

**Using the Theory of Planned Behavior to Assess Sustainable Agricultural
Practice Adoption Among Cacao Farmers in Davao Region, Philippines: A PLS-
SEM and Multivariate Probit Approach**

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Ethics Statement

An ethics clearance for this study was issued by the University of the Philippines Los Baños Research Ethics Board with protocol code UPLB REB-2022-0009. All the actual procedures employed followed the approved protocols for the conduct of the study, including the secured informed consent forms and handling of data collected.

Abstract

Conventional agricultural intensification, driven by global demand, poses significant environmental and sustainability threats to the Philippine cacao sector. This study investigates the adoption of sustainable agricultural practices (SAPs) using a Theory of Planned Behavior framework; and the partial least squares structural equation model and multivariate probit model based on a survey of 271 farmers. Results reveal complex adoption patterns; while high-yielding varieties and irrigation show complementarity, substitution occurs between labor-intensive practices. A key theoretical finding is that perceived ecological benefits influence intention both directly and indirectly, yet personal attitude lacks a statistically significant direct effect on adoption intent. This suggests that adoption is driven more by social norms and structural constraints such as land ownership, income, and irrigation; than by individual preference. These findings emphasize that policy should address specific socio-economic barriers and resource interdependencies to foster long-term SAP adoption.

Keywords

Cacao; Sustainable Agricultural Practices; Multivariate Probit, Partial Least Squares-Structural Equation Model, Theory of Planned Behavior, Technology Adoption

JEL Codes: C35, Q01, Q15, Q18, Q56

1. Introduction

Cacao is a globally important and widely traded crop which contributes greatly to the social and economic growth of countries engaged in its production, processing, and trade (Vega and Kwik-Urbe, 2012). The Philippines is among the cacao producing countries although its production only accounts for less than 0.1% of global production and is recorded to be a net importer of all cacao products, except for cacao beans. While production volume has gone up to an average of 10,308 metric tons (MT) in 2020-2024 from an average of 7,153 MT in 2015-2019 due to expansion of area planted, productivity slightly declined to an average of 0.32 MT per hectare (ha) from 0.36 MT per ha (Philippine Statistics Authority, 2025). Despite this, the suitability of the growing conditions in the Philippines signifies an income-earning opportunity to be harnessed. With this, sector expansion efforts were noted through its intercropping with pre-existing coconut and banana farms all over the country. The bulk of the production (80%) is recorded to be from the Davao Region but even with the efforts to expand, cacao productivity per bearing tree has been declining. This downturn can be attributed to weather disturbances, prevalence of pests and diseases, land-use competition with other plantation crops, aging cacao trees, and poor quality of planting materials. Other factors include peace and order conditions, lack of innovation and adoption of postharvest technologies, and limited access to quality input (Department of Agriculture [DA], 2017). These limit farmers' income potential. On top of this, volatility in market prices also adds up to the uncertainty and risk on farmers' profit (Hamrick et al., 2017; Voora et al., 2019).

To address productivity concerns, farmers tend to intensify production by using chemical inputs and other unsustainable practices indiscriminately, increasing the environmental costs of agricultural production. Further, the Food and Agriculture Organization (FAO) (2018) reports that prevailing agricultural systems are unsustainable, causing land degradation, resource overexploitation, and a loss of genetic diversity due to monocropping.

For cacao production in the Philippines, a life cycle assessment (LCA) showed that Cacao production impacts the environment through N_2O and CO_2 emissions from fertilizers and transport, while pesticides drive terrestrial ecotoxicity. Consequently, mitigating these impacts requires reducing the use of fossil fuels, chemical fertilizers, and synthetic pesticides (Leyte et al., 2017).

Unique to the Philippine cacao sector is its strategic position to expand supply and capitalize on global market opportunities, particularly for smallholder farmers whose livelihoods can be significantly enhanced by its cultivation. However, the production sector remains hampered by systemic hurdles such as gaps in technical expertise, limited access to market information, and increasing vulnerabilities to climate risks. This distinct combination of opportunities and issues distinguishes cacao from other agricultural systems in the country, necessitating a focused investigation (Soledad-Dalumpines, 2025).

Philippine cacao sustainability is governed by a mix of policies and market-driven incentives. The High-Value Crops Development Act (RA 7900) mandates support for cacao to ensure long-term land productivity. This is facilitated by voluntary

certification schemes like Good Agricultural Practices (GAP) and Rainforest Alliance, which align farmers with international standards and offer premium prices. Despite these benefits, adoption remains limited by high compliance costs and technical barriers (DA, 2017; Rainforest Alliance, 2025).

Emerging evidence from the Philippines highlights that cacao promotes economic and ecological resilience when integrated into diversified farming systems (Komarudin et al., 2025). Studies in Davao del Norte and Camarines Sur show that sustainability is driven by institutional support, organizational membership, and the crop's natural adaptability to climate variability (Penora and Magallon, 2024; Komarudin et al., 2025). Locally, the use of GAP and regenerative techniques further bridges the gap between productivity and climate adaptation.

Further evidence shows that economic incentives and livelihood diversification enhance climate resilience and income stability (Komarudin et al., 2025). Human capital and technical training are critical drivers for adopting soil conservation and pest management (Madarang et al., 2021; Lafuente et al., 2024), while institutional support through cooperatives and government programs ensures long-term sustainability (Penora and Magallon, 2024). Additionally, access to technology and bioscience-based inputs reduces production risks (Balatico, 2025), and gender dynamics—specifically women's decision-making power—significantly shape farm management outcomes (Obsioma et al., 2014). Understanding these economic, institutional, and socio-behavioral drivers is essential to designing targeted policies that increase farmers' propensity to adopt sustainable practices. These findings are comparable to those from

other developing country contexts where psychological, institutional, socio-economic, and biophysical factors influence SAP adoption. Recent global evidence suggests that while adoption likelihood is shaped by psychological factors structural barriers such as land tenure security, limited access to climate information, limited access to market information, access to credit, high labor costs, access to extension services, and membership to producer organizations (POs) often influence the potential to adopt SAPs (Krumbiegel and Tillie, 2024; Mutyasira et al., 2018; Oyetunde-Usman et al., 2018; Teklewold et al., 2013; Yiridomoh et al., 2022).

