Journal of Multidisciplinary in Social Sciences
Journal homepage : https://so03.tci-thaijo.org/index.php/sduhs

The Dynamics of Farm Machinery Adoption among Rice and Maize Farmers in Nan, Thailand

Rungroge Kamondetdacha*

School of Agricultural Resources, Chulalongkorn University, Bangkok, 10330 Thailand

Article info

Article history:
Received: 13 May 2025
Revised: 10 October 2025
Accepted: 17 October 2025

Keywords:
Innovation-decision process, Adoption, Discontinuance, Rejection

Abstract

This study employed Rogers' five-stage model of the innovation-decision process to investigate the dynamics of farm machinery adoption, with a particular focus on the confirmation stage. An exploratory case study survey was conducted with 18 rice and maize farmers in Wiang-Sa district, Nan province, Thailand. Participants were recruited using purposive and convenience sampling methods, and data were analyzed through thematic analysis. The findings revealed four decision patterns: continued adoption, discontinuance, later adoption, and continued rejection. Two key rationales underpinning these decisions were identified: the perceived effectiveness of farm machinery and the availability of financial resources for adoption. From a policy perspective, the study suggests that research and development on farm machinery should be strengthened to enhance its effectiveness, while agricultural extension services should provide guidance on the selection and use of appropriate machinery. Furthermore, it is recommended that tailored financial measures, such as low-interest loans and subsidies, be introduced to support farmers with investment potential but insufficient financial resources.

Introduction

As the agricultural workforce shrinks and the remaining population ages, farm machinery becomes increasingly crucial for maintaining production levels. Farm machinery increases food production and makes farm work more efficient. It also helps to lower production costs and reduce the physical demands on farm workers (Rijk, 1986; 1989). In addition, the potential of farm machinery and mechanization to increase agricultural efficiency and productivity may contribute to making the agricultural sector more economically attractive and potentially spark a renewed interest in agricultural careers among young people.

While farm machinery holds potential, several factors can influence its widespread adoption among farmers. There are a number of studies that have analyzed the factors influencing the adoption of farm machinery by farmers (Azumah et al., 2022; Carrer et al., 2017; Donkoh et al., 2019; Fischer & Wollni, 2018; Fischer et al., 2018; Li et al., 2018). These factors include demographic characteristics, costs and availability of machinery, market access, economic incentives, institutional influences as well as the attributes of the

* Corresponding Author
email: Rungroge.K@chula.ac.th

machinery itself. In essence, these studies offer valuable insights that not only deepen our understanding of farm machinery adoption by farmers but also suggest potential policy recommendations for its continued support.

The adoption of farm machinery by farmers, however, is better characterized as a continuous decision-making process rather than a single adoption choice. This dynamic nature of decision-making aligns with Rogers' conceptual work on the innovation-decision process, a five-stage model that captures the progression of an individual's adoption of an innovation. This model outlines a sequential progression through time comprised of: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation stages. Yet, with a substantial body of literature already dedicated to the decision stage or the first point of adoption or non-adoption, the studies exploring the confirmation stage, crucial for understanding the process' dynamic nature, remain extremely scarce. Furthermore, previous studies examining the decisions of individuals regarding discontinuance after previously adopting or maintaining rejection of the innovation are particularly rare (Azumah et al., 2022; Rogers, 2003). This dearth of research on the confirmation stage highlights a significant gap in understanding with regards to the innovation-decision process, particularly concerning farm machinery.

This study aims to address a significant gap in existing literature regarding the dynamic nature of the technology adoption process. Specifically, it investigates the confirmation stage, the period following initial adoption, where individuals may continue, discontinue, switch, or maintain a rejection of a technology (Rogers, 2003). It uses a case concerning farm machinery adoption among rice and maize farmers in the Wiang-Sa district of Nan province, Thailand to explore the dynamics of farm machinery adoption through an understanding of the underlying rationals or motivations behind farmers' decisions at the confirmation stage. To this end, this understanding can potentially have significant economic and social impacts on the agricultural sector. Adopting farm machinery can increase agricultural output and quality and also lead to improved living standards for farmers and their families. In addition, the Nan context is highly relevant because there have been recent changes in development strategies, economic incentives, and institutions in the agricultural sector in Nan province, Thailand towards sustainability (Kamondetdacha & Janhom, 2022; Tanwattana et al., 2018). Nan's focus on its local food systems aligns with the need for sustainable and resilient agricultural practices, which often require the adoption of farm machinery.

Objectives

This exploratory case study research of rice and maize farmers in Nan, Thailand has two objectives.

1) To understand the underlying rational or motivations behind farmers' decisions regarding farm machinery adoption at the confirmation stage

2) To suggest policy recommendations for improving farm mechanization in Thailand, as the key factors influencing farmers' decisions on farm machinery adoption are uncovered

Conceptual Framework

Farm Machinery Development and Utilization in Thailand

The increasing utilization of farm machinery has become a critical factor in sustaining agricultural production levels while mitigating the challenges associated with an aging farmer population. It contributes to the reduction of production costs and the alleviation of physical demands placed upon farm workers (Rijk, 1986; 1989). In the domain of agriculture, farm machinery encompasses a diverse array of power-driven equipment utilized for the execution of various farm operations. Normally, the adoption of farm machinery progresses through distinct stages (Takeshima & Salau, 2010). Initially, power-intensive machines with little control replace human labor for tasks requiring high power. Later, the focus shifts to control-intensive machines, mechanizing tasks demanding greater operational control. Ultimately, this progression culminates in the automation of agricultural production.

