Heliyon 10 (2024) e28576

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Farmers' perceptions of sustainable agriculture in the Red River Delta, Vietnam

Quang Anh Phung *, Nga Dao

Department of Social Science, York University, Toronto, ON, M3J1P3, Canada

ARTICLE INFO

Keywords:
Sustainable agriculture
Gender
Age
Red River Delta
Vietnam
Theory of planned behavior

ABSTRACT

While economic growth and food security in Vietnam's Red River Delta are heavily reliant on agriculture, the intensive use of agricultural land has resulted in various negative impacts on the environment, such as soil degradation, water pollution, biodiversity loss, and health effects on humans and animals. The current situation emphasizes an increased need for sustainable agriculture practices in the region. Understanding farmers' decision-making processes and identifying factors that influence their choices is crucial in order to promote their adoption of sustainable agriculture practices. This study examines the impact of attitudes, subjective norms, perceived behavioral control, age, and gender on farmers' intention to adopt sustainable agriculture practices using the Theory of Planned Behavior and Partial Least Squares Structural Equation Modeling. The results show that attitude towards sustainable agriculture practices showed a path coefficient of 0.310 ($p < 0.001$), and perceived behavioral control had a coefficient of 0.305 ($p < 0.001$), indicating strong positive relationships with intention. However, subjective norms, despite a positive coefficient, did not significantly affect intentions (path coefficient 0.099, $p > 0.05$). Age was found to have a moderating effect; older farmers are less likely to adopt sustainable agriculture practices compared to their younger counterparts. Gender, however, did not present a significant influence. In light of these findings, policymakers face a challenge in creating incentives to encourage farmers' engagement in sustainable agriculture practices in the Red River Delta and at the same time discourage youth out-migration from the agricultural sector more generally. Overall, this study enriches our theoretical understanding of the factors influencing sustainable agriculture adoption in developing countries and offers practical insights for policymakers and agricultural stakeholders in the Red River Delta to promote more effective and targeted sustainable agriculture practices.

1. Introduction

Agriculture plays a vital role in Vietnam's economic development and food security as it is the main source of national income and employs about 40% of the labor force [1,2]. The Red River Delta (RRD) in Vietnam has dense networks of rivers, canals, ditches, dikes, sluice gates, and compartmented fields, which produce 18% of the country's rice, 26% of its vegetables, and 20% of captured and farmed aquaculture [3]. The RRD is particularly susceptible to climate change, largely due to its low elevation, dense population, and dependence on agriculture and natural resources [4,5]. In line with global trends, the RRD is confronting shifts in weather patterns,

* Corresponding author. 5011 Carrieridge Dr, Columbia, MO, 65203, USA.
E-mail address: qap8r8@umsystem.edu (Q.A. Phung).

https://doi.org/10.1016/j.heliyon.2024.e28576
Received 2 November 2023; Received in revised form 2 February 2024; Accepted 20 March 2024
Available online 27 March 2024

extreme weather events, and rising sea levels [2,4,6]. These changes threaten the region's water supply, which is vital for irrigation, by disrupting rainfall patterns and increasing the occurrence of droughts and floods [7,8]. Further, these climatic variations have directly harmed agriculture by degrading soil quality, impairing crop health, and heightening salinization risks in coastal farming zones [9–11]. For example, a majority of the literature focusing on the impact of climate change on rice production in Vietnam concludes that climate change will result in a substantial decrease in rice yield by 2050, though the extent of this reduction varies significantly depending on the specific rice crop season and geographical area [12].

Given the agricultural sector's crucial role in the region, implementing sustainable practices will not only have an impact locally, but also on a national and even global level [13,14]. The primary objective of sustainable agricultural policies (SAP) is to ensure that environmental sustainability is achieved while either improving or maintaining agricultural productivity levels [15,16]. In 2012, Vietnam's Prime Minister approved the Vietnam Sustainable Development Strategy for 2011–2020, which aimed to actively and effectively respond to climate change [17]. The National Sustainable Agriculture and Rural Development Strategy 2021–2030, vision to 2050,[1] has two main objectives: building a commodity-producing agricultural sector while developing specific agriculture plans based on local advantages, with high productivity, quality, efficiency, and sustainability. By 2030, the prime minister's aim is to make strides toward sustainable agriculture to ensure adaptability and resilience to changes and reduce rural environmental pollution in order to meet the Strategy's objectives.

The implementation of SAP can bring farmers multiple benefits, including improved crop yields and household income, enhanced food security, and reduced input costs incurred from the restricted use of chemical fertilizers, pesticides, and herbicides [14,18–20]. SAP also bring benefits to consumers and other stakeholders with the reduction of food contamination due to the minimization of harmful synthetic inputs, the efficient use of natural resources, and the improvement of the ecological system [14,21,22]. Despite the proven benefits in various regions around the world, SAPs' adoption rates remain low across Vietnam [14]. Various and complicated factors influence a farmer's decision to adopt SAP: resource endowments, socioeconomic status, demographic characteristics, and access to institutional services [14,23,24]. In addition, not everyone has the capability to properly adopt SAP to improve their food security and income due to various reasons such as limitations in access to and control over resources or social and cultural factors [25]. Women and older farmers can be affected by constraints that would limit their capacity to adopt new agricultural technologies [26,27]. For example, research found that the generally high age and low education level of rural farmers, with most respondents aged between 40 and 60 years old and approximately 69.8% having received an education up to junior school (up to the ninth grade in a 12-grade system), contribute to poor learning abilities regarding green agricultural production technology and acquiring new knowledge in general [27]. In particular, women small farm holders' adoption of conservation agricultural practices is hindered by various constraints, including limited access to credit and extension services, restricted membership in farmers' cooperatives, lack of access or rights to land, inadequate skill training opportunities, insufficient access to information such as the selection and proper use of herbicides and pesticides or information about improved seeds, and constrained mobility [28]. Another crucial factor is farmers' perceptions of SAPs' characteristics; multiple studies point out that farmers' perceptions of social pressure and their ability to engage in sustainable agriculture shape their intention (or lack of) to adopt SAP [29,30]. Therefore, determining farmers' intention and capacity to adopt SAP are necessary for the government to develop policies that promote large-scale SAPs' implementation.

In this study, we draw on the Theory of Planned Behavior (TPB) to investigate farmers' intention to implement SAP. Researchers have utilized the TPB to interpret farmers' environmental decision-making across various socioeconomic and geographic contexts [29, 31–33]. The TPB proposes that the likelihood of an individual adopting a new behavior is determined by their attitude towards the behavior, the social norms surrounding it, and their perceived behavioral control. The theory also suggests that an individual's intention to adopt the behavior is also a key predictor [34]. For example, researchers employed a psycho-behavioral approach, including the TPB, when investigating the determinants affecting farmers' inclination to embrace Geographical Indication (GI) practices within the Indonesian coffee industry. They found that attitude, perceived behavioral control, and perceived economic benefits play a crucial role in influencing the readiness to adopt GI practices [35]. Furthermore, the TPB is flexible, allowing for the incorporation of extra predictors, provided that they demonstrate a substantial contribution to the variance in behavior or intention after accounting for the theory's current variables [34]. Gender, age, and TPB constructs may interact to explain the intention or lack thereof to adopt SAP. The impact of gender and age on individual perceptions, attitudes, and performance is widely recognized, making it crucial to study their role in shaping attitudes in various domains (i.e., computer and information technologies, consumer intention) [36–38]. For example, younger consumers generally exhibit a more positive attitude towards adopting technology compared to older consumers [38]. Additionally, gender emerges as a distinct characteristic influencing individuals' readiness to adopt new technology, with findings indicating that men are often more adept at advanced computer skills when compared to women. These differences with regard to TPB constructs could also help to clarify the reasons for variations in SAPs' adoption among different groups in the RRD. In addition, gender and/or age may influence the link between TPB constructs and SAPs' implementation. For example, gender and age have been found to be moderating effects on the relationships between TPB constructs in a pro-environment context (i.e., green restaurant patronage) [39].

Although several studies have utilized the TPB to investigate the influence of attitude, subjective norms, and perceived behavioral control on an individual's intention to adopt pro-environmental practices in agriculture [29,40,41], the majority of this research has overlooked the potential moderate effects of gender and age. Thus, this study aims to identify farmers' intention toward SAP by relying on an extension of the TPB with two additional moderators: gender and age.

[1] Decision No. 150/QD-TTg, dated 28 January 2022.

Overall, the main issue driving this research is the notably low adoption rate of sustainable agriculture practices in Vietnam's Red River Delta [3]. Despite the clear environmental and economic benefits of these practices, there is a critical knowledge gap regarding the specific factors influencing farmers' decisions to adopt them. This study aims to bridge this gap by thoroughly analyzing the behavioral, demographic, and socio-economic elements that either facilitate or impede the adoption of SAP in this region. Such an understanding is essential for crafting effective strategies and policies that could bolster the adoption of sustainable practices in similar, low-income agricultural areas.

