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Influence of perceived risks in farmer's decision towards sustainable farm practices, Evidence from Northern Thailand

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Abstract Under the sustainable development goals, nations worldwide are enjoined to take immediate action through sustainable adaptations to mitigate climate variability and change. At the same time, agriculture is both a victim and a contributor to climate change. The situation prompted Thailand's agriculture to explore sustainable practices for food security and deliver environmental services. Using a binary logit model, the potential effects of farmers' perceived risks on adopting sustainable farming practices were investigated. The study revealed that farmers are somewhat hesitant to radically shift from their usual practices due to associated costs and the perceived potential risks. In addition, the study found that factors affecting adoption were site-specific. Hence, government actions should be flexible and tailored to a local level while still aligning with the national policy goals. For this, inter-agency coordination at the local, provincial and central levels is needed for agricultural support and enable farmers to make necessary changes to successfully adapt to emerging risks.

Keywords: Risk, Sustainable farming, Adoption

Introduction

Southeast Asian member states have been considered vulnerable to climate variability and change (Amnuaylojaroen *et al*., 2021; Ramsden *et al*., 2017). While a substantial portion of the population of its member states, such as in the agricultural sector, is reliant on nature for livelihood (Lee, 2021). These countries are already fighting poverty, and climate change-related issues constitute an additional burden. The adverse consequences warranted a global action which is one of the priorities under the Sustainable Development Goals (SDG) (UNDP, 2016). The SDG 13 calls on countries to take immediate action to combat climate change through sustainable adaptation and mitigation plans (Appiah, 2019; UNDP, 2016).

Particularly in Thailand, the agricultural sector takes a vital role in the country's economic system. For instance, the sector provides livelihood to more than thirty percent of the country's workforce (Rayfuse and Weisfelt, 2012). On

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the other hand, agriculture is both a victim and a contributor to climate change (Knowler and Bradshaw, 2007; Lee, 2021). For example, agricultural production emits greenhouse gases (GHG) which contribute considerably to global warming and climate change (Lee, 2021).

Thailand has also been included as the world's leading user of agricultural chemicals. Next to Argentina, China, and United States, the country ranked fourth in the annual pesticides usage in April 2017 (Ekachai, 2016; Pariona, 2017). In response, the country's Climate Change Master Plan 2015-2050 commits to a 20-25 percent reduction in GHG emissions relative to the business-as-usual level (ONEP, 2018). According to the second Biennial Update Report of Thailand, agriculture contributed to 21.9 percent of the country's net GHG emission, with rice cultivation accounting for over 55 percent of the net emission (Lee, 2021; ONEP, 2018). The situation shifted agriculture not only by focusing on food supply but also by delivering environmental services. This prompted the government and farmers to delve into alternative production methods such as limited tillage, the use of cover crops, crop rotation, and straw mulch, to mention a few. These practices are put together under the concept of "sustainable farming" or "conservation agriculture" (Knowler and Bradshaw, 2007).

The concept of sustainable farming aims to improve the use of agricultural resources through integrated management of farm resources while minimizing the associated negative externalities. The practices under sustainable farming somewhat overlap with the concept of organic farming and good agricultural practices (GAP). However, in this study, we did not attempt to distinguish practices under organic farming or GAP like most of the studies in the literature related to adoption intention. Instead of undertaking another adoption intention of specific farm practices, the paper aggregates these practices under the concept of sustainable farming. Most farmers adopt more than one sustainable farming practices, and adopting one practice will most likely decrease the likelihood of adopting the other alternatives as it needs to complement previously adopted practices (Fosso and Nanfosso, 2016). By aggregation, it provides a unifying label for several closely related practices. This approach has already been applied in the study of García-Torres *et al*. (2003) and Knowler and Bradshaw (2007).

Notwithstanding farmers' risk perceptions of whether new farm technology is risk-increasing or risk-decreasing may influence whether they embrace sustainable methods (Pilarova *et al*., 2018; Ramsden *et al*., 2017). As a result, farmers' apprehension to accept innovation may not be solely attributable to irrational behavior but rather their efforts to reduce potential risks (Fosso and Nanfosso, 2016). Following this notion, the study's objective investigates how farmers' perceptions of risk affect their decision to embrace sustainable farming practices. These risks may include natural risks such as floods, changing weather conditions, and rising temperatures. In addition, market-related risks, including the uncertainty of product price and demand, the influence of middlemen, and market access, were also studied.

