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ARTICLE

Factors Influencing the Adoption of Good Agricultural Practices (GAP) Standards by Small-Scale Vegetable Farmers in the Northeast of Thailand

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ABSTRACT

The main purpose of the study was to investigate the determinants of adopting GAP standards. Based on this, a simple random sampling method would be used to select 300 farmers, and binary logistic regression would be used to assess the factors influencing the adoption of GAP. The findings showed that the average income of vegetable farmers who implemented GAP standards was significantly higher than that of farmers who did not. The land area under vegetable production was also much greater for GAP adopters than for non-adopters. The cultivation area ($p < 0.01$), training frequency ($p < 0.01$), average income per production cycle ($p < 0.01$), educational level ($p < 0.05$), age of the farmers ($p < 0.05$), and family size ($p < 0.05$) were the significant factors influencing GAP adoption. Specifically, the cultivation area had a peak exposure to suitable physical resources, which is vital for effective compliance with GAP standards. As a result of such findings, this study provides several contributions in terms of policy recommendations, such as targeted investments in improving agricultural structures, the continuing training of farmers and dissemination of information, the support of low-income farmers in managing their finances and resources, and the continuous learning incentive that may assist in transitioning small-scale farmers to eco-friendly production processes.

Keywords: Safety Vegetable; Good Agricultural Practice (GAP); Smallholder Farmers; Adoption; Technology

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1. Introduction

In the agricultural and economic system of Thailand, vegetables are a key economic crop, since both domestic sales and income from exports to foreign markets can be earned from this crop. For example, vegetables, which can be fresh, chilled, frozen, dried, and also processed, can be exported from Thailand and average around 244.35 million USD each year based on data from 2013–2018 (with an average growth rate of about 7.63%) [1]. This growth has been justified by several justifications: population growth, the growth of the service sector, and the rising trend in safe food consumption, which has created a continuous increase in the demand for quality and safe vegetables [2, 3]. Responding to this demand, the government has issued regulations to encourage the production of safe vegetables by encouraging farmers to implement Good Agricultural Practices (GAP) in their production, which is an important standard in the control of food safety, environmental health, and farmers' own health. The Ministry of Agriculture and Cooperatives introduced a "large-scale farming system" in 2018, which clusters farmers to enable systematic production management across the value chain, including production, marketing, and quality control [1]. According to the Department of Land Development reports [4] from 2018 to 2022, the number of large-scale farming groups of vegetable growers increased by 80 groups, and the number of farmers joining the system increased by more than 2300. Meanwhile, there are 261,643 farmers with GAP certification, with an area of more than 14,400 hectares, or about 20,415 GAP certified farmers in the Northeast area. Kalasin has the most farmers who are certified in the province, with 2642, which is consistent with the province's plan to be a "Smart Green City" and the centre of safe food. While this is a positive sign and there is genuine support from the government, it is observed that a large number of these produce vegetables without entering the GAP system, which is about 40 percent of the total vegetable growers. They are limited in adoption because the production structure, knowledge management, attitudes, and resource perspectives that farmers can access are still within the realm of what was already established. Age, income, education, farming experience, and training were hypothesized as major factors determining whether to adopt GAP standards. Training imparts technical knowledge, insight about the benefits of GAP, and introduces farmers to new marketing alternatives. Regular participation in training leads not only to compliance with technical standards but also to the development of the confidence of farmers that they can seek access to markets. This result indicates that constant programmes to train packages and establish new packages are necessary to go from an adoption tipping point of the few farms with access to non-agrochemical technologies produced locally, towards large-scale use of GAP.

