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Risks and Risk Management Strategies in Rubber Farming: Evidence from New Areas of Northeastern in Thailand

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ABSTRACT

Rubber plantations in Northeastern Thailand play a central role in poverty reduction, income generation, and rural livelihoods. Farmers in these areas face diverse risks that threaten production and income stability, making effective risk management essential. This study aims to identify key risks, examine the strategies used by farmers to manage them, and analyze the relationships between risk factors and management responses. Data were collected through structured household interviews with 260 farmers selected purposively from Ubon Ratchathani and Bueng Kan provinces. Factor analysis was employed to identify the dimensions of risk and management strategies, while path analysis was used to examine their interrelationships. The results revealed seven categories of risk: technical and management, production, price and market, natural disaster, income, middleman, and farm skill and competency. These factors together explained 63.63 percent of the total variance. Farmers adopted eight main categories of management strategies: participation in government programs, improvement of farm skills and workforces, sale of high-quality rubber through auction markets, flexible tapping systems, updated market and production information, engagement in farmer groups, household financial and debt management, and production diversification. These strategies explained 60.64 percent of the variance. Price and market risks were perceived at the highest level. They were positively associated with reliance on updated production and market information, and negatively associated with participation in government programs, auction market sales, and structured debt management. The findings suggest that most farmers are risk averse and rely primarily on reactive coping strategies rather than proactive approaches. To strengthen resilience, government support should move beyond short term assistance toward proactive strategies that include price stabilization mechanisms, forward contracts, income diversification, and climate adaptive practices.

Keywords: Agricultural risk, risk management, rubber farmers, production strategies, Thailand

INTRODUCTION

Rubber is one of the most important crops in Thailand and plays a vital role in both the national economy and rural livelihoods. It provides income for more than 1.7 million households and generates an annual economic value of over 300,000 million baht. Thailand has established itself as the leading producer and exporter of natural rubber worldwide, supplying industries in Asia, Europe, and North America. Since 2004, the government has encouraged the expansion of rubber plantations into nontraditional regions, particularly the Northeast and the North. This policy aimed to reduce rural poverty, create employment opportunities, and diversify the agricultural sector.

Provinces such as Ubon Ratchathani and Bueng Kan now represent the largest rubber areas in the Northeastern region.

Despite these opportunities, rubber production in the Northeast faces structural and environmental challenges that differentiate it from traditional growing areas in the South. Soils in the region are often shallow, poorly drained, or compacted, while land conversion from rice farming to rubber cultivation reduces productivity potential (Rubber Research Institute of Thailand, 2012). Climatic conditions further constrain production. Irregular rainfall, frequent drought, and rising temperatures have led to leaf destruction, dieback, and in severe cases tree mortality (Office of Agricultural Research and Development, 2013). These conditions make farmers in the region more vulnerable to production-related risks compared with their southern counterparts.

Economic pressures intensify this vulnerability. Farmers face volatile global rubber prices, high input costs, and dependence on intermediaries with greater bargaining power. After 2013, a steep decline in rubber prices reduced farm income and forced households into greater indebtedness. Some farmers responded with high frequency tapping during the leaf fall period in order to increase short term cash flow. This practice weakened tree health, lowered productivity, and reduced latex quality (Office of Agricultural Economics, 2019). Debt accumulated during the period of high prices in 2011 and 2012 has become more difficult to repay. At the same time, demographic changes and labor shortages have created new structural risks, particularly as the farming population grows older and the supply of farm labor declines (Bank of Thailand, 2019).

Previous research has highlighted risk perception and management among farmers of different crops and regions. Limsomboonchai et al. (2011) found that maize farmers in Nakhon Ratchasima identified drought, input costs, and price fluctuations as their main risks. Aditto (2013) showed that rice farmers in Khon Kaen regarded price volatility, yield uncertainty, and debt as critical concerns, with differences between irrigated and non irrigated areas. Kongmanee and Longpichai (2017) reported that rubber farmers in the South prioritized declining prices, rising input costs, and climate related risks, adopting strategies such as diversification, cost reduction, and off farm employment. Phraymool et al. (2018) observed that lychee farmers in central Thailand managed risks at a moderate level, with greater emphasis on production and farmer related risks. However, very limited research has addressed the unique conditions of rubber farmers in the Northeast, where ecological constraints, weaker market structures, and heavy dependence on government programs create a distinct set of challenges.

This study addresses that gap by analyzing the risks perceived by rubber farmers in Ubon Ratchathani and Bueng Kan and the strategies they use to manage them. The research examines both the magnitude of risks and the relationships between risk factors and management strategies. By doing so, it contributes new evidence on risk behavior in nontraditional rubber areas and informs policies that aim to improve farmer resilience and strengthen the sustainability of the rubber sector.

The objectives of this study are:

1. To identify and analyze the risks faced by rubber farmers in new planting areas of Northeast Thailand.
2. To examine the relationship between risk levels and the risk management strategies adopted by these farmers.

