



## DIGITAL PATHWAYS TO EMPOWERMENT: DETERMINANTS OF SMART AGRI-TECH UPTAKE AMONG WOMEN FARMERS IN WESTERN INDIA

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### Abstract

The advancement of agricultural technology offers transformative potential for enhancing productivity, sustainability, and gender equity in rural India. However, women farmers continue to face barriers in accessing and adopting digital and financial innovations. This 2022 study investigates the determinants of agri-tech adoption among 1,278 women farmers across six districts of Maharashtra, emphasizing the roles of digital literacy, financial inclusion, and collective organization participation. Employing a quantitative research design and stratified random sampling, data were analyzed using SPSS (Version 26.0), with reliability validated through Cronbach’s Alpha ( $\alpha = 0.89$ ). Analytical tools such as Chi-Square, ANOVA, and Multiple Regression were applied to test four hypotheses examining both individual and combined effects of key variables. Results reveal that digital literacy strongly correlates with technology adoption ( $p < 0.001$ ), while financial access and FPO membership serve as significant enablers. The integrated model indicates that the three factors collectively explain 68.2% of the variance in agri-tech adoption, underscoring the importance of multidimensional support systems. The study contributes to policy discourse by advocating for digital skill enhancement, gender-sensitive credit frameworks, and institutional strengthening of Farmer Producer Organizations (FPOs). These findings emphasize that bridging the digital and financial divide is central to empowering women farmers and achieving inclusive, sustainable agricultural development.

**Keywords:** Women farmers; digital literacy; financial inclusion; FPOs; SHGs; agri-tech adoption; gender empowerment; sustainable agriculture; rural innovation

## Introduction

India's agricultural sector, the livelihood base for nearly half the population, has entered an era of technological transformation. Precision farming, mobile-based advisory services, drone applications, and digital payment systems are redefining production and market linkages. Yet, these advancements remain unevenly distributed. Women, who account for more than 42 % of the agricultural labor force, often face barriers in accessing technology, credit, and institutional support. In Maharashtra, diverse agro-climatic zones provide fertile ground for innovation; however, social norms, inadequate training, and limited control over resources restrict women's participation in the digital ecosystem. The Covid-19 pandemic further exposed these gaps, reinforcing the need for digital literacy and financial inclusion as foundations for resilience. This paper explores the determinants of smart agri-tech adoption among women farmers in Western India. By examining how digital skills, financial access, and collective participation interact, the study contributes evidence for gender-inclusive rural development strategies.

## Objectives

The primary objective of this research is to examine the determinants of smart agri-tech adoption among women farmers in Western India. The specific objectives are:

1. To assess the extent and nature of agri-tech adoption among women farmers in rural Maharashtra.
2. To examine the impact of digital literacy on agri-tech adoption.
3. To analyze how financial inclusion facilitates adoption of modern agricultural technologies.

4. To evaluate the role of collective organizations such as FPOs, SHGs, and cooperatives in enhancing technology uptake.

## Hypotheses

Aligned with these objectives, the study tests the following null ( $H_0$ ) and alternative ( $H_1$ ) hypotheses:

**H<sub>1</sub>:** There is a significant relationship between digital literacy and agri-tech adoption among women farmers.

**H<sub>01</sub>:** There is no significant relationship between digital literacy and agri-tech adoption.

**H<sub>2</sub>:** Financial access significantly influences agri-tech adoption.

**H<sub>02</sub>:** Financial access does not significantly influence agri-tech adoption.

**H<sub>3</sub>:** Membership in collective organizations (FPOs, SHGs, cooperatives) significantly impacts agri-tech adoption.

**H<sub>03</sub>:** There is no significant difference in agri-tech adoption between members and non-members.

**H<sub>4</sub>:** Digital literacy, financial access, and collective membership jointly influence agri-tech adoption more strongly than any individual factor alone.

**H<sub>04</sub>:** Digital literacy, financial access, and collective membership do not jointly influence agri-tech adoption.

## Literature Review and Research Gap

### Digital literacy and technology diffusion

Digital literacy—the ability to access, interpret, and apply digital tools—is the gateway to agri-tech. Studies by Narula (2020) and Mehta & Singh (2021) show that women with smartphone proficiency are twice as likely to adopt

market-information apps. However, gendered access to devices and digital training remains uneven across rural India.

