



Exploring Sustainable Practices in Fish Farming: A Structural Equation Modeling Approach

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Abstract—Fish farming is a significant contributor to the global food security, income and employment, and aligns itself with the Sustainable Development Goals (SDGs). However, concern over the adoption of sustainable methods in fish farming has grown as the demand for fish throughout the world rises. In response, this study takes into account select elements of the Theory of Planned Behaviour (TPB). AEI (Awareness of Environmental Issues), PEB (Perceived Economic Benefits), PU (Perceived Usefulness), and SI (Social Influence) are hypothesised to influence both AI (Adoption Intention) and SAP (Sustainable Fish farming Practices), which includes environmental and economic dynamics. AES (Access to Extension Services) has been proposed as a moderator to assess the strength of the relationship between intention and practice.

This study uses quantitative survey data from 320 fish farmers from two districts of Assam, Kamrup (M) and Nagaon. The data were analysed using Structural Equation Modeling (SEM). The findings show that all exogenous variables have a significant impact on the intention. However, only SI and AI influenced SAP. AES had a significant negative moderating effect on the Intention–Behaviour link. The insights of this study provide guidance in designing strategies in policy making, eventually helping in directing the farmers' actions towards desired behavioural outcomes.

Keywords—Sustainability, Fish Farming, Extension Services, Theory of Planned Behaviour, Structural Equation Modeling.

1. Introduction

Aquaculture has seen significant growth in recent years. This growth has been rapid, and therefore, it is now the fastest-growing food production sector in the world. Pisciculture, a specialised practice within aquaculture, has been playing an important role in this expansion (Garlock et al., 2024; FAO, 2024). The Food and Agriculture Organisation (FAO, 2024) estimates that there are more than 61.8 million people engaged in primary sector fisheries and aquaculture activities, making the fishery sector one of the major sources of employment, food security and livelihood for a large number of people. By pisciculture, we refer to the activities associated with cultivating (breeding, transplantation, and rearing) fish in a controlled environment (Murray, 1909), and aquaculture includes cultivating a wide range of aquatic organisms like fish, molluscs, and aquatic plants. Pisciculture is generally understood as fish farming, and it is the branch of aquaculture where fish are raised using artificial means, where tanks or ponds are constructed.

The Fishery sector includes both capture and culture fisheries. Historically, capture fisheries have been the major source of fish for human consumption; however, in recent decades, culture fisheries have surpassed capture fisheries in terms of global production. This is largely attributed to factors like overfishing, habitat destruction, and the effects of climate change (Olagunju et al., 2025). As capture fisheries face challenges in fulfilling the rising demand (Chuenpagdee et al., 2021), fish farming offers a sustainable alternative, especially in developing economies.

In India, agriculture is a major source of income and employment. Additionally, fish farming plays a vital role in generating additional revenue. India is the second-largest producer of fish in the world, sharing 8% of the overall global fish production. India produced 184.02 lakh tonnes of fish during 2023–24 (Press Information Bureau, Government of India, 2025). The topography of the country comprises extensive channels of rivers, ponds, tanks, lakes, and reservoirs, which have made the culture-fisheries highly suitable. Among all sectors, the fishery sector in India showed the highest annual decadal growth of 9.08% from 2014–15 to 2022–23, indicating a significant rise in recent years. It is also included in the category of “sunrise sector” by the NITI Aayog (Ministry of Fisheries, Animal Husbandry & Dairying, 2025), and receives special attention not only through policy support but also financial support for sustainable, responsible, inclusive and equitable growth.

An important feature of fish farming is that it is an estimate-based enterprise, unlike other farm-based activities like animal husbandry or poultry. The traditional farmers do not have full visibility of what is grown and lack exact

knowledge of fish growth, health, and production conditions; they rely on past experience, judgment, and continuous monitoring rather than precise measurements (Brummett, 2008). This uncertainty, especially in the absence of a reliable forecasting tool or any real-time data, makes fish farming difficult and a high-risk venture. Additionally, farmers operating their businesses on a small scale often face challenges in increasing their earnings as they are unable to meet economies of scale. This creates an environment where survival becomes a major concern rather than putting an emphasis on long-term sustainability, and immediate economic returns become the goal of the farmers. The increasing demand for fish in recent years has also created additional pressure on the fishery sector, eventually putting the entire aquatic ecosystem at risk. To address and eliminate such problems, institutional support plays an important role. Extension services help farmers equip themselves with knowledge, tools, and resources, enabling them to make informed decisions, adopt better techniques, and manage environmental risks effectively. It transfers innovation and technical information, thus minimising the gap between research and actual practice, and leading to capacity building (Anderson & Feder, 2007; Aker, 2011; Mungai et al., 2024).