There is a significant variation in farm machinery development and utilization across farm sizes, countries, and regions (Paman et al., 2018; Rijk, 1986; Takeshima & Salau, 2010). While developed countries boast highly developed and extensively utilized farm machinery, many developing countries are strikingly and rapidly catching up to full mechanization (Mongkoltanatas, 1998; Paman et al., 2018; Rijk, 1989).

Thailand's agricultural sector has experienced a rapid rise in farm mechanization, evident in the growing number and size of machinery in use (Thepent & Chamsing, 2009; National Statistical Office, 2013). The development of farm machinery in Thailand started with power-intensive machines such as irrigation pumps, power tillers and threshers. In particular, Thepent and

Chamsing (2009) observed the dynamics in the adoption and diffusion of farm machinery in Thailand. The adoption initially commenced in the central region and subsequently diffused to other regions. This process of mechanization is not merely characterized by its expanding reach, but also by a shift in the types of machinery employed. In the central region, there has been a transition from power-intensive machinery to equipment that is control-intensive. This is evidenced by the stability in the utilization of power tillers, irrigation pumps, and power threshers, while the number of rice combine-harvesters has experienced a rapid increase. Conversely, other regions are experiencing a surge in the adoption of power tillers.

In addition, Thailand's large-scale agricultural machinery service markets significantly promote the use of farm machinery such as tractors and harvesters (Thailand Development Research Institute (TDRI), 2020; Thepent & Chamsing, 2009. Local tractor owners offer land preparation services before planting, while large farmers in the central region, who own rice harvesters, address labor shortages in the north and northeast by providing harvesting services. This is particularly beneficial because the rice cultivation practices in Thailand favor photosensitive rice varieties that mature unevenly (TDRI, 2020).

While Thailand's agricultural sector has made significant progress in farm machinery development and utilization, along with the expansion of agricultural machinery service markets, small farmers in many areas still face challenges in using agricultural machinery (TDRI, 2020; Thepent & Chamsing, 2009). The relatively small plot sizes for crop production, particularly rice in northern and northeastern Thailand, hinder the efficient use of agricultural machinery. This limitation reduces the field capacity of the machinery, leading to high costs as a result of increased energy consumption per unit area, especially for larger equipment. Additionally, conventional agricultural machinery designed for the flat and open fields of the central plains may not be suitable for the mountainous terrain and smaller plots characteristic of the northern highlands (TDRI, 2020).

Nonetheless, while the development of agricultural machinery suited to smaller plots and diverse terrain is crucial for northern Thailand, promoting adoption may require a deeper understanding of the reasons and motivations leading to adoption or dis-adoption of farm machinery. These will, in effect, help design government policy support such as financial incentives, training programs, and infrastructure improvements alongside technological advancements for improving, and ultimately accelerating, farm mechanization in Thailand.

Innovation-Decision Process

Rogers (2003) conceptualized the innovation-decision process as an information-seeking and information-processing activity undertaken by individuals to mitigate uncertainty regarding the advantages and disadvantages of adopting an innovation. Specifically, a five-stage model of the innovation-decision process was proposed as a sequential progression that individuals encounter, comprised of: (1) knowledge; (2) persuasion; (3) decision; (4) implementation; and (5) confirmation stages (Rogers, 2003). In essence, the innovation-decision process is dynamic and progresses through five stages.

The knowledge stage serves as the initial point of engagement. Here, individuals encounter an innovation and embark on a quest for information to comprehend its essence and functionality. Central to this knowledge stage are questions concerning the innovation's nature, operation, and significance (Rogers, 2003).

The persuasion stage involves the formation of a positive or negative attitude towards the innovation (Rogers, 2003). Following the knowledge stage, where individuals gain initial awareness and understanding of the innovation, the persuasion stage centers on the development of affective attitudes towards it, contrasting with the more cognitive focus of the knowledge stage. The degree of uncertainty about the innovation's effectiveness and social reinforcement received from their colleagues or peers significantly influence individuals' beliefs and opinions about it. In fact, while the information about the innovation is usually available from external experts or scientific evaluations, individuals commonly seek information from trusted friends and colleagues whose subjective opinions of the innovation are most convincing (Sherry, 1997).

During the decision stage, individuals can make their decision to adopt or reject the innovation. Adoption, as defined by Rogers (2003), signifies the full utilization of an innovation as the optimal course of action. Conversely, rejection indicates the individuals' decision to decline the adoption of the innovation (Rogers, 2003). Previous studies have analyzed the factors influencing the adoption of innovations, particularly regarding farm machinery by farmers (Carrer et al., 2017; Fischer & Wollni, 2018; Fischer et al., 2018; Li et al., 2018; 2023; Quan & Doluschitz, 2021). These influencing factors

include demographic characteristics, costs and availability of machinery, market access, economic incentives, institutional influences as well as the effectiveness of the machinery itself.

