



The perceived efficiency and advantages of farm machinery: Evidence from paddy rice farmers in Nong Saeng district, Saraburi province, Thailand

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Abstract

Background and Objective: Farm mechanization plays a critical role in enhancing agricultural productivity. However, limited empirical evidence exists on how farmers' operational experience influences their perceptions of machinery efficiency and advantages. This study aimed to evaluate farmers' perceived efficiency and advantages of farm machinery and to examine the relationship between operational experience and these perceptions among paddy rice farmers in Nong Saeng district, Saraburi province, Thailand.

Methodology: A cross-sectional survey was conducted with 93 paddy rice farmers using a structured questionnaire. Perceived efficiency and advantages across six dimensions were assessed using a 5-point Likert scale. Data were analyzed using descriptive statistics and Spearman's rank correlation coefficient to determine relationships between years of operational experience and perception variables.

Main Results: Farmers generally rated farm machinery efficiency as high, with tractors receiving the highest scores, while trucks showed comparatively lower evaluations. Tractors were the only machinery consistently rated "very good" across all advantage dimensions. "Increased working speed" was the most positively perceived benefit across all machinery types. Correlation analysis revealed a significant negative relationship between operational experience and perceived efficiency for tractors ($r_s = -0.361$, $P < 0.05$). Additionally, longer experience with tractors was negatively associated with perceived advantages in multiple dimensions, including labor reduction, productivity, output quality,

and cost reduction. Similar negative correlations were observed in selected dimensions for other machinery types.

Conclusions: The findings indicate a perception gap between less experienced and more experienced users, with recent adopters exhibiting more favorable perceptions. This suggests the need for targeted extension strategies that consider farmers' experience levels to enhance perception accuracy and support sustained adoption of mechanization.

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INTRODUCTION

As the agricultural workforce contracts and the rural population ages, farm machinery has become increasingly essential for sustaining production levels. Mechanization not only scales food production but also enhances operational efficiency while lowering production costs and mitigating physical demands on farm labor (Rijk, 1986; 1989). Furthermore, the potential for mechanization to improve agricultural productivity and output quality may enhance the sector's economic viability, potentially revitalizing interest in agricultural careers among the youth (Daum, 2023).

Significant variation exists in the development and utilization of farm machinery across different farm scales, countries, and regions (Rijk, 1986; Takeshima and Salau, 2010; Paman *et al.*, 2018). While developed nations maintain advanced levels of mechanization, many developing countries are currently in a transitional phase toward comprehensive mechanization (Rijk, 1989; Mongkoltanatas, 1998; Paman *et al.*, 2018; Cramb and Thepent, 2020; Guru *et al.*, 2025). In Thailand, the agricultural sector has experienced a rapid expansion in the quantity, scale, and diversity of machinery (Thepent and Chamsing, 2009; National Statistical Office, 2013; 2024). However, smallholder

farmers continue to face challenges in machinery adoption and utilization (Thepent and Chamsing, 2009; Cramb and Thepent, 2020; Thailand Development Research Institute, 2020). For instance, small plot sizes impede efficient machinery operation, thereby reducing field capacity and increasing unit costs through higher energy consumption, particularly when deploying larger-scale equipment (Thailand Development Research Institute, 2020).

In the rice cultivation of Thailand's Central Plain Basin, the level of farm mechanization is the highest in the nation, approaching comprehensive mechanization (Soni, 2016; Cramb and Thepent, 2020). Land preparation typically utilizes tractors and power tiller-operated implements, followed by planting via rice transplanters. Crop maintenance is primarily conducted using knapsack sprayers and high-pressure pumps, while harvesting predominantly employs combine harvesters. Finally, for transporting the harvest to rice mills or local collectors, farmers utilize four- or six-wheel trucks.

A 2015 study on farm mechanization in the Asia-Pacific region indicated that Thailand's available farm power (2.50 kW/ha) was lower than China's (5.70 kW/ha), but exceeded that of India (2.02 kW/ha) and Vietnam (1.70 kW/ha) among Asian rice-producing

nations (Singh, 2015; Khan and Rehman, 2019). Within Southeast Asia, Thailand's mechanization level remains among the highest (Cramb and Thepent, 2020). Data from Thailand's National Statistical Office reveal that 71.35% of Thai farms currently utilize machinery (National Statistical Office, 2024). Specifically, 50.83% of these farms utilize four-wheel tractors, while 27.96% employ combine harvesters. The use of specialized equipment is also prevalent, with 35.36% of farms utilizing knapsack sprayers. Other equipment adoption rates range from 20% to 22%, including lawnmowers (22.06%), high-pressure water pumps (21.24%), and power tillers (20.94%), while planters remain less common at 12.61%.