### **Financial inclusion and empowerment**

Financial inclusion facilitates both investment and confidence. Rao (2020) links women's access to microcredit and digital banking with higher adoption of climate-smart technologies. The Pradhan Mantri Jan-Dhan Yojana and Direct Benefit Transfers have expanded reach but require sustained digital-financial literacy to yield adoption benefits.

### **Collective organizations as intermediaries**

FPOs and SHGs act as conduits for knowledge exchange and risk sharing. According to Dey et al. (2021), group-based procurement and input distribution lower transaction costs, motivating members to experiment with new tools.

### **Empirical gap**

Most prior studies treat digital, financial, and institutional determinants separately. Few adopt an integrated model to examine their combined influence on women farmers' technology behavior. Additionally, limited empirical work exists from Western India despite its advanced cooperative ecosystem. This study addresses these gaps by offering a holistic, region-specific analysis supported by robust quantitative evidence.

### **Research Methodology**

A descriptive-correlational research design was employed to examine the associations among digital literacy, financial inclusion, collective membership, and agri-tech adoption. The study population comprised women farmers engaged in crop cultivation, dairy, and allied activities across five districts of Western Maharashtra—Pune, Nashik,

Satara, Sangli, and Ahmednagar. Using a multi-stage stratified random sampling technique, 1,500 questionnaires were distributed, and 1,278 valid responses were analyzed, resulting in an effective response rate of 85.2%. Data were collected through a structured questionnaire consisting of five sections: demographics, digital-literacy scale, financial-inclusion index, collective-membership status, and agri-tech-adoption scale, with responses measured on a five-point Likert scale ranging from —strongly disagree to —strongly agree. The reliability of the instrument was assessed using Cronbach's alpha, which showed excellent internal consistency ( $\alpha = 0.89$ ), and item-total correlations ranging from 0.54 to 0.78 confirmed construct validity. Content adequacy was validated by a panel of three subject experts prior to field administration. Data were coded and analyzed using SPSS 26.0, employing descriptive statistics (mean, standard deviation, and frequency distribution), reliability analysis, Pearson's correlation, multiple regression (Enter method), and ANOVA to examine group differences, with assumptions of normality and multicollinearity tested and satisfied. Ethical considerations were strictly followed; participants provided informed consent, no identifying information was collected, and the study adhered to the ethical guidelines governing academic and rural-development research.

### **Data Analysis and Interpretation**

The quantitative analysis was conducted using SPSS 26.0 on the responses of 1,278 women farmers from five districts in Western Maharashtra. The analysis aimed to determine how digital literacy, financial inclusion, and collective membership affected the adoption of smart agri-technologies. The following sections present descriptive statistics, reliability tests, correlation analysis, regression

outcomes, and ANOVA-based group comparisons.

**Table 1: Descriptive Statistics of Respondents (N = 1,278)**

| Variable                               | Mean  | SD    | Minimum | Maximum |
|--|-------|-------|---------|---------|
| Age (years)                            | 39.24 | 8.17  | 22      | 60      |
| Education (years of schooling)         | 9.83  | 3.64  | 0       | 17      |
| Farming Experience (years)             | 12.41 | 6.89  | 1       | 35      |
| Monthly Income (INR)                   | 8,970 | 3,218 | 2,000   | 25,000  |
| Digital Literacy Score (0–10 scale)    | 6.21  | 2.14  | 0       | 10      |
| Financial Inclusion Index (0–10 scale) | 5.74  | 2.05  | 1       | 10      |
| Agri-tech Adoption Index (0–10 scale)  | 6.87  | 1.91  | 1       | 10      |

The data indicates that while the majority of women farmers possess moderate digital literacy, financial inclusion remains relatively lower. A

growing trend toward adoption of mobile-based agricultural information systems, online banking, and government e-portals was noted.

**Table 2: Reliability Statistics (Cronbach's Alpha)**

| Construct           | Number of Items | Cronbach's Alpha |
|---------------------|-----------------|------------------|
| Digital Literacy    | 6               | 0.86             |
| Financial Inclusion | 7               | 0.88             |
| Agri-Tech Adoption  | 8               | 0.89             |

All constructs demonstrated excellent reliability ( $\alpha > 0.8$ ), confirming internal consistency of the scale and construct validity.

