

International Journal of Agriculture Extension and Social Development

Volume 9; Issue 2; February 2026; Page No. 279-288

Received: 03-12-2025
Accepted: 09-01-2026

Indexed Journal
Peer Reviewed Journal

Factors influencing farmers' perception of agri-tech startup: Farmer Producer Organizations (FPO) integration for improved extension advisory services

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DOI: <https://www.doi.org/10.33545/26180723.2026.v9.i2d.3051>

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Abstract

The integration of Agri-Tech Startups with Farmer Producer Organizations (FPOs) has emerged as a promising approach to enhance Extension Advisory Services and support smallholder farmers in India. This study explores the factors influencing farmers' perception of such integration in Telangana and Chhattisgarh, two states with contrasting agro-economic and digital adoption contexts. A total of 300 farmers from ten purposively selected FPOs (five per state) were surveyed during 2022-2024, and 21 socio-personal, economic, behavioral, communicational, and institutional variables were analyzed using correlation, multiple regression, and stepwise regression techniques. In the overall pooled analysis, correlation analysis revealed that 4 variables were significant at the 0.05 level: age, Information seeking behaviour, Farmers empowerment and training received. Further, 12 variables showed significance at the 0.01 level: education, annual income, extension contact, innovativeness, risk orientation, mobile inclination, FPO membership, attitude of farmers towards FPO, Cosmopolitanism, Social participation and satisfaction level of farmers towards FPO. Notably, experience, landholding, economic orientation, management orientation and credit acquisition remained non-significant, suggesting that integration potential is less dependent on resource capacity and more on adaptive behavior, technology inclination, and trust in FPO mechanisms. Multiple regression models explained 67.7% of perception variation in Telangana, 59.7% in Chhattisgarh, and 63.0% overall, indicating substantial explanatory power of the selected variables. Stepwise regression identified ten key predictors: age, annual income, innovativeness, mobile inclination, FPO membership, cosmopolitanism, social participation, participation in FPO activities, satisfaction, and empowerment. Among these, satisfaction emerged as the strongest predictor, highlighting the role of positive prior experiences and trust in fostering favorable perceptions. The findings underline the importance of enhancing satisfaction, encouraging digital adoption, and strengthening empowerment to promote positive perceptions and wider acceptance of Agri-Tech-FPO integration in agricultural advisory systems. The findings provide a comprehensive understanding of how farmers perceive the potential of Agri-Tech-FPO collaborations in enhancing agricultural advisory systems, highlighting dimensions that can guide targeted interventions, training, and policy measures to strengthen digital agriculture initiatives in diverse regional contexts.

Keywords: Factors, agri-tech startup, FPO, integration, perception, extension advisory services

1. Introduction

India is strengthening its position in global agriculture, yet about 82% of farmers are small or marginal landholders who face low productivity and persistent poverty. Fragmented holdings limit adoption of innovative practices, mixed cropping, and economies of scale, while restricting access to quality inputs, advanced seeds, and modern technologies (Adhikari *et al.*, 2021) ^[1]. Integrating farmers into collective structures is essential to overcome these barriers (Vadivelu and Kiran, 2013) ^[20]. Farmer Producer Organizations (FPOs) have emerged as transformative models, legally recognized as cooperatives or producer companies, owned and governed by farmers. They enable collective procurement, produce aggregation, and access to finance and institutional support (Kurien, 2004) ^[11], empowering smallholders and enhancing market participation (Markelova *et al.*, 2009) ^[12]. Agri-tech startups complement FPOs by providing digital tools, precision

technologies, crop monitoring, mobile advisory services, and smart supply chains. Partnerships between FPOs and startups improve farmers' access to markets and technologies while addressing operational and quality challenges in connecting with agribusiness corporates (Spender, 2014, Colombo & Piva, 2008; Davila *et al.*, 2003; Mustar *et al.*, 2008) ^[18, 5, 7, 14].

The adoption of Agri-tech innovations is a decision-making process influenced by a complex confluence of socio-economic, perceptual, technological, institutional, and behavioral factors (Cui & Wang, 2023) ^[6]. The adoption is not solely an economic calculation but is deeply influenced by a farmer's personal context and external support systems. Socio-economic features consistently emerge as fundamental determinants, with studies acknowledging the roles of age, education, marital status, income, gender, health, and cooperative membership in shaping opinions toward digital agriculture (Meijer *et al.*, 2015; Pfeiffer *et al.*,

2021; Cui & Wang, 2023; Izuogu *et al.*, 2022; Pishnyak & Khalina, 2021) ^[13, 15, 6, 9, 16]. Specific findings indicate that older individuals and part-time farmers often express more negative perceptions due to limited digital familiarity (Bontsa *et al.*, 2023) ^[3]. Conversely, while farming experience and income show a positive correlation with technology utilization, higher education does not always translate to positive attitudes, particularly when technologies fail to align with local practices (Bontsa *et al.*, 2023; Izuogu *et al.*, 2022; Kaur & Singh, 2021) ^[3, 9, 10]. Furthermore, farm-specific factors, such as farm size or the type of farming enterprise, indirectly affect the perceived feasibility and evaluation of digital tools (Cui & Wang, 2023; Reissig *et al.*, 2022) ^[6, 17].