Nonetheless, the adoption of farm machinery is a complex decision-making process, as characterized by Rogers' five-stage model of the innovation-decision process (Rogers, 2003). This sequential progression consists of five distinct stages: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation (Rogers, 2003). Previous studies have extensively analyzed the factors influencing the adoption of innovations – particularly farm machinery – including demographic characteristics, investment costs, market accessibility, economic incentives, institutional influences, and the effectiveness of the technology itself (Carrer *et al.*, 2017; Fischer and Wollni, 2018; Li *et al.*, 2019; Quan and Doluschitz, 2021).

While the adoption of agricultural technologies at Rogers' decision stage is influenced by diverse factors, utilization during the implementation stage depends heavily on the user's ongoing perception of benefits or advantages (Li *et al.*, 2020; Fragomeli *et al.*, 2024). However, previous scholarship has rarely examined users' perceived efficiency and advantages of agricultural technologies – and more specifically, how the length of operational experience correlates with these perceptions. Without an empirical understanding of this relationship, it remains difficult to determine whether users with varying levels of operational

experience require tailored communication to mitigate uncertainties, improve perceptions, and facilitate the confirmed adoption of agricultural technologies. Consequently, this study examined the perceived efficiency and advantages of farm machinery and analyzed the relationship between farmers' operational experience and these perceptions among paddy rice farmers in Nong Saeng district, Saraburi province, Thailand.

This research was guided by the following two research questions: (1) What are the perceived levels of efficiency and advantages reported by farmers across the various machinery types currently in use? and (2) To what extent does the length of operational experience (measured in years) correlate with farmers' perceptions of machinery efficiency and advantages? To this end, understanding farmers' perceived efficiency and advantages of farm machinery, and the relationship between their operational experience and these perceptions, can yield significant economic and social impacts. For agricultural extension officers, these findings provide critical insights to refine communication strategies and mitigate user uncertainties, thereby facilitating successful adoption. Furthermore, the results offer manufacturers data-driven indicators of which machinery types require technical enhancement, as lower assessments signal a demand for targeted research and development (R&D). Ultimately, aligning technology with farmers' specific needs enhances adoption rates, leading to improved agricultural productivity and elevated living standards for rural households.

MATERIALS AND METHODS

Study Area

The study was conducted in Nong Saeng district, Saraburi province, situated between latitudes 14°25'N and 14°32'N and longitudes 100°43'E and 100°52'E, in the upper central region of Thailand (Figure 1). Saraburi province encompasses 13

administrative districts, covering a total land area of 3,576 km² and forming part of the Chao Phraya Central Plain Basin (Saraburi Provincial Administration, 2024). As of December 2024, Saraburi had a population of 637,035, ranking 64th out of 77 provinces (Department of Provincial Administration, 2024).

Nong Saeng district is a key administrative division of Saraburi, covering approximately 87 km². It was selected for this study because it represents the largest agricultural area within the province (Nong Saeng District Agricultural Extension Office, 2022). Agriculture serves as the primary economic driver, with approximately 61.2% of the district's total area dedicated to crop and livestock production. The terrain is characterized by flat, low-lying clay soils, and approximately 90% of agricultural activities are supported by irrigation systems. The regional climate features an average annual rainfall of 1,133.6 mm, concentrated between July and September, with mean temperatures ranging from 25°C to 30.5°C (Nong Saeng District Agricultural Extension Office, 2022).

The district comprises 1,836 agricultural households, accounting for 35.8% of the total household population (Nong Saeng District Agricultural Extension Office, 2022). Among these farmers, approximately 87.98% identify agriculture as their primary occupation, while 12.02% pursue it as a secondary livelihood (Nong Saeng District Agricultural Extension Office, 2022). This distribution underscores the dominance of agriculture as the principal income source for the majority of Nong Saeng district. The average annual household income is approximately 267,747 Baht. Notably, many households maintain significant debt, primarily owed to the Bank for Agriculture and Agricultural Cooperatives (BAAC) (Nong Saeng District Agricultural Extension Office, 2022).

