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RESEARCH ARTICLE

Socio-economic determinants of willingness to expand palmyrah palm cultivation: An econometric analysis

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Abstract

The Palmyrah palm (*Borassus flabellifer* L.), often referred to as the "Tree of Life". It holds a significant cultural and economic significance, serving as a cornerstone for rural livelihoods and environmental sustainability. Despite its numerous advantages, the expansion of Palmyrah palm cultivation is influenced by a range of socio-economic factors. This study examines the socio-economic determinants affecting farmers' willingness to expand Palmyrah palm cultivation in Vembar South Gram panchayat, located in the Thoothukudi district of Tamil Nadu, South India. To analyse the binary nature of the outcome variable, the Probit Econometric Model was employed to assess the factors influencing the likelihood of expanding Palmyrah cultivation based on various socio-economic parameters. The findings reveal that farming experience, higher income and larger landholdings significantly increase the likelihood of expansion, whereas gender, occupation (agriculture) and family size are associated with a decreased likelihood. Notably, female landowners, non-agricultural workers and farmers from smaller families with higher income levels are particularly inclined to expand Palmyrah cultivation. The study's findings provides important insights for policymakers aiming to promote Palmyrah cultivation and foster rural economic development through targeted interventions that could effectively support the socio-economic well-being of the farming communities.

Keywords

palmyrah palm; probit model; rural development; socio-economic factors; willingness for area expansion

Introduction

The Palmyrah palm (*Borassus flabellifer* L.) provides a diverse range of products, including Neera (a sweet sap), jaggery, toddy, fibre and edible fruits, serving as a vital source of income for rural farming communities. Renowned for its ability to thrive under harsh environmental conditions, the Palmyrah palm is a crucial resource for rural livelihoods in the arid and semi-arid regions of Southern India. Its resilience and diverse utility highlight its role in supporting rural development, prompting environmental sustainability and socio-economic benefits.

The cultivation and utilization of the Palmyrah palm have deep historical

roots in rural Tamil Nadu, which hosts 60% of India's Palmyrah population, comprising approximately 51 million trees. This prevalence highlights its integral role in the rural agrarian systems (1). Palm products, including jaggery, toddy and handicrafts, significantly contribute to rural economies by generating income and employment opportunities. Neera and jaggery, in particular, are widely sold in local and regional markets, supporting commercial trade, while Palmyrah fibers are used in traditional handicrafts, thereby preserving cultural heritage and sustaining livelihoods. In 2022-23, India exported 761640.19 MT of jaggery and confectionery products valued at ₹4330.07 crores to countries including Sudan, Indonesia, Tanzania, the United Arab Emirates and Kenya. Additionally, Palmyrah leaves historically served as a medium for writing ancient scriptures, further emphasizing the tree's cultural importance (2, 3).

Ecologically, the Palmyrah palm enhances environmental resilience through its extensive tap root system, which aids groundwater recharge and maintain soil moisture in dry regions It serves as a natural barrier against soil erosion and protects the impact of natural disasters such as cyclones and tsunamis. Notably, during the 2004 tsunami in Southern India, Palmyrah palms withstood and mitigate the impact of the waves, illustrating their potential as a natural defense mechanism in coastal regions (2). Furthermore, the Palmyrah palm also plays a role in combating climate change, mainly through its ability to absorb and sequester carbon from the atmosphere, making it a valuable asset to achieve carbon neutrality in rural areas (4, 5).

Despite its numerous benefits, the expansion of Palmyrah palm cultivation has been limited and influenced by various socio-economic factors. This study addresses these issue by employing a Probit Regression model to examine the socio-economic determinants influencing landowners' willingness to expand Palmyrah palm cultivation. These findings aim to bolster rural economic resilience and leverage the environmental benefits of expanding Palmyrah palm cultivation.

