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DETERMINANTS OF HOME COMPOSTING BEHAVIOR IN SUPPORTING SUSTAINABLE AGRICULTURE AMONG SMALLHOLDER FARMERS: A CASE STUDY IN THE THAI NGUYEN PROVINCE OF VIETNAM

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Abstract

Home composting is a practical and sustainable approach for the management of organic waste generated in the home and agricultural production that contributes to both organic waste management and soil fertility enhancement. In the northern mountainous regions of Vietnam, smallholder farmers face limited adoption of sustainable waste management practices due to behavioral constraints, limited technical knowledge, and resource constraints affecting agricultural productivity. This study applies and extends the Theory of Planned Behavior (TPB) by integrating behavioral and contextual determinants to examine home composting adoption among smallholder farmers in rural Vietnam. Principal Component Analysis (PCA) was used to reduce and structure latent behavioral constructs, while a binary logit regression model was applied to estimate the probability of composting adoption based on survey data from smallholder farmers. The results indicate that composting knowledge (OR=2.4253) and social influence (OR=1.3028) are the strongest determinants of adoption, followed by farmer's attitudes (OR=1.1782) and gardening practices (OR=1.1626), all of which positively influence composting behavior. Policy interventions should prioritize knowledge enhancement and community-based diffusion mechanisms, as these factors have the strongest empirical influence on adoption, while integrating composting training into agricultural extension services. This study extends the TPB framework by incorporating context-specific behavioral constructs derived from PCA, including psychological attitudes, social influence, and resource-related constraints influencing adoption decisions. The findings provide evidence-based guidance for designing targeted behavioral and knowledge-driven interventions to improve adoption of sustainable composting practices in rural agricultural systems.

Keywords: Adoption behavior; Home composting; Theory of Planned Behavior; Smallholder farmers; Vietnam

1. Introduction

Agricultural systems are facing climate change and environmental degradation, which can reduce agricultural production. Adopting of sustainable agricultural practices is a suitable solution to these challenges (Ward et al., 2018; Foguesatto et al., 2019). Home composting offers smallholder households a potentially low-cost means of converting organic waste into soil amendments and reducing dependence on external fertilizer inputs (Kumar, 2011). In smallholder farming systems, home composting may involve the controlled decomposition of household food waste, crop residues, and livestock manure for subsequent use in gardens or agricultural fields (Colón et al., 2010). Treating organic waste at the household or farm level

may reduce open burning, uncontrolled disposal, and the direct application of untreated manure (Tanaka, 2007), and minimizing the loss of organic materials typically associated with landfilling (Smith & Jasim, 2009). By converting organic residues into stabilized soil amendments, home composting may reduce harmful disposal practices while improving soil structure and nutrient availability (Andersen et al., 2012; Barrena et al., 2014). Although home composting is not suitable to all waste streams or household conditions (Andersen et al., 2011), it can provide a feasible management option where adequate space, organic feedstock, labor, and technical knowledge are available (Getahun et al., 2012; Faverial & Sierra, 2014). Its combined functions of waste reduction and nutrient recovery position home composting as a household-level mechanism for circular agriculture (Viaene et al., 2016; Lhaj et al., 2024).

Previous research has identified both psychological and practical determinants of household composting behavior. Favorable attitudes, perceived social approval, and perceived behavioral control are associated with stronger composting intentions and, in some contexts, actual participation (White et al., 2019; Lin & Guan, 2021). Practical barriers, including odor, pests, and inconvenience, often discourage participation, whereas access to bins, availability of garden space, and habit formation are enabling factors (Oskamp et al., 1991). Studies on the determinants of composting behavior have frequently applied the Theory of Planned Behavior (TPB), which emphasizes the influence of attitudes, subjective norms, and perceived behavioral control on individual intentions (Ajzen, 1991). Capability-related and contextual factors, including access to organic feedstock, land availability, time, tools, and technical knowledge, also significantly influence composting practices (De Boni et al., 2022). Variations in household behavior are explained by sociodemographic characteristics such as educational level, household size, gardening experience, and community effects (Loan et al., 2019). However, limited evidence explains how attitudes, social influence, gardening engagement, and access to composting knowledge are associated with actual adoption among rural smallholder farmers. For smallholder farmers, this behavior is particularly relevant because compost can be reintegrated into on-farm nutrient cycle.