Predominantly, crop production in Nong Saeng district is dedicated to wet-season rice (98.3%), spanning an area of 52.36 km². The cultivation calendar involves planting from May to August and harvesting

from August to December, with peak activities occurring in June (planting) and November (harvesting). In 2021, the district's rice yield totaled 22,018.40 tons, with an average of 4.25 tons/ha, surpassing both the central regional and national averages (Nong Saeng District Agricultural Extension Office, 2022; Office of Agricultural Economics, 2023). Within irrigated areas, the production cost for wet-season rice is 26,788 Baht/ha, with sales revenue of 42,500 Baht/ha, yielding a net profit of 15,712 Baht/ha (Nong Saeng District Agricultural Extension Office, 2022).

In 2021, a significant majority (64%) of agricultural household heads in Nong Saeng district were over the age of 56 (Nong Saeng District Agricultural Extension Office, 2022). This demographic trend underscores a pressing need for farm mechanization to compensate for a declining agricultural labor force. Machinery requirements for rice production in Nong Saeng district are categorized into three primary functional areas: (1) land preparation, planting, and irrigation; (2) crop maintenance; and (3) harvesting and post-harvest transport (Nong Saeng District Agricultural Extension Office, 2022).

Research Design

This cross-sectional exploratory research examined farmers' perceived efficiency and advantages of farm machinery, focusing on paddy rice farmers in Nong Saeng district, Saraburi province, Thailand. The study employed a case study survey method to describe the characteristics of the target population (Chmiliar, 2010). From the total population of 1,836 agricultural households, the sample size was determined using Yamane's formula (Yamane, 1967). Based on a 95% confidence level and a 10% margin of error, the required sample size was calculated at 92. The final sample consisted of 93 paddy rice farmers.

As this was preliminary research, purposive and convenience sampling methods were employed to recruit research participants. The inclusion criteria were:



Figure 1 Map of the study area: Saraburi province, Thailand (left, shaded), and Nong Saeng district, Saraburi (right, shaded). Adapted from Wikipedia (2011; 2014), used under Creative Commons CC BY 3.0 and CC BY 4.0 licenses, respectively.

(1) active status as a paddy rice farmer in Nong Saeng district, Saraburi province; and (2) a voluntary willingness to participate in the research. Conversely, the exclusion criteria included: (1) farmers who did not cultivate rice, focusing instead on alternative crops or livestock production; and (2) individuals unwilling to participate or unable to complete at least 50% of the questionnaire. While these sampling methods may introduce potential bias and limit generalizability, the process was conducted in close consultation with an agricultural extension officer from Nong Saeng District Agricultural Extension Office. This officer possessed extensive experience and familiarity with the local farming community. Furthermore, the participants were located in a targeted site designated

for future projects aimed at upgrading the capabilities of rice farmer groups through agricultural machinery and smart farming technology.

Ethical Consideration

This research was conducted in accordance with international standards for the protection of human subjects. The research protocols were reviewed and approved by the Institutional Review Board (IRB) of the Office of the Research Ethics Review Committee for Research Involving Human Subjects at Chulalongkorn University. The research proposal underwent an expedited review category conducted by the Research Ethics Review Committee for Research Involving Human Subjects: The Second Allied Academic Group

in Social Sciences, Humanities, and Fine and Applied Arts. Ethical approval was granted on January 2, 2024 (COA No. 006/67).

Data Collection

Primary data were collected through face-to-face interviews using a structured questionnaire between January and February 2024. To ensure instrument validity, the questionnaire was developed following a pilot survey involving two rounds of consultation with potential farmer participants to gather specific insights on machinery utilization. The instrument was subsequently revised and verified by three experienced agricultural extension officers from Nong Saeng District Agricultural Extension Office, each possessing extensive expertise in farm mechanization. Additionally, secondary data regarding the demographic and socioeconomic characteristics of the district's farmers were provided by the same office.

The questionnaire consisted of two primary sections. The first section gathered demographic and professional background information, including gender, age, educational attainment, farming experience, and employment classification (primary or secondary/full-time or part-time). The second section focused on farm machinery utilization. Respondents identified the specific machinery currently in use and the year of adoption for each type. Subsequently, respondents evaluated their perceptions of the efficiency and advantages of the identified machinery.