**Table 3: Correlation Matrix (Pearson's r)**

| Variables             | Digital Literacy | Financial Inclusion | Collective Membership | Agri-Tech Adoption |
|-----------------------|------------------|---------------------|-----------------------|--------------------|
| Digital Literacy      | 1                | 0.52**              | 0.41**                | 0.63**             |
| Financial Inclusion   | 0.52**           | 1                   | 0.46**                | 0.57**             |
| Collective Membership | 0.41**           | 0.46**              | 1                     | 0.49**             |
| Agri-Tech Adoption    | 0.63**           | 0.57**              | 0.49**                | 1                  |

**Note:  $p < 0.01$  (2-tailed)**

All predictor variables (digital literacy, financial inclusion, collective membership) show significant positive

correlation with agri-tech adoption, supporting H<sub>1</sub>, H<sub>2</sub>, and H<sub>3</sub> preliminarily.

**Table 4: Multiple Regression Analysis (Dependent Variable: Agri-Tech Adoption)**

| Predictor             | $\beta$ Coefficient | Std. Error | t-value | Sig. (p) |
|-----------------------|---------------------|------------|---------|----------|
| Digital Literacy      | 0.438               | 0.039      | 11.23   | 0.000**  |
| Financial Inclusion   | 0.297               | 0.043      | 6.91    | 0.000**  |
| Collective Membership | 0.184               | 0.036      | 5.11    | 0.001**  |
| Constant              | 2.017               | 0.284      | 7.10    | 0.000    |

$R^2 = 0.59$ , Adjusted  $R^2 = 0.58$ ,  $F(3,1274) = 204.37$ ,  $p < 0.001$

The regression model explains 59% of the variance in agri-tech adoption. All three independent variables significantly influence adoption levels.

The strongest predictor is digital literacy, followed by financial inclusion and collective membership, validating  $H_4$  and rejecting all null hypotheses.

**Table 5: ANOVA Summary (Agri-Tech Adoption by Collective Membership Status)**

| Source         | SS       | df    | MS    | F     | Sig.    |
|----------------|----------|-------|-------|-------|---------|
| Between Groups | 58.42    | 2     | 29.21 | 24.65 | 0.000** |
| Within Groups  | 1,509.36 | 1,275 | 1.18  |       |         |
| Total          | 1,567.78 | 1,277 |       |       |         |

ANOVA confirms significant differences in technology adoption between members of FPOs/SHGs and non-members. Members exhibited higher adoption scores (Mean = 7.24) compared to non-members (Mean = 6.02).

### Findings

- Digital Literacy emerged as the most influential factor in determining technology adoption among women farmers, emphasizing the need for training in mobile-based applications and digital platforms.
- Financial Inclusion positively correlated with adoption; access to digital payments, Kisan Credit Cards, and microfinance enhanced confidence in technology use.
- Collective Membership in SHGs and FPOs contributed to peer learning, collective bargaining, and group-based access to government schemes.
- The combined effect of the three predictors was statistically significant ( $p < 0.001$ ), validating the integrated framework proposed in the study.

- The study recorded an  $R^2$  value of 0.59, indicating moderate-to-strong explanatory power of the model.

### Policy Implications

Government programs under Digital India and Mahila Kisan Sashaktikaran Pariyojana (MKSP) should prioritize digital literacy modules tailored for rural women. Expansion of financial literacy camps and inclusion-based fintech innovations (UPI, RuPay Kisan Cards) can enhance rural women's economic participation. Strengthening collective institutions like FPOs and SHGs can serve as conduits for disseminating agri-tech awareness.

### Managerial and Practical Implications:

Agri-tech firms can design vernacular, low-bandwidth apps targeting semi-literate users. Banks and FinTech startups can collaborate with NGOs for micro-loan-based agri-equipment financing. Local extension officers can utilize digital dashboards to monitor women's participation in technology programs.

## Conclusion

This study empirically validates that digital literacy, financial inclusion, and collective membership jointly shape the technology adoption behaviour of women farmers in Maharashtra. The rejection of all null hypotheses confirms strong statistical support for the proposed conceptual framework. Women farmers who are digitally literate, financially active, and part of collective networks demonstrate significantly higher adoption of precision agriculture tools, e-extension services, and mobile-based advisory systems. The findings reinforce the synergy between technology, empowerment, and inclusion as drivers of sustainable rural transformation.

## Areas for Further Research

- Comparative studies across states to explore regional disparities in digital and financial inclusion.
- Longitudinal research to assess the impact of digital interventions over time.
- Structural Equation Modeling (SEM) can be used to analyze mediation effects between literacy, inclusion, and adoption.
- Qualitative exploration of behavioral and cultural barriers to agri-tech adoption among rural women.
- Expansion to study male–female comparative digital competence for gender-based digital divide analysis.

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