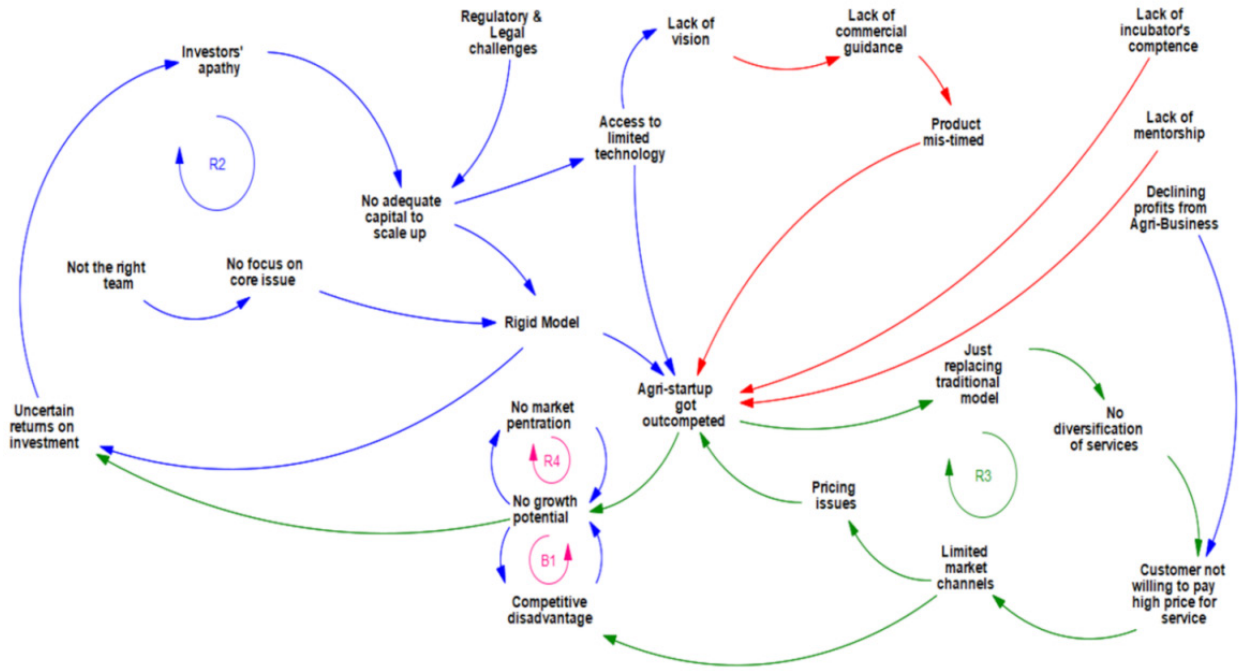

Figure 6. Constraints faced by agri-startups in the ecosystem.

ics. This rigidity stems from a reluctance to embrace innovation or pivot in response to shifting consumer demands. Consequently, these startups become entrenched in outdated practices, eroding their competitive edge and impeding their ability to thrive in dynamic market environments. In contrast, (R3) illuminates a feedback loop wherein startups, outmatched by more agile and innovative counterparts, find themselves marginalized in the market. The absence of product differentiation, coupled with ineffective marketing strategies and pricing issues, leaves these startups vulnerable to losing market share to more competitive rivals. As a result, they encounter mounting challenges in sustaining operations and remaining relevant in the industry. Additionally, (R4) portrays a feedback loop wherein startups grapple with inadequate market penetration, constraining their growth prospects and viability.

Factors contributing to this predicament include poor distribution networks, ineffective branding, and insufficient market research. Without a robust market presence, these startups face hurdles in attracting customers and generating revenue, perpetuating a cycle of limited growth and market obscurity [63]. These feedback loops underscore the imperative for agility, innovation, and market responsiveness among agri-startups to maintain competitiveness and sustainability in the ever-evolving agricultural landscape. Failure to address these challenges can lead to stagnation, diminished market relevance, and ultimately, the failure of agri-startup ventures. Addressing these constraints necessitates comprehensive solutions that foster a supportive regulatory environment, provide access to capital and mentorship, promote innovation and technological adoption, and enhance market access and competitiveness for agri-startups. By implementing such measures, the agri-startup ecosystem can overcome hurdles, unlock growth opportunities, and thrive amidst dynamic market forces [64].

