FARMER SATISFACTION WITH AUTOMATED MICRO-IRRIGATION TECHNOLOGY IN WESTERN TAMIL NADU, INDIA: A STRUCTURAL EQUATION MODELLING APPROACH

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ABSTRACT

The success of agricultural innovations largely depends on farmers' satisfaction with the technology. Automated micro-irrigation technology has emerged as an important intervention for addressing water scarcity and labour shortages in agriculture. The present study aimed to assess farmers' satisfaction with automated micro-irrigation technology and identify the key factors influencing satisfaction and its long-term technology use. A field survey was conducted among 300 adopters of automated micro-irrigation technology using a structured questionnaire. Farmers' satisfaction was quantified using the Customer Satisfaction Index (CSI), while the determinants of satisfaction were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The results revealed that the largest proportion (33.67%, n=101) of farmers held more than 10 hectares of farmland. The overall CSI value of 79.81% indicated that farmers were satisfied with the adoption of automated micro-irrigation technology. Among the service-quality dimensions, assurance significantly influenced farmers' satisfaction (β= 0.456, $p \leq 0.001$). Satisfaction further showed a significant positive influence on loyalty towards the technology (β=0.192, p=0.004). Mediation analysis indicated that commitment strongly mediated the relationship between satisfaction and loyalty (β=0.159, $p \leq 0.001$), while trust acted as a partial mediator (β= - 0.030, p=0.039). The findings emphasize the importance of reliable technical support, responsive service systems and effective grievance-handling mechanisms for enhancing long-term adoption and sustained use of automated micro-irrigation technology.

Keywords: Automated micro-irrigation; Farmer satisfaction; PLS-SEM; Sustainable irrigation; Technology adoption

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INTRODUCTION

Agriculture is under increasing pressure to enhance productivity while conserving limited natural resources. Climate change, rapid population growth and declining fresh water availability have intensified the need for sustainable farming practices. Water scarcity and inefficient energy use remain major constraints to agricultural productivity and sustainability. Agriculture is the largest consumer of freshwater globally, accounting for over 70% of total withdrawals and thus plays a central role in water resource depletion (Lamastra *et al.,* 2014; Aivazidou *et al.,* 2016). Water scarcity is particularly severe in semi-arid and arid regions due to increasing competition for water, groundwater depletion and degradation of freshwater resources (Saraiva *et al.,* 2019, 2020).

These issues create an urgent need to adopt sustainable farming practices that improve water-use efficiency, reduce the degradation of freshwater sources and enhance water quality, thereby contributing to Sustainable Development Goal 6 (SDG 6) (Gleick and Cooley, 2021). In this context, automated micro-irrigation technologies have gained traction as an effective intervention to increase crop yield and water-use efficiency while reducing environmental impact (Mohan *et al.,* 2024; Zhang *et al.,* 2022; Zouizza *et al.,* 2023). The integrated use of sensor-based controls and timers improves system efficiency and responsiveness to changing environmental conditions (Godase *et al.,* 2025). By enabling effective resource management, precise water delivery and minimizing losses, automated micro-irrigation technologies directly support SDG 6 and long-term agricultural sustainability. The growing need for sustainable water management solutions is expected to propel the global market for automated irrigation systems to exceed USD 16.7 billion by 2032 (Iskandar *et al.,* 2023; Nisrina *et al.,* 2024).

Despite technological progress and supportive policies, the adoption of automated micro-irrigation technology has been slower than expected in many regions. It is widely acknowledged that end-user acceptance and satisfaction are crucial to the success of such innovative technologies (Luo and Timothy, 2017). Earlier studies have focused on technical feasibility and economic viability, frequently ignoring post-adoption experiences of farmers and influence of their expectations and perceptions on long-term use of the technology (Yazdanpanah *et al.,* 2014; Kule *et al.,* 2025). However, user satisfaction, which influences users' loyalty and willingness to continue using the technology, is directly related to its long-term adoption and diffusion (Van Rijn *et al.,* 2012; Mottaleb, 2018). User dissatisfaction may lead to the failure of newly introduced irrigation technologies (Lopus *et al.,* 2017). Therefore, assessing farmers' satisfaction is essential to monitor performance, identify gaps and implement improvements, enabling technology providers, extension organizations and policymakers to enhance adoption outcomes (Elias *et al.,* 2016; Mottaleb, 2018).

In India, agriculture is the dominant consumer of freshwater resources, making efficient water management a critical concern (Gleick and Cooley, 2021). Tamil Nadu has experienced significant groundwater depletion and increasing water stress in recent decades (Chinnasamy & Agoramoorthy, 2015). The Western Zone of Tamil Nadu, characterized by a semi-arid climate and intensive cultivation of high-value crops, faces persistent challenges related to groundwater depletion, water availability and irrigation efficiency (Chinnasamy & Agoramoorthy, 2015; Sekar *et al.,* 2025).