The remainder of the paper is organized as follows. The next section reviews the literature on agricultural risk and risk management, with attention to evidence from Thailand. The methodology section describes the study area, sampling procedures, data collection tools, and statistical techniques. The results section presents the socio economic characteristics of respondents, the factor analysis of risk perceptions, the classification of risk levels, the factor analysis of management strategies, and the findings from path analysis. The discussion section interprets the results in relation to previous studies and highlights implications for farmer behavior and policy. The final section presents the conclusion and suggestions, outlining policy directions and practical measures to strengthen resilience in the rubber sector of Northeastern Thailand.

LITERATURE REVIEW

Concept of Risk and Risk Management in Agriculture

Decision-making in agriculture inevitably involves uncertainties arising from physical, economic, and environmental changes. These uncertainties are shaped by climate variability, natural disasters, shifts in market demand, volatility in input and output prices, market imperfections, and unpredictable government policies. Such events affect not only farm-level production but also broader economic, environmental, and social systems (FAO, 2008). Agricultural risks are multidimensional, and their effective management requires an understanding of their diverse sources.

Scholars generally classify the sources of agricultural risk into four interrelated domains. Market and price risks originate from fluctuations in demand, supply, and production costs, which create unstable prices and undermine farmers' ability to predict future income. Production risks are linked to biological processes, which are highly

sensitive to weather conditions, pest and disease outbreaks, and natural disasters. Technological shifts may also contribute to reductions in agricultural output. Financial risks stem from uncertainties regarding interest rates, access to credit, and the capacity to service debt, all of which directly affect household stability. Institutional and legal risks, meanwhile, are associated with sudden changes in formal and informal institutions, policies, subsidies, and regulatory frameworks that shape production, marketing, and profitability.

Given the unpredictability of these risks, forecasting their patterns is crucial for improving risk management strategies (OECD, 2013). Risk management approaches can be broadly divided into ex ante measures, which are implemented before risks materialize, and ex post coping mechanisms, which are adopted after risks occur. Furthermore, FAO (2008) emphasizes that strategies may be aligned with the source of risk. For example, production risk management often involves crop diversification and adoption of flexible farming systems. Market and price risks can be mitigated through contractual agreements, direct marketing, and forward pricing. Financial risks may be managed by maintaining liquidity, assessing borrowing capacity, and employing insurance mechanisms. Institutional risks are often addressed through farmer participation in policy processes, close monitoring of government programs, and strengthening community networks.

Agricultural Risk and Risk Management Strategies in Thailand

Empirical studies in Thailand reveal the diversity of risks faced by farmers and the range of strategies employed to mitigate them. Limsombunchai et al. (2011) investigated maize farmers in Pak Chong District, Nakhon Ratchasima Province. Their findings highlighted drought as the most severe risk, followed by energy costs, rising seed and fertilizer prices, fluctuating maize prices, and floods. Farmers responded with multiple strategies, with participation in an income insurance scheme ranked highest, alongside maintaining creditworthiness for loan access, relying on government assistance in times of crop failure, selling farmland to exit farming, and, in extreme cases, abandoning agriculture altogether.

Aditto (2013) compared rice farmers within irrigated and non-irrigated zones in Khon Kaen Province to understand how different production environments shape risk perceptions. Both groups identified price fluctuations for inputs and outputs as the most significant risk, while also highlighting uncertainties in yield and high indebtedness as major concerns. Policy changes, economic fluctuations, and political instability were also considered crucial risk factors. Farmers in irrigated areas placed greater emphasis on the risks of flooding, excessive rainfall, and pest outbreaks, while those in non-irrigated areas perceived drought as the primary threat. Their management responses also diverged: farmers in irrigated zones stored seeds and feed and invested in machinery to reduce dependence on labor, whereas farmers in non-irrigated zones prioritized constructing reservoirs and farm ponds as well as seed storage.

Kongmanee and Longpichai (2017) turned their attention to rubber farmers in Southern Thailand. Their study identified a wide range of risks, including those associated with production, marketing, finance, labor, climate, natural disasters, and policy frameworks. Farmers perceived declining rubber prices and increasing input costs as the most pressing challenges, followed by climatic variability and financial risks. In response, they adopted strategies such as production diversification, cost reduction, flexible production systems, improved financial management, contractual labor arrangements, off-farm employment, and, in some cases, high-frequency tapping systems.