The objective of this study was to assess farmers' intention to adopt SAPs and determine the factors affecting such adoption in Davao Region, the country's largest cacao-producing region. This study considered the SAPs defined by Oberč and Arroyo Schnell (2020) of the International Union for Conservation of Nature, which included multicropping, use of organic inputs, use of improved varieties, water conservation, integrated pest management (IPM), and livestock integration.

A wealth of studies on SAP adoption or agricultural technology in general, is underpinned by the frameworks such as Theory of Planned Behavior (TPB) (Fishbein and Ajzen 2011), Technology Acceptance Model (TAM) (Davis 1989), and Diffusion of Innovations (DOI) (Rogers 2003). Among these, TPB is particularly appropriate for analyzing the adoption of SAPs as it models farmers' intentions, incorporates social and normative influences, and accounts for perceived constraints that are critical in developing-country contexts. While TAM and DOI provide valuable insights, on technology usability and diffusion patterns respectively, TPB offers a more

comprehensive and behaviorally grounded framework for understanding SAP adoption decisions at the individual farmer level.

Specifically, TPB posits that the adoption intention is influenced by attitude, perceived behavioral control, and subjective norm. Attitude refers to the perception on the desirability of the behavior's outcomes. Perceived behavioral control describes the agent's autonomy to perform the behavior. This varies with their perceived ease or difficulty, including both internal self-efficacy and external resource constraints. Lastly, the subjective norm depicts the perceived social pressure to perform a behavior. These perceptions build the pressure on the agents' decision to perform the behavior or not (Fishbein and Ajzen 2011; Sok et al. 2021; Tatarko and Schmidt 2016). Extensions of the original TPB framework have been developed across adoption literature. Social Identity Theory suggests that injunctive norm or the societal pressure from a specific relevant group is also relevant in adoption intention on top of subjective norm. Particularly for behaviors that promote sustainability, perceived ecological benefit is also incorporated in understanding adoption intention (Bonke and Musshoff, 2020). This construct specifies the individual's perception on the behavior's ecological benefit towards adoption intention.

The TPB is uniquely suitable for the Philippine cacao sector, where high climate and economic risks often lead to farm abandonment, making observed behavior inconsistent (Meijer et al. 2015). By focusing on intention to adopt, the framework captures the latent psychological drivers that underpin environmental and social sustainability (Ajzen, 1991; Sok et al., 2021).

2. Material and methods

2.1. Data Collection and Sampling

A face-to-face survey was conducted among 271 cacao farmers across Region XI (Davao Region), the Philippines' primary cacao-producing hub in July 2022. To ensure a representative sample from the 20,769 farmers identified by the Department of Trade and Industry (DTI), a stratified random sampling technique was employed. The sample size was determined using Cochran's formula, assuming a 90% confidence interval, a 5% margin of error, and a maximum variability of $p = 0.5$.

Participants were selected from each province using proportional allocation based on DTI's farmer profiles. To execute the survey, local agricultural extension workers were consulted to identify eligible respondents within the selected strata. These farmers were contacted through coordination activities by extension agents, ensuring a high response rate and data accuracy. Ethics clearance was secured for the study. Hence, informed consent forms were secured and ethical considerations were employed during the data collection. Enumerators were trained to validate responses in real time while the survey was administered. This resulted to zero-missing-data for the 271 cases. Additionally, data collected may be made available upon request.

The adequacy of the 271-respondent sample was validated through a post-hoc power analysis using G*Power 3.1. A statistical power of 0.99 was computed implying that this is sufficiently powered for detecting medium effect sizes ($f^2 = 0.15$) at a significance level of $\alpha = 0.05$.

2.2. Data Analysis

In identifying drivers for SAP adoption, Multivariate Probit (MVP) and Partial Least Squares Structural Equation Modeling (PLS-SEM) were selected as the primary

analytical tools. The MVP model is selected over binary probit models because it relaxes the assumption of independence between decisions. It assumes that the adoption of various SAPs is interdependent, with correlated error terms that capture unobserved complementarities or trade-offs between practices. Complementing this, PLS-SEM is employed to model the latent psychological drivers of these decisions. This choice is particularly suited for the Philippine smallholder context, as it is a non-parametric model, that does not require multivariate normality, making it robust for the typical skewness found in agricultural survey data.

2.2.1. Structural Equation Model

Focusing on understanding the drivers of intention to adopt SAPs, SEM is commonly utilized as a tool to validate the theorized relationships among the constructs from the TPB framework. This estimation uses the PLS-SEM through the SmartPLS 4 software (Ringle et al. 2015) to validate the significance of the hypothesized relationships. PLS-SEM is beneficial when the objective of the estimation is to predict the targeted outcomes. Further, it also tolerates smaller sample sizes and non-normal distributions by iterative optimization between the measurement and the structural model. While much of the TPB literature use the covariance-based (CB) SEM, much of the recent literature now employs PLS-SEM for similar reasons cited. Moreover, this paper's objective is more predictive than confirmatory, to support external validity and inform policy recommendations, making PLS-SEM a more ideal choice (Hair and Alamer, 2022).