Agriculture remains central to food security and rural livelihoods in Vietnam, particularly in Northern mountainous regions dominated by smallholder production (GSO, 2022). The increasing pressure on arable land coupled with the overuse of chemical fertilizers has led to declining soil health and environmental degradation (Kebede et al., 2023). In these regions, declining soil quality and continued reliance on chemical fertilizers create a need for locally available nutrient-management alternatives. Currently, crop residues and livestock manure are frequently burned, discarded, or applied without adequate treatment. These practices may contribute to air pollution, nutrient loss, greenhouse-gas emissions, and health risks in the region (Truong et al., 2018). Home composting has emerged as a potential solution to these challenges by promoting the recycling of organic materials and enhancing soil fertility (Sayara et al., 2020). Converting household and agricultural organic residues into compost could reduce harmful disposal practices while returning stabilized nutrients to agricultural soils, thereby supporting circular resource use (Bhatia & Sindhu, 2024).

Home composting, an old practice of converting organic waste into nutrient-rich compost, has gained renewed attention as a sustainable waste management approach. This potential is particularly relevant in northern mountainous Vietnam, where many households depend on small-scale farming and locally available agricultural resources (Keck & Hung, 2019). Despite these potential benefits, the extent and determinants of home composting adoption among smallholder households in the region remain insufficiently documented. The present study focuses on gardening engagement, attitudes toward composting, pro-environmental behavior, social influence, and access to composting knowledge. Community interaction may nevertheless influence adoption by circulating practical information and reinforcing local behavioral norms (Son et al., 2021). What remains unclear is the relative importance of these behavioral and context-specific factors in explaining actual adoption among smallholder

farmers in northern mountainous Vietnam. Identifying these factors can help agricultural extension agencies and local authorities target the specific informational, social, and practical constraints that limit adoption.

Thai Nguyen province, a predominantly agricultural region in the Northern mountainous region of Vietnam, offers a meaningful case study because smallholder farming is widespread and household management of crop residues, livestock manure, and domestic organic waste remains a practical environmental concern. Farmers in the study area face declining soil quality, continued dependence on chemical fertilizers, and limited development of circular organic-waste practices (Chien et al., 2019), while circular economy practices remain underdeveloped (Phuong et al., 2022). Examining this setting addresses a context-specific evidence gap concerning composting adoption among rural smallholder farmers and may inform locally appropriate extension strategies. This study investigates the factors associated with household adoption of home composting among smallholder farmers in Vietnam's northern mountainous region. A binary logit model is used to estimate the associations between selected behavioral and contextual predictors and the probability of adoption. Although previous composting studies have focused primarily on urban households and municipal waste programs, limited evidence explains actual adoption among rural smallholder farmers. This study therefore examines how gardening engagement, attitudes toward composting, pro-environmental behavior, social influence, and access to composting knowledge are associated with household adoption in Thai Nguyen province. Using a TPB-informed framework and a binary logit model, the study provides context-specific evidence on rural composting behavior and identifies potential intervention points for agricultural extension and community-based organic-waste management.

2. Research Design and Methodology

2.1 Conceptual framework

The Theory of Planned Behavior proposed by Ajzen (1991) has been widely used to examine environmental and agricultural decision-making through the relationships among attitudes, subjective norms, perceived behavioral control, behavioral intention, and actual behavior (White et al., 2019; Emmanouil et al., 2024). Within the TPB, attitudes, subjective norms, and perceived behavioral control are expected to shape behavioral intention, while intention and perceived behavioral control subsequently influence the performance of the behavior (Ajzen, 1991). Attitude toward composting refers to a farmer's overall favorable or unfavorable evaluation of practicing home composting. Subjective norms refer to the perceived approval, expectations, or social pressure communicated by family members, neighbors, community leaders, and other relevant individuals. Perceived behavioral control refers to farmers' perceived ability to perform home composting, including their confidence in having sufficient time, space, materials, skills, and control over the process (Ajzen, 1991). In addition to the core constructs of TPB, variables "gardening" and "pro-environmental behavior" were incorporated as two extended variables in the model. Gardening engagement was included because households that actively cultivate gardens have both a practical use for compost and greater familiarity with soil-management activities. Pro-environmental behavior was also included to examine whether participation in other environmentally responsible practices is associated with home composting adoption. Collectively, these components influence behavioral intentions, which in turn shape actual behavior.

In the context of home composting, attitude toward composting should be measured through farmers' overall evaluations of the practice, including perceived benefits such as improved soil fertility and waste reduction, as well as perceived disadvantages such as inconvenience, odor, labor requirements, and processing time. Subjective norms capture the extent to which farmers perceive that family members, neighbors, community leaders, and other relevant actors approve of or expect them to practice home composting in rural Vietnam.

Perceived behavioral control relates to farmer's perceived ease or difficulty in adopting composting, which is influenced by knowledge, access to organic materials, and time availability.