Beyond static personal attributes, a farmer's perceptual and behavioral dimensions are key drivers of adoption. The perceived characteristics of the technology itself, specifically usefulness, ease of use (Caffaro *et al.*, 2020) ^[4], reliability, and safety (Pishnyak & Khalina, 2021) ^[16], are critical. Innovations perceived to contribute to better productivity, enhanced precision, and improved results are seen favorably (Adrian *et al.*, 2005) ^[1]. At a psychological level, perceived profitability and risk tolerance significantly shape adoption attitudes (Cui & Wang, 2023) ^[6]. However, these benefits are frequently tempered by constraints. Negative perceptions are associated with high costs, digital inequality, and the inadequate integration of Indigenous Knowledge systems (Caffaro *et al.*, 2020) ^[4]. Challenges such as poor internet access, high costs of tools, and limited digital skills act as key deterrents, alongside concerns that digital technologies may displace traditional knowledge and limit social interaction (Izuogu *et al.*, 2022) ^[9].

Finally, the social and institutional environment plays a crucial, mediating role. Subjective norms, like beliefs and practices accepted by peers, can profoundly shape a farmer's perception of innovation, often holding more weight than the technical attributes (Dissanayake *et al.*, 2022) ^[8]. Social structures like cooperative membership are vital, enhancing peer learning, reducing uncertainty (Caffaro *et al.*, 2020; Meijer *et al.*, 2015) ^[4, 13], and utilizing informal communication channels as trusted sources of information (Thomas *et al.*, 2023) ^[19]. Institutionally, factors such as government subsidies, extension services, and access to credit enhance adoption by mitigating financial and perceived risks (Cui & Wang, 2023) ^[6]. Therefore, promoting Agri-tech requires addressing not only technical gaps but also infrastructural deficits and ensuring the local relevance and affordability of the solutions to secure inclusive and sustained adoption (Izuogu *et al.*, 2022) ^[9].

2. Methodology

The present study employed an exploratory research design to investigate the relatively nascent and under-explored ecosystem of Agri-Tech startups and Farmer Producer Organizations (FPOs) in the context of Extension Advisory Services (EAS). This design was considered appropriate for capturing emerging institutional linkages, operational mechanisms, and contextual dynamics in a domain where empirical evidence is still evolving.

The research was conducted during 2022 to 2024 in the Indian states of Telangana and Chhattisgarh. These states were purposively selected to represent contrasting

agricultural and socio-economic environments. Telangana is characterized by relatively higher levels of digital adoption, stronger institutional support, and improved market connectivity, whereas Chhattisgarh reflects a transitional agricultural landscape where modernization processes are progressively unfolding. Examining these diverse contexts enabled the development of insights that are both regionally grounded and broadly applicable.

An initial database of active FPOs was compiled from multiple institutional sources, including the Small Farmers' Agribusiness Consortium (SFAC), National Bank for Agriculture and Rural Development (NABARD), State Departments of Agriculture, and relevant non-governmental organizations. From this pool, ten FPOs—five from each state—were purposively selected based on the following criteria: (i) a minimum operational history of four years, (ii) at least 350 member farmers, (iii) active engagement in core business functions such as aggregation, input supply, marketing, value addition, or processing, (iv) adoption of at least one digital or Agri-Tech tool, and (v) established institutional linkages with startups, Krishi Vigyan Kendras (KVKs), NGOs, or government agencies.

Subsequently, 30 member farmers were randomly selected from each FPO, resulting in a total sample size of 300 respondents, with equal representation (150 each) from both states. This sampling approach ensured adequate heterogeneity while maintaining statistical robustness.

The study incorporated 21 independent variables, i.e., age, education, farming experience, landholding, annual income, extension contact, innovativeness, risk orientation, economic orientation, information-seeking behavior, mobile inclination, management orientation, FPO membership, attitude toward FPOs, credit acquisition, cosmopolitanism, training received, social participation, participation in FPO activities, level of satisfaction, and farmer empowerment. The dependent variable was to study the farmers' perception of Agri-Tech startup-FPO integration in enhancing extension advisory services.

Primary data pertaining to farmers' socio-personal, economic, communicational, and institutional characteristics were systematically collected using a structured interview schedule. The data were coded, tabulated, and analyzed to examine the distribution of respondent characteristics and their relationship with the dependent variable. To identify the determinants influencing farmers' perceptions of Agri-Tech-FPO integration for improved advisory services, correlation analysis and stepwise multiple regression were performed using the IBM SPSS Statistics platform. These statistical techniques facilitated the identification of significant predictor variables and provided a robust explanation of the factors shaping farmers' views regarding the relevance and effectiveness of such collaborative extension models.

3. Results

3.1 Profile characteristics of farmers (Independent variables)

The data presented in Table 1 reflect the profile characteristics of farmers from Telangana and Chhattisgarh. Across both states, most respondents (37%) belonged to the 46-57 years' age group. Regarding education, 25.67% had completed high school (9th-10th class). A considerable share