Although micro-irrigation adoption has been widely encouraged through subsidies and government initiatives, there is still limited empirical research examining farmers' satisfaction with automated micro-irrigation technology and the key factors influencing it. Existing studies have primarily focused on determinants of adoption such as cost, technical knowledge and access to credit (Zhang *et al.*, 2019; Mohan *et al.*, 2024; Selva and Shanthasheela, 2024). However, limited studies have employed rigorous latent-variable modelling approaches such as Structural Equation Modelling (SEM) to examine how behavioural factors and service-quality dimensions jointly influence farmers' satisfaction and loyalty (Rouzaneh *et al.,* 2021; Yazdanpanah *et al.,* 2023).

Thus, the current state of knowledge indicates that while the determinants of adoption have been widely studied, there is limited understanding of farmers' post-adoption satisfaction and its behavioural implications using robust analytical frameworks. The present study addresses this gap by integrating service quality and behavioural constructs within a SEM framework to provide a comprehensive understanding of farmers' satisfaction and its influence on long-term technology use. Therefore, the present study aims to (i) assess the level of farmers' satisfaction with automated micro-irrigation technology and (ii) identify the key factors influencing satisfaction and its relationship with farmers' loyalty using Structural Equation Modelling (SEM).

MATERIALS AND METHODS

Study area: The present study was conducted in the Western Zone of Tamil Nadu, comprising the districts of Coimbatore, Erode and Tiruppur. This region is characterised by semi-arid climatic conditions, intensive cultivation of high-value crops and a relatively higher level of irrigation technology adoption, making it suitable for examining farmers' experiences with automated micro-irrigation technology. The geographical delineation of the study area is presented in Figure 1.

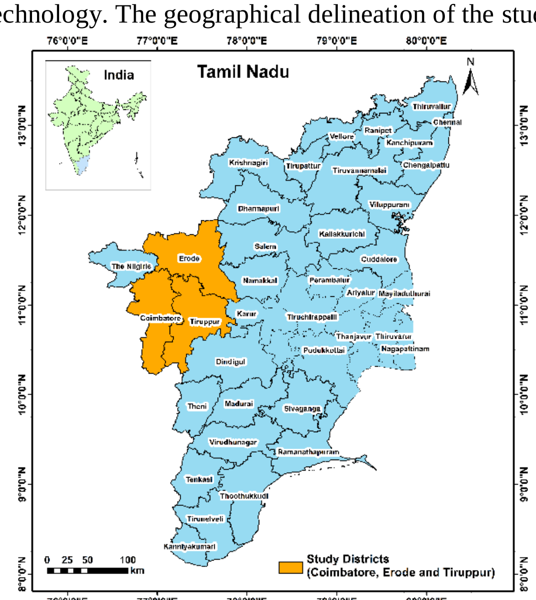

Fig. 1. Study area showing the location of Coimbatore, Erode and Tiruppur districts in Tamil Nadu, India

Sampling procedure and data collection: A verified list of adopters of automated micro-irrigation technology was obtained from agri-tech firms operating in the region and further validated through field visits. This verification ensured the authenticity of the sampling frame and confirmed that the selected respondents had adequate experience with the technology. Proportional random sampling was employed to ensure representation of respondents from each district, resulting in a total sample of 300 farmers. The distribution of respondents across the selected districts is presented in Table 1.

Table 1: Distribution of respondents

District	Total adopters	Sample size
Coimbatore	397	140
Erode	316	112
Tiruppur	137	48
Total	**850**	**300**

Field-level data were collected through face-to-face interviews using a structured questionnaire (Appendix I). The questionnaire captured information on socio-economic characteristics, service-quality perceptions, satisfaction, trust, commitment and loyalty related to automated micro-irrigation technology.

Pilot testing and validation of the instrument: The questionnaire was pre-tested on 30 farmers (10% of the total sample size) from a non-sample area to assess the clarity, relevance and comprehensibility of the items. Based on the feedback obtained, necessary modifications were made to improve the wording and structure of the questionnaire. Content validity was ensured through consultation with subject-matter experts in agricultural extension and irrigation management. Construct reliability was assessed using Cronbach's alpha (Cronbach, 1951) and construct validity was evaluated within the SEM framework (Hair *et al.*, 2019).

Measurement of constructs and conceptual framework: The constructs used in this study were operationalised using established scales. Service quality was measured using the five dimensions of the SERVQUAL model, namely assurance, empathy, reliability, responsiveness and tangibles (Parasuraman *et al.*, 1988). Each dimension consisted of multiple items and was measured on a five-point Likert scale ranging from strongly disagree to strongly agree. Reliable and valid multi-item constructs adapted from Johnson *et al.* (2001) and related literature were used to measure satisfaction, trust, commitment and loyalty. Based on these constructs, a conceptual framework was developed to examine the direct and mediated relationships among service-quality dimensions, satisfaction, trust, commitment and loyalty. The conceptual framework of the study is presented in Figure 2.