But earlier studies had produced conflicting conclusions, and none provided a decisive conclusion for each factor. For example, while younger farmers are more willing to accept on-farm innovations [5, 6], it was claimed that older and more experienced farmers are better at implementing GAP technology [7]. Variables related to income also have conflicting effects: while some studies find that income is positively related to the adoption of GAP [8, 9], others do not find a significant association. Along with other factors such as education, experience, and training, GAP standards are supported by educated or experienced farmers [2, 3]. In addition to the standards of adequate training, implementation of standards in practice also depends on government support in the form of (a) training activities or (b) transfer of technology [10, 11]. However, there are few detailed studies on certain sectors with a high chance of diversity, both by the province of Kalasin, which has been under an old pressure policy in the past few years, but there are still a lot of farm owners who have not yet entered the GAP system. It also implies that despite strong government promotion, the adoption level in Kalasin is low (approximately 40 per cent), which emphasizes an important research void that the present study attempts to fill. In Thailand and throughout the ASEAN region, use of GAP has been extensively promoted, but acceptance is varied. More than 265,000 farmers are certified across the country, but about 40% of vegetable growers, particularly in the Northeast, have not joined the system. Equivalent discrepancies are present in ASEAN nations where institutional capability, market motivation, and level of farmer knowledge differ greatly [12, 13]. The originality of this work is in its provincial case study of Kalasin, mixed with the development application of logistic regression, allowing for a deeper understanding that goes into a more extensive evaluation of socioeconomic, demographic, and institutional factors affecting adoption. This approach also provides more detailed perspectives beyond national scale analysis on local level barriers and opportunities in promoting GAP. As a result of the above, the research will investigate the economic and social situation of safe vegetable farmers and general farmers in Kalasin Province and examine the factors that influence acceptance of GAP or good agricultural practices standards, particularly for small farmers, in issuing the policy guidelines and promotions in accordance with the area context effectively.

The recent digital revolution has also spotlighted the possibility of linking computational advances to agricultural practice. For instance, a recent study investigated the use of NLP and quantum computing for agricultural data analysis and decision-making in order to show that the digital tools can increase the pace of innovation in farm management [14]. Moreover, new ontology frameworks have been developed for the structured ontological representation of agricultural knowledge to enhance data interoperability and enable advanced decision-support systems in agriculture [15]. Moreover, some recent works in crop protection have also focused their attention on the use of hybrid artificial intelligence models, like Vision Transformers paired with Convolutional Neural Networks, to better detect plant diseases and elaborate early-warning systems for farmers [16]. These trends indicate that the future of GAP implementation is shaped by not only socioeconomic and structural factors, but also digitally-driven efficiencies, sustainability, and resilience for agricultural production. Thus, the objectives of this study were to explore the factors influencing the decision to adopt GAP standards by smallholder vegetable farmers in Kalasin Province, Thailand. The specific objectives are (1) to describe the farmers' socio-economic and demographic profile, (2) to assess the determinant factors associated with GAP adoption through binary logistic regression, and (3) to draw policy implications. The impetus for this has been the low uptake of GAP despite intensive government promotion. This study was particularly focused on small-scale vegetable producers in Kalasin Province, and these selected provinces represent some economic and institutional situations in the Northeast.