Recently, researchers have been increasingly studying factors influencing sustainable practices in fisheries and aquaculture (Jana & Jana, 2003; Boyd et al., 2020). Additionally, behavioural studies are conducted in the area of agriculture and environmental management with increasing attention on elements like attitudes, motivations, and perception in understanding technology and practice adoption (Dessart et al., 2019; Swart et al., 2023). Also, efforts have been made at the policy level to determine the factors that influence sustainable practices among farmers (Dwyer et al., 2007; OECD, 2012), and are largely confined to behavioural economics and communication science. While these studies have generated important insights, the determinants are context-specific. Thus, using it in studying pisciculture opens up additional perspectives, especially useful in implementing new policies and programmes. However, behaviour and motivational factors associated with pisciculture, in particular, remain underexplored as emphasis is laid on understanding production efficiency, environmental management, and economic dimensions (Verdegem et al., 2023; Ahmed, 2019; Carballeira Braña et al., 2021).

In studying a behaviour, intention is a prerequisite for an action. However, it may not always guarantee a desired behavioural outcome. For instance, farmers intending to adopt sustainable behaviour may fail due to factors like lack of technical support, capital constraints, and/or institutional gaps. In this study, the Adoption of sustainable practices in fish farming has been analysed from the environmental and economic perspectives. The study develops a conceptual framework, analysing the influence of psychological attributes: AEI, PEB, PU, and SI on both AI and SAP. The influence of AI on SAP is also studied. Additionally, AES is introduced as a moderator, focusing on assessing whether it strengthens or weakens the relationship between AI and SAP. This study gives institutional dimension a new angle via AES and shifts from “what should be done” (technical perspective) to “why or why not it is done” (behavioural and institutional perspective). This study adds to the current literature, giving a holistic perspective on what drives sustainable practices in fish farming.

This study has been conducted in two districts of Assam—Kamrup Metropolitan (M) and Nagaon. This was done taking into account the diverse socioeconomic and institutional dynamics having an influence on fish farming. This helps in understanding the extension service outcomes involving diverse settings.

2. Conceptual Framework & Hypotheses Formulation

2.1. Awareness of Environmental Issues (AEI)

Recent years have attracted significant attention towards environmental sustainability, with growing emphasis on the role of agriculture in shaping the ecology (Sulewski & Gołaś, 2019). Farmers and their choices have a direct bearing on the environment, and therefore, AEI plays an important role in promoting SAP. Literature has struggled in developing a universal definition that explains environmental awareness, as the concept itself is multifaceted (Cynk, 2017; Despotović et al., 2021). Ali (2015) defines it as the perception of environmental problems within the rational/experiential and emotional/psychological domains. In the context of this study, it explains the farmer’s perception and sensitivity to the environmental risks associated with unsustainable practices.

The Theory of Planned Behaviour (TPB) explains that attitude influences intention (Ajzen, 1985) and awareness acts as a precedent in the formation of attitude, shaping intention (Maichum et al., 2016; Zhang et al., 2019). Existing studies using the TPB have shown earlier that environmental concerns are more likely to generate pro-environmental intentions (Kotzya et al., 2024). This strengthens the explanation that awareness also predicts intention. A study by Bhujel & Joshi (2023) also supports the fact that environmental consciousness significantly affects intention to adopt sustainable practices, bringing in a clear idea that awareness eventually brings out the desired behavioural outcomes.

While studies have been conducted in broader environmental contexts, literature supports that people with high environmental awareness are more inclined towards adopting sustainable practices (Kollmuss & Agyeman, 2002; Ashrit & Joshi, 2024; Garcia-Salirrosas et al., 2024). Conceptually, this link therefore suggests that awareness strongly influences actual adoption. However, awareness may not necessarily lead to adoption (Kim & Lee, 2023) as it may be

affected by other underlying factors. Therefore, to understand the relationship of AEI, AI and SAP, the following hypotheses are formulated:

H1: Awareness of Environmental Issues positively influences Adoption Intention.

H2: Awareness of Environmental Issues positively influences farmers' sustainable practices.

2.2. *Perceived Economic Benefits (PEB)*

PEB refers to an individual's subjective evaluation of the financial gains or advantages resulting from a particular activity or behaviour. Literature suggests that economic benefits can generate positive emotional responses, leading to the creation of intention (Liu et al., 2020; Tran, 2021). Agricultural studies highlight that both economic and non-economic benefits are assessed by the farmers when it comes to the adoption of new technology and practices (Munguia et al., 2021). Therefore, considering economic returns as a factor while implementing new programmes would prove to be beneficial in real-world scenarios, as it forms a basis for decision-making.

In the context of pisciculture, intention captures the willingness of farmers to adopt sustainable practices. Building on this, this study aims to understand the influence of PEB on the intention of fish farmers. Sustainability will be adopted when it economically pays off. Additionally, in aquaculture contexts, with better management practices and technological upgrades, consistent productivity, cost advantage, reduced disease risk, feed efficiency, and ultimately increased returns are observed—thereby activating not only intention but also behaviour. For instance, Sivaraman et al. (2019) found that economic efficiency and lower environmental impact create a relative advantage, bringing in more farmers to adopt sustainable practices.

