Research article

Assessing Determinants and Adoption Patterns of Sustainable Rice Cultivation in Central Northeast Thailand

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Abstract This study evaluated the determinants and adoption patterns associated with sustainable rice farming practices in Central Northeast Thailand. A sample of 109 farmers was selected using multistage sampling, targeting regions with a high number of GAP-certified or organic rice farmers. Data were collected through structured interviews and analyzed using descriptive statistics and stepwise regression. The findings revealed that the most widely adopted sustainable rice farming practice was manure application (89.91%), whereas more advanced practices, such as climate-smart or precision agriculture, exhibited low adoption rates (9.17%). Participation in farmer groups played a crucial role in promoting sustainable practices, with 93.75% of high adopters engaging in farmer groups, underscoring the importance of local institutions in facilitating adoption. Risk attitude also influenced adoption, with risk-tolerant farmers more likely to embrace sustainable practices, particularly among the high-adoption group (56.25%). Economic awareness was significantly correlated with higher adoption levels, with an average Likert score of 4.41 among high adopters. The regression analysis confirmed that farmer group participation and economic awareness had statistically significant positive effects on adoption, whereas risk aversion had a statistically significant negative effect. Additionally, challenges related to pest and weed management have encouraged farmers to seek more effective solutions, thereby facilitating the adoption of sustainable practices. These results indicate that enhancing local institutional support and promoting superior rice varieties are crucial for increasing sustainable rice farming practices in this region.

Keywords sustainable rice farming, adoption patterns, Central Northeast Thailand, farmer group participation, agronomic challenges

INTRODUCTION

Rice farming, a crucial component of Thailand's economy, is an enduring cultural and social fixture. Apart from its economic significance, rice is the national food of the Thai people. Rice is a symbol of food security and prosperity, and it plays an integral role in Thai traditions, rituals, and daily life. (Suebpongsang et al., 2020). Thailand's agriculture and economy revolve around rice production. Rice cultivation remains the cornerstone of Thai agriculture, with roughly 45-50% of the national agricultural land consistently devoted to it (FAO, 2025). Rice is Thailand's number one agricultural product, accounting for 15% of the agricultural gross domestic product (GDP). Rice is Thailand's second most valuable agricultural export. However, rice cultivation faces increasing challenges as it strives to balance productivity and sustainability. Climate change, fluctuating market demand, and increasing global market competition exacerbate the vulnerability of Thailand's rice farmers (IPCC, 2021). These challenges necessitate a shift toward more resilient and sustainable agricultural practices that can safeguard the future livelihoods of farmers and ensure the nation's food security. This transition is crucial for maintaining Thailand's competitive edge in the international rice market while addressing environmental concerns and meeting global sustainability targets (Connor et al., 2023).

Conventional rice farming practices worldwide, including dependence on synthetic fertilizers and chemical pesticides, have led to environmental and economic challenges. These practices are significant sources of greenhouse gases, such as methane and nitrous oxide, and thus lead to the worsening of climate change (Sari et al., 2023). In addition, the rapid development of intensive rice production systems has intensified soil degradation, water pollution, and ecological risks, particularly in developing regions of the world. These deleterious effects are mainly related to the overuse of agrochemicals to achieve high yields (Tran et al., 2024).

In response, sustainable agriculture has received growing attention as an option to reduce the rate of environmental degradation while continuing to guarantee food security and support rural farmers and communities. Rice production in particular is a resource-demanding and environmentally relevant crop. Rice paddy growing alone substantially contributes, both in terms of total yearly global methane emissions and water use (IPCC, 2021). For example, research in Northeast Thailand found that rice has significantly lower water productivity than other crops, such as field corn, highlighting its high-water demands (Promkhambut et al., 2014). As one of the world's leading rice producers, Thailand faces mounting pressure to transition toward more sustainable agricultural practices to address environmental and economic vulnerabilities.