2. Materials and Methods

Kalasin Province is located in the Northeastern region of Thailand with a total population of 977,175 persons and is administratively divided into 18 districts and 135 sub-districts, with a total area of 4,715,494 rai, most of which is agricultural land of 2,832,889.64 rai (453,262.34 ha) or 60.08 percent of the total area used for growing rice, field crops, fruit trees, perennial plants, vegetables, flowering plants, and ornamental plants, totalling 21,783.83 rai or 3,485.41 ha [11]. From large-scale plot registration data, it was found that there was a total of 1036 vegetable farmers in Kalasin Province in the latest year, of which 60 percent, or 622 farmers, grew vegetables according to Good Agricultural Practices (GAP) standards, and another 40 percent, or 414 farmers, still used conventional production methods [4]. This research aimed to study the factors influencing the adoption of GAP standards by vegetable farmers in Kalasin Province by using a representative sample of 300 farmers growing vegetables according to GAP standards and common vegetable farmers through calculation based on Yamane's formula appropriate for the population size known, and setting a reliability level at 95 percent and an error at 0.05. Model validity was confirmed by the Hosmer–Lemeshow test ($p = 0.604$), Cox & Snell R^2 (0.497), and Nagelkerke R^2 (0.672). For more completeness of data analysis, the researcher increased the sample size to 300 subjects, divided into 180 farmers adopting GAP and 120 common farmers sampled by simple random sampling. Descriptive statistics were used for data analysis, namely frequency, percentage, mean, standard deviation, and maximum and minimum values, to describe the general characteristics of the representative sample, such as gender, age, educational level, agricultural area size, vegetable-growing area, and vegetable-growing experience. For inferential data analysis, the binary logistic regression model was used. This statistical technique was appropriate for the case where the dependent variable was a binary outcome, such as adoption or rejection of GAP standards (1 = adopt GAP, 0 = reject GAP). The model looked at the relationship between the chances of adopting or rejecting GAP standards, which was then used in a logarithmic equation (log odds) to effectively evaluate how each independent variable affected the likelihood of adopting GAP standards [17, 18]. The independent variables studied included AGE [19, 20], educational level (EDU) [4, 21], agricultural area size (AREA) [20, 22], income (INCOME) [2, 16], vegetable-growing experience (EXP) [23, 24], attending training (TRAIN) [25, 26], government support (SUPPORT) [27–29], environmental knowledge and attitudes (KNOWLEDGE) [12, 30–32] and gender (GEN) as summarized in **Table 1**. This is in accordance with regular procedures employed in binary logistic regression [17, 18]. The good recovery of the binary logistic regression model was further validated by a series of diagnostic tests. The model fit was good (Hosmer–Lemeshow goodness-of-fit test: $p = 0.604 > 0.05$). Cox and Snell R^2 (0.497) and Nagelkerke R^2 (0.672) showed that the model accounted for an appreciable amount of variance in the adoption behavior. Furthermore, the total accuracy of 89.3% indicated the excellent ability of the model to differentiate the adopters from non-adopters. These results validate the robustness of the assessment methodology used in this study. This model had the advantage of interpreting the analysis results through odds ratio, which could reflect the change in the likelihood of adopting GAP standards when the value of the independent variable changed by one unit while other variables remained constant, thus being optimal for the research objective to analyse the impact of multiple factors on farmers' GAP standard adoption behaviour by setting the regression equation with specified equation form as follows. Data analysis was carried out using SPSS version 28 for binary logistic regression. Excel was used for data entry and cleaning. Data collection in the field was based on structured questionnaires delivered through face-to-face interviews with farmers.

$$\mathrm{Logit}(P_i) = \ln\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \beta_1 \mathrm{GEN} + \beta_2 \mathrm{AGE} + \beta_3 \mathrm{EDU} + \beta_4 \mathrm{EXP} + \beta_5 \mathrm{TRE} + \beta_6 \mathrm{ARE} + \beta_7 \mathrm{INC} + \beta_8 \mathrm{MEM} + \beta_9 \mathrm{OPI} + e$$

Where Pi = Probability or likelihood of a situation of interest

1 = Adopt GAP standards, 0 = Not adopt GAP standards

β_0 = Constant or vertical y-intercept when x = 0

$\beta x_1 \ldots \beta x_n$ = Coefficient showing the change in Y when X_n changes by 1 unit (where other independent variables remained constant)

GEN = Gender (0 = Female 1 = Male)

AGE = Age (years)

EDU = Number of education years (years)

EXP = Vegetable-growing experience (years)

TRE = Number of GAP training (times)

ARE = Vegetable -growing area (ha)

INC = Income per production cycle ($)

MEM = Number of household members (person)

OPI = Opinion on suitability of vegetable -growing area (0 = Disagree, 1 = Agree)

e = Estimation error

Table 1. Variables used in the study of factors affecting the adoption of GAP standards.

Variable	Meaning	Unit	Symbol
Gen	Gender	0 = Female 1 = Male	+
AGE	Age	Year	-
EDU	Number of education years	Year	+
EXP	Vegetable-growing experience	Year	+
TRE	Number of training times on GAP	Time	+
ARE	Vegetable- growing area	Ha	+
INC	Income per production cycle	$	+
MEM	Number of household members	Person	+
OPI	Opinions on the suitability of a vegetable-growing area	0 = Disagree Value 1 = Agree	+

Note: + means positive and – is negative.