(30.67%) had more than 18 years of farming experience. The majority (83%) reported an annual income between Rs. 50,000 and Rs. 1,50,000 lakhs, with 42.33% earning Rs. 1 to 1.5 lakh and 40.67% between Rs. 0.5-1 lakh. Marginal farmers (up to 1 ha) constituted the largest group (41%). In terms of extension contact, 70.33% of respondents were in the medium category, while 57% exhibited a medium level of information-seeking behaviour. Social participation was moderate, with 53% holding memberships in multiple organizations and 22.33% in leadership roles. Similarly, 62.67% showed a medium level of cosmopolitanism and 49% a medium level of innovativeness. More than half (53%) displayed a high level of risk orientation, and 52% had high economic orientation. Management orientation was moderate among 43.33% of respondents. With respect to

mobile inclination, 56.67% demonstrated medium mobile inclination. A majority (77%) had undergone some form of training, and 74.33% had accessed agricultural credit, with a slightly higher share in Chhattisgarh (78.67%) than Telangana (70%). Among FPO activities, participation was highest in training orientation (69.50%), followed by market orientation (67.33%), formation of FPOs (64.83%), and production orientation (63.17%). In terms of attitude towards FPO, 59.34% exhibited a moderately favourable attitude, while 24.33% had a highly favourable one. Overall satisfaction with FPOs was medium among 60.67% of respondents. Half of the respondents (50%) reported a medium level of empowerment, reflecting balanced social, economic, and leadership gains through FPO participation.

Table 1: Distribution of respondents according to their profile characteristics

Category	Telangana (n = 150)		Chhattisgarh (n = 150)		Overall (n = 300)	
	F	%	F	%	F	%
Age						
24-34 years	51	34.00	45	30.00	96	32.00
35-45 years	40	26.67	53	35.33	93	31.00
46-57 years	59	39.33	52	34.67	111	37.00
Education						
Illiterate	0	0.00	21	14.00	21	7.00
Primary (Up to 5th class)	36	24.00	22	14.67	58	19.33
Middle (6th to 8th class)	25	16.67	33	22.00	58	19.33
High School (9th to 10 th class)	34	22.67	43	28.67	77	25.67
Higher Secondary (11th to 12 th class)	33	22.00	23	15.33	56	18.67
Graduate and above	22	14.66	8	5.33	30	10.00
Farming Experience						
3 to 7 years	26	17.33	38	25.33	64	21.33
8 to 12 years	35	23.33	39	26.01	74	24.67
13 to 17 years	35	23.33	35	23.33	70	23.33
Above 18 years	54	36.01	38	25.33	92	30.67
Annual income						
Up to Rs. 50,000	4	2.67	21	14.00	25	8.33
Rs. 50,001 to Rs. 1,00,000	59	39.33	51	34.00	110	40.67
Rs. 1,00,001 to Rs. 1,50,000	71	47.34	68	45.33	139	42.33
Rs. 1,50,001 to Rs. 2,00,000	12	8.00	7	4.67	19	6.33
More than Rs. 2,00,000	4	2.67	3	2.00	7	2.33
Land Holding						
Marginal (Up to 1.0 ha)	47	31.33	76	50.67	123	41.00
Small (1.0 to 2.0 ha)	32	21.33	51	34.00	83	27.67
Medium (2.0 to 3.0 ha)	39	26.00	20	13.33	59	19.66
Large (Above 4.0 ha)	32	21.33	3	2.00	35	11.67
Extension contact						
Low (8 to 11 score)	14	9.33	36	24.00	50	16.67
Medium (12 to 15 score)	113	75.33	98	65.33	211	70.33
High (Above 16 score)	23	15.33	16	10.67	39	13.00
Information seeking behaviour						
Low (38 to 45 score)	40	26.67	18	12.00	58	19.33
Medium (46 to 53 score)	87	58.00	84	56.00	171	57.00
High (Above 54 score)	23	15.33	48	32.00	71	23.67
Social Participation						
Membership in one organization	37	24.67	37	24.67	74	24.67
Membership in more than one organization	81	54.00	78	52.00	159	53.00
Holding position in an organization	32	21.33	35	23.33	67	22.33
Cosmopolitanism						
Low (11 to 15 score)	20	13.33	31	20.67	51	16.33
Medium (16 to 19 score)	97	64.67	91	60.66	188	62.67
High (Above 20 score)	33	22.00	28	18.67	61	20.33
Innovativeness						
Low (29 to 33 score)	22	14.67	29	19.33	51	17.00
Medium (34 to 38 score)	75	50.00	72	48.00	147	49.00
High (Above 39 score)	53	35.33	49	32.67	102	34.00