Materials and Methods

Study area

Vembar South Gram panchayat, located in the Vilathikulam block of Thoothukudi district, Tamil Nadu, was purposively chosen for this study due to its dense concentration of Palmyrah palm trees. Thoothukudi district hosts 5.19 crore palm trees, accounting for over 60% of Tamil Nadu's total Palmyrah population of 8.59 crore trees, making it an ideal location for this research. Within the district, the Vilathikulam block is particularly notable for its extensive Palmyrah cultivation, which increased from 705.55 ha in 2021-22 to 719.99 ha in 2022-23. Of this, Vembar South contributes significantly with 220.56 ha under cultivation, providing valuable insights into the region's agricultural practices and community dynamics.

The local economy is primarily driven by Palmyrah palm climbing, with palm jaggery emerging as a key product, underscoring the economic importance of this crop. These factors make Vembar south a strategic site for studying the community's willingness to expand Palmyrah cultivation. Fig. 1 illustrates the geographic location of the study area.

Data collection

The data for this study were collected using a structured and pre-tested questionnaire administered to a sample of 124 households, of which 34 were landowners involved in palm tree cultivation. Given the rural community's characteristics, the snowball sampling method was employed. Initial respondents referred the researchers to other potential respondents within the village, ensuring that the sample accurately represented individuals with experience and interest in Palmyrah cultivation.

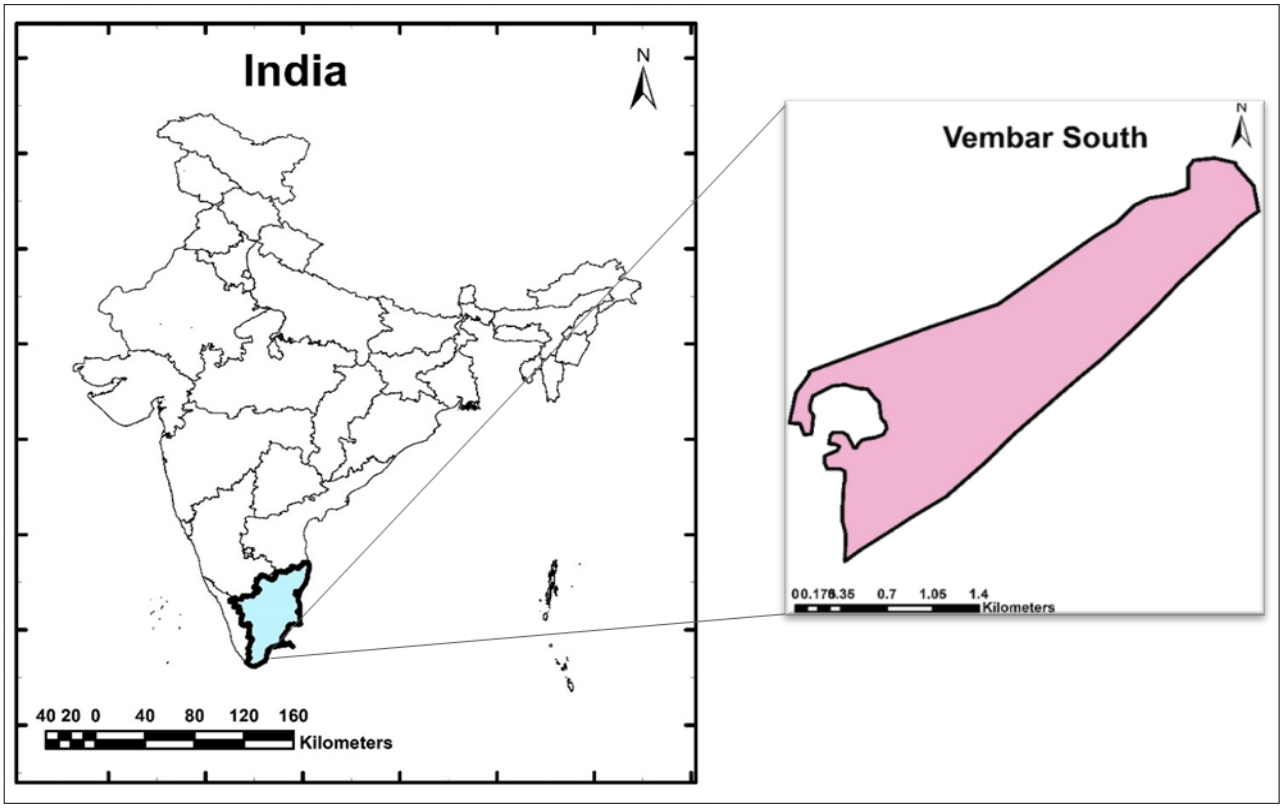

Fig. 1. Study area map: Vembar south gram panchayat in Thoothukudi district, India.