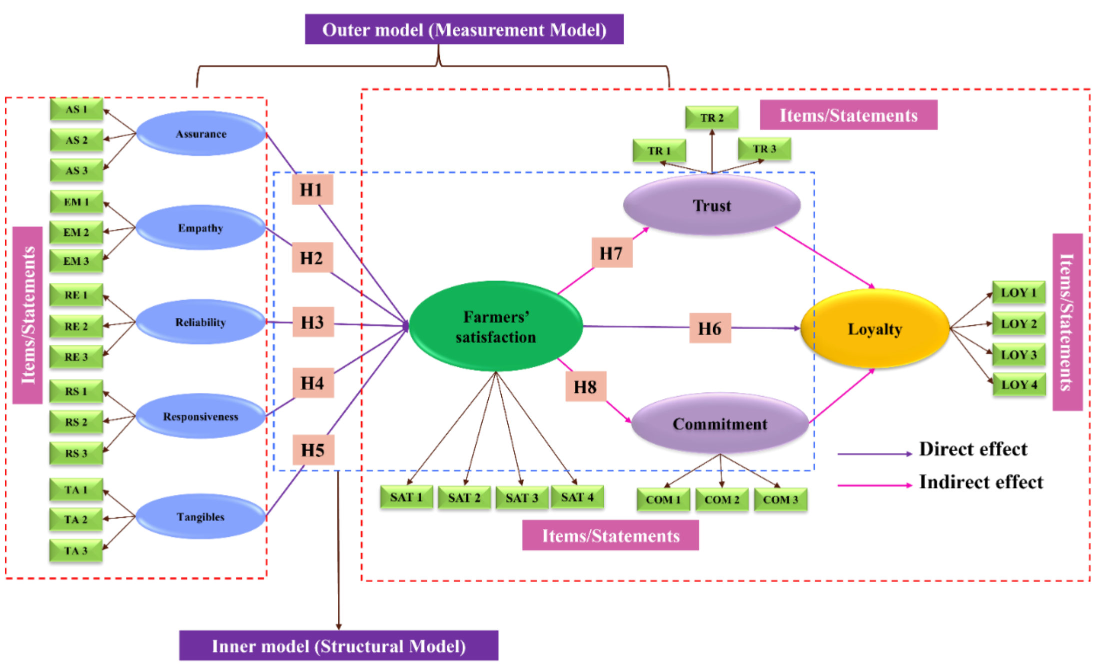

Fig. 2. Conceptual framework of the study

Development of hypotheses: The following hypotheses were formulated based on theoretical foundations empirical evidence:
H1: Assurance has a direct and positive effect on farmers' satisfaction.
H2: Empathy has a direct and positive effect on farmers' satisfaction.
H3: Reliability has a direct and positive effect on farmers' satisfaction.
H4: Responsiveness has a direct and positive effect on farmers' satisfaction.
H5: Tangibles have a direct and positive effect on farmers' satisfaction.
H6: Farmers' satisfaction has a direct and positive influence on loyalty towards the technology
H7: Trust mediates the relationship between satisfaction and loyalty.
H8: Commitment mediates the relationship between satisfaction and loyalty.

Customer Satisfaction Index (CSI): Farmers' satisfaction with automated micro-irrigation technology was assessed using the Customer Satisfaction Index (CSI), adapted from Shaba and Alam (2024). The CSI provides an overall measure of satisfaction by considering the relative importance of different service quality dimensions.

The five dimensions (assurance, empathy, reliability, responsiveness and tangibles) were measured using a set of structured statements (totaling 15 items), on a five-point Likert scale. Mean importance and satisfaction scores were computed for each dimension. Weight factors were calculated by comparing the importance of each dimension with the total importance score. Weighted satisfaction scores were obtained by multiplying each weight factor with the corresponding satisfaction score. The CSI was calculated using the following expression:

$$CSI = \frac{\sum_{i=1}^{p} W_i S_i}{K} \times 100$$

where $W_i$represents the weight factor, $S_i$denotes the satisfaction score and K represents the maximum possible score. CSI values were interpreted using predefined categories, as presented in Table 2.

Table 2: Classification of customer satisfaction index

Index Value (%)	Classification
81 – 100	Very much satisfied
66 - 80.99	Satisfied
51 - 65.99	Moderately satisfied
35 - 50.99	Slightly satisfied
0 - 34.99	Not satisfied

Statistical analysis: The determinants of farmers' satisfaction with automated micro-irrigation were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM). SEM enables the estimation of both direct and indirect relationships among latent variables and is suitable for analyzing complex causal relationships (Prasetyo *et al.*, 2020). PLS-SEM was performed using Smart PLS 4.0 software. The measurement model was assessed for indicator reliability, internal consistency reliability, convergent validity and discriminant validity using factor loadings, Cronbach's alpha, composite reliability, average variance extracted (AVE) and the heterotrait - monotrait ratio (HTMT). Subsequently the structural model was evaluated using path coefficients, coefficient of determination (R^2), effect size (f^2) and bootstrapping procedures to examine the hypothesized relationships among the constructs. Mediation analysis was performed to assess the indirect effects of trust and commitment on the relationship between satisfaction and loyalty. PLS-SEM has been widely applied in studies involving service quality and behavioural constructs (Vatolkina *et al.*, 2020).

RESULTS

The study obtained complete responses from 300 farmers adopting automated micro-irrigation technology. The respondents were cultivating crops such as coconut, arecanut, nutmeg, turmeric, fruit crops (mango, pomegranate, guava, banana), drumstick and various vegetables

Profile characteristics of the farmers: The profile characteristics presented in Table 3 indicate that a majority of the farmers were moderately educated. The largest proportion (28.33%) had completed higher secondary education (11^{th}-12^{th}), followed by those educated upto secondary level (6^{th}-10^{th}) (20.67%), diploma or certificate holders (17.33%), graduates (15.67%), primary education (7.67%) and postgraduates (6.00%) while only 4.33% were illiterate.