Several studies have extended TPB to environmental and agricultural behaviors such as recycling, organic farming, and resource conservation (Tama et al., 2021; Czyzewski et al., 2025). These studies support the relevance of TPB-informed variables for explaining pro-environmental practices. However, evidence remains limited regarding their association with actual home composting adoption among smallholder farmers in developing-country settings. Applying TPB in this study offers a means to identify not only the psychological and social drivers of composting adoption but also practical barriers such as lack of technical knowledge.

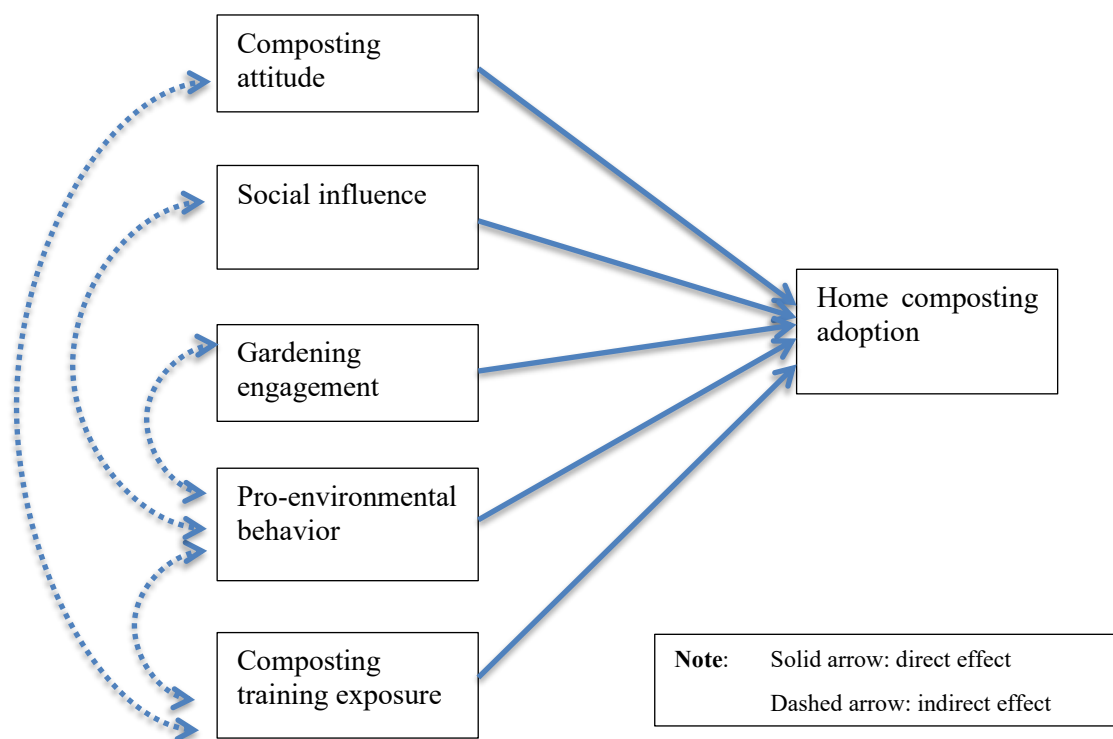


Figure 1. TPB-informed extended adoption framework
(Adapted from Ajzen, 1991)

2.2 Survey area and data collection

Thai Nguyen province is located in the northern mountainous region of Vietnam, which is characterized by diverse ethnic groups and traditional farming practices. Vo Nhai district was selected because smallholder crop and livestock production is widespread, and households generate organic materials that may be suitable for composting. The study was conducted in three communes (Dan Tien, Trang Xa, and Lien Minh) selected to represent variation in agricultural activity and local waste-management conditions.

The study primarily employed a quantitative cross-sectional survey. Key informant interviews were used to provide contextual information about local waste-management practices and agricultural support services, but were not treated as a separate qualitative analytical component. The survey sample was randomly drawn from eligible household lists within the selected communes; therefore, the findings are primarily generalizable to the surveyed communities rather than to the entire northern mountainous region of Vietnam.

A purposive and random sampling technique was employed to select the study sites and respondents. First, the Vo Nhai district of the Thai Nguyen province was identified to have varying levels of agricultural activity and waste management practices. Then, households within 3 communes (Dan Tien, Trang Xa, and Lien Minh) of the district were randomly

selected for the survey, ensuring representation across socio-economic strata through simple random sampling based on household lists obtained from local authorities. Data were collected through direct face-to-face interviews. The sample size of 346 observations was considered adequate for both Principal Component Analysis (PCA) and logistic regression, because it exceeded the recommended thresholds for multivariate analysis and provided sufficient observations for stable parameter estimation (Hair et al., 2010).