The implementation stage entails putting the innovation into practice, although some degrees of uncertainty regarding its outcomes remain inherent in the diffusion process (Rogers, 2003). Uncertainty about the innovation's effectiveness can persist during the implementation, potentially hindering its successful adoption and thus requiring further assistance regarding utilization of the innovation.

Lastly, in proceeding from the decision for implementation to eventually the confirmation stage, the individuals who previously adopted the innovation can confirm their decision on adoption or swift to dis-adoption of the innovation. Conversely, those who did not adopt earlier can adopt at this stage or confirm their non-adoption.

Rogers (2003) proposed four outcomes of this confirmation stage. Firstly, 'Continued Adoption' implies that individuals find the innovation favorable and therefore continue to adopt it. Secondly, 'Discontinuance' means individuals previously adopting the innovation, conversely decide to reject it. Rogers (2003) identified two types of discontinuance: 1) replacement discontinuance and 2) disenchantment discontinuance. In replacement discontinuance, individuals reject the previously adopted innovation in favor of a better alternative. This typically occurs when a newer innovation emerges offering a perceived relative advantage. Conversely, disenchantment discontinuance involves rejecting the innovation due to dissatisfaction with its performance or because it fails to meet individual needs. Thirdly, 'Later Adoption' indicates that individuals perceive the innovation favorably and intend to adopt it. However, a delay in adoption may occur because of financial constraints or other social concerns. Fourthly, 'Continued Rejection' confirms the individuals' decision concerning the rejection of the innovation. In short, at the confirmation stage, individuals can confirm their decision by continuing use or reverse their decision and discontinue adoption. Meanwhile, the individual who previously rejected the innovation can maintain or confirm their rejection or reconsider and adopt it later at the confirmation stage.

Yet, with a substantial body of literature already dedicated to the decision stage or the first point of adoption/non-adoption decision, studies exploring the confirmation stage, crucial for understanding the process's dynamic nature, remain extremely scarce (Rogers, 2003). This dearth of research, particularly on the potential change of the individuals' decision regarding the innovation for this confirmation stage, highlights a key gap in our understandings of technology and the innovation adoption process, especially with regards to farm machinery. Greater understandings will in effect help promote the development and utilization of farm machinery, and thereby improving the productivity of the agricultural sector in many countries.

Individual Farmer's Innovation-Decision at the Confirmation Stage: A conceptual framework

Individual farmers made decisions regarding the adoption of farm machinery following the Rogers' five-stage model of an innovation-decision process, of which the confirmation stage was the focus of this study. The decision at the confirmation stage regarding different types of farm machinery include (1) continued adoption, (2) discontinuance, (3) later adoption, or (4) continued rejection. In addition, farmer attributes including gender, age, education level, years of farming experience and size of farm were considered in order to understand if any of these attributes might impact a farmer's decision at the confirmation stage regarding the adoption of farm machinery. Figure 1 illustrates the line of thematic analysis of an individual farmer, representing a conceptual framework of this research.

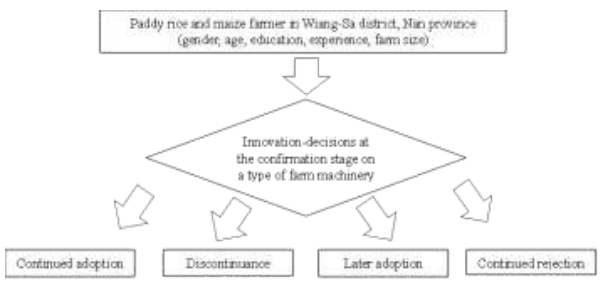

Figure 1 Conceptual Framework

Research Methodology

1. Population and Samples

The present study was undertaken in Nan province, situated in northern Thailand. Nan province encompasses 15 districts covering a total land area of 11,472 km2 (Nan Provincial Office, 2021). Notably, approximately 85% of this area comprises mountains and forests. As of 2020, Nan province boasted a population of 476,727 (Nan Provincial Office, 2021). While tourism has recently been promoted, agriculture

remains the dominant economic sector in Nan. Nearly half (45.32%) of Nan households are engaged in agriculture (Nan Agriculture and Cooperatives Office, 2022).

Nan experiences a single annual growing season, spanning from mid-April to late-September. Rain-fed agriculture dominates, with paddy rice and maize constituting the primary crops cultivated in the highland and mountainous areas. However, crop yields for both paddy rice (523 kg/rai) and maize (665 kg/rai) in 2021 fell below the northern regional averages (539 kg/rai and 710 kg/rai, respectively) (Office of Agricultural Economics, 2023). The adoption of farm machinery can help improve crop yields in Nan province.

This study employed a case study survey method, which allows researchers to collect data through surveys administered to a specific case, either a small group or an entire population (Chmiliar, 2010). In this case, the case study encompassed rice and maize farmers residing in the Wiang-Sa district of Nan province. The recent shift in Nan's agricultural sector towards sustainability through development strategies, economic incentives, and institutional changes (Kamondetdacha & Janhom, 2022; Tanwattana et al., 2018) makes the Nan context particularly relevant. Nan's focus on its local food systems aligns with the needs for sustainable and resilient agricultural practices, which often require the adoption of farm machinery. The selection of Wiang-Sa district in Nan was strategic, as it boasted the highest number of agricultural households among all 15 districts in Nan province (Nan Agriculture and Cooperatives Office, 2022). In short, the concentration of rice and maize farming in the Wiang-Sa district of Nan province makes it a well-suited case for studying the dynamics of farm machinery adoption.