The interplay between the lack of growth potential and the competitive disadvantage within the agri-startup ecosystem forms a balanced feedback loop (B1), which sheds light on the intricate challenges faced by emerging ventures. When agri-startups encounter competitive disadvantages, such as constrained access to resources, outdated technology, or ineffective market positioning, their ability to penetrate the market diminishes (R4). This setback hampers their capacity to attract customers, secure investment, and expand operations, thus constraining their growth prospects. In turn, their limited growth potential exacerbates their competitive disadvantage. As agri-startups struggle to achieve significant growth or market penetration, they fall behind more prosperous counterparts, further eroding their competitiveness. Conversely, the competitive disadvantage experienced by agri-startups reinforces their limited growth potential. The challenges they face in gaining traction within the market hin-

der their ability to scale operations, secure necessary resources, or exert influence within the industry. This downward trajectory perpetuates a cycle wherein their stagnant growth trajectory compounds their competitive disadvantage, leading to a vicious cycle of underperformance and market obscurity. Together, these two feedback loops create a reinforcing cycle wherein the competitive disadvantage of agri-startups amplifies their limited growth potential, while their constrained growth trajectory exacerbates their competitive disadvantage due to ineffective market penetration. Understanding and addressing this balanced feedback loop is crucial for nurturing a vibrant and sustainable agri-startup ecosystem. By overcoming competitive disadvantages, enhancing growth potential, and fostering market penetration, agri-startups can unlock opportunities for innovation, expansion, and long-term success within the agricultural industry [65,66].

4.9 Sustainability Perspectives of Agri-startups

The causal loop diagram sheds light on the sustainability perspectives of agri-startups, emphasizing the significance of investing in pioneering advancements to optimize resource utilization and mitigate environmental degradation within the agricultural sector (Figure 7). The agri-startup investments should prioritize fostering innovative solutions such as, regenerative agriculture, agroecology, and precision farming. By embracing cutting-edge technologies and methodologies, agri-startups contribute towards minimizing environmental footprint. Initiatives within agri-startups should emphasize collaborative research and development endeavours, engaging with stakeholders across the agricultural value chain. By fostering partnerships and knowledge-sharing initiatives, agri-startups can achieve economies of scale and spur heightened market demand for sustainable agricultural products and services. Comprehensive training and extension programs play a vital role in empowering farmers with the skills and knowledge needed to adopt sustainable practices effectively [67]. Furthermore, global trends highlight the growing importance of sustainability in agriculture, driven by concerns such as climate change, resource depletion, and food security. Agri-startups can capitalize on these trends by aligning their strategies with sustainability goals and leveraging emerging opportunities in sustainable agriculture markets world-wide. With expanded market share, they contribute to economic growth while adhering to regulatory requirements and sustainability principles. This iterative process creates a self-reinforcing loop wherein ongoing innovation leads to a broader spectrum of sustainable offerings for both new and existing clientele. By driving sustainable development within the agricultural startup ecosystem, agri-startups contribute towards a more resilient and environmentally sustainable future [63].

The feedback loops (R5) and (R6) are pivotal in ensuring the sustainability of the agri-startup ecosystem. Investment in agri-startups and technological interventions (R5) serves as the cornerstone for innovation and growth within the sector. Injecting capital enables