A structured questionnaire was developed using TPB-informed constructs and items adapted from previous composting studies. The questionnaire was designed in Vietnamese, reviewed by subject experts, pilot-tested with respondents outside the final sample, and revised to improve clarity and contextual relevance. The questionnaire included sections on the smallholder farmer's socio-economic characteristics, attitudes toward composting, subjective norms, perceived behavioral control, and current composting practices. Eight key informants were purposively selected based on their involvement in agricultural extension, waste management, or local administration. For each commune, one extension worker and one commune leader will be selected, together with one district extension officer and one district leader. Semi-structured interviews examined local waste practices, composting support, regulations, and extension services.

2.3 Measurement of the variables

2.3.1 Adoption of home composting

Home composting adoption was coded as 1 when a household reported actively processing household or farm-generated organic materials into compost during the previous 3 months, and 0 when no such activity was reported. This binary measure was used to distinguish households that had engaged in composting practices from those that had not adopted composting at the time of the survey.

2.3.2 Behavioral and contextual explanatory variables

Motivational variables were selected based on previous study's findings and the characteristics of the study site. Gardening: how keen an individual is to garden (Edgerton et al., 2009; Loan et al., 2019). This is a composite score based on responses to 3 questions about interest in gardening, gardening knowledge, and gardening activity frequency. Attitude toward gardening is recognized using a set of questions in a 5-point Likert scale format, ranging from "never at all" to "very frequently." Composting attitude: a farmer's perception of what is involved in composting (Edgerton et al., 2009; Loan et al., 2019) was measured through survey questions on household composting practices and related behaviors. This is also a composite score based on responses to 5 questions relating to perceptions of inconvenience or barriers to composting. Responses to these statements were made on a 5-point Likert scale, ranging from "agree strongly" to "disagree strongly". Pro-environmental behavior: whether farmers participate in four other pro-environmental behaviors (Edgerton et al., 2009; Loan et al., 2019). Newspaper recycling, glass recycling, can recycler, and buying recycled products. This is a composite score based on the answer of "never"=0, "occasionally" =1, "frequently"=2 for each behavior. Social diffusion: reflecting the influence of friends, relatives, and community members on farmers' decisions to practice home composting (Edgerton et al., 2009) was measured on the survey responses, using the average of two questions "A farmers did home composting because of their friends and relatives". These two questions were answered using a 5-point scale ranging from "strongly agree" to "strongly disagree". Composting training exposure (Andersen et al., 2012; Bertoldi et al., 2015; Edgerton et al., 2009; Loan et al., 2019) measured by farmers' understanding of composting practices, including participation in training programs or related access to information where applicable. This variable was coded as 1 when a respondent had previously received formal training or structured composting information and 0 otherwise. A farmer who participated in a composting training course would be 1; otherwise, it would be 0.

However, the results may not fully reflect differences in depth, quality, or retention of knowledge among farmers, which is a limitation of the study.

2.4 Analytical techniques

Because home composting adoption was measured as a binary outcome, a binary logistic regression model was used to estimate the probability that household i practiced home composting. In this study, the dependent variable equals 1 if the respondent practices home composting and 0 otherwise. Following this specification, the binary logit model was employed.

Both the logit and probit models provide similar qualitative results. However, the logit model was selected due to its computational simplicity and the ability to interpret coefficients in terms of odds ratios, which facilitates policy and behavioral discussion (Train, 2002). The probability that household i practices home composting can be expressed as follows:

$$p_i = \exp(\beta'x_i) / [1 + \exp(\beta'x_i)] \quad (1)$$

where x_i is vector of variables and β is a vector of parameters. The odds ratio, which defines the probability of practicing home composting relative to non-practicing home composting, is given as follows:

$$[p_i / (1 - p_i)] = \exp(\beta'x_i) \quad (2)$$

Taking the natural logarithm yields the following logit specification:

$$\ln[p_i / (1 - p_i)] = \beta'x_i \quad (3)$$

Several statistical assessments were performed to evaluate the adequacy of the proposed logistic regression model in describing the data. These assessments aimed to examine (a) the multicollinearity among the predictor variables and (b) the potential omission of relevant explanatory variables.

3. Results

3.1 Sources of household's waste and treatment methods

Table 1 presents the different categories of household waste and the households' corresponding waste treatment methods. The table provides an overview of waste sources and illustrates how each type of waste is commonly managed. The study area reveals two primary categories of household waste. The first category primarily originates from agricultural and livestock activities, such as crop residues and animal manure. These materials, which are rich in nutrients, can be composted and used as fertilizers, thereby supporting circular agricultural practices. The second category comprises hazardous waste, which requires proper management to mitigate the risks of environmental pollution and health hazards.