The remainder of the study proceeds as follows. The following section presents the methods and analysis employed in the study. Next, we discuss the survey results and research model findings on farmers' perceptions of associated risks. Finally, we provide the conclusion and implication of the study.

Materials and methods

Sample and data collection

The study used a cross-sectional data set from farmer interviews in Chiang Rai province, northern Thailand. First, a focus group discussion with selected farmers and group leaders was organised to understand the study area's overall situation. Second, we asked farmers about their farming practices and perceptions of several risks they often experience in their farming activities summarized in Table 1.

In measuring the sustainable practices as the outcome variable of the study, farmers rate how frequently they have applied the provided elicited practices from 0 as never to 5 as always. Afterward, we adopted the method of Jeong and Lee (2016) in transforming the scale into a binary or dichotomous scale which stated that the dichotomous scale performs well compared to the original scale. The result justified the approach in generating a binary outcome variable used in the econometric model employed in the study.

Binary logit model

Using a binary logit model, we assessed the effects of perceived risk on farmers' decisions to adopt sustainable practices. The method evaluates the likelihood of sustainable practices adoption in terms of the farmer's characteristics and perceived risks outlined in Table 1. The binary logit model is expressed as follows:

$$Y_i = \beta_j X_{ij} + \delta_k R_{ik} + \varepsilon_i \qquad (1)$$

Wherein X_{ij} refers to the vector of farm and sociodemographic characteristics and R_{ik} is a vector of the explanatory variable representing the perceived risks among sampled farmers presented in Table 1. While β_j and δ_k is a vector of parameters to be estimated and ε_i is an error term. The Y_i refers to the binary outcome variable, which takes a value of 1 if farmers frequently applied the elicited sustainable farm practices and 0 if otherwise, that is expressed as follows:

$$Y_i = \begin{cases} 1 & if\ Y_i > 0 \\ 0 & otherwise \end{cases} \tag{2}$$

Table 1. Definition and descriptive statistics of variables in the binary logit model

Variable	Description	Mean	Std. Dev.
Sustainable practices	Application of sustainable practices	0.34	0.47
Area	Farm size	11.39	7.85
Years in farming	The number of years farming.	31.04	14.19
Non-farm income	Non-farm source of income (0=no; 1=yes)	0.27	0.44
Access to credit	Avail of credit services (0=no; 1=yes)	4.52	1.94
Land ownership	If farmer own the land (0=no; 1=yes)	0.70	0.46
Good soil quality	Perception of soil quality (0-5 scale)	0.95	0.21
Pest and disease	Perception of pest infestation (0-5 scale)	4.64	1.78
Flooding	Perception of flood occurrence (0-5 scale)	3.92	2.55
Unpredictable weather	Perception of unpredictable weather (0-5 scale)	4.52	1.78
Rising temperature	Perception of rising temperature (0-5 scale)	4.39	1.73
Market access	Perception of market access (0-5 scale)	4.15	1.90
Middlemen	Perception of middlemen influence (0-5 scale)	5.31	1.84
Uncertain price	Perception of uncertain price (0-5 scale)	5.38	1.96
Uncertain demand	Perception of uncertain demand (0-5 scale)	4.58	1.84

Note: 0-5 scale refers to 0 as no effect and 5 as with very high effect on production.

Accuracy metrics and cross-validation

In assessing the performance of the binary model specified in equation (2), we included a confusion matrix with its accuracy metrics. The confusion matrix for the binary logit model is shown in Figure 2, and the associated accuracy metrics are summarised in Table 2. The confusion matrix summarises the correct prediction (i.e., true positive and true negative) of the employed model in the study. It also provides an easier comparison of the observed actual values from what is predicted by the model.

		Actual values	
		Positive (1)	Negative (0)
Predicted values	Positive (1)	True positive (TP)	False positive (FP)
	Negative (0)	False negative (FN)	True negative (TN)

Figure 1. Confusion matrix for the binary logit model

Table 2. Summary of the accuracy metrics for the confusion matrix using the binary logit model

Metrics	Derivation	Description
Accuracy	$\frac{TP+TN}{TP+TN+TF+FN}$	Indicate the percentage of correct prediction of the model.
Cohen's kappa	$\frac{2(TP \times TN - FN \times FP)}{(TP+FP)(FP+TN)+(TP+FN0(FN+TN)}$	Measure how well the classification performs when compared to the model prediction simply by chance.
Precision	$\frac{TP}{TP+FP}$	Represent the ratio of the total correctly classified true positive by the total predicted positive classes.
Recall	$\frac{TP}{TP+FN}$	Represent the total correctly classified true positive by the total predicted classes.
F-measure	$\frac{2 \times Recall \times Precision}{Recall + Precision}$	Represent the weighted average of the true positive value and precision.