The data collection process included structured surveys and personal interviews with the selected households to gain deeper insights into the socio-economic factors influencing the expansion of Palmyrah palm cultivation. The survey questionnaire was meticulously designed to capture detailed information on household demographics, land ownership, agricultural practices and respondents' willingness to expand Palmyrah cultivation.

Variables selection

The independent variables for this study were selected based on prior research on agricultural decision-making (6-8). A detailed description of the selected variables is provided in Table 1.

Binary Probit Regression- model specification

The Binary Probit Model is widely used to examine the influence of socio-economic variables on decision-making, particularly in the context of farmers' adopting new technologies or agricultural practices. In this study, the Binary Probit Model was employed to analyse the likelihood of landowners expanding Palmyrah palm cultivation.

The dependent variable is binary (Yes=1; otherwise=0), representing the willingness to expand the number of Palmyrah palms under cultivation. The Probit Model was chosen for its ability to handle dichotomous outcomes and its reliance on the normal distribution for the error term (9).

The model is based on a continuous latent variable denoted by Y^*, which represents an underlying propensity or probability that determines the observed binary outcome. The model specification is expressed as:

$$Y^* = Xb + e,\ e \sim N(0,1) \qquad \text{(Eqn. 1)}$$

In Eqn.1, X represents the matrix of independent variables, b is the vector of coefficients associated with the predictors and e is the error term following a standard normal distribution. This ensures theoretical consistency, symmetry and mathematical convenience (10).

The observed outcome Y is derived from Y^* according to the following rule:

$$Y = \begin{cases} 1 \ if \ Y^* > 0 \\ 0 \ if \ Y^* \leq 0 \end{cases} \qquad \text{(Eqn. 2)}$$

Thus, Y=1 is observed when the latent variable exceeds zero and Y=0 otherwise. This approach allows the Probit Model to capture the non-linear relationship between the predictors and the binary outcome while assuming normally distributed errors (11).

The Probit model was chosen due to its theoretical consistency and superior fit for the data compared to alternative models, such as Logit and GAMs.

Probit Link function

The Probit Model employs the Probit Link Function, which is based on the cumulative distribution function (CDF) of the standard normal distribution. The probability of the binary outcome Y=1Y = 1Y=1 is modeled as:

$$P(Y=1 \mid X) = f(Xb) \qquad \text{(Eqn. 3)}$$

Here, Φ(-) represents the CDF of the standard normal distribution and Xb is the linear predictor formed by the independent variables and their corresponding coefficients (12).

This specification ensures that the predicted probabilities remain within the interval [0, 1], making the probit model particularly suitable for binary outcomes, where probabilities must be constrained.

The choice of the Probit Link Function was driven by the assumption that the cumulative effect of the predictors on the outcome could be effectively captured through a normally distributed latent variable. This assumption supports estimating how changes in the independent variables affect the likelihood of the observed outcome.

The Probit model is a widely employed statistical framework that effectively captures the relationships between explanatory variables and binary outcomes while ensuring statistical efficiency (13).

Estimation via maximum likelihood

Probit models are estimated using Maximum Likelihood Estimation (MLE), a widely adopted method for deriving parameter estimates that maximizes the likelihood of observing the data given under the specified model (14). For each observation i, the likelihood function is expressed as:

$$L_i(\beta) = [\Phi(X_i\beta)]^{Y_i}[1 - \Phi(X_i\beta)]^{1-Y_i} \qquad \text{(Eqn. 4)}$$

Here, $\Phi(X_i\beta)$ represents the probability that $Y_i=1$ and $1-\Phi(X_i\beta)$ denotes the probability that $Y_i=0$.