In terms of waste treatment methods, households use 3 approaches: burning, landfill disposal, and home composting. Burning is prevalent in rural areas because it may be associated with its convenience and quick disposal capabilities. Although home composting is good to manage crop residues and animal manure, many households continue to burn crop residues, driven by the belief that this practice benefits their rice fields in subsequent seasons. It is also noteworthy that untreated animal manure is still frequently applied by households to vegetable gardens and fruit farms.

Table 1. Types of household's waste and treatment methods

Sources of household's waste	Number of households
- Waste from cultivation activities/by-product	140
- Livestock waste as animal manure	114
- Plastic waste as a pesticide package	115
- Daily household waste	194
Waste treatment method	
- Burning	265
- Landfill	36
- Home composting	63
- Collected by the local service	63

3.2 Descriptive statistics of the socio-economic variables

Table 2 presents a basic overview of the demographic and socioeconomic characteristics of the 346 households surveyed in the Thai Nguyen province. The average age of the respondents was 52.67 years, with a gender distribution ratio of approximately 45.10% males and 54.90% females. Educational levels show that approximately 20.23% of household heads completed primary school, 56.07% attended secondary school, 14.45% finished high school, and 9.15% pursued higher education. On average, each household comprises 4.29 members, including 3.45 working-age laborers. A significant majority (84.39%) of households are members of the local farmer union, while 15.61% are not. Wealth status was classified according to the official poverty classification criteria in the region conducted by local authorities. 5.49% of households fall below the poverty line, 5.20% are near the poverty line, 77.46% are classified as middle-income, and 11.85% are well-off. These data provide valuable insights into the surveyed population's household structure, education, labor resources, and economic conditions, offering a good foundation for further analysis and policy recommendations.

Table 2. Profile of the surveyed households in the Thai Nguyen province

Variables	Unit	Frequency/Percentage (%)
Age	Years	52.67
Gender	Dummy	
Male		156 (45.09)
Female		190 (54.91)
Education	Levels	
Primary school		70 (20.23)
Secondary school		194 (56.07)
High school		50 (14.45)
Higher level		32 (9.15)
Household size	Persons	4.29
Laborer	Persons	3.45
Member of farmer union	Dummy	
Yes		292 (84.39)
No		54 (15.61)
Wealth status	Households	
Under poverty line		19 (5.49)
Near poverty line		18 (5.20)
Middle income		268 (77.46)
Well-off household		41 (11.85)

3.3 Reliability analysis

To evaluate their internal consistency, reliability analysis was conducted on items from four question groups in the questionnaire. Cronbach's alpha coefficients were used as internal consistency measures for these dimensions. The Cronbach's alpha values exceeded 0.7 for all groups, meeting the recommended threshold of 0.7–0.8 (Hair et al., 2019). The results are summarized in Table 3.

Table 3. Cronbach's alpha values for the dimensions

Dimensions and related items	Cronbach's Alpha
1. Gardening engagement	0.7349
How often do you work in your garden?	
How would you describe your interest in gardening?	
How knowledge would you say you are about gardening?	
2. Composting attitude	0.7559
Composting takes much time	
Composting requires a lot of effort	
Composting demands a high degree of technical knowledge	
Composting requires a large amount of space	
Composting is not worthwhile unless there is a lot of waste	
3. Pro-environmental behavior	0.7373
Do you participate in any of the following "environmental" activities	
Newspaper recycling	
Glass recycling	
Can recycle	
Buying recycled products	
4. Social influence	0.8304
I composted because of my friend's advice	
People in my family advised me to do composting	

Multicollinearity was evaluated using two approaches. First, the correlation matrix of predictor variables revealed that no pair exhibited a correlation coefficient exceeding 0.8. Second, the Variance Inflation Factor (VIF) values for all predictors were below 10, and the tolerance statistics were greater than 0.2. These findings confirm the absence of multicollinearity among the model's predictor variables. Finally, to obtain additional information so that the model does not suffer from the omitted variable bias, the link test was also performed. In this case, the coefficient for *_hat* is 0.8850, and its statistically significant p-value is 0.000. This indicates that the model has predictive power and that the fitted values (*_hat*) are associated with the dependent variable. The coefficient for *hatsq* was 0.2140, and its p-value was 0.281 (not statistically significant). This suggests that there is no strong evidence of misspecification, which includes omitted variable bias.

