Fostering innovations in agriculture: an analysis of agri-startups and stakeholders' engagement

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Abstract: This study explores the potential of agri-startups to address critical challenges in the agriculture sector, focusing on their ability to thrive in countries with untapped problems. A conceptual framework is proposed to understand stakeholder roles and interactions in the agri-startup ecosystem. The research methodology involved data collection from 108 agri-startups incubated at MANAGE-Center for Innovations and Agripreneurship (CIA). An exploratory factor analysis using principal component analysis (PCA) identified five factors based on 15 variables. The stakeholder engagement index revealed effective engagement with potential customers (farmers), scoring 0.79, while NGOs scored the lowest at 0.64. Recommendations to strengthen the ecosystem include fostering support, encouraging mentorship, promoting market access, and enhancing digital literacy. The study contributes to understanding the dynamics of the agri-startup ecosystem and provides insights for policymakers, researchers, and stakeholders to foster innovation and sustainable growth in the agriculture sector.

Keywords: agri-startups; stakeholder; principal component analysis; PCA; ecosystem; policymakers.

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1 Introduction

Startup entrepreneurship's economic dynamics have become critical driving forces for a nation's growth and progress, accounting for roughly one-third of the factors responsible for economic development. Startups not only contribute to economic growth, but they also play an important role in advancing research and innovation, fostering a forward-thinking mindset in society. With their ambition and potential for rapid growth, startups are frequently referred to as 'gazelles' in the business world, capable of creating many new jobs and having a significant impact on the future. Most developed nations actively foster the formation of a vibrant startup ecosystem as an intrinsic aspect of their long-term economic strategy and future investment in today's knowledge-based society. This proactive strategy has encouraged emerging and poor countries to boost their investments in startups, seeing the potential for stimulating innovation, creating new job opportunities, and promoting economic progress. These countries hope to alter their communities and foster a sense of proactivity in their citizenry by incorporating competitive dynamics into their economic systems.

In recent years, the agricultural sector has witnessed a surge in innovative startups leveraging cutting-edge technologies to revolutionise farming practices and create new industries. These agri-startups are at the forefront of developing solutions that not only enhance traditional agriculture but also pioneer entirely new approaches to food production and distribution. For instance, companies like Plenty and AeroFarms are leading the vertical farming revolution, growing crops in controlled indoor environments with significantly reduced water usage and no pesticides. Meanwhile, startups like Indigo Agriculture are using microbiology and data sciences to enhance crop resilience and yield, while Beyond Meat and Impossible Foods are disrupting the protein market with plant-based alternatives.

Recognising the vast potential of agri-startups, governments worldwide have launched initiatives to support innovation in agriculture. In India, for example, the Startup India program has specific provisions for agri-startups, offering tax benefits, funding support, and incubation services. This initiative aims to foster a conducive ecosystem for agri-startups to grow and thrive. In a similar vein, institutions like the National Institute of Agricultural Extension Management (MANAGE) have also taken

the initiative to support agri-startups. In October 2020, MANAGE launched an open webinar series, covering various topics within the agri-startup ecosystem. This series has been successful, with 215 webinars conducted every Saturday, catering to a wide audience of aspiring entrepreneurs and stakeholders (Raj and Raahalya, 2024). Globally, the European Union's Horizon 2020 program has also dedicated significant resources to fostering innovation in agriculture and food systems. This program has been instrumental in promoting cutting-edge research and development in the field, with a focus on sustainable and resilient food systems.

The impact of startups in driving economic growth extends beyond their size. While startups may be relatively small in scale, they play a significant role in job creation, leading to increased employment rates and improved economies. Moreover, startups foster innovation and generate healthy competition, contributing to the overall development and transformation of societies. This impact permeates the social fabric of the cities where startups operate, resulting in structural transformations and the introduction of knowledge-intensive products and services, ultimately boosting the economy and giving rise to new industries. In this context, stakeholders play a crucial role in the success of startups and their ability to make a substantial impact. Stakeholders encompass individuals, organisations, or associations that possess a vested interest in the growth of startups and exert influence, whether positive or negative, on their outcomes. Their presence and input are indispensable for the success of startups, as they provide access to financing, markets, knowledge, intellectual property rights, and opportunities through partnerships and collaborations. Startups actively engage in building networks with companies, universities, and other relevant actors, recognising the importance of these relationships in their growth and development. Networks serve as tools for reputation building, product launch, and driving innovation. However, challenges arise due to limited information about partners, uncertainties in networking, and the prioritisation of technology within networks, neglecting other critical aspects. Furthermore, startups often face resource and time constraints in creating and maintaining effective networks. Innovation, a vital component of startups' success, is closely tied to knowledge creation within the entrepreneurial system. Identifying sources of information and forging alliances with network actors are essential for startups to thrive in the ecosystem. The concept of an ecosystem emphasises the interrelated and mutually exclusive nature of innovation and the ecosystem, highlighting shared interdependencies among stakeholders and resources. Building upon the established concepts of a holistic ecosystem approach, a comprehensive framework is required to identify and develop the agri-startup system. Such a framework will enable the evaluation of stakeholder analysis within the agri-startup ecosystem and examine the impact of advisory services on farmers. Understanding the role and influence of stakeholders, along with the assessment of advisory services, will provide valuable insights into the dynamics of the agri-startup ecosystem and its potential for transforming the agriculture sector.

In this research paper, we aim to delve into the stakeholder analysis of the agri-startup ecosystem, exploring the various actors involved and their contributions to startup growth. By examining these aspects, we aim to contribute to a deeper understanding of the agri-startup ecosystem and its potential for driving positive socio-economic change. By addressing these research objectives, this study will shed light on the complex dynamics of the agri-startup ecosystem and provide valuable insights for policymakers,

researchers, and stakeholders seeking to foster innovation, sustainable growth, and positive transformations within the agriculture sector.

2 Review of literature

Stakeholder engagement encompasses the practices that an organisation adopts to actively involve stakeholders in organisational activities positively (Greenwood, 2007). An organisation must engage with its stakeholders to understand their expectations of implemented strategies and balance their interests in the value creation process (Freeman, 2010) through fair mechanisms (Venkataraman, 2002). Effective stakeholder engagement means that each group feels connected to the organisation's mission and activities. This connection is achieved when stakeholders are committed, perceive their values as aligned with the organisation's values (Kumar and Pansari, 2016), express consent (van Buren, 2001), and recognise the organisation's legitimacy. The ultimate goal of stakeholder engagement is to create value by fostering sustainable relationships between the business and its stakeholders. The association between stakeholder engagement and company benefits, consequently contributing to overall company growth, is a common perspective (Schaltegger et al., 2019) Start-up companies typically view stakeholder engagement favourably, establishing positive correlations with company growth across various benefits. Notably, customers and suppliers are frequently highlighted as key drivers of product innovation, market expansion, and sales growth, thereby directly impacting financial performance (Du and Kadyova, 2016). Yoon et al. (2018) found that government sector involvement is crucial for converting scientific knowledge into innovative new ventures. Their study indicates that government policies related to labour, credit, and business operations that support entrepreneurs can significantly boost innovation management and entrepreneurial development. When a company aims to engage low-power stakeholders, the initial step is to identify power asymmetries and understand their impacts. The company then takes actions to mitigate these asymmetries through empowerment. The goal of empowerment is to enable stakeholders to express their views (Dawkins, 2014) and become stronger, more competent counterparts, facilitating effective dialogue (O'Riordan and Fairbrass, 2014). This approach helps in establishing trustful, long-term relationships and transforming stakeholders into active partners in co-creation.