A farmer's perceived efficiency regarding machinery refers to the degree to which an individual evaluates the operational performance of specific equipment. This encompasses a subjective appraisal of reliability, ease of use, and economic value, rather than objective mechanical metrics. Evaluations were recorded on a 5-point Likert scale, ranging from "very poor" (1) to "very good" (5).

Respondents further assessed the advantages of mechanized operations compared to traditional

manual methods across six distinct dimensions: (1) increased working speed, (2) reduced labor requirements, (3) higher output productivity, (4) improved output quality, (5) reduced farm inputs, and (6) lower overall production costs. For each dimension, an ordinal 5-point Likert scale was utilized, ranging from "very poor" (1) to "very good" (5).

To ensure a comprehensive analysis, the specific types of farm machinery were not predetermined. Respondents utilizing multiple machinery types provided individual evaluations for each. Conversely, participants did not rate equipment they did not currently employ. This approach was adopted to mitigate potential response bias, specifically under- or over-estimation, arising from a lack of direct operational experience (Lencsés *et al.*, 2014; Agussabti *et al.*, 2022).

In total, 93 face-to-face interviews were conducted, each lasting approximately 20–30 min. To maintain data integrity, the interviewer provided clarification when necessary, resulting in zero missing data points across the 93 completed questionnaires.

Data Analysis

Data from the 93 paddy rice farmers were analyzed using descriptive statistics, including frequencies, means, and standard deviations. Descriptive statistics were calculated for all identified machinery types. To interpret the findings, the calculated mean values for perceived efficiency and advantages were categorized according to the following criteria: 1.00–1.80 (very poor); 1.81–2.60 (poor); 2.61–3.40 (fair); 3.41–4.20 (good); and 4.21–5.00 (very good). Furthermore, Spearman's rank correlation coefficients (r_s) were employed to evaluate the relationships between farmers' operational experience, defined as the number of years from initial adoption to the survey year (2024), and their perceived efficiency and advantages of farm machinery. For the correlation analysis, the 5-point Likert scale responses for perceived efficiency and advantages were treated as

ordinal variables, while operational experience was measured as a continuous quantitative variable. The strength and direction of the relationship between operational experience and perceptions were determined with r_s values ranging from -1 to +1. A negative correlation indicates that the variables change in opposite directions, whereas a positive correlation indicates they move in the same direction. Statistical significance (P-value) was determined at the 1% and 5% probability levels. All statistical analyses were conducted using Microsoft Excel.

RESULTS AND DISCUSSION

Background of Farmers

The demographic and professional profiles of the 93 farmers were classified by gender, age, educational attainment, farming experience, and employment status, as summarized in Table 1. The data reveal that 63.44% of the respondents were female. Regarding age distribution, nearly half (48.39%) of the farmers were over 60 years old, while 47.31% were aged between 40 and 60. Notably, only 4.30%

were under the age of 40. These findings confirm a predominantly aging farmer population. In terms of education, the majority of respondents (58.07%) had completed primary education as their highest level of attainment. Furthermore, most farmers (58.06%) possessed more than 20 years of experience, whereas fewer than one-fifth (18.28%) had less than 10 years. Respondents were nearly equally divided between full-time (51.61%) and part-time (48.39%) employment.

Types of Farm Machinery

Farm machinery utilized by farmers in Nong Saeng district included heavy equipment for land preparation, planting, harvesting, and transport, as well as smaller implements for crop protection and maintenance. Heavy machinery consisted primarily of four-wheel tractors (26–67 kW) for land preparation. Power tiller-operated implements (6–11 kW) were also employed, particularly by farmers without four-wheel tractors, to invert soil, bury crop residues, and aerate fields prior to planting. For seeding, two-row planters were utilized. During the growing season, farmers

Table 1 Background information of the paddy rice farmers in the survey

Characteristics of farmers	Value	Frequencies	
		Count	Percentage
Gender	Male	34	36.56
	Female	59	63.44
Age	< 40 years	4	4.30
	40–60 years	44	47.31
	> 60 years	45	48.39
Education level	Primary	54	58.07
	Secondary	31	33.33
	Bachelor's	8	8.60
Farming experiences	1–5 years	9	9.68
	6–10 years	8	8.60
	11–20 years	22	23.66
	> 20 years	54	58.06
Classification of employment	Full-time	48	51.61
	Part-time	45	48.39

Note: Author's compilation based on the structure questionnaire

employed knapsack sprayers (15–20 L) for fertilizer and pesticide application. Water management relied on centrifugal water pumps (3.7–7.5 kW) for irrigation, while lawnmowers were used for weed control on field boundaries. Combine harvesters with cutting widths of 2.0–4.5 m were utilized for cutting, threshing, and cleaning grain. Finally, four- and six-wheel trucks were used to transport the harvest to the mills.