For a dataset containing n observations, the overall likelihood function is the product of the individual likelihoods across all observations:

Table 1. Description of the independent variables

Variables	Units	Description	Variable encodings
		Dependent variable	
Willingness to expand Palmyrah cultivation (Y)	Binary	Willingness to expand Palmyrah palm cultivation	Yes = 1, No = 0
		Independent variables	
Age (X_1)	Years	Age of the landowner	Continuous: Represents the actual age
Gender (X_2)	Binary	Gender of the landowner	Male = 1, Female = 0
Education (X_3)	Binary	Literacy status of the landowner	Literate = 1, Illiterate = 0
Primary occupation (X_4)	Binary	Primary occupation of the landowner	Agriculture = 1, Other = 0
Family type (X_5)	Binary	Type of family structure	Nuclear Family = 1, Joint Family = 0
Family size (X_6)	Count	Total number of family members in the household	Continuous: Represents the actual number of members
Experience in occupation (X_7)	Years	Years of experience in primary occupation	Continuous: Represents the total years in farming
Annual income (X_8)	Rupees	Annual household income	Continuous: Represents the total annual income
Land ownership (X_9)	Hectares	Land owned by the farmer	Continuous: Represents the total land area owned

$$L(\beta) = \prod_{i=1}^{n} [\Phi(X_i\beta)]^{Y_i} [1 - \Phi(X_i\beta)]^{1-Y_i} \quad \text{(Eqn. 5)}$$

MLE estimates the parameters β by finding the values that maximize the log-likelihood function, ensuring the best fit for the observed data (15).

The coefficients estimated in the Probit model reflect the influence of each independent variable on the latent variable Y*, not directly on the probability of the outcome Y=1. Because the relationship between X and P(Y=1|X) is non-linear, the direct interpretation of these coefficients is limited.

To provide a clearer understanding of how changes in the independent variables affect the probability of the binary outcome, marginal effects are calculated. The marginal effect of an independent variable Xk on the probability of Y=1 is given by:

$$\frac{\partial P(Y = 1 \mid X)}{\partial X_k} = \phi(X\beta)\beta_k \quad \text{(Eqn. 6)}$$

In this equation, ϕ (·) is the probability density function (PDF) of the standard normal distribution. Marginal effects quantify the change in the predicted probability for a one-unit change in the independent variable, holding all other variables constant.

Marginal effects can be evaluated at the mean values of the independent variables or averaged across all observations to provide a more interpretable measure (9). Reporting these marginal effects in applied research is essential, as they offer a more intuitive understanding of how each variable influences the probability of the event occurring (14).

Results

The descriptive statistics offers insights into the socio-economic characteristics of the sampled households. The descriptive statistics of the selected independent variables are presented in Table 2.

The average age of the respondents was approximately 44.8 years, with a standard deviation of 12.3 years, indicating that the sample primarily consisted of middle-aged and older individuals. The gender distribution was nearly balanced, with 52.94% male and 47.06% female respondents. Educational status revealed that 82.35% of the respondents were literate, while 17.65 % were illiterate.

The primary occupation of the respondents showed a greater inclination towards non-agricultural activities, with 55.88% engaged in other occupations, compared to 44.12% involved in agriculture. In terms of family structure, nuclear families dominated the sample, accounting for 82.35%, while joint families constituted 17.65%. The average household size was about 5 members, with a standard deviation of 1.78 members.

On average, respondents had 20 years of experience in their respective occupations, with a significant variability (standard deviation of 16.48 years). The annual income of the respondents ranged widely, with an average income of approximately ₹135971. Land ownership averaged 1.71 ha per household.

Results of Probit Model Regression

The probit regression analysis was conducted to identify the socio-economic factors influencing the willingness to expand Palmyrah palm cultivation. The results are presented in Table 3.

The results indicated that gender, primary occupation, family size, experience in occupation, annual income and land ownership were significant variables in the model.