The role of financial technology is crucial for business operations, indirectly influencing financial transactions, facilitating access to funding, and enhancing the operational efficiency of businesses (Kaewsuwan and Kajornkasirat, 2023). It is noteworthy that independent startups are excelling in innovation compared to large companies with substantial financial resources and established R&D labs (Anupam and Saravanan, 2019). Furthermore, enterprises in the nascent (29.4%) and young (64.7%) stages initially exhibit strong legitimacy and sufficient access to financial resources, enabling their progression to private, partnership, limited liability entities, among others (Thomas et al., 2021). A study examining the contribution of agri-tech startups to inclusive finance for farmers revealed challenges faced by these startups, including farmers' reluctance to participate in programs, the dominance of middlemen in the agricultural sector, inadequate infrastructure in farming areas, and farmers' limited proficiency in digital technology (Aziz et al., 2024). Women entrepreneurs commonly encounter obstacles such as lack of financial support, inadequate transportation, and

limited access to entrepreneurial development training. Additionally, some women-led startups face gender bias, with doubts raised by bank agents regarding their entrepreneurial abilities. Moreover, challenges related to physical mobility in remote areas with underdeveloped infrastructure impede market access for these entrepreneurs (Devi et al., 2023).

3 Conceptual framework

3.1 Stakeholders in the agricultural enterprise

The agricultural enterprise, particularly in the context of agri-startups, involves a complex ecosystem of stakeholders, each playing crucial roles in the success and sustainability of these ventures. Figure 1 illustrates the diverse group of stakeholders involved in the agri-startup ecosystem, which has been the subject of various research studies.

- *Startup entrepreneurs:* Tripathi et al. (2019) conducted a study on 170 agri-startups in India, finding that the entrepreneurs' background, particularly their education and prior experience in agriculture, significantly influenced the startups' success. This study also noted that entrepreneurs with a combination of technical and agricultural knowledge were more likely to develop successful innovations.
- *Potential customers:* Bahn et al. (2021) surveyed 450 farmers across three states in India to understand their adoption of agri-tech solutions and found that farmers' willingness to adopt new technologies was significantly influenced by factors such as ease of use, perceived benefits, and trust in the startup. This highlights the crucial role of potential customers in driving market demand for agri-startup innovations.
- *Policy-related stakeholders:*
  a Government institutions: Klerkx et al. (2019) analysed agricultural innovation systems in 12 countries, emphasising the critical role of government policies in creating an enabling environment for agri-startups. This study found that countries with specific policies supporting agri-entrepreneurship had a higher rate of successful agri-tech innovations.
  b Research and development institutions: Pant and Hambly-Odame (2017) studied the role of agricultural universities in fostering agri-entrepreneurship in India. This study found that universities played a crucial role in knowledge creation and technology transfer, but noted gaps in translating research into commercially viable innovations.
- *Financial stakeholders:* Graef et al. (2018) analysed funding patterns of 245 agri-tech startups globally. This study found that while venture capital was the largest source of funding, government grants and angel investors played a crucial role in early-stage funding. Interestingly, study observed that startups with diverse funding sources were more likely to succeed in the long term.

- *Supporting stakeholders:* Eastwood et al. (2017) conducted a comprehensive review of digital agriculture projects and emphasised the importance of technical experts in translating agricultural needs into technological solutions. This study also highlighted the role of incubators and accelerators in providing crucial support to early-stage agri-startups.
- *Non-governmental organisations (NGOs):* Glover et al. (2019) studied the role of NGOs in promoting agricultural innovations in Sub-Saharan Africa and found that NGOs were instrumental in bridging the gap between agri-startups and small-scale farmers, particularly in promoting sustainable and climate-resilient agricultural practices.
- *Marketing networks:* Pigford et al. (2018) examined the role of agricultural innovation platforms in fostering collaboration between startups, established companies, and farmers and found that these platforms facilitated knowledge exchange and helped startups scale their innovations more effectively.
- *Social associations:* de Roo et al. (2019) studied the adoption of agricultural innovations in rural communities in Ethiopia. Study found that community associations played a significant role in the diffusion of new agricultural technologies, highlighting the importance of these social structures in the success of agri-startups.

The interaction between these stakeholders is complex and multifaceted. Schut et al. (2016) used a systems approach to analyse agricultural innovation processes in 12 countries. This study found that successful innovation required alignment between technological, social, and institutional dimensions, emphasising the need for effective stakeholder engagement across all levels.

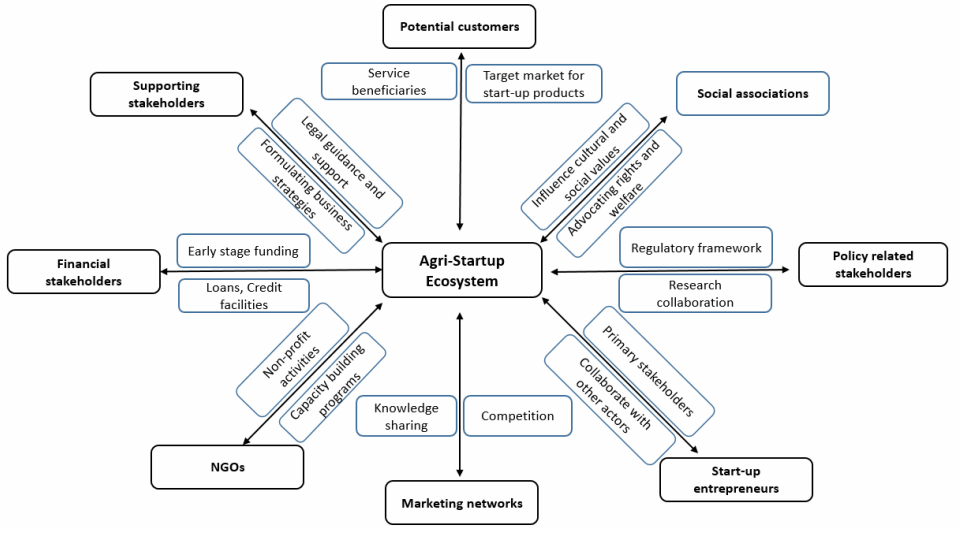
Turner et al. (2020) conducted a meta-analysis of 89 studies on stakeholder engagement in agricultural research for development and found that while stakeholder engagement was widely recognised as important, there were significant challenges in practice, particularly in balancing diverse stakeholder interests and power dynamics.

In the context of agri-startups, Steinke et al. (2022) studied 46 digital agriculture projects in developing countries and found that projects that actively engaged a diverse range of stakeholders from the outset were more likely to develop sustainable and scalable solutions. However, study also noted challenges in managing expectations and maintaining engagement over time.

Understanding and effectively managing these diverse stakeholder relationships is crucial for the success of agri-startups. Fielke et al. (2020) proposed a framework for responsible innovation in digital agriculture, emphasising the need for inclusive stakeholder engagement throughout the innovation process. This approach not only leads to more effective solutions but also helps address ethical concerns and promotes equitable outcomes.

This research-based overview underscores the complexity of the agri-startup ecosystem and the critical importance of effective stakeholder engagement. It highlights the need for agri-startups to develop strategies that consider the diverse needs and interests of all stakeholders, as illustrated in Figure 1, to create sustainable and impactful agricultural innovations.

Figure 1 Conceptual framework of the agri-startup ecosystem (see online version for colours)



Source: Authors elaboration

4 Methodology

The methodology employed in this study adhered to a systematic procedure for data collection and objective exploration. The study sample encompassed startups incubated at MANAGE-CIA. MANAGE-Centre for Innovation and Agripreneurship (CIA) recognised as a centre of excellence (CoE) in agribusiness incubation and acts as a Knowledge Partner to strengthen, guide, and demonstrate the best practices for agri-business incubators. The centre has incubated over 425 startups across various sectors within the agricultural domain under the RKVY RAFTAAR project till 2024. The questionnaire was electronically distributed via email to 239 agricultural startups out of which 108 startups responded which are incubated till 2023. The study focused on these 108 startups, which are involved in precision farming, supply chain management, animal husbandry, farm machinery, food processing, farmer and agri-input service centres, and consultancy.

4.1 Data collection

Data collection was executed through a well-structured online questionnaire, designed with the input of professionals with relevant expertise. An online survey questionnaire in the form of Google Form was utilised. The questionnaire was electronically distributed via email.