Utilization of Farm Machinery

Table 2 provides a summary of farm machinery utilization by type among the 93 sampled farmers. According to the survey, water pumps were the most commonly utilized farm machinery, with 78.49% (73 of the 93 respondents) employing them. Knapsack sprayers were the second most prevalent, used by 62.37% (58 respondents). The next most frequently utilized equipment included power tiller-operated implements, used by 58.06% of farmers (54 respondents), followed by combine harvesters (50 respondents). Other machineries, including four-wheel tractors (33 respondents), lawnmowers (22), two-row planters (11), and trucks (6), were utilized by fewer than 50% of the sampled farmers. These utilization patterns, characterized by a high reliance on knapsack sprayers and power tiller-operated implements, align with previous observations among smallholder farmers in the Philippines (Bautista *et al.*, 2017).

Farmers' Perceived Efficiency of Farm Machinery

Table 3 presents the farmers' perceived efficiency ratings for the eight machinery types, arranged in descending order. According to the survey, seven of the eight farm machinery types were perceived as having "very good" efficiency (4.21–5.00), while trucks were the only category rated as "good" (3.41–4.20). This suggests that the farmers were generally highly satisfied with their equipment's operational performance. Among the top five, four-wheel tractors received the highest mean efficiency ratings (4.69 ± 0.47), followed by combine harvesters (4.67 ± 0.56), knapsack sprayers (4.60 ± 0.53), power tiller-operated implements (4.52 ± 0.61), and water pumps (4.43 ± 0.60). Planters (4.27 ± 0.64) and lawnmowers (4.24 ± 0.62) were ranked sixth and seventh, respectively, while trucks received the lowest efficiency ratings (4.00 ± 0.00). These findings offer manufacturers and innovators critical insights into which machinery types require the most significant technical improvement. Specifically, equipment designs should incorporate features that accommodate small plot sizes to reduce unproductive time during headland turns and field access (Bautista *et al.*, 2017). For instance, a study in Central Thailand found that power tillers attached to moldboard plows achieved high efficiency due to superior maneuverability and travel speed during primary tillage (Khaehanchanpong, 2018).

Table 2 Farmers' utilization of farm machinery

Farm machinery	Frequencies	
	Count	Percentage
Water pump	73	78.49
Knapsack sprayer	58	62.37
Power tiller-operated implement	54	58.06
Combine harvester	50	53.76
Tractor	33	35.48
Lawnmower	22	23.66
Planter	11	11.83
Truck	6	6.45

Note: Author's compilation based on the structure questionnaire

Table 3 Farmers' perceived efficiency of farm machinery

Farm machinery	Average $\pm$ SD	Interpretation of perceived efficiency	Ranking
Tractor	4.69 $\pm$ 0.47	Very good	1 st
Combine harvester	4.67 $\pm$ 0.56	Very good	2 nd
Knapsack sprayer	4.60 $\pm$ 0.53	Very good	3 rd
Power tiller-operated implement	4.52 $\pm$ 0.61	Very good	4 th
Water pump	4.43 $\pm$ 0.60	Very good	5 th
Planter	4.27 $\pm$ 0.64	Very good	6 th
Lawnmower	4.24 $\pm$ 0.62	Very good	7 th
Truck	4.00 $\pm$ 0.00	Good	8 th

Note: The sample size utilized in this study consisted of a total of 93 farmers. The average was calculated on a 5-point Likert scale: from 5 (very good), 4 (good), 3 (fair), 2 (poor), and 1 (very poor). The average perceived efficiency was interpreted as follows: “very good” corresponds to a value between 4.21 and 5.00, “good” corresponds to a value between 3.41 and 4.20, “fair” corresponds to a value between 2.61 and 3.40, “poor” corresponds to a value between 1.81 and 2.60, and “very poor” corresponds to a value between 1.00 and 1.80. SD = standard deviation.