3.4 Descriptive statistics of the variables of behavior and attitude

Table 4 presents the descriptive statistics of the behavior variables associated with home composting participation. Factor scores were generated for each corresponding variable group after conducting the PCA procedure. The values reported under the significance (Sig.) column correspond to the p-values from mean difference tests (t-tests) for continuous variables and proportion tests (chi-square tests) for dummy variables. The purpose of including these tests in the descriptive statistics table is to examine whether statistically significant differences exist between groups. Gardening interest shows a significant positive difference between groups, as participants scored higher (0.1368) than non-participants (-0.1919), with a significance level of 5%. Composting attitude was significantly more favorable among participants (0.2690) than non-participants (-0.3773), with strong significance at the 1% level. Similarly, social diffusion has a notable influence, with participants scoring higher (0.2496) than non-participants (-0.3501), also significant at the 1% level. Composting knowledge displays a clear difference in proportion, with 57.92% of participants possess composting knowledge compared to 35.41% of non-participants, with high significance. However, pro-environmental behavior did not significantly differ between the two groups. These results suggest that attitudes, knowledge, and social factors are variables that differ significantly between adopters and non-adopter, while general pro-environmental actions may not directly influence participation.

Table 4. Descriptive statistics of the behavior variables used in the model

Variables	Unit	Home composting		
		Yes (SE)	No (SE)	Significance
Gardening engagement	Factor score	0.1368 (0.1050)	-0.1919 (0.1037)	-2.1606**
Composting attitude	Factor score	0.2690 (0.1077)	-0.3773 (0.1424)	-3.6866***
Pro-environmental behavior	Factor score	-0.0480 (0.1123)	0.0674 (0.1170)	0.6968
Social influence	Factor score	0.2496 (0.0894)	-0.3501 (0.1070)	-4.3079***
Composting training exposure	dummy	0.5792 (0.0348)	0.3541 (0.0399)	-4.2219***

Note: *** and ** indicates significance at the 1% or 5% levels.

3.5 Determinants of participation in home composting

The binary logit results presented in Table 5 identify several factors associated with household participation in home composting. The Pseudo R-squared indicates a modest model fit. Although the Pseudo R-squared of the Logit regression model is moderate, it is commonly observed in household and environmental behavior studies, where decisions are shaped by numerous socioeconomic, psychological, and contextual factors (McFadden, 1974).

The gardening factor score was positively associated with home composting adoption at the 10% significance level ($\beta=0.1507$, $p=0.072$). The corresponding odds ratio of 1.16 indicates that a one-unit increase in the factor score was associated with 16% higher odds of adoption, although the evidence did not meet the conventional 5% significance threshold. The findings of this study are similar to those of Loan et al. (2019) but differ from those of Edgerton et al. (2009). One possible interpretation is that households engaged in gardening have a more immediate use for compost; however, this mechanism was not directly tested in the present analysis.

Composting attitude with a coefficient of 0.1640 is significant at the 5% level ($p=0.032$), highlighting the importance of positive attitudes toward home composting behavior. The odds ratio (OR=1.18) for composting attitude suggests that improved attitudes are likely to increase the odds of adoption by 18%. This result underscores the role of psychological factors in adopting environmentally friendly practices, aligning with the TPB (Ajzen, 1991), which confirms that attitudes strongly influence intentions and behaviors.

The variable “social diffusion” exhibited a strong effect among the predictors (coefficient=0.2645, $p=0.006$). Its odds ratio (OR=1.30) implies that stronger social exposure potentially increases the odds of composting adoption by approximately 30%. The result provides evidence that advice or encouragement from friends and family is associated with adoption in the surveyed communities. The finding may indicate that interpersonal advice and community-based information exchange are relevant to adoption decisions in the study area. This result differs from Edgerton et al. (2009), although direct comparison should be made cautiously because the studies may differ in population, social-context measures, and composting systems. A possible explanation for that is that this study was conducted in a rural area of Vietnam, where social networks often serve as channels for knowledge exchange. Individuals could learn about the benefits of new techniques, and problem-solving strategies through interactions with other members of the rural community who have experience in composting.

Exposure to composting training or structured information was positively associated with adoption ($\beta=0.8859$, $p<0.001$). The odds ratio (OR=2.43) indicates that households that had received training or information had approximately 2.43 times the odds of adopting home composting compared with households without such exposure. The result suggests that access to composting training and information may be relevant to adoption. However, reverse causality cannot be excluded because households already practicing composting may be more likely to participate in training. For this factor, our finding is consistent with the result of Loan et al. (2019). The association supports further evaluation of practical training and extension

programs as potential strategies for increasing adoption, preferably through longitudinal or experimental designs.