In terms of landholdings, large farmers constituted the largest group (33.67%), followed by medium (26.33%) and semi-medium farmers (20.00%). Small and marginal farmers accounted for 14.33% and 5.67% respectively. Regarding farming experience, half of the respondents (50.00%) had 11-20 years of experience, while 26.33% had less than 10 years and 23.67% had more than 21 years. With respect to farm proximity, 41.67% of the farmers had fields located more than 50 km away, whereas 36.00% had moderately accessible farms (25-50 km) and 22.33% had farms within 25 km range.

Table 3: Profile characteristics of farmers

Profile	Category	Frequency (n)	Percentage (%)
Educational status	Illiterate	13	4.33
	Up to primary education	23	7.67
	6^{th} to 10^{th}	62	20.67
	11^{th} and 12^{th}	85	28.33
	Diploma or certificate holders	52	17.33
	Graduate	47	15.67
	Postgraduate and above	18	6.00
Farm size (ha)	Marginal (≤1.00)	17	5.67
	Small (1.00 – 2.00)	43	14.33
	Semi- medium (2.01 – 4.00)	60	20.00
	Medium (4.01 – 10.00)	79	26.33
	Large (>10.01)	101	33.67
Farm experience (years)	Up to 10	79	26.33
	From 11 to 20	150	50.00
	21 and more	71	23.67
Farm proximity (km)	Easily Accessible Farmland (≤ 25)	67	22.33
	Moderately Accessible Farmland (25-50)	108	36.00
	Remotely Located Farmland (> 50)	125	41.67

Customer Satisfaction Index (CSI): The Customer Satisfaction Index (CSI) was computed using weighted importance and satisfaction scores of service quality dimensions (Table 4). The overall CSI value was 79.81%, indicating that farmers were generally satisfied with the automated micro-irrigation technology. Among the dimensions, assurance and empathy contributed relatively higher weighted scores compared to other dimensions.

Table 4: Customer Satisfaction Index (CSI) of farmers using automated micro-irrigation technology

Dimension	Item	MIS	WF (%)	MSS	WS
Assurance	AS1	4.60	7.023	4.15	29.16
	AS2	4.50	6.870	3.95	27.14
	AS3	4.30	6.565	3.85	25.28
Empathy	EM1	4.40	6.717	4.00	26.87
	EM2	4.20	6.412	3.75	24.05
	EM3	4.70	7.176	4.20	30.34
Reliability	RE1	4.50	6.870	4.05	27.81
	RE2	4.40	6.717	3.95	26.54
	RE3	4.30	6.565	3.85	25.28
Responsiveness	RS1	4.10	6.259	3.65	22.84
	RS2	4.20	6.412	3.85	24.70
	RS3	4.60	7.023	4.10	28.79
Tangibles	TA1	4.40	6.717	3.95	26.54
	TA2	4.30	6.565	3.90	25.60
	TA3	4.00	6.106	3.70	22.20
Total					399.05
Customer Satisfaction Index (CSI)					**79.81%**

Note: AS=Assurance; EM=Empathy; RE=Reliability; RS=Responsiveness; TA=Tangibles; MIS=Mean Importance Score; WF=Weight Factor; MSS=Mean Satisfaction Score; WS= Weight Score

Determinants of farmers' satisfaction

Measurement model assessment: The measurement model was evaluated to assess the reliability and validity of the constructs. Convergent and discriminant validity were used as the primary criteria.

Internal Consistency: Internal consistency was assessed using Cronbach's alpha and composite reliability (CR). All constructs exhibited values greater than the recommended threshold of 0.70, indicating acceptable reliability (Table 5).

Table 5: Construct reliability and validity

Construct	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Assurance	0.915	0.926	0.946	0.854
Commitment	0.888	0.895	0.931	0.817
Empathy	0.802	0.878	0.876	0.702
Loyalty	0.822	1.053	0.851	0.589
Reliability	0.877	0.935	0.922	0.798
Responsiveness	0.888	1.025	0.921	0.797
Satisfaction	0.862	0.917	0.903	0.702
Tangibles	0.962	0.838	0.938	0.835
Trust	0.950	0.955	0.968	0.909

Convergent Validity: Convergent validity was assessed using factor loadings and Average Variance Extracted (AVE). All indicator loadings exceeded 0.70 and AVE values were above 0.50, confirming adequate convergent validity (Table 6).

