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RESEARCH ARTICLE

Perception and adoption of drip irrigation technology among beneficiaries of the Tamil Nadu Irrigated Agriculture Modernization Project: A Structural Equation Modelling approach

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Abstract

The article examines the beneficiaries' perceptions of Drip Irrigation Adoption under the Tamil Nadu Irrigated Agriculture Modernization Project using a quantitative research approach and Structural Equation Modelling (SEM). A survey was conducted with 559 respondents from different districts of Tamil Nadu using the Technology Acceptance Model (TAM). Perceived Usefulness (PU), Perceived Ease of Use (PEU), Attitude Toward Use (ATU) and Behavioural Intension (BI) were some of the key constructs in the study. The study utilized a structured questionnaire for data collection, which was then analyzed using percentage analysis and SEM to explore the relationships among the constructs. The results showed that the respondents were predominately older, more experienced farmers with small to marginal landholdings. Educational levels among the respondents were diverse but skewed toward middle and secondary schooling, with (47.39 %) having received this level of education. Incomes were predominantly in the lower-middle-class range, with respondents showing moderate interest in scientific practices and a high degree of openness to innovation. The study established that Perceived Usefulness and Perceived Ease of Use were crucial factors influencing farmers' attitudes toward drip irrigation, affecting their behavioural intention to adopt the technology. This study concludes that perceived benefits and ease of use are critical drivers in encouraging the adoption of water-saving technologies such as drip irrigation among farmers. Future research could include longitudinal studies on whether drip irrigation is eventually adopted and impacts farm productivity and water conservation. It may be possible to extend the model to include external variables, such as social influence, economic incentives and policy support, to better understand adoption dynamics.

Keywords

drip irrigation; precision farming; perceived usefulness (PU); SEM analysis; technology acceptance

Introduction

Drip irrigation, or micro-irrigation, is an advanced irrigation technique that delivers water directly to plant roots through valves, pipes and emitters. This system provides slow and uniform water delivery, reducing waste and maximizing efficiency. Drip irrigation is recognized as the most water-efficient irrigation method, as it minimizes evaporation and runoff by delivering water directly to the plant's root zone (1).

Traditional, flood or sprinkler irrigation systems often result in significant losses due to evaporation, runoff and inefficient water distribution (2). Drip irrigation can increase water-use efficiency by up to 90 %, drastically reducing water use and improving crop yield, especially in arid and semi-arid regions (3).

In addition to water saving, drip irrigation promotes better crop growth by providing a uniform water supply. It enables control over soil moisture and significantly reduces weed growth and diseases associated with over-irrigation. Drip irrigation also decreases weed growth since the water will be supplied directly to the base of the plants, leaving the soil dry in the surroundings and preventing weeds from germinating through moisture. This localized watering minimizes weed competition for nutrients and water, thus enabling crops to grow more vigorously. This, in turn, limits the humid conditions that often lead to fungal and bacterial diseases, therefore keeping plants healthier and less susceptible to disease. By preventing over-irrigation, drip systems help reduce the risk of diseases in crops (4). Drip irrigation can also be combined with fertigation, which delivers fertilizers through the irrigation system to provide nutrients more efficiently to crops (5).

In India, the adoption of drip irrigation has increased significantly due to growing water scarcity and government initiatives promoting water-conserving technologies. In Tamil Nadu, farmers have benefited from the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and Tamil Nadu Irrigated Agriculture Modernization Project (TN-IAMP) schemes, which provide subsidies and encourage the adoption of efficient irrigation techniques (6). Despite its advantages, the adoption of drip irrigation faces several challenges, including high initial investment costs, maintenance issues and a lack of awareness and technical knowledge among farmers (7).

The drip irrigation system has recently emerged as an essential agricultural innovation that improves water use efficiency and crop productivity. The Tamil Nadu Irrigated Agriculture Modernization Project (TN-IAMP) has significantly promoted the adoption of advanced irrigation technologies in the region. Drip irrigation will be crucial in managing water resources and sustaining agricultural productivity in water-scarce areas like Tamil Nadu (8).

The Government of Tamil Nadu initiated the TN-IAMP to address water resource gaps and inadequate irrigation practices by modernizing the existing infrastructure and adopting advanced technologies. The project provided financial support, technical assistance and training to help farmers adopt a drip irrigation system. However, it is essential to consider how beneficiaries perceive these intervention strategies to assess the program's success.

According to existing literature, drip irrigation increases water use efficiency and reduces labour costs, positively affecting crop yield (8, 9). The effectiveness of these technologies depends on the beneficiaries' perceptions and how their contextual factors influence the adoption process (10). Given the highly traditional nature of agricultural practices in Tamil Nadu, it is essential to understand how farmers' attitudes toward irrigation are changing.