SEM constructs were adapted from Ajzen (2002), Mutyasira et al. (2018), and Nguyen and Drakou (2021), using a five-point Likert scale. To ensure validity, statements were carefully phrased and translated to preserve their conceptual intent. Reliability was confirmed through internal consistency checks, retaining only items with loadings

above 0.70 and an Average Variance Extracted (AVE) exceeding 0.50. Finally, the measurement model was validated for reliability and discriminant validity using the heterotrait-monotrait (HTMT) ratio. Particularly, the study adopts the original TPB framework and proposes the following main hypotheses (Ajzen, 1991; Bonke and Musshoff, 2020; Mutyasira et al., 2018).

Hypothesis 1: Farmer's attitude towards SAPs (ATT) positively affects intention to adopt SAPs (INT).

Hypothesis 2: Subjective norm (SN) has a positive influence on INT.

Hypothesis 3: The farmer's perception of behavioral control (PBC) over the activities in the SAPs has a positive effect on INT.

An extension of the TPB framework roots from the Social Identity Theory which posits that on top of SN, adoption is more likely to be influenced by societal pressures from reference groups that are relevant to the activity. Stronger influence is expected from peer groups which the farmer strongly identifies with (Bonke and Musshoff, 2020; van Dijk et al., 2016). This warrants the inclusion of injunctive group norm (IN) as a separate construct affecting intention. With this, it is proposed that:

Hypothesis 4: IN positively affects INT.

Extensions of TPB, as applied in adoption of sustainable and conservation practices, have incorporated the role of the perceived ecological benefits (PEB) of the practice to INT. Previously, the recognized PEB of the practice were seen to improve intention to use conservation and sustainable practices (Arbuckle and Roesch-McNally, 2015; Bonke and Musshoff, 2020; Reimer et al., 2012). Following these studies, it is postulated that PEB create a two-pronged influence such that:

Hypothesis 5: PEB positively affects ATT.

Hypothesis 6: PEB positively affects INT.

To ensure content validity, survey items were drawn from validated scales in existing agricultural adoption literature (Oyetunde-Usman et al. 2021; Teklewold et al., 2013) and adapted to the specific socio-economic context of the Philippine cacao sector. Prior to the survey administration, the instrument underwent pilot testing with a small group of cacao farmers in the Davao Region. This process evaluated the items for clarity, accuracy, and ease of administration, resulting in minor linguistic refinements and phrasing adjustments to suit the local farming terminology.

2.2.2. Multivariate Probit Model

The adoption decision on which SAPs to employ is not limited to one activity alone. Farmers may adopt a mix of practices within the farm. This necessitated a multivariate approach in measuring farmers' adoption of SAPs to capture simultaneity and interdependency. MVP estimates the possible correlation between unobserved disturbances and interdependencies between different practices being adopted. Specifically, the correlation could arise from complementarity (positive correlation) or substitutability (negative correlation) among the different SAPs (Teklewold et al., 2013). Thus, the second stage in this analysis is the MVP model which estimated the adoption likelihood from a set of variables concerning socio-economic, psycho-social, farm characteristics, and exogenous aspects. The behavioral component of the TPB, specifically, predicted values of intention from PLS-SEM, was included as an independent variable. The SAPs considered in this estimation were multi-cropping, use of organic inputs, improved varieties, water conservation, integrated pest management (IPM), and livestock integration (Jara-Rojas et al., 2013; Oberč and Arroyo Schnell, 2020; Oyetunde-Usman et al., 2021; Tey et al., 2014).

STATA 15 was used to estimate the MVP model developed by Cappellari and Jenkins (2003). To ensure the reliability of the parameter estimates and account for potential

heteroscedasticity within the survey data, the model was fitted using robust standard errors. The Geweke-Hajivassiliou-Keane (GHK) simulator was utilized with the default settings for all unspecified parameters to maintain model parsimony. The MVP modeled the adoption of multiple SAPs using a random utility framework where a farming household i ($i=1, \dots, N$) faces a decision on the adoption of any of the SAP s ($s=s^{\text{th}}$ SAP). The utility of a non-adopting farmer is given by U_0 . The benefits from adopting the s^{th} SAP is given by U_s : where s may be specified as multicropping (M), use of organic inputs (O), improved varieties (I), water conservation (W), integrated pest management (N), or livestock integration (L). The farmer's adoption decision to use s^{th} SAP is realized when $Y_{is}^* = U_s^* - U_0 > 0$. From the adoption of s^{th} SAP, the farmer receives a net benefit Y_{is}^* where $Y_{is}^* = X_i \beta_s + \varepsilon_{is}$ that is a latent variable from the observed farming household and farm characteristics X_i and the error term ε_i . The definitions of these variable are shown in Table 1.

The indicator function for each choice outcome is given by the dichotomous outcome equation:

$$Y_{is} = \begin{cases} 1 & \text{if } Y_{is}^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{Equation 1}$$

Since MVP allows for multiple SAP adoption, the error terms follow a multivariate normal distribution with a conditional mean equal to zero and a unitary variance. The covariance matrix is symmetric and is given as Ω .

$$\Omega = \begin{bmatrix} 1 & \rho_{MO} & \rho_{IO} & \rho_{NO} & \rho_{LO} & \rho_{WO} \\ \rho_{MO} & 1 & \rho_{IM} & \rho_{NM} & \rho_{LM} & \rho_{WM} \\ \rho_{IO} & \rho_{IM} & 1 & \rho_{NI} & \rho_{LI} & \rho_{WI} \\ \rho_{NO} & \rho_{NM} & \rho_{NI} & 1 & \rho_{LN} & \rho_{WN} \\ \rho_{LO} & \rho_{LM} & \rho_{LI} & \rho_{LN} & 1 & \rho_{WL} \\ \rho_{WO} & \rho_{WM} & \rho_{WI} & \rho_{WN} & \rho_{WL} & 1 \end{bmatrix} \quad \text{Equation 2}$$

The off-diagonal elements describe the unobserved correlation between the errors across the different SAPs. The specification with non-zero elements in the off-diagonal of Ω permits error term correlations from different latent equations which describe the unobserved features influencing the choice of alternative SAPs (Oyetunde-Usman et al., 2021; Teklewold et al., 2013). Table 1 also lays out the dependent and explanatory variables and their corresponding measurement specifications.