Table 5. Binary logistic regression estimates for household home composting adoption

Predictor variables	Odds ratios	Coef.	SE	P> z
Gardening factor score	1.1626*	0.1507*	0.0837	0.072
Composting attitude factor score	1.1782**	0.1640**	0.0766	0.032
Pro-environmental behavior factor score	0.9276	-0.0750	0.0782	0.337
Social-influence factor score	1.3028***	0.2645***	0.0958	0.006
Composting training exposure	2.4253***	0.8859***	0.2364	0.000
Constant	0.9505	-0.0507	0.1571	0.074
LR chi(2)	41.89			
Prob > chi(2)	0.0000			
Pseudo R ²	0.0892			
Log likelihood	-213.9979			

Note: Dependent variable: Household adoption of home composting, coded 1 for adopters and 0 for non-adopters; *** and ** indicate significance at the 1% or 5% levels

Conversely, the pro-environmental behavior score was not statistically associated with home composting adoption ($\beta=-0.0750$, $p=0.337$). Its odds ratio (OR=0.93) further suggests no meaningful change in the odds of adoption. Regarding recycling, some researchers have found that environmental concern is a highly significant predictor of actual recycling behavior (Lansana, 1993; Schultz & Oskamp, 1996), whereas others have found a very weak relationship (Derksen & Gartrell, 1993; Shrum et al., 1995). In terms of composting behavior, the findings of this study are consistent with those of Edgerton et al. (2009). This finding may reflect the specificity of home composting as an action requiring more than just environmental concern, such as practical knowledge and resources.

3.6 Discussion

This study provides empirical evidence on factors associated with home composting adoption among smallholder farmers in selected communes of Vo Nhai District, Thai Nguyen Province, a rural context that has received limited attention in the composting literature. Using a TPB-informed framework, the study examines how composting attitudes, social influence, gardening engagement, general pro-environmental behavior, and exposure to composting training are associated with reported adoption. The findings contribute to a more nuanced understanding of how sustainable waste management practices are adopted in developing-country agricultural systems.

At a general level, the findings indicate that home composting adoption is associated with practical, informational, and social factors, whereas the general pro-environmental behavior score was not statistically associated with adoption. This pattern is broadly consistent with studies suggesting that sustainable-practice adoption in rural areas depends on context-specific opportunities and constraints. However, the present analysis does not directly test a complete livelihood-capital framework (Pham et al., 2021; Nguyen et al., 2024).

The positive associations observed for the composting-attitude and social-influence scores are broadly consistent with TPB-informed expectations. However, the study does not test the complete TPB model because behavioral intention and perceived behavioral control were not directly measured. However, the pattern of associations differs from some findings reported in urban settings, although cross-study comparisons should be interpreted cautiously because the studies use different populations, measurements, and analytical specifications. First, exposure to composting training or structured information showed the largest estimated odds ratio among the included predictors. This association suggests that access to technical information may be an important enabling condition for adoption, but it should not be interpreted as direct evidence of perceived behavioral control. This finding is broadly consistent with studies reporting

positive relationships between technical information, training participation, and sustainable-practice adoption in developing-country contexts (Loan et al., 2019; De Boni et al., 2022), where limited access to extension services constrains the uptake of environmentally beneficial practices.

Within the variables included in the model, training or information exposure was strongly associated with adoption. Its relative importance compared with infrastructure, labor, space, and material availability remains to be tested. By providing knowledge, practical skills, and social support, these interventions directly address barriers such as lack of awareness, perceived effort, and limited peer influence. Integrating composting into agricultural training programs further enhances adoption potential by embedding composting practices within existing learning frameworks, reinforcing knowledge through hands-on experience, and linking them to tangible agricultural benefits, thereby increasing motivation and likelihood of sustained practice. Second, the social-influence score was positively associated with adoption, indicating that advice from friends and family may be relevant to household composting decisions. One possible explanation is that interpersonal networks play an important role in circulating practical information in rural communities. However, network density, kinship structures, farmer-union influence, and ethnic-community practices were not directly tested. This finding extends Edgerton et al.'s (2009) earlier work by demonstrating that social influence may outweigh individual attitudes in collectivist rural contexts. The finding is compatible with the broader proposition that interpersonal networks may facilitate information exchange, although the study did not directly measure social capital (Nguyen et al., 2024). Third, the positive effect of gardening factor score reflects practical composting behavior orientation. A plausible explanation is that gardening households have an immediate use for compost and more frequent contact with soil-management activities, although this mechanism was not directly tested. The finding may indicate that the agricultural usefulness of compost is relevant to adoption, but it does not establish that production motives are more important than waste-management motives. Similar patterns have been observed in smallholder systems in Southeast Asia, where farmers prioritize technologies with immediate agronomic returns (Pham et al., 2021).