Finally, Praimoon et al. (2018) studied lychee farmers in Samut Songkhram Province, emphasizing the multidimensionality of risk management. Seven domains of risk management were identified, including production, marketing, policy, technology, finance, farmer-related, and climate-related risks. Farmers generally managed risks at a moderate level, with the most active engagement directed toward production-related challenges and those linked to farmer-specific characteristics. Table 1 synthesizes empirical studies on agricultural risk and management strategies in Thailand

Table 1. Summary of Key Studies on Agricultural Risk in Thailand

Author(s) and Year	Crop/Region	Key Risks Identified	Main Risk Management Strategies
Limsombunchai et al. (2011)	Maize, Pak Chong, Nakhon Ratchasima	Drought, energy costs, seed and fertilizer price increases, maize price fluctuations, floods	Income insurance, maintaining creditworthiness, reliance on government support, farmland sale, exit from farming
Aditto (2013)	Rice, Khon Kaen Province (irrigated vs. non-irrigated)	Input and output price volatility, yield uncertainty, indebtedness, policy and economic changes, drought or flooding	Seed and feed storage, acquisition of machinery (irrigated); construction of reservoirs, farm ponds, seed storage (non-irrigated)

Kongmanee & Longpichai (2017)	Rubber, Southern Thailand	Declining rubber prices, rising input costs, climate variability, financial risks, labor shortages	Production diversification, cost reduction, flexible production, financial management, contractual labor, off-farm employment, high-frequency tapping
Praimoon et al. (2018)	Lychee, Samut Songkhram	Production, marketing, government policy, technology, finance, farmer-related, and climate risks	Moderate overall management, with strongest focus on production-related and farmer-specific strategies

METHODS

Study Area and Sample Selection

This study was conducted in new rubber-growing areas of Northeastern Thailand. Purposive sampling was employed to select two provinces with the largest rubber plantation areas: Ubon Ratchathani and Bueng Kan. Within each province, districts were purposively chosen to ensure broad representation. Respondent selection was based on three criteria: (1) being the owner of a rubber plantation not exceeding 50 rai (approximately 8 hectares), (2) cultivating mature rubber trees currently in tapping stage, and (3) having at least one year of experience in rubber farming. From each province, 130 farmers were selected, resulting in a total sample size of 260 respondents.

Data Collection Tools and Procedures

Data were collected between April and June 2023 through household interviews using a structured questionnaire. The questionnaire was developed based on document analysis and refined through in-depth interviews with 30 key informants from the study areas. It was reviewed by subject matter experts to ensure content validity.The instrument consisted of three parts: demographic and farm characteristics, risk perception, and risk management strategies. Risk importance and likelihood were each assessed using a five-point Likert scale ranging from 1 (very low) to 5 (very high). Similarly, the perceived importance of risk management strategies was measured on a five-point scale from 1 (least important) to 5 (most important) (Kongmanee & Longpichai, 2017). The questionnaire was pre-tested with 10 rubber farmers from neighboring areas not included in the final sample. Feedback from the pre-test was used to refine wording, sequence, and clarity of items. This process ensured reliability and reduced ambiguity in responses.

Data Analysis

Data analysis followed three stages. First, **Principal Component Analysis (PCA)** was applied to identify underlying factors of farm risk and risk management strategies. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was required to exceed 0.50, and Bartlett's Test of Sphericity was set at a significance level of 0.05. Factor extraction was conducted using Varimax orthogonal rotation. Only components with eigenvalues greater than 1.0 were retained, and items with factor loadings above 0.40 were considered significant. Internal consistency was evaluated through Cronbach's Alpha, with a threshold of 0.50 or higher regarded as acceptable (Hair et al., 2009). Risk items and strategies reported by fewer than 20 percent of respondents were excluded prior to PCA. Second, the magnitude of each risk factor was calculated using the formula:

$$\text{Risk level} = \text{Perceived impact} \times \text{Likelihood}$$

The mean risk score was computed for each factor and classified into three levels based on Standards Australia (2004): low risk (1.00–8.99), moderate risk (9.00–14.99), and high risk (15.00–25.00).

Finally, Path Analysis was employed to examine the relationship between risk levels and risk management strategies. Path Analysis, as a component of Structural Equation Modeling (SEM), evaluates causal relationships among observed variables without the use of latent constructs. In this study, two groups of variables were modeled. The first group comprised the risk levels, derived from factor-analyzed mean scores of risk items across dimensions. The second group represented risk management strategies, constructed similarly from factor-analyzed mean scores of strategy items. Structural diagrams and regression-based equations were used to estimate direct and indirect effects. The results of the path analysis were used to identify how different levels of risk influenced the adoption of risk management strategies among rubber farmers.

RESULTS

Socio-economic Characteristics of Respondents

The socio-economic profile of the 260 sampled farmers is presented in Table 2. A majority of respondents were male (56.6%), while females accounted for 43.4%. The average age was 54 years, reflecting the predominance of middle-aged and elderly farmers in rubber production. With respect to education, 59.7% had completed only primary school, suggesting relatively low levels of formal education among the farming population. Rubber cultivation was identified as the main occupation for 87.3% of households, underscoring its role as a central source of livelihood.

Membership in farm groups or agricultural cooperatives was reported by 83.0% of respondents, indicating strong engagement in collective farming institutions. On average, households reported savings of 68,367.50 baht but carried a mean debt of 203,007.21 baht, suggesting that while some capital accumulation exists, debt burdens remain substantial. Family labor averaged 3.6 persons per household, with most members directly contributing to rubber production. Monthly household income averaged 17,983.15 baht, of which rubber farming contributed 10,928.61 baht, representing 60.8% of total household income. This reflects the high dependency of households on rubber cultivation for economic security.