Table 6: Indicator factor loadings for measurement items

Construct	Item	Loading
Assurance	AS1	0.928
	AS2	0.934
	AS3	0.910
Commitment	COM1	0.926
	COM2	0.902
	COM3	0.884
Empathy	EM1	0.844
	EM2	0.806
	EM3	0.864
Loyalty	LOY1	0.713
	LOY2	0.779
	LOY3	0.720
	LOY4	0.851
Reliability	RE1	0.892
	RE2	0.815
	RE3	0.966
Responsiveness	RS1	0.851
	RS2	0.891
	RS3	0.933
Satisfaction	SAT1	0.927
	SAT2	0.881
	SAT3	0.857
	SAT4	0.763
Tangibles	TA1	0.928
	TA2	0.981
	TA3	0.826
Trust	TR1	0.964
	TR2	0.952
	TR3	0.945

Note: AS = Assurance; COM = Commitment; EM= Empathy; LOY=Loyalty;RE=Reliability; RS=Responsiveness; SAT=Satisfaction; TA= Tangibles; TR=Trust

Discriminant Validity: Discriminant validity was evaluated using the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio. The square root of AVE for each construct exceeded the corresponding inter-construct correlations, satisfying the Fornell-Larcker criterion (Table 7). Additionally, HTMT values were below the threshold of 0.85, confirming discriminant validity (Figure 3).

Table 7: Discriminant validity (Fornell-Larcker criterion)

Construct	AS	COM	EM	LOY	RE	RS	SAT	TA	TR
AS	**0.924**								
COM	0.561	**0.904**							
EM	0.413	0.444	**0.838**						
LOY	0.378	0.387	0.323	**0.767**					
RE	0.139	0.163	0.416	0.194	**0.893**				
RS	0.091	0.133	0.237	0.258	0.221	**0.893**			
SAT	0.471	0.462	0.237	0.280	0.095	0.224	**0.838**		
TA	0.391	0.393	0.662	0.503	0.384	0.201	0.205	**0.914**	
TR	0.126	0.134	0.791	0.197	0.214	0.366	0.126	0.329	**0.953**

Note: AS = Assurance; COM = Commitment; EM= Empathy; LOY=Loyalty; RE=Reliability; RS=Responsiveness; SAT=Satisfaction; TA= Tangibles; TR=Trust

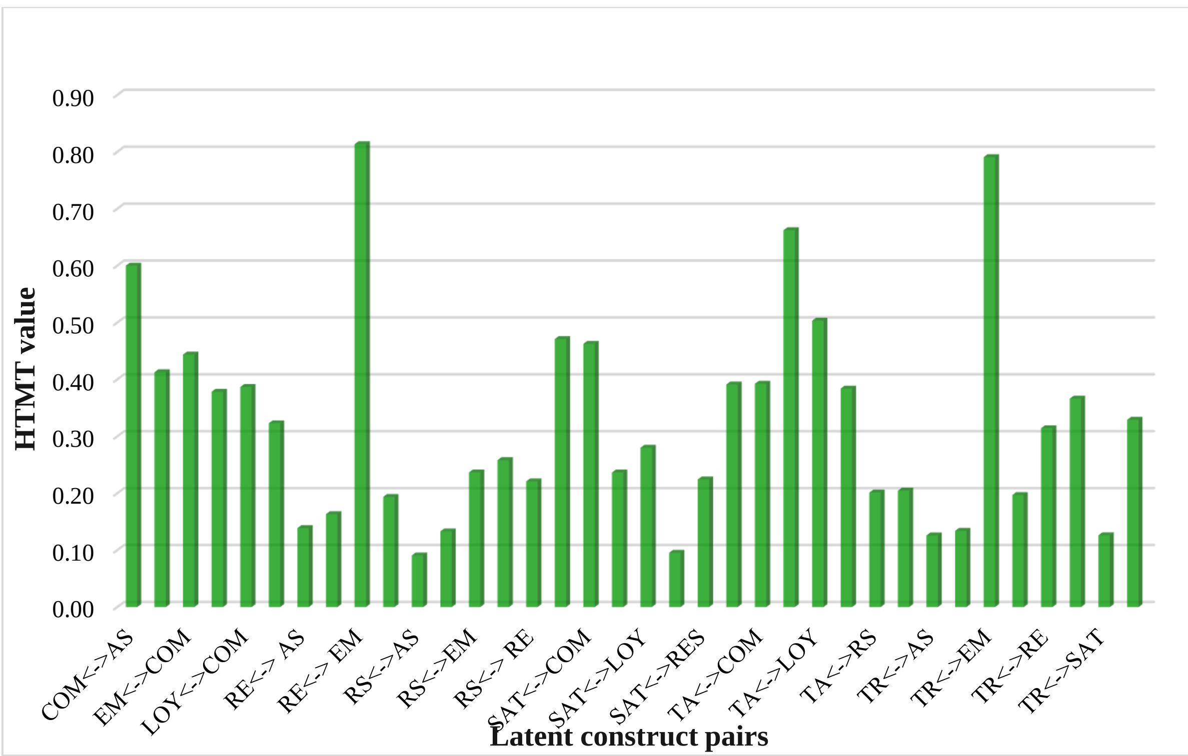

Fig. 3. Heterotrait-Monotrait ratio (HTMT) values among the latent constructs. All HTMT values were below the recommended threshold of 0.85, indicating adequate discriminant validity. AS = Assurance; COM = Commitment; EM = Empathy; LOY = Loyalty; RE = Reliability; RS = Responsiveness; SAT = Satisfaction; TA = Tangibles; TR = Trust

Structural Model Assessment: The structural model was evaluated using the coefficient of determination (R^2), effect size (f^2) and hypothesis testing through bootstrapping (p-values). The structural model is presented in Figure 4.