4.2 Data analysis

Descriptive statistics were employed to calculate the means and standard deviations for each item. In order to identify the underlying factor structure of the data, principal

component analysis was conducted. The KMO and Bartlett's test of sphericity measures used to understand the collinearity and redundancy between the individual components. Chi-square test is used to determine the significant association between the profile characteristics of entrepreneurs. It is essential to recognise that the findings of this study are specific to the startups benefiting from registration under the RKVY RAFTAAR project and may not be generalised to the broader agricultural startup ecosystem.

5 Results and discussion

5.1 Profile characteristics of entrepreneurs

Age, gender, education, and past job experience are key factors that influence startup entrepreneurship in the agricultural sector.

5.1.1 Age

The calculated value being 31.481 is higher than the TV = 11.345 @ 1% level of significance with df = (n – 1) = (4 – 1) = 3 failed to accept H0 and accepts H1. Therefore, it was concluded that there exists significant variation in the age group of participants. Young entrepreneurs between the ages of 25 and 35 have shown a greater level of activity in startup ventures, comprising nearly 40% of the entrepreneurs (Kerr et al., 2018). The average age of agriculture startup entrepreneurs is decreasing as more young individuals establish their own firms, leveraging advancements in agricultural technology and the supportive ecosystem. Today's youth are not only more educated and technologically aware but also driven, possessing fundamental management principles and business insights. These characteristics indicate the potential for training the younger generation in agricultural business. Research by the Syngenta Foundation India (2022) suggests that being between the ages of 25 and 30 is an optimal time for entrepreneurs in agriculture to have a solid start. Despite the disadvantages of limited experience and finances associated with starting a business at a young age, many young entrepreneurs have proven that age is no barrier to success when guided and dedicated appropriately (Ahn and Park, 2018; Mawardi et al., 2021).

Table 1 Distribution of respondents based on age

Sl. no.	*Age in years*	*Frequency*	*Percentage*	*Chi square*
1	Less than 25	04	04.60	31.48@ <0.001 significant level
2	25 to 35	41	37.60	
3	35-45	25	22.90	
4	More than 45	38	34.90	
Ho	There exists no significant variation in the age of the startup entrepreneurs			Reject
H1	There exists significant variation in the age of the startup entrepreneurs			Accept
Chi-square value	*Significance level*	*Degrees of freedom*	*Table value*	
31.481	1%	4-1=3	11.345	

5.1.2 Gender

The calculated value being 50.70 is higher than the TV = 6.635 @ 1% level of significance with df = (n – 1) = (2 – 1) = 1 failed to accept H0 and accepts H1. Therefore, it was concluded that there exists significant variation in the gender of participants.

Table 2 Distribution of respondents based on gender

Sl. no.	Gender	Frequency	Percentage	Chi-square
1	Male	91	84.25	50.70, p <0.001 significant level
2	Female	17	15.74	
	Total	108	100	
Ho	There exists no significant variation in the gender of the startup entrepreneurs			Reject
H1	There exists significant variation in the gender of the startup entrepreneurs			Accept
Chi-square value	*Significance level*	*Degrees of freedom*	*Table value*	
50.70	1%	2-1=1	6.635	

The study also revealed a significant gender disparity, with 84.25% of the respondents being male, and only 15.74% of agritech firms led by women. Although there is a growing trend of women entering the startup field, they still face obstacles such as obtaining financing, overcoming gender prejudices, and cultural expectations. The underrepresentation of women in leadership positions hampers diversity and inclusion in the agriculture industry. However, research suggests that firms led by women tend to have a stronger focus on social impact and diversity, leading to more varied and inclusive workplaces. Therefore, it is crucial to encourage and support women in the startup environment, as they bring unique perspectives and ideas to the table (Guzman and Kacperczyk, 2019).

5.1.3 Education

The calculated value being 71.72 is higher than the table value of 13.27 @ 1% level of significance with df = (n – 1) = (5 – 1) = 4 failed to accept H0 and accepts H1. Therefore, it was concluded that there exists significant variation in the education of the startup entrepreneurs. Education plays a vital role in equipping individuals with knowledge, skills, and a positive attitude toward their living environment. In the agricultural startup landscape, the educational background of founders varies significantly. Many possess higher degrees of graduation (29.6%) and post-graduation (46.2%) in subjects such as engineering, agriculture, and business, while a small percentage have not attended college. Success in agricultural entrepreneurship is not solely dependent on formal education but also on access to knowledge systems and trial-and-error learning (Agbim et al., 2013; Setia, 2018; Dey et al., 2019).

Table 3 Distribution of respondents based on education

Sl. no.	*Education*	*Frequency*	*Percentage*	*Chi-square*
1	Secondary and higher secondary education (10th to 12th level)	3	2.77	71.72, $p < 0.001$ significant level
2	Vocational education / Diploma holders	5	4.62	
3	Graduation	32	29.62	
4	Post graduation	50	46.29	
5	PhD	18	16.66	
Ho	There exists no significant variation in the educational status of the startup entrepreneurs			Reject
H1	There exists significant variation in the educational status of the startup entrepreneurs			Accept
Chi-square value	*Significance level*	*Degrees of freedom*		*Table value*
71.72	1%	5 – 1 = 4		13.27

5.1.4 Academic background

The calculated value 38.51 is higher than table value of 18.475 @ 1% level of significance with df (8 – 1) = 7. Therefore, it was concluded that there exists a significant variation in the academic and professional background of the startup entrepreneurs. More than one fourth (28.7%) of the startup entrepreneurs come from engineering and architecture backgrounds, mostly contributing to technological innovations in agriculture while 16.7% of individuals have a background directly in agriculture and 13.8 % of them from different back grounds. This can be understood that diverse backgrounds contributing to the agricultural startup ecosystem, emphasising the interdisciplinary nature of innovation in agriculture. These findings are in line with Kumar et al. (2021).

Table 4 Distribution of respondents based on academic background

S. no.	*Category*	*Frequency*	*Percentage*	*Chi square*
1	Agriculture	18	16.7	38.51, $p < 0.001$ significant level
2	Agri allied subjects	11	10.2	
3	Engineering and architecture	31	28.70	
4	Arts	5	4.6	
5	Science	10	9.3	
6	Commerce and finance	5	4.6	
7	Business administration and management	13	12	
8	Others	15	13.8	
Ho	There exists no significant variation in the academic background of the startup entrepreneurs			Reject
H1	There exists significant variation in the academic background of startup entrepreneurs			Accept
Chi-square value	*Significance level*	*Degrees of freedom*		*Table value*
38.51	1%	8 – 1 = 7		18.475

5.1.5 Total work experience

Over half of the entrepreneurs surveyed had more than 12 years of work experience in various domains. Previous employment provides valuable insights, transferable skills, and networking opportunities that can be leveraged in the startup setting. Entrepreneurs with relevant work experience can make informed decisions, identify potential risks, and develop effective strategies for mitigating them. Familiarity with the industry also aids in recruiting and managing staff, contributing to the overall growth and expansion of the startup (Kozak, 2021).

Table 5 Distribution of respondents based on total work experience

Sl. no.	*Working experience*	*Frequency*	*Percentage*	*Chi square*
1	0 to 3 years	18	16.6	81.537, $p < 0.001$ significant level
2	4–6 years	24	22.2	
3	7–9 years	7	6.48	
4	10–12 years	3	2.77	
5	More than 12 years	56	51.85	
Ho	There exists no significant variation in the work experience of the startup entrepreneurs			Reject
H1	There exists significant variation in the work experience of the startup entrepreneurs			Accept

Chi-square value	*Significance level*	*Degrees of freedom*	*Table value*
81.537	1%	5 – 1 = 4	13.277

5.2 Exploratory factor analysis

Kaiser-Meyer-Olkin (KMO) of sampling adequacy and the Bartlett's test of sphericity (BTS) (with $p < 0.05$) to determine if the selected variables were adequate for the factor structure. In general, KMO value ranges from 0 to 1, but for the variables to be selected, their KMO value should be equal to or greater than 0.6 (Fekete, 2012). Kaiser (1974) criterion for retention, i.e., eigenvalue greater than 1 was adopted for this study. Varimax rotation applied to minimise the number of resulting factors and maximise the sum of variances (Aksha and Emrich, 2020). Batrlett's test of sphericity was also significant, which means there was no redundancy and multicollinearity in the data as it tests the null hypothesis that there is no correlation and redundancy between the two individual indicators in a correlation matrix. A certain degree of correlation should exist between the indicators' measures for PCA to work. In this study, Bartlett's test of sphericity is highly significant ($p < 0.001$) and, hence, it is appropriate to conduct PCA on the data.