In terms of landholdings, respondents reported an average of 25.70 rai, with the primary rubber plot averaging 13.03 rai. Most agricultural land was thus devoted exclusively to rubber cultivation. The average number of tapping days per year was 154, reflecting the seasonal rhythm of rubber harvesting. Average yield was reported at 339.7 kilograms per rai, serving as a benchmark for productivity assessment. Collectively, these findings highlight the vulnerability of rubber farmers, who are characterized by small to medium landholdings, strong reliance on rubber income, relatively low education levels, and considerable financial liabilities.

Table 2. Socio-economic characteristics of respondents (n = 260)

Variable	Result
Gender (%)	Male 56.6; Female 43.4
Age (years)	54.0
Education (%)	Primary school 59.7
Main occupation (%)	Rubber farming 87.3
Member of farm groups (%)	83.0
Savings (baht)	68,367.50
Debt (baht)	203,007.21
Family labor (persons)	3.60
Household income (baht/month)	17,983.15
Rubber income (baht/month)	10,928.61
Landholding (rai)	25.70
Rubber plot size (rai)	13.03
Tapping days (days/year)	154.0
Yield (kg/rai)	339.7

Perceived Risks of Rubber Farmers

The results of the factor analysis confirmed the suitability of the dataset, with a Kaiser-Meyer-Olkin (KMO) value of 0.893 and a statistically significant Bartlett's Test of Sphericity ($p < 0.01$). Seven components of risk were extracted, explaining 63.63% of the total variance. Cronbach's Alpha values ranged from 0.610 to 0.901, indicating acceptable to excellent internal consistency (Hair et al., 2009). Details of the factor loadings are presented in Table 3.

The first factor, Technical and farm management risk (R1), accounted for 22.95% of the variance and included poor farm practices such as limited fertilizer application, reliance on low-quality inputs, and inadequate financial capital. The second factor, Production risk (R2), explained 12.18% of the variance and reflected monoculture practices, declining yields, and the exclusive production of cup-lump rubber. The third factor, Price and market risk (R3), accounted for 10.24% of the variance and encompassed price volatility, global market downturns, rising input costs, and declining rubber demand.

The fourth factor, Natural disaster risk (R4), explained 5.88% of the variance and included storms, floods, and fire hazards. The fifth factor, Income risk (R5), contributed 4.89% of the variance and reflected declining incomes, rising household expenses, and dependence on rubber income. The sixth factor, Middleman risk (R6), explained 3.98% of the variance and was defined by price suppression and collusion among traders. The final factor, Farm skill and farmer competency risk (R7), accounted for 3.51% of the variance, capturing limitations in farmer knowledge, particularly in intercropping and diversified farming.

Table 3. Factor analysis of risk perception using Varimax rotation

Risk Lists	R1	R2	R3	R4	R5	R6	R7	communality
incorrectly use of latex stimulants	0.719	0.092	0.119	0.095	-0.003	0.102	0.067	0.806
not applying fertilizer	0.701	0.045	0.065	0.127	-0.006	0.129	0.004	0.770
use less fertilizer than usual	0.696	0.117	0.041	0.057	0.169	0.035	0.020	0.761
inadequate or insufficient capital for farm management	0.615	0.187	0.074	0.152	0.156	0.082	-0.035	0.752
the use of sulfuric acid	0.591	0.182	0.151	0.087	0.221	0.099	-0.056	0.750
using low-quality production inputs (fertilizers, chemicals, rubber clones)	0.511	0.127	0.181	0.104	0.084	0.123	0.077	0.817
monoculture rubber plantation	0.203	0.678	0.225	0.123	0.123	0.099	0.122	0.771
producing only cup-lump form of rubber	0.169	0.612	0.193	0.234	0.197	0.144	-0.031	0.734
declining rubber yield	0.263	0.601	0.042	0.153	0.059	0.101	0.185	0.741
rubber price volatility	0.147	0.051	0.748	0.134	0.039	0.006	0.098	0.688
global economic downturns or low rubber demand from china	0.177	0.135	0.667	0.003	0.064	0.136	0.023	0.692
rising production input costs	0.152	0.272	0.625	0.070	0.149	0.176	0.103	0.669
low rubber prices	0.204	0.117	0.541	0.013	0.119	0.033	-0.021	0.756
insufficient rainfall	0.189	0.160	0.111	0.735	0.112	-0.002	0.140	0.704
drought	0.114	0.332	0.224	0.711	-0.028	0.075	0.072	0.689
rising temperatures	0.210	0.074	0.093	0.565	0.170	-0.030	0.069	0.747
declining household income	0.151	0.188	0.081	0.136	0.781	0.129	0.128	0.640
rising household or farm expenses	0.029	0.173	0.103	0.153	0.741	0.100	0.077	0.657
sole dependence on rubber income	0.170	0.145	0.078	0.114	0.528	0.162	-0.035	0.637
price suppression by traders or middleman (e.g., manipulating scales or lowering drc)	0.207	0.211	0.154	0.050	0.081	0.792	0.047	0.650
trader or middlemen collusion	0.150	0.203	0.109	0.059	0.042	0.761	0.024	0.647
limited number of local traders/middlemen	-0.022	0.001	0.053	0.179	0.142	0.531	0.086	0.692
lack of agricultural skills, knowledge, and capability	0.200	0.188	0.114	-0.006	0.031	0.031	0.855	0.685
inadequate knowledge and experience with intercropping	0.044	0.158	0.019	-0.126	-0.007	-0.066	0.831	0.647
household heads being elderly or physically declining	-0.129	0.156	0.241	0.075	0.051	-0.100	0.733	0.717
Eigenvalues	9.14	4.37	3.75	2.52	2.12	1.93	1.68	
% total of Variance	22.95	12.18	10.24	5.88	4.89	3.98	3.51	
Cronbach's Alpha	0.901	0.866	0.777	0.760	0.735	0.610	0.667	