Several previous studies on the adoption of Good Agricultural Practices (GAP) and sustainable farming standards have been informative, but there are also several weaknesses in the literature. For one, there are inconsistent findings in the literature regarding the effects of socio-economic variables such as income, age, and education. For example, education and previous experience were found to positively affect GLOBALG adoption [8]. Regarding agricultural practice adoption in Thailand, while other studies indicated that income or age were not significant or even contradict in different contexts [12, 13]. Second, many of the models have tended to be of a compartmentalized nature, with focus on specific determinants such as training or farm size, giving less emphasis on the interactive effects of human capital, resource endowments, and institutional support. Studies in Central Java discovered that technology adoption must not only follow the normal socio-demographic features, but also be compatible with cropping systems and farmers' risk perception [33], which are usually neglected in the single-factor models. Third, there are also methodological limitations: some studies employ descriptive statistics or simple regressions without proper diagnostics, and others use small or nonrepresentative samples, which limit the generalizability of results [34]. In addition, most studies focus on the analysis at the national or cross-country level, and thus understate local heterogeneity. Contextual, place-based factors, including land attributes, the presence of infrastructure, and the degree to which provincial policies are supported, are often ignored despite the fact that they play a key role in influencing the behavior and choices of potential adopters [35, 36]. In particular, little data is available on the process of GAP adoption in Northeastern Thailand, an area that possesses special socio-economic and environmental attributes. Therefore, there is no empirical evidence on how local production structures, household characteristics, and government programs interact in determining decision-making. For instance, in China and in Indonesia's findings emphasized the significance of socio-economic and institutional factors [12, 13], while there has been heterogeneity resulting for Ireland [36]. These results are consistent with the diffusion of innovation theory which focuses on the roles of innovators and early adopters, as well as with models highlight contextual as key resources determinants [24, 35]. It is in this literature that the present study situates itself, focusing, however, on the ASEAN and Thai provincial perspectives. To address these gaps, this study applies a binary logistic regression model to smallholder farmers in Kalasin Province, with the inclusion of demographic, economic, and structural factors that capture the local conditions that enhance the academic understanding and the policy formulation.

3. Results

3.1. General Social Conditions of Vegetable Farmers

From the study on the economic and social characteristics of vegetable farmers in Kalasin Province by comparing the group following Good Agricultural Practices (GAP) standards with common farmers, the findings were as follows. In both groups of farmers, more than half were women (GAP = 44.44%, non-GAP = 43.33%), and there was no significant difference between the two groups ($p = 0.850$), showing that women play an important role in vegetable farming, which needs more careful work than growing field or industrial crops as summarized in **Table 2**. In terms of age, GAP farmers had an average age of 53.12 years, while the common group had an average age of 60.51 years, with a statistically significant difference ($p < 0.001$), reflecting that most GAP farmers were middle-aged, still had the potential to adapt, were more open to innovation, and adopted standard systems. This conclusion was consistent with the proposals indicating that younger age was positively associated with the adoption of agricultural innovation [26, 28]. As to educational level, GAP farmers had an average of 8.74 years of education, while the non-GAP group had an average of only 6.79 years, with a statistically significant difference ($p < 0.001$). This trend was consistent with the results of the studies indicating that education was a key human capital for promoting the decision to adopt new technologies [3, 10, 34]. As to vegetable-growing experience, GAP farmers had an average of 11.33 years, while the common group had only 8.44 years, with a statistically significant difference ($p = 0.014$). This conclusion was consistent the view that specialized experience is more influential than overall experience in determining technology adoption behaviour [23]. In terms of training on GAP standards, it was found that GAP farmers attended training an average of 5.28 times, while the common group attended only 3.16 times on average, with a statistically significant difference ($p < 0.001$), indicating GAP farmers' greater access to knowledge and support from the government authorities. This conclusion was consistent with findings that training significantly affected knowledge, attitudes, and adoption of innovation [26, 37]. Regarding landholding size, GAP farmers had an average area of 0.171 hectares, while the common group had only 0.09 hectares ($p < 0.001$). Moreover, the average income per production cycle of the GAP group was as high as 7,719 baht, or approximately 211.47 dollars, compared to the non-GAP group with only 2355 baht, or 64.52 dollars ($p < 0.001$), showing the economic advantage of the GAP group being able to invest and improve production systems to meet the standards more. This result was consistent with the view that economic capital and resources influenced the adoption of production standards [11, 35]. As for household structure, the GAP group had an average of 3.70 members, while the common group had 4.10 members, with a statistically significant difference ($p = 0.016$), probably indicating the characteristic of small households with higher flexibility in resource management.