Table 6 Results of KMO and Barlett's test of sphericity

Kaiser-Meyer-Olkin test	KMO measure of sampling adequacy	0.783
Bartlett's test of sphericity	Approximate chi-square	3,224.746
	df	1,176
	Significance value	.000

Table 7 Eigenvalues of the variables

Component	*Initial eigenvalues*			*Extraction sum of squared loadings*	
	Total	*% variance*	*Cumulative %*	*Total*	*% variance*
X_1	2.004	15.416	15.416	2.004	15.416
X_2	1.652	12.708	28.124	1.652	12.708
X_3	1.507	11.590	39.714	1.507	11.590
X_4	1.212	9.323	49.037	1.212	9.323
X_5	1.098	8.443	57.480	1.098	8.443
X_6	0.983	7.565	65.044		
X_7	0.893	6.871	71.915		
X_8	0.837	6.439	78.354		
X_9	0.792	6.091	84.445		
X_{10}	0.693	5.333	89.778		
X_{11}	0.573	4.405	94.183		
X_{12}	0.419	3.226	97.409		
X_{13}	0.337	2.591	100.00		

Table 8 Factor wise variables with factor loadings

Factor	*Factor name*	*Variables*	*Component loadings*
1	Time frame	Finding investors	0.730
		Infrastructure setup	0.883
		Idea to launch startup	0.606
2	Line of activity	Year of establishment	0.743
		Legal form of business	0.501
		Category of innovation	0.748
3	Startup infrastructure	Resources used for market research	0.694
		Business plan preparation	0.785
		Source of fund	0.648
4	Innovativeness	% profit share	0.650
		No of patents granted	0.696
		Training programs attended	0.755
		Frequency of validation	0.682
5	Product/service category of startups	Focus area	0.665

Table 7 explains the specification of eigenvalue and percentage of variance explained by the factors in the study. The factors having an eigenvalue of more than one was selected. PCA revealed five components that had eigenvalues greater than one and which explained. Out of thirteen variables, five factors were extracted and together they explained the total variance of 57.48%. The first principal component explained 15.41% of the variance followed by second principal component (28.12%) of variance, the third

principal component (39.71%) of variance and the fourth component (49.03%) of variance. The factor names and their loadings are given in Table 8.

The variables within each factor are those that are closely related or share common characteristics, as indicated by their component loadings. The five components are named as time frame (factor 1), line of activity (factor 2), startup infrastructure (factor 3), innovativeness (factor 4) and product/service category (factor 5).

5.2.1 Factor 1: time duration for the development of infrastructure

The time it takes to establish infrastructure in agricultural technology startups varies based on numerous factors. The length of the development process is mostly determined by the size of the enterprise and the complexity of the framework required. Smaller infrastructure startups may take less time to establish, whilst bigger infrastructures may take years to finish.

Table 9 Distribution of respondents based on the time duration for the development

	Category	*Frequency*	*Percentage*
Finding investors	<6 months	29	26.9
	6–12 months	33	30.6
	1–2 years	23	21.3
	2 to 4 years	12	11.1
	>4 years	11	10.2
Infrastructure setup	<1 months	7	6.5
	1–3 months	22	20.4
	4–8 months	24	22.2
	9–12 months	24	22.2
	1–2 years	16	14.8
	2–3 years	6	5.6
	More than 3 years	9	8.3
Idea to launching startup	<1 year	51	47.2
	1–2 years	40	37.0
	2–3 years	10	9.3
	>years	7	6.5

From the factor 1, it was noted that 30.6 per cent of the startups find investors within the first year, with the majority securing investment within two years. However, there's still a notable portion that takes longer to secure investment, with a small fraction requiring more than four years. These findings are in line with Mubeena et al. (2020).

Regarding infrastructure setup, a similar percentage (22.2%) of startups take 4–8 months and 9–12 months to establish their infrastructure. This indicates a significant portion of startups need a longer timeframe, possibly due to more complex infrastructure requirements or bureaucratic processes. Around one-fifth (20.4%) of startups require 1 to 3 months to set up their infrastructure. This timeframe is relatively common and indicates a reasonable period for startups to organise their resources and operational setup.

The majority of startups (47.2%) are able to move from idea conception to launching their startup within a relatively short timeframe of less than one year. This suggests a significant proportion of startups are agile and efficient in executing their plans, possibly leveraging existing resources or market opportunities. A meagre section (6.5%) of startups take more than three years to move from idea to launching their startup. This could be due to various factors such as encountering unexpected obstacles, conducting extensive market research, or pursuing complex technological innovations.

5.2.2 Factor 2: line of activity

The line of activities involved in establishing a startup encompasses the type of innovation, focus area, and legal structure of the business. Meanwhile, the infrastructure details encompass resource allocation, the formulation of a master plan, and the process of innovation adoption. These aspects significantly influence a startup's collaborations and connections with stakeholders. Investing time and money in these areas fosters an ecosystem of stakeholders that promotes long-term success.

Table 10 Distribution of respondents based on the line of activity

	Category	*Frequency*	*Percentage*
Year of establishment	2023	6	5.5
	2021–2022	33	30.5
	2019–2020	39	36.1
	2017–2018	19	17.5
	Before 2017	11	10.1
Legal form of business	Partnership firm	12	11.1
	Limited liability partnership	15	13.9
	Private limited company	73	67.6
	Public limited company	2	1.9
	Unregistered	3	2.8
	Others	3	2.8
Category of innovation	Product innovation	80	74.1
	Process innovation	49	45.4
	Service innovation	37	34.3
	Marketing innovation	26	24.1
	Social innovation	39	36.1
	Others	7	6.50

More than one-third (36.1%) of startups were established during the two-year period of 2019 to 2020. Relatively, (30.5%) of startups were established between 2021 and 2022. This suggests a significant influx of new startups in these two years, possibly influenced by favourable market conditions, technological advancements, or supportive policies encouraging entrepreneurship. A small proportion (5.5%) of startups were established in 2023. This indicates recent entries into the startup ecosystem, potentially reflecting emerging trends, market opportunities, or entrepreneurial initiatives in the most recent year. The findings were consistent with those of Reddy et al. (2023).

The legal structure of agritech startups may vary based on factors such as activity size, ownership, and liability protection requirements. The study revealed that more than two-thirds (67.60%) of startups opt for a private limited company or a personal company (Prajapati and Kureshi, 2022). These legal forms have gained popularity due to their associated benefits. They provide limited liability protection for entrepreneurs at the initial stages, and their separate legal entity makes it easier to access capital and investment opportunities. Additionally, they offer a permanent existence and a well-organised management structure, which reduces disputes and improves decision-making processes. Furthermore, companies with these legal structures tend to have greater credibility and trust among customers and suppliers, attracting more business and increasing profits (Verma and Kumar, 2021).

The study revealed that approximately three-fourths (74.10%) of startup entrepreneurs adopted product innovation, which correlates with the focus areas of their products and services. Among these entrepreneurs, a significant portion focuses on agricultural input production, such as seeds, fertilisers, crop protection inputs, farm machinery, irrigation units, and polyhouse installation units. Some organisations claim to have implemented multiple types of innovation, with process innovation (45.40%) and service innovations (34.30%) being preferred by startups (Bjerke and Johansson, 2022). Startups often provide a range of products and services, including forward linkages, market connections, consultancy and advisory services, alongside their primary offerings. It is worth noting that while service innovations dominate other industries, process innovations also play a significant role in the agricultural sector.