This heightened awareness and the trade-offs between productivity and natural resource degradation have contributed to Thailand's promotion of sustainable farming practices, such as organic matter addition, crop rotation, and water-saving methods, such as alternate wetting and drying (AWD). These practices are increasingly recognized globally as achieving a good balance between high production and environmental sustainability (FAO, 2023). In the context of the most recent Food and Agriculture Organization (FAO) policy framework, sustainable rice systems and cultivation practices should improve productivity while conserving ecosystems, contributing to climate adaptation and mitigation (FAO, 2021). Likewise, the IPCC (2022) indicated that climate-resilient technologies, including reduced agrochemical use, AWD irrigation, and improved rice varieties, are crucial for reducing emissions and enhancing food security.

Despite the increased recognition of the benefits of sustainable agriculture by policymakers, researchers, and development organizations, the adoption rates of these practices among smallholder farmers remain limited (Pierrette et al., 2021). The adoption of sustainable methods is influenced by financial resources, attitudes towards risks, and knowledge of the economy of farmers (Pannell et al., 2006). This study aims to fill these knowledge gaps by analyzing the determinants and major drivers of the adoption patterns of sustainability-related practices for rice cultivation in Central Northeast Thailand. Utilizing descriptive statistics and stepwise regression analysis, this study identified key drivers of adoption, including farmer group affiliation, economic knowledge, and agronomic challenges, offering valuable insights for the development of future sustainability policies in Thailand.

OBJECTIVE

This study aimed to explore the socioeconomic, agronomic, and institutional factors influencing the adoption of sustainable rice farming practices. The research findings will provide insights for policymakers and stakeholders to design targeted interventions that promote sustainable rice farming and enhance farmers' resilience to environmental and economic challenges in the region.

METHODOLOGY

Study Areas, Data Collection, and Sampling Method

This study was conducted in the Maha Sarakham and Khon Kaen provinces in Central Northeastern Thailand, which are major rice-producing provinces. To provide broad data, Maha Sarakham Province was selected because of its primary irrigation reliance on a rain-fed ecosystem and the variable and unpredictable seasonal rainfall, and Khon Kaen Province was selected because of its access to a well-established irrigation system, including reservoirs and canal networks, that supports double-cropping.

This study utilized cross-sectional data collected through structured interviews with 109 rice farmers. The data encompassed household, demographic, and socioeconomic characteristics, land use, cultivation practices, input use, labor practices, production costs, organizational membership, agricultural experience, and farmer awareness of sustainable farming practices. Additional information included challenges in rice cultivation, problem-solving strategies, production goals, and participation in training and field visits.

The population for this study comprised rice farmers from the Central Northeastern region of Thailand who practiced sustainable rice production, including biocontrol and natural extraction methods. Given the absence of precise statistical data regarding the population, the sample size was estimated using a standard formula for sample size determination based on the proportions. Using a 95% confidence level (Z = 1.96), 5% margin of error (E), and estimated adoption proportion (p) of 7.63% (based on GAP and organic rice farming statistics) (Srisompun et al., 2019), the calculated sample size was 108.23. The sample size was rounded up to 109 farmers for the analysis.

A multistage sampling technique was used to ensure a representative sample of rice farmers who adopted sustainable practices. Farmers were purposively selected from Maha Sarakham and Khon Kaen provinces of Thailand. In each province, districts with the highest concentrations of GAP-certified or organic rice farmers were identified. From these districts, one sub-district per province was purposively sampled, and the farming households were listed. Finally, farmers were randomly selected using simple random sampling to ensure equal representation within the sub-districts.

Data Analysis and Model

Descriptive statistics and stepwise regression were used to analyze the data collected. The sustainable rice farming practice adoption patterns were summarised using descriptive statistics, describing these practices' frequencies compared with other planting practices, such as resource use. We used stepwise regression to investigate the determinants influencing the adoption of sustainable practices. The number of sustainable practices adopted was the dependent variable in the model, with independent variables being a combination of farmer characteristics (age, education, farm size, and income), institutional factors (farmer group participation and access to extension services), and agronomic challenges (pest and weed problems). Economic awareness was also included as a variable and was measured on a Likert scale ranging from 1 (very low) to 5 (very high). This method ensured that only the most impactful variables related to adoption were retained, as non-significant variables were removed (Frost, 2020).