Table 1 Variable descriptions for the MVP model

Variable	Description and measurement
Y_{iM}	=1 if used multicropping;
Y_{iO}	=1 if used organic inputs;
Y_{iI}	=1 if used improved varieties;
Y_{iW}	=1 if used water conservation;
Y_{iN}	=1 if used IPM;
Y_{iL}	=1 if applied livestock integration; =0 otherwise
$Intention_i$	Predicted values for behavioral intention (\widehat{INT}_i) from the results of SEM
Age_i	Age of farmer
Sex_i	1 if male; 0 if female
$Household\ size_i$	Number of members in the household
$Farm\ Income_i$	Annual Income generated from all activities in the farm in PhP
$Education_i$	Years in formal education
$Farm\ Experience_i$	Years in cacao farming
$Farm\ Size_i$	Size of cacao farm in hectares
$Land\ Ownership_i$	1 if owned; 0 otherwise
$Capital_i$	Access to credit and similar financial instruments
$Irrigation_i$	1 if access to irrigation or water source is available; 0 otherwise
$Training_i$	1 if participated in trainings, 0 otherwise
$Membership_i$	1 if member of a producer organization; 0 otherwise

Model diagnostics were performed using the Wald chi-square (χ^2) test to evaluate the overall goodness-of-fit and the joint significance of the independent variables across the equations. Furthermore, marginal effects were calculated. This allowed for the

quantification of the change in the probability of adopting specific SAPs relative to a unit change in the explanatory variables.

3. Results and Discussion

3.1. Descriptive Statistics

The 271 cacao farmer-respondents had a mean age of 54, with 39% over 60 years old, consistent with the aging farming population in the Philippines. The covered cacao sector is well-represented by female farmers (50.2%), reflecting the high level of gender inclusivity in the regional high-value crops sector. The mean farming household size is four members. In terms of education, the sample is representative of rural smallholders, with secondary school graduates (36%) predominating, followed by elementary graduates (18.1%), and those reaching secondary (15.1%), college level (11.8%), or completing a college degree (8.9%).

The average annual income from farming is PhP 71,895; including income from intercrops such as coconut and banana. Notably, 47.8% earn less than PhP 50,000 annually. Farming experience averages 17 years, although a majority (52%) have less than 10 years, suggesting a recent influx of farmers following the cacao industry revitalization programs. The average farm size of 1.9 hectares, with 55.7% managing less than one hectare, mirrors the DTI's regional profile of a sector dominated by smallholders. For land tenure, 90% reported owning their land, including 26.6% who are beneficiaries of the Comprehensive Agrarian Reform Program (CARP). Institutional presence is established, as 80% are members of POs, and 66% have participated in technical trainings on production and marketing. These characteristics align with regional benchmarks, confirming the sample's representativeness of the Davao Region cacao sector. The summary of adoption rates of SAPs is shown in Figure

1.

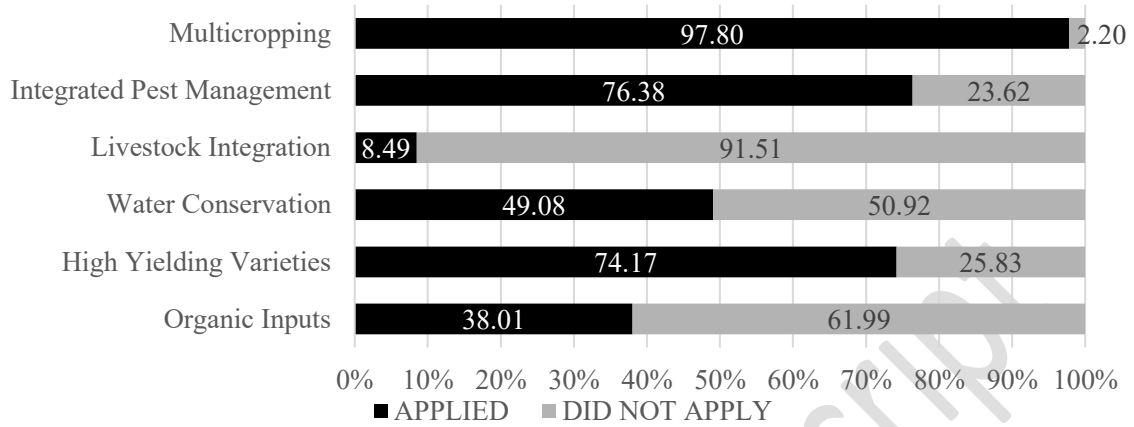


Figure 1. Adoption levels for the identified SAPs among cacao farmers

3.2. Structural Equation Model- Factors Affecting Intention to Adopt SAPs

The factors influencing the intention to adopt SAPs were estimated using the indicators detailed in Table 2. These indicators were based on a five-point Likert scale, with 1=strongly disagree and 5=strongly agree.