Purposive and convenience sampling methods were employed to recruit participants for the interviews. The inclusion criteria for participant samples were: 1) paddy rice and maize farmers in the Wiang Sa district of Nan province; (2) users of at least one type of farm machinery for at least 10 years; and (3) willingness to participate in the research. Conversely, exclusion criteria included: 1) farmers cultivating commodities other than paddy rice and maize in Wiang-Sa district; (2) non-users of any farm machinery or users with less than 10-year usage experience; and (3) unwillingness to participate or unable to complete at least 50% of the interview questions.

2. Research Instrument

The author conducted data collection through face-to-face interviews utilizing a semi-structured questionnaire. The interview guide was developed based on a review of existing literature, drawing upon the innovation-adoption decision process (Rogers, 2003). The questionnaire consisted of two sections. The first section gathered background information on respondents (gender, age, education, work experience, and cultivated land size). The second section focused on farm machinery usage. Here, respondents indicated the source of their initial information about each machinery type, the year of adoption (and abandonment, if applicable), reasons for adoption (and abandonment, if applicable), and financing methods. The interview discussions then transitioned to specifically address the participants' decision-making processes at the confirmation stage regarding farm machinery. The confirmation stage is the fifth stage of the five-stage sequential progression model through which individuals encounter innovation decisions (Rogers, 2003). In this study, the 10-year mark after the first use of a particular machinery type was chosen as an indicator of this confirmation stage. Over a decade, technological advancements can render older machinery less efficient or even obsolete representing the end of economic life of a machine (Chen, 2018; Edwards, 2015). This makes the 10-year mark a reasonable point to assess the continued viability and relevance of a item of particular farm machinery. Each interview lasted approximately 40 minutes on average. All interviews were recorded and transcribed verbatim to ensure accuracy and capture the participants' responses in detail.

This research was conducted under international standards for the protection of human subjects, and 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, Chulalongkorn University. The proposal of this research was reviewed 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 under an expedited review category. It was approved on 17 September 2023 with the project reference code number 349/66.

3. Data Collection

Data collection for the study was conducted in the Wiang Sa district of Nan province, Thailand, in

November 2023. The timing coincided with a period of a short break in the farmers'routines, facilitating data collection. The author contacted the farmers for permission to interview and include them in the study. During the two-week fieldwork period (November 16-29, 2023), a total of 18 paddy rice and maize farmers, who met the pre-established inclusion and exclusion criteria, were successfully interviewed. All responses were assigned identifiers regarding their farming activities and their decisions regarding farm machinery to protect their identities and maintain confidentiality. Table 1 illustrates the list of 18 participants.

Table 1 Participant List

Participant No.	Gender	Age	Education level	Years of farming experience	Farm size (rai)
1	Female	46	Secondary	25	42
2	Female	55	Primary	20	6
3	Male	50	Secondary	26	16
4	Female	63	Secondary	40	2
5	Female	64	Primary	34	16
6	Female	60	Secondary	26	18
7	Female	58	Primary	41	10
8	Female	43	Secondary	10	20
9	Female	56	Secondary	30	7
10	Female	39	Secondary	10	50
11	Male	56	Primary	38	55
12	Male	70	Primary	50	55
13	Male	46	Primary	15	15
14	Male	61	Primary	24	16
15	Female	51	Primary	11	21
16	Male	48	Secondary	24	10
17	Male	58	Primary	13	11
18	Female	55	Bachelor's	14	12

4. Data Analysis

Thematic analysis was employed to analyze the interview data. The interviews were transcribed and analyzed using template analysis (King & Brooks, 2017). The main theme refers to the topic of investigation whereas the subordinate theme refers to the results identified by the researcher based on the literature and data obtained from the interviews. A coding template was developed based on innovation-adoption decision process literature (Rogers, 2003), guiding four subordinate themes, including: (1) continued adoption; (2) discontinuance; (3) later adoption; and (4) continued rejection. The next step was to meaningfully assign the data obtained from the interviews to the guided four subordinate themes. This step involved two researchers to ensure coding reliability. The author was the first reader and coder, and another researcher in the social science discipline at another university served as the second reader and coder. The second reader was informed about the study, and both the concept and methodology adopted in this study were explained. The use of the second coder was to verify the coding results of the first coder. The matching of the coding results indicated a 98% reliability. The remaining 2% was subsequently discussed between the first and second coders until an agreement was reached. Table 2 illustrates the main theme and four subordinate themes.

Table 2 Coding Template: Main Theme and Subordinate Theme

Main theme	Subordinate theme
Innovation-decisions at the confirmation stage	Continued adoption Discontinuance Later adoption Continued rejection

Results

Individual farmers made their decisions regarding the adoption of farm machinery aligned with Roger's five-stage model of an innovation-decision process, of which the confirmation stage was the focus of this study. Eighteen paddy rice and maize farmers residing in the Wiang-Sa district of Nan made their decisions at the confirmation stage to (1) continued adoption, (2) discontinuance, (3) later adoption, or (4) continued rejection regarding different types of farm machinery.