Risk orientation						
Low (18 to 23 score)	1	0.67	28	18.67	29	9.67
Medium (24 to 29 score)	32	21.33	80	53.33	112	37.33
High (Above 30 score)	117	78.00	42	28.00	159	53.00
Economic orientation						
Low (21 to 25 score)	4	2.67	12	8.00	16	5.33
Medium (26 to 30 score)	52	34.66	76	50.67	128	42.67
High (Above 31 score)	94	62.67	62	41.33	156	52.00
Management orientation						
Low (6 to 9 score)	48	32.00	48	32.00	96	32.00
Medium (10 to 11 score)	63	42.00	67	44.67	130	43.33
High (Above 12 score)	39	26.00	35	23.33	74	24.67
Mobile inclination						
Low (38 to 42 score)	4	2.67	60	40.00	64	21.33
Medium (43 to 47 score)	89	59.33	81	54.00	170	56.67
High (Above 48 score)	57	38.00	9	6.00	66	22.00
Training received						
Training received	125	83.33	106	70.67	231	77.00
Training not received	25	16.67	44	29.33	69	23.00
Credit Acquisition						
Acquired	105	70.00	118	78.67	223	74.33
Not acquired	45	30.00	32	21.33	77	25.67
FPO Membership:						
Member of FPO						
Yes	150	100.00	150	100.00	300	100.00
No	0	0.00	0	0.00	0	0.00
Years of Membership in FPO						
1 to 2 years	28	18.67	29	19.33	57	19.00
2 to 4 years	32	21.33	39	26.00	71	23.67
More than 4 years	90	60.00	82	54.67	172	57.33
Participation in FPO activities*						
Formations of FPO	211	70.33	178	59.33	389	64.83
Production orientation activities of FPO	196	65.33	183	61.00	379	63.17
Training orientation activities of FPO	217	72.33	200	66.67	417	69.50
Market orientation activities of FPO	211	70.33	193	64.33	404	67.33
Attitude towards FPO						
Less favourable (67 to 76 score)	32	21.33	17	11.33	49	16.33
Moderately favourable (77 to 85 score)	93	62.00	85	56.67	178	59.34
High favourable (Above 86 score)	25	16.67	48	32.00	73	24.33
Satisfaction towards FPOs						
Low (37 to 44 score)	35	23.33	32	21.33	67	22.33
Medium (45 to 51 score)	88	58.67	94	62.67	182	60.67
High (Above 52 score)	27	18.00	24	16.00	51	17.00
Farmers empowerment						
Low (26 to 35 score)	34	22.67	39	26.00	73	24.33
Medium (36 to 45 score)	74	49.33	76	50.67	150	50.00
High (Above 46 score)	42	28.00	35	23.33	77	25.67

Dependent variable (Perception of farmers about Agri-Tech startups - Farmer Producer Organization (FPO) integration for improved Extension Advisory Services)

The data presented in the table 2 indicates that perception level of farmers regarding the integration of Agri-Tech startups with Farmer Producer Organizations (FPOs). At the Overall level, 62.00% of respondents demonstrated a medium perception, while both low and high perception categories were evenly distributed at 19.00% each. This

pattern highlights the need for targeted sensitization and digital literacy initiatives, to enhance understanding and confidence in Agri-Tech-FPO integration. Improving farmers' exposure to successful models, facilitating participatory training, and showcasing real-time benefits could help shift perception levels from medium or low to high, thus fostering greater adoption of digital innovations in agriculture.

Table 2: Distribution of respondents according to their level of perception towards Agri-Tech startups - Farmer Producer Organization (FPO) integration

S. No	Category	Telangana (n = 150)		Chhattisgarh (n = 150)		Overall (n = 300)	
		F	%	F	%	F	%
1.	Low (66 to 78 score)	16	10.67	41	27.33	57	19.00
2.	Medium (79 to 92 score)	102	68.00	84	56.00	186	62.00
3.	High (Above 93 score)	32	21.33	25	16.67	57	19.00

4. Discussion

4.1 Factors influencing farmers' perception of Agri-Tech startups-FPO integration

In this section, an attempt was made to identify the various factors (independent variables) that influence the perception of farmers towards the integration of Agri-Tech Startups with Farmer Producer Organizations (FPOs) for improved Extension Advisory Services. To achieve this, both correlation analysis and stepwise regression analysis were

carried out.

4.1.1 Correlation Analysis

The data presented in table 3 provides insights into the relationship between the selected independent variables and the farmers' perception towards the integration of Agri-Tech Startups with Farmer Producer Organizations (FPOs) for improved Extension Advisory Services.

Table 3: Correlation coefficient between independent variables and perception of farmers towards the integration of Agri-Tech Startups with Farmer Producer Organizations (FPOs) for improved Extension Advisory Services

S. No	Variables	Correlation Coefficient		
		Telangana (n=150)	Chhattisgarh (n=150)	Overall (n=300)
1.	Age	-0.178*	-0.165*	-0.172*
2.	Education	0.218**	0.219**	0.251**
3.	Experience	-0.171*	0.210**	0.063 NS
4.	Land holding	0.034 NS	0.108 NS	0.135 NS
5.	Annual income	0.192*	0.167*	0.185**
6.	Extension contact	0.215**	0.192*	0.248**
7.	Innovativeness	0.228**	0.168*	0.249**
8.	Risk orientation	0.186*	0.249**	0.255**
9.	Economic orientation	0.078 NS	0.047NS	0.108 NS
10.	Information seeking behaviour	0.172*	0.182*	0.141*
11.	Mobile inclination	0.214**	0.212**	0.258**
12.	Management orientation	0.089 NS	0.030NS	0.057 NS
13.	FPO membership	0.172*	0.210**	0.235**
14.	Attitude of farmers towards FPO	0.219**	0.226**	0.298**
15.	Credit acquisition	0.089 NS	-0.164*	-0.063 NS
16.	Cosmopoliteness	0.181*	0.173*	0.186**
17.	Social participation	0.188*	0.037NS	0.179**
18.	Participation in FPO activities	0.197*	0.209*	0.244**
19.	Training received	0.174*	0.040 NS	0.126*
20.	Satisfaction level of farmers towards FPO	0.242**	0.213**	0.212**
21.	Farmers empowerment	0.171*	0.179*	0.218*

*Correlation is significant at the 0.05 level

NS = Not Significant

**Correlation is significant at the 0.01 level.

- 1. Age and Perception:** Age demonstrated a negative and statistically significant correlation with farmers' perception of Agri-Tech Startup and FPO integration in Telangana (-0.178*), Chhattisgarh (-0.165*), and overall (-0.172*). This indicates that younger farmers expressed a more favourable perception toward the integration of Agri-Tech Startups with FPOs for strengthening extension advisory services. Younger farmers are typically more tech-oriented, adaptable, and receptive to digital innovations, while older farmers may show reluctance due to limited digital exposure and reliance on conventional practices. These findings underscore the importance of designing age-responsive awareness and training programmes, especially to enhance the digital readiness of senior farmers.
- 2. Education and Perception:** Education exhibited a positive and highly significant correlation with farmers' perception of Agri-Tech-FPO integration in Telangana (0.218**), Chhattisgarh (0.219**), and overall (0.251**). This indicates that better-educated farmers are more receptive to digital and institutional innovations. Education improves their ability to access, understand, and apply new technologies, enabling effective engagement with extension advisory services.