Empirical studies in the fish farming contexts highlight the fact that SAP enhances welfare and income generation (Aung et al., 2021). Market incentives and economic benefits also play an important role in generating desired behaviour. For instance, organic labelling provides price premiums, which is a reward to the farmers resorting to sustainable practices (Ankamah-Yeboah et al., 2016). Thus, for exploring the link between PEB, AI and SAP, the following hypotheses are formulated:

H3: Perceived Economic Benefits positively influence adoption intention.

H4: Perceived Economic Benefits positively influence farmers' sustainable practices.

2.3. *Perceived Usefulness (PU)*

PU, one of the central constructs in the Technology Acceptance Model (TAM), is defined by Davis (1989) as "the degree to which a person believes that using a particular system would enhance his or her performance." Literature indicates that PU influences AI positively while adopting precision agriculture technologies (Schaak & MuBhoff, 2018; Rezaei et al., 2020; Bagheri et al., 2021; Thomas et al., 2023). Therefore, in context of fish farming, an attempt was made to link PU with AI.

Again, beyond intention, PU can also directly impact the actual implementation of SAP. With an increase in PU, farmers tend to bypass AI, resulting in changed behaviour. For instance, a study conducted by Pandeya et al. (2025) on precision agriculture among small-scale farmers mentioned that beliefs about productivity and profitability, reflecting perceived usefulness, influence adoption behaviour. To analyse the link, the following hypotheses are proposed.

H5: Perceived Usefulness positively influences adoption intention.

H6: Perceived Usefulness positively influences farmers' sustainable practices.

2.4. *Social Influence (SI)*

SI draws ascendancy from subjective norm within the TPB framework. According to Ajzen (1985), it refers to the influence from close individuals, including family and friends, concerning whether one should engage in a particular behaviour or not.

Empirical studies state that SI positively influences AI (Strydom, 2018; Silva et al., 2020; Bhujel & Joshi, 2023; Wang & Xu, 2024; Erekaló et al., 2025; Ninsiima et al., 2025). Additionally, systematic evidence from Erekaló et al. (2025) on climate-smart agriculture adoption suggests that social norms reflecting the influence of value chain actors shape farmers' willingness to adopt sustainable practices in agriculture. Thus, when farmers see their peers and community members adopting sustainable practices, they develop a belief that it is socially approved, leading to stronger adoption intention.

However, on the contrary, evidence within the TPB framework also suggests that SI has no positive influence on intention (Li et al., 2024) or is the least influential antecedent (Wankel & Mummery, 1993; Armitage & Conner, 2001). Therefore, to explore the role of SI on AI, the following hypothesis is formulated.

H7: Social Influence positively influences the adoption intention.

Further, studies also demonstrate that social influence can directly drive adoption (Bell, 2018; Tran-Nam & Tiet, 2022). Social capital, including social trust, networks, and norms, affects farmers' adoption decisions (Zheng et al., 2022). Therefore, to explore the role of SI on SAP, the following hypothesis is formulated.

H8: Social Influence positively influences farmers' sustainable practices.

2.5. Adoption Intention (AI)

Within the context of TPB, intention is the most immediate predictor of behaviour. Behavioural intention, according to Ajzen (1985), is an individual's readiness or likelihood to perform a given action. Sheeran (2002) further describes intention as motivational stimulation to enact behaviour. Empirical studies provide confirmations that stronger intentions significantly influence sustainable practices (Wang et al., 2019; Yulihardi et al., 2025). However, on the contrary, studies argue that the intention-behaviour link is not always consistent and intentions do not necessarily translate into practice (Khan et al., 2020; Swart et al., 2023; Byfuglien et al., 2025). Thus, in the context of fish farming, to explore the AI and SAP relationship, the following hypothesis is formulated:

H9: Adoption Intention positively influences sustainable practices.

The TPB assumes the mediating role of intention (Ajzen, 1991); in light of this, exploring the role of AI as a mediator becomes relevant. Therefore, the following hypotheses are formulated:

H11: Adoption Intention mediates the relationship between Awareness of Environmental Issues and Sustainable Practices.

H12: Adoption Intention mediates the relationship between Perceived Economic Benefit and Sustainable Practices.

H13: Adoption Intention mediates the relationship between Perceived Usefulness and Sustainable Practices.

H14: Adoption Intention mediates the relationship between Social Influence and Sustainable Practices.

2.6. Access to Extension Services (AES)

Extension services essentially link researchers with development workers and farmers, where hands-on training, advisory services, demonstrations, and field visits are provided, aimed at influencing farmers' behaviour. Leeuwis and Van den Ban (2004) describe extension as "a series of embedded communication interventions meant to develop and/or induce innovations which help resolve problematic situations." Similarly, Briner et al. (2009) define extension services as organised efforts to transfer agricultural technology and knowledge to farmers through diverse educational methods. While extension plays a defining role, access to such intervention programmes, especially to marginal groups, is one of the major constraints (FAO, 2024). Studies show that in spite of good access, farmers often face problems like information asymmetry, improper credit markets, and other inefficiencies (Wossen et al., 2017). However, with greater AES, the likelihood of translating awareness, social influence, and perceived benefits increases, leading to behavioural changes (Sánchez Bogado et al., 2024). Thus, the following hypothesis is formulated:

H10: Access to extension services moderates the relationship between Adoption Intention and farmers' sustainable practices.

