DoI: https://doi.org/10.58537/jorangrau.2025.53.1.11

J. Res. ANGRAU 53 (1) 105-113, 2025

EXAMINING THE FACTORS AFFECTING FARMERS WILLINGNESS TO ADOPT AI-DRIVEN SMART FARMING TECHNOLOGIES FOR SUSTAINABLE BANANA CULTIVATION

KRITHI M R

PhD Research Scholar, Department of Econometrics,
University of Madras, Chennai-600005

Date of Receipt : 10-01-2025 Date of Acceptance : 01-03-2025

ABSTRACT

The present study explores the willingness of banana farmers in Theni district, Tamil Nadu, to adopt AI technology conducted in 2023. The analysis focuses on the socio-economic and demographic factors influencing the adoption of AI-ML technologies in banana cultivation, with a sample size of 260, analyzed using a multinomial logit model. However, many farmers are efficiently using AI-based mobile applications, soil spectra, drones for fertigation, etc. In Theni, the study tends to identify the reasons for the non-adoption of technologies among the other groups of farmers.The results of the variables like education (0.730), current use of precision farming tools (9.279), understanding of AI (13.18), use of updated irrigation methods (3.950), market price of banana (0.10), and skill (18.877), show a positive and significant effect on the likelihood of willingness to adopt AI technology in banana cultivation. At the same time, the age of the farmer (-0.146), male gender (-3.072), and area (-0.515) have a significant negative impact on the likelihood of AI adoption among farmers. Moreover, experienced farmers (-0.253) are still interested in following traditional farming rather than switching to innovative technologies. Innovation is long-termand gradually leads to enhanced profitability and quality production. Therefore, the integration of AI in banana cultivation emerges not only as a transformative technological advancement but as a key catalyst poised to revolutionize productivity, optimize resource allocation, elevate sustainable practices, etc.

Keywords: AI-ML, Banana, Smart farming, Sustainability, Theni

INTRODUCTION

Agrarian economies strive to secure livelihoods by fostering demand for agricultural goods in domestic and international markets. Ensuring an adequate food supply is a critical challenge with limited resources and a rapidly growing population. Emerging technologies like Artificial Intelligence (AI), Machine Learning (ML), the Internet of Things (IoT), and Big Data are transforming agriculture by creating innovative farming ecosystems (Javaid *et al.,* 2022; Goel *et al.,* 2021). These technologies enhance efficiency, address labor shortages, and optimize outputs by utilizing field-generated data for weather monitoring, soil testing, and seed treatment (Javaid *et al.,*

Corresponding author: krithinair123@gmail.com

Table 1: Variables Used for the Analysis of Willingness on Adopting AI

Variables	Categories	Description
Willingness to Adopt (Dependent Variable)	Yes, if it outweighs the concern/Yes/ No, prefer traditional farming/Undecided	If it outweighs the concern, the farmer is willing to adopt AI technology only if it eliminates the risks or problems caused by traditional farming methods.Yes: It reflects the farmers' willingness to take a chance and invest in AI without pointing out the future benefits derived from the same.No, I prefer traditional farming—those farmers who do not believe in modern farming techniques and are happy with what they do. Undecided: Farmers who are confused between AI and traditional farming may be confused due to a lack of knowledge.
Irrigation	Drip Irrigation/ Sprinkler/ Channel Irrigation/ Surface Irrigation	The type of irrigation followed by the farmer.
Market Price of Banana	Rs Per kg	The average market price of a banana in Theni
Skill	Skilled/ Unskilled	Whether the farmer is skilled or not, new agricultural technologies
Experience	In years	Farming experience
Description of Understanding of AI	Very Limited/ Limited/ Moderate/Extensive	How far does the farmer generally know about the AI tools
Age	In years	Age of the farmer
Gender	Male/ Female	Gender of the farmer
Education qualification	High school/12th/ Degree/Diploma/Post-Graduation	Education qualification of the farmer (all the farmers completed primary education)
Technology currently using	Conventional Farming/ Precision Farming/ Neutral Farming	Which is the existing farming method used by the farmer.
Awareness of AI in agriculture	Yes/ No	Whether the farmer is aware of the usage of AI in the agriculture sector
The area under cultivation of banana	In acres	The area is owned by the farmer and is used exclusively for banana cultivation.
General Awareness of AI	Yes/ No	Does the farmer have a general awareness of AI