The findings suggest that strengthening rural education and digital literacy can enhance farmer acceptance of Agri-Tech-driven extension models.

- 3. Experience and Perception:** Experience showed contrasting correlations with farmers' perception of Agri-Tech-FPO integration, being significantly negative in Telangana (-0.171*), significantly positive in Chhattisgarh (0.210**), and non-significant overall (0.063NS). This indicates region-specific effects of farming experience. In Telangana, experienced farmers may rely more on traditional practices, whereas in Chhattisgarh, institutional exposure may foster positive perceptions. The weak overall association suggests that experience alone is not a universal predictor, highlighting the need for region-specific training and awareness programmes.
- 4. Land Holding and Perception:** Landholding showed a non-significant correlation with farmers' perception towards the integration of Agri-Tech Startups with FPOs for improved Extension Advisory Services in Telangana (0.034 NS), Chhattisgarh (0.108 NS), and overall (0.135 NS). This indicates that farm size does not meaningfully influence perception, as farmers across landholding categories are equally receptive or

skeptical. The neutrality may reflect the inclusive nature of FPO- and startup-led services, suggesting that extension strategies should focus more on awareness and digital readiness than landholding size.

5. **Annual Income and Perception:** Annual income showed a positive and significant correlation with farmers' perception towards the integration of Agri-Tech Startups with FPOs for improved Extension Advisory Services in Telangana (0.192*), Chhattisgarh (0.167*), and overall (0.185**). This indicates that farmers with higher income levels perceive the integration more favourably, as they are better positioned to invest in digital tools and advisory services. In contrast, lower-income farmers may view such integration as financially risky. The findings highlight the role of economic capacity and suggest the need for supportive and subsidized extension models for resource-poor farmers.
6. **Extension Contact and Perception:** Extension contact showed a positive and statistically significant correlation with farmers' perception in Telangana (0.215**), Chhattisgarh (0.192*), and overall (0.248**). This indicates that farmers who interact more frequently with extension personnel tend to hold a more favourable perception of digital and institutional innovations. Regular extension contact enhances awareness, trust, and understanding of new advisory approaches, thereby reinforcing acceptance. The findings highlight the crucial role of extension systems and personnel in shaping positive farmer perceptions and facilitating the diffusion of Agri-Tech-based advisory models.
7. **Innovativeness and Perception:** Innovativeness showed a positive and significant correlation with farmers' perception in Telangana (0.228**), Chhattisgarh (0.168*), and overall (0.249**). This indicates that farmers who are more open to experimentation and early adoption tend to view digital and institutional innovations more favourably. Their willingness to try new practices enhances acceptance of technology-based advisory approaches. Such farmers often act as early adopters and influencers, suggesting that engaging innovative farmers can accelerate wider diffusion of Agri-Tech-driven extension models.
8. **Risk Orientation and Perception:** Risk orientation showed a positive and statistically significant correlation with farmers' perception in Telangana (0.186*), Chhattisgarh (0.249**), and overall (0.255**). This indicates that farmers with higher risk tolerance are more receptive to digital and institutional innovations. Their willingness to experiment and move beyond traditional practices enhances acceptance of startup-led advisory approaches. The findings suggest that minimizing perceived risks through demonstrations, evidence of success, and incentives can improve perceptions even among more risk-averse farmers.
9. **Economic Orientation and Perception:** Economic orientation showed a non-significant correlation with farmers' perception in Telangana (0.078 NS), Chhattisgarh (0.047 NS), and overall (0.108 NS). This suggests that a farmer's profit or commercial outlook

alone does not strongly shape perception. While income improvement is important, favourable perceptions appear to depend more on awareness, accessibility, and demonstrated benefits. The findings imply that perception-building efforts should emphasize clear outcomes, ease of use, and practical advantages rather than relying solely on economic motivation.