Continued adoption

Eight out of eighteen (44.4%) paddy rice and maize farmers confirmed their continued use of all machinery types at the confirmation stage, i.e., ten years following the initial adoption of the farm machinery. Table 3 summarizes the individual paddy rice and maize farmers who continued using all machinery types at the confirmation stage, the specific types of farm machinery used by these farmers, and their main reasons for continued adoption.

Based on Table 3, the data suggests a possible trend where female paddy rice and maize farmers above 50 years old maintained use of all machinery types compared to males over 40. Additionally, it suggests a potential difference in the rationale underlying continued use of the existing machinery between genders. Female farmers may be potentially influenced by perceived effectiveness, while males may be influenced by other factors such as financial constraints for purchasing new machinery. However, there was no clear trend emerged regarding farmers' education level, farming experience and farm size in continued adoption of machinery.

"I use farm machinery to save time and solve labor shortage. I adopted farm machinery to enhance operational efficiency, focusing on practicality such as

Table 3 Paddy Rice and Maize Farmers who Continued Using All Farm Machinery Types at the Confirmation Stage and the Farm Machinery Types Used by the Farmers

Participant No.	Gender	Age	Type of Farm Machinery – Continued	Main Reason for Continued Adoption
2	Female	55	Planter	Effectiveness of current machinery
			Harvester	Effectiveness of current machinery
			Truck	Effectiveness of current machinery
6	Female	60	Shoulder-carried Lawnmower	Effectiveness of current machinery
			Automated Fertilizer Sprayer	Effectiveness of current machinery
			Manual Pesticide Sprayer	Effectiveness of current machinery
7	Female	58	Wheel Plough	Effectiveness of current machinery
			Shoulder-carried Lawnmower	Effectiveness of current machinery
			Automated Pesticide Sprayer	Effectiveness of current machinery
9	Female	56	Shoulder-carried Lawnmower	Effectiveness of current machinery
			Water Pump	Effectiveness of current machinery
			Automated Pesticide Sprayer	Effectiveness of current machinery
13	Male	46	Wheel Plough	Lack of fund for purchasing newer equipment
			Walking Lawnmower	Effectiveness of current machinery
			Water Pump	Effectiveness of current machinery
			Manual Pesticide Sprayer	Effectiveness of current machinery
15	Female	51	Walking Lawnmower	Effectiveness of current machinery
			Chain Saw	Effectiveness of current machinery
16	Male	48	Tractor	Lack of fund for purchasing newer equipment
			Rice Mill	Lack of fund for purchasing newer equipment
			Maize Mill	Lack of fund for purchasing newer equipment
18	Female	55	Tractor	Effectiveness of current machinery
			Water Pump	Effectiveness of current machinery
			Manual Fertilizer Sprayer	Effectiveness of current machinery
			Manual Pesticide Sprayer	Effectiveness of current machinery
			Harvester	Effectiveness of current machinery

reliability and cost-effectiveness, rather than the latest advancements." (Participant No. 2, 6, 7, 9, 15, 18)

"I bought this wheel plough for 60,000 Baht and have used it for about 16 years. If I had money, I would have bought a tractor." (Participant No. 13)

"I have two tractors. The second tractor was brought three years after the first one. They were second-hand. I use them to operate with the rice mill and maize mill. I plan to invest in a combine-harvester once the financial resources become available." (Participant No. 16)

Discontinuance

A discontinuation rate of 55.6% (10 out of 18) was observed among paddy rice and maize farmers for at least one of their farm machinery types at the confirmation stage. Details regarding individual paddy rice and maize farmers, the specific types of machinery discontinued, and their main reasons for discontinuance are presented in Table 4.

Table 4 Paddy Rice and Maize Farmers who Discontinued at Least One Type of Farm Machinery at the Confirmation Stage and the Discontinued Farm Machinery Types

Participant No.	Gender	Age	Type of Farm Machinery – Discontinued	Main Reason for Discontinuance
1	Female	46	Wheel Plough	New machinery with higher efficiency – Tractor
3	Male	50	Walking Lawnmower	New machinery with higher efficiency – Shoulder-carried Lawnmower
			Manual Pesticide Sprayer	New machinery with higher efficiency – Automated Pesticide Sprayer
4	Female	63	Wheel Plough	No operator for existing machinery & new machinery with higher efficiency – Tractor
			Walking Lawnmower	No operator for existing machinery & new machinery with higher efficiency – Shoulder-carried Lawnmower
5	Female	64	Walking Lawnmower	No operator for existing machinery & new machinery with higher efficiency – Shoulder-carried Lawnmower
8	Female	43	Manual Pesticide Sprayer	New machinery with higher efficiency – Automated Pesticide Sprayer
10	Female	39	Single-axel Tractor	New machinery with higher efficiency – Tandem-axel Tractor
			Manual Pesticide Sprayer	New machinery with higher efficiency – Automated Pesticide Sprayer

Table 4 (Continue)