RESULTS AND DISCUSSION

The study of the rates and scales of adaptation to recommended rice management practices by rice farmers in central northeastern Thailand reflects a varied picture of agricultural practices in the region. According to Table 1, the highest adoption level was for manure application, which was practiced by 89.91% of the farmers, indicating that it is widely accepted and perceived to be effective. On the other hand, modern techniques like Climate Smart or Precision Agriculture remained less adopted, at only 9.17%. The adoption rate of organic rice cultivation is moderate and is used by more than half (59.63%) of the farmers. Biocontrol and water-efficient rice varieties, although increasingly heavily promoted, still face limited adoption at 32.11% and 22.94%, respectively.

The rightmost columns in Table 1 present the adoption distribution of farmers by the 15 sustainable practices studied. These data demonstrate that some farmers applied only a few practices (13.89% applied four), while a smaller proportion adopted a wide range of sustainable practices.

Table 1 Adoption rates and patterns of sustainable rice practices among farmers

Sustainable rice practice	Number of farmers	% Adoption	Number of practices adopted	Number of farmers	% Adoption
Organic rice	65.00	59.63	0.00	1.00	0.93
System of rice intensification (SRI)	24.00	22.02	1.00	6.00	5.56
Apply manure	98.00	89.91	2.00	7.00	6.48
Reduce chemical fertilizers	81.00	74.31	3.00	4.00	3.7
Reduce pesticide	56.00	51.38	4.00	15.00	13.89
Crop rotation	51.00	46.79	5.00	14.00	12.96
Cover crop	33.00	30.28	6.00	10.00	9.26
Alternate wetting and drying	30.00	27.52	7.00	14.00	12.96
Direct seeding	8.00	7.34	8.00	6.00	5.56
Water conservation	28.00	25.69	9.00	8.00	7.41
Water-efficient rice varieties	25.00	22.94	10.00	8.00	7.41
Biocontrol	35.00	32.11	11.00	2.00	1.85
Natural extracts	33.00	30.28	12.00	8.00	7.41
Native rice varieties	25.00	22.94	13.00	1.00	0.93
Climate-smart/Precision agriculture	10.00	9.17	14.00	3.00	2.78
			15.00	1.00	0.93

Source: Authors survey. Note: The left side presents the adoption rates of individual practices; the right side presents the distribution of farmers by the total number of sustainable practices they adopted.

The analysis presented in Table 2 provides illuminating insights into the adoption levels across different farmer groups and their associated risk attitudes and economic indicators. The farmers were classified into three categories based on the number of sustainable practices adopted: minimal adoption (1–5 practices), medium adoption (6-10 practices), and high adoption (more than ten practices). A key observation was the significantly higher participation in farmer groups among the high adoption group (93.75%) than the low (57.45%) and medium (69.57%) groups. This suggests that group membership plays a vital role in promoting the adoption of sustainable practices, as farmer groups offer improved access to extension services and technical information (Mtega, 2021) and serve as effective channels for knowledge dissemination (Rahmadanih et al., 2018). This trend is paralleled by an increase in risk tolerance attitudes among the high adoption group (56.25%), suggesting a potential correlation between a farmer's willingness to embrace risk and their engagement in sustainable practices. Additionally, adoption levels increased with increased economic awareness, with the high adoption group scoring an average of 4.41 on a Likert scale, compared to 3.92 and 3.99 in the low and medium groups, respectively. This suggests that greater awareness of economic impacts may be linked to higher adoption rates. Furthermore, the high adoption group experienced the most substantial challenges with weed issues (62.5%), indicating that while these farmers are willing to adopt sustainable practices, they also face significant agronomic challenges in doing so.