2022). India has increasingly adopted smart agricultural technologies to improve productivity, double farmers' income, and ensure food security for its growing population. Among crops, bananas are nutritionally rich and globally significant, with world production reaching 116,781,658 (000 MT) in 2020-21.

Tamil Nadu, particularly the Theni district, has emerged as a frontrunner in integrating IoT-based solutions in banana cultivation. The farmers are highly motivated to cultivate bananas instead of other tropical crops like paddy, which is more remunerative and profitable in Theni (Sivarajah, 2022). These include drones for fertilizer and pesticide spraying under the Sub-Mission on Agricultural Mechanization (SMAM) project, mobile applications like Fasal agri-tech for pest and disease management, and soil testing technologies like Soil Spectra for real-time soil analysis. Additionally, the Tamil Nadu Supply Chain Management (TNSCM) project facilitates end-to-end traceability, enhancing the export potential of value-added banana products. Theni has gained prominence through its focus on cultivating the Grand Naine banana variety for international markets, aligning with initiatives like "One District One Product" (ODOP) and "Districts as Export Hubs". These programs aim to unlock the district's export potential, create employment opportunities, and promote rural entrepreneurship, contributing to the vision of AtmaNirbhar Bharat.

This study examines the factors influencing farmers' willingness to adopt innovative farming technologies in banana cultivation in Theni, Tamil Nadu. By understanding their accessibility and motivation to adopt IoT-based innovations, the study seeks to contribute to the broader goal of achieving sustainable agricultural practices and enhancing the global competitiveness of India's banana sector.

MATERIAL AND METHODS

The factors affecting the willingness of the farmers to adopt innovative farming technologies in their farmlands for banana cultivation were analyzed using qualitative response models, i.e., the multi-nominallogit model. For this, the following variables are used:

Econometric Methodology

The multinomial logit model is used in the present study as it is suitable for analyzing categorical dependent variables with more than two outcomes. The multi-nominal logit model is used extensively to understand individuals' behavioral choices. The present study uses this model to examine the factors influencing farmers' willingness to adopt innovative farming technologies in banana cultivation by categorizing their willingness into multiple choices or levels.The model can calculate the probability of farmers' showing their desire to adopt AI technologies through a utility function. The likelihood that n^{th} respondent chooses i^{th} willingness to adoption behaviour is

$$P_n(i) = Prob\left(U_{ni} \geq U_{nj}, J \in J_n, i \neq j\right) \text{----------(1)}$$

$$= Prob\left(V_{ni} + \varepsilon_{ni}, j \in J_n, \ i \neq j\right) \text{---------- (2)}$$

$$= Prob\left(V_{ni} + \varepsilon_{ni} \geq \max\left(V_{ni} + \varepsilon_{ni}\right)\right) \text{---------- (3)}$$

Where n^{th}respondent chooses the effect of i^{th} willingness to adopt AI technology as U_{ni}

V_{ni} is βX_{nk}

ε_{ni} Is the random white noise error term

X_{nk} is the K factor which affects the nth respondent's choice

β is the parameter to be estimated

According to th e results in Table 2, the following variables are explained based on their significant effect on the willingness to adopt AI technologies. The table is presented based on the three thresholds- Threshold 1 between Yes, if outweighs concern vs undecided category; Threshold 2 between Yes & Undecided category; Threshold 3 between No prefer traditional farming vs Undecided.

A confusion matrix is a tabular representation used to evaluate the performance of a classification model by comparing its predicted labels with the actual labels. It categorizes predictions into four groups: True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN). This method helps identify correct and incorrect predictions, offering valuable insights into the model's accuracy, errors, and effectiveness across different classes in the dataset.