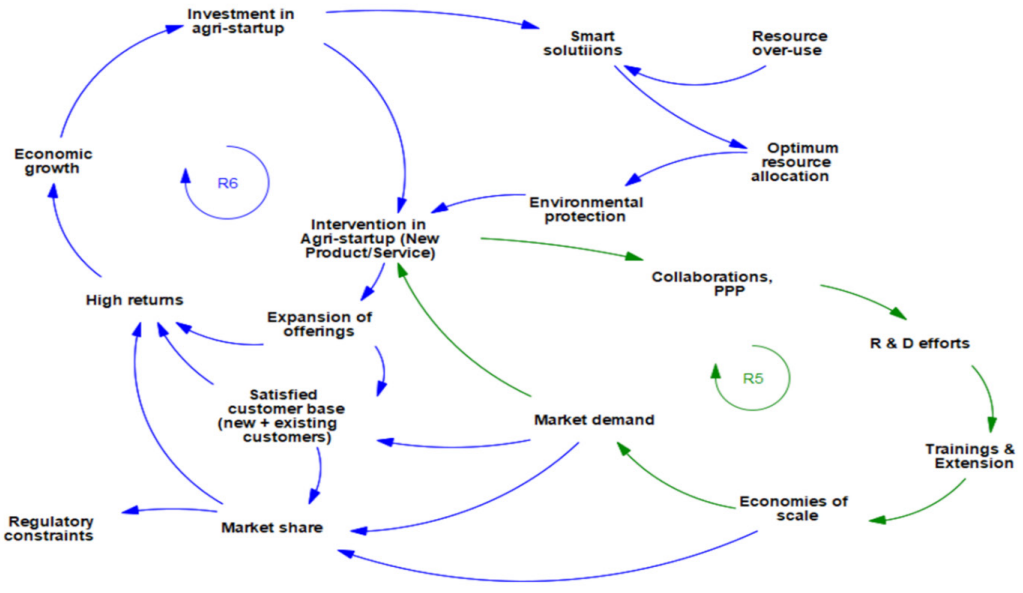

Figure 7. Sustainability perspectives of agri-startups ecosystem.

startups to acquire advanced technologies, develop innovative solutions, and expand operations, thereby integrating cutting-edge technologies into agricultural practices to enhance productivity, efficiency, and sustainability. Conversely, collaborations, research and development (R & D), training and extension, market demand, and technological interventions (R6) constitute a multifaceted approach to supporting agri-startups and driving ecosystem sustainability. Partnerships with research institutions, industry stakeholders, government bodies and Public-Private Partnership (PPP) facilitate knowledge exchange and technology transfer, while R & D investments spur innovation and competitiveness. Training programs empower entrepreneurs with the skills and resources needed to navigate agricultural complexities, aligning with evolving market demands that prioritize sustainability and ethical sourcing. Moreover, technological interventions, such as precision agriculture and AI-driven analytics, optimize resource utilization and minimize environmental impact, ensuring product quality and traceability. These interconnected feedback loops reinforce one another, fostering innovation, knowledge sharing, and technological adoption to create a resilient and sustainable agri-startup ecosystem. Ultimately, these efforts drive positive economic, social, and environmental outcomes within the agricultural sector [68].

The real-life examples of agristartups like DeHaat, RML AgTech, Ninjacart, and CropIn add tangible depth to the discussion of India's agritech landscape. These startups exemplify how innovative technologies and business models are transforming agriculture by directly engaging with smallholder farmers. For instance, DeHaat's mobile app and advisory services empower farmers with tailored recommendations, while RML AgTech's precision agriculture solutions optimize resource usage. Ninjacart streamlines market access for farmers, and CropIn ensures traceability and quality compliance. These examples illustrate how agristartups are driving impact on the ground, enhancing productivity, market access, and sustainability for smallholder farmers in the Indian context.

5. Conclusions

Agri-Startups are encouraged to incorporate sustainable practices throughout their operations, from production and distribution to waste management and resource utilization. This entails embracing eco-friendly technologies, implementing efficient agricultural practices, and promoting responsible supply chain management. Moreover, the emphasis on sustainability within agri-startups aligns with global trends and commitments towards environmental stewardship and climate resilience. By adhering to sustainable principles, agri-startups not only contribute to long-term health of the planet but also enhance their competitiveness and market appeal in an increasingly discerning consumer landscape. The convergence of Governmental support, PPP initiatives, foreign collaborations, and a steadfast commitment to sustainability underscores the transformative potential of agri-startups in driving inclusive growth, fostering innovation, and addressing pressing challenges in the agricultural sector.