In summary, the success of agritech startups depends on the infrastructure and line activities they adopt, encompassing factors such as resources, financial capital, technology adoption, innovation, and workforce. The legal structure of startups, such as private limited companies and one one-person companies, offers numerous advantages, including limited liability protection, access to capital, and organised management structures. Choosing the right innovation, particularly product innovation, aligned with the startup's focus areas contributes to differentiation and market success. Furthermore, the incorporation of process and service innovations enhances the range of offerings and overall competitiveness of the startup.

5.2.3 Factor 3: startup infrastructure

Conducting a physical market survey is an essential tool for agri-startup entrepreneurs who aim to gain a deeper understanding of their target customers, primarily farmers. In line with this objective, a majority of the entrepreneurs in this study (83.30%) opted for conducting primary physical market surveys. These surveys involve visiting agricultural stores where the product will be sold (if the innovation is a product) and engaging in conversations with potential customer farmers. By doing so, startups can gather valuable insights into the needs and preferences of farmers and other consumer segments. Through primary research methods such as surveys and interviews, more specific and detailed information can be obtained. This data can then be utilised to enhance the product or service, ensuring that it better meets the demands of the agricultural market. Physical market surveys and primary research play a crucial role in enabling startups to align their offerings with the requirements of the agriculture sector and stay ahead of the competition.

Table 11 Distribution of respondents based on the startup infrastructure

	Category	*Frequency*	*Percentage*
Resources used for market research	Physical market survey	90	83.3
	Secondary research	44	40.7
	Business experts	46	42.6
	Reports of industry	31	28.7
	Consultants	28	25.9
	Others	8	7.40
Business plan preparation	By the founder	72	66.7
	Management team	28	25.9
	Incubation centre	7	6.5
	Others	1	0.9
Sources of fund	Self-funding	93	86.1
	Friends/family	39	36.1
	Startup incubator seed funding	34	31.5
	Angel investment	6	5.6
	Government grants	35	32.4
	NGO grants	4	3.7
	Business loans	20	18.5
	Venture capital funds	3	2.8
	Crowd funding	2	1.9
	Others	3	2.77

The majority (66.7%) of startups formulate their business plans directly by the founder(s) themselves. This suggests a hands-on approach by the entrepreneurs in shaping the vision, strategy, and operational details of their startups, leveraging their personal insights, experiences, and expertise.

From the multiple responses of startup entrepreneurs, it is evident that self-funding was the priority basis for majority (86.10%) of the startups. Self-funding is becoming increasingly popular among startups. Bootstrapping is a common strategy in which companies utilise their own money or personal resources to support their company endeavours. Self-funding is a challenging option to follow, but it gives companies more control over their business decisions and allows them to retain a larger amount of ownership in their firm. The findings are in line with

The Government of India has implemented several schemes to support agri-tech startups. Notably, the Rashtriya Krishi Vikas Yojna – Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (RKVY-RAFTAAR) is a key initiative of the Ministry of Agriculture and Farmers' Welfare (MoA&FW). This scheme aims to enhance agricultural infrastructure and promote agripreneurship and agribusiness by providing financial support and fostering an incubation ecosystem. As part of the 'Startup India' program, the Government of India enhanced funding for the startups through Start-up India seed fund and scheme for promoting innovation, venture capital assistance (VCA) was introduced by the Small Farmers' Agri-Business Consortium (SFAC) and rural

entrepreneurship (ASPIRE) and these programs motivate entrepreneurs to take up government grants as a source of funding (Kumar et al., 2022).

5.2.4 Factor 4: innovativeness

A majority (46.3%) of startups report a profit share exceeding 10%. This indicates a higher level of profitability for these startups, potentially reflecting successful business models, efficient operations, or strong market demand for their products or services.

Table 12 Distribution of respondents based on the innovativeness

	Category	*Frequency*	*Percentage*
% profit share	<5%	17	15.7
	5–10%	41	38.0
	>10%	50	46.3
No. of patents granted	No patents	60	55.5
	In process	33	30.5
	1 patent	11	10.18
	2 patents	4	3.70
	>2	0	0
Training programs attended	1-2	21	19.4
	2-5	35	32.4
	>5	42	38.9
	No training	10	9.3
Frequency of validation	Weekly	0	0
	Once in 3months	10	9.3
	Once in 6 months	42	38.9
	Once in a year	35	32.4
	Need basis	21	19.4

Patents and innovation are closely linked because patents provide a legal framework for protecting novel ideas and technologies. Patents promote innovation by offering a means for startup entrepreneurs to safeguard their ideas and innovations from competitors. The majority (55.5%) of startups have not been granted any patents. This suggests that a significant portion of startups may not have developed or successfully filed for patents for their innovations, due to various factors such as the nature of their products or services, limited resources for intellectual property protection, or prioritisation of other business activities. A smaller portion (10.18%) of startups have been granted one patent and a few startups (3.70%) have been granted two patents. This suggests that some startups have successfully secured intellectual property rights for specific innovations, potentially enhancing their competitive advantage and market positioning. These findings are in line with the Jyoti and Singh (2020)

The majority (38.9%) of individuals have attended more than five training programs. This indicates a strong commitment to ongoing education and skill enhancement, suggesting a culture of continuous learning and innovation within the startup environment. A smaller portion (9.3%) of individuals within startups have not attended

any training programs. While relatively low, this category highlights the presence of individuals who may not have had opportunities or resources to engage in formal training activities, potentially indicating areas for improvement in promoting professional development and learning opportunities within the startup ecosystem.

Regarding validation, the largest portion (38.9%) of startups conduct validation once every 6 months. This indicates a semi-annual review cycle, where startups assess the effectiveness and performance of their products, services, or business models, potentially aligning with milestone achievements or strategic planning cycles. None of the startups indicated conducting validation on a weekly basis. This suggests that the validation process may not be perceived as requiring such frequent assessments, or it could indicate that startups prioritise other forms of feedback or iteration in their development cycles.

5.2.5 Factor 5: product/service category of startups

Agri startups have initiated a revolution in the agri-sector by offering innovative solutions that aid farmers in optimising yields, reducing costs, and enhancing profitability. Typically, these startups operate across various stages of the agricultural value chain, encompassing farming as a services (FaaS) and the integration of automation and data analysis in production (Chandra and Collis, 2021). These agritech startups leverage advanced technology to enhance agriculture and the agri-industry, including the digitalisation of data, the provision of software as a service (SaaS), the utilisation of machine learning and data analytics, artificial intelligence (AI), the internet-of-things (IoT), satellite data, drones, and blockchain (Mikhailov et al., 2019).

Table 13 Distribution of respondents based on the product/service

	Category	*Frequency*	*Percentage*
Focus area	Farmer service centre	7	6.5
	Agricultural input service	24	22.2
	Financial services	3	2.8
	Supply chain management	13	12.0
	Animal husbandry	12	11.1
	Precision farming	17	15.7
	Others	32	29.6

The largest portion (22.2%) of startups is involved in providing agricultural input services. This could encompass activities related to the production, distribution, or sale of seeds, fertilisers, pesticides, and other agricultural inputs essential for farming operations. Small proportion (15.7%) of startups focus on precision farming technologies and practices. This includes the use of data analytics, sensors, drones, and other advanced technologies to optimise resource use, increase productivity, and minimise environmental impact in agriculture.