A word cloud visualization is a technique for visually representing textual data by displaying words in varying sizes, where more prominent words signify higher frequency or significance. This method creates a cloud-like arrangement, emphasizing the most commonly occurring terms in a dataset, making identifying key themes and patterns easier.

RESULTS AND DISCUSSION

Table 2 offers key insights into the factors affecting farmers' willingness to adopt AI technology under different choices. For the category "Yes, if it outweighs concern" versus the undecided farmers, results show that age negatively impacts willingness, with each additional year reducing the probability by 0.023 units, though statistically insignificant. Gender also appears insignificant, as male farmers are 1.718 times less likely to consider adopting AI than females. Educational qualifications, however, show a significant effect—farmers with 12th-grade, degree, and diploma qualifications are more likely to embrace AI compared to those with high school education, with 0.34, 3.79, and 2.11 units, respectively, highlighting the positive role of higher education in fostering adoption. Precision farming significantly enhances willingness, with a 3.75 units higher likelihood than conventional methods. However, more extensive landholdings reduce the probability, with a one-acre increase lowering the odds by 0.618 units. General awareness about AI and its agricultural applications remains insignificant, though understanding its potential benefits increases the probability by 0.97 units. Farmers with extensive, moderate, or limited knowledge of AI have a significantly higher likelihood (13.18, 9.66, and 10.1 times, respectively) of adopting AI than those with minimal knowledge.

Additionally, advanced irrigation methods such as drip and sprinkler systems positively influence willingness, significantly increasing log odds compared to surface irrigation. Among the benefits, improved pest management, resource efficiency, and increased yield motivate farmers to adopt AI, with skilled farmers showing a notable likelihood of 6.44 times higher than unskilled workers. Farming experience, however, remains insignificant, with only a slight increase in probability.

For the "Yes" versus undecided threshold, age has a significant negative impact, indicating younger farmers are more likely to adopt AI, with each additional increase

Table 2: Multi-nominal Logit results for different Threshold Values

Variable	Categories	Threshold 1		Threshold 2		Threshold 3	
		Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
INTERCEPT		-25.487	0.0000**	-19.210	0.000**	22.469	0.0417**
Age	-	-0.0238	0.5662	-0.146	0.0026**	0.1241	0.1044
Gender	Male	-1.7183	0.1779	-3.072	0.0213**	-0.3862	0.7883
Education	12th	0.3400	0.8193	2.704	0.2003	4.0945	0.0285**
	Degree	3.7989	0.0436**	5.976	0.0124**	-3.609	0.1960
	Diploma	2.1153	0.2381	3.2940	0.1592	2.003	0.411
	Post-Graduation	0.0843	0.9708	0.730	0.792	-13.560	0.0000**
Technology	Precision	3.759	0.002**	9.279	0.000**	-12.859	0.0000**
	Neutral	2.6854	0.0620	9.598	0.0000**	4.363	0.0103**
Area	-	-0.6181	0.004**	-0.515	0.0236**	-0.119	0.7407
Awareness on AI	Yes	-1.225	0.3194	-4.730	0.0000**	-0.9423	0.3687
Description on understanding of AI	Extreme	13.1843	0.000**	2.306	0.3194	-1.5440	0.4201
	Moderate	9.6611	0.000**	-3.044	0.010**	-5.387	0.3108
	Limited	10.103	0.000**	-2.510	0.010**	-2.261	0.010**
Awareness of AI in Agri	Yes	-1.225	0.3194	-4.7303	0.000**	-0.9423	0.3682
Irrigation	Drip	3.0950	0.046**	2.8592	0.0831	0.0912	0.9691
	Sprinkler	1.653	0.5206	2.1568	0.41326	-0.989	0.746
	Channel	4.2709	0.027**	4.0628	0.0600	-1.637	0.4915
Market Price	-	0.110	0.219	0.1010	0.2772	-0.653	0.0181**
Awareness on potential benefits of AI	Yes	0.9730	0.3717	1.0052	0.3785	4.055	0.023**
Skill	Yes	6.4452	0.006**	18.877	0.000**	-8.496	0.000**
Experience	-	0.0862	0.1804	0.0839	0.223	-0.2538	0.048**