Table 2. Comparison of social and economic differences classified by vegetable cultivation standards.

Variable	GAP (N= 180)			Non-GAP (N = 120)			*t*-Statistic
	Mean	SD	%	Mean	SD	%	
Gender of the farmer							
0 = Female	-	-	44.44	-	-	43.33	-0.189^{ns}
1= Male	-	-	55.56	-	-	56.67	
Age (years)	53.12	11.49		60.51	6.78		7.272^{***}
Education (year)	8.74	3.65		6.79	3.86		-4.373^{***}
Experience (year)	11.33	10.14		8.44	9.79		-2.470^{**}
Training (Number of times)	5.28	2.10		3.16	1.89		-9.125^{***}
Area (ha)	1.07	0.75		0.59	0.66		-5.921^{***}
Income ($)	7719	7175		2355	1602		-9.673^{***}
Member (person)	3.70	2.01		4.10	1.60		2.423^{**}
Opinions on the suitability of the planting area							
0 = No	-	-	13.33	-	-	48.33	-6.681^{***}
1 = Yes	-	-	86.67	-	-	51.67	

Note: Significant levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, ns = non-significant.

With respect to opinions on area suitability, it was found that 86.67% of GAP farmers assessed that their area was appropriate for growing safe vegetables, while only 51.67 percent of the common group had the same view, with a significant difference ($p < 0.001$). This supported the idea that emphasized that the availability of physical resources such as soil, water, and infrastructure was a major variable in the adoption of standard systems [18, 22, 28, 38]. Overall, the structural and behavioural differences between GAP farmers and common farmers indicated the important role of human capital, social networks, resources, and government support in driving the adoption of GAP standards at the local level effectively and sustainably.

From the data analysis in **Table 3**, it was found that farmers who cultivated vegetables according to GAP standards had significantly more access to diverse and high-value marketing channels than ordinary farmers. The majority of GAP farmers sold products through community markets, along with middlemen (52.22%). The other part was the sale through mixed channels that included niche markets or consumer groups (28.89%). Additionally, it was possible to sell to hospitals and private companies (2.22%) as channels with product safety and quality requirements. Meanwhile, non-GAP farmers mostly relied heavily on single-channel outlets, selling in community markets (49.17%) and depending solely on middlemen (14.17%) without access to high-standard markets. Significantly, 16.11% of GAP farmers were involved with institutionalized and high-end outlet markets such as hospitals or private companies, a pathway entirely missing among non-GAP farmers. This demonstrates the power of GAP certification in opening up higher-value markets that require food safety and quality. These results reflected the structural advantages of GAP farmers in accessing supply chains with specific standards and requirements. This was consistent with previous studies, which stated that GAP-certified farmers tended to access markets with high purchasing power and could significantly increase household income [12]. This also supported the findings that GAP helped increase bargaining power and expand distribution channels, especially in export markets [39]. These indications emphasize the structural benefits of adopting GAP: certified farmers diversified their marketing channels and not only invested in commercialization but also gained access to institutional markets with higher purchasing power and consistent demand. In this regard, the research suggested that farmers in networks or groups supported by the government sector were more likely to access market information, liaise with large buyers, and enter the market with a higher quality mechanism than the common group [31, 40]. Therefore, the adoption of GAP standards was not only effective at the farm level but was also a strategic factor in helping drive farmers' marketing capabilities, increase bargaining power, and enhance the economic potential of small-scale farmers at local and national levels sustainably [41].

Table 3. Vegetable product distribution locations of farmers classified by cultivation standards.