Results

Perceived risks on farming

The perceived magnitude of the effect of farming risks on production among sampled farmers is shown in Figure 2. Perception of the uncertainty of the market price was highly likely to be considered a leading limiting factor that affected farm production. At the same time, the perceived magnitude of influence of middlemen in the production operation of the farmers was similar to both adopters and non-adopter. Whereas the perceived effect of flooding was larger among non-adopter than adopters. While the perceived effects of market access, uncertain demand, and unpredictable weather were slightly lower among adopters of sustainable practices.

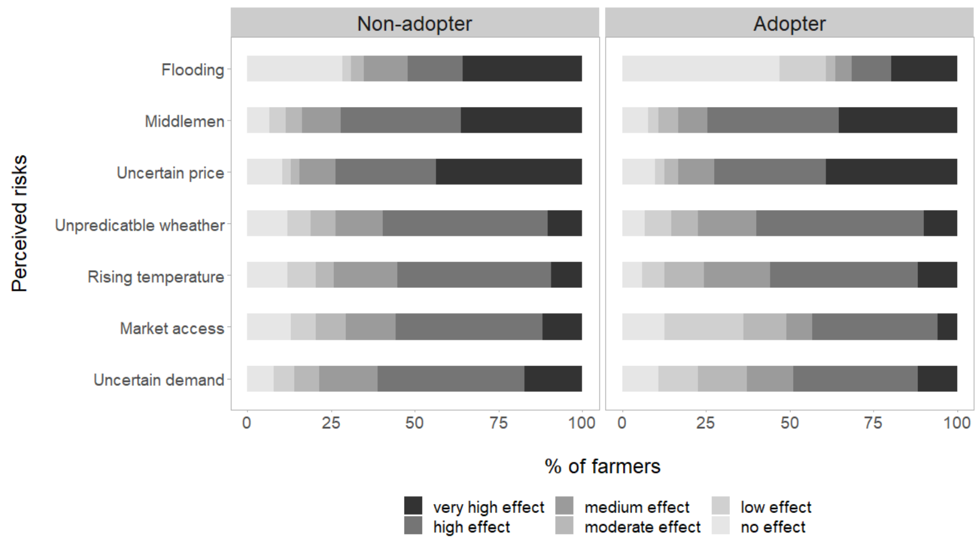

Figure 2. Farmer’s perception on the magnitude of the effect of the natural and farming risks on agricultural production

Effects of perceived risks on the adoption of sustainable farming practices

Results of the binary logit model for unbalanced and balanced outcome variables are presented in

Table ***3***. In the unbalanced outcome variable, the number of farmers who have not adopted sustainable practices was twice that of those who adopted (adopter=102, non-adopter=201). We estimated the model for unbalanced and balanced outcome variables to assess if the estimated parameters are consistent. The result shows that the odds ratios and the qualitative conclusion for both models are consistent. Furthermore, we tested the model for possible high multicollinearity using the variance inflation factor (VIF). The explanatory variables have VIF values within the range of 1-2.5, which is below the recommended threshold of 5. Therefore, the test results imply the absence of potential collinearity issues.

The study result found farming area, land ownership, flooding, unpredictable weather condition, rising temperature, the influence of middlemen, and the uncertainty of market price and demand to be statistically significant factors in the decision of farmers to apply a sustainable farming method. In terms of farming area, the results imply that farmers with larger farming size and who own the land are more likely to adopt sustainable farming practices. On the other hand, increasing flooding occurrences, uncertainty in the market price, and lesser access to the market lower the odds of farmers' decision to adopt. At the same time, farmers who perceived the greater effect of unpredictable weather conditions and rising temperature on their agricultural production were 1.2 times the odds of adopting a sustainable farming practice. This suggests the effects of farmer's initiatives mitigated the impact of the changing environment.