The coefficient for gender was -2.491, with a p-value of 0.023, indicating that male landowners were significantly less likely to expand Palmyrah cultivation compared to female landowners.. Primary occupation also played a significant role, as the coefficient of -2.875 with a p-value of 0.038 suggested that individuals primarily engaged in agriculture were less likely to expand Palmyrah cultivation compared to those in other occupations. Family size was another important factor, with a coefficient of -0.889 and a p-value of 0.037, revealing a negative association between larger family sizes and the willingness to expand cultivation. A positive coefficient of 0.103 with a p-value of 0.067 indicated that individuals with greater occupational experience were somewhat more likely to expand Palmyrah

Table 3. Binary probit results for Palmyrah palm expansion

Independent variables	Coefficient	Standard error	p-value
Age	-0.0392	0.0426	0.358
Gender	-2.4911**	1.0963	0.023
Education	-0.9768	1.1939	0.413
Primary occupation	-2.8751**	1.3834	0.038
Family type	0.9812	2.0107	0.626
Family size	-0.8891**	0.4269	0.037
Experience in occupation	0.1035*	0.0565	0.067
Annual income	0.00002**	0.00001	0.034
Land ownership	1.3492*	0.7492	0.072
Constant	4.4747	2.9707	0.132
Log likelihood	-9.9443		
Pseudo R^2	0.5493		
Prob > Chi^2	0.0039		
LR Chi^2 (9)	24.26		
Number of observations	34		

note: **p<0.05, **p<0.10, significance at 5% and 10% levels respectively

Table 2. Descriptive statistics of the sample respondents

Independent Variables	Mean	Std. Dev	Minimum	Maximum
Age (Years)	44.79	12.30	21	67
Family size (Nos)	5.08	1.78	1	9
Farming experience (Years)	20	16.48	1	56
Annual income (Rs.)	135971	78654	50000	385000
Land ownership (ha)	1.71	1.87	0.15	7
Gender	Male: 18 Nos		Female: 16 Nos	
Educational status	Illiterate: 6 Nos		Literate: 28 Nos	
Primary occupation	Agriculture: 15 Nos		Others: 19 Nos	
Family type	Nuclear Family: 28 Nos		Joint Family: 6 Nos	

cultivation, though this variable was marginally significant. . The coefficient for annual income was 0.000023, with a p-value of 0.034, demonstrating a positive association between higher income levels and the willingness to expand cultivation. Lastly, the coefficient for land ownership was 1.349, with a p-value of 0.072, indicating a positive relationship between larger landholdings and the willingness to expand, albeit with slightly less significance.

The overall significance of the probit model (LR chi-square = 24.26, p = 0.0039) and a pseudo R-squared value of 0.5495 suggested that the selected socio-economic variables accounted for a substantial proportion of the variance in willingness to expand Palmyrah palm cultivation.

Results of marginal effects

The marginal effects provided a clearer interpretation of the Probit model's coefficients, representing the change in the probability of the outcome variable (willingness to expand Palmyrah cultivation) for a one-unit change in the predictor variable, as shown in Table 4.

The marginal effect for gender was -0.4019, with a p-value of 0.001. This suggests that male landowners were 40% points less likely to express a willingness to expand Palmyrah cultivation compared to female landowners.

The marginal effect for primary occupation was -0.4639, with a p-value of 0.007, indicating that individuals engaged in agriculture were approximately 46% points less likely to expand Palmyrah cultivation compared to those in non-agricultural occupations. .

A marginal effect of -0.1434, with a p-value of 0.008, revealed that each additional family member decreased the probability of willingness to expand cultivation by 14% points. Experience showed a positive marginal effect of 0.0167, with a p-value of 0.025, indicating that each additional year of occupational experience increased the likelihood of willingness to expand cultivation by 1.67% points.

The marginal effect of annual income was 0.000004, with a p-value of 0.004, reflecting a small but statistically significant positive impact. While the effect size is minimal, it suggests that higher incomes slightly increase the probability of expansion. However, the relatively modest effect may indicate that respondents prioritize income for essential needs, such as education, healthcare and family maintenance, rather than investing in expanding Palmyrah cultivation.