Distribution Location	**GAP Vegetable Farmer N = 180**		**Common Vegetable Farmers (Non-GAP) N = 120**	
	Number (Person)	**Percent**	**Number (Person)**	**Percent**
Community markets	0	0	59	49.17
Middlemen	0	0	17	14.17
Sell to groups	5	2.78	7	5.83
Community markets and middlemen	94	52.22	20	16.67
Middlemen and groups	0	0	14	11.67
Community markets, middlemen, selling to groups	52	28.89	3	2.50
Hospitals, middlemen, and community markets	25	13.89	0	0
Hospitals and private companies	4	2.22	0	0
Total	**180**	**100.00**	**120**	**100.00**

Source: Survey (2023).

3.2. Factors Affecting the Adoption of GAP Good Agricultural Practices (GAP) Standards by Small-Scale Vegetable Farmers

The factors associated with the adoption of Good Agricultural Practices (GAP) standards among small-scale vegetable farmers in the northeastern region of Thailand were assessed using binary logistic regression analysis, and the fit of the model was statistically significant (Chi-square = 206.031, df = 9; $p < 0.001$). High level of dependent variables explained variances were reflected by Cox and Snell R Square (0.497) and Nagelkerke R Square (0.672). The outcome indicated that the model could account for the 67.2 percent variance of the adoption behavior of GAP; the model was able to predict with an accurate rate of 89.3 percent, and the −2 log likelihood reached 197.776 as compared to GU, which was involved in predicting the outcome, signifying that the model was therefore efficient. From 9 independent variables, the statistically significant variables were 6, namely age (AGE), average income per production cycle (INC), suitability of cultivation area (LAN), number of times of training on GAP (TRE), number of household members (MEM), and number of education years (EDU). Notably, this model indicated that LAN (coefficient = 1.690, Exp(B) = 5.417; $p < 0.01$) was the most influential variable. This implies that farmers who evaluated their area as suitable for production through GAP are 5 times more likely or 441.7% more likely to adopt the standards compared to those in unsuitable areas, alluding to the impact of physical factors such as soil conditions, irrigation systems, drainage, and access to infrastructure on compliance with GAP requirements in practice. This implies that the GAP adoption is more likely to be adopted by farmers who have access to fertility and a regular supply of irrigation water, since these are factors that can limit production risks as well as catalyze GAP compliance. The outcome highlights the need for investment in soil conditioning and water conservation infrastructure. This aligns with the finding that the availability of natural resources is a key component in reducing adaptation costs and increasing its probability [22]. It also supports the view that, despite sufficient knowledge or motivation, farmers who lack these physical resources are unable to fully implement the standards [35]. In addition, the factors, average income per production cycle (INC), GAP training (TRE), and the number of education years (EDU) were positively correlated and statistically significant with the coefficient of INC as 0.001 and Exp (B) $= 1.001$ ($p < 0.01$), it implies that each additional unit increase in income would increase GAP adoption probability by approximately 0.1%. Although not high, the figures expressed that those farmers with a stable economic position were able to invest and modify their production processes better. The important effect of income suggests that if a household has higher or stable current-annual personal earnings, it is more capable of investing in production adjustments, which are required for GAP. Economic Capital: Catalyst and Condition. It appears that economic capital acts as an accelerator as well as a conditionality for adoption. In contrast, the negative coefficient of the household size indicates that bigger families face financial and labor constraints that limit their ability to adhere to GAP practices. These results have important policy implications: subsidies/grants or credit access for low-income and large families would alleviate the economic constraint to encourage more equitable adoption of GAP. This finding is in agreement with the studies [36, 42]. The important effects of income imply that child households with high or positive income are able to invest in presage changes imposed by GAP. This indicates that economic capital is both a motive and a condition for adoption. On the other hand, the negative influence of family size implies that larger families tend to be financially and labor-constrained, which may minimize their adaptive capacity to adopt GAP regulations. The findings have important policy implications: the provision of subsidies or credit access to low-income or large-household farmers can alleviate economic constraints and contribute to an inclusive adoption of GAP. The coefficient was 0.348 and Exp(B) $= 1.417$ ($p < 0.01$), meaning that the more a farmer attended training, the more likely a farmer was to adopt GAP up to 41.7%, which confirmed the role of knowledge promotion and attitude development of farmers [28, 43]. EDU Exp(B) $= 1.129$ ($p < 0.05$), suggesting every year of increased education would increase the odds that GAP was adopted by 12.9 percent. This aligned with the view that educated farmers were better able to evaluate the impacts, risks, and returns of innovation adoption [34]. All other factors, i.e., age (AGE) and the number of household members (MEM), negatively affected the same (**Table 3**). AGE's Exp(B) $= 0.914$ ($p < 0.01$) indicated that the increase in age by one year decreased the 8.6 percent chance of GAP adoption. This could be explained that innovation adoption theory, which provides the basis to understand that young farmers are comparatively more open towards change [24]. The household's members, Exp(B) $= 0.609$ ($p < 0.01$) of MEM, indicated that when one member was added, the household would have a 39.1 percent lower probability of adopting GAP, which was likely attributed to household resource constraints. This finding was in agreement with the view that increasing family burden is likely to discourage farmers from investing or taking the risks of changed production systems [35]. In short, the results of the analysis were consistent with the consequence that the promotion of GAP adoption should be carried out in an integrated manner that connects the merits of human capital, physical capital, and government supporting system to formulate spatial strategies to deal with effectively and sustainably with the restrictions faced by farmers and the particular potential of farmers in each region (**Table 4**).