2.7. Variables and Measurements

Table 1

Variables and Corresponding Sources

Variables	Source
. Awareness of Environmental Issues (AEI)	Hassan et al. (2010)
. Perceived Economic Benefits (PEB)	Abila & Kantola (2019) Dabbous & Tarhini (2019)
. Perceived Usefulness (PU)	Syan et al. (2019)
. Social Influence (SI)	Venkatesh & Davis (2000) Ajzen (1985) Syan et al. (2019)

Intention to Adopt Sustainable Fish Farming Practices (AI)	Raghu & Rodrigues (2021)
Access to Extension Services (AES)	Penchansky & Thomas (1981) Khaleque (2010) Coombs et al. (2021) Beyene et al. (2024)
Sustainable Practices (SAP)	DFID (1999) Chambers & Convey (1991)

2.8. Diagrammatic Representation of Conceptual Framework

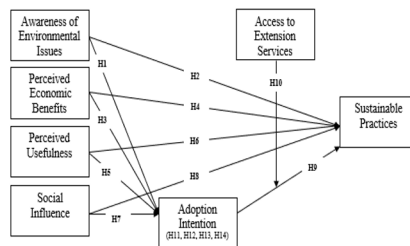


Fig. 1. Conceptual Framework

3. Objectives

1. To examine the effects of Awareness of Environmental Issues, Perceived Economic Benefits, Perceived Usefulness, and Social Influence on Adoption Intention.
2. To evaluate the effects of Awareness of Environmental Issues, Perceived Economic Benefits, Perceived Usefulness, and Social Influence on farmers' sustainable practices.
3. To test the direct effect of Adoption Intention on Sustainable Practices
4. To assess the mediating role of Adoption Intention in the relation between Awareness of Environmental Issues, Perceived Economic Benefits, Perceived Usefulness, Social Influence and farmers' Sustainable practices.
5. To examine the moderating role of Access to Extension Services in the relation between Adoption Intention and Sustainable Practices.

4. Research Methodology

4.1. Research Design

This study includes a quantitative, cross-sectional, explanatory research design and takes into account select constructs from the TPB, and extends the theory to examine the mediating role of AI and the moderating role of AES in the intention-behaviour relationship.

4.2. Population and Sampling Design

Fish farmers of Kamrup (M) and Nagaon district who have received extension services at least once before the current production cycle are the population of this study. Non-probability purposive sampling was used for the study in two stages:

1st Stage: Kamrup (M) and Nagaon districts were selected purposively based on i) High concentration of fish farming activities and ii) Active presence of extension services.

2nd Stage: 320 respondents were taken in total from both districts (160 each). The researcher applied 10:1 guideline for calculating the sample size. With 30 observed variables, the minimum sample size is 300, $n=320$, thus exceeding the threshold. According to the rule of thumb proposed by Comrey & Lee (2013), 300 falls in the good benchmark, thus $n=320$ is fit for conducting factor analysis.

4.3. Eligibility

The study includes farmers receiving some form of extension services prior to the current production cycle and excludes farmers with first exposure to extension services only during the current production cycle. Multiple channels were used to identify the farmers. On-farm visits, farmers' meetings, and local referrals, including village heads (Gaon bura).

4.4. Data Collection Procedure

The data were collected between the months of March and July, 2025, using a structured interview schedule. Prior to each interview, the purpose of the study was clearly explained, and for ethical considerations, informed consent was taken verbally.

4.5. Data Analysis

The data were analysed using Excel, SPSS and AMOS software. After screening of data, sampling adequacy was measured using the KMO statistic and Bartlett's test of sphericity. Reliability and validity assessment was performed using Confirmatory Factor Analysis (CFA). Finally, to test the Hypotheses, Structural Equation Modeling (SEM) was applied.

5. FINDINGS AND DISCUSSIONS

5.1. Demographic Profile

This section provides demographic profile of 320 fish farmers, taken from two select districts—Kamrup (M) and Nagaon—of Assam. It shows that majority of respondents are male (66.9%, n = 214) and the females accounted for 33.1% (n = 106). Most participants were aged between 31 and 40 years (56.3%, n = 180), followed by 51–60 years (16.3%, n = 52), 18–30 years (14.7%, n = 47), and 41–50 years (12.8%, n = 41). Regarding experience in pisciculture, 40.6% of respondents had 11–20 years of experience, 29.7% had 0–10 years, 20.9% had 21–30 years, and 8.8% had more than 30 years of experience.