Table 2. Summary of indicators for the latent variables used in PLS-SEM with mean

Construct	Variable Name	Description	Mean (Std. Dev.)
Attitude (ATT)	ATT1	I think using SAPs offers many advantages in terms of crop yields and farm income.	4.200 (0.842)
	ATT2	I think that the economic importance of mixed cropping is going to increase in the future.	4.192 (0.876)
	ATT3	Sustainable agriculture is useful to maintain long-term productivity of farming system.	4.332 (0.724)
Subjective Norm (SN)	SN1	I think using SAPs can improve my reputation in the society.	4.162 (0.852)
	SN2	I feel like I am under the pressure to use SAPs in my community.	3.387 (1.221)
	SN3	Most farmers of cacao adopt SAPs except me.	3.140 (1.321)

Perceived Behavioral Control (PBC)	PBC1	I have the necessary knowledge to try out SAPs	3.554 (1.132)
	PBC2	I am confident that I have or can acquire enough physical and financial resources to cultivate cacao using SAPs	3.616 (1.156)
	PBC3	I think it is easy to adopt at least one or one more SAP.	3.661 (1.053)
Injunctive Norm (IN)	IN1	In terms of farming practices, I want to use what other farmers in my community practice.	3.859 (0.932)
	IN2	Farmers in my community believe that SAPs are more beneficial than conventional agriculture.	3.941 (0.978)
	IN3	I think that my family, neighbors, and community may support or agree with me to practice SAPs.	3.904 (0.994)
Perceived Ecological Benefits (PEB)	PEB1	I think SAPs positively affect biodiversity.	4.277 (0.825)
	PEB2	I think SAPs can preserve and improve soil quality.	4.292 (0.801)
	PEB3	I think SAPs can improve water and nutrient utilization.	4.365 (0.711)
Intention (INT)	INT1	I intend to adopt at least one or one more SAP in the long term.	4.162 (0.852)
	INT2	I intend to promote SAPs to others.	4.103 (0.878)
	INT3	I have plans to improve on the SAPs which I have adopted or will adopt in the future.	4.170 (0.876)

To ensure the robustness of the structural model, the measurement (outer) model was subjected to diagnostic testing for reliability and validity, as summarized in Figure 2.

Construct Reliability					Convergent Validity			Discriminant Validity										
Cronbach's alpha (>0.7)		Composite reliability (0.7-0.95)			Average Variance Extracted (>0.5)			Heterotrait-Monotrait Matrix (<0.90)										
Var.	Cron. α		CR		Var.	AVE		ATT	IN	INT	PBC	PEB						
ATT	0.71	✓	0.83	✓	ATT	0.63	✓											
IN	0.79	✓	0.88	✓	IN	0.71	✓	IN	0.74	✓								
INT	0.91	✓	0.94	✓	INT	0.85	✓	INT	0.61	✓	0.82	✓						
PBC	0.85	✓	0.91	✓	PBC	0.77	✓	PBC	0.54	✓	0.86	✓	0.74	✓				
PEB	0.89	✓	0.93	✓	PEB	0.83	✓	PEB	0.71	✓	0.82	✓	0.89	✓	0.68	✓		
SN	0.56		0.74	✓	SN	0.50	✓	SN	0.71	✓	0.74	✓	0.61	✓	0.61	✓	0.56	✓

Figure 2. Summary of PLS-SEM model diagnostic results showing the tests and critical values

All constructs met the Cronbach's alpha criterion of 0.7, with the exception for SN. However, since Cronbach's alpha is often considered a conservative estimate that may underestimate reliability in PLS-SEM, Composite Reliability (CR) was used as the primary benchmark. All constructs yielded CR scores within the satisfactory to acceptable range (0.70–0.95), justifying the retention of SN indicators; and implying internal consistency. Furthermore, convergent validity was established with all constructs achieving AVE above the 0.50 threshold. This implies that the survey instrument sufficiently captured the latent constructs. Discriminant validity was confirmed using the HTMT ratio; all cross-construct scores remained below the conservative 0.85 – 0.90 threshold (Henseler et al., 2015), ensuring that the constructs are empirically distinct. Hence, the model provides a reliable foundation for evaluating the structural relationships and predictive power of the framework.

Figure 3 shows the estimated relationship between TPB factors and the significance of the hypothesized paths using bootstrapped PLS-SEM. The values on the arrows represent the coefficients. From the outer model, all the identified indicators are

statistically significant in measuring the reflective constructs. The inner model confirmed the hypothesized relations between latent constructs and adoption intention, which were statistically significant at 5%, except for the effect of attitude. The quality criteria for model fit include the coefficient of determination, specifically, R^2 and adjusted R^2 . The equation predicting attitude has a relatively low score of 0.356 and 0.354 for R^2 and adjusted R^2 , respectively. However, the model for intention has a relatively high score of 0.713 and 0.708 for R^2 and adjusted R^2 , respectively. While this demonstrates strong predictive power, this is limited by the actual difference between stated intention and actual adoption. Furthermore, the framework does not fully account for other factors, such as policy landscapes, climate vulnerabilities, and price fluctuations, which can influence a farmer's psychological intent. This creates an opportunity for future research to incorporate these themes in the analysis.

From the TPB constructs hypothesized, PEB, IN, PBC, and SN were found to significantly affect INT.

Specifically, PEB from SAPs significantly improved ATT with a coefficient of 0.597 and effect size of 0.553. It also significantly affected INT with a coefficient of 0.542 and effect size of 0.498. The surveyed cacao farmers expressed that SAPs potentially provide positive ecological benefits. This can be related to cacao farmers' vulnerability to climate. Farmers frequently identified the intensifying climate change effects, specifically unpredictable weather patterns, as a primary barrier to productivity and long-term viability. Hence, PEB leads to the recognition that SAPs may improve resilience, demonstrating a stronger intention to adopt SAPs.

Interestingly, a null relationship between ATT and INT was found, which diverges from TPB studies. This possibly implies that for Davao cacao farmers, the decision to adopt SAPs is not only a matter of personal preference, but also a response to structural barriers and social obligations.