Table 4. Factors affecting the adoption of GAP safe vegetable cultivation standards.

Variables	Coefficient	Wald	Exp(B)
GEN	-0.108^{ns}	0.084	0.898
AGE	-0.090^{***}	15.799	0.914
EDU	0.121^{**}	5.029	1.129
EXP	-0.006^{ns}	0.079	0.994

Table 4. *Cont.*

Variables	Coefficient	Wald	Exp(B)
INC	0.001***	17.861	1.001
ARE	−0.571*	3.570	0.565
TRE	0.348***	15.685	1.417
LAN	1.690***	11.595	5.417
MEM	−0.497***	8701	0.609
Constant	1.912	1.482	6.767
Predicted = 89.3, Cox and Snell R-squared = 0.497, Nagelkerke R Square = 0.672 –2 log likelihood = 197.776; Chi-square = 206.031; df = 9; p = 0.000			

Note: Significant levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, ns = non-significant.

4. Discussion

The results of the quantitative analysis based on the binary logistic regression model to analyze the factors of vegetable farmers in Northeastern Thailand adopting Good Agricultural Practices (GAP) standards showed that the suitability of the vegetable-growing area variable (LAN) was the most influential variable in the model, which had an odds ratio (Exp(B)) of 5.417, meaning that farmers with cultivation areas suitable for GAP standards-based production would have the highest likelihood of adopting and implementing the standards, 4.417 times greater than that of farmers with less suitable areas. What is unique in this study is its provincial scope of inquiry and unified analytical approach. Unlike some of the earlier studies conducted in Thailand that explored predominantly the national-level trends of GAP adoption [8], the evidence generated herein is specific to Kalasin Province, which still remains a low adopter, even though the government encourages adoption. What is also clear, even if studies here consolidated their findings with research in China and Indonesia, which focused on socio-economic and institutional determinants, is that structural factors such as land suitability (LAN) and household size (MEM) are equally important [12, 13]. This comparative examination demonstrates the context-specific nature of adoption dynamics and reinforces the value of our analysis in combining socio-economic, demographic, and structural factors in a unified model [43]. This factor explored the physical resources required for production systems, such as soil fertility, drainage systems, safety from contamination, and access to adequate water sources, which were items considered to enter into full compliance with GAP requirements and directly influenced the affordability of adaptation of production systems to comply with the standards (in terms of cost, time, and labor). This was in line with a study, which found that Irish farmers with farms endowed with physical resources such as good quality soil and water were more likely to adopt standardized systems. In the same context, a study in China found that farmers in lowland regions with high-quality irrigation systems were more likely to receive GAP certification compared to farmers facing environmental constraints who were more likely to have previously been able to access high-grade markets like supermarkets or export channels [20, 36]. The structural factors that significantly affected GAP participation were also evident in a study analyzing GAP promotion systems of developing Southeast Asian countries which emphasized farm resources such as soil, water, and topography [38].