5.3 Role of stakeholder engagement in agri-startup performance

All startup companies involve various stakeholders in the process of developing their products. They universally acknowledge the importance of stakeholders in providing valuable ideas for product development. To better understand the contribution of each

stakeholder's role in the performance of agri-startups, an index was developed. Figure 2 shows the index values of stakeholder engagement.

$$Stakeholder\ engagement\ index = \frac{Total\ score}{Maximum\ score} \times 100$$

Table 14 Stakeholder engagement index

S. no.	*Stakeholders*	*Index*
1	Potential customers	0.79
2	Financial stakeholders	0.77
3	Policy related stakeholders	0.68
4	Supporting stakeholders	0.69
5	NGOs	0.64
6	Marketing networks	0.73
7	Social associations	0.75
	Overall	0.720

The overall stakeholder engagement index is calculated as 0.720 which shown in Table 14. Among all stakeholders, the index value of potential customers, financial stakeholders, marketing networks and social associations was more than the overall index value which means that these stakeholders play a major role in the performance of agri-startups indicating a moderate to strong level of engagement across all stakeholder groups. Figure 2 shows the index values of stakeholder engagement.

- Potential customers (index: 0.786): this includes farmers and farmer interest groups in most cases. Findings indicate that the startup has effectively engaged potential customers, resulting in a high index score. Engaging potential customers is crucial as they directly contribute to the startup's revenue generation and market growth. This is due to the fact that most of the cutting-edge products and services offered by agri-tech startups were tailored exclusively for farmers to increase their farm productivity and to address their specific broad needs. These finding are in line with results of Reddy et al. (2023).
- Financial stakeholders (index: 0.767): financial stakeholders include investors, banks, and other financial institutions. The high index score suggests strong engagement with these stakeholders, which is essential for securing funding, investment, and financial support necessary for the startup's operations and expansion.
- Social associations (index: 0.756): this includes community and employees' associations. The index score indicates a good level of engagement with social associations. Collaborating with social associations can enhance the startup's reputation, credibility, and social impact. It also opens avenues for community involvement, corporate social responsibility initiatives, and partnerships that align with the startup's values and objectives.

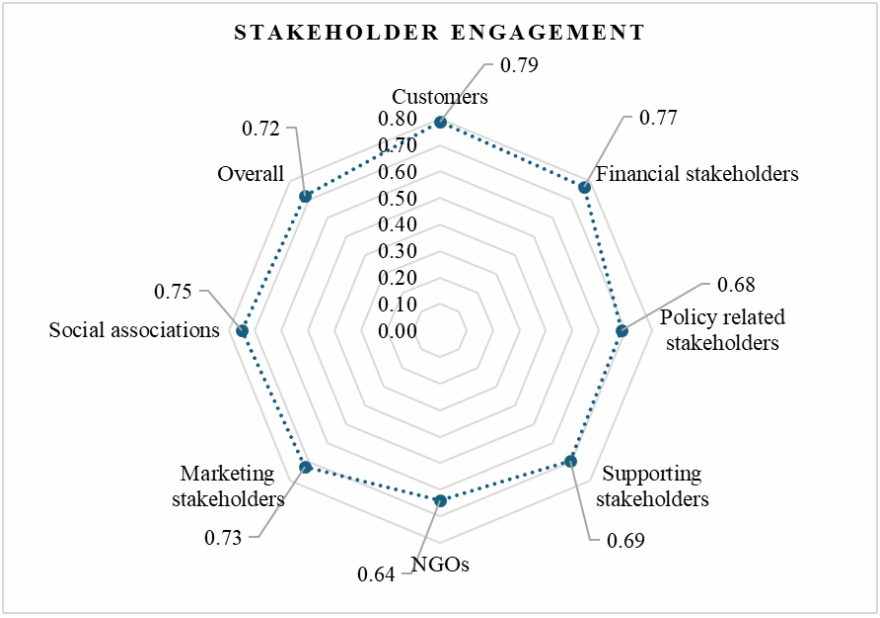
- Marketing networks (index: 0.725): this includes industrial associations or entrepreneurial network corporations and multinational corporations. Effective engagement with marketing networks is reflected in the relatively high index score. Leveraging marketing networks can help in reaching target audiences, building brand awareness, and driving sales, thereby contributing to the startup's growth and market presence.
- Policy-related stakeholders (index: 0.686): policy-related stakeholders may include government agencies, regulatory bodies, and policymakers. While the engagement with these stakeholders is decent, there might be room for improvement. Building strong relationships with policy-related stakeholders is vital for navigating regulatory frameworks, accessing incentives, and ensuring compliance, which can significantly impact the startup's operations and growth trajectory.
- Supporting stakeholders (index: 0.699): supporting stakeholders could include technical experts, business incubators, accelerators and consultants. The index score indicates a moderate level of engagement with these stakeholders. Strengthening relationships with supporting stakeholders is important for ensuring a smooth supply chain, accessing resources, and reducing operational risks.
- NGOs (index: 0.632): the index score suggests a relatively lower level of engagement with NGOs. NGOs can play a crucial role in providing expertise, resources, and networking opportunities, especially in areas like sustainable agriculture, community development, and environmental conservation. Enhancing collaboration with NGOs could benefit the startup in various aspects of its operations and social impact.

Table 15 Distribution of respondents based on stakeholder engagement

S. no.	*Criteria*	*Frequency*	*Percentage*
1	Low	19	17.6
2	Medium	74	68.5
3	High	15	13.9
Total		108	100

From Table 15, the majority of respondents (68.5%) reported medium levels of stakeholder engagement. This indicates that a substantial portion of agri-startups have established some degree of engagement with their stakeholders and they recognise the importance of stakeholders in their operations. They understand that stakeholders play crucial roles in influencing their success, whether through providing resources, support, market access, or regulatory compliance. A meagre portion (17.6%) of the respondents indicated low levels of stakeholder engagement and very less (3.9%) of the respondents reported high levels of stakeholder engagement in their startups.

Figure 2 Index values of stakeholder engagement (see online version for colours)



5.4 Challenges faced by agri-startups

5.4.1 Startup establishment challenges

The most prominent challenge identified was the establishment of agri-startups, with access to capital being the primary concern (index value: 85.19). This aligns with findings by Tripathi et al. (2019), who noted that limited access to finance was a significant barrier for agri-startups in India. This results further emphasise this issue, showing that 66.7% of startups relied on self-funding, indicating a gap in external funding sources.

Budget allocation (index value: 84.88) and finding suitable manpower (index value: 82.41) were also significant challenges. This corroborates with Pant and Hambly-Odame's (2017) study, which highlighted the skills gap in the agri-startup sector. Findings extend this by specifically pointing out the difficulty in finding personnel with both technological skills and farming experience. The scarcity of professionals with the necessary technical and managerial skills in the agricultural sector further compounds this challenge. Since agricultural technologies are often new and not included in traditional agricultural education, finding personnel with both technological skills and farming experience becomes a hurdle. Moreover, agriculture is often considered a low-status and unattractive occupation among young people, making it challenging for agri-startups to attract and hire talented staff. Additionally, rural communities may lack the social and cultural amenities that young people seek, exacerbating the talent deficit. It is worth noting that a significant proportion of startup founders do not come from an agricultural background, which also contributes to their lack of knowledge and difficulty in accessing suitable manpower for their startups (Mahawar et al., 2019).

Agri-startups face challenges when it comes to obtaining approval and clearance for their establishment due to regulatory mechanisms imposed by the government and other stakeholder institutions (Pareek et al., 2023). These startups encounter obstacles such as acquiring licenses and permissions, complying with environmental and safety laws, and navigating through bureaucratic procedures. Despite some improvements, registering a firm in India remains a complex process, as it involves adherence to strict regulations governing labour laws, intellectual property rights, and dispute resolution. Compared to OECD nations where the registration process takes approximately 9 days, in India, it typically takes around 30 days (Mittal and Madan, 2020). This situation is reflected in India's ranking of 142 out of 189 economies in the World Bank's 'World Bank Ease of Doing Business' report.