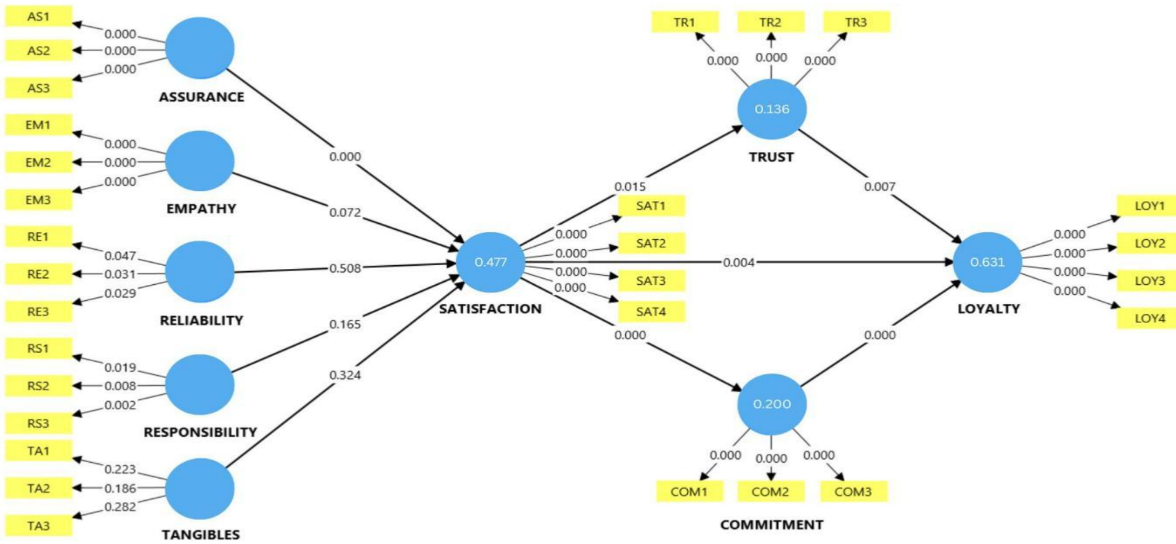

Fig. 4. Structural model of the PLS-SEM analysis showing the relationships among service-quality dimensions, satisfaction, trust, commitment and loyalty. Values inside the circles represent the coefficient of determination (R^2) of the endogenous constructs, whereas values on the arrows indicate bootstrapped p-values

Coefficient of determination (R^2): Service-quality dimensions explained 47.7% of the variance in satisfaction (R^2 = 0.477). Satisfaction explained 13.6% of the variance in trust (R^2 = 0.136) and 20.0% in commitment (R^2 = 0.200). Satisfaction, trust and commitment together explained 63.1% of the variance in loyalty (R^2 = 0.631), indicating substantial predictive power.

The effect size (f^2): Effect size analysis was performed to assess the relative contribution of each exogenous construct to the explained variance of the endogenous constructs. According to Hair *et al.* (2019), f^2 values of 0.02, 0.15 and 0.35 represent small, medium and large effects, respectively.

Assurance exerted a medium effect on satisfaction (f^2 = 0.218), while tangibles (f^2 = 0.063) and empathy (f^2 = 0.023) exhibited small effects. Reliability (f^2 = 0.004) and responsiveness (f^2 = 0.007) showed negligible effects on satisfaction (Figure 5). These findings are consistent with the bootstrapping results, wherein assurance was the only service-quality dimension that exerted a statistically significant influence on satisfaction, while empathy, tangibles, reliability and responsiveness exhibited small to negligible effect sizes and non-significant path coefficients.