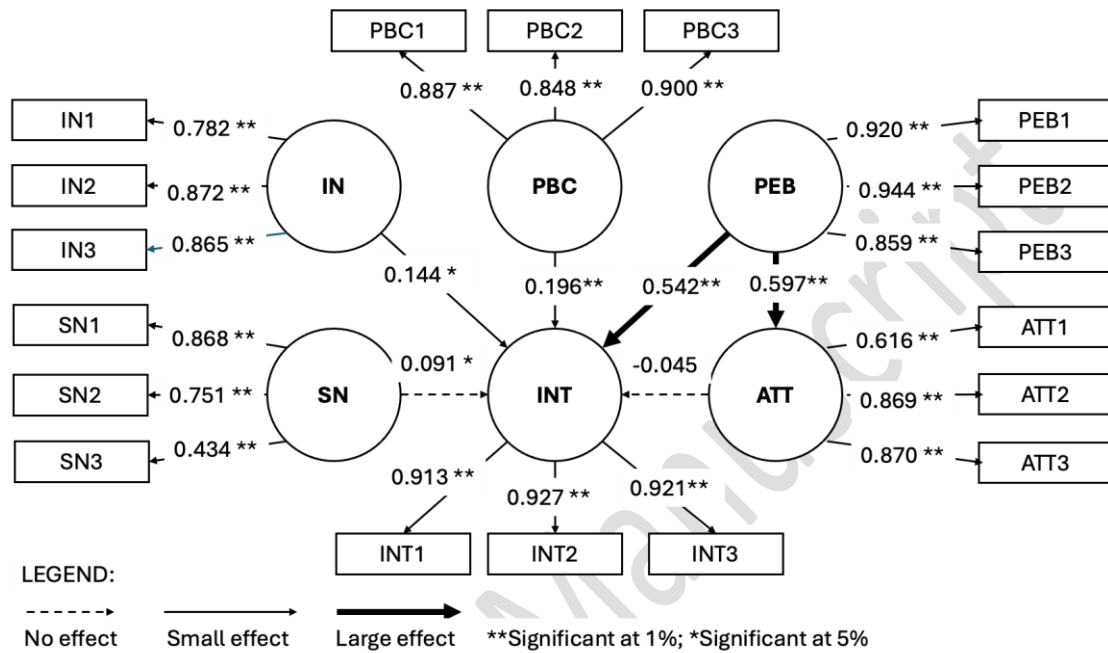


Figure 3. PLS-SEM Path Coefficients of the latent constructs predicting cacao farmers' intention to adopt SAP.

IN affected INT with a coefficient of 0.144. Its effect size was 0.024 implying a small effect on INT. Since IN captures the cacao farmers' idea of whether their significant peers approve of the adoption or not, this heightens the importance of the enabling role of farming communities in promoting a certain desired behavior. Cacao farmers perceive that their potential adoption of SAPs will be supported by their significant peers and this also heightens their intention to adopt SAPs.

PBC influenced INT with a coefficient score of 0.196 and a small effect size of 0.063. PBC covers the cacao farmers' assessment of their own ability to successfully employ SAPs. One of the issues they identified is the limited sources of sustainable inputs such as organic materials. Although some could potentially produce their own, they lack the

technical expertise to process these. Other activities such as pod sleeving and pruning under integrated pest management were laborious and costly so farmers, do not intend to adopt.

Finally, SN also appeared to be statistically significant with a coefficient of 0.091, but its effect size on INT to adopt SAPs of 0.017 is negligible. SN depicts conformity behavior among farmers on what other peers practice and how they are influenced by what other farmers do. The cacao farmers agree that the observed practices of peers have influenced the practices they employ which highlights the role of POs in influencing cacao farmers' own practices. However, its negligible effect on SAP adoption is supported by the low uptake of some SAPs.

3.3. MVP Results- Adoption of SAPs

3.3.1 Adoption of Multiple SAPs

The adoption of the SAPs was measured through the MVP model. The correlation of the error terms were computed to see the unobserved joint effects of adopting different SAPs simultaneously.

Table 3 Correlation coefficients of residuals from the MVP model

	ρ_O	ρ_M	ρ_I	ρ_N	ρ_L	ρ_W
ρ_O	-					
	0.564					
ρ_M	(0.306)	-				
	0.063	0.119				
ρ_I	(0.129)	(0.183)	-			
	0.003	-0.256	-0.003			
ρ_N	(0.149)	(0.213)	(0.148)	-		
	0.538 **	0.266	-0.468 *	0.143		
ρ_L	(0.179)	(0.329)	(0.218)	(0.270)	-	
	0.115	-0.015	0.302 *	0.144	-0.324 *	
ρ_W	(0.123)	(0.260)	(0.148)	(0.136)	(0.149)	-

Likelihood ratio test of $\rho_{MO} = \rho_{IO} = \rho_{NO} = \rho_{LO} = \rho_{WO} = \rho_{IM} = \rho_{NM} = \rho_{LM} = \rho_{WM} = \rho_{NI} = \rho_{LI} = \rho_{WI} = \rho_{LN} = \rho_{WN} = \rho_{WL} = 0$: $\chi^2(15) = 27.370^{**}$; Prob $> \chi^2 = 0.0259$

* and ** show significance at 5%, and 1% α , respectively

Residual correlations reveal possible interdependencies among the adoption of SAPs, likely driven by unobserved joint determinants such as shared technical constraints or resource allocation strategies. A significant positive correlation exists between livestock integration and organic inputs ($\rho_{LO} = 0.538$). This suggests that unobserved factors may lead to the simultaneous adoption of both SAPs. One potential link is through the wastes from livestock or poultry which may serve as organic inputs, and may be a cost-effective nutrient source for cacao.

Conversely, a significant negative correlation between livestock integration and adoption of HYVs ($\rho_{LI} = -0.468$) was found. This contradicts the findings of the studies of Teferi et al. (2015) and Ullah et al. (2018). The farmers expressed apprehension regarding livestock damaging low-growing blooms on HYV trees, indicating that the risk of yield loss acts as a potential deterrent to introduce livestock in systems with HYVs.