Additionally, 61.3% (n = 196) of respondents completed secondary education, followed by graduates (18.8%, n = 60), higher secondary (9.7%, n = 31), postgraduates or above (5.9%, n = 19), and 4.4% (n = 14) of respondents had education below secondary level. Regarding income, 5.3% (n = 17) earned below ₹50,000, 37.5% (n = 120) of respondents earned between ₹1–₹2 lakhs annually, 27.5% (n = 88) earned ₹50,000–₹1 lakh, 19.7% (n = 63) earned ₹2–₹3 lakhs, and 10% (n = 32) earned above ₹3 lakhs. This shows that pisciculture in Assam is mostly male-dominated, involving farmers mostly having secondary-level education and reasonably moderate-income levels.

5.2. Exploratory Factor Analysis

Kaiser-Meyer-Olkin (KMO) and Bartlett's test of Sphericity were used to evaluate the data's suitability. The KMO Measure of Sampling adequacy is 0.911, and the Bartlett's Test of Sphericity is highly significant (Chi-square = 6196.837, df = 435, p < 0.001). (See Table 2 below).

Table 2

KMO and Bartlett's Test of Sphericity

Test	Value	df	p-value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.911	–	–
Bartlett's Test of Sphericity (Approx. χ^2)	6196.837	435	< 0.001

5.3. Eigenvalue and Scree Plot

The Eigenvalue represents the total variance explained by the factors. Factors with an eigenvalue of more than one are chosen. The scree plot helps in retaining the optimal number of factors. Figure 2 shows the curve flattens after the seventh factor; thus, seven factors are retained for analysis.

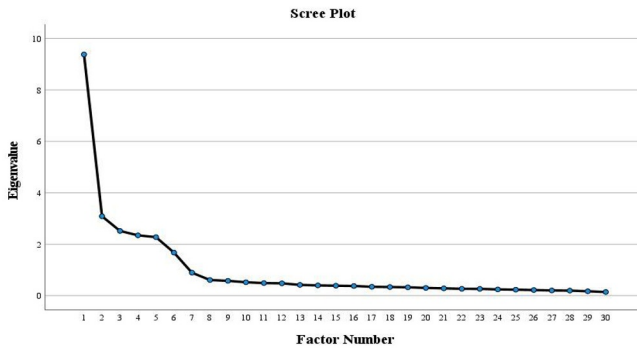


Fig. 2. Scree Plot of Eigenvalues for Factor Extraction

5.4. Rotated Factor Matrix

The seven factors identified align with the conceptual framework proposed in this study. Factor 1 includes items from SAP1 to SAP10, Factor 2 (AES1 to AES5), Factor 3 (PU1 to PU3), Factor 4 (SI1 to SI3), Factor 5 (AEI1 to AEI3), Factor 6 (PEB1 to PEB3), and Factor 7 include AI2. This is shown in Table 3, below.

However, noticeably, AI1 and AI3 showed loading > 0.50 , however, in further analysis (CFA), the loading for AI1 is 0.74, AI2 is 0.685 and AI3 is 0.649, all above 0.60, which is acceptable (Hair et al., 2017). The items loaded significantly on their corresponding constructs; thus, the items were retained (Brown, 2015; Hair et al., 2021)

Table 3
Rotated Factor Matrix

	Factor						
	1	2	3	4	5	6	7
AEI1					.852		
AEI2					.815		
AEI3					.778		
PEB1						.809	
PEB2						.786	
PEB3						.819	
PU1			.776				
PU2			.776				
PU3			.854				
SI1				.829			
SI2				.824			
SI3				.800			
AI1							.478
AI2							.605
AI3							.420
AES1		.725					
AES2		.726					
AES3		.725					
AES4		.622					
AES5		.698					
SAP1	.780						
SAP2	.796						
SAP3	.822						
SAP4	.850						
SAP5	.807						
SAP6	.819						
SAP7	.848						
SAP8	.803						
SAP9	.863						

SAP10 .783

Extraction Method: Maximum Likelihood.

Rotation Method: Varimax with Kaiser Normalization.

Note: AEI = Awareness of Environmental Issues; PEB = Perceived Economic Benefits; PU = Perceived Usefulness; SI = Social Influence; AI = Intention to Adopt Sustainable Fish Farming Practices; AES = Access to Extension Services; SAP = Adoption of Sustainable Fish Farming Practices.

5.5. **Confirmatory Factor Analysis (CFA)**

The CFA shows how well the observed variable represents the latent constructs. The uniqueness of the constructs from one another is also analysed (Kline, 2008). All the constructs are first drawn and subsequently covariate with each other, as shown in Fig. 3.

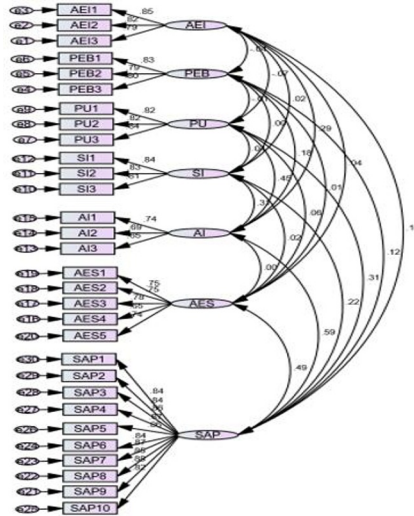


Fig. 3. Measurement Model

5.6. **Construct Reliability, Validity and Inter-construct Correlations**

To measure the internal consistency of the constructs, Composite Reliability (CR) was used. CR is considered a superior alternative to Cronbach’s Alpha, because it accounts for differences in item loadings (Hair et al., 2019). To measure the convergent validity, Average Variance Extracted (AVE) was used (Fornell & Larcker, 1981). Maximum Shared Variance (MSV) was used for calculating discriminant validity (Hair et al., 2019). The results are shown in Table 4 below.