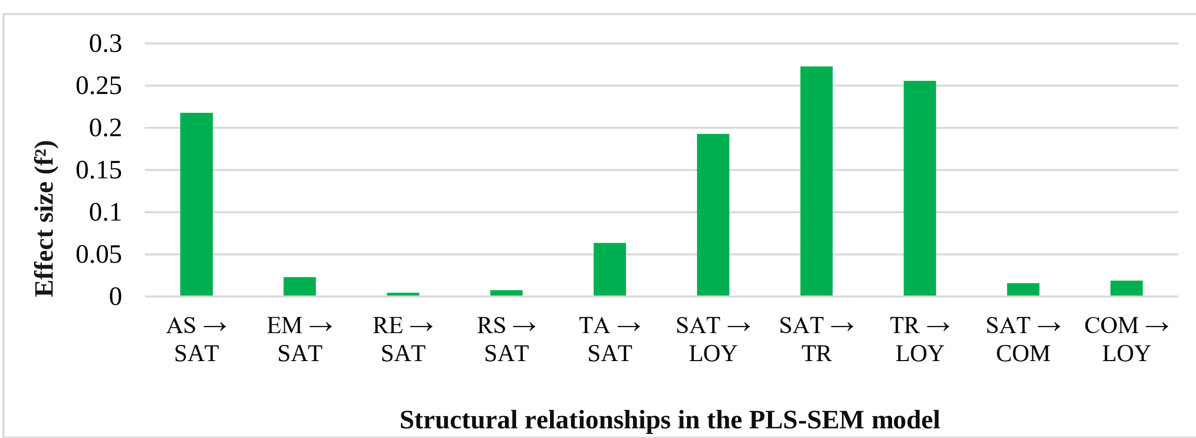

Fig. 5. Effect size (f^2) estimates for the structural relationships in the PLS-SEM model. The f^2 statistic indicates the relative contribution of each exogenous construct to the explained variance of the corresponding endogenous construct. According to Hair *et al.* (2019), f^2 values of 0.02, 0.15 and 0.35 represent small, medium and large effects, respectively. AS = Assurance; COM = Commitment; EM = Empathy; LOY = Loyalty; RE = Reliability; RS = Responsiveness; SAT = Satisfaction; TA = Tangibles; TR = Trust

Hypothesis testing

Direct effects: Bootstrapping results (Table 8) indicated that assurance had a positive and significant effect on satisfaction ($\beta = 0.456$, $t = 6.992$, $p \leq 0.001$), thereby supporting H1. However, empathy (H2), reliability (H3), responsiveness (H4) and tangibles (H5) did not show significant effects on satisfaction. Satisfaction had a positive and significant effect on loyalty ($\beta = 0.192$, $t = 2.868$, $p = 0.004$), supporting H6.

Table 8: Bootstrapping results for direct effects

Hypothesis	Path	β (O)	M	SD	t-value	p-value	Decision
H1	AS → SAT	0.456	0.486	0.065	6.992	0.000	Supported
H2	EM → SAT	-0.258	-0.317	0.143	1.801	0.072	Not supported
H3	RE → SAT	0.099	0.081	0.149	0.662	0.508	Not supported
H4	RS → SAT	0.080	0.085	0.058	1.387	0.165	Not supported
H5	TA → SAT	0.273	0.212	0.277	0.986	0.324	Not supported
H6	SAT → LOY	0.192	0.194	0.067	2.868	0.004	Supported

Note: β (O) = standardized path coefficient (original sample); M=sample mean; SD=standard deviation; AS = Assurance; EM= Empathy; RE=Reliability; RS=Responsiveness; TA=Tangibles; SAT=Satisfaction; LOY=Loyalty

Mediation analysis: Trust exhibited a significant but weak negative mediating effect between satisfaction and loyalty ($\beta = -0.030$, $t = 2.069$, $p = 0.039$), supporting H7. While satisfaction exhibited a significant positive direct effect on loyalty ($\beta = 0.192$, $t = 2.868$, $p = 0.004$), the indirect effect through trust was negative, indicating that the mediation pathway operated in the opposite direction to the direct effect. Commitment showed a significant positive mediating effect between satisfaction and loyalty ($\beta = 0.159$, $t = 4.009$, $p \leq 0.001$), thereby supporting H8 (Table 9).

Table 9: Bootstrapping results for mediation effects

Hypothesis	Path	β (O)	M	SD	t-value	p-value	Decision
H7	SAT → TR → LOY	-0.030	-0.029	0.014	2.069	0.039	Supported
H8	SAT → COM → LOY	0.159	0.162	0.040	4.009	0.000	Supported

Note: β (O) = standardized path coefficient (original sample); M=sample mean; SD=standard deviation; COM = Commitment; LOY = Loyalty; TR=Trust; SAT = Satisfaction

DISCUSSION

Assessing farmers' satisfaction is essential for evaluating the effectiveness of automated micro-irrigation technology. Hence, the present study examined the key factors influencing satisfaction among end users of the technology.

The educational attainment of farmers significantly influences agricultural practices, particularly the adoption of modern technologies. In the present study, 88% of farmers had education beyond primary level, highlighting the role of education in the uptake of modern farming technologies. Similar results were reported by Sajid *et al.* (2017) regarding the adoption of advanced irrigation technologies in Pakistan. Farooq *et al.* (2022) also reported that education influences farmers' knowledge levels and the adoption of smart agricultural technologies. Das *et al.* (2019) further observed that farmers with secondary and higher education showed greater interest in adopting automated technologies. However, education alone does not necessarily ensure technology adoption, as institutional support, access to credit and extension services also play crucial roles (Gautam *et al.*, 2024; Nhuong and Truong, 2024; Asmare *et al.*, 2025).

The current study showed that 26.33% of the farmers possessed 4.01 to 10.00 hectares of farmland, while 33.67% had more than 10 hectares, together accounting for 60% of the respondents. Farm size plays an important role in the adoption of modern agricultural technologies, as larger farms have greater capacity to invest in such innovations. Similar studies conducted in Pakistan and Iran reported that farm size is a significant determinant of the uptake of water-saving irrigation technologies, with larger landholdings more likely to adopt such innovations (Razzaq *et al.*, 2018; Yazdanpanah *et al.*, 2023). Nevertheless, smallholders are more likely to adopt micro-irrigation technologies when supported by subsidies, access to credit and community-based systems, indicating that institutional mechanisms can mitigate the challenges associated with limited farm size (Gautam *et al.*, 2024; Chand and Kishore, 2025).