This study is necessary to understand the perceptions and motivations of farmers regarding drip irrigation adoption, especially as part of the Tamil Nadu Irrigated Agriculture Modernization Project. Examining these perceptions through a structured framework like the Technology Acceptance Model (TAM) and analyzing them via Structural Equation Modelling (SEM) can offer deep insights into the behavioural and attitudinal factors that drive or hinder adoption.

This study aims to understand the perceptions of TN-IAMP beneficiaries regarding drip irrigation systems. In light of the experience, this research evaluates beneficiary satisfaction with the drip irrigation technology and provides recommendations for future irrigation projects. The outcomes will contribute to a deeper understanding of the factors influencing the adoption of drip irrigation and its impact on rural livelihoods in Tamil Nadu.

Theoretical framework

Davis developed a Technology Acceptance Model (TAM) based on the Theory of Reasoned Action (TRA), a psychological model. TAM is a framework used to predict the adoption of new technology based on attitudes toward innovation and it is considered both valid and reliable (11). Therefore, TAM was applied in this study to measure the beneficiaries' intent to adopt Precision Agriculture (PAs). TAM assumes that an individual's attitude determines their behaviour regarding accepting a particular technology (12). This model explains short-term behaviours, such as acceptance and adoptio and long-term behaviours, such as continued use (13). According to Davis (14), Perceived Usefulness (PU) refers to the extent to which a person believes using a technology will enhance their performance. Perceived Ease of Use (PEU) refers to the degree to which a person finds the technology accessible to understand and use. In TAM, an Attitude Toward Use (ATU) refers to an individual's perception of how well the technology will perform. Intention to Use (BI) is how an individual plans to engage with the technology. As postulated by Davis (14), TAM is based on TRA and defines perceived usefulness and ease of use as crucial constructs that predict an individual's intention and behaviour in using technology. Table 1 outlines the definitions of the critical constructs explained below.

- ***Perceived usefulness (PU):*** According to Davis (14), PU is the belief that technology will enhance a user's job performance.
- ***Perceived ease of use (PEU):*** According to Davis (14), PEU is the belief that adopting a technology will require minimal physical and psychological effort.
- ***Attitude to use (ATU):*** In TAM, AU refers to the user's overall positive or negative feelings about using a specific technology.
- ***Intention to adaptation (BI):*** According to (15), behavioural intention measures how strongly an individual intends to perform a specific behaviour. Behavioural intention refers to an individual's willingness to perform a particular behaviour in the future (16).

Table 1. Operationalization of the Variable

Variable	Measurement
Perceived usefulness (PU)	1.Precision agriculture tools can increase profits. 2.Precision agriculture tools can increase productivity. 3.Precision agriculture tools can provide information for better decision making. 4.Precision agriculture tools are effective. 5.Precision agriculture tools support work quickly.
Perceived ease of use (PEU)	1.Precision agriculture tools are controllable. 2.Precision agriculture tools are flexible. 3.The uses of precision agriculture tools are clear and understandable. 4.Learning to use precision agriculture tools will be easy. 5.It will be easy for me to remember how to perform tasks
Attitude to use (AU)	1.Farming through e-agriculture is a good idea. 2.It positively influences me to use precision agriculture on the farm. 3.I think it is a trend to use precision agriculture on the farm.
Behavioural intention to Adopt (BI)	1.I intend to use a precision farming (PA) system. 2.I would recommend the adoption of the PA system for other farmers in my region. 3.I will also adopt PA if the neighbouring farmers adopt.

Materials and Methods

This study aims to understand beneficiaries' perceptions of drip irrigation systems under the Tamil Nadu Irrigated Agriculture Modernization Project (TN-IAMP) using a structural equation modelling (SEM) approach. The study was designed as a quantitative survey with primary data collected from farmers across various districts in Tamil Nadu. The study is based on Davis's technology acceptance model (TAM), published in 1989, with critical measures including Perceived Usefulness (PU), perceived ease of use (PEU), attitude toward Use (ATU), and behavioural intention to use (BI). A sample size of 559 respondents was selected from TN-IAMP beneficiaries in Tamil Nadu who have adopted drip irrigation systems through the project. Respondents from eight sub-basins (Lower Vellar, CDZ - Nagapattinam, Sathiyar, Sirumalaiyar sub-basins of phase I) and (Uppar, Aliyar, Lower Coleroon - Aduthurai, Lower Coleroon- Vridhachalam sub-basins of phase II) were selected based on highest number of TN-IAMP beneficiaries and the adjoining sub-basins with complete sampling technique. A structured questionnaire was administered to farmers to collect primary data. The questionnaire was divided into several sections, i.e., demographic variables, which included age, gender, education, farm size (landholding), crops grown and years of farming experience. Perception Measurement: Constructs influencing the adoption of drip irrigation systems were measured on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Perceived usefulness (PU): Measures how farmers find drip irrigation to save water, reduce labour and increase crop yield. Perceived Ease of Use (PEU) can measure how easily farmers find the system to install, use and maintain. Attitude Toward Use (ATU) can Capture farmers' attitudes toward adopting drip irrigation. Behavioural Intention to Use (BI) measures farmers' likelihood to continue using or expanding their drip irrigation use.