Table 3. Effects of perceived risk on the adoption of sustainable farming practices using a logistic regression model

Variables	Unbalance outcome variable			Balanced outcome variable		
	OR	CI	p-value	OR	CI	p-value
Intercept	0.48	0.08–2.80	0.41	1.46	0.18–3.22	0.72
Area	1.04**	1.00–1.07	0.03	1.02*	1.00–1.09	0.07
Years in farming	1.01	0.99–1.03	0.31	1.01	0.99–1.04	0.24
Non-farm income	0.69	0.37–1.27	0.24	0.74	0.34–1.56	0.42
Access to credit	1.10	0.95–1.28	0.20	1.04	0.87–1.25	0.65
Land ownership	1.68*	0.93–3.13	0.09	1.85	0.89–3.91	0.10
Good soil quality	0.46	0.14–1.50	0.19	0.66	0.15–2.62	0.56
Pest and disease	0.89	0.74–1.08	0.23	0.92	0.72–1.16	0.48
Flooding	0.76***	0.66–0.85	0.00	0.72***	0.61–0.83	0.00
Unpredictable weather	1.22*	0.99–1.51	0.06	1.12	0.87–1.46	0.39
Rising temperature	1.26**	1.03–1.55	0.02	1.35**	1.05–1.76	0.021
Market access	0.92	0.79–1.09	0.33	0.91	0.75–1.11	0.353
Middlemen	1.27**	1.02–1.59	0.03	1.34**	1.02–1.78	0.04
Uncertain price	0.92	0.77–1.10	0.37	0.83	0.66–1.04	0.11
Uncertain demand	0.72***	0.59–0.87	0.00	0.69***	0.53–0.88	0.00
Observations	303			202		
R-square	0.176			0.224		

OR = Odd ratio; CI = Confidence interval
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

Accuracy and cross-validation results

The confusion matrix in Tables 4 and 5 summarised the model's performance in predicting whether a farmer adopts sustainable farming practices. The true positive was 43 and 64 for a balanced and unbalanced outcome variable, respectively. On the other hand, the true negative was 180 and 73 for a balanced and unbalanced outcome variable, respectively. A true positive and a true negative imply that a prediction is true in actuality among the sampled farmers.

Table 4. Confusion matrix for the unbalanced outcome variable

N=303	Actual No	Actual Yes
Predicted No	180	89
Predicted Yes	21	43

Table 5. Confusion matrix for a balanced outcome variable

N=202	Actual No	Actual Yes
Predicted No	73	35
Predicted Yes	27	67

Whereas the accuracy metrics for the research model are outlined in Table 6. Regarding the percentage of correct prediction, the binary logit model with an unbalanced outcome variable showed higher accuracy than the unbalance model. Cohen's kappa showed lower similarity when the classification performance is compared to a model prediction simply by chance. This implies that each model has a lower agreement percentage between the predicted and actual values. However, other remaining accuracy metrics showed acceptable range values indicating both models perform fairly.

Table 6. Accuracy metrics for the model prediction

Metrics	Unbalanced	Balanced
Accuracy	0.736	0.693
Cohen's kappa	0.349	0.387
Precision	0.753	0.676
Recall	0.896	0.730
F-measure	0.818	0.702

Discussion

Farm and farmer's characteristics towards adoption

In terms of the farm and farmer characteristics effects, we found the size of the farming area and land ownership to be a statistically significant factor in farmers' decision to adopt innovations towards sustainable farming practices. Larger farms are typically associated with a higher capital endowment, increasing farmers' capacity to explore alternatives (Willy *et al*., 2014). This reflects the observed higher likelihood of larger farms to adopt than smaller farms. On the other hand, smaller farms tend to be less flexible due to resource constraints, potentially leading to a higher perceived risk. Although some authors argued that there is no priori reason that adoption of agricultural innovations will be enhanced by larger farm size (Saka and Lawal, 2009; Shakya and Flinn, 1985). The increasing farming area will more likely increase farmers' propensity to increase input usage under conventional production among non-adopters.

Whereas the observed positive association of land ownership and the likelihood of adopting could be due to the fact that landowners are more likely to consider the adverse long-term effects of harmful farming practices such as excessive use of chemicals as input in production (Fosso and Nanfosso, 2016). The study results are plausible since farm owners will bear more risks during crop failure than leased farmland.

Although the model did not find enough evidence for a significant effect of farming experience, the availability of non-farm income and access to credit the observed effects still provide valuable insights. For example, the increase in the farming experience is positively associated with the likelihood of adopting, although the effect size is small, reflecting a non-significant result. In addition, as most sampled farmers in the study area are in the older age bracket, the results may also imply that older farmers with high farming experience are more likely traditional in their farming practices. For instance, in the study by Pilarova *et al*. (2018), they found that older farmers in Moldova are less likely to adopt sustainable agricultural practices. This contrasts with García de Jalón *et al*. (2014), which found older farmers to have a higher likelihood of adopting than younger farmers. The differing observation may be accrued with associated risks of shifting from the accustomed traditional practices towards new farming practices.