Source: Authors estimation using primary data

in age reducing willingness by 0.146 units. Educational qualifications again play a pivotal role, with degree holders being the most likely to adopt AI, followed by diploma and 12th-grade farmers, compared to high school graduates. Precision and neutral farming methods foster higher probabilities of adoption, with significant 9.27 and 9.59 units, respectively, over conventional practices. More extensive landholdings again show a negative effect, with a one-acre increase lowering the probability of adoption by 0.51 units. Awareness variables remain insignificant, but farmers with extensive knowledge of AI have a 2.03 times higher likelihood of willingness. Irrigation methods and the market price of bananas show no considerable effect on willingness. However, skilled farmers demonstrate a significant possibility of adopting AI, with a probability of 18.87 units compared to unskilled farmers. Among benefits, increased crop yield emerges as an essential driver, raising the likelihood of willingness by 5.26 units. Farming experience contributes positively, with a one-year increase raising the probability of adopting AI.

For the "No, prefer traditional farming" versus undecided threshold, older farmers are more likely to prefer traditional practices, with each additional year increasing the probability by 0.12 units. Male farmers are 3.07 times less likely than females to stick to conventional farming, though this remains insignificant. Educational qualifications reduce the likelihood of preferring traditional agriculture, with postgraduates being the least likely to continue traditional methods. More extensive landholdings discourage traditional farming, as each additional acre reduces the probability by 0.119 units. Whether extensive, moderate, or limited, knowledge about AI decreases the likelihood of sticking to traditional practices, with significant reductions of 1.54, 5.38, and 2.26 times, respectively, compared to minimal knowledge. Irrigation methods have no substantial impact. Awareness of AI's benefits also reduces the probability of traditional farming, especially for benefits like pest management and yield improvement. Skilled farmers are significantly less likely to prefer traditional methods, with a probability of 8.49 units, and experienced farmers are also more inclined toward modern practices, with a one-year increase in experience reducing the probability by 0.25 units.

The study identifies the socio-economic and demographic characteristics of banana farmers willing to adopt AI-based technologies. The higher the age, the lesser the probability of farmers adopting smart farming in banana cultivation (Chuchird *et al.*, 2017). Female farmers were more inclined towards adopting AI technologies than male farmers (Dissanayake *et al.*, 2022). Higher education positively influences willingness to adopt AI technology (Worku, 2019). Farmers holding higher education – particularly degrees/ diplomas- are significantly more likely to adopt AI in banana cultivationthan those with lower education qualifications. Farmers already using precision farming showed a higher probability of adopting AI technologies,which is statistically significant compared to those using conventional cultivation methods. Larger landholders were less likely to adoptinnovative farming (Li *et al.*, 2023). They often rely on traditional methods that have worked for them over time and may perceive AI adoption as unnecessary or too risky. Additionally, the higher upfront costs and complexity of implementing smart technologies across larger areas could deter them compared to smallholders seeking efficiency gains. Farmers were more willing to adopt AI in banana cultivation, mainly when there was a shift in choice from surface irrigation to drip and sprinkler irrigation. Skilled farmers were more likely to adopt the technology than unskilled farmers. The higher the experience in banana cultivation, the lower the chances for adopting

AI, giving more preference to traditional farming (Olatade *et al.*, 2016). The market price of bananas can significantly affect farmers' willingness to adopt AI technologies, as higher prices incentivize farmers to invest in advanced methods like AI to maximize profits.In contrast, price reductions discourage adoption by limiting their financial capacity and perceived return on investment. In Theni, a one-unit price increase decreases the likelihood of traditional farming by 0.65 units, highlighting a shift toward modern practices driven by better market prices.The negative relationship between AI awareness and the possibility of adoption could indicate that farmers aware of AI's complexities, costs, or limitations in agriculture may perceive it as less practical or beneficial for their specific needs, leading to hesitation in adopting smart technologies. This highlights the need for better-targeted awareness campaigns emphasizing AI's tangible benefits and ease of use in farming.