One of the most notable findings of this study is the lack of a significant relationship between general pro-environmental behavior and home composting participation. Although earlier studies in urban contexts have reported mixed evidence (Lansana, 1993; Schultz & Oskamp, 1996; Edgerton et al., 2009), this result is particularly meaningful in the setting of rural developing countries. The result may indicate that participation in general environmental activities does not necessarily correspond to composting adoption. It may also reflect limited contextual validity of the recycling and recycled-product items used in the scale. Behavioral choices in resource-constrained environments are primarily guided by tangible benefits, feasibility, and risk considerations rather than broad environmental values. This finding is consistent with previous studies (Foguesatto et al., 2019; Rizzo et al., 2024; Diana et al., 2024), which similarly report that environmental concern alone does not necessarily translate into the adoption of sustainable agricultural practices, it is different from the finding of Kunszabó et al. (2022). The result instead highlights the importance of distinguishing general environmental behavior from behavior-specific TPB constructs.

The study offers several contextual and empirical contributions. First, it shows that attitude- and social-influence-related variables are associated with actual composting adoption in a rural smallholder setting, while also demonstrating the limitations of applying a TPB label when intention and perceived behavioral control are not directly measured. Second, it identifies training or information exposure and social influence as potentially relevant correlates of adoption, providing hypotheses for future TPB-informed and livelihood-oriented research. Third, it provides context-specific evidence from smallholder households in a mountainous district of northern Vietnam, where composting adoption remains insufficiently studied.

The novelty of this study lies in its focus on smallholder farmers in a mountainous region of a developing country, its integration of psychological and socio-economic determinants, and its explicit comparison with findings from urban and high-income contexts. Unlike most existing studies that emphasize municipal waste management, this study positions household-level home composting as a potential component of sustainable agriculture and circular nutrient management.

From a practical perspective, the findings suggest several actionable insights for promoting participation in home composting in northern Vietnam. Interventions promoting home composting should prioritize knowledge-based and community-driven approaches over generic environmental awareness campaigns. Agricultural-extension programs could combine technical instruction with on-farm demonstrations to strengthen practical capability, but their effects on perceived control and adoption require direct evaluation. Moreover, efforts to increase composting knowledge, such as training sessions or informational materials, are likely to have the most substantial association on participation rates. Additionally, farmer unions, local leaders, and peer-learning groups could be evaluated as delivery channels for composting information, particularly because interpersonal advice was associated with adoption. Framing composting as a solution for soil fertility improvement, cost reduction, and fertilizer substitution is likely to resonate more strongly with smallholder farmers than framing it solely as an environmental action. This approach aligns composting promotion with farmers' production objectives, increasing the likelihood of sustained adoption.

4. Conclusion

This study examined factors associated with household adoption of home composting among smallholder farmers in selected communes of Vo Nhai District, Thai Nguyen province, Vietnam, contributing to the growing body of literature on sustainable agriculture and waste management practices. The results showed that the composting-attitude and social-influence scores, together with exposure to composting training or information were positively associated with adoption, while the gardening factor showed only marginal evidence of an association. The findings indicate that training or information exposure and interpersonal social influence are relevant correlates of home composting participation. Interestingly, the gardening factor showed a positive but marginal association with adoption, whereas the pro-environmental behavior score was not statistically associated with participation in the estimated model.

This pattern suggests that behavior-specific practical and interpersonal factors may be more directly related to composting adoption than the general environmental activities measured in this study. From a practical perspective, the results identify technical information and interpersonal communication as relevant targets for future composting interventions. Agricultural training, community-based information exchange, and messages linking composting to farmers' production needs should be evaluated as potential strategies for increasing adoption. Future longitudinal research should examine whether the observed associations persist over time and whether training or community-based interventions produce sustained adoption in other rural settings. Moreover, the analysis did not directly assess socio-cultural mechanisms such as mutual-help traditions, farmer-union influence, or community leadership, and the cross-sectional design prevents causal interpretation. Qualitative and mixed-method studies could clarify how household decision-making, local norms, institutional support, and practical resource constraints influence composting adoption.

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Author Contribution

Conceptualization, B.H.V. and H.V.T.; Methodology, B.H.V. and H.V.T.; Software, B.H.V.; Validation, B.H.V. and H.V.T.; Formal Analysis, B.H.V.; Investigation, B.H.V. and X.H.L.; Resources, B.H.V.; Data Curation, B.H.V.; Writing-Original Draft Preparation, B.H.V.; Writing – Review & Editing, B.H.V. and H.V.T.; Visualization, B.H.V. and X.H.L.; Supervision, B.H.V. All authors have read and approved the final manuscript.

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Ethical Clearance Number

Not applicable.

Informed Consent Statement

All participants were informed about the purpose of the study, voluntary nature of their participation, and their right to withdraw at any time.

Data Availability Statement

The dataset generated and analyzed during the current study are not publicly available due to a part of ongoing project but are available from the corresponding author on reasonable request.

Conflicts of Interest

No potential conflict of interest was reported by the authors.

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