10. **Information Seeking Behaviour and Perception:** Information seeking behaviour showed a positive and significant correlation with farmers' perception in Telangana (0.172*), Chhattisgarh (0.182*), and overall (0.141*). This indicates that farmers who actively search for agricultural information tend to hold more favourable perceptions of digital and institutional innovations. Their curiosity and awareness enhance receptiveness to advisory services and new practices. The findings emphasize the need to strengthen information access and ICT-based dissemination to improve farmer engagement and perception.
11. **Mobile Inclination and Perception:** Mobile Inclination exhibited a highly significant positive correlation with farmers' perception in Telangana (0.214**), Chhattisgarh (0.212**), and Overall (0.258**). Farmers who actively use mobile phones for agricultural purposes are more favorable toward Agri-Tech-FPO integration. Familiarity with mobile technology facilitates access to digital advisory services, market updates, weather alerts, and mobile applications, improving knowledge sharing and decision-making. This strong relationship highlights the importance of promoting mobile literacy and smartphone adoption to enhance the effectiveness, reach, and impact of digital agriculture interventions among farmers.
12. **Management Orientation and Perception:** Management Orientation showed a non-significant correlation in Telangana (0.089 NS), Chhattisgarh (0.030 NS), and Overall (0.057 NS), indicating that a farmer's planning and decision-making skills do not significantly influence their perception of Agri-Tech-FPO integration. While managerial aptitude is valuable for farm operations, it alone does not determine receptiveness to technology-based advisory services. Awareness, training, and exposure to digital tools are essential to enhance understanding and adoption, as farmers may rely on traditional knowledge despite strong management skills.
13. **FPO Membership and Perception:** FPO Membership showed a positive and significant correlation in Telangana (0.172*), Chhattisgarh (0.210**), and Overall (0.235**), indicating that farmers who are members of FPOs have a more favorable perception of Agri-Tech adoption. Membership exposes farmers to collective decision-making, institutional services, and startup-driven technologies. This experience fosters understanding of digital advisory benefits and encourages participation. Strengthening FPOs and promoting membership can enhance awareness, trust, and acceptance of Agri-Tech initiatives among rural farmers.
14. **Attitude of Farmers towards FPO and Perception:** Farmers' positive attitude toward FPOs showed a

strong correlation in Telangana (0.219**), Chhattisgarh (0.226**), and Overall (0.298**), reflecting that trust and satisfaction with FPOs enhance perception of Agri-Tech services. Favorable attitudes increase openness to innovations introduced through FPOs, reinforcing credibility and acceptance of digital advisory services. Building positive institutional image and trust in FPOs is crucial, as it enables effective dissemination of Agri-Tech solutions and supports scalable, farmer-centric extension interventions.

15. Credit Acquisition and Perception: Credit Acquisition showed mixed correlations: Telangana (0.089 NS), Chhattisgarh (-0.164*), and Overall (-0.063 NS), indicating inconsistent influence on farmers' perception of Agri-Tech adoption. While access to credit can provide financial security for technology adoption, in some cases, credit-related stress or dissatisfaction with formal systems may reduce receptiveness. These results highlight that credit alone is insufficient; financial literacy, supportive mechanisms, and risk mitigation strategies are essential to ensure that farmers can effectively engage with technology-driven advisory services.

16. Cosmopolitanism and Perception: Cosmopolitanism showed a positive correlation in Telangana (0.181*), Chhattisgarh (0.173*), and Overall (0.186**), indicating that farmers who frequently interact with cities, institutions, and markets have a more favorable perception of Agri-Tech. Exposure to innovations, success stories, and broader agricultural developments enhances acceptance of digital advisory services. Cosmopolite farmers also act as influencers and information carriers within their communities. Encouraging mobility, exposure visits, and farmer exchange programs can strengthen awareness and adoption of Agri-Tech initiatives in rural areas.

17. Social Participation and Perception: Social Participation displayed a positive correlation in Telangana (0.188*), Chhattisgarh (0.037 NS), and Overall (0.179**), suggesting that socially active farmers are more receptive to Agri-Tech. Engagement in groups, cooperatives, and village institutions provides access to shared experiences, collaborative decision-making, and peer learning, which promotes understanding and acceptance of digital solutions. Though non-significant in Chhattisgarh, overall results show that social structures and community participation facilitate trust and knowledge flow, supporting the diffusion of Agri-Tech initiatives among rural farmers.

18. Participation in FPO Activities and Perception: Participation in FPO activities correlated positively in Telangana (0.197*), Chhattisgarh (0.209*), and Overall (0.244**), indicating that farmers actively involved in training, meetings, marketing, or planning perceive Agri-Tech more favorably. Engagement exposes farmers to startup collaborations and practical applications of digital tools, shaping positive perceptions. Active participants often serve as early adopters and influencers within FPOs. Promoting participation not only strengthens the organization but

also provides a platform for scaling Agri-Tech adoption at the grassroots level.

19. Training Received and Perception: Training participation showed a positive correlation in Telangana (0.174*), was non-significant in Chhattisgarh (0.040 NS), and weakly positive Overall (0.126*). Farmers exposed to relevant training demonstrate better understanding and perception of Agri-Tech. Training familiarizes them with new technologies, institutional mechanisms, and success stories, fostering trust and interest in innovation-led advisory systems. The non-significance in Chhattisgarh may reflect limited or ineffective content delivery. Regionally tailored, well-structured training is essential to enhance knowledge, awareness, and adoption of digital services through FPOs.

20. Satisfaction Level of Farmers towards FPO and Perception: Satisfaction with FPOs showed a strong positive correlation in Telangana (0.242**), Chhattisgarh (0.213**), and Overall (0.212**), indicating that content farmers perceive Agri-Tech more favorably. Satisfaction stems from efficient service delivery, transparency, economic gains, and trust in leadership, which builds confidence in institutional innovations. Satisfied members are more willing to adopt digital advisory services and innovations facilitated through FPOs. Strengthening internal governance, accountability, and responsiveness can enhance farmer trust and support for scaling Agri-Tech initiatives.

21. Farmers' Empowerment and Perception: Farmers' empowerment positively correlated with perception in Telangana (0.171*), Chhattisgarh (0.179*), and Overall (0.218*). Empowered farmers, confident in decision-making, resource control, and market participation, show a favorable outlook toward Agri-Tech. Empowerment enhances awareness, assertiveness, and readiness to adopt innovations, encouraging engagement with startups and FPO platforms. This highlights the importance of programs promoting self-reliance, leadership, and voice, as empowered farmers are more likely to embrace digital advisory services and contribute to the successful adoption of Agri-Tech in rural communities.

4.1.2 Multiple Regression Analysis

The multiple regression analysis, as shown in the table 4, conducted to determine the influence of 21 independent variables on farmers' perception towards Agri-Tech Startup-FPO integration revealed noteworthy findings. In Telangana, the model explained 67.7% of the variation in perception ($R^2 = 0.677$), suggesting a strong influence of the selected variables on farmers' attitudes towards enhanced extension advisory services. In Chhattisgarh, the R^2 value was 0.597, indicating that 59.7% of the variation in perception was explained by the model, reflecting a moderately strong association. At the overall level, the R^2 value stood at 0.637, confirming the substantial explanatory power of these variables across both states.

Table 4: Multiple regression analysis between independent variables and dependent variable

S. No	Variable	Telangana (n = 150)		Chhattisgarh (n = 150)		Overall (n = 300)	
		B value	t value	B value	t value	B value	t value
1.	Age (X ₁)	-0.120**	-2.441	-0.157**	-2.564	0.176**	-2.527
2.	Education (X ₂)	0.570*	2.076	0.286**	2.645	0.510**	2.015
3.	Experience (X ₃)	-0.104	-1.284	0.178**	2.032	0.040*	1.970
4.	Landholding (X ₄)	-0.424	-1.034	0.466	0.628	0.130	0.848
5.	Annual income (X ₅)	1.157*	1.953	1.995**	2.071	1.680**	2.256
6.	Extension contact (X ₆)	0.441	1.630	0.586*	1.965	0.481	1.840
7.	Innovativeness (X ₇)	0.334**	2.086	0.117*	2.236	0.214*	1.911
8.	Risk orientation (X ₈)	0.468	1.867	0.527*	3.146	0.462*	2.980
9.	Economic orientation (X ₉)	-0.298	-1.303	0.134	0.536	-0.032	-1.238
10.	Information seeking behaviour (X ₁₀)	0.152	1.337	0.095	1.039	0.088	1.247
11.	Mobile inclination (X ₁₁)	0.369**	2.539	0.291*	2.586	0.373*	3.195
12.	Management orientation (X ₁₂)	0.788**	2.829	-0.232	-0.663	0.215	0.964
13.	FPO membership (X ₁₃)	0.236*	1.997	0.411*	3.123	0.608*	2.436
14.	Attitude towards FPO (X ₁₄)	0.138	1.363	0.197	1.777	0.158	2.197
15.	Credit acquisition (X ₁₅)	0.415	1.607	-0.503*	-1.998	-0.034*	-1.976
16.	Cosmopolitaness (X ₁₆)	0.455**	2.178	0.591**	2.295	0.410**	2.526
17.	Social participation (X ₁₇)	1.938**	2.291	0.388	0.564	0.540*	1.932
18.	Participation in FPO activities (X ₁₈)	0.681**	2.503	0.117*	2.371	0.477*	2.378
19.	Satisfaction (X ₁₉)	0.436**	3.247	0.419**	3.821	0.272**	2.799
20.	Empowerment (X ₂₀)	0.281**	3.102	0.313**	3.635	0.260**	3.123
21.	Training received (X ₂₁)	0.592	0.376	-0.819	-0.667	0.549	0.596

* Significant at 0.05% level of probability, ** Significant at 0.01% level of probability
R² value (Telangana): 0.67, R² value (Chhattisgarh): 0.59, R² value (Overall): 0.63

4.1.3 Step-wise Regression Analysis

To determine the most significant variables influencing farmers' perception regarding the integration of Agri-Tech Startups with Farmer Producer Organizations (FPOs), a Step-wise Multiple Regression Analysis was conducted. This statistical approach enabled the systematic elimination of non-significant variables to arrive at a more parsimonious and interpretable model while retaining sufficient explanatory power.

The data presented in the table 5 reflects that, the initial

model (Model-I) included all twenty-one independent variables (X₁ to X₂₁) and yielded a multiple R² value of 0.637, indicating that approximately 63.7% of the variation in farmers' perception could be explained by the full set of predictor variables. Subsequently, less contributing variables were removed in a sequential manner across successive models (Model II to Model XII), with a gradual reduction in the R² value, reflecting a trade-off between explanatory strength and model simplicity.

Table 5: Step wise regression analysis predicting influence of selected variables on Perception of farmers about Agri-Tech startups - FPO integration for improved Extension Advisory Services (n = 300)

Model No.	Variables included in the models	Coefficient of Determination R ²
Model-I	X ₁ , X ₂ , X ₃ , X ₄ , X ₅ , X ₆ , X ₇ , X ₈ , X ₉ , X ₁₀ , X ₁₁ , X ₁₂ , X ₁₃ , X ₁₄ , X ₁₅ , X ₁₆ , X ₁₇ , X ₁₈ , X ₁₉ , X ₂₀ and X ₂₁	0.637
Model-II	X ₁ , X ₂ , X ₅ , X ₇ , X ₁₁ , X ₁₃ , X ₁₆ , X ₁₇ , X ₁₈ , X ₁₉ and X ₂₀	0.603
Model-III	X ₁ , X ₅ , X ₇ , X ₁₁ , X ₁₃ , X ₁₆ , X ₁₇ , X ₁₈ , X ₁₉ and X ₂₀	0.591
Model-IV	X ₁ , X ₅ , X ₁₁ , X ₁₃ , X ₁₆ , X ₁₇ , X ₁₈ , X ₁₉ and X ₂₀	0.589
Model -V	X ₁ , X ₁₁ , X ₁₃ , X ₁₆ , X ₁₇ , X ₁₈ , X ₁₉ and X ₂₀	0.576
Model-VI	X ₁ , X ₁₁ , X ₁₃ , X ₁₆ , X ₁₈ , X ₁₉ and X ₂₀	0.551
Model-VII	X ₁ , X ₁₁ , X ₁₃ , X ₁₈ , X ₁₉ and X ₂₀	0.544
Model -VIII	X ₁₁ , X ₁₃ , X ₁₈ , X ₁₉ and X ₂₀	0.531
Model -IX	X ₁₃ , X ₁₈ , X ₁₉ and X ₂₀	0.520
Model -X	X ₁₈ , X ₁₉ and X ₂₀	0.514
Model -XI	X ₁₉ and X ₂₀	0.501
Model -XII	X ₁₉	0.485

X₁ = Age, X₂ = Education, X₃ = Experience, X₄ = Landholding, X₅ = Annual income, X₆ = Extension contact, X₇ = Innovativeness, X₈ = Risk orientation, X₉ = Economic orientation, X₁₀ = Information seeking behaviour, X₁₁ = Mobile inclination, X₁₂ = Management orientation, X₁₃ = FPO membership, X₁₄ = Attitude towards FPO, X₁₅ = Credit acquisition, X₁₆ = Cosmopolitaness, X₁₇ = Social participation, X₁₈ = Participation in FPO activities, X₁₉ = Satisfaction, X₂₀ = Empowerment, and X₂₁ = Training received.

4.1.3.1 Final Selected Model: Model III

Model III, as shown in the table 6, was identified as the final and most appropriate model based on its relatively high coefficient of determination (R² = 0.591) and reduced number of variables, which improved model interpretability without significant loss of explanatory power. The variables

retained in Model M₃ were age (X₁), annual income (X₅), Innovativeness (X₇), mobile inclination (X₁₁), FPO membership (X₁₃), Cosmopolitaness (X₁₆), social participation (X₁₇), participation in FPO activities (X₁₈), satisfaction (X₁₉), and empowerment (X₂₀). These nine variables collectively explained 59.10% of the variability in

farmers' perception toward Agri-Tech-FPO integration. The inclusion of these factors underscores their relevance in

shaping farmers' behavioural and attitudinal responses to institutional and technological interventions.

Table 6: Summary of final selected regression model with key predictor and model fit

Final selected model	Variables in the model	Coefficient of Determination (R^2)	Key predictor variable
Model - III	$X_1, X_5, X_7, X_{11}, X_{13}, X_{16}, X_{17}, X_{18}, X_{19}$ and X_{20}	0.591	X_{19}

4.1.3.2 Identification of Key Predictor Variable

Among the retained variables, Satisfaction (X_{19}) was identified as the most influential predictor. This suggests that positive experiences with FPOs, Agri-Tech services, or extension interventions enhance trust, acceptance, and willingness to adopt collaborative models. Improving satisfaction through responsive services, capacity building, and access to relevant technologies can strengthen perception and engagement. Additionally, promoting factors like mobile inclination, social participation, empowerment, and cosmopolitanism can accelerate the adoption and diffusion of innovations. Targeted strategies that enhance digital readiness, social and economic empowerment, and active engagement with FPOs are crucial for successful Agri-Tech-FPO convergence.

5. Conclusion

The study concludes that farmers' perception of Agri-Tech Startup-FPO integration for improved extension advisory services is largely shaped by behavioural, communicational, and institutional factors rather than structural farm characteristics. Correlation analysis revealed that younger age, higher education, income, extension contact, innovativeness, risk orientation, information-seeking behaviour, mobile inclination, FPO membership, positive attitude towards FPOs, satisfaction, participation in FPO activities, and empowerment significantly influenced perception across regions, while landholding, economic orientation, and management orientation remained largely non-significant. Step-wise regression analysis identified age, annual income, innovativeness, mobile inclination, FPO membership, cosmopolitanism, social participation, participation in FPO activities, satisfaction, and empowerment as key predictors, jointly explaining 59.10% of the variation in perception. Satisfaction emerged as the strongest determinant, underscoring the central role of positive institutional experiences. Therefore, policy and extension efforts should prioritize strengthening FPO service quality, enhancing farmer satisfaction, promoting digital and mobile literacy, encouraging active participation in FPO activities, and empowering farmers through targeted training and exposure to Agri-Tech innovations to ensure effective and sustainable integration.

6. Acknowledgement

I would like to extend my heartfelt gratitude to my advisors, Dr. M. L. Sharma and Dr. Arun Kumar, for their trust, insightful discussions, invaluable advice, and unwavering support throughout the entire study. The authors of this research study are thankful and acknowledge the help, support and co-operation from staff of Department of Agricultural Extension, IGKV, Raipur and Transfer of Technology (TTT), IIRR, Rajendranagar, Hyderabad.

7. Conflict of Interest

The authors of the paper declare no conflict of interest.

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