The CR values range from 0.732 to 0.964, exceeding the threshold limit of 0.70, indicating stronger internal consistency (Hair et al., 2019). The AVE of AI is 0.477, below the desirable 0.50 threshold. However, the CR of AI is above the 0.70 threshold; thus convergent validity is considered adequate (Hair et al., 2021). All other AVE values range from 0.538 to 0.729, above the 0.50 threshold, showcasing sufficient convergent validity (Fornell & Larcker, 1981). The MSV is used to indicate discriminant validity. All the values are lower than the AVE values, confirming the validity (Hair et al., 2021). The square root of AVE is greater than the inter-construct correlations, represented in bold diagonal values. Thus, further supporting discriminant validity.

5.7. **Structural Model Assessment**

SEM was used to understand the relationship between Independent Variables (AEI, PEB, PU, SI), Mediator (AI), Moderator (AES), and Dependent variable (SAP) (see Fig. 4).

A good fitting model is accepted if the value of the CMIN/df is < 5, the Goodness-of-Fit Index (GFI) indices (Hair et al., 2021); the Tucker and Lewis Index (TLI) (Tucker & Lewis, 1973); and the Confirmatory Fit Index (CFI) (Bentler, 1990) is > 0.90 (Hair et al., 2010). In addition to this, an adequate fitting model is accepted if the AMOS computed value of the Standardised Root Mean Square Residual (SRMR) < 0.05, and the Root Mean Square Error of Approximation (RMSEA) is between 0.05 and 0.08 (Hair et al., 2010). This study shows the fit indices fall within the

acceptable range: CMIN/df = 1.184, GFI = 0.994, TLI = 0.983, CFI = 0.996, SRMR = 0.0279, and RMSEA = 0.024. The squared multiple correlation was 0.272 for AI and 0.501 for SAP (See Fig. 4 below).

(a) Structural Path Estimates

AEI, PEB, PU, and SI were tested for their impacts on AI and SAP. The findings suggest all IVs significantly impacted the mediator, AI. Thus, H1, H3, H5, and H7 are supported. However, AEI and PEB did not have any impact on SAP; thus, H2 and H4 are not supported. PU and SI have a significant impact on SAP; therefore, H6 and H8 are supported. AI had a positive and significant impact on SAP; thus, H9 is supported. The interaction term AI x AES has a significant negative impact on SAP, indicating that AES weakened the positive relationship between AI and SAP; therefore, H10 is supported. (See Table 5 below).

	CR	AVE	MSV	MaxR (H)	AES	AEI	PEB	PU	SI	AI	SAP
AES	0.853	0.538	0.241	0.857	0.733						
AEI	0.861	0.673	0.081	0.863	0.044	0.820					
PEB	0.849	0.652	0.034	0.850	0.006	-0.043	0.807				
PU	0.865	0.681	0.206	0.865	0.063	-0.065	-0.006	0.825			
SI	0.867	0.685	0.099	0.868	0.020	0.020	0.001	0.037	0.827		
AI	0.732	0.477	0.354	0.736	-0.002	0.285	0.184	0.454	0.314	0.691	
SAP	0.964	0.729	0.354	0.965	0.491	0.116	0.124	0.315	0.219	0.595	0.854

Table 4
Reliability, Validity, and Inter-construct Correlations

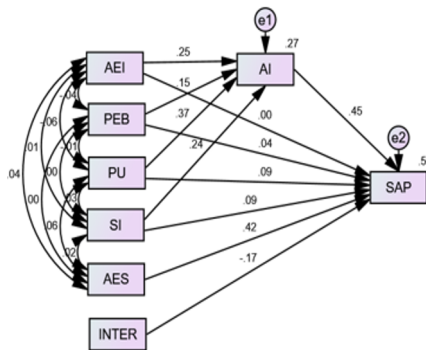


Fig.4. Structural Model

Note: AEI=Awareness of Environmental Issues; PEB= Perceived Economic Benefits; PU= Perceived Usefulness; SI= Social Influence; AI=Adoption Intention; SAP=Sustainable Practices; AES=Access to Extension Services; INTER=Interaction term (AI×AES)

(b) Moderation Assessment

Second-stage moderation analysis was conducted to understand whether AES moderates the relation between AI and SAP. The path from AI to SAP was positive and significant, indicating that higher AI leads to an increase in SAP. Similarly, the direct path from AES to SAP was also positive and significant (Estimate = 0.430, S.E = 0.041, C.R = 10.549, p value = <0.001). The moderating effect of the interaction term (AI x AES) on SAP was significantly negative ($\beta = -0.169$, 95% CI [-0.240, -0.080]). This indicates that the positive relationship between AI and SAP weakens with the increase in AES. (See Fig. 5 below)