All collected data were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM) after preliminary pre-processing in Statistical Package for Social Sciences (SPSS) software. The 2 stages of the analysis used were (I) Descriptive Statistics: A summary of the socio-demographic characteristics of the sample was provided using descriptive statistics. Additionally, means and standard deviations for the TAM constructs (PU, PEU, ATU and BI) were calculated. (II) Cronbach's alpha was computed to test the internal consistency of the scales, with a reliability threshold set at 0.70 or higher (17). Confirmatory factor analysis, along with tests for convergent and discriminant validity, was conducted to assess the validity of the questionnaire. Average Variance Extracted (AVE) and Composite Reliability (CR) were calculated, with AVE values above 0.50 and CR values above 0.70 considered satisfactory for validation (18).

Model specification and path analysis

Based on the Technology Acceptance Model (TAM), the initial measurement model was developed to assess relationships between the key constructs. Goodness-of-fit measures included the GFI, CFI and RMSEA indices. A good model fit was indicated by a CFI > 0.90, RMSEA < 0.08 and GFI > 0.90 (19). After confirming the measurement model's good fit, a structural model was developed to assess the relationships between the constructs PU, PEU, ATU and BI. Maximum Likelihood Estimation (MLE) was used to estimate direct and indirect effects.

Hypothesis testing

Three relationships between the TAM variables were evaluated for strength and significance for hypotheses testing. The significance was assessed at a 95 % confidence level, using a *p*-value threshold of $p < 0.05$. Indirect effects between the TAM variables were explored using mediation analysis.

In line with the study's objectives, the following hypotheses were tested using the developed conceptual model to measure beneficiaries' perceptions of precision farming (Fig. 1).

- *H1: PU statistically significantly impacts behavioural intention to adopt precision agriculture technologies.*
- *H2: PU statistically significantly influences attitudes toward using precision agriculture Technologies.*
- *H3: PU has a statistically significant influence on perceived ease of use towards using precision agriculture technologies.*
- *H4: PEU has a statistically significant impact on behavioural intention to adopt precision agriculture technologies.*

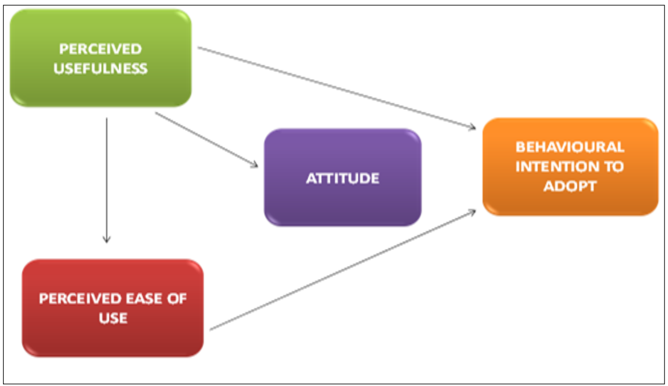

Fig. 1. Conceptual model to measure the perception of precision farming

Results and Discussion

The data was gathered and analyzed using descriptive statistics to profile the respondents. The proposed conceptual model was evaluated in 2 stages: first, through the assessment of the measurement model and second, through testing the structural model. IBM SPSS and PLS-SEM were used for these analyses.

Socio-economic characteristics of farmers

Table 2 indicates the socio-economic characteristics of respondents and farm organizations in the study area. According to Table 2, 48.12 % of beneficiaries were over 45, 31.12 % were aged 35-45 and 20.75 % were under 35. The data showed that 7.69 % of respondents were illiterate and 6.26 % were functionally literate. Regarding education, 9.66 % had primary education, 23.07 % had middle education, 24.32 % had secondary education, 19.67 % had higher secondary education, 2.32 % held a diploma and 6.97 % had completed collegiate education.

The study results showed that 55.81 % of respondents had more than 10 years of farming experience, 35.95 % had 5 to 10 years of experience and 8.22 % had less than 5 years of experience.