The confusion matrix further shows the actual and predicted results into different outcomes (Table 3). The result suggests that 17 among the total 240 were predicted correctly, belonging to the Undecided category. 83, 60, and 35 observations are predicted trueat the 'Yes, if outweighs concern,''Yes' and 'No, prefer traditional farming' categories, respectively. The rest were predicted as false. The accuracy or success rate of the model was tested. Accuracy was calculated at 81.25 percent. Therefore, the model's error ratewas 1- Accuracy, i.e., 18.75% is the error rate.

A word cloud shows the suggestions given by the farmers that could help them adopt AI-ML smart farming technologies in their farmlands. The word cloud illustrates the precise form of representing farmers' recommendations/ suggestions to ensure the practical possibilities of adopting smart farming technologies in future. The word having the highest weight is"Support" followed by the words – "Government", "technical", "intermediaries", "subsidies", and "financial". It suggests that farmers expect support from the Government for incentives and other policies that promote and support the adoption of smart farming technologies. Affordability plays a vital role in deciding the adoption of these technologies, behind why farmers expect Government (Jabbari *et al.*, 2023) and cooperative institutions to provide loans, subsidies, and other financial support (Dong *et al.*, 2023). Access to technical support and trainingfrom respective authorities is crucial for farmers who encounter issues or fear in

Table 3: Confusion matrix

Actual class/ classified data	Predicted-Class/ Reference data			
	Unde-cided	**Yes, if it outweighs the concern**	**Yes**	**No, prefer traditional farming**
0 (Undecided)	**17 (6.54%)**	6 (2.31%)	2 (0.77%)	1 (0.38%)
1 (Yes, if it outweighs the concern)	3 (1.15%)	**83 (31.92)**	17 (6.54%)	0 (0%)
2 (Yes)	1 (0.38%)	14 (5.38%)	**60 (23.08%)**	0 (0%)
3 (No, prefer traditional farming)	1 (0.38%)_	0 (0%)	0 (0%)	**35 (13.46%)**

Source: Authors estimation using primary data
Note: Frequency Percentage in parenthesis

Figure 1. Word Cloud Visualization of Farmers' Suggestion to make improvements in the agriculture sector in Theni

Source: Author's representation

technology usage (Li *et al.*, 2023). Farmers consider intermediaries as the biggest reason for their limited access to AI technologies (in terms of distribution rights), delayed adoption (they slow down the process), conflict of interest, complex supply chain, limited accountability etc. In addition to this, farmers suggest improving internet connectivity in rural Theni for ensure better adoption of techniques requiring internet connectivity, and the operations through mobile devices will be highly practical. The farmers are likely to ensure with better market planning and better prices for their product before investing in such technologies.

CONCLUSIONS

The study establishes that AI adoption in agriculture is influenced by a combination of demographic, economic, and policy-driven factors. age negatively impacts adoption, with younger farmers exhibiting a higher willingness to embrace AI. Education plays a crucial role, with farmers holding higher qualifications (diploma, degree) being significantly more likely to adopt AI (up to 3.79 times more likely than high school graduates). Precision farming techniques enhance willingness by 3.75 units, while larger landholdings reduce the probability of adoption (-0.618 units per acre).