Participant No.	Gender	Age	Type of Farm Machinery – Discontinued	Main Reason for Discontinuance
11	Male	56	Wheel Plough	New machinery with higher efficiency – Tractor
			Walking Lawnmower	New machinery with higher efficiency – Shoulder-carried Lawnmower
			Manual Pesticide Sprayer	New machinery with higher efficiency – Automated Pesticide Sprayer
12	Male	70	Wheel Plough	New machinery with higher efficiency – Tractor
			Walking Lawnmower	New machinery with higher efficiency – Tractor-mounted Mower
			Manual Pesticide Sprayer	New machinery with higher efficiency – Automated Pesticide Sprayer
14	Male	61	Manual Pesticide Sprayer	New machinery with higher efficiency – Automated Pesticide Sprayer
17	Male	58	Manual Fertilizer Sprayer	Ineffectiveness of current machinery & reversion to manual operation

Across gender and age, paddy rice and maize farmers were observed to adopt and subsequently discontinue their existing farm machinery for diverse reasons, as detailed in Table 4. In addition, there was no clear trend that emerged regarding farmers' education level, farming experience and farm size regarding machinery discontinuance. Their decisions to abandon the existing equipment spanned from the superior efficiency offered by newer equipment to a lack of skilled operators, and the non-effectiveness of the existing equipment and reversion to manual operations.

"I replaced the wheel plough with a tractor, after using it for 10 years. The wheel plough was slow in operation and required high maintenance costs." (Participant No. 1)

"I replaced the inefficient walking lawnmower with a shoulder-carried model. Also, I replaced the heavy and inefficient hand-operated pesticide sprayer with a battery-powered automated sprayer that allows for faster operation." (Participant No. 3)

"I had to terminate the use of the walking lawnmower and wheel plough because there was no skilled labor to operate them. So, I replaced the walking lawnmower with a more manageable shoulder-carried model and a tractor for the wheel plough." (Participant No. 4)

"I used a walking lawnmower for stump removal for about 18 years. However, the lack of skilled labor to operate it effectively and the introduction of a more efficient equipment ultimately led to its abandonment." (Participant No. 5)

"To improve application efficiency, I replaced the hand-operated pesticide sprayer, which required manual exertion, with a battery-powered automated sprayer that allows for faster operation." (Participant No. 8)

"To achieve greater efficiency, I switched from the single-axle tractor to a tandem-axle model. Also, I replaced the hand-operated pesticide sprayer with a battery-powered automated sprayer." (Participant No. 10)

"In search for increased efficiency, I replaced the laborious wheel plough with a powerful tractor, the cumbersome walking lawnmower with a more manageable shoulder-carried model, and the laborious manual pesticide sprayer with a modern automated alternative." (Participant No. 11)

"I abandoned three equipment that I used before. I looked for newer equipment with better efficiency. I transitioned from a wheel plough to a tractor, from a walking lawnmower to a tractor-mounted mower, and from manual pesticide sprayer to automated pesticide sprayer." (Participant No. 12)

"I initially employed a manually operated pesticide sprayer. However, its operation resulted in arm discomfort, prompting a transition to an automated spraying system." (Participant No. 14)

"Initially, I employed a manually operated fertilizer sprayer. However, the significant weight of the equipment rendered its use impractical. Consequently, I shifted back to manual labor for fertilizer application. In the future, I may use drone technology for the application." (Participant No. 17)

Later adoption

Observations revealed later adoption within both the continued adoption and discontinuance groups. Paddy rice and maize farmers initially delayed adoption due to financial constraints. Table 5 presents data on paddy rice and maize farmers who deferred adoption of farm machinery until the confirmation stage and the specific types of farm machinery adopted by these farmers.

Table 5 Paddy Rice and Maize Farmers who Deferred Adoption of Farm Machinery and the Adopted Farm Machinery Types

Participant No.	Gender	Age	Farm Machinery – Later Adopted	Main Reason for Deferred Adoption
11	Male	56	Tractor	Lack of fund for purchasing equipment
13	Male	46	Wheel plough	Lack of fund for purchasing equipment

Two paddy rice and maize farmers were identified as making later-adoption decisions at the confirmation stage. Notably, the types of machinery delayed in adoption were tractors and wheel ploughs. Compared to other equipment such as lawnmowers, fertilizer sprayers, pesticide sprayers, or water pumps, both tractors and wheel ploughs represented a significantly higher financial investment. Consequently, these farmers might have required external financial resources such as loans or land sales.

"The arrival of the Hongsa Power Plant whose production facilities are located in Laos, has brought about changes for some farmers in the region. The land expropriation process and the installation of power lines and pylons across their properties have provided these farmers with a large financial boost. For me, this newfound income has enabled me to purchase a new tandem-tractor, capable of operating both in wet paddy fields and on dry land." (Participant No. 11)

"Two decades ago, I was initially unable to buy a wheel plough due to its high price tag of 60,000 Baht. However, following the introduction of a loan payment installment plan by Wiang Sa Agricultural Cooperative, I could buy the wheel plough." (Participant No. 13)

Continued rejection

Only one maize farmer was found to have continued rejection of farm machinery, a maize planter. This farmer was also in the discontinuance group as he abandoned a manual fertilizer sprayer. Table 6 below presents data on the maize farmer who continued to reject farm machinery at the confirmation stage.

Table 6 A Maize Farmer who Continued to Reject Farm Machinery and Rejected Farm Machinery Type

Participant No.	Gender	Age	Farm Machinery – Continually Rejected	Main Reason for Continued Rejection
17	Male	58	Maize Planter	Ineffectiveness of the machinery

In fact, the farmer conducted a brief trial with a maize planter but discovered a significant shortcoming. So, this farmer decided not to adopt the maize planter.