The data also shows 37.74 % respondents have marginal up to 1 ha land, followed by 32.20 % have small land holdings from 1.1-2.0 ha, 14.84 % have semi–medium 2.1-4.0 ha, 9.12 % have medium land holdings with 4.1-10 ha and 6.08 % have significant land holdings of more than 10 ha.

The data shows that 47.04 % of respondents had a medium income, ranging from less than 1,00,001 to 4,00,000 lakhs per annum. Similarly, 37.74 % of respondents had a low income earning less than 1,00,000, while 15.20 % had a high income earning more than 4,00,000 per annum. 69.94 % of respondents had a medium scientific orientation, 18.24 % had a high level, and 11.80 % had a low-level scientific orientation.

The data also revealed that 67.08 % of respondents exhibited a high level of innovativeness, 22.54 % had a medium level and 10.37 % had a low level of innovativeness.

The population was dominated by older, more experienced farmers with small to marginal landholdings. Educational levels were diverse, skewed towards middle and secondary schooling as 23.07 % had middle education and 24.32 % had secondary education. Incomes were concentrated in the lower-middle-class with a moderate scientific orientation (69.94 %) and a high degree of innovativeness (67.08 %), indicating openness to new agricultural technologies and practices.

Table 2. Demographics of the respondents.

Sl. No.	Category	Frequency	Per cent (%)
	Age		
1.	Young age (Upto 35 years)	116	20.75
2.	Middle age (35 to 45 years)	174	31.12
3.	Old age (More than 45 years)	**269**	**48.12**
	Education		
1.	Illiterate	43	7.69
2.	Functionally literate	35	6.26
3.	Primary education	54	9.66
4.	Middle education	129	23.07
5.	Secondary education	**136**	**24.32**
6.	Higher secondary education	110	19.67
7.	Diploma	13	2.32
8.	Collegiate education	39	6.97
	Farming Experience		
1.	Upto 5 years	46	8.22
2.	5 – 10 years	201	35.95
3.	> 10 years	**312**	**55.81**
	Land Holdings		
1.	Marginal (Up to 1 ha)	**211**	**37.74**
2.	Small (1.1-2.0 ha)	180	32.20
3.	Semi-medium (2.1-4.0 ha)	83	14.84
4.	Medium (4.1-10 ha)	51	9.12
5.	Large (>10 ha)	34	6.08
	Annual Income		
1.	Low (<100000/-)	211	37.74
2.	Medium (100001/-to 400000/-)	**263**	**47.04**
3.	High (>400000/-)	85	15.20
	Scientific Orientation		
1.	Low (<13)	66	11.80
2.	Medium (13 to 21)	**391**	**69.94**
3.	High (>21)	102	18.24
	Innovativeness		
1.	Low (<14)	58	10.37
2.	Medium (14 to 22)	126	22.54
3.	High (>22)	**375**	**67.08**

Structural Equation Modelling

The measurement and structural models were validated using a 2-stage Structural Equation Modelling (SEM) approach to test the proposed hypotheses. Structural modelling should be conducted after assessing the measurement model (20). Model fitness testing on the measurement model was supported to test the reliability and validity of the constructs. The 2 stages of SEM include Confirmatory Factor Analysis (CFA) and testing of the structural model to ensure measurement accuracy and assess theoretical relationships. The correlation between the constructs and their associated measurements was computed in CFA to determine how well the observed variables represent the latent constructs. Understanding the implementation of Precision Agriculture (PA) technologies by beneficiaries involves identifying the primary factors driving adoption and exploring why beneficiaries choose to accept or reject these technologies (21, 22).

Evaluation of the measurement model

Fig. 2. presents an SEM model showing relationships between latent constructs (blue nodes) and their observed indicators (yellow boxes).

Variables (latent constructs)

Perceived Usefulness (PU) is a Latent construct measured by 5 indicators: PU1, PU2, PU3, PU4 and PU5. Perceived Ease of Use (PEU) is a latent construct measured by PEU1, PEU2, PEU3, PEU4 and PEU5. Attitude (A) is a latent construct measured by 3 indicators: A1, A2, and A3. Behavioural Acceptance (BA) is a