Table 5 Distribution of startups according to the various challenges faced by them

Sl. no.		*Factors*	*Major challenge*	*Minor challenge*	*Not a challenge*	*Index value*	*Rank*
1		*Startup establishment challenges*				79.06	I
	a	Access to capital as the initial funds from banks	72	24	12	85.19	I
	b	Budget allocation for different activities	66	35	7	84.88	II
	c	Finding the suited manpower supply	62	35	11	82.41	III
	d	Issues with the multiple regulatory clearances	64	26	18	80.86	IV
	e	Lack of mentorship in the ideation stage	58	31	19	78.70	V
	f	Taking license and approval from the regulatory system	54	38	16	78.40	VI
	g	Finding the location	42	32	14	62.96	VII
2		*Marketing challenges*				78.93	II
	a	Ensuring the quality of products and services while keeping it low cost	75	24	9	87.04	I
	b	Pricing of the services for the farmers	58	40	10	81.48	II
	c	Lack of branding strategy for the company	58	34	16	79.63	III
	d	Long gestation period from farmers because of the attitude of towards the technological setup	51	41	16	77.47	IV
	e	Less opportunity for the promotional activities	46	46	16	75.93	V
	f	Understanding and dealing with the farmers need	47	43	18	75.62	VI
	g	Low skill adaptability and digital literacy of the farmers	47	42	19	75.31	VII

Table 5 Distribution of startups according to the various challenges faced by them (continued)

Sl. no.		*Factors*	*Major challenge*	*Minor challenge*	*Not a challenge*	*Index value*	*Rank*
3		*Financial challenges*				75.62	III
	a	Effective cash management	59	37	12	81.17	I
	b	Managing the team	39	44	25	70.99	II
	c	Taxation as a hurdle	47	40	21	74.69	II
4		*Other challenges*				73.87	IV
	a	Lack of information about the govt policies and programs to promote startups	58	36	14	80.25	I
	b	Lack of access to support mechanisms such as business development centers/ Incubators/consultants	48	45	15	76.85	II
	c	Issues with the procedural formalities of intellectual property rights (patents)	48	41	19	75.62	III
	d	Influence of external organisations which try to control, manage, take advantage of their events, in the name of mentoring	49	35	24	74.38	IV
	e	Competition from the public advisory service system	44	42	22	73.46	V
	f	Issues with cyber security	23	49	36	62.65	VI

5.4.2 Marketing challenges

Ensuring product quality while maintaining low costs emerged as the primary marketing challenge (index value: 87.04). Given that India is predominantly an agrarian economy with a large proportion of small and marginal farmers, startups must ensure that their products or services are accessible and affordable. Striking a balance between the cost of technology adoption and pricing mechanisms becomes a hurdle for these startups. Moreover, farmers tend to have a strong inclination towards traditional farming practices, making it essential for marketing strategies to not only raise awareness but also foster a positive attitude among farmers. This process can be time-consuming due to farmers' cautious decision making when it comes to adopting new technologies. The rural context, characterised by low digital literacy and limited technological skills, further compounds the marketing challenges faced by agritech startups. This challenge is particularly acute in the agricultural sector, as noted by Bahn et al. (2021) in their study of farmers' technology adoption. These findings provide additional context, showing that startups struggle to balance innovation with affordability for their primary customers – farmers.

Pricing of services (index value: 81.48) and lack of branding strategy (index value: 79.63) were also significant challenges. These findings expand on Pigford et al.'s (2018) work on agricultural innovation platforms by highlighting specific marketing hurdles faced by agri-startups.

The long gestation period for farmer adoption (index value: 77.47) was another key challenge identified in this study. This aligns with de Roo et al.'s (2019) research on technology adoption in rural communities, but findings provide a quantitative measure of this challenge in the agri-startup context.

5.4.3 Financial challenges

Effective cash management emerged as the primary financial challenge (index value: 81.17). This finding adds nuance to Graef et al.'s (2018) study on funding patterns in agri-tech startups. While their research focused on sources of funding, this study highlights the operational challenges of financial management faced by startups. Effective cash management for working capital is a major concern, especially since many startups rely on self-funding as a bootstrap source. The seasonal nature of agriculture adds to the complexity of managing cash flow during off-seasons. Startups focused on a single crop or product are particularly vulnerable to revenue fluctuations caused by market forces or weather-related events. The upfront costs associated with agriculture contribute to a longer time to reach breakeven, further exacerbating the challenges related to cash management. Additionally, the lack of leadership skills to effectively manage the enterprise is identified as a difficult task for startup founders.

5.4.4 Other challenges

Lack of information about government policies and programs to promote startups was the most significant challenge in this category (index value: 80.25). This finding contrasts with Klerkx et al.'s (2019) emphasis on the importance of government policies, suggesting a gap between policy creation and dissemination in the agri-startup ecosystem.

Issues with intellectual property rights (index value: 75.62) also emerged as a significant challenge. This aligns with Fielke et al.'s (2020) framework for responsible innovation in digital agriculture, which emphasises the importance of addressing ethical and legal concerns.

This study also revealed challenges related to the influence of external organisations (index value: 74.38) and competition from public advisory services (index value: 73.46). These findings provide new insights into the complex ecosystem dynamics faced by agri-startups, extending beyond the focus of previous studies. Overall, the research findings shed light on the multiple challenges faced by agri startups, encompassing issues related to startup establishment, marketing, finance, and external stakeholders. Recognising and addressing these challenges is crucial for the growth and success of agri startups in the agricultural sector.

5.5 Practical cases illustrating stakeholder roles and relationships

5.5.1 Case 1: AgroStar (India)

AgroStar, a digital farmer network and agri-inputs platform, demonstrates the power of effectively engaging multiple stakeholders:

- Farmers (customers): Mehta et al. (2020) analysed AgroStar's approach of building trust through free agronomic advice, addressing the challenge of farmer adoption. Their study found that this strategy increased farmer engagement by 40% over a two-year period.
- Financial stakeholders: Raj et al. (2021) documented AgroStar's success in raising multiple rounds of funding, totaling over $60 million, overcoming the self-funding trap that Tripathi et al. (2019) identified as a common challenge for agri-startups.
- Government: Singh and Patel (2022) examined how AgroStar navigated regulatory challenges to sell agri-inputs directly to farmers, highlighting the importance of policy engagement for agri-startups.
- Telecommunication groups: Kumar (2023b) analysed AgroStar's partnerships with telecom providers, showing how these collaborations increased the platform's reach by 65% in rural areas.

5.5.2 Case 2: DeHaat (India)

DeHaat, providing end-to-end agricultural services to farmers, highlights several ecosystem dynamics:

- Power of partnerships: Mehta and Joshi (2021) studied DeHaat's collaboration with over 100 institutional partners, demonstrating a 30% increase in service efficiency due to these partnerships.
- Technology adoption: Sharma and Rao (2023) examined DeHaat's successful introduction of AI-based customised crop advisory, showing a 25% increase in crop yield for adopting farmers, thus navigating the challenge of technological adoption among farmers.

5.5.3 Case 3: Fasal (India)

Fasal, an AI-powered IoT-SaaS platform for horticulture, illustrates the impact of technological advancements:

- Precision agriculture: Reddy (2022) studied Fasal's use of IoT and AI for precise farming advice, finding a 20% reduction in water usage and a 15% increase in crop quality among users.
- Research collaboration: Deshmukh and Patel (2021) analysed Fasal's partnerships with agricultural universities, showing how these collaborations accelerated the development and validation of new technologies.
- Investor confidence: Kumar (2023a) documented Fasal's success in securing funding from both domestic and international investors, totalling $12 million, demonstrating how innovative agri-tech solutions can attract diverse financial stakeholders.

5.5.4 The agricultural startup ecosystem: interactions and dynamics

The agricultural startup ecosystem, as depicted in Figure 1, is a complex adaptive system characterised by multiple stakeholders, intricate interactions, and feedback loops.

Understanding these dynamics is crucial for comprehending the challenges and opportunities faced by agri-startups.

5.5.4.1 Core interactions and primary feedback loops

At the center of the ecosystem are the startup entrepreneurs, who interact directly with potential customers (primarily farmers). This interaction forms a critical feedback loop:

- Entrepreneurs develop innovative solutions → Farmers adopt and provide feedback → Entrepreneurs refine their products/services.