Farmers' Perceived Advantages of Farm Machinery

Tables 4–5 provide a detailed summary of these perceived advantages across the six identified dimensions. The findings reveal significant variations in how farmers perceived the advantages of different machinery types. Tractors were the only equipment to consistently achieve “very good” ratings (4.21–5.00) across all six dimensions of advantages. Knapsack sprayers ranked second, achieving “very good” ratings in four dimensions, while “reduced farm inputs” and “lower overall production costs” were evaluated as “good” (3.41–4.20). Combine harvesters, power tiller-operated implements, water pumps, and planters were similarly evaluated as “very good” for “increased working speed” and “reduced labor requirements”, but were rated “good” across all other dimensions. Finally, lawnmowers and trucks were perceived as “very good” exclusively in the “increased working speed” dimension. Other ratings for lawnmowers ranged from “fair” to “good” (2.61–4.20). Notably, trucks were the only machinery type to receive “poor” ratings (1.81–2.60) for “reduced farm inputs” and “lower overall production costs”, as well as “very poor”

ratings (1.00–1.80) for “higher output productivity” and “improved output quality”. These lower evaluations stem from the fact that trucks are utilized exclusively for hauling inputs and harvests, rather than for active rice cultivation (Bautista *et al.*, 2017). Overall, “increased working speed” was the only dimension to consistently achieve “very good” ratings across all machinery types evaluated. These findings suggest that while mechanization effectively addresses time and labor constraints, significant opportunities exist for research and development (R&D) to enhance output productivity, output quality, and overall cost-efficiency.

Correlation between Operational Experience and Perceived Efficiency and Advantages of Farm Machinery

As illustrated in Tables 6–7, Spearman's rank correlation analysis revealed a significant negative correlation specifically for tractors ($r_s = -0.361$, $P = 0.046$) between farmers' operational experience and their perceived efficiency. No significant correlations ($P > 0.050$) were observed for other machinery types.

This suggests that, for tractors exclusively, more recent adopters perceive higher machinery efficiency than their more experienced counterparts.

Additionally, significant negative correlations were observed between farmers' operational experience and the perceived advantages for specific machinery types across multiple dimensions (Tables 6–7). Farmers' operational experience with tractors was significantly negatively correlated with perceived advantages across four dimensions: reduced labor requirements ($r_s = -0.640$, $P = 0.000$), higher output productivity ($r_s = -0.503$, $P = 0.003$), improved output quality ($r_s = -0.458$, $P = 0.008$), and lower overall production costs ($r_s = -0.350$, $P = 0.049$). Similar negative correlations were identified for the "improved output quality" dimension regarding water pumps ($r_s = -0.294$, $P = 0.013$) and planters ($r_s = -0.605$, $P = 0.048$). Furthermore, significant negative correlations were observed for "lower overall production costs" in the case of combine harvesters ($r_s = -0.335$, $P = 0.024$) and "higher output productivity" for lawnmowers ($r_s = -0.602$, $P = 0.003$). These results indicate that more recent users, or those with less operational experience, perceive significantly higher advantages in these specific dimensions than those with more extensive experience.

These findings may suggest a higher degree of optimism among recent adopters compared to experienced users regarding the perceived efficiency and advantages of specific machinery. This aligns with previous research on precision farming technology adoption (Lencsés *et al.*, 2014), which indicates that

public information, such as that found in media or at exhibitions, is often more optimistic than the advantages realized in practice. Conversely, experienced users may lack updated information on emerging methods to improve the performance of their existing machinery. Furthermore, experienced farmers may evaluate efficiency and advantages more critically due to the cumulative impact of rising maintenance and fuel costs over time. This reinforces the importance of increased consultation with farmers regarding their specific operational needs, alongside tailored communication strategies that address the varying concerns of different user groups (Aubert *et al.*, 2012; Clark *et al.*, 2018; Bolfe *et al.*, 2020; Li *et al.*, 2020; von Veltheim and Heise, 2021; Agussabti *et al.*, 2022; Fragomeli *et al.*, 2024).