The risk levels derived from mean scores are summarized in Table 3. The highest-ranked risk was Price and market risk (mean = 20.20), followed by Income risk (mean = 17.20) and Production risk (mean = 16.10), all of which were classified as high. Technical and farm management risk (mean = 13.82), Natural disaster risk (mean = 13.63), Middleman risk (mean = 12.74), and Farm skills and competency risk (mean = 12.60) were classified as moderate. These findings indicate that rubber farmers perceive economic and market-related uncertainties as the most severe threats, while technical and institutional risks are viewed as less urgent but still significant.

Table 4. Risk levels of rubber farmers

Risk Factor	Mean	Risk Level
Price and market risk	20.20	High
Income risk	17.20	High
Production risk	16.10	High
Technical and farm management risk	13.82	Moderate
Natural disaster risk	13.63	Moderate
Middleman risk	12.74	Moderate
Farm skills and competency risk	12.60	Moderate

Risk Management Strategies of Rubber Farmers

Factor analysis of risk management strategies confirmed high data adequacy (KMO = 0.879, Bartlett's $p < 0.01$). Eight components were identified, explaining 60.64% of the variance, with Cronbach's Alpha values ranging from 0.688 to 0.838, indicating good reliability. The components are summarized as follows.

Participation in government programs (RMS1) explained 22.61% of the variance and reflected strategies such as involvement in policy formulation, collaboration with RAOT officials, and reliance on government input and income support schemes. Enhancing farm skills and workforce (RMS2) accounted for 10.77% and included training, workshops, online learning, and community support networks. Sales of high-quality rubber through auction markets (RMS3) contributed 6.99% and emphasized quality production and participation in RAOT-managed auction systems.

Flexibility of tapping systems (RMS4) explained 5.52% of the variance and highlighted adaptive tapping practices. Updated production and market information (RMS5) accounted for 4.70% and emphasized timely access to climate, market, and price data. Engagement with farm groups (RMS6) contributed 3.80% and reflected collective bargaining, cooperative purchasing, and group-based marketing. Household financial and debt management (RMS7) explained 3.22% and included debt restructuring and negotiation with financial institutions. Finally, Production diversification (RMS8) accounted for 3.03% of the variance and focused on cultivating alternative crops and raising livestock.