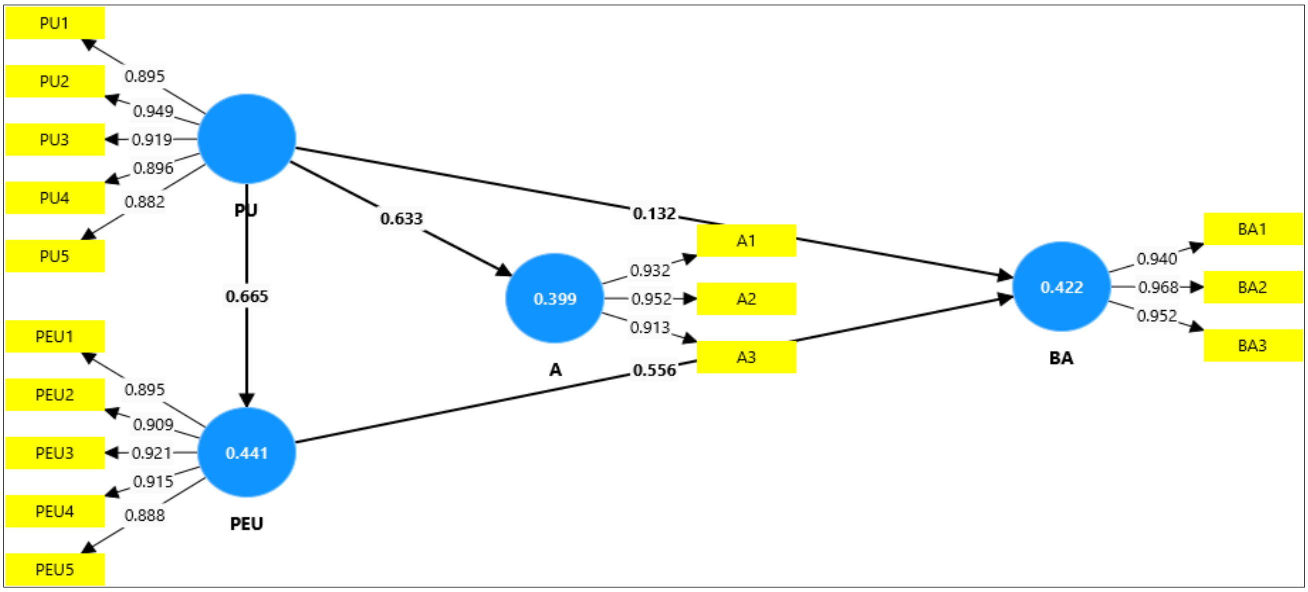

Fig. 2. Measurement Model

latent construct measured by BA1, BA2, and BA3.

Path coefficients

PU → PEU (0.665): There is a positive relationship between Perceived Usefulness and Perceived Ease of Use. PU → A (0.633): Perceived Usefulness strongly impacts attitude, with a path coefficient of 0.633. PEU → A (0.556): Perceived Ease of Use has a moderate to strong positive influence on attitude. A → BA (0.422): Attitude has a mild positive impact on Behavioural Acceptance, with a path coefficient of 0.422. PU → BA (0.132): Perceived Usefulness has a weak positive relationship with Behavioural Acceptance, indicating that its direct influence on acceptance is limited.

Indicator loadings

Perceived Usefulness (PU): PU1 0.895, PU2 0.949, PU3 0.919, PU4 0.882, PU5 0.896: These high loadings indicate that each indicator represents the construct well. Perceived ease of use (PEU): PEU1 0.895, PEU2 0.909, PEU3 0.921, PEU4 0.915, PEU5 0.888: These high factor loadings indicate that PEU indicators are strong measures of the construct. Attitude (A): A1 (0.932), A2 (0.952), A3 (0.913): The factor loadings for the Attitude construct are all high, indicating good measurement. Behavioural Acceptance (BA): BA1 (0.940), BA2 (0.968), BA3 (0.952): These high loadings indicate that the items are suitable measures of Behavioural Acceptance.

Interpretation

Perceived Usefulness (PU) and Perceived Ease of Use (PEU) both contributed significantly to the development of Attitude (A) towards a system or technology. Attitude (A) moderately impacts Behavioural Acceptance (BA), indicating that a positive attitude is associated with higher acceptance or adoption of the technology. Perceived Usefulness (PU) has a weak direct impact on Behavioural Acceptance (BA), suggesting that its effect is mainly mediated through Attitude (A). The model shows strong indicator loadings, implying that the latent constructs are well-measured by their indicators. The model suggests that usefulness and ease of use significantly influence user attitudes, stimulating technology acceptance. However, Perceived Usefulness has an indirect, but more negligible, effect on Behavioural Acceptance.

Table 3 summarizes the validity and reliability measures for the four latent constructs: attitude, behavioural intention to adopt, perceived ease of use and perceived usefulness. Cronbachs' alpha, average variance extracted (AVE) and composite reliability (rho_a and rho_c) were computed for each construct. Attitudes (0.925), behavioural intention (0.950), perceived ease of use (0.945) and perceived usefulness (0.947) all have values well above the commonly accepted threshold of 0.7. This exemplifies high internal consistency for each construct. This indicates that the items within each construct are highly reliable and consistently measure the same underlying concept. The rho_a and rho_c are reliability measures similar to Cronbachs' Alpha, but they are less likely to underestimate reliability when item loadings vary. For both rho_a and rho_c, a value above 0.7 is considered acceptable.