This primary loop is fundamental to the success of agri-startups. Study found that 87.04% of startups considered ensuring product quality while keeping costs low as a major challenge, highlighting the importance of this feedback mechanism.

5.5.4.2 Financial stakeholder interactions

Financial stakeholders, including angel investors, banks, and venture capital firms, interact with startups through funding mechanisms. This creates another crucial feedback loop:

- Startups demonstrate potential → Financial stakeholders provide funding → Startups develop and grow → Increased potential attracts more funding

This study finding that 86.1% of startups relied on self-funding indicates a potential breakdown in this loop, suggesting a need for stronger connections between startups and financial stakeholders.

5.5.4.3 Policy and regulatory feedback mechanisms

Policy-related stakeholders, including government institutions and research organisations, create an enabling environment for startups. This forms a slower, but equally important feedback loop:

- Startups innovate and grow → Policy makers observe impact → Policies are adjusted to support innovation → Startups respond to new policy environment.

The challenge of multiple regulatory clearances (80.86% index value) identified in this study suggests friction in this feedback loop, indicating a need for more responsive policy mechanisms.

5.5.4.4 Knowledge and support network dynamics

Supporting stakeholders, including technical experts, incubators, and consultants, form a knowledge network around startups. This creates a continuous learning loop:

- Startups identify challenges → Support network provides expertise → Startups implement solutions → New challenges emerge.

The importance of this loop is evident in finding that 78.70% of startups cited lack of mentorship in the ideation stage as a major challenge.

5.5.4.5 Market and competition dynamics

Marketing networks, including industry associations and competitors, create a complex competitive environment. This forms a dynamic feedback loop:

- Startups enter the market → Competitive pressures increase → Startups innovate to differentiate → Market evolves.

This study finding that 79.63% of startups struggle with branding strategy underscores the challenges within this competitive dynamic.

5.5.4.6 Social and community feedback mechanisms

Social associations, including community groups and employee associations, provide a grassroots feedback mechanism:

- Startups introduce innovations → Communities adopt or resist → Startups adjust strategies → Community perceptions evolve.

The long gestation period for farmer adoption (77.47% index value) identified in this study highlights the complexity of this social feedback loop.

5.5.4.7 Information and media dynamics

Telecommunication and media groups play a crucial role in information dissemination, creating an overarching feedback loop:

- Startups launch products/services → Media coverage influences perceptions → Public and stakeholder awareness shifts → Startups adjust messaging and strategies.

The challenge of low skill adaptability and digital literacy among farmers (75.31% index value) underscores the importance of effective information dynamics in the ecosystem.

These interconnected feedback loops create a dynamic, nonlinear system where changes in one area can have cascading effects throughout the ecosystem. For example, a policy change aimed at easing regulatory burdens could simultaneously affect funding availability, market competition, and community adoption rates.

Moreover, these interactions occur across different time scales. While customer feedback might be relatively rapid, policy adjustments and community adoption patterns typically evolve more slowly. This temporal aspect adds another layer of complexity to the ecosystem.

The complexity of these interactions is further evidenced by this finding that 68.5% of startups reported medium levels of stakeholder engagement, suggesting that many are still grappling with effectively navigating these multifaceted relationships.

Understanding these dynamics is crucial for developing effective support strategies for agri-startups. For instance, interventions aimed at improving access to finance need to consider not just the availability of funds, but also how this interacts with regulatory environments, market dynamics, and community adoption patterns.

5.6 Impact of external environmental changes

5.6.1 Policy adjustments

Ayyagari et al. (2017) demonstrated that changes in agricultural or technology policies can reshape entire entrepreneurial ecosystems. For instance, Singh (2020) analysed the Indian Government's recent reforms in agricultural marketing laws, showing how these opened up new opportunities for agri-startups in supply chain management. The current study's finding that 80.25% of startups lack information about government policies aligns with Klerkx et al.'s (2019) observations on the critical role of policy awareness in agri-innovation systems.

5.6.2 Market fluctuations

Anand (2016) highlighted the notorious volatility of agricultural markets due to factors like weather conditions and global trade dynamics. Pingali et al. (2019) showed how these fluctuations can rapidly change the viability of certain startup models. Their study found that startups focused on export-oriented crops struggled during trade disputes, while those working on climate-resilient solutions saw increased interest during periods of extreme weather.

5.6.3 Technological advancements

Wolfert et al. (2017) documented how rapid advancements in technologies like AI, IoT, and biotechnology create new opportunities but also render some existing solutions obsolete. The challenge of low skill adaptability and digital literacy among farmers (75.31% index value in the current study) corroborates findings by Trendov et al. (2019), who highlighted how technological changes can create new barriers and opportunities simultaneously in agricultural innovation.

5.6.4 Environmental and climate changes

Lipper et al. (2014) demonstrated how climate change impacts agriculture and shapes the agri-startup ecosystem. Their study showed that startups focusing on sustainable and climate-resilient agriculture found increasing support and market demand. This trend is further supported by Steenwerth et al. (2014), who highlighted the growing importance of climate-smart agricultural innovations.

The system's response to these changes often involves a reconfiguration of stakeholder roles and relationships. Barrett (2020) analysed how, during the COVID-19 pandemic, many agri-startups pivoted to focus more on digital solutions and local supply chains. Their study revealed the necessity for closer collaboration with telecom stakeholders and local community associations in response to the crisis.

6 Conclusions

The rise of agricultural startups is driving a technological revolution within the agricultural industry. These startups are developing innovative solutions across various market connections, including retail, B2B, B2C marketplaces, and digital agronomy

platforms. The findings indicate that innovation in agricultural startups is primarily driven by younger, educated, and experienced individuals, predominantly males. There is a critical need to support female entrepreneurs and diversify the educational and professional backgrounds to enhance innovation and sustainability in the agricultural sector. The majority of respondents (68.5%) reported medium levels of stakeholder engagement, indicating a substantial recognition of stakeholders' importance in their operations. However, with only 3.9% reporting high engagement levels, there remains significant room for improvement. Agri startups should aim to enhance their stakeholder engagement strategies to fully leverage the support, resources, and opportunities offered by various stakeholder groups, thereby driving their growth and success more effectively. The analysis of stakeholder engagement within agri startups reveals a moderate to strong level of engagement across various stakeholder groups, with an overall stakeholder engagement index of 0.720. This indicates a generally positive but varied interaction with different stakeholders, each contributing uniquely to the performance and growth of agri startups. Engaging with diverse stakeholders ranging from investors, customers, and government bodies to industry experts and the broader community provides startups with essential resources, knowledge, and support. Despite the promising potential, agricultural startups face challenges such as small landholdings, limited returns on investments, affordability constraints, and skill gaps among farmers, which require immediate attention. To ensure their prosperity, startups must align with farmers' needs, boost productivity, and develop business models tailored to their target audience. Addressing these challenges will require extensive effort and a deep understanding of the agricultural sector's intricacies.

7 Recommendations

1 Develop comprehensive engagement strategies: startups should create targeted strategies for engaging different stakeholder groups, focusing on high-potential areas such as potential customers, financial stakeholders, social associations, and marketing networks.

2 Improve policy-related and supporting stakeholder engagement: invest in building stronger relationships with government bodies, regulatory agencies, and supporting stakeholders like technical experts and business incubators. This can help navigate regulatory frameworks and access essential resources more efficiently.

3 Initiate support programs for women: implement programs that encourage and support female entrepreneurs in the agricultural sector. This includes providing mentorship, funding, and networking opportunities specifically tailored to women.

4 Support small landholdings and improve ROI: develop business models that are scalable and provide adequate returns on investment even for small-scale farmers. This may include collaborative farming models or technology solutions that enhance yield.

5 Collaborate with social associations and NGOs: engage more effectively with social associations and NGOs to enhance community involvement, social impact, and corporate social responsibility initiatives. These collaborations can also help in addressing broader societal issues like sustainability and environmental conservation.

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