Entrepreneurship in India extends beyond mere business creation; it embodies innovation, aiming to benefit both enterprises and society. This endeavour requires foresight, unwavering dedication, and a willingness to undertake calculated risks. Entrepreneurship has propelled India's rise as a prominent global economic force, generating employment opportunities and driving economic expansion. To sustain this momentum, the Indian agricultural entrepreneurial ecosystem must embrace values like resilience, innovation, customer-centricity, risk-taking propensity, and adaptability. The burgeoning agri-startup ecosystem in India owes its growth to various factors, including emerging markets, political commitment, Government support, technological advancements and changing societal attitudes. However, one indispensable factor that contribute towards nurturing and growth of agri-preneurs is the pivotal role played by incubation centers. These serve as vital catalysts in fostering innovation and providing crucial support to budding entrepreneurs in the agricultural sector. They offer a nurturing environment where aspiring agri-preneurs can access mentorship, guidance, infrastructure, and networking opportunities. Additionally, they facilitate collaboration and knowledge-sharing among entrepreneurs, researchers, industry experts, and policymakers, fostering a culture of innovation and entrepreneurship within the agricultural ecosystem.

The agri-tech investments and number of transactions in India showed significant growth. There is a growing recognition of potential and the adaptability of Agri-Tech startups in responding to market demands.

Initiatives such as Technology Business Incubator (TBI) of Department of Science and Technology in Vignan's Foundation for Science, Technology and Research (VFSTR) and Tree-Based Enterprise Incubation Centre (TBEIC) funded by United States Agency for International Development (USAID) and spearheaded by

Center for International Forestry Research (CIFOR)—International Centre for Research in Agroforestry (ICRAF) play a significant role in fostering a conducive environment for agri-startups to thrive. In the future, incubation centers can act as hubs for research and development, enabling agri-preneurs to leverage cutting-edge technologies and scientific advancements to enhance productivity, sustainability, and resilience in agriculture [66].

Despite the conducive environment, agri-startups in India grapple with several challenges. Access to skilled manpower remains a significant constraint, as the agricultural sector requires specialized skills in technology adoption, market analysis, and supply chain management. Navigating complex policy frameworks and regulatory hurdles is another obstacle for agri-startups, impeding their smooth operation and growth trajectory. Efficient marketing value chains are essential for reaching consumers effectively, yet many startups struggle to establish robust distribution networks and ensure product quality and safety standards. Additionally, competing against larger corporations with greater resources and scale presents a daunting challenge for agri-preneurs, necessitating innovative strategies and differentiation to carve out a niche in the market.

To address these challenges and capitalize on emerging global trends in agri-startups, several strategies can be pursued. Firstly, fostering collaborations and partnerships within the startup ecosystem and with established industry players can facilitate knowledge sharing, resource pooling, and market access. Leveraging technology and digital platforms for market expansion, e-commerce, and supply chain optimization will enhance the efficiency and competitiveness of agri-startups. Moreover, advocating for conducive policy environments, streamlined regulations, and incentives for innovation and entrepreneurship can create an enabling ecosystem for agri-preneurs. By aligning agri-startup strategies with global trends such as sustainable agriculture, precision farming, vertical farming, and agri-tech innovations, will enhance their resilience and adaptability. Embracing circular economy principles, value-added products, and agrifood innovations can enhance resilience and sustainability.

Author Contributions

K. Nirmal Ravi Kumar: Conceptualization, review, methodology, data collection, data curation, data analysis, writing initial draft; T. Ramesh Babu: conceptualization, expert comments and suggestions; Sagar Surendra Deshmukh: data analysis, interpretation, expert suggestions.

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Data Availability Statement

The data presented in this study are available on request from the authors.

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Conflicts of Interest

The authors declare no conflict of interest.

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