The results of the stepwise regression analysis, presented in Table 3, highlight the critical factors influencing the adoption of sustainable agricultural practices. Of particular interest is that participation in farmer groups was a positive predictor (Beta = 1.557, $p = 0.011$). The results support earlier work underlining the importance of social networks and collective learning in increasing the adoption of innovative practices (Pretty, 2003; Bandiera and Rasul 2006). Farmer groups frequently operate as knowledge-sharing centers, where individuals gain insight from their peers and can efficiently connect to extension services, thereby alleviating the uncertainty surrounding sustainable adoption of new practices. However, risk attitude was negatively correlated with adopting sustainable practices (coefficient = −0.262; $p = 0.027$). This seems to indicate that risk-averse individuals do not adopt sustainable practices, as they perceive higher levels of uncertainty and lower short-term returns compared to existing conventional practices. This finding corresponds with that of Marra et al. (2023), who suggested that risk aversion may largely suppress the adoption of agricultural innovations, as they typically impose high switching costs in terms of either disruption to routine farming practices or upfront investments.

Table 2 Adoption levels of sustainable rice farming practices and associated risk and economic indicators

Variables	Group of adoption level[1/]			Overall
	Low	Medium	High	
Farmer group participation (%)	57.45	69.57	93.75	67.89
Risk attitude score				
- Risk lover (%)	23.40	23.91	56.25	28.44
- Medium risk (%)	55.32	63.04	43.75	56.88
- Risk aversion (%)	21.28	13.04	0	14.68
Issues faced (%)				
- Pest issues	2.13	13.04	25.00	10.09
- Weed issues	17.02	17.78	62.50	24.07
- Labour cost issues	2.13	28.26	18.75	15.60
Economic awareness (Likert 1–5)[2/]	3.92	3.99	4.41	4.02

Source: Author's Calculation

Note: [1/]Group of Adoption Level defined as: Minimal (<5 practices), Medium (6-10 practices), High (>10 practices).
[2/] Economic Awareness Scale: 1 = Very Low, 2 = Low, 3 = Medium, 4 = High, 5 = Very High.

Table 3 Stepwise regression results for factors influencing sustainable agriculture adoption

Variable	Coefficient	Std. error	t-statistic	p-value[1/]	
Farmer group participation	1.557	0.600	2.590	0.011	***
Risk attitude	− 0.262	0.117	− 2.240	0.027	**
Economic awareness	0.727	0.347	2.100	0.039	**
Pest issues	3.112	0.924	3.370	0.001	***
Weed issues	2.324	0.642	3.620	0.001	***
Labor cost issues	2.716	0.730	3.720	0.001	***
Constant	2.430	1.638	1.480	0.141	

Source: Author's Calculation

*Note: [1/] ** statistically significant at p-value ≤ 0.05; *** statistically significant at p-value ≤ 0.01*

The results indicate that economic awareness significantly and positively influences the adoption of sustainable agricultural practices, with a coefficient value of 0.727 ($p = 0.039$). This highlights how important economic incentives are in shaping farmer behavior. More precisely, when farmers recognize the economic benefits of sustainable practices such as lower input costs, increased efficiency, and access to premium markets they are more likely to adopt these practices. This is in line with the basic principles of the Diffusion of Innovation Theory (Xia et al., 2022), which states that innovation adoption is determined by its relative advantages. One of the most important components of relative advantage is economic benefit, which strongly influences decisions. For example, farmers who are aware of the cost savings associated with decreased chemical usage or higher selling prices for sustainable or certified products are more likely to adopt sustainable farming systems. In addition, economic incentives play a prominent role in adopting innovative processes in the agricultural sector. Taylor and Bhasme (2024) noted that farmers tend to abandon or reject innovations when the sustained economic benefits are not clear-cut, particularly if they do not match the socioecological context of those who could benefit from adopting new practices. They observed that farm and ranch sustainability is required to maintain the long-term adoption of agricultural innovations.