Table 4. Marginal effect results

Independent variables	dy/dx	Standard error	p-value
Age	-0.0063	0.0065	0.337
Gender	-0.4019***	0.1195	0.001
Education	-0.1576	0.1864	0.398
Primary occupation	-0.4639***	0.1721	0.007
Family type	0.15832	0.3212	0.622
Family size	-0.1434***	0.0537	0.008
Experience in occupation	0.0167**	0.0074	0.025
Annual income	0.000004***	0.000001	0.004
Land ownership	0.2177**	0.2177	0.036

note: ***p<0.01, **p<0.05, significance at 1% and 5% levels respectively

Lastly, Land ownership demonstrated a marginal effect of 0.2177, with a p-value of 0.036. This indicates that each additional hectare of land owned increased the probability of willingness to expand Palmyrah cultivation by approximately 22% points.

These findings provide a nuanced understanding of the factors influencing landowners' decisions to expand Palmyrah cultivation in the study area. The results highlight the significant roles of socio-economic characteristics, with gender, primary occupation, family size, experience, income and land ownership emerging as critical determinants of decision-making. This detailed analysis underscores the complex interplay of individual and household-level factors in shaping agricultural expansion strategies.

Discussion

The Probit regression analysis yielded critical insights into the factors influencing the expansion of Palmyrah cultivation. Notably, key variables such as farming experience, income and land ownership positively associated with the likelihood of expansion, whereas gender, occupation and family size showed negative effects.

Gender emerged as a significant determinant, with male-headed households being less likely to expand Palmyrah cultivation than female-headed households. This finding underscores a notable gender disparity in agricultural decision-making. Male-headed households' reluctance to increase the number of Palmyrah palms aligns with earlier studies. This aligns with the (16, 17). For instance, research in Malawi observed that agricultural decisions are often dominated by men, but joint decision-making with women can result in improved outcomes, such as higher tree densities.

Primary occupation was another significant factor. Households engaged primarily in agriculture were less inclined to expand Palmyrah cultivation compared to those involved in non-agricultural activities. This observation is consistent with findings from Sumatra, where the adoption of oil palm cultivation was more prevalent among households with non-agricultural occupations (18).

Family size negatively influenced the willingness to expand Palmyrah cultivation. Larger families faced challenges in allocating limited resources such as labor, time and finances, prioritizing stability over expansion, particularly in uncertain environments. This result aligns with prior research (19), which found that larger families often prioritize subsistence crops over expanding cash crop cultivation, including tree plantations.

On the other hand, experience in occupation showed positive associated with the willingness to expand palm cultivation. More experienced household heads were more likely to embrace the expansion of palm cultivation. This finding aligns with the study in Sumatra, where more experienced household heads were more inclined to expand oil palm plantations (18).

Annual income demonstrated a significant positive effect on expansion decisions. Households with higher income levels were more likely to expand their Palmyrah cultivation, consistent with findings from other studies which reported that higher income levels often correlate with increased tree plantation expansion. However, this raises potential concerns about

environmental trade-offs that may accompany such growth (20).

Similarly, land ownership was positively influenced the willingness to expand Palmyrah cultivation. Households with larger landholdings are more likely to consider further expansion, as they may have more resources and a greater capacity to manage additional land. This result aligns with findings from a study, who observed that landholding size was a significant factor in influencing willingness to expand tree plantations (21).

Interestingly, variables such as age, education and family type did not exhibit significant effects in this study. This may be attributed to uniform economic pressures across age groups, reliance on traditional knowledge and shared resource management priorities across different family structures. However, the insignificance of these variables in this specific context does not negate their relevance in other settings. . For instance, studies in Northeastern Thailand have demonstrated that age and education significantly influence the adoption of oil palm cultivation (22).

These discrepancies highlight the importance of contextual socio-economic and cultural factors in shaping agricultural decisions.

This study's findings emphasize the need to consider local socio-economic contexts when evaluating agricultural expansion determinants. While variables like income and land ownership consistently show positive impacts across diverse studies, others, such as gender and primary occupation, may vary in significance based on cultural and economic landscapes. For example, cultural beliefs in Shinyalu limit women's involvement in tree planting, viewing it as a male responsibility (23). In contrast, men in Jordan often avoid tree planting in favor of higher-paying jobs (24). However, in Rwanda, women predominantly lead in agricultural labor and decision-making (25).