The present study revealed that 50% (n=150) of the farmers had farming experience of 11-20 years. This finding is consistent with previous research by Sajid *et al.* (2021), which indicated that experienced farmers are more receptive to improved irrigation practices. The current study reported that nearly half of the respondent farmers (41.67%) had farms located at a considerable distance (more than 50 km), while 36% had their landholding in the range of 25 to 50 km. Greater distance to farmland increases the need for labour-saving and energy-efficient technologies, thereby encouraging the adoption of automated systems. A similar pattern was reported by Sajid *et al.* (2021), who noted that limited accessibility to farmland influences farmers' preference for automated technologies.

The higher proportion of educated farmers, larger landholdings and considerable farming experience among the respondents may have facilitated the effective use of automated micro-irrigation technology. In addition, the greater distance between residence and farmland may have increased the usefulness of automation, thereby contributing to the favourable satisfaction levels observed in the present study. With regard to farmers' satisfaction, the CSI value of 79.81% indicated that farmers were satisfied with automated micro-irrigation technology, reflecting a positive user experience. Assurance emerged as the most significant factor influencing satisfaction, indicating that reliable service interactions, knowledgeable staff and trustworthy support are critical for building user confidence. Similar studies have reported that competence and professionalism enhance user satisfaction in technology utilisation (Elmadag *et al.*, 2008; Janahi and Al Mubarak, 2017). The significance of assurance may be attributed to the technical nature of the automated micro-irrigation technology, which requires proper installation, operational guidance and periodic technical support. Consequently, farmers may place greater importance on service providers' knowledge and competence, thereby enhancing their confidence in the technology.

The non-significant effects of empathy, reliability, responsiveness and tangibles suggest that farmers prioritize outcome-oriented benefits over relational or service-based attributes. The results are consistent with previous studies on agricultural technological innovations, which highlight that farmers emphasize measurable outcomes such as reduced labour, efficient water use and reliable system performance (Awan *et al*., 2011; Nambisan *et al.*, 2016; Balinado *et al.*, 2021). However, contrasting evidence has indicated that responsiveness and reliability significantly influence farmers' satisfaction, particularly when technical support and service delivery are inconsistent, suggesting that the importance of these dimensions may vary across adoption contexts (Zhang *et al.*, 2024; Su *et al.*, 2026).

Satisfaction emerged as a significant determinant of loyalty. This confirms that a satisfactory user experience fosters continued use, repeated engagement and positive word-of-mouth. Similar findings have been reported in previous studies, which demonstrated that satisfaction positively influences loyalty and continued engagement with agricultural technologies and services (Rouzaneh *et al.*, 2021; Shyu *et al.*, 2023; Jabbari *et al.*, 2023). The association between satisfaction and loyalty has also been reported in earlier, studies on farmers' technology adoption behaviour (Jabbari *et al.*, 2023; Mathuabirami *et al.*, 2025; Raza *et al.*, 2025).

The mediation analysis revealed that commitment strongly mediates the relationship between satisfaction and loyalty, whereas trust exhibited a significant but weak negative mediating effect between satisfaction and loyalty. This indicates that commitment is a key psychological factor translating satisfaction into long-term use. Various studies have highlighted that in the context of agricultural technology adoption, trust acts as a mediator between satisfaction and loyalty, while commitment plays a crucial role in sustaining long-term utilization (Jayashankar & Nilakanta, 2018; Shyu *et al.*, 2023). However, in the present study, the indirect effect of satisfaction on loyalty through trust was negative, operating in the opposite direction to the positive direct effect of satisfaction on loyalty. This finding indicates that trust did not enhance the positive relationship between satisfaction and loyalty.

The significant effect of satisfaction on loyalty suggests that satisfied farmers are more likely to continue using the technology and remain loyal over time. While commitment positively contributed to the translation of satisfaction into loyalty, the indirect effect through trust was negative. Overall, the findings suggest that farmers evaluate automated micro-irrigation technology not only in terms of technical performance but also based on long-term value and service support. Reliable system operation, timely technical support and farmers' commitment to the technology may further enhance satisfaction and sustained adoption.

Conclusions: The present study provides insights into farmers' satisfaction with automated micro-irrigation technology and identifies the major factors influencing satisfaction and farmers' loyalty towards the technology. The findings revealed that farmers were generally satisfied with the adoption of automated micro-irrigation technology. Among the service-quality dimensions, assurance emerged as the most significant determinant of satisfaction, which subsequently exerted a positive influence on farmers' loyalty. The mediation analysis further indicated that commitment positively mediated the relationship between satisfaction and loyalty, while trust exhibited a significant but weak negative mediating effect. These findings highlight the importance of reliable technical support, service competence and user confidence in enhancing farmers' satisfaction and loyalty towards automated micro-irrigation technology. However, the study was confined to adopters of automated micro-irrigation technology in selected districts of the Western Zone of Tamil Nadu. Future studies may compare adopters and non-adopters across different regions to obtain a broader understanding of technology adoption and user satisfaction.

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Authors' Contribution Statements: IV conducted field survey and data analysis. KC conceived the idea and supervised the study. ND, RK and PM provided technical and methodological guidance. VG assisted in tool refinement and manuscript editing.

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