- Attitude: rho_a = 0.929, rho_c = 0.952
- Behavioural Intention to Adopt: rho_a = 0.950, rho_c = 0.968
- Perceived Ease of Use: rho_a = 0.945, rho_c = 0.958
- Perceived Usefulness: rho_a = 0.951, rho_c = 0.959

All constructs report values above 0.9, demonstrating excellent composite reliability. This indicates that the constructs are highly reliable, the measurement model is stable and each construct is well measured by its indicators.

Table 3. Validity assessment.

	Cronbachs' Alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Attitude	0.925	0.929	0.952	0.870
Behavioural intention to adopt	0.950	0.950	0.968	0.909
Perceived ease of use	0.945	0.945	0.958	0.820
Perceived usefulness	0.947	0.951	0.959	0.826

3. *Average Variance Extracted (AVE)*

AVE measures convergent validity, representing the percentage variance in the indicators explained by the latent construct. The minimum acceptable cutoff for AVE is 0.5 and values above 0.7 indicate strong validity.

- Attitude: AVE = 0.870
- Behavioural Intention to Adopt: AVE = 0.909
- Perceived Ease of Use: AVE = 0.820
- Perceived Usefulness: AVE = 0.826

All AVE values exceed 0.7, indicating very high convergent validity. The high variance explained by each construct's indicators confirms that they accurately reflect their respective constructs. The measurement model demonstrates excellent reliability and validity through internal solid consistency, robust composite reliability and high convergent validity.

Structural model and hypotheses testing

The image shows a structural equation modelling (SEM) diagram, a statistical technique that examines complex relationships between multiple variables. SEM is particularly useful in testing theoretical models and evaluating direct and indirect effects.

Variables (Nodes)

- PU1, PU2, PU3, PU4, PU5: observed variables (used to measure perceived usefulness)
- PEU1, PEU2, PEU3, PEU4, PEU5: observed variables (used to measure perceived ease of use)
- A1, A2, A3: observed variables (used to measure attitude)
- BA1, BA2, BA3: observed variables (used to measure behavioural acceptance)

Path Coefficients

The Numbers along the (paths) represent the standardized path coefficients, indicating the strength and direction of relationships between variables. Higher values reflect stronger relationships. Here are the key relationships:

- PU → PEU (0.442): There is a moderate positive relationship between Perceived Usefulness and Perceived Ease of Use, indicating that users who find the helpful system are likelier to perceive it as easy to use.
- PEU → A (0.401): Perceived Ease of Use has a moderate positive impact on attitude, suggesting that users who find the system easy to use tend to have a more positive attitude toward it.
- A → BA (0.425): Attitude has a moderate positive influence on Behavioural Acceptance, meaning that a positive attitude toward the system is associated with higher acceptance or likelihood to adopt it.
- PU → BA (0.006): Perceived Usefulness has a fragile positive relationship with Behavioural Acceptance, indicating that the direct effect of usefulness on acceptance is minimal in this model.
- Several paths show a coefficient of 0.000, indicating no direct relationship between those specific variables.

- ♦ Perceived usefulness (PU) influences perceived ease of use (PEU). Still, it does not directly impact attitude (A) or behavioural acceptance (BA), suggesting that usefulness primarily affects user perceptions of ease rather than directly shaping overall attitudes or acceptance.
- ♦ Perceived ease of use (PEU) is a critical factor in shaping attitude (A) and attitude plays a vital role in influencing behavioural acceptance (BA), highlighting the indirect effect of ease of use on acceptance through attitude formation.
- ♦ Attitude (A) is the strongest predictor of behavioural acceptance (BA) in this model, indicating that users' positive feelings toward the system are the most significant driver of their acceptance.

This model suggests that ease of use significantly influences user attitudes, leading to higher acceptance or likelihood to adopt the technology, as supported by the positive path coefficients between PEU, attitude and behavioural acceptance. However, in this model, perceived usefulness has little direct effect on behaviour, though its impact might be felt indirectly through its influence on perceived ease of use and attitude.

Table 4 shows the results of the SEM analysis, focusing on path coefficients, their significance (T-statistics, P-values) and other relevant statistics. Each path in the model corresponds to a hypothesis being tested, providing insight into the strength and direction of the relationships between key variables.

PEU -> BA (perceived ease of use → behavioural intention to adopt)

- Original Sample (O): 0.556 (indicates a positive effect of PEU on BA).
- T-statistics: 9.625 (high value, indicates vital significance).
- P-value: 0.000 (significant at $p < 0.001$).