"Following a short experiment with a maize planter obtained through an external service, I discovered a critical drawback. The planter wasted a lot of seeds because it could not control how many went in each hole. While I initially considered adopting this machinery, I ultimately decided against it." (Participant No. 17)

Discussion

The present study employed Rogers' five-stage model of the innovation-decision process to explore the dynamics of decision changes regarding farm machinery at the confirmation stage. The study in the Wiang-Sa district of Nan province, Thailand investigated how 18 paddy rice and maize farmers made decisions regarding farm machinery adoption. The research revealed four main patterns in decision making.

Firstly, continued adoption was observed in eight farmers who confirmed usage of all the machinery they adopted, even ten years later. This group of farmers displayed an interesting age and gender trend. Female farmers (over 50) were slightly older than their male (over 40) counterparts. Their reasons for sticking with existing equipment also differed. Female farmers seemed more concerned with the perceived effectiveness of their current machinery, while finances appaered to be a bigger concern for male farmers when considering new equipment purchases. This suggests that older female farmers with reliable machinery might be less likely to adopt newer models. However, there were no clear trends linking educational level, experience, or farm size to continued adoption.

Secondly, discontinuance emerged as a pattern for ten farmers who abandoned at least one type of machine for various reasons. These reasons included the superior efficiency of newer models, a lack of skilled labour to maintain the machines, or the ineffectiveness of the current equipment itself. However, the study did not identify any clear connections between farmer characteristics such as gender, age, education, experience, or farm size, and their decisions to abandon certain machinery.

Thirdly, later adoption was identified in two farmers, one from each of the previous groups. These farmers demonstrated a pattern of later adoption. Their decisions involved either adopting entirely new technology, as with using a wheel plough for the first time, or upgrading existing equipment, with regards to transitioning from a wheel plough to a tractor. Importantly, these delayed adoptions, such as tractors

and wheel ploughs, required a higher financial investment compared to other equipment such as lawnmowers, fertilizer sprayers, pesticide sprayers, or water pumps. In essence, financial constraints likely played a role in the initial delay for these farmers.

Fourthly, continued rejection was observed in a single case. This maize farmer persistently refused to adopt a maize planter. Notably, the farmer had already trialed a planter but encountered a critical issue. The planter couldn't precisely control seed placement, resulting in excessive seed dispensing per planting hole. Consequently, the farmer decided against adoption, even after initial consideration.

By way of summarizing farmers' decisions regarding farm machinery adoption at the confirmation stage, Table 7 illustrates four themes for these decisions (Subordinate theme – level 1) and the potential underlying rational of each theme (Subordinate theme – level 2).

Table 7 Themes of Decisions at the Confirmation Stage and Rational Underlying Decisions

Main theme	Subordinate theme – level 1 Decisions at confirmation stage	Subordinate theme – level 2 Rational underlying decisions
Innovation-decisions at the confirmation stage	Continued adoption	• Effectiveness of current machinery • Unavailability of finance for purchasing newer machinery
	Discontinuance	• Ineffectiveness of current machinery or no operator for current machinery (Disenchantment discontinuance) • New machinery with higher efficiency (Replacement discontinuance)
	Later adoption	• Unavailability of finance for purchasing new machinery
	Continued rejection	• Ineffectiveness of machinery trial

The study identified (in)effectiveness of farm machinery and (un)availability of finances as major underlying rationales for farmers' decisions at the confirmation stage. Ineffective machinery can lead to discontinuance, either through replacement discontinuance with more efficient models or disenchantment discontinuance, or continued rejection. Conversely, effective machinery encourages continued adoption. In addition, financial constraints can result in later adoption of expensive equipment and can also influence continued use of existing machinery when replacement might be preferable. The major findings in this study of two key factors influencing farmer decisions regarding farm machinery adoption at the confirmation stage, i.e., (in) effectiveness of the machinery and (un)availability of finance, were also found in previous studies in other countries and regions. For instance, Quan and Doluschitz (2021) highlighted financial subsidies and scales of production as critical factors for promoting agricultural machinery adoption among maize farmers in China. Focusing on discontinuance, Azumah et al. (2022) indicated unsuitability and costs reasons for paddy rice farmers' dis-adoption of improved rice varieties in Ghana.

This study contributes to 'explaining theory' by clarifying the rationale behind farmers'decisions at the confirmation stage in the specific context of rice and maize farming in Nan, Thailand (Sandberg & Alversson, 2020). It deepens our understanding of the dynamic nature of the innovation-adoption process, highlighting continued adoption, discontinuance, later adoption, and continued rejection of innovation, originally proposed by Rogers (2003). Finance and effectiveness emerge as key factors while other farmer attributes show less influence at the confirmation stage. However, the study acknowledges the need for a larger sample size to confirm these findings.

Suggestions

The present study explored the underlying rationales behind farmers' decisions regarding farm machinery adoption at the confirmation stage of the innovation-decision making process (Rogers, 2003). This stage focuses on decisions including continued adoption, discontinuance, later adoption, and continued rejection of machinery after initial decisions. The findings highlight two key factors influencing farmer decisions, namely (in)effectiveness of the machinery and (un) availability of finances.