Furthermore, the positive correlation between water conservation and HYV ($\rho_{WI} = 0.302$) possibly highlights that farmers perceive moisture as a prerequisite for maximizing the yield potential of HYVs, particularly given cacao's sensitivity to water stress during pod development (Lahive et al., 2019).

Finally, the significant negative correlation between water conservation and livestock integration ($\rho_{WL} = -0.324$) contradicts some existing literature (Yifru and Miheretu, 2022). This divergence could suggest that in this context, unobserved factors such as a prioritized focus on cacao yield over secondary livestock income, drive farmers to

allocate limited water and resources specifically toward intensive cacao management rather than integrated animal systems.

3.3.2 Adoption of Independent SAPs

The results of the MVP estimation which show the drivers of SAP adoption are shown in Table 4. The log pseudolikelihood ratio is -427.506, and the Wald χ^2 statistic with 78 degrees of freedom was computed to be 283.420 which is significant at $p < 0.01$ suggesting the model's goodness of fit. The model was run using robust standard errors to control for the effects of heteroscedasticity. The estimation for marginal effects and separate binary probit models are shown in the Table 1 of the supplementary file.

Table 4. MVP estimation coefficients and standard errors on SAP adoption

Variable	<u>Organic</u>	<u>Multicrop</u>	<u>HYV</u>	<u>IPM</u>	<u>Livestock</u>	<u>Water</u>
	<u>Inputs</u>				<u>Integ.</u>	<u>Conservation</u>
	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Age	0.016 (0.010)	-0.041* (0.018)	-0.009 (0.009)	0.016 (0.010)	0.012 (0.013)	-0.023* (0.010)
Sex	0.188 (0.210)	-1.222** (0.373)	-0.105 (0.217)	0.217 (0.236)	0.664* (0.271)	-0.051 (0.215)
Household Size	0.077 (0.069)	-0.086 (0.170)	0.021 (0.065)	0.121 (0.082)	0.112 (0.074)	0.032 (0.067)
Intention	0.119 (0.103)	0.563** (0.209)	0.044 (0.105)	0.317** (0.113)	-0.066 (0.138)	0.028 (0.103)
Education	-0.028 (0.040)	-0.241** (0.091)	0.009 (0.042)	-0.040 (0.045)	0.262** (0.072)	-0.056 (0.041)
Farm Experience	-0.034** (0.009)	-0.015 (0.018)	-0.016 (0.009)	-0.018* (0.009)	-0.031* (0.016)	-0.025** (0.010)
Farm Size	0.082 (0.086)	0.051 (0.169)	-0.019* (0.009)	0.020 (0.014)	0.000 (0.006)	-0.117 (0.127)
Farm Income	0.002 (0.002)	0.018* (0.008)	0.004* (0.002)	0.002 (0.002)	-0.005 (0.003)	0.002 (0.002)
Training	-0.620** (0.228)	0.165 (0.601)	0.135 (0.241)	-0.305 (0.251)	0.508 (0.309)	-0.454 (0.247)
Membership	0.104 (0.287)	1.481** (0.361)	-0.116 (0.256)	0.178 (0.265)	0.321 (0.370)	-0.116 (0.246)

Irrigation	-0.651**	1.409*	0.777**	0.632*	-0.550	0.454
	(0.246)	(0.568)	(0.290)	(0.309)	(0.540)	(0.264)
Capital	-0.292	0.178	-0.048	0.267	0.086	-0.012
	(0.358)	(0.456)	(0.387)	(0.404)	(0.524)	(0.391)
Land Ownership	-0.857*	0.648	0.999**	0.878*	-0.911	-0.040
	(0.374)	(0.665)	(0.362)	(0.392)	(0.525)	(0.416)
Constant	0.501	5.589	-0.023	-1.314	-4.488**	2.424**
	(0.915)	(1.920)	(0.881)	(1.087)	(1.138)	(1.012)

Log pseudolikelihood = -427.50621; Wald $\chi^2(78) = 283.42$; Prob > $\chi^2 = 0.000$

Note: ME are marginal effects; * and ** show significance at $\alpha = 5\%$, and $\alpha = 1\%$, respectively

The adoption of organic inputs is significantly influenced by farming experience, training, irrigation, and land tenure. Seasoned farmers often rely on familiar traditional methods and those with more experience proved more hesitant to switch to organic systems. Interestingly, training attendance negatively impacted organic adoption; this is likely because local programs prioritize productivity over sustainable practices. This reflects a broader policy conflict where expansion-focused goals often crowd out conservation-oriented strategies (OECD, 2001).

Irrigation also plays a critical role in organic input use. Since stable water access reduces the risks associated with flowering and yield (Carr and Lockwood, 2011), irrigated farmers are more willing to invest in expensive conventional inputs. Conversely, those without irrigation facing the double risk of unpredictable rainfall and high costs often opt for organic alternatives to minimize potential financial losses. Finally, land ownership decreased the likelihood of organic input adoption. Non-owners were more likely to use organic inputs than landowners. With larger average farm sizes (2.47 ha vs. 1.88 ha), these non-owners appear to leverage scale efficiencies through leased land, adopting sustainable practices more aggressively than smaller-scale landowners.

The adoption of multi-cropping is driven by a combination of demographic constraints and resource availability. The lower adoption rate among older farmers, aged 60 and above, likely reflects the high labor demands of diversified systems. Managing multiple crops requires complex production planning, varied harvest cycles, and intensive pest management, which can be physically and logistically overwhelming for older smallholders (Bonke and Musshoff, 2020).

Similar to the findings of Ureta et al. (2016), female farmers were significantly more likely to adopt multi-cropping, often integrating vegetables alongside traditional intercrops like coconut and banana. This reflects a distinct preference for household food security and dietary diversity. In contrast, male farmers tended toward less diverse systems, typically focusing on a single additional cash crop like coconut.