Policy or training factors were secondary contributors. This is in line with the concept of "enabling resources," which suggests that the successful implementation of standards largely rests on access to underpinning basic resources, not merely motivation or awareness. Our findings were also confirmed by research on GAP adoption among vegetable farmers in Ecuador, which showed that farm physical factors such as land arrangement and access to water systems strongly influenced differentiation towards high-value market value chains [31]. By contrast, a study on GAP adoption by farmers in East Africa emphasized that continued participation in standards-holding markets directly dependent on the ability to act on the on-farm environment [21]. In addition to this, the research on farmers in the west of China found that infrastructure-related factors such as the management of on-farm water systems and the quality of soil resources were significantly and positively associated with GAP certification and access to the central market[33]. Hence, the adoption of the GAPs was not just a matter of farmers' attitude or motivation, but it embodied the structural conditions regarding natural resources, playing a role in the probability of effective compliance with the standards. Main strategic policies to promote GAP include the GAP zoning which refers to the distribution of areas deemed qualified and with high potential to be GAP promotion zones, allocation of a budget to support GAP promotion through infrastructure development such as irrigation systems, soil quality improvement, area analysis services, and technology transfer, enabling farmers to realistically access the GAP certification system sustainably and efficiently in the long term.

5. Conclusions

This study was to examine factors impacting the adoption of Good Agricultural Practices (GAP) standard among small-scale vegetable farmers in Northeast Thailand. The binary logistic regression model tested the association of independent variables with GAP adoption behaviour. The independent variables were peaches GAP adoption after statistically significant analysis of 6 independent variables that affected GAP adoption: the suitability of the vegetable-growing area, number of training times, average income per production cycle, number of education years, age of farmers, and number of household members. The variable, i.e., the suitability of vegetable-growing areas with the highest odds ratio, highlighted the significant role that physical resources play in supporting effective compliance with GAP standards. At the same time, factors of human and economic capital, including educational attainment, income level, and training, were positively correlated with the adoption of those standards. However, the factors, i.e., age and household members, had a negative association, which indicates that some groups of farmers have limitations associated with motivation, burden of household members with respect to involvement in agricultural practices, and also flexibility to adapt to technology changes.

The question that arises is that for farmers to adhere to GAP standards, contextual analysis in spatial structure, economy, society, and human capital is key. This leads us to the conclusion that encouraging farmers towards GAP standards is intrinsically linked to effective evaluation on the said fronts. In particular, focus should be given on the forging of agricultural infrastructure on growing GAP breeding (e.g., soil management, plot establishment, irrigation, and pollution control on agricultural plots) standards, development of GAP zoning strategies to identify high-potential areas, and custom-focused support. Moreover, the public sector must set up systems for training and transfer of GAP knowledge based on frequency, accessibility to target audiences, and compatibility with the capabilities of the localities, especially smallholder farmers with low income or education levels, who should have opportunities to develop their potential through lifelong learning and support from the respective agencies. It is also important that financial assistance is properly targeted to groups faced with structural constraints (e.g., households with high burdens or sensitive areas that need to be invested in improvement to actually access and comply with standards) to ensure that financial support produces the intended effectiveness. Simultaneously, there should be incentives sculpting certification systems and market access that reward farmers producing standard products, such as tying with niche markets or through government procurement systems. Such will generate an economic value of the GAP system and turn its implementation from just a technical burden into an opportunity to develop farmers' quality of life in a sustainable way. These measures all need systematic cooperation among the government and private sectors, local organizations, and civil society in order to better strengthen the safe, efficient agriculture ecosystem in accordance with international standards in the long run.

Author Contributions

S.P. conceptualized the study, designed the methodology, collected data, performed the analysis using binary logistic regression, and participated in writing the manuscript. K.M. participated in the data collection process, performed the statistical analysis, and was a major contributor in writing the manuscript and revising it critically for important intellectual content. Both authors have read and agreed to the published version of the manuscript.

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Not applicable.

Data Availability Statement

The datasets analyzed during the study are not publicly available due to privacy and ethical restrictions. However, interested parties may contact the corresponding author for further information.

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Conflicts of Interest

The authors declare no conflict of interest.

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