To achieve this, our overarching goal is to delve into the factors affecting the adoption of SAP in Vietnam, paying special attention to moderating influences. We aim to evaluate how farmers' attitudes, subjective norms, and perceived behavioral control, as outlined in the TPB, shape their intentions toward sustainable practices, while also considering the impact of demographic factors like age and gender. This comprehensive approach not only seeks to deepen our theoretical understanding of behavioral dynamics in sustainable agriculture but also to provide practical insights for policymakers and stakeholders. These insights are aimed at enhancing the promotion of sustainable agriculture practices in the region, guided by the interrelations among TPB constructs.

2. Materials and methods

2.1. Study region: the Red River Delta

The Red River Delta is situated in northern Vietnam and encompasses a flood plain area of 21,051 km^2 (Fig. 1). The majority of the soil found here is alluvial soil, with medium texture and a neutral pH, making it ideal for cultivating annual cash crops [42]. The RRD's population in 2019 was about 20.2 million people, an increase of 7.4% when compared with 2009 [43]. The same report also highlights the challenges of an aging population in the RRD, with the aging ratio in its rural areas—the percentage of those aged 60 and over compared to the population under age 15—being the highest in the country at 58%. Additionally, the report indicates a decreasing rural workforce in the RRD due to out-migration. Specifically, between 2009 and 2019, there was a significant migration of around 400,000 individuals from rural to urban areas within the region, ranking the RRD as the second highest in the nation for population migration. In Vietnam's labor force, there had been a pronounced aging trend in the agricultural sector with a 20% decline in the proportion of workers under age 50 from 2007 to 2016 [44].

In the context of extensive male out-migration in rural Vietnam, women, especially in the RRD, continue to constitute the main work force in agricultural production in general, and rice production in particular, due to the social norm that considers rice farming as women's responsibility [44,45]. From 2007 to 2016, women constituted approximately 53–54% of the agricultural labor force in Vietnam and were the key source of labor in rice production [44,45]. If women work in factories near their village and can return home daily, they still actively engage in farming outside of their waged work responsibilities [45]. Even if women migrate to work in other

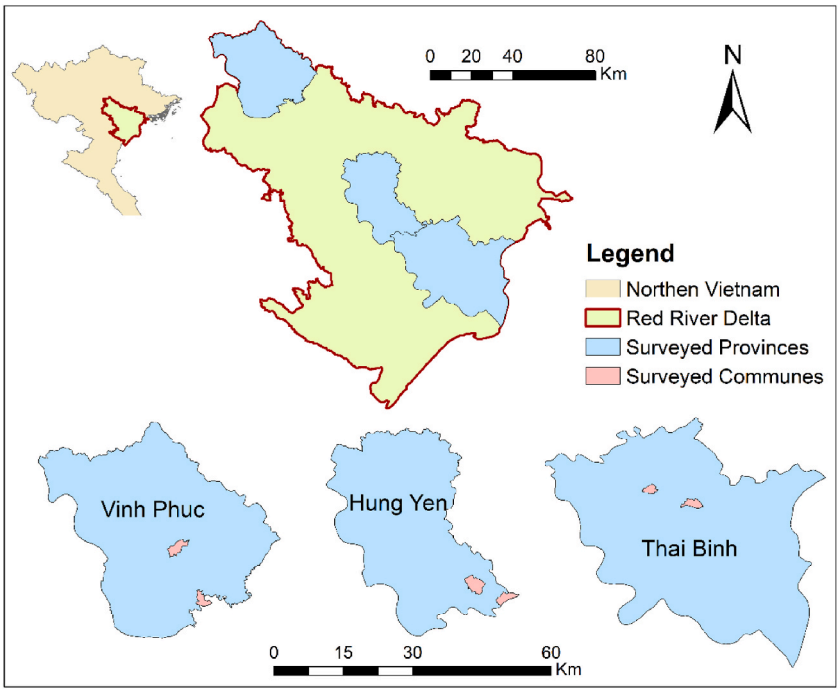

Fig. 1. The Red River Delta region and the location of the communes that are home to the farmers who participated in this study. The national and provincial boundaries are drawn from The Humanitarian Data Exchange Database (https://data.humdata.org/dataset/cod-ab-vnm, accessed June 10, 2023).

provinces, they continue to contribute to their household's agricultural activities by returning home for important periods in the crop cycle such as transplanting rice seedlings and harvesting.

The climate of the RRD is classified as tropical monsoon, which is comprised of a dry season from November to April and a wet season from May to October [46]. The RRD's annual average temperature is 23.5 °C and annual average rainfall is 1667 mm [3]. About five to six typhoons make landfall along Vietnam's coast annually and the majority of them impact central and northern Vietnam [47]. The precipitation from these events can result in significant flood damage in the RRD lowlands [48]. The crop year is divided into three seasons: summer (June to October), winter (October to January), and spring (February to June) [49]. Due to the region's climate conditions, diseases and pests are present year-round. The hot and wet season with its frequent rainfall can exacerbate their spread by extending the period of time in which leaves remain wet. The hotter weather also has a direct impact on pests' reproduction, survival, spread, and population dynamics [42,50].

In the RRD, crop production has its foundation in small-scale farms where the average size of an agriculture plot is about 400 m^2. The majority of respondents' farms in this study are small-scale family farms, with 96% of them farming an area of less than 0.5 ha. While small-scale farming can have some advantages, such as lower investment and greater flexibility, the scale of the operation leads to several disadvantages. The implementation of new technologies is limited on these farms due to the lack of resources and capacities. In many cases, small-scale farmers are forced to sell their produce to middlemen who dictate the prices.

2.2. Study sites and data collection

This study is based on data from a structured survey of famers' perceptions of sustainable agriculture. The data that we employ in the study were collected during a comprehensive survey in six communes within three RRD provinces: Hung Yen, Thai Binh, and Vinh Phuc. Each province in this study has its own unique characteristics and represents a different ecosystem within the RRD. Hung Yen, located in the center of the region, is characterized by its relatively flat topography [51]. According to Hung Yen province's report on its economic and social situation in the first five months of 2021, the agricultural sector accounts for 7.5% of the overall economic structure [52]. Out of a total annual cultivated land area of 34,845 ha in Hung Yen province, 28,056 ha are dedicated to rice cultivation, accounting for 80.5% of the overall land area. Additionally, the current area of perennial plants amounts to 15,502 ha, which corresponds to 44.5% of the annual crop area. However, there is a noteworthy trend occurring in the province as there is a shift away from annual crops towards the cultivation of fruit trees. Thai Binh, situated in the northeast of the RRD, is a coastal province with low plains, flat topography, and is known for its extensive network of rivers, canals, and wetlands [53,54]. For 2019, Thai Binh province reported record contributions from its agricultural sector to its provincial Gross Domestic Product (GDP), surpassing the RRD's nine other provinces, with rice cultivation accounting for 58% of the total crop production value [55]. Vinh Phuc is located in the northwest of the RRD. The province has a mix of agricultural land, forested areas, and hilly terrain with the altitude gradually decreasing from the northeast to the southwest, showcasing three distinctive regions with characteristic topography: plains, hills, and low to medium-altitude mountains [56]. Accounting for 74.8% of the total land area, the province's agricultural land area reached 92,823 ha in 2017 [57]. In each province, we selected two communes in which to conduct interviews with farmers (Fig. 1). This selection was based on their agriculture production, percentage of the population working as farmers as well as recommendations from provincial government officials. The study involved face-to-face interviews with 50 farmers in each commune, resulting in 300 farmers being surveyed. We selected the type of farms and respondents to be surveyed through random sampling from each of the commune's village lists. The research team designed the questionnaire to collect relevant basic information for the study, including the respondents' demographic information and questions to capture farmers' perceptions, attitudes, and intentions that range from strongly disagree (1) to strongly agree (5). The survey form can be found in the Supplementary Material. To ensure participants' anonymity, they were informed that all individual responses provided as part of the questionnaire would remain confidential. Participation in the survey was voluntary.

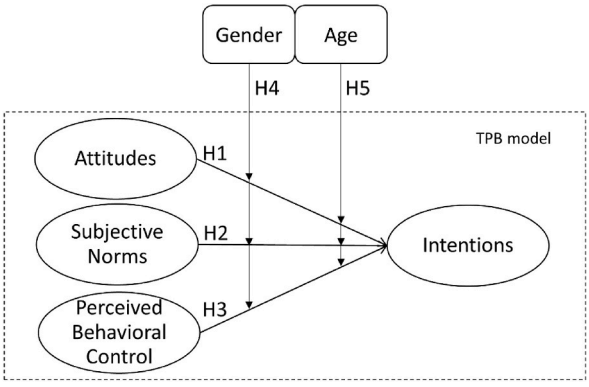

Fig. 2. Hypothetical relationships of the extended TPB model in exploring the intention to adopt sustainable agriculture used in this study and based on our data.