The hypothesis is that PEU positively affects BA. The path coefficient of 0.556 indicates a strong positive relationship and the T-statistic and P-value confirm that this effect is statistically significant.

PU -> A (perceived usefulness → attitude)

- Original Sample (O): 0.633 (indicates a positive effect of PU on A).
- T-statistics: 13.578 (very high, showing statistically solid significance).
- P-value: 0.000 (significant at $p < 0.001$).

The evidence supports the hypothesis that perceived

Table 4. Results of the test of hypotheses.

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
PEU -> BA	0.556	0.554	0.058	9.625	0.000
PU -> A	0.633	0.630	0.047	13.578	0.000
PU -> BA	0.132	0.133	0.048	2.731	0.006
PU -> PEU	0.665	0.662	0.055	12.101	0.000

usefulness (PU) positively affects Attitude (A). The path coefficient of 0.633 indicates a robust positive effect and the very high T-statistic with the low P-value confirms it to be highly significant.

PU -> BA (perceived usefulness → behavioural intention to adopt)

- Original Sample (O): 0.132 (indicates a weaker positive effect of PU on BA).
- T-statistics: 2.731 (above the typical threshold of 1.96 for significance).
- P-value: 0.006 (significant at $p < 0.01$).

It supports the hypothesis that PU positively impacts BA; however, the effect size was moderate. The path coefficient of 0.132 indicates a weaker positive relationship compared to PEU's influence on BA, suggesting that usefulness has a more minor direct impact on adoption. However, the relationship is statistically significant with a T-statistic of (2.731) and a P-value of 0.006.

PU -> PEU (perceived usefulness → perceived ease of use)

- Original Sample (O): 0.665 (indicates a strong positive effect of PU on PEU).
- T-statistics: 12.101 (very high, showing statistically solid significance).
- P-value: 0.000 (significant at $p < 0.001$).

The hypothesis of a positive association between PU and PEU was strongly supported. The path coefficient of 0.665 indicates a strong positive relationship and the high T-statistic of 12.101 and a P-value of 0.000 confirm the result is highly significant.

The data support all hypothesized relationships in the SEM model, though the strengths of the relationships vary. PEU and PU play critical roles in shaping Behavioural Intention to Adopt and Attitude, with PEU having a more substantial influence than PU. T-statistics and P-values confirm that these relationships are statistically significant and dependable for conclusions.

The weak relationship between Perceived Usefulness (PU) and Behavioural Intention to Adopt (BA), reflected by a path coefficient of 0.132, suggests that while usefulness does have an influence, it is less crucial in driving farmers' intentions to adopt drip irrigation technology. This may be because, in this context, perceived ease of use (PEU) and attitude toward the technology play more substantial roles in shaping adoption behaviours. For many farmers, especially those with limited technical experience, ease of use may be a more immediately relevant factor than usefulness, as the initial learning curve and operational comfort are essential to their willingness to adopt.

Contextual and external factors also explain why perceived usefulness plays a lesser role in influencing behavioural intention than ease of use and attitude. Many farmers in the study may already recognize the theoretical benefits of water-saving technology due to awareness campaigns or observed outcomes in their communities. However, practical challenges such as initial costs, the need for maintenance, or lack of technical support may cause farmers to weigh ease of use and attitude more heavily in their decision-making. While perceived usefulness remains a positive factor, the immediate ease and the personal positive attitude toward the technology appear to hold more significant influence over farmers' willingness to adopt, suggesting that external factors like cost, support and ease of integration into existing farming practices could be pivotal in this context.

Research on information systems has highlighted how attitudes towards technology, mainly perceptions of farmers' ability to learn and use new technologies, are critical for technology adoption (23). Similarly, a study showed how farmers' perceptions and attitudes directly impact their adoption of precision agriculture technologies (24). As observed in this study, the influence of perceived ease of use on the perceived usefulness of technology is consistent with earlier findings (25). Moreover, it demonstrated that perceived ease of use indirectly influences a farmer's intention to adopt new technology, primarily through its impact on perceived usefulness (26, 27). However, perceived ease of use is not always critical in determining whether farmers intend to adopt new technologies (28).

In the suggested conceptual models, the accuracy of estimates for the key constructs is characterized by the coefficient of determination (R^2). As shown in Fig. 3, the R^2 value for Attitude toward Usage is at 0.34, meaning that 34 % of the variance in attitude can be explained by Perceived Usefulness and Perceived Ease of Use. Similarly, the R^2 value for Behavioural Intention is 0.44, indicating that 44 % of the variance in Behavioural Intention toward adopting Precision Agriculture Technologies is explained by Attitude toward Usage. Significant positive relationships were noticed between perceived ease of use, perceived usefulness, behavioural intention and attitude toward technology use (26).