Table 5
Path Estimates

Hypothesis	Path	Estimates	S. E	C.R	p-value	Result
H1	AEI→AI	0.184	0.035	5.223	<0.001	Supported
H3	PEB→AI	0.112	0.035	3.187	0.001	Supported
H5	PU→AI	0.270	0.035	7.726	<0.001	Supported
H7	SI→AI	0.170	0.034	4.973	<0.001	Supported
H2	AEI→SAP	-0.004	0.034	-0.104	0.917	Not Supported
H4	PEB→SAP	0.036	0.033	1.088	0.277	Not Supported
H6	PU→SAP	0.074	0.036	2.075	0.038	Supported
H8	SI→SAP	0.071	0.033	2.151	0.031	Supported
H9	AI→SAP	0.511	0.052	9.773	<0.001	Supported
H10	AI x AES→SAP	-0.383	0.090	-4.274	<0.001	Supported (Negative)

(c) Direct Effect

To examine the direct effect, a bootstrapping process with 2000 resamples was done. The bias-corrected confidence interval was 95%. The direct effect of AEI, PEB, PU and SI on AI was statistically significant. PU has the strongest positive effect on AI ($\beta = 0.370$), followed by AEI ($\beta = 0.250$), SI ($\beta = 0.238$), and lastly by PEB ($\beta = 0.152$). The direct effect of AEI, PEB, and PU on SAP was not statistically significant. The direct effect of SI and AI on SAP was significantly positive. AI has the strongest positive effect on SAP ($\beta = 0.453$). See Table 6 below.

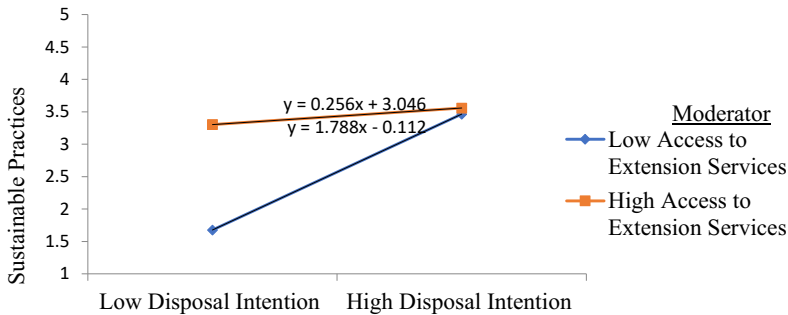


Fig. 5. Moderation Graph

Table 6
Direct Effect

Path	β	95% Bootstrap CI	Significance
AEI→AI	0.250	[0.160, 0.336]	Significant
PEB→AI	0.152	[0.047, 0.256]	Significant
PU→AI	0.370	[0.264, 0.465]	Significant
SI→AI	0.238	[0.146, 0.329]	Significant
AEI→SAP	-0.004	[-0.083, 0.079]	Not Significant
PEB→SAP	0.044	[-0.038, 0.119]	Not Significant
PU→SAP	0.090	[-0.004, 0.182]	Not Significant
SI→SAP	0.088	[0.002, 0.169]	Significant
AI→SAP	0.453	[0.369, 0.535]	Significant

(d) Indirect path

To examine the mediating role of AI, a bootstrapping process with 2000 resamples was done. The bias-corrected confidence interval was 95%. The direct effect of AEI, PEB, PU on SAP were not significant, whereas, the direct effect of SI on SAP is significant. However, the indirect effect of AEI on SAP via AI ($\beta = 0.113$, 95% CI [0.072,0.163]), PEB on SAP via AI ($\beta = 0.069$, 95% CI [0.022,0.121]), PU on SAP via AI ($\beta = 0.168$, 95% CI [0.115,0.229]), SI on SAP via AI ($\beta = 0.108$, 95% CI [0.067,0.159]) are statistically significant, thus, the analysis showcased indirect-only (full) mediation for the relationship between AEI and SAP, PEB and SAP, PU and SAP (Zhao et al., 2010), as their effects on SAP were transmitted only through AI. SI exerts both direct and indirect influence on SAP, thus indicating complementary (partial) mediation. None of the confidence intervals includes zero. AI mediates the relationship between AEI, PEB, PU, SI, and SAP; thus, H11, H12, H13, and H14 are supported. This is shown in Table 7 below.