The analysis revealed that pest and weed management challenges significantly limited the adoption of sustainable agricultural methods, with coefficients of 3.112 and 2.324, respectively, and p-values of less than 0.001. These findings underscore the critical role of effective pest and weed control in crop performance and farm profitability. Farmers may perceive sustainable practices as less reliable in managing these issues than conventional methods, leading to adoption hesitancy. Farmers often view sustainable practices as inadequate for addressing pest and weed problems because they directly affect crop yields and economic returns. This perception creates a substantial barrier to the widespread implementation of sustainable methods (Finger et al., 2024). Conventional methods are often regarded as more efficient and reliable by farmers, particularly in pest and weed management, because of the quick and bio-efficient effects of spraying chemicals. In contrast, sustainable approaches, such as integrated pest management (IPM) or cover cropping, require more time, labor, and knowledge, with benefits that are less immediate or more difficult to quantify (Pretty, 2008). Such perceptions add to the resistance to alternative approaches, especially among farmers with a short-term financial outlook. It is essential to respond to these challenges with integrated and diverse strategies. Increasing extension services to deliver more specific training and local support may provide farmers with the skills, knowledge, and experience required to efficiently implement integrated management practices. Moreover, governments should provide financial incentives to facilitate the transition to more sustainable methods. Potential amendments to pricing schemes could include tiered pricing for biocontrol products to improve affordability, as well as subsidies or cost-sharing programs that reduce the economic burden associated with typically labor-intensive sustainable practices (Pannell et al., 2006).

Additionally, labor costs have emerged as a pivotal factor influencing the adoption of sustainable agricultural practices, as evidenced by a coefficient value of 2.716 ($p < 0.001$). In many sustainable practices, the labor-intensive nature often discourages their adoption, especially in locations with scarce and/or expensive labor availability. If farmers recognize a decrease in the total amount of labor required, they are more likely to adopt these practices. This agrees with previous studies, such as that by Silva and Ratnaweera (2020), who indicated that labor shortages and the high cost of labor are major obstacles to the adoption of input-intensive agricultural technology. Because the economic benefits of transitioning to sustainable practices are, in many cases, not immediate, the need for additional labor inputs further exacerbates farmers' reluctance to use sustainable methods. This calls for the development and diffusion of labor-saving technologies and working practices. To solve this challenge, mechanization, precision agriculture tools, and better management practices should all play an important role in decreasing the labor intensity of sustainable farming-type systems to make them more appealing to farmers. Chindasombatcharoen et al. (2024) argued that the adoption of such labor-saving innovations is crucial for the broader implementation of sustainable agricultural systems. By alleviating labor constraints, these technologies can not only improve efficiency but also foster greater resilience in agricultural systems, particularly in labor-constrained environments.

CONCLUSION

This study focused on the determinants of adoption of sustainable rice farming practices in the Maha Sarakham and Khon Kaen provinces in Central Northeast Thailand. The findings confirm that farmer group participation and economic awareness are key drivers of adoption, underlining the critical role of social networks and financial considerations in facilitating the transition to sustainable agriculture. Despite these benefits, the adoption of sustainable practices is uneven, as risk-averse farmers may be reluctant to adopt them because of perceived risks and short-term costs. There are also major challenges with agronomics, mainly weed and pest management and high labor requirements. Sustainable practices are often perceived as more labor-intensive and less effective for pest control than conventional methods, limiting their adoption in areas with labor constraints. To address these challenges and promote wider adoption, we propose the following recommendations.

1. Local institutions should be empowered by motivating farmer groups and cooperatives to improve learning, collective decision-making, and technical assistance to build trust, facilitate learning and evolution, and make sustainable practice adoption ready.
2. Encourage economic incentives, such as subsidizing sustainable inputs, market access, and premium pricing of certified sustainably produced rice. Such rewards lower financial risks and enhance the attractiveness of sustainable practices.
3. Government agencies, research institutions, and development partners should invest in appropriate technologies, such as labor-saving equipment, precision farming tools, and integrated pest management (IPM) solutions. This could reduce the physical effort required for sustainable farming, making such methods more effective and scalable.
4. Strengthening and updating extension services or their development, and the combination of sustainable agriculture in rural development programs with recurring analysis and feedback,

capacity building, and credit or crop insurance. Extension officers should be trained to address risk perception and help farmers build long-term resilience.

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ETHICAL STATEMENT

This study was conducted in accordance with the institutional ethical guidelines. Ethical approval was obtained from the Human Research Ethics Committee of Mahasarakham University (Approval No. [487-459/2567]). Prior to the interviews, all participants were informed about the purpose of the study, assured of the confidentiality of their responses, and provided written or verbal consent to participate voluntarily.

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