Table 5. Factor analysis of risk management strategies using Varimax rotation

Risk Management Strategies	**RS1**	**RS2**	**RS3**	**RS4**	**RS5**	**RS6**	**RS7**	**RS8**	**communality**
Participate in the rubber policy development, either individually or through farmer representatives	0.779	0.100	0.058	0.186	0.026	-0.118	0.068	0.078	0.665
Monitoring and assessing the effects of government policies and initiatives	0.763	0.038	0.237	0.174	0.161	-0.003	0.244	0.031	0.760
Work closely with RAOT officials	0.702	0.090	0.232	0.195	0.142	0.053	0.246	0.034	0.754
Getting support of production input from government programs	0.652	0.245	0.183	0.152	0.164	0.163	0.214	0.007	0.645
Obtaining income support from government programs (income insurance, income compensation)	0.611	0.261	0.051	-0.079	0.009	0.201	0.104	-0.070	0.630
Maintaining good relationships within the household and community	0.144	0.848	0.055	0.070	0.030	0.089	0.083	0.094	0.725
Undergoing annual health check-ups	0.087	0.835	0.121	-0.029	0.087	0.277	0.199	-0.033	0.641
Participating in study tours, training courses, and hands-on workshops related to agriculture (rubber, diversify, intercropping, etc.)	0.122	0.652	-0.030	-0.028	0.105	0.022	0.096	-0.044	0.680
Acquiring agricultural knowledge through online platforms (e.g., YouTube, Facebook, Line)	0.093	0.595	-0.049	-0.011	0.046	0.150	-0.143	0.182	0.677
Encouraging household members (children) to work at farms	0.123	0.528	0.120	0.057	0.036	0.014	0.098	0.006	0.661
Using rubber auction prices to sell rubber	0.144	-0.033	0.755	0.263	0.177	-0.005	0.231	0.094	0.698
Selling rubber in RAOT auction markets	0.221	0.108	0.735	0.056	0.086	0.189	0.067	0.054	0.735
Producing high-quality or certified-standard rubber products	0.078	0.033	0.710	-0.024	0.154	0.315	0.114	0.139	0.695
Pricing by rubber central markets (CRM)	0.121	-0.121	0.640	0.291	0.111	0.007	0.313	0.113	0.597
Flexibility of tapping time on rainy days (e.g., tapping later in the day or in the evening)	0.129	-0.134	0.066	0.767	0.025	0.022	-0.055	-0.027	0.751
Tapping on all non-rainy days during the rainy season	0.117	0.059	0.118	0.713	0.130	-0.035	0.058	0.027	0.706
Adjusting tapping schedules (e.g., during rainy or cold seasons)	0.133	-0.012	0.187	0.623	0.159	0.109	-0.039	0.079	0.742
Closely monitoring market information (e.g., rubber prices, input costs)	0.128	0.190	0.042	0.141	0.733	-0.029	0.344	0.101	0.730
Monitoring the impacts of global market changes	0.132	-0.066	0.126	0.157	0.722	0.257	0.074	-0.082	0.684
Keeping monitoring of and studying information related to climate change and natural disasters	0.239	0.051	0.074	0.146	0.681	0.217	0.013	-0.006	0.696
Installing firebreaks in nearby areas of rubber plantations	-0.075	0.228	0.210	0.170	0.635	-0.160	0.063	0.305	0.635
Participating in farmer groups or cooperatives to strengthen market bargaining power and sell products	0.090	0.201	-0.024	0.081	0.034	0.829	0.050	0.039	0.668
Establishment of farmer groups or cooperatives to arrange production and purchase production inputs collectively	-0.027	0.136	0.035	-0.038	0.092	0.783	0.117	0.132	0.617
Participating in farmer groups for processing rubber and farm products	0.121	0.212	0.124	0.078	0.341	0.693	0.131	0.068	0.625
Adjusting plans for repaying household loans	0.198	0.044	0.181	0.026	0.075	0.047	0.768	0.054	0.781

Risk Management Strategies	RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	communality
Negotiating a debt suspension arrangement with banks or other financial institutions	0.168	0.179	0.166	-0.009	0.038	0.205	0.757	0.016	0.769
Expanding the cultivation area for other economic crops (e.g., fruit trees, rice, cassava, sugarcane, vegetables, etc.)	0.024	-0.048	0.119	0.180	-0.008	0.035	0.105	0.811	0.730
Increasing the production of food and livestock for household consumption or commercial purposes	0.066	0.150	0.037	-0.074	0.141	0.155	0.025	0.785	0.724
Eigen values	10.81	3.88	2.49	2.26	1.85	1.76	1.57	1.44	
% total of Variance	22.61	10.77	6.99	5.52	4.70	3.80	3.22	3.03	
Cronbach's Alpha	0.838	0.787	0.781	0.766	0.692	0.688	0.827	0.689	

Relationship Between Risks and Risk Management Strategies

The results of the path analysis are presented in Figure 1 and Table 5. The model demonstrated a good fit, with $\chi^2 = 61.25$ (not significant) and $R^2 = 0.71$, indicating that the selected factors explained a substantial proportion of the variance in risk management strategies.

Technical and farm management risk (R1) was negatively associated with sales through auction markets (RMS3) and financial management (RMS7), but positively associated with information-seeking strategies (RMS5). Production risk (R2) was positively associated with debt management strategies (RMS7), suggesting that unstable yields directly influence financial behavior.

Price and market risk (R3) showed negative associations with government program participation (RMS1), auction market participation (RMS3), and debt management (RMS7), but a positive association with information seeking (RMS5). Natural disaster risk (R4) was positively associated with auction market strategies (RMS3) but negatively associated with tapping flexibility (RMS4) and information-seeking (RMS5).

Farm skill and competency risk (R7) was positively associated with farm group participation (RMS6) and diversification (RMS8), indicating that knowledge gaps lead farmers to rely on collective strategies and alternative income sources.