The study explored the relations between perceived usefulness, perceived ease of use, attitude to using technology and the intention to use information technology (29). They also found a positive and significant connection between attitude toward use and intention to use as well as between perceived ease of use and attitude toward use.

The perceived net benefit directly impacted the intention to adopt precision agriculture, primarily through perceived usefulness (24). Furthermore, perceived net benefit indirectly influenced attitudes toward using and the intention to increase the use of precision agriculture technologies in tillage (30). Profitability is crucial for adopting PA tools (31). Several researchers believe tallying a few more variables to the TAM would make it even more robust (32). Beneficiaries' attitudes toward PA technologies were influenced by their perceptions of net benefits, which positively impacted their intention to adopt PA technologies (33). In addition, the PEU significantly impacted the perception of net benefit (24). Hence, beneficiaries were willing to adopt these emerging technologies in the study region.

Conclusion

This study reveals that the adoption of drip irrigation systems by the TN-IAMP farmers depends mainly on the perceptions of the systems' usefulness and ease of use. Perceived Usefulness (PU) was found to have a more substantial influence on

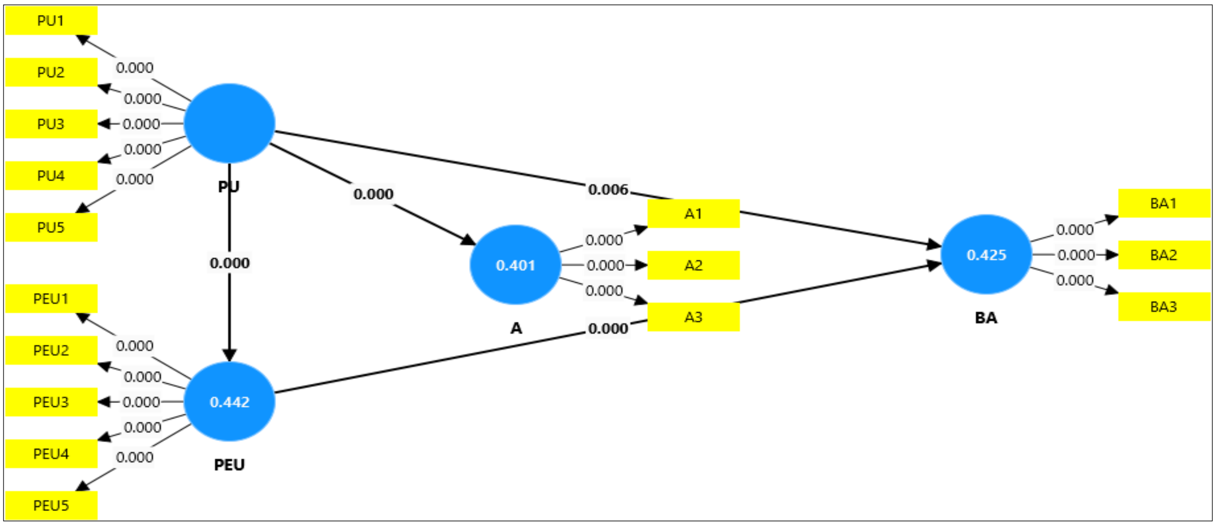

Fig. 3. Structural Model

Behavioural Intention (BI), while Perceived Ease of Use (PEU) significantly influenced both PU and Attitude Toward Use (ATU). These findings highlight the need for policymakers and stakeholders to focus on increasing awareness of the direct benefits of drip irrigation and simplifying the setup and maintenance process. Sustainable irrigation in Tamil Nadu is more likely to be adopted if it offers improved water efficiency and increased agricultural productivity. Despite the valuable insights provided, this study has several limitations. First, the geographic scope is limited to Tamil Nadu, which may not represent the broader Indian context or other regions facing similar agricultural challenges. The study's cross-sectional nature also means that it captures a specific point in time, which may not accurately reflect changes in attitudes or adoption behaviours over time. Future research could include longitudinal studies to assess whether drip irrigation is eventually adopted and its impacts on farm productivity and water conservation. Future research could focus on longitudinal studies to determine the sustained adoption of drip irrigation and its effects on farm productivity and water conservation over time. Expanding the model to include external variables such as social influence, economic incentives and policy support could provide a more comprehensive understanding of adoption dynamics. Exploring these factors could offer valuable insights for policymakers and stakeholders aiming to enhance technology uptake and optimize resource use in agriculture.

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Authors' contributions

DAD carried out the entire research, data collection and analysis. MA guided the research by formulating the concept, helped secure research funds and approved the final manuscript. PB helped provide funds and summarize the manuscript. PK helped in revising and summarizing the manuscript.

Compliance with ethical standards

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