2.3. Theory of planned behavior

The Theory of Planned Behavior (TPB) is a highly influential and widely used conceptual framework for studying human behavior [58,59]. In 1985, Icek Ajzen first introduced the TPB to suggest that people's intention towards a particular behavior is influenced by their beliefs about the factors that enable or impede the behavior's performance, which could be based on their past experiences or their observation of others performing the behavior [60]. According to the TPB, the behavior intention is determined by three key factors: attitude, subjective norm, and perceived behavioral control (Fig. 2) [32,34]. In this study, the behavioral intention can be defined as the farmers' intention to adopt SAP such as intercropping, applying best management practices, and reducing chemical inputs. Attitude can be understood as the farmers' personal evaluation of sustainable farming. Subjective norm can be defined as farmers' perception of their social circle's views on sustainable agriculture. Finally, perceived behavior control can be referred to as the farmers' perceived ability to adopt sustainable agricultural practices.

Researchers have recently conducted studies to identify various factors affecting farmers' intention to practice sustainable agriculture globally [29,40,61]. A study on coffee farmers' intention to adopt sustainable agriculture in the context of climate change using the TPB in Vietnam extends the TPB to include climate change perception and farmers' past behavior and found that social norm, perceived behavioral control, and climate change perception significantly influenced the farmers' behavioral determinants [29]. The TPB was applied to study farmers' intention to use green pesticides in Iran, where researchers examined the inclusion of self-identity and moral norm in the TPB framework; the final analysis revealed that attitude, moral norm, and self-identity have a significant impact on intention [62]. Another study examined Bangladesh farmers' intention towards conservation agriculture by using the extended TPB, which includes perceived threat of conventional farming and knowledge [40]. This study found that all independent variables significantly impact farmers' intention to adopt conservation agriculture. Despite previous studies' valuable contributions, there remains a research gap in our understanding of the moderating effects of category variables (i.e., gender and age) within TPB-based studies on sustainable agriculture. Therefore, further research is needed to explore these areas and enhance our knowledge of the factors that influence individuals' decision-making processes and behaviors in relation to supporting environmentally friendly agriculture practices.

This study examines the moderating effects of gender and age. A moderator variable is defined as a factor that systematically alters the form and/or strength of the relationship between a predictor variable and a criterion variable [63]. In the context of this study, a moderator variable is a factor that influences or alters the strength and direction of the relationship between the predictor variables (attitude, subjective norm, perceived behavioral control) and the intention to engage in SAP. The moderator helps us to understand how and under what conditions the relationships between the predictor variables and the intention might differ.

2.4. Hypotheses development

Based on the TPB framework, we propose the following hypotheses to investigate the factors influencing the adoption of Sustainable Agriculture Practices (SAP) in the Red River Delta (Fig. 2):

- **Hypothesis 1 (H1):** There is a positive relationship between farmers' attitude towards sustainable agriculture and their intention to adopt SAP.
- **Hypothesis 2 (H2):** Subjective norms are directly and positively associated with farmers' intention to adopt SAP.
- **Hypothesis 3 (H3):** There is a positive relationship between perceived behavioral control and farmers' intention to adopt SAP.
- **Hypothesis 4 (H4):** Individuals' age has a moderating effect on the relationship between the intention to adopt SAP and its direct predictors.
- **Hypothesis 5 (H5):** Gender has a moderating effect on the relationship between the intention to adopt SAP and its direct predictors.

These hypotheses are grounded in the TPB model's core constructs and are further expanded by including demographic factors such as age and gender, which we hypothesize to have moderating effects on the adoption of SAP.

2.5. Analytical framework

There are various methods to test interaction or moderation effects for the TPB model [64–66]. One commonly employed approach is multiple linear regression, which is a widely employed statistical method in the field of behavioral sciences. The technique enables the measurement of linear associations between multiple independent variables and a single dependent variable [67,68]. By utilizing this technique, it becomes possible to assess the unique contributions of each independent variable to the dependent variable as well as determine the overall variance in the dependent variable that can be attributed to the combined effect of the independent variables.

In addition to multiple linear regression technique, researchers have increasingly advocated for the use of structural equation models when studying the TPB model and potential moderators [64,66,69]. Structural Equation Modeling (SEM) can be viewed as an extension of multiple regression and encompasses a collection of statistical techniques [64,69,70]. While multiple regression focuses on examining relationships between independent variables and a single dependent variable, SEM expands the analysis by allowing for the investigation of complex relationships among multiple variables simultaneously. SEM also offers a more comprehensive modeling approach when compared with multiple regression modeling. Researchers can specify a model that examines the influence of multiple variables on multiple other variables. This means that the entire TPB can be assessed in relation to a dataset within a single analysis,

eliminating the need for separate analyses [64,69,70]. In addition, SEM offers the advantage of providing statistical significance tests for the hypothesized relationships within the model. This allows researchers to assess the strength and significance of the relationships between variables. Furthermore, SEM provides valuable insights into the overall fit of the model, indicating how well the proposed model aligns with the observed data [64,69].

Given the non-normality issues addressed in this study, we chose Partial Least Squares Structural Equation Modeling (PLS-SEM) as the primary analysis technique for estimating the parameters of the TPB model. PLS-SEM is a variance-based approach utilized for estimating structural equation models that simultaneously estimates the associations between observed variables and their corresponding measurement indicators (measurement model) as well as the interrelationships among unobserved latent variables (structural model) [31]. In PLS-SEM, the Ordinary Least Squares (OLS) estimation method based on regression is utilized to explain the variance of latent constructs. The aim is to minimize the error terms and maximize the R2 values of the endogenous constructs that are being targeted. Furthermore, PLS-SEM imposes fewer restrictions to the assumptions and requirements, such as those related to large sample sizes and data normality, yet still maintains robustness in estimations [32].

In this study, the latent variables include attitude, subjective norm, perceived behavioral control, intention, gender, and age. We created the model of this study using SmartPLS software [71], and followed a two-stage approach to analyze and interpret the PLS-SEM model [31]. The first step of the approach involves evaluating the reliability and validity of the collected data as well as the structural model that depicts the relationships between constructs. The second step was to evaluate the relationships among the variables. When examining the moderating effects using PLS-SEM, a multi-group approach can be used to investigate potential variations in parameter values across categorical variables [69]. This approach allows for the exploration of potential variations in these parameters, such as the intention-behavior relationship across different groups, and categories based on gender or age. If the parameters demonstrate significant differences across groups, it indicates that the categorical variable acts as a moderator, influencing the relationship between predictor variables (attitude, subjective norm, perceived behavioral control) and the intention. In this study, gender is categorized into male and female, while age is divided into two groups including older respondents (>51 years old) and younger respondents (<51 years old). The split at 51 years old is due to the lack of younger respondents. The option of group division containing both gender and age was not an option due to a limitation in the data.

To evaluate the internal consistency and construct reliability of the model variables, multiple indicators including reliability, internal consistency, convergent validity, and discriminant validity need to be calculated [62]. The reliability can be measured by the factor loadings, which are used to measure the strength of the relationship between the observed variables and the underlying construct they are intended to measure [72]. The factor loading needs to be more than 0.5 to be considered acceptable, but a value greater than 0.7 is preferred [73]. Cronbach's alpha (>0.7) is a widely used measure for evaluating the internal consistency of indicators that measure a specific construct [73,74]. Composite reliability is another statistical measure used to assess internal consistency, which can be estimated using the rho_a coefficient [75]. A value of rho_a greater than 0.7 indicates the model's composite reliability. The average variance extracted (AVE) can be used to assess the convergent and discriminant validity of the measurement models. The AVE value needs to surpass 0.50 to achieve convergent validity [72,73]. The extent to which a construct is distinct from other constructs is referred to as discriminant validity, for which we employed the Heterotrait-Monotrait (HTMT) ratio [76]. The next step was to test the hypothesized relationships from the structure models. We employed bootstrapping techniques with 5000 resamples to obtain two-tailed t-tests of significance at 5% to test the statistic significant of the structure model's relationships [31].

Table 1
Sample profiles of respondents.

Item		Value		Percentage	
		Man	Woman	Man	Woman
Gender		70	230	23.3	76.7
Age Group	=<40	5	9	7.1	3.9
	41–50	12	25	17.1	10.9
	51–60	21	105	30.0	45.7
	61–70	27	76	38.6	33.0
	>70	5	15	7.1	6.5
Education	None	0	8	0.0	3.5
	Primary school	0	7	0.0	3.0
	Secondary school	35	119	50.0	51.7
	High school	34	93	48.6	40.4
	Vocational degree	1	3	1.4	1.3
Years of Agriculture Experience	<20	2	4	2.9	1.7
	20–29	1	8	1.4	3.5
	30–39	29	71	41.4	30.9
	≥40	38	147	54.3	63.9
Item		Value		Percentage	
Household size	1–2	143		47.7	
	3–4	99		33.0	
	5–6	48		16.0	
	≥7	10		3.3	

3. Results

3.1. Demographics

The socio-demographic characteristics of the respondents (n = 300) can be found in Table 1. There were more female respondents (n = 230) when compared with male respondents (n = 70). This result reflects the gender dynamics of the agricultural workforce, with the sector's increasing feminization in the RRD [77,78]. Respondents' ages revealed another trend in the sector with the majority of respondents between 50 and 69 years of age. As most farmers have worked in their family's fields since a young age, more than 95% have more than 30 years of farming experience. For both men and women, almost everyone completed their secondary education and about half of respondents attended high school. Less than 2% have a vocational degree, and no one has a bachelor's or a higher education degree. Almost half of the respondents indicated that their household has only 1–2 people. Some households with 3–4 people include the grandparents who take care of their grandchildren while the parents out-migrate to cities in the RRD and across Vietnam for better employment opportunities.

3.2. Measurement models analysis

Table 2 shows the descriptive statistics of the TPB items that include the mean, standard deviation, and factor loading of all of the latent variables. Among the factors that impact intention, according to the TPB, perceived behavioral control mean values are lower compared with the attitudes and subjective norms towards sustainable agriculture. This result indicates that even though the farmers are aware of the importance of sustainable agriculture, they are less certain about their capacity to adopt sustainable agriculture practices. The intention towards sustainable agriculture has the mean values of 3.79 and 3.40, which are the lowest among the four basic TPB constructs, suggesting that farmers will lean towards practicing sustainable agriculture in the future, but hesitancies remain. All of the factor loadings are greater than the acceptable threshold, ranging from 0.88 to 0.98, suggesting good contributions of the items to the TPB model. Age and gender have the loading of 1 as they are defined by just one indicator each.

Table 3 reports on the construct reliability and its validity. Cronbach's alpha values of all variables are greater than 0.7 with the lowest value of 0.822 (intention) and the highest value of 0.971 (attitude). These values indicate the high reliability of the model's variables. The rho_a of all of the constructs greater than 0.7 implies that the model has good composite reliability. In terms of convergent validity, the Average Variance Extracted (AVE) values need to exceed 0.5. Based on the results shown in Table 3, the AVE values were greater than 0.50, providing evidence that the study's convergent validity is acceptable. The discriminant validity of HTMT ratios of correlations (Table 4) were below 0.85, suggesting that the measurement models have high discriminant validity. This indicates that the variables we examined in the study are sufficiently distinct, ensuring that each model captures unique constructs, thereby upholding the integrity and specificity of the study's measurements.

3.3. Hypothesis testing

Table 5 reports the hypothesis testing for the model. The table shows the path coefficient, T statistics, and P values of all variables in the model, revealing their effect on sustainable agriculture. The path coefficient reflects the positive or negative relationships between two latent variables or between a latent variable and its observed indicators. On the other hand, the T statistic and P value are used to

Table 2
Descriptive statistics of the items used for TPB and factor loadings.

Items	Mean	Standard deviation	Loadings
Attitude towards sustainable agriculture			
Practicing sustainable agriculture on your farm within the next five years would be a good idea	4.09	0.56	0.96
Practicing sustainable agriculture on your farm within the next five years would be possible	4.06	0.56	0.98
Practicing sustainable agriculture on your farm within the next five years would be more profitable than conventional farming	4.09	0.58	0.97
Subjective norm towards sustainable agriculture			
Your family favors the idea that you should practice sustainable agriculture on your farm within the next five years	4.09	0.54	0.98
In general, people whose opinion is important to you approve of you practicing sustainable agriculture on your farm within the next five years	4.05	0.55	0.98
Perceived behavioral control towards sustainable agriculture			
You think that you have the technical ability to practice sustainable agriculture on your farm within the next five years	3.87	0.73	0.90
You think that you are capable of dealing with sustainable farming on your farm within the next five years	3.86	0.71	0.95
You think that you can meet the regulations of sustainable farming on your farm within the next five years	3.96	0.64	0.88
You think that you can afford the costs of conversion to sustainable farming on your farm within the next five years	3.88	0.72	0.94
You think that you can meet the amount of work needed for sustainable farming on your farm within the next five years	3.92	0.70	0.91
Age	58.49	9.17	1.00
Gender	1.77	0.42	1.00
Intention towards sustainable agriculture			
How likely is it that you will practice sustainable agriculture on your farm in the near future?	3.79	0.90	0.93
Do you intend to practice sustainable agriculture on your farm within the next five years?	3.40	1.24	0.91

Table 3
Construct reliability and validity.

	Cronbach's alpha	Composite reliability (rho_a)	Average variance extracted (AVE)
Attitude	0.971	0.973	0.945
Subjective norm	0.952	0.952	0.954
Perceived behavior control	0.952	0.954	0.840
Intention	0.822	0.830	0.848

Table 4
Discriminant validity—Heterotrait-monotrait ratio.

	Attitude	Subjective norm	Perceived behavior control	Intention
Attitude				
Subjective norm	0.813			
Perceived behavior control	0.622	0.628		
Intention	0.636	0.591	0.619	

Table 5
Hypothesis testing.

	Hypothesis	Path Coefficient	T value	P value
Attitude -> Intention	H1	0.310	3.241	0.001
Subjective norm -> Intention	H2	0.099	1.034	0.301
Perceived behavioral control -> Intention	H3	0.305	5.911	0.000

assess the statistical significance of the relationships between behavioral intentions and the three latent variables. If the T value is greater than a critical value (i.e., 1.96 for a two-tailed test at a 5% level of significance), the relationship is considered statistically significant [79]. The results in Table 5 show the positive coefficients for all of the TPB's variables, which indicate that there is a direct relationship between the farmers' attitude, subjective norm, and perceived behavioral control as well as their intention to practice sustainable agriculture. In other words, the higher the level of attitude, subjective norm, and perceived behavioral control a farmer has, the greater their intention to adopt sustainable agriculture. However, among the three latent variables, attitude and perceived behavioral control have a statistically significant relationship with the intention, while the relationship between subjective norm and intention is not statistically significant. This means that social pressure or influence that individual farmers perceive from their social environment, such as family, friends, peers, and neighbors, does not have a significant impact on their intention to practice sustainable agriculture. Furthermore, according to the R2 value, the constructs of all of the variables accounted for 39.7% of the variance in farmers' intention to adopt sustainable agriculture.

Overall, Hypotheses H1 and H3 are accepted, while H2 is rejected. Specifically, H1, suggesting a positive impact of farmers' attitudes on adopting sustainable agriculture, is supported. H3, relating to the positive influence of perceived behavioral control on adoption intentions, is also validated. However, our findings do not support H2, concerning the influence of subjective norms on these intentions.

The findings in Table 6 below show that gender does not have a significant moderating effect on the relationship between the three determinants and behavioral intention in the model. Therefore, hypothesis H5 should be rejected. The path coefficients between subjective norm and intention are the weakest when compared to other relationships for both males and females. These coefficients have values close to zero, indicating that the relationship between these two variables is weak and neutral. This result further supports hypothesis H2's rejection.

Meanwhile, Table 7 below shows that age has a significant moderating effect on the relationship between perceived behavioral control and intention ($T = 2.192$, $P = 0.032$). The path coefficient between perceived behavior control and intention in younger respondents is higher than with older respondents, indicating that the relationship becomes stronger for younger respondents. The path coefficient between subjective norm and intention in younger respondents is 0.417, while this value for older respondents is only 0.084, indicating that subjective norm likely does not affect older respondents' intention regarding the application of SAP. As a result,

Table 6
Results for the moderation of gender using the Welch-Satterthwaite Test.

	Male		Female		Male vs. Female		
	P1	STD1	P2	STD2	P1–P2	T value	P value
Attitude -> Intention	0.112	0.150	0.339	0.111	−0.228	1.227	0.223
Subjective norm -> Intention	0.026	0.195	0.111	0.109	−0.085	0.384	0.702
Perceived behavioral control -> Intention	0.337	0.142	0.313	0.051	0.024	0.157	0.875

Note: P1 and P2 are path coefficients for male and female, respectively. STD1 and STD2 are standard errors of P1 and P2, respectively.

Table 7
Results for moderation of age using the Welch-Satterthwaite Test.

	Younger		Older		Younger vs. Older		
	P1	STD1	P2	STD2	P1 – P2	T value	P value
Attitude -> Intention	−0.220	0.413	0.345	0.095	−0.565	1.345	0.184
Subjective norm -> Intention	0.417	0.415	0.084	0.105	0.333	0.785	0.436
Perceived behavioral control -> Intention	0.530	0.097	0.286	0.057	0.244	2.192	0.032

Note: P1 and P2 are path coefficients for younger and older, respectively. STD1 and STD2 are standard errors of P1 and P2, respectively.

the findings partially support hypothesis H5 regarding age's moderating effect on the relationships between intention and its three predictors.

4. Discussion

In brief, this study's findings provide evidence supporting the TPB's validity as a suitable model for predicting the likelihood of SAPs' implementation. Attitude and perceived behavior control relationships with intention were statistically significant. Notably, attitude was the most influential factor that impacted farmers' intention to adopt SAP. Although the relationship between subjective norm and intention was statistically insignificant, this finding is consistent with other related studies [33,80,81]. A meta-analysis study also showed that subjective norm-intention relationship is significantly weaker than attitude-intention and perceived behavioral control-intention relationships [82].

Furthermore, this study contributes to the limited body of research that investigates the moderating effects of gender and age on the relationships between TPB constructs within the context of SAP's implementation. Gender and age are fundamental demographic factors, and understanding their impacts on intention studies is crucial for developing theoretically robust research models. By investigating these moderating effects, this study provides valuable insights into the influences of gender and age on the relationships between TPB constructs in the SAP context, contributing to a more comprehensive understanding of behavioral intention in this domain.

Research shows that age tends to influence subjective norms while simultaneously impacting on intention [83]. For example, age has a significant impact on farmers' intention to rejuvenate idle homesteads [84]. This includes a notable moderating effect of age on the relationship between subjective norms and farmers' intentions, indicating that the influence of social pressures on their decision-making varies with age. Our study revealed that the farmers we interviewed, who were predominantly middle-aged or older, were less influenced by social pressure in their decision-making processes. This finding reinforces the significance of age differences in resistance to peer and social pressure. The consistency between our study and previous studies highlights the observed phenomenon's robustness and reliability. For example, peer pressure can have little impact on adults regarding risk-taking tasks [85]. When we asked farmers if they think about changing their current farming practices to sustainable practices, 72% (204/300) indicated that it is a risky transition. Farmers have become conscious of the ecological impacts of their agriculture management practices [86]. However, this awareness has not led to a significant willingness to modify their farming practices, due to the lack of incentives for compliance and disincentives for noncompliance with new regulations. Overall, our study contributes to the growing body of evidence supporting the understanding of how an individual's age influences their ability to withstand peer and social pressures.

Our study also reveals that age has a significant moderating impact on the relationship between farmers' perceived behavioral control and intention to practice sustainable agriculture. As the farmers age, they do not think that their health or energy permits a transition to sustainable agriculture. For example, over the past decade, technology and machinery have been introduced into various aspects of rice production, including planting, harvesting, fertilizer and pesticide application as well as transportation. Now less labor-intensive, minimum effort is required from farmers due to these innovations. Should farmers decide to practice sustainable agriculture, they will need to allocate more time and labor to their farms since their use of pesticides, herbicides, and chemical fertilizers would be limited. They may also have to plant other crops, i.e., vegetables or fruits, to make the practice economically viable.

Interestingly, this study found that gender does not impact farmers' intention regarding their adoption of sustainable agriculture. When asked about who in the household would make the decision to shift agricultural management practices, 60% (179/300) of the respondents indicated that it would be a joint decision between spouses. This result further demonstrates that gender does not significantly influence agriculture production decision-making in the household. Specifically, 80 out of 300 of our respondents said that women were the decision-makers in the household regarding agriculture production; 12 out of 300 respondents said men were the decision-makers. This reveals a trend in the agriculture sector's femininization in Vietnam as men tend to take temporary or permanent non-farm jobs, while women at home have greater involvement in agriculture work [87,88]. As women play an increasingly important role in this sector, their decision-making power also increases, leading to a shift towards more balanced gendered decision-making regarding farm work [87]. However, it is worth noting that while women now have more decision-making power in farm work, this added responsibility also places additional burden on them, as they remain responsible for the majority of household cares [78].

Overall, our research findings contribute to existing literature by addressing the gap concerning the moderating role of gender and age in explaining farmers' intention to adopt SAP. Unlike other studies that often focus on the moderating variables affecting single relationships, this study investigates the moderating effect of the whole model using multigroup analysis. Moreover, the study reveals significant differences between younger and older groups when considering perceived behavioral control's impact on intention. This highlights the need for future studies to address the moderating effects of age as well as the combination of age and gender when

investigating farmers' intentions toward changing management practices or products produced.

From a practical standpoint, the study offers recommendations for policymakers, manufacturers, marketers, and retailers in the agricultural sector. To encourage farmers to practice sustainable agriculture, policymakers should prioritize the TPB model's attitude and perceived behavioral control and then familiarize themselves with their specific underlying beliefs. Among these determinants, attitude emerges as the most significant factor influencing intention. When considering that many Vietnamese farmers lack comprehensive knowledge about sustainable agriculture and its products, manufacturers and retailers should engage in communication and knowledge sharing activities to educate farmers and familiarize them with sustainable agriculture concepts that can contribute to a change in farmers' attitudes and promote a better understanding and acceptance of sustainable agriculture. To improve farmers' perceived behavioral control, policymakers should consider amending or enacting laws and regulations in the agriculture industry, particularly in the sustainable and organic food segments. For example, policymakers could implement a comprehensive law specifically dedicated to sustainable farming, outlining the standards, certification processes, labeling requirements, and enforcement mechanisms. This law would provide a legal framework for the development, promotion, and regulation of sustainable agriculture in Vietnam. Our results reveal that age has significant moderating effect, suggesting that this variable should be considered when developing engagement strategies for sustainable agriculture. Younger participants are more influenced by perceived behavioral control in adopting SAP. Therefore, incentives to improve younger farmers' perceived behavioral control should be implemented. These incentives could also attract young people to return to the agricultural sector, reducing the burden of older farmers.

This study's comprehensive analysis has significantly illuminated the dynamics of SAPs' adoption in Vietnam's Red River Delta. By thoroughly exploring farmers' attitudes, societal norms, and perceived control, we have gained deep and multifaceted insights. This exploration has led to a substantial refinement of our conceptual framework, enhancing it to provide a richer, more detailed depiction of the factors influencing SAPs' adoption. This refined framework now intricately interweaves farmers' perspectives with broader socio-economic considerations, offering a holistic view of the agricultural decision-making landscape in this region.

Our findings shed light on the intricate web of internal motivations and external influences that guide sustainable agriculture decisions, highlighting the complex interplay between personal beliefs, community pressures, and practical realities. This nuanced understanding has significant theoretical implications, providing a leap forward in our comprehension of behavioral dynamics within sustainable agriculture. Practically, it translates into a valuable resource for policymakers and practitioners. These stakeholders can now draw upon a more informed basis for designing and implementing strategies that are sensitive to the unique needs and challenges faced by farmers in the Red River Delta.

Beyond its theoretical advancements, this research makes several key contributions to the field of sustainable agriculture, particularly within the context of developing regions. Through the application of the TPB in a distinct socio-economic and cultural context, this study broadens our comprehension of the factors influencing SAPs' adoption by combining behavioral, demographic, and socio-economic factors. These aspects, which have not been extensively explored in the context of Vietnamese agriculture, offer a glimpse into the important cultural and demographic factors that shape sustainable farming decisions. This study enhances the literature by providing a nuanced understanding of how cultural and demographic factors play a crucial role in the decision-making processes of sustainable farming.

Moreover, the practical implications of this study are far reaching. We provide actionable recommendations tailored to the unique context of the Red River Delta, thereby contributing to more effective and targeted strategies for promoting sustainable agriculture in similar low-income, agrarian regions grappling with the impacts of climate variability and environmental changes. Our study not only pushes the boundaries of understanding in the field of SAP but also offers a nuanced and detailed analysis of the factors influencing their adoption. This is especially critical for Vietnam, a key agricultural hub, where such insights can drive transformative change in sustainable agriculture practices.

5. Limitations of the study and implications for further research

One of our study's main limitations is the lack of younger participants. In Vietnam, the age of farmers is becoming an issue as more and more youth are leaving agriculture for better economic opportunities in non-farm, urban sectors. In rural households, the dependence on agricultural livelihoods has declined, with a significantly smaller proportion of workers employed in agriculture—from 48.4% in 2007 to 39.4% in 2016—while agriculture households were reduced from 83.5% in 1992 to 62.9% in 2016 [44]. As a result, our sample of farmers was mostly comprised of farmers aged 51 and older. However, sustainable agriculture's adoption is more likely among young farmers, highlighting the importance of studying young people' perspectives toward sustainable agriculture [89]. For future studies, research focused on collecting data on young farmers' behavior and attitudes could help us to understand their intention to adopt and practice sustainable agriculture.

Other factors that can influence farmers' adoption of SAP should be considered in future research to better explain the likelihood of sustainable agriculture growth in the RRD. For example, expanding the TPB to include the climate perception variable would not only contextualize the theory locally, but also enhance the data [29]. This expansion could be significant as climate perception directly impacts climate adaptation, including sustainable agriculture. A farm's characteristics, including farm size, could be statistically significantly in determining farmers' intention toward sustainable agriculture, which may lead to a negative regression coefficient between farm size and farmers' willingness to adopt Integrated Pest Management, an environmentally friendly approach to pest control [90]. In other locales like Serbia, research found that large farms may prioritize more intensive agricultural production and are less willing to take the risk of reducing pesticide use [90]. However, their finding is not in line with the preliminary results from our in-depth interviews with farmers in the RRD. The farmers that we interviewed mentioned that larger farms have more resources and technical capacity to adopt sustainable agriculture. We do not include farm size as a factor in our analysis as most farms in this study

are small family farms; 96% have an area of less than 0.5 ha. In a future study, large farms could be targeted to increase our understanding of these farmers' intention toward sustainable agriculture.

6. Concluding remarks

The intensive utilization of agricultural land in the RRD has resulted in significant negative impacts on the environment, including soil degradation, water pollution, loss of biodiversity, and negative impacts on the health of humans and animals. Moreover, the effects of climate change have exacerbated the disruption of growing seasons and reduced crop yields, highlighting the pressing need for the implementation of sustainable agricultural practices in the RRD. Gaining an understanding of farmers' decision-making processes and identifying the factors that can influence their farming choices is, therefore, crucial for promoting a transition towards more environmentally SAP. To address the aforementioned needs, this study's objective is to enhance our understanding of farmers' intention to adopt sustainable agricultural practices.

In this study, we used the TPB in combination with PLS-SEM to examine the impact of attitude, subjective norm, and perceived behavioral control on the intention of farmers toward sustainable agriculture. The study reveals that all three TPB variables have a positive relationship with intention, even though only attitude and perceived behavioral control have a significant impact. This result indicates that in order to encourage more farmers to adopt SAP, the government needs to implement special policies and incentives to enhance farmers' receptiveness, attitude, and perceived behavioral control toward sustainable agriculture. For example, to improve farmers' attitude, workshops, training, public awareness campaigns, and field demonstrations could be carried out to help educate and raise awareness among farmers of SAPs' benefits. Training will also improve farmers' perceived behavioral control as this variable indicates a farmer's perception of their ability to perform a practice. Policies that support SAP and provide financial incentives could also improve perceived behavioral control among farmers.

Regarding the influence of personal characteristics on intention, age has a moderating effect on the TPB model. There is a statistically significant difference between younger and older respondents when considering the relationship between perceived behavioral control and intention. In the RRD, the current trend of young people abandoning the agriculture sector to seek opportunities elsewhere presents a significant challenge for policymakers who need to create incentives that discourage youth from out-migration and promote engagement in agriculture—SAP more specifically. Meanwhile, gender does not seem to play a significant role in influencing farmers' intention to adopt SAP. This result can be attributed to the trend of feminization in agriculture within the region, whereby women are assuming a progressively significant role in this sector, which is simultaneously contributing to a more balanced distribution of decision-making power between genders. Overall, the findings of this study, set against the backdrop of environmental challenges and the pressing need for SAP in the RRD, underscore the importance of understanding farmer decision-making in this transition. While the study reveals the positive relationship of attitude and perceived behavioral control with the intention to adopt sustainable practices, it also acknowledges limitations due to the sample's age demographic. This highlights the need for future research to include delta's younger farmers' perspectives and examine additional factors like climate perception and farm size. Such expanded research would provide more comprehensive insights, crucial for policy formulation, aimed at encouraging the younger generation to engage in sustainable agriculture and addressing the feminization trend in the sector. Addressing these gaps in future studies will be instrumental in shaping effective strategies to bolster sustainable agriculture in regions facing similar challenges.

Data availability

The data used in the study that informs this paper is confidential.

CRediT authorship contribution statement

Quang Anh Phung: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Nga Dao:** Writing – review & editing, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Nga Dao reports financial support was provided by Global Challenges Research Fund.

Acknowledgements

The authors would like to recognize the Center for Water Resources Conservation and Development personnel who supported the survey that informed this study. Additionally, we would like to thank all of the participants who took part in the survey. The authors have produced this article with funding received from the UKRI GCRF Living Deltas Research Hub (www.livingdeltas.org) under Grant Reference NE/S008926/1.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e28576.

References

[1] T.A. Trinh, The impact of climate change on agriculture: findings from households in Vietnam, Environ. Resour. Econ. 71 (2018) 897–921, https://doi.org/10.1007/s10640-017-0189-5.
[2] T.L.H. Nguyen, Y.S. Bo, S. Fahad, Economic impact of climate change on agriculture using Ricardian approach: a case of northwest Vietnam, J. Saudi Society Agric. Sci. 18 (2019) 449–457, https://doi.org/10.1016/j.jssas.2018.02.006.
[3] L.W. Morton, Working toward sustainable agricultural intensification in the Red River Delta of Vietnam, J. Soil Water Conserv. 75 (2020) 109A–116A, https://doi.org/10.2489/jswc.2020.0304A.
[4] J. Ylipaa, S. Gabrielsson, A. Jerneck, Climate change adaptation and gender inequality: insights from rural Vietnam, Sustainability 11 (2019) 2805, https://doi.org/10.3390/su11102805.
[5] T.T.T. Tran, K.H. Pham, D.B. Dao, H.A. Pham, Assessment the impact of climate change and sea level rise on the unconfined aquifer at the Red-River Delta of Vietnam: a case study at Thai Binh Province, in: Proceedings of the International Conference on Innovations for Sustainable and Responsible Mining: ISRM 2020-Volume 2, Springer, 2021, pp. 326–348, https://doi.org/10.1007/978-3-030-60269-7_17.
[6] Q.A. Phung, A.L. Thompson, C. Baffaut, C. Costello, E.J. Sadler, B.M. Svoma, A. Lupo, S. Gautam, Climate and land use effects on hydrologic processes in a primarily rain-fed, agricultural watershed, JAWRA J. Am. Water Resour. Assoc. (2019), https://doi.org/10.1111/1752-1688.12764.
[7] Q.A. Phung, A.L. Thompson, C. Baffaut, C. Costello, E. John Sadler, Assessing future water allocation under climate variability and land management change in an agricultural watershed, JAWRA J. Am. Water Resour. Assoc. 58 (2022) 1575–1591, https://doi.org/10.1111/1752-1688.13059.
[8] Q.V. Dau, K. Kuntiyawichai, A.J. Adeloye, Future changes in water availability due to climate change projections for Huong Basin, Vietnam, Environ. Processes 8 (2021), https://doi.org/10.1007/s40710-020-00475-y.
[9] K.D. Nguyen, T. Ancev, A. Randall, Evidence of climatic change in Vietnam: some implications for agricultural production, J. Environ. Manag. 231 (2019) 524–545, https://doi.org/10.1016/j.jenvman.2018.10.011.
[10] Q. Phung, A. Thompson, C. Baffaut, L.M. Witthaus, N. Aloysius, T.L. Veith, D.D. Bosch, G. McCarty, S. Lee, Assessing Soil Vulnerability Index classification with respect to rainfall characteristics, J. Soil Water Conserv. 78 (2023) 209–221, https://doi.org/10.2489/jswc.2023.00065.
[11] T.S. Ngo, D.B. Nguyen, Predicting land use and climate changes scenarios impacts on runoff and soil erosion: a case study in hoa binh province, lower da river basin, northwest Vietnam, Environment (Wash. D C) 12 (2020), https://doi.org/10.14456/ea.2020.30.
[12] L.T. Thuy, N. Nguyen, M. Simioni, H. Phan, H. Arai, S. Mermoz, A. Bouvet, I. de Eccher, Y. Diallo, H.D. Trinh, Agriculture in Viet Nam under the impact of climate change, Climate Change in Viet Nam. Impacts and Adaptation, in: A COP26 Assessment Report of the GEMMES Viet Nam Project, 2021.
[13] K. Pawlak, M. Kołodziejczak, The role of agriculture in ensuring food security in developing countries: considerations in the context of the problem of sustainable food production, Sustainability 12 (2020) 5488, https://doi.org/10.3390/su12135488.
[14] H.-G. Pham, S.-H. Chuah, S. Feeny, Factors affecting the adoption of sustainable agricultural practices: findings from panel data for Vietnam, Ecol. Econ. 184 (2021) 107000, https://doi.org/10.1016/j.ecolecon.2021.107000.
[15] E. Jeronen, Sustainable development, in: Encyclopedia of Sustainable Management, Springer, 2020, pp. 1–7.
[16] V. Piñeiro, J. Arias, J. Dürr, P. Elverdin, A.M. Ibáñez, A. Kinengyere, C.M. Opazo, N. Owoo, J.R. Page, S.D. Prager, A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes, Nat. Sustain. 3 (2020) 809–820.
[17] M. Nachmany, S. Fankhauser, J. Davidová, N. Kingsmill, T. Landesman, H. Roppongi, P. Schleifer, J. Setzer, A. Sharman, S.C. Singleton, J. Sundaresan, T. Townshend, Climate Change Legislation in Vietnam an Excerpt from the 2015 Global Climate Legislation Study A Review of Climate Change Legislation in 99 Countries, the Grantham Research Institute on Climate Change and the Environment, The Global Legislators Organisation, The Inter-Parliamentary Union, Paris, 2015. https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2015/05/VIETNAM.pdf.
[18] J. Manda, A.D. Alene, C. Gardebroek, M. Kassie, G. Tembo, Adoption and impacts of sustainable agricultural practices on maize yields and incomes: evidence from rural Zambia, J. Agric. Econ. 67 (2016) 130–153, https://doi.org/10.1111/1477-9552.12127.
[19] H. Teklewold, M. Kassie, B. Shiferaw, Adoption of multiple sustainable agricultural practices in rural Ethiopia, J. Agric. Econ. 64 (2013) 597–623, https://doi.org/10.1111/1477-9552.12011.
[20] S. Asfaw, M. Kassie, F. Simtowe, L. Lipper, Poverty reduction effects of agricultural technology adoption: a micro-evidence from rural Tanzania, J. Dev. Stud. 48 (2012) 1288–1305, https://doi.org/10.1080/00220388.2012.671475.
[21] A. Wezel, C. David, A. Ferrer, A. Letort, S. Feret, J. Peigné, J.-F. Vian, F. Celette, Agroecological practices supporting the provision of goods and services in agriculture, in: Examples from France and Europe, ISARA-Lyon, 2014. https://isara.hal.science/hal-03672996/document.
[22] Y.S. Tey, The Adoption of Sustainable Agricultural Practices: an Integrative Approach for Malaysian Vegetable Farmers, University of Adelaide, 2013. https://digital.library.adelaide.edu.au/dspace/handle/2440/83762.
[23] V.T. Nguyen, C. Yapwattanaphun, Banana farmers' adoption of sustainable agriculture practices in the Vietnam uplands: the case of Quang Tri province, Agric. Agric. Sci. Procedia 5 (2015) 67–74, https://doi.org/10.1016/j.aaspro.2015.08.010.
[24] N. Siebrecht, Sustainable agriculture and its implementation gap—overcoming obstacles to implementation, Sustainability 12 (2020) 3853, https://doi.org/10.3390/su12093853.
[25] T.D. Beuchelt, L. Badstue, Gender, nutrition-and climate-smart food production: opportunities and trade-offs, Food Secur. 5 (2013) 709–721, https://doi.org/10.1007/s12571-013-0290-8.
[26] M. Tsige, G. Synnevåg, J.B. Aune, Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers, Scientific African 7 (2020) e00250, https://doi.org/10.1016/j.sciaf.2019.e00250.
[27] Y. Li, Z. Fan, G. Jiang, Z. Quan, Addressing the differences in Farmers' willingness and behavior regarding developing green agriculture—a case study in Xichuan County, China, Land 10 (2021) 316, https://doi.org/10.3390/land10030316.
[28] M. Tsige, G. Synnevåg, J.B. Aune, Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers, Scientific African 7 (2020) e00250, https://doi.org/10.1016/j.sciaf.2019.e00250.
[29] N. Nguyen, E.G. Drakou, Farmers intention to adopt sustainable agriculture hinges on climate awareness: the case of Vietnamese coffee, J. Clean. Prod. 303 (2021) 126828, https://doi.org/10.1016/j.jclepro.2021.126828.
[30] K. Talanow, E.N. Topp, J. Loos, B. Martín-López, Farmers' perceptions of climate change and adaptation strategies in South Africa's Western Cape, J. Rural Stud. 81 (2021) 203–219, https://doi.org/10.1016/j.jrurstud.2020.10.026.
[31] J. Josefsson, A.M. Lokhorst, T. Pärt, Å. Berg, S. Eggers, Effects of a coordinated farmland bird conservation project on farmers' intentions to implement nature conservation practices–Evidence from the Swedish Volunteer & Farmer Alliance, J. Environ. Manag. 187 (2017) 8–15, https://doi.org/10.1016/j.jenvman.2016.11.026.
[32] C. Lucarelli, C. Mazzoli, S. Severini, Applying the theory of planned behavior to examine pro-environmental behavior: the moderating effect of COVID-19 beliefs, Sustainability 12 (2020) 10556, https://doi.org/10.3390/su122410556.
[33] I. Issa, U. Hamm, Adoption of organic farming as an opportunity for Syrian farmers of fresh fruit and vegetables: an application of the theory of planned behaviour and structural equation modelling, Sustainability 9 (2017) 2024, https://doi.org/10.3390/su9112024.
[34] I. Ajzen, The theory of planned behavior, Organ. Behav. Hum. Decis. Process. 50 (1991) 179–211, https://doi.org/10.1016/0749-5978(91)90020-T.
[35] P. Laksono, J.H. Mulyo, A. Suryantini, Farmers' willingness to adopt geographical indication practice in Indonesia: a psycho behavioral analysis, Heliyon 8 (2022) e10178. https://www.cell.com/heliyon/pdf/S2405-8440(22)01466-9.pdf. (Accessed 13 October 2023).
[36] M.G. Morris, V. Venkatesh, P.L. Ackerman, Gender and age differences in employee decisions about new technology: an extension to the theory of planned behavior, IEEE Trans. Eng. Manag. 52 (2005) 69–84, https://doi.org/10.1109/TEM.2004.839967.
[37] Z. Zaremohzzabieh, S.E. Krauss, J.L. D'Silva, N. Tiraieyari, I.A. Ismail, D. Dahalan, Towards agriculture as career: predicting students' participation in the agricultural sector using an extended model of the theory of planned behavior, J. Agric. Educ. Ext. 28 (2022) 67–92, https://doi.org/10.1080/1389224X.2021.1910523.

[38] A. Garg, Investigating the moderating effects of age and gender on customers' use of tablet menu in casual dining restaurants, J. Qual. Assur. Hospit. Tourism 23 (2022) 1509–1547, https://doi.org/10.1080/1528008X.2021.2002786.
[39] S.-J. Moon, Investigating beliefs, attitudes, and intentions regarding green restaurant patronage: an application of the extended theory of planned behavior with moderating effects of gender and age, Int. J. Hospit. Manag. 92 (2021) 102727, https://doi.org/10.1016/j.ijhm.2020.102727.
[40] R.A.Z. Tama, L. Ying, M. Yu, M.M. Hoque, K.M. Adnan, S.A. Sarker, Assessing farmers' intention towards conservation agriculture by using the Extended Theory of Planned Behavior, J. Environ. Manag. 280 (2021) 111654, https://doi.org/10.1016/j.jenvman.2020.111654.
[41] I. Senger, J.A.R. Borges, J.A.D. Machado, Using the theory of planned behavior to understand the intention of small farmers in diversifying their agricultural production, J. Rural Stud. 49 (2017) 32–40, https://doi.org/10.1016/j.jrurstud.2016.10.006.
[42] T.T.H. Pham, A.P. Everaarts, J.J. Neeteson, P.C. Struik, Vegetable production in the Red River Delta of Vietnam. I. Opportunities and constraints, NJAS - Wageningen J. Life Sci. 67 (2013) 27–36, https://doi.org/10.1016/j.njas.2013.09.002.
[43] Vietnam General Statistics Office, Results of the Population and Housing Census at 0:00 on April 1, 2019, Statistical Publishing House, Hanoi, Vietnam, 2019. https://www.gso.gov.vn/wp-content/uploads/2019/12/TDT-Dan-so-2019-1.pdf.
[44] Y. Liu, C.B. Barrett, T. Pham, W. Violette, The intertemporal evolution of agriculture and labor over a rapid structural transformation: lessons from Vietnam, Food Pol. 94 (2020) 101913, https://doi.org/10.1016/j.foodpol.2020.101913.
[45] T.M.K. Nguyen, T.D. Nguyen, T.M.C. Le, P. Burny, P. Lebailly, Leaving the village but not the rice field: role of female migrants in agricultural production and household autonomy in Red River Delta, Vietnam, Soc. Sci. 7 (2018) 202, https://doi.org/10.3390/socsci7100202.
[46] Y.T.B. Nguyen, A. Kamoshita, H. Matsuda, H. Kurokura, Salinity intrusion and rice production in Red River Delta under changing climate conditions, Paddy Water Environ. 15 (2017) 37–48, https://doi.org/10.1007/s10333-016-0526-2.
[47] K.-A. Nguyen, Y.-A. Liou, J.P. Terry, Vulnerability of Vietnam to typhoons: a spatial assessment based on hazards, exposure and adaptive capacity, Sci. Total Environ. 682 (2019) 31–46, https://doi.org/10.1016/j.scitotenv.2019.04.069.
[48] J.E. Neumann, K.A. Emanuel, S. Ravela, L.C. Ludwig, C. Verly, Risks of coastal storm surge and the effect of sea level rise in the Red River Delta, Vietnam, Sustainability 7 (2015) 6553–6572, https://doi.org/10.3390/su7066553.
[49] Y. Kono, D.T. Doan, Effect of water control on rice cultivation in the Red River Delta, Vietnam: a cace study in the nhue river irrigation system, Japanese J. Southeast Asian Stud. 32 (1995) 425–445, https://doi.org/10.20495/tak.32.4_425.
[50] S. Skendžić, M. Zovko, I.P. Živković, V. Lešić, D. Lemić, The impact of climate change on agricultural insect pests, Insects 12 (2021) 440, https://doi.org/10.3390/insects12050440.
[51] V.Q.C. Phan, A. Fujimoto, Land tenure and tenancy conditions in relation to rice production in three villages in the Red River Delta, Vietnam, Int. Soc. Southeast Asian Agric. Sci. 18 (2012) 31–48.
[52] Hung Yen Statistical Office, Report on the economic and social situation in May and the first five months of 2021 in Hung Yen province. https://hungyen.gov.vn/portal/VanBan/2023-01/ebdf7c0af2ff0b1d173%20bc.pdf, 2021.
[53] H.L.T. Thuy, M.T. Tan, T.T.T. Van, L.B. Bien, N.M. Ha, N.T. Nhung, Using sentinel image data and plot survey for the assessment of biomass and carbon stock in Coastal Forests of Thai Binh Province, Vietnam, Appl. Ecol. Environ. Res. 18 (2020) 7499–7514, https://doi.org/10.15666/aeer/1806_74997514.
[54] B.T. Bui, T.P. Vu, T.V.H. Do, Detection and assessment of the spatio-temporal land use/cover change in the Thai Binh province of Vietnam's Red River delta using remote sensing and GIS, Modeling Earth Syst. Environ. 9 (2023) 2711–2722, https://doi.org/10.1007/s40808-022-01636-8.
[55] N.N.T. Hai, Farm mechanization and its impact on labour use among rice farming households: an experience from Thai binh province in Vietnam, Int. J. Agric. Ext. 10 (2022) 135–148.
[56] K.R. Singh, K.S. Ghosh, N.T. Nguyen, X.C. Pham, Simulation of runoff and sediment yield for the calo watershed, Vinh Phuc province by using swat model, VNU J. Sci. Earth Environ. Sci. 27 (2011). https://js.vnu.edu.vn/EES/article/view/1514.
[57] T.H.T. Nguyen, T.Q.N. Thai, V.T. Tran, T.P. Pham, Q.C. Doan, K.H. Vu, H.G. Doan, Q.T. Bui, Land consolidation at the household level in the red River Delta, Vietnam, Land 9 (2020) 196, https://doi.org/10.3390/land9060196.
[58] J. Maes, H. Leroy, L. Sels, Gender differences in entrepreneurial intentions: a TPB multi-group analysis at factor and indicator level, Eur. Manag. J. 32 (2014) 784–794, https://doi.org/10.1016/j.emj.2014.01.001.
[59] I. Ajzen, Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior 1, J. Appl. Soc. Psychol. 32 (2002) 665–683, https://doi.org/10.1111/j.1559-1816.2002.tb00236.x.
[60] I. Ajzen, From Intentions to Actions: A Theory of Planned Behavior, Springer, 1985.
[61] P. Ataei, S. Gholamrezai, R. Movahedi, V. Aliabadi, An analysis of farmers' intention to use green pesticides: the application of the extended theory of planned behavior and health belief model, J. Rural Stud. 81 (2021) 374–384, https://doi.org/10.1016/j.jrurstud.2020.11.003.
[62] P. Ataei, S. Gholamrezai, R. Movahedi, V. Aliabadi, An analysis of farmers' intention to use green pesticides: the application of the extended theory of planned behavior and health belief model, J. Rural Stud. 81 (2021) 374–384, https://doi.org/10.1016/j.jrurstud.2020.11.003.
[63] S. Sharma, R.M. Durand, O. Gur-Arie, Identification and analysis of moderator variables, J. Market. Res. 18 (1981) 291–300, https://doi.org/10.1177/002224378101800303.
[64] M. Hankins, D. French, R. Horne, Statistical guidelines for studies of the theory of reasoned action and the theory of planned behaviour, Psychol. Health 15 (2000) 151–161, https://doi.org/10.1080/08870440008400297.
[65] X. Yang, L. Chen, L. Wei, Q. Su, Personal and media factors related to citizens' pro-environmental behavioral intention against haze in China: a moderating analysis of TPB, Int. J. Environ. Res. Publ. Health 17 (2020) 2314, https://doi.org/10.3390/ijerph17072314.
[66] P. Sultan, T. Tarafder, D. Pearson, J. Henryks, Intention-behaviour gap and perceived behavioural control-behaviour gap in theory of planned behaviour: moderating roles of communication, satisfaction and trust in organic food consumption, Food Qual. Prefer. 81 (2020) 103838, https://doi.org/10.1016/j.foodqual.2019.103838.
[67] J. Cohen, P. Cohen, S.G. West, L.S. Aiken, Applied Multiple Regression/correlation Analysis for the Behavioral Sciences, Routledge, 2013.
[68] D. Maulud, A.M. Abdulazeez, A review on linear regression comprehensive in machine learning, J. Appl. Sci. Technol. Trends 1 (2020) 140–147, https://doi.org/10.38094/jastt1457.
[69] G.-J. De Bruijn, S.P. Kremers, E. De Vet, J. De Nooijer, W. Van Mechelen, J. Brug, Does habit strength moderate the intention–behaviour relationship in the Theory of Planned Behaviour? The case of fruit consumption, Psychol. Health 22 (2007) 899–916, https://doi.org/10.1080/14768320601176113.
[70] J.F. Hair Jr., G.T.M. Hult, C.M. Ringle, M. Sarstedt, N.P. Danks, S. Ray, J.F. Hair, G.T.M. Hult, C.M. Ringle, M. Sarstedt, An Introduction to Structural Equation Modeling, Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook, 2021, pp. 1–29.
[71] C. Ringle, D. Da Silva, D. Bido, Structural equation modeling with the smartPLS, Braz. J. Marketing 13 (2015) 1–18.
[72] K.K.-K. Wong, Partial least squares structural equation modeling (PLS-SEM) techniques using SmartPLS, Market. Bull. 24 (2013) 1–32.
[73] A. Kamis, R.A. Saibon, F. Yunus, M.B. Rahim, L.M. Herrera, P. Montenegro, The SmartPLS analyzes approach in validity and reliability of graduate marketability instrument, Soc. Psychol. Educ. 57 (2020) 987–1001.
[74] L.J. Cronbach, Coefficient alpha and the internal structure of tests, Psychometrika 16 (1951) 297–334, https://doi.org/10.1007/bf02310555.
[75] T.K. Dijkstra, J. Henseler, Consistent partial least squares path modeling, MIS Q. 39 (2015) 297–316. https://www.jstor.org/stable/26628355.
[76] J. Henseler, C.M. Ringle, M. Sarstedt, A new criterion for assessing discriminant validity in variance-based structural equation modeling, J. Acad. Market. Sci. 43 (2015) 115–135, https://doi.org/10.1007/s11747-014-0403-8.
[77] T.H.N. Nguyen, P. Lebailly, M.D. Nguyen, The Red River Delta, Vietnam: how does industrialization change the use of labor in agricultural production at farm households? Asia Life Sci. 27 (2018). https://hdl.handle.net/2268/233143.
[78] E.S. Bacud, R. Puskur, T.N.L. Duyen, B.O. Sander, J. Luis, Rural outmigration–feminization–agricultural production nexus: case of Vietnam, Migration Devel. 10 (2021) 442–466, https://doi.org/10.1080/21632324.2019.1679962.
[79] N.N.N.M. Hassan, J.M.A. Kadir, N.N. Abd Aziz, Examining a TPB model towards intention to use biodegradable drinking straw using PLS-SEM, Environ.-Behav. Proc. J. 5 (2020) 13–18, https://doi.org/10.21834/ebpj.v5i15.2428.