Access to credit among selected farmers has a beneficial impact on their likelihood of adoption, and most farmers show a willingness to adopt. However, there are certain financial requirements. Farmers must have some financial ability to invest in modern agricultural technologies, yet most cannot attain the required level (Pilarova *et al*., 2018). This raises the difficulty of implementing sustainable farming methods.

Furthermore, although credit assistance may help alleviate the financial constraints, there are instances when credit may be diverted for other purposes rather than solely on-farm production purposes (Fosso and Nanfosso, 2016). For instance, a portion of the credit amount may be used for household consumption, educational expenses, and other possible immediate use of the loaned money. In addition, the availability of an off-farm source of income among sampled farms constrains the likelihood of adoption. For example, this could be related to the case when off-farm employment competes for the on-farm managerial time, resulting in less time to engage in new technology (García de Jalón *et al*., 2014).

Farmer's risks perceptions towards adoption

The perceived risks of adopting sustainable practices may also play a role in the effectiveness of its implementation. It is crucial to note that farmers are reluctant to make drastic changes to their conventional methods if costs or risks are involved, especially if the decisions could result in unfavorable consequences. As a result, farmers' aversion to embracing new technologies may not be attributable to irrational behavior but rather their desire to avoid risks (Fosso and Nanfosso, 2016).

Farmers recognized that market price uncertainty had a significant impact on their farming operations. The impact is stronger among non-adopters than among adopters. As a result, increased market pricing uncertainty is associated with a lower likelihood of adoption. It may be attributable to the revenue anticipation, based on the quantity of output and the prevailing market price. Normally, farmers do not have the ability to influence the latter. It appears that if farmers perceive a high uncertainty of the market price, they will be more uncertain about whether the farm operation will be profitable. In addition, we found that uncertainty of product demand is statistically significant and inversely related to adoption intention. Thus, uncertainty about the current market price coupled with fluctuating demand added risk to farmers and could considerably affect whether farmers would transition from their conventional practices to adopt new farm practices.

Consequently, perceived risks regarding natural hazards show differing effects on adoption. For instance, we found the perceived risks of flood occurrences, unpredictable weather conditions, and rising temperature to be statistically significant. For instance, farmers who are more aware of the perceived risks of changing climatic conditions, such as unpredictable weather and rising temperatures, are more inclined to adopt alternative sustainable methods. A higher understanding of the effects of changing climatic conditions is 1.2 times more likely to contemplate adopting. Discussion among farmers reveals unpredictable weather condition was widely experienced as they find it harder to predict the usual seasonal weather condition unlike in the past.

Moreover, the findings suggested that a higher frequency of floods in the area decreases the likelihood of adoption among the farmers studied. Ward *et al*. (2016) and Pilarova *et al*. (2018) found similar effects that flooding experiences increase perceived risks affecting farmers' agricultural productivity, limiting the adoption of sustainable farming. In addition, we found that non-adopters had a perceived effect of flooding than adopters. It may be due to the adoption of sustainable techniques, such as using more flood-tolerant cultivars, which could help lessen the adverse effects of floods and reduce the perceived risk among adopters.

In conclusion, several studies have already investigated the adoption of individual sustainable practices. In comparison, this study uses aggregation of related sustainable practices to understand farmer's adoption decisions. The study demonstrated how natural hazards, farms, and farmers' characteristics affect farmers' decision-making in adopting sustainable practices. However, it is important to note that adoption studies are site-specific since agricultural practices differ across countries, regions, and localities. In addition, farmers are heterogeneous and individual behavior is dynamic. Therefore, despite similarities in the employed antecedents of adoption intention studies, the qualitative inference may differ across adoption studies globally.

Farmers are hesitant to radically shift from their usual practices due to costs or risks, primarily when decisions result in unfavorable outcomes. As a result, farmers' aversion to embracing emerging innovations may not be attributable to irrational behavior but rather their desire to minimize risks. Nonetheless, governmental action is needed to reduce the risks associated with adoption, particularly in the early years, when farmers are more vulnerable as they shift from traditional to newly introduced farming technology. As the study found that factors affecting adoption are site-specific, government action and support should be flexible and tailored to a local level while still aligning with the national policy goals. For this, inter-agency coordination at the local, provincial, and central levels is needed for agricultural support and enabling farmers to make necessary changes to successfully adapt to emerging risks.

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