In terms of practical implications, the findings from Nong Saeng district suggest that extension officers and farm machinery providers should enhance consultation with diverse farmer groups to better understand their perceptions of equipment efficiency and advantages. Strengthening these communication engagements may improve how farmers perceive the intrinsic value of farm mechanization. Enhancing these perceptions during the implementation stage can facilitate the critical transition to the confirmation stage (Rogers, 2003; Azumah *et al.*, 2022; Kamondetdacha, 2025). Ultimately, such strategic actions may contribute to higher levels of farm mechanization, improved agricultural productivity, and enhanced livelihoods for the farmers and their families.

Table 4 Farmers' perceived advantages of farm machinery: tractor, knapsack sprayer, combined harvester, and power tiller-operated implement

Perceived advantages of farm machinery	Tractor		Knapsack sprayer		Combine harvester		Power tiller-operated implement	
	Average $\pm$ SD	Interpretation	Average $\pm$ SD	Interpretation	Average $\pm$ SD	Interpretation	Average $\pm$ SD	Interpretation
Increased working speed	4.45 $\pm$ 0.62	Very good	4.43 $\pm$ 0.57	Very good	4.78 $\pm$ 0.42	Very good	4.37 $\pm$ 0.59	Very good
Reduced labor requirements	4.61 $\pm$ 0.61	Very good	4.52 $\pm$ 0.63	Very good	4.49 $\pm$ 0.58	Very good	4.54 $\pm$ 0.69	Very good
Higher output productivity	4.30 $\pm$ 0.92	Very good	4.36 $\pm$ 0.62	Very good	3.76 $\pm$ 1.45	Good	4.11 $\pm$ 1.13	Good
Improved output quality	4.33 $\pm$ 0.92	Very good	4.40 $\pm$ 0.65	Very good	3.81 $\pm$ 1.33	Good	4.06 $\pm$ 1.17	Good
Reduced farm inputs	4.42 $\pm$ 0.79	Very good	4.14 $\pm$ 0.87	Good	3.90 $\pm$ 1.29	Good	4.04 $\pm$ 1.05	Good
Lower overall production costs	4.42 $\pm$ 0.83	Very good	3.95 $\pm$ 1.34	Good	3.75 $\pm$ 1.36	Good	4.04 $\pm$ 1.30	Good

Note: The sample size utilized in this study consisted of a total of 93 farmers. The average was calculated on a 5-point Likert scale: from 5 (very good), 4 (good), 3 (fair), 2 (poor), and 1 (very poor). The average perceived advantage score was interpreted as follows: "very good" corresponds to a value between 4.21 and 5.00, "good" corresponds to a value between 3.41 and 4.20, "fair" corresponds to a value between 2.61 and 3.40, "poor" corresponds to a value between 1.81 and 2.60, and "very poor" corresponds to a value between 1.00 and 1.80. SD = standard deviation.

Table 5 Farmers' perceived advantages of farm machinery: water pump, planter, lawnmower, and truck

Perceived advantages of farm machinery	Water pump		Planter		Lawnmower		Truck	
	Average $\pm$ SD	Interpretation	Average $\pm$ SD	Interpretation	Average $\pm$ SD	Interpretation	Average $\pm$ SD	Interpretation
Increased working speed	4.33 $\pm$ 0.63	Very good	4.27 $\pm$ 0.65	Very good	4.32 $\pm$ 0.72	Very good	4.50 $\pm$ 0.55	Very good
Reduced labor requirements	4.46 $\pm$ 0.65	Very good	4.36 $\pm$ 0.67	Very good	4.05 $\pm$ 0.65	Good	3.67 $\pm$ 0.52	Good
Higher output productivity	4.06 $\pm$ 1.11	Good	4.09 $\pm$ 0.83	Good	4.09 $\pm$ 0.61	Good	1.67 $\pm$ 0.52	Very poor
Improved output quality	4.11 $\pm$ 1.07	Good	3.55 $\pm$ 0.93	Good	3.86 $\pm$ 0.94	Good	1.50 $\pm$ 0.84	Very poor
Reduced farm inputs	4.14 $\pm$ 1.07	Good	4.09 $\pm$ 0.70	Good	3.55 $\pm$ 1.01	Good	2.33 $\pm$ 1.03	Poor
Lower overall production costs	3.89 $\pm$ 1.30	Good	3.45 $\pm$ 0.82	Good	3.27 $\pm$ 1.49	Fair	2.17 $\pm$ 0.98	Poor

Note: The sample size utilized in this study consisted of a total of 93 farmers. The average was calculated on a 5-point Likert scale: from 5 (very good), 4 (good), 3 (fair), 2 (poor), and 1 (very poor). The average perceived advantage score was interpreted as follows: "very good" corresponds to a value between 4.21 and 5.00, "good" corresponds to a value between 3.41 and 4.20, "fair" corresponds to a value between 2.61 and 3.40, "poor" corresponds to a value between 1.81 and 2.60, and "very poor" corresponds to a value between 1.00 and 1.80. SD = standard deviation.