This study offers two policy implications and suggestions. Firstly, to improve the situation regarding the ineffectiveness of farm machinery, considered by the groups of discontinuance and continued rejection, the government should provide support for research and development of farm machinery to increase its effectiveness. It is important for researchers to identify problems or constraints through testing and evaluation of machinery in the field for precise assessments (TDRI, 2020; Thepent & Chamsing, 2009). In addition, organizations in charge of agricultural extension services should guide farmers in selecting and using suitable farm machinery. For instance, the setting up of pilot projects or field trips can introduce and demonstrate various types

and sizes of farm machinery for potential farmers (Thepent & Chamsing, 2009). Secondly, to improve access to financial resources for farmers, mainly in the groups of continued adoption and later adoption, the government should provide financial support to farmers who have potential for farm machinery investment but lack financial resources. By offering targeted financial assistance, such as low-interest loans and subsidies, the government can empower farmers to potentially invest in modern farm machinery, thereby boosting agricultural productivity and improving their economic well-being (TDRI, 2020; Thepent & Chamsing, 2009).

Acknowledgement

The author is extremely grateful for the financial support provided by Grants for Development of New Faculty staff, Ratchadaphiseksomphot Endowment Fund, Chulalongkorn University.

References

Azumah, S. B., Lamptey, C. Y., Sulemana, N., Donkoh, S., Zakaria, A., & Maanikuu, P. M. I. (2022). An explorative study on the adoption and dis-adoption of improved rice varieties among farmers in the northern region of Ghana. *Journal of Experimental Biology and Agricultural Sciences, 10*(2), 323-334.

Bank for Agriculture and Agricultural Cooperatives (BAAC). (2020). *Machinery Innovation Loan*. Bank for Agriculture and Agricultural Cooperatives [สินเชื่อนวัตกรรมเครื่องจักรเครื่องยนต์]. https://www.baac.or.th/th/content-news.php?content_id=14974&content_group_sub=1&content_group=3&content_group_semi=0002&inside=1

Carrer, M. J., Filho, H. S., & Batalha, M. O. (2017). Factors influencing the adoption of farm management information systems (FMIS) by Brazilian citrus farmers. *Computers and Electronics in Agriculture, 138,* 11-19.

Chen, G. (Ed.). (2018). *Advances in Agricultural Machinery and Technologies.* Florida, USA: CRC Press.

Chmiliar, L. (2010). Case study surveys. In A. J. Mills, G. Durepos, & E. Wiebe (Eds.), *Encyclopedia of case study research* (pp. 125-126). SAGE.

Donkoh, S. A., Azumah, S. B., & Awuni, J. A. (2019). Adoption of improved agricultural technologies among rice farmers in Ghana: A multivariate probit approach, *Ghana Journal of Development Studies, 16*(1), 46-67.

Edwards, W. (2015). *Estimating Farm Machinery Costs*. Retrieved from https://www.extension.iastate.edu/agdm/crops/html/a3-29.html

Fischer, G., Wittich, S., Malima, G., Sikumba, G., Lukuyu, B., Ngunga, D., & Rugalabam, J. (2018). Gender and mechanization: Exploring the sustainability of mechanized forage chopping in Tanzania. *Journal of Rural Studies, 64,* 112-122.

Fischer, S., & Wollni, M. (2018). The role of farmers' trust, risk and time preferences for contract choices: Experimental evidence from the Ghanaian pineapple sector. *Food Policy, 81,* 67-81.

Kamondetdacha, R., & Janhom, T. (2022). The dynamics of university's roles in the participatory guarantee system (PGS) learning process: A case of the Nan agricultural communities in Thailand. *Kasetsart Journal of Social Sciences, 43*(4), 1059-1066.

King, N., & Brooks, J. M. (2017). *Template analysis for business and management students.* London, UK: SAGE Publications.

Li, H., Chen, L., & Zhang, Z. (2023). A study on the utilization rate and influencing factors of small agricultural machinery: Evidence from 10 hilly and mountainous provinces in China. *Agriculture, 13*(1), 51.

Li, W., Wei, X., Zhu, R., & Guo, K. (2018). Study on Factors Affecting the Agricultural Mechanization Level in China Based on Structural Equation Modeling. Sustainability, 11, 51.

Mongkoltanatas, J. (1998). Current situation and trend of using and manufacturing of agricultural machinery in Thailand. [Paper presentation]. In *Seminar on current situation and trend of using and manufacturing of agricultural machinery in Southeast Asia.* Bangkok, Thailand.

Nan Agriculture and Cooperatives Office. (2022). *Five-year agricultural and cooperatives of Nan province, (2023-2027) (2023 revision)* [in Thai]. Nan, Thailand: Nan Agriculture and Cooperatives Office, Ministry of Agriculture and Cooperatives.

Nan Provincial Office. (2021). *Administrative information.* Retrieved from http://www.nan.go.th/about-article/6/

National Statistical Office. (2013). *2013 Agricultural Census.* Bangkok, Thailand: National Statistical Office, Ministry of Information and Communication Technology.

Office of Agricultural Economics. (2023). *Agricultural production data*. Bangkok, Thailand: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Paman, U., Bahri, S., Khairizal, A., & