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MANAGEMENT STUDIES

DIGITAL EMPOWERMENT AND INCLUSIVE AGRI-TECHNOLOGY: DETERMINANTS OF SUSTAINABLE ADOPTION AMONG WOMEN FARMERS IN MAHARASHTRA

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Abstract

Women farmers are key to India's agriculture, yet still face challenges in accessing digital tools, financial services, and institutional support. This study explores what drives agri-tech adoption among women in Maharashtra, focusing on digital literacy, financial inclusion, and collective organization membership. Surveying 1,210 women and analyzing data with SPSS (Chi-Square tests, regression, ANOVA), we find that higher digital literacy and better financial access significantly boost agri-tech use, and membership in FPOs and SHGs further improves adoption. Together, these factors account for much of the variation in technology uptake. The study concludes that integrated efforts in digital skills, financing, and collective structures are vital to close the gendered digital divide and support sustainable agriculture. Policy suggestions include inclusive digital infrastructure, tailored credit schemes, and capacity-building via FPOs.

Keywords: Women farmers; agri-tech adoption; digital literacy; financial inclusion; FPOs; sustainable agriculture; gender empowerment; technology diffusion; rural development

Introduction

Agriculture is central to India's economy (Government of India, 2021). Women make up over 60% of the agricultural workforce (Agarwal, 2018; FAO, 2020), yet continue to face barriers to resources, markets, and decision-making (Kabeer, 2019; Meera et al., 2019). The gendered digital divide—limited digital literacy, smartphone/net access, financial exclusion, and social norms—further limits their adoption of agri-tech (Kumar & Singh, 2020; Meera, Jhamtani, & Rao, 2019; Kabeer & Natali, 2019; Parida & Kumar, 2021). Digital literacy, financial inclusion (microcredit, SHGs), and institution-membership (FPOs, cooperatives) increase women's readiness to adopt agri-tech. Yet most research treats these factors separately. There is limited integrated empirical work on how all three jointly influence women farmers' adoption of agri-tech, especially in Maharashtra.

Research Objectives

1. To examine the impact of digital literacy on agri-tech adoption among women farmers.
2. To analyze how financial access influences the adoption of modern agricultural technologies.
3. To evaluate the role of collective organizations such as Farmer Producer Organizations (FPOs), Self-Help Groups (SHGs), and cooperatives in promoting agri-tech adoption.
4. To assess the combined influence of digital literacy, financial access, and collective membership on agri-tech adoption among women farmers.

Research Hypotheses

In alignment with the above objectives, the following null and alternative hypotheses were formulated and tested using SPSS statistical analysis:

H_1: There is a significant relationship between digital literacy and agri-tech adoption among women farmers.

H_{01}: There is no significant relationship between digital literacy and agri-tech adoption.

H_2: Financial access significantly influences agri-tech adoption.

H_{02}: Financial access does not significantly influence agri-tech adoption.

H_3: Membership in collective organizations (FPOs, SHGs, or cooperatives) significantly impacts agri-tech adoption.

H_{03}: There is no significant difference in agri-tech adoption between members and non-members of collective organizations.

H_4: Digital literacy, financial access, and collective membership collectively influence agri-tech adoption more strongly than any individual factor alone.

H_{04}: Digital literacy, financial access, and collective membership do not collectively influence agri-tech adoption.

Literature Review and Research Gap

The studies show that digital literacy**,** financial inclusion**,** and collective institutions each play vital—and interconnected—roles in enabling agri-tech adoption by women farmers. Digital literacy goes beyond mere access; comprehension, confidence and contextual learning determine how well farmers use advisory systems (Aker, 2017). Despite efforts like Digital India or Digital Saksharta Abhiyan, women in Maharashtra lag in agri-tech uptake due to language barriers, low confidence, and lack of localized content (Kumar & Singh, 2020;

Meera et al., 2019). Training helps: women who complete structured digital-literacy programs were ~40 % more likely to use ICT tools such as Kisan Suvidha or eNAM platforms (Anand et al., 2021).

Financial inclusion through microfinance or SHG credit enables women to invest in technology, experiment with new farming practices, and participate more actively in digital marketplaces (Demirgüç-Kunt et al., 2018; Kabeer & Natali, 2019; Narayanan, 2020). Collective organisations—such as SHGs, FPOs and cooperatives—provide peer learning, social trust, training, and scale that help women adopt mobile-based record-keeping, online procurement, market linkages and reduce perceived risk (Agarwal, 2018; NABARD, 2020; Singh & Mehta, 2021). Yet few studies have examined how all three factors together drive agri-tech uptake; the interaction among digital literacy, financial inclusion, and institutional membership is seldom modeled jointly for women farmers in Maharashtra (Parida & Kumar, 2021; Agarwal, 2018; Meera, Jhamtani, & Rao, 2019; Kumar & Singh, 2020; Narayanan, 2020).

This gap underscores the need for an integrated empirical study. By combining variables for digital literacy, financial inclusion, and membership in collective organisations in a unified model, especially using quantitative methods for Maharashtra's women farmers, we can better identify the synergies among capability, capital, and institutional support. That insight would help design more effective, coordinated policies to boost agri-tech adoption among rural women farmers.

Research Methodology

Research Design

The study employs a quantitative explanatory research design, aimed at identifying cause-effect relationships among digital literacy, financial inclusion, and agri-tech adoption. A cross-sectional survey design was selected to collect data from a large, representative sample of women farmers.

Population and Sampling

The target population comprised women farmers across six districts of Western Maharashtra, Pune, Nashik, Satara, Ahmednagar, Kolhapur, and Solapur—known for diversified cropping patterns and emerging digital agriculture initiatives.

A stratified random sampling technique was applied to ensure representation across FPO members, SHG participants, and independent farmers. Out of 1,100 distributed questionnaires, 1,047 valid responses were retained after data cleaning and validation. The sample size meets the statistical reliability requirements based on Cochran's formula (95% confidence, 5% margin of error).

Data Collection Tools

Data were collected through a structured questionnaire, comprising both close-ended and Likert-scale items. The questionnaire had five sections:

1. Demographic profile of respondents
2. Assessment of digital literacy
3. Evaluation of financial inclusion (access to credit, digital banking usage, etc.)
4. FPO/SHG membership status and benefits
5. Agri-tech adoption level (measured on a 5-point scale)

To ensure accuracy, data were collected through face-to-face interviews and Google Forms, translated into Marathi

for rural respondents with limited English proficiency.

Reliability and Validity

Reliability was confirmed using Cronbach's Alpha, which yielded values above the acceptable threshold ($\alpha > 0.7$) for all key constructs:

Construct	No. of Items	Cronbach's Alpha (α)	Interpretation
Digital Literacy	8	0.84	Highly Reliable
Financial Inclusion	6	0.81	Reliable
FPO Membership Effectiveness	5	0.79	Acceptable
Agri-Tech Adoption	7	0.86	Highly Reliable

Content validity was established through expert reviews from agricultural economists and digital innovation specialists, while construct validity was tested through Exploratory Factor Analysis (EFA) using principal component extraction (KMO = 0.812; Bartlett's Test of Sphericity $p < 0.001$).

Data Analysis Tools

The data were analyzed using SPSS Version 28 and cross-validated through R (v4.2) for advanced modeling. Analytical techniques included: Chi-Square Test for association between digital literacy and adoption, Simple Linear Regression to assess financial access impact, One-Way ANOVA for FPO membership differences & Multiple Regression Analysis to measure combined influence of key factors Significance level (α) was set at 0.05, and all tests adhered to standard statistical assumptions of normality, independence, and homoscedasticity.

Data Analysis and Interpretation

After preliminary data screening and coding in SPSS (Version 28)**,** the dataset of 1,047 valid responses was analyzed through descriptive, inferential, and multivariate statistical techniques. The following section presents the results aligned with the four major hypotheses of the study.

Descriptive Profile of Respondents

Table 1 presents the demographic characteristics of the sample.

Table 1: Demographic Profile of Respondents (N = 1,047)

Variable	Category	Frequency	Percentage
Age (Years)	21–30	183	17.5
	31–40	362	34.6
	41–50	314	30.0
	51 and above	188	17.9
Education	No formal education	96	9.2
	Primary	247	23.6
	Secondary	402	38.4
	Higher Secondary and above	302	28.8
Farm Size	< 2 acres (marginal)	462	44.1
	2–5 acres (small)	393	37.5
	> 5 acres (medium/large)	192	18.3

Variable	Category	Frequency	Percentage
FPO Membership	Member	617	58.9
	Non-member	430	41.1
Annual Household Income	Below ₹1 lakh	311	29.7
	₹1–2 lakh	388	37.0
	₹2–5 lakh	274	26.2
	Above ₹5 lakh	74	7.1

The majority of women farmers are in the 31–50-year age range, indicating an active working population with moderate exposure to farming technologies. Approximately 59% are members of FPOs or SHGs, while 38% possess at least a secondary level of education, which correlates positively with digital awareness.

Hypothesis 1: Digital Literacy and Agri-Tech Adoption

To test the association between digital literacy and agri-tech adoption, a Chi-Square Test of Independence was conducted.

Table 2: Chi-Square Test: Digital Literacy and Agri-Tech Adoption

Value	df	Asymp. Sig. (2-sided)
924.34	16	0.000

The p-value (0.000) is less than 0.05, leading to the rejection of the null hypothesis **(H_{01}).** Thus, there exists a significant positive association between digital literacy and agri-tech adoption. Farmers scoring above 3.5 on the digital literacy scale reported markedly higher adoption of technologies like mobile-based crop advisory apps, e-wallet transactions, and precision irrigation systems.

Hypothesis 2: Financial Inclusion and Agri-Tech Adoption

To determine the influence of financial inclusion on agri-tech adoption, a Simple Linear Regression Analysis was conducted, with "Agri-Tech Adoption" as the dependent variable and "Financial Inclusion" as the independent variable.

Table 3: Model Summary and ANOVA

Model	R	R^2	Adjusted R^2	F	Sig.
1	0.642	0.412	0.411	328.45	0.000

Table 4. Coefficients of Regression (Dependent Variable: Agri-Tech Adoption)

Predictor	Unstandardized B	Std. Error	t	Sig.
(Constant)	1.14	0.31	3.67	0.000
Financial Inclusion	0.59	0.05	18.12	0.000

The model explains approximately 41.2% of the variance in agri-tech adoption ($R^2 = 0.412$), with a significant F-statistic ($p < 0.001$). The positive standardized coefficient ($\beta = 0.59$) indicates that higher financial inclusion—measured by access to bank credit, use of mobile banking, and participation in microfinance programs—substantially increases the likelihood of adopting agri-tech solutions. SPSS scatter plots displayed a clear upward linear trend,

confirming the predictive strength of financial inclusion.

Hypothesis 3: FPO Membership and Agri-Tech Adoption

To assess whether FPO membership contributes to higher technology adoption, a One-Way ANOVA was applied.

Table 5: ANOVA: FPO Membership and Agri-Tech Adoption

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	142.36	1	142.36	132.81	0.000
Within Groups	1119.52	1045	1.07		
Total	1261.88	1046			

Since $p < 0.05$, the null hypothesis **(**H_{03}**)** is rejected. There is a statistically significant difference in agri-tech adoption between FPO members and non-members. Members of FPOs reported an average adoption score of 4.12 (SD = 0.81) compared to 2.94 (SD = 0.93) among non-members. Boxplots indicated higher median scores and less variability within the member group, showing that collective participation promotes both consistency and depth of technology usage.

Hypothesis 4: Combined Influence of Digital Literacy, Financial Access, and FPO Membership

A Multiple Linear Regression was conducted to examine how the three independent variables jointly influence agri-tech adoption.

Table 6: Model Summary

R	R^2	Adjusted R^2	Std. Error of Estimate	F	Sig.
0.788	0.621	0.619	0.692	569.23	0.000

Table 7: Coefficients of Predictors (Dependent Variable: Agri-Tech Adoption)

Predictor	Unstandardized B	Std. Error	Beta	t	Sig.
(Constant)	0.98	0.29	—	3.38	0.001
Digital Literacy	0.42	0.03	0.49	14.12	0.000
Financial Access	0.31	0.04	0.37	10.68	0.000
FPO Membership	0.46	0.05	0.32	9.18	0.000

The model accounts for 62.1% of the variance in agri-tech adoption, suggesting a strong combined influence. All three predictors are statistically significant ($p < 0.001$), with digital literacy having the highest standardized coefficient ($\beta = 0.49$)**,** followed by financial access ($\beta = 0.37$) and FPO membership ($\beta = 0.32$). This result underscores that a multifaceted approach—enhancing digital education, financial empowerment, and institutional support—produces the highest adoption levels.

Findings

The study highlights several key findings about what drives agri-tech adoption by women farmers in rural Maharashtra. First, digital literacy emerges as a strong determinant: women who understand smartphones, digital payments, and internet use are much more likely to use agricultural technology. Second,

financial inclusion—through access to credit, microfinance, and digital banking—boosts their ability to invest in innovations. Third, membership in collective organisations like FPOs and SHGs enables sharing of knowledge and peer learning, which supports adoption. Finally, the regression results show that the combined influence of digital literacy, financial inclusion, and collective organization membership is more powerful than any one factor on its own—underscoring the need for holistic policy approaches targeting all three areas.

Institutional & Practical Implications

Universities and agricultural extension centres should introduce digital-skill certification programs for women farmers, while FPOs must deploy field-level digital mentors to build confidence among first-time tech users. Development agencies can complement this by integrating AI-driven learning apps in vernacular languages. At the same time, agri-tech startups should focus on designing women-centric, affordable and user-friendly platforms. Linking FPOs with Fintech companies would also help by enabling easier access to loans and real-time market analytics.

Conclusion

The study finds that digital literacy, financial inclusion, and FPO membership are key drivers of agri-tech adoption among women farmers. Women with stronger digital and financial access, supported by collective institutions, are more likely to embrace agricultural technologies. Despite their central role in India's agriculture, women face barriers due to structural inequalities. Bridging the gendered digital divide can enhance productivity, sustainability, and women's empowerment, strengthening their economic independence and leadership in rural communities.

Areas for Further Research

This study focuses on Western Maharashtra, but its approach could be extended to other states. Future work might use longitudinal designs to track how digital behaviours and tech use change over time; explore social norms, gender bias, or mobility constraints as barriers; assess emerging tools such as AI-based advisory apps, blockchain supply chains and IoT precision farming; and carry out comparisons between men and women farmers to measure the gender gap in digital agriculture.

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