Table 6. Path analysis of relationships between risk factors and risk management strategies

R/RMS	Participation in government programs (RMS1)	Enhancing farm skills and work forces (RMS2)	Sales of high-quality rubber through rubber auction market (RMS3)	Flexibility of rubber tapping systems (RMS4)	Updated information of production and markets (RMS5)	Engagement with farm groups for production and market (RMS6)	Household financial and debt management (RMS7)	Production diversification (RMS8)
Technical and farm management risk (R1)			-0.025**		0.036**		-0.031*	
Production risk (R2)							0.050***	
Price and market risk (R3)	-0.020***		-0.022**		0.037**		-0.025**	
Natural disaster risk (R4)			0.015*	-0.012*	-0.025*			
Income risk (R5)								
Middleman risk (R6)								
Farm skill and farmer competency risk (R7)						0.018**		0.023**
χ^2= 61.25 AIC = 2,573.67 BIC = 2,676.12 R^2=0.71								

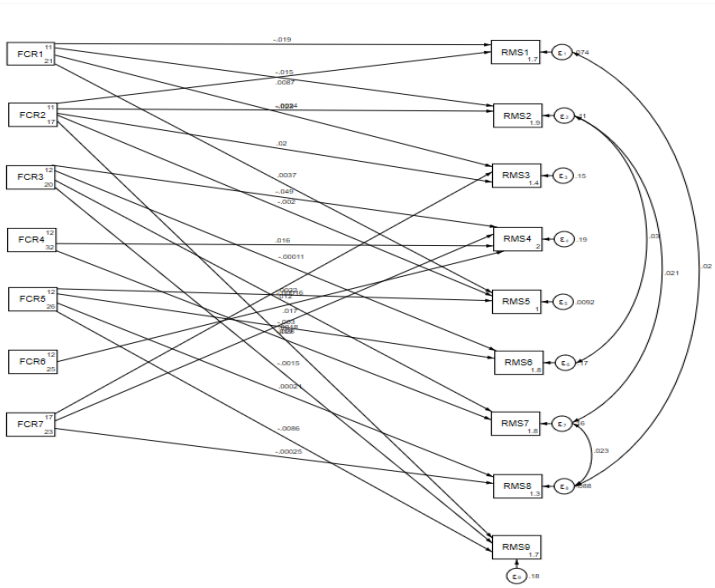

Figure 1. Path analysis of relationships between risk levels and management strategies of rubber farmers in Northeastern Thailand

DISCUSSION

Increasing Exposure to Market, Price, Income, and Financial Risks

The results of this study demonstrate that rubber farmers in newly established plantations in Northeastern Thailand face considerable risks from market volatility, declining prices, and unstable incomes. As reported in Table 4, price and market risk was ranked as the most significant factor, with an average score of 20.20, followed by income risk (mean = 17.20) and production risk (mean = 16.10). This contrasts with the findings of Kongmanee and Longpichai (2017) in Southern Thailand, where risk perceptions were more evenly distributed across production, marketing, financial, labor, climatic, natural disaster, government, and farmer-related categories.

The heightened sensitivity to price and income risks in the Northeast is consistent with national price trends. Between 2012 and 2019, the price of ribbed smoked sheets dropped from 96.97 THB/kg to 47.23 THB/kg, exposing farmers to sharp income losses. The underdeveloped nature of central and local rubber markets, combined with price suppression by intermediaries (see Table 3, Factor R6), further exacerbates exposure. These findings are aligned with OECD (2013), which identifies market and price fluctuations as among the most critical agricultural risks.

Production-related risks were also identified at a high level. Although technical and farm management risk was classified as moderate (mean = 13.82 in Table 4), farmers highlighted inadequate inputs, low-quality clones, and weak farm management practices as key concerns (see Table 3, Factor R1). This reflects the challenges of cultivating rubber in marginal areas with poor soils and irregular rainfall (Somkiat & Tipyarat, 2014; Kulwanaroj, 2017). Similar to Komarek et al. (2020), our findings indicate that production risks are amplified when farming technologies are not well adapted to local conditions or when adoption is incomplete.

Risk Management Strategies Focused on Mitigation but Not Fully Effective

The eight factors of risk management strategies derived from the factor analysis (see Table 5) reveal that farmers rely on a wide portfolio of measures, combining institutional support (RMS1, RMS6), human capital investment (RMS2), market-oriented strategies (RMS3, RMS5), adaptive production (RMS4), and financial coping mechanisms (RMS7, RMS8). Among these, participation in government programs (RMS1) emerged as the most dominant strategy, explaining 22.61% of the variance, underscoring the central role of state income support and policy interventions.

Compared with rubber farmers in Southern Thailand, who emphasized production diversification, labor management, and cost reduction (Kongmanee & Longpichai, 2017), farmers in the Northeast placed stronger reliance on government-led risk-sharing schemes, particularly income guarantee programs. Farmers also adopted auction sales of high-quality rubber, flexible tapping practices, and access to updated market information (see Table 5, Factors RMS3–RMS5) to mitigate price and market volatility. Engagement with farmer groups (RMS6) and production diversification (RMS8) were adopted to a lesser but notable extent.

However, the results of the path analysis (see Figure 1 and Table 6) suggest that some strategies may be reactive and insufficiently aligned with the sources of risk. For instance, technical and farm management risk (R1) was negatively associated with participation in quality-sensitive auction markets (RMS3), indicating that weak technical capacity limits entry into high-value channels. Similarly, price and market risk (R3) showed negative associations with government program participation (RMS1), auction markets (RMS3), and debt management (RMS7), but a positive association with information seeking (RMS5). This indicates that market volatility drives farmers toward short-term coping behaviors rather than structural solutions, reflecting the predominance of ex post rather than ex ante risk management (FAO, 2008; OECD, 2013).