Table 7
Indirect path

Hypothesis	Indirect Path (via AI)	β	95% Bootstrap CI	Significance
H11	AEI→AI→SAP	0.113	[0.072, 0.163]	Significant
H12	PEB→AI→SAP	0.069	[0.022, 0.121]	Significant
H13	PU→AI→SAP	0.168	[0.115, 0.229]	Significant
H14	SI→AI→SAP	0.108	[0.067, 0.159]	Significant

(e) Total Effect

Standardised total effects with bias-corrected 95% bootstrap CI with 2000 resamples were done to analyse the total effect of AEI, PEB, PU and SI on SAP. All the IVs showed a positive total effect on SAP. PU has the largest total effect ($\beta = 0.257$, 95% CI [0.158,0.352]), followed by SI ($\beta = 0.196$, 95% CI [0.100,0.287]), PEB ($\beta = 0.113$, 95% CI [0.020,0.197]) and at last by AEI ($\beta = 0.109$, 95% CI [0.030,0.194]). All the CI excluded zero, thus indicating statistical significance. See Table 8 below.

Table 8
Total effect

Path	β	95% Bootstrap CI	Significance
AEI→SAP	0.109	[0.030, 0.194]	Significant
PEB→SAP	0.113	[0.020, 0.197]	Significant
PU→SAP	0.257	[0.158, 0.352]	Significant
SI→SAP	0.196	[0.100, 0.287]	Significant

6. Conclusion, Implications And Future Directions

6.1. Summary of the Study

This study examines the adoption of sustainable fish farming practices in Assam, providing strong evidence on the determinants that are responsible for the adoption of such practices. To understand this, the Theory of Planned Behaviour (TPB) was implemented, focusing on the psychological attributes. The findings reveal that attributes like AES, PEB, PU and SI shape the intention of the farmers in adopting SAP. Here, PU has the strongest influence, indicating that usefulness plays a defining role in shaping the behavioural choice of farmers.

The study aligns with the theory that intention results in behaviour formation, evident from the study as AI mediates the relationship between IVs and SAP. This shows that, in the pisciculture context also, intention transforms intrinsic motivation into concrete actions. The study also finds that AES negatively moderates the AI and SAP relationship. This indicates that, while external support is important, easy AES makes people highly reliant on it, thereby reducing internal

motivations and self-efficacy, affecting decision-making. This finding provides a new insight and perspective on understanding the external institutional mechanism in shaping the behavioural outcomes.

6.2. Theoretical and Practical Implications

This study builds on TPB and further extends the framework in understanding SAP in pisciculture. It contributes to the growing behavioural research as it focuses on pisciculture and farmers' adoption of sustainable behaviour in fish farming. Strong evidence from this study showcases that institutional mechanisms play a defining role in shaping the intention-behaviour relationship.

Additionally, from a practical point of view, the study provides valuable insight for both policymakers and extension agencies. It may aid in redesigning strategies that create a lasting impact on the fish farmers, since AES negatively moderates the AI and SAP relationship. With this study, plans can be made to reduce the negative impact on internal motivation, changing the role of extension services from merely providing to empowering. While institutional arrangements cannot be ignored, encouragement of learning through peer groups, hands-on training, capacity building, and promotion of a collaborative culture can ensure that external support has a positive and long-lasting effect.

6.3. Novel Insight and Future Directions

This study provides a new understanding in the pisciculture context and questions the conventional belief that institutional support results in development. Analysing the moderating role of the AES, this study provides that excessive external guidance can weaken the intention-behaviour link, thereby challenging the implied assumption, "more intervention equals better results", laying a foundation for optimal intervention as a proper approach in achieving the desired behavioural outcomes.

The study opens up a new perspective, sustainable development does not only imply "resource access" but also "empowerment". Simply, the role of extension services has to be translated from a mere advisory to a behavioural ecosystem. Future research may thus explore the threshold limit at which institutional mechanisms have the maximum effect on the behavioural outcomes, and gradually it may be explored in other areas based upon its suitability.

6.4. Limitations and Scope for Future Research

While the contributions of this study are enormous, it is not free from limitations. This study is confined to two districts of Assam, Kamrup (Metropolitan) and Nagaon. These districts depict contrasting socio-economic conditions, but are not sufficient to generalise as a representative of the diversity of pisciculture in the entire state. Secondly, the cross-sectional design of this research eliminates gathering knowledge on how any changes, if implemented, result over time, thereby demanding a longitudinal study. Farmers in rural areas do not make decisions independently but rather collectively, so future research can expand the TPB by taking into account the collective decision-making to generate new insights. Finally, future studies should explore the micro-level dynamics, which account for the role of institutional support and its effect on the farmer's intrinsic motivations. Addressing these limitations would further provide a new understanding and enhance the practical implementation of sustainability in pisciculture.

6.5. Concluding Remarks

This study provides an understanding of the sustainable fish farming practices adoption in Assam and factors that influence this behaviour. Based on TPB, this study finds that AES, PEB, PU and SI significantly influence AI. Also, AI mediates the relationship between the psychological attributes and actual behaviour, providing a confirmation that intention creates action, which also holds true in the pisciculture context. A relatively new understanding from this study is that increased AES diminishes internal motivation. This shows a need to redesign extension programmes that are targeted towards strengthening their decision making without merely relying on external support. Using this study as a base, future studies may explore the optimal intervention thresholds, thereby contributing to the subject.

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