The classification results (Table 3) indicate that the model effectively predicts adoption patterns among farmers, demonstrating its robustness. Among those who are willing to adopt AI if their concerns are addressed, the model correctly predicts 83 farmers (31.92%), while 60 farmers (23.08%) are accurately classified as definite adopters. Additionally, 35 farmers (13.46%) who prefer traditional farming were correctly identified.The minimal misclassification, such as 6 farmers (2.31%) from the undecided group being classified under 'Yes, if it outweighs concerns,' further supports the model's effectiveness in predicting AI adoption. Figure 1 (Word Cloud) reinforces the role of government support, technical assistance, and financial incentives in driving AI adoption. The prominence of terms like "subsidies," "technical support," and "intermediaries" suggests that policymakers should focus on improving AI accessibility, training, and financial assistance for smallholders. Overall, the findings suggest that

targeted policy interventions, including subsidies for AI tools, skill development programs, and better connectivity in rural areas, are essential to drive adoption. Addressing concerns related to cost, accessibility, and ease of use can further enhance farmers' willingness to integrate AI, ultimately contributing to a more efficient and resilient agricultural sector.

ACKNOWLEDGEMENT

This research was supported by Malcolm & Elizabeth Adhiseshiah Trust, Chennai. I acknowledge that the financial support received from Malcolm & Elizabeth Adhiseshiah Trust for publishing the report in parts to this reputed journal.

REFERENCES

Chuchird, R., Sasaki, N and Abe, I. 2017. Influencing factors of the adoption of agricultural irrigation technologies and the economic returns: A case study in Chaiyaphum Province, Thailand. Sustainability, 9: 1524, doi:10.3390/su9091524

Dissanayake, C.A.K., Wgan, Jayathilake., Wickramasuriya, H, V, A., Dissanayake., U, S and Wasala, W, M, C, B. 2022. A review on factors affecting technology adoption in agricultural sector. Journal of agricultural sciences, 17(2), doi: 10.4038/jas.v17i2.9743

Dong, C., Hainan, Wang., Wenjin, Long., Jiujie, Ma and Yi, Cui. 2023. Can agricultural cooperatives promote Chinese farmers' adoption of green technologies? International Journal of Environmental Research and Public Health, 20(5): 4051, doi: 10.3390/ijerph20054051

Goel, R. K., Yadav, C. S., Vishnoi, S., and Rastogi, R. 2021. Smart agriculture–Urgent need of the day in developing countries. Sustainable Computing: Informatics and Systems, 30, 100512.

Jabbari, A., Humayed, A., Reegu, F. A., Uddin, M., Gulzar, Y and Majid, M. 2023. Smart farming revolution: Farmer's perception and adoption of smart IoT technologies for crop health monitoring and yield prediction in Jizan, Saudi Arabia. Sustainability, 15(19), 14541.

Javaid, M., Haleem, A., Singh, R. P and Suman, R. 2022. Enhancing smart farming through the applications of Agriculture 4.0 technologies. International Journal of Intelligent Networks, 3, 150-164.

Li, J., Liu, G., Chen, Y. and Li, R. 2023. Study on the influence mechanism of adoption of smart agriculture technology behavior. Scientific Reports, 13(1): 8554. doi: 10.1038/s41598-023-35091-x

Olatade K.O., Olugbire, O.O., Adepoju. A.A., Aremu, F.J and Oyedele, P.B. 2016. How does farmers' characteristics affect their willingness to adopt agricultural innovation? The case of Biofortified Cassava in Oyo State, Nigeria. AFRREV STECH: An International Journal of Science and Technology, *5*(2): 59-75 doi: 10.4314/STECH.V5I2.5

Sivarajah, P. 2022, January 21. Tamil Nadu farmers go bananas over tropical cash crop. The Times of India. https://timesofindia.indiatimes.com/city/chennai/tamil-nadu-farmers-go-bananas-over-tropical-cash-crop/articleshow/89029979.cms

Worku, A.A. 2019. Factors affecting diffusion and adoption of agricultural innovations among farmers in Ethiopia case study of Ormia regional state Westsern Sewa. The Journal of Agricultural Extension, *7*(2): 137-147 doi: 10.33687/IJAE.007.02.2864.

Krithi, M. R. 2025. Examining the factors affecting farmers' willingness to adopt ai-driven smart farming technologies for sustainable banana cultivation. The Journal of Research, ANGRAU. Vol. 53 (1): 105-113