Aligning Risk Management with Sources of Risk

While farmers employ a broad set of strategies, the degree of alignment between risk sources and management responses remains partial. For market and price risks, which were the most severe (Table 4), strategies included participation in government programs, auction sales, market information monitoring, and collective action (Table 5, RMS1, RMS3, RMS5, RMS6). Yet these approaches remain vulnerable to structural limitations, as they do not address underlying exposure to global price volatility. More effective approaches, such as price insurance, forward contracts, and futures markets (FAO, 2008; OECD, 2009; Glauber et al., 2021), remain underutilized or inaccessible to smallholders.

For income risks, farmers tended to increase tapping intensity or expand tapping days to sustain household earnings. While this approach mirrors coping strategies reported by Southern farmers (Kongmanee & Longpichai, 2017), it risks undermining tree health and long-term productivity. More sustainable responses should include income diversification, cost reduction, and structured financial planning. Our results (see Table 6) also show that production risks (R2) were positively associated with debt management strategies (RMS7), suggesting that farmers attempt to stabilize household finances in response to yield fluctuations.

Farm skill and competency risk (R7) was positively associated with engagement in farm groups (RMS6) and diversification strategies (RMS8), as shown in Table 6. This indicates that knowledge gaps drive reliance on collective mechanisms and alternative income sources. This finding highlights the potential role of farmer cooperatives and training programs in enhancing adaptive capacity.

Overall, the findings suggest that rubber farmers predominantly adopt risk-averse and reactive strategies that emphasize coping after risks materialize. To build resilience, greater emphasis is required on proactive ex ante strategies, such as improving production efficiency, adopting climate-smart practices, diversifying incomes, and integrating formal financial instruments. Policy interventions should focus on facilitating access to risk-sharing mechanisms, including income insurance and forward pricing, while simultaneously strengthening farmers' technical capacity and institutional networks.

CONCLUSION AND SUGGESTIONS

This study identified seven major sources of risk affecting rubber farmers in Northeastern Thailand. These include technical and farm management risks, production risks, price and market risks, middleman risks, natural disaster risks, income risks, and farm skill and competency risks. Together, these factors show the complex nature of vulnerability. Market and price risks were the most severe, driven by global price changes, higher input costs, and weak domestic markets. Income risks reflected the financial fragility of households that depend almost entirely on rubber. Production and management risks pointed to poor use of inputs, dependence on monoculture, and weak farm practices. Natural disaster risks reflected storms, floods, and fire events linked to climate change. Farm skill and competency risks showed the lack of technical knowledge and experience in alternative practices such as intercropping.

The analysis of risk management strategies revealed eight factors that can be grouped into three broad categories. The first group is risk mitigation, which includes strategies such as improving farm skills, adjusting tapping systems, monitoring market information, and diversifying production. The second group is risk coping, which involves responses after risks have occurred, such as joining government programs, selling high quality rubber through auction markets, and managing household finances. The third group is risk avoidance, which includes participation in farm groups and cooperatives that help farmers strengthen bargaining power and reduce exposure to market fluctuations. The findings suggest that farmers rely more on coping strategies than on proactive mitigation or avoidance.

Policy and Practical Suggestions

Price and market risks remain the most serious challenge. Farmers depend on government support and auction markets, but these are mostly reactive. There is a need to promote forward looking approaches such as price

stabilization schemes, forward contracts, and futures markets. The Rubber Authority of Thailand should play a stronger role in building cooperative based marketing channels and digital systems for price information to reduce the power of middlemen.

Farmers should reduce dependence on rubber by adopting mixed farming, agroforestry, and livestock production. Off farm and non farm employment opportunities can also improve household stability during periods of low prices. Training programs should promote financial literacy, income diversification, and awareness of farm risk management strategies.

Production risks must be addressed through proactive measures. Many farmers adopt technologies that are not suitable for their areas, which increases exposure to risk. Extension services should focus on locally adapted technologies such as improved rubber clones, fertilizer regimes, and tapping systems. Research and extension partnerships should promote area specific innovations that are both productive and cost effective. Good Agricultural Practices should be scaled up through training centers and on farm learning programs.

Climate variability has become a critical driver of risk. Climate resilient practices should be promoted, including the use of rain guards, latex stimulants, flexible tapping systems, and agroforestry. These efforts should be supported with financial and institutional measures such as affordable credit, crop insurance, and early warning systems. Stronger cooperatives will also help farmers adopt new technologies and strengthen resilience at the community level.

Rubber farmers in Northeastern Thailand remain vulnerable to market volatility, unstable income, and production challenges. Their strategies are mainly reactive and focus on coping after risks occur. A stronger policy focus on proactive measures is required. Improved market structures, diversified incomes, climate adaptive farming, and stronger institutional support will be essential for building a sustainable and resilient rubber sector.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The datasets used and analyzed during the current study are available from the first author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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