[80] H. Ateş, Merging theory of planned behavior and value identity personal norm model to explain pro-environmental behaviors, Sustain. Prod. Consum. 24 (2020) 169–180, https://doi.org/10.1016/j.spc.2020.07.006.
[81] K.M.R. Taufique, S. Vaithianathan, A fresh look at understanding Green consumer behavior among young urban Indian consumers through the lens of Theory of Planned Behavior, J. Clean. Prod. 183 (2018) 46–55, https://doi.org/10.1016/j.jclepro.2018.02.097.
[82] C.J. Armitage, M. Conner, Efficacy of the theory of planned behaviour: a meta-analytic review, Br. J. Soc. Psychol. 40 (2001) 471–499, https://doi.org/10.1348/014466601164939.
[83] V. Venkatesh, M.G. Morris, G.B. Davis, F.D. Davis, User acceptance of information technology: toward a unified view, MIS Q. (2003) 425–478, https://doi.org/10.2307/30036540.
[84] M. Lu, B. Guo, G. Chen, L. Yuan, R. Xing, Y. Huang, A study on the factors influencing farmers' intention to revitalize idle homesteads based on improved TPB framework—analysis of the moderating effect of farmer differentiation, Sustainability 14 (2022) 15759, https://doi.org/10.3390/su142315759.
[85] M. Gardner, L. Steinberg, Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: an experimental study, Dev. Psychol. 41 (2005) 625–635, https://doi.org/10.1037/0012-1649.41.4.625.
[86] D.D. Tran, J. Weger, Barriers to implementing irrigation and drainage policies in an giang province, mekong delta, Vietnam, Irrigat. Drain. 67 (2017) 81–95, https://doi.org/10.1002/ird.2172.
[87] E. Simelton, T.M. Duong, E. Houzer, When the "strong arms" leave the farms—migration, gender roles and risk reduction in Vietnam, Sustainability 13 (2021) 4081, https://doi.org/10.3390/su13074081.
[88] A. Gallina, C.R. Farnworth, Gender Dynamics in Rice-Farming Households in Vietnam: A Literature Review, CCAFS Working Paper No. 183, 2016.
[89] S.O. Oyewole, S.O. Sennuga, Factors influencing sustainable agricultural practices among smallholder farmers in Ogun state of Nigeria, Asian J. Adv. Agric. Res. 14 (2020) 17–24, https://doi.org/10.9734/AJAAR/2020/v14i130120.
[90] J. Despotović, V. Rodić, F. Caracciolo, Factors affecting farmers' adoption of integrated pest management in Serbia: an application of the theory of planned behavior, J. Clean. Prod. 228 (2019) 1196–1205, https://doi.org/10.1016/j.jclepro.2019.04.149.