Table 6 The Spearman's rank correlation coefficient (r_s) between farmers' operational experience and farmers' perceived efficiency, and advantages of farm machinery: tractor, knapsack sprayer, combined harvester, and power tiller-operated implement

Factors	Tractor		Knapsack sprayer		Combine harvester		Power tiller-operated implement	
	r_s	P-value	r_s	P-value	r_s	P-value	r_s	P-value
Perceived efficiency	-0.361	0.046	-0.155	0.253	-0.263	0.078	0.042	0.762
Perceived advantages								
Increased working speed	-0.341	0.056	-0.209	0.118	-0.062	0.683	-0.052	0.711
Reduced labor requirements	-0.640	0.000	-0.095	0.482	-0.030	0.841	-0.181	0.190
Higher output productivity	-0.503	0.003	0.051	0.707	-0.283	0.056	-0.167	0.228
Improved output quality	-0.458	0.008	-0.130	0.340	-0.265	0.079	-0.194	0.160
Reduced farm inputs	-0.225	0.216	-0.158	0.240	-0.250	0.098	-0.063	0.652
Lower overall production costs	-0.350	0.049	-0.207	0.126	-0.335	0.024	-0.204	0.139

Table 7 The Spearman's rank correlation coefficient (r_s) between farmers' operational experience and farmers' perceived efficiency, and advantages of farm machinery: water pump, planter, lawnmower, and truck

Factors	Water pump		Planter		Lawnmower		Truck	
	r_s	P-value	r_s	P-value	r_s	P-value	r_s	P-value
Perceived efficiency	-0.097	0.423	-0.164	0.629	-0.306	0.177	-0.220	0.675
Perceived advantages								
Increased working speed	-0.123	0.307	0.144	0.673	-0.118	0.601	0.311	0.548
Reduced labor requirements	0.047	0.698	0.374	0.257	-0.080	0.724	0.220	0.675
Higher output productivity	-0.112	0.354	-0.160	0.638	-0.602	0.003	-0.440	0.383
Improved output quality	-0.294	0.013	-0.605	0.048	-0.306	0.165	-0.575	0.233
Reduced farm inputs	-0.176	0.142	-0.124	0.717	-0.381	0.080	-0.097	0.855
Lower overall production costs	-0.165	0.169	-0.512	0.107	-0.322	0.144	-0.164	0.756

CONCLUSIONS

This study examined the perceived efficiency and advantages of farm machinery among paddy rice farmers in Nong Saeng district, Saraburi province, Thailand. The findings indicate that farmers' perceptions vary significantly across eight types of farm machinery. Notably, only tractors exhibited a significant negative correlation ($r_s = -0.361$, $P = 0.046$) between operational experience and perceived efficiency, whereas no significant correlations were observed for other equipment types. However, divergent patterns of negative correlation emerged when examining specific dimensions of perceived advantage. These results suggest the existence of a 'perception gap' between user groups. This gap implies that recent adopters may hold overly optimistic views of machinery performance, while experienced users may lack the updated information necessary to optimize their existing equipment.

While this study provides valuable insights into farmers' perceptions, several limitations must be noted. Firstly, the cross-sectional design captures only a single point in time, which prevents the establishment of a definitive causal relationship between experience and perception. Secondly, the reliance on self-reported measures for efficiency and advantages may introduce subjective bias compared to objective mechanical performance data. Furthermore, certain machinery

types, specifically planters and trucks, had low reporting rates (less than 20% of the sample). Consequently, these specific findings should be considered exploratory. To address these limitations, future research should incorporate objective performance metrics to bridge the gap between subjective perceptions and technical data. Additionally, longitudinal studies with larger sample sizes are essential to confirm these trends over time.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this research.

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