Education was found to negatively influence multi-cropping adoption, which diverges from the findings of Boora et al. (2023) and Chichongue et al. (2020). In this context, farmers with higher educational attainment often prioritize monocrop intensification, treating cacao as a specialized, primary income source that requires a more focused production system. Higher educational attainment often facilitates off-farm employment, leading farmers to prefer simplified monocultures that require less daily supervision. Further, Pazeres et. al (2023) found a similar finding and discussed that those with higher educational levels tend to focus on productive efficiency, which is perceived to be achieved by specializing with a singular crop.

Financially, higher annual farm income appears as a critical enabler for diversification.

Because multi-cropping systems involve more varied input requirements, farmers with

higher income are better positioned to fund these additional expenses. This capacity for investment is further improved by membership in POs. With 80% of surveyed farmers as members, these organizations provide essential platforms for marketing cooperation and access to processing facilities. Consistent with Zhang et al. (2020), membership to POs was found to increase the potential of member-farmers to receive interventions, from public and private sources.

Irrigation facilitated the adoption of multi-cropping. Waha et al. (2020) stated that multi-cropping is more widespread where rainfall is well-distributed or viable irrigation systems are present to meet moisture requirements and ensure productivity of all crops as cropping intensity increases. Access to irrigation would ensure improved adaptation to climate stresses of multiple crops.

The adoption of HYVs is driven by farm size, farm income, irrigation, and land ownership. While farm size negatively influenced adoption, this suggests that smallholders utilize HYVs to achieve higher productivity, compensating for their limited land area by maximizing productivity per hectare (Taher, 1996).

Conversely, annual farm income and irrigation both serve as critical enablers; higher income provides the liquidity needed to procure quality seedlings and survive the unproductive juvenile period, while irrigation ensures the consistent moisture required for HYVs to reach their yield potential (Valleser et al., 2023). Lower-income farmers may face a poverty trap, where the inability to absorb temporary yield dips prevents them from adopting.

Similarly, land ownership positively influenced adoption of HYVs. Tenure security allows for farmers to leverage on using their own land and make more long-term investments for land productivity (Jaza Folefack and Darr, 2021) such as the use of HYVs.

Adoption of IPM, on the other hand, is influenced negatively by farm experience, and positively by predicted intention, irrigation, and land ownership. The predicted positive value for INT confirms that the farmers' intention to adopt actually translates to the adoption of IPM. As previously discussed, this is influenced by PBC, PEB, SN, and IN. In contrast, farming experience negatively affects adoption, suggesting that seasoned farmers may develop a resistance to changing established routines. This inertia is often compounded by insufficient technical support or weak incentives to transition away from traditional pest control methods (Parsa et al., 2014).

Structural factors like irrigation and land ownership positively influence IPM adoption. Access to irrigation stabilizes productivity that encourages farmers to invest in labor-intensive practices like pod-sleeving and systematic pruning. Furthermore, tenure security through land ownership reduces the financial burden of lease payments and provides the long-term certainty required to invest in productivity-enhancing measures (Jaza Folefack and Darr, 2021).

Livestock integration, on the other hand, is less practiced among cacao farmers, adopted by only 8.5% of respondents, and is driven primarily by gender roles and educational attainment. Results show that males are significantly more likely to manage livestock, attributed to prevailing social norms that favor male decision-making and the physically

demanding nature of tasks like tethering (Bonis-Profumo et al., 2022; Mollel and Mtenga, 2000).

Furthermore, higher education enhances adoption by improving a farmer's ability to process additional information required for silvopastoral management; this technical knowledge helps mitigate common cacao farmers' apprehensions regarding farm hygiene, labor costs, and potential crop damage (Smith et al., 2022; Paltasingh and Goyari, 2018).

Conversely, farming experience negatively affected livestock integration. During the early establishment phase, farmers often integrate livestock to diversify income while cacao yields are low. However, as trees reach peak maturity (25–40 years) and begin producing pods on the trunks, cauliflory, many farmers abandon livestock integration to prevent animals from damaging the fruits (Niemenak et al., 2010).

The adoption of water conservation in the Davao Region is primarily driven by age and farming experience. Rainwater harvesting using drums and gutter systems is the most common practice among adopters. Younger farmers are significantly more likely to implement these, as they possess the physical stamina required for the activities associated with water conservation (Belachew et al., 2020).

4. Conclusions

The study demonstrates that the intention to adopt SAPs is driven by a complex interplay of PEB, PBC, SN, and IN. Hence, policy and extension efforts must look beyond technical support to address these psychological drivers by developing social networks, enhancing environmental awareness, and building the technical and financial

confidence of farmers. Furthermore, MVP results confirm that SAPs are not uniform in their adoption pathways; this suggests that one-size-fits-all interventions could be ineffective. Policies must instead be strategically differentiated, prioritizing bundling of practices with identified synergies such as that of organic adoption and livestock integration; and water conservation and HYV adoption.

Further, interventions may be used to harness the relevance of SN in adoption intention. Leveraging social networks and strengthening horizontal and vertical integration through POs or clusters to achieve scale, and deploying targeted capacity-building programs that utilize information and education campaigns tailored to specific SAPs may be pursued. Additionally, addressing the aging demographic requires greater youth involvement to ensure succession. Models for youth engagement may be explored such as *agri-preneurship* models and digitalization. Finally, there may also be a need to look into land tenure conditions and infrastructure investments, such as irrigation, to potentially provide the structural foundation which aid in SAP adoption.

This study advances TPB by demonstrating that PEB serves as a significant driver, expanding the framework beyond intrinsic motivations. In this context, the public good aspect of sustainability is an identified antecedent to intention. This suggests that for environmental technologies, PEB is a critical consideration, a construct often overlooked in similar applications of TPB. Future research using Multi-criteria Decision Making will be essential to further substantiate and prioritize these strategic policy options.

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