Conclusion

This study aimed to understand the socio-economic factors influencing landowners' willingness to expand Palmyrah palm cultivation, in Vembar South, Tamil Nadu. The probit regression analysis identified gender, primary occupation, family size, experience in occupation, annual income and land ownership as significant determinants. Specifically, female landowners, those engaged in non-agricultural primary occupations, individuals with larger family sizes, greater occupational experience, higher income levels and larger landholdings were more likely to consider expanding Palmyrah cultivation.

These findings contribute to the broader literature on agricultural decision-making by offering a nuanced understanding of the factors shaping the expansion of Palmyrah cultivation in rural India. The study underscores the intricate interplay between socio-economic characteristics and agricultural decisions, highlighting the importance of targeted interventions to promote sustainable practices like Palmyrah cultivation.

The practical implications of this research include the necessity for gender-sensitive policies, financial support mechanisms to facilitate expansion and educational programs tailored to different occupational groups. These insights can aid policymakers and agricultural extension services in developing effective strategies to encourage sustainable Palmyrah cultivation, thereby enhancing both environmental sustainability and rural livelihoods.

Policy implications

The findings of this study underscore several factors that significantly influence the willingness of landowners to expand Palmyrah palm cultivation. These findings have important implications for the expansion of Palmyrah palm cultivation in Vembar South and similar rural contexts. The observed gender disparity in decision-making suggests the need for gender-specific approaches to promote Palmyrah cultivation, ensuring that both male and female landowners are equitably engaged and supported.

The negative association between agricultural occupation and willingness to expand indicates that targeted education and support programs are essential. These programs could address the perceived risks associated with expansion and provided strategies to mitigate them effectively. Furthermore, the positive influence of income and land ownership underscores the importance of financial capacity in agricultural decision-making. This suggests that financial incentives or support mechanisms, such as subsidies or credit facilities, could be instrumental in encouraging the expansion of Palmyrah cultivation.

However, the negative impact of family size on willingness to expand points to unique challenges faced by larger families, such as constraints in resource allocation and labor management. These factors should be carefully considered when formulating policies to support Palmyrah cultivation expansion.

While this study offers valuable insights, it is important to acknowledge its limitations. The relatively small sample size, though representative of Vembar South, may limit the applicability of the findings to broader contexts. Future research with larger sample sizes and in diverse geographical settings would help validate and extend these findings, offering a more comprehensive understanding of the determinants of Palmyrah cultivation expansion.

Future research

While this study has provided valuable insights into the determinants of land-use decisions, several avenues for future research remain open for exploration. One critical area for further investigation is the role of environmental awareness in agricultural decision-making. Understanding how landowners' knowledge of climate change and the environmental benefits of sustainable practices influence their choices could offer crucial insights for designing more effective policies and interventions. Additionally, broadening the scope of this study to encompass other regions with varying socio-economic and environmental contexts would provide a more comprehensive understanding of the factors driving Palmyrah cultivation. Comparative studies across diverse regions could help identify universal drivers and barriers to expansion, as well as region-specific challenges that require tailored policy approaches. Further research could also examine the long-term impacts of Palmyrah palm expansion on soil health, local biodiversity and the economic stability of farming households. Such studies would be instrumental in assessing the sustainability of Palmyrah cultivation and informing strategies to balance environmental conservation with economic benefits. These future research directions have the potential to deepen our understanding of agricultural decision-

making and support the development of policies that promote sustainable land-use practices.

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Authors' contributions

SK participated in collection, analysis of the data and drafted the manuscript. SS finalized the conceptualization of the study and contributed to its design. ET reviewed and refined the research methodology. JP performed English language correction and manuscript editing. BK provided critical input on data interpretation and assisted with the methodology review. SR and IM supported literature sourcing and provided feedback on the theoretical framework. NM assisted with data analysis and statistical interpretation. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no competing interests.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used Chat GPT and Claude to improve the language. After using this tool/ service, the author reviewed and edited the content as needed and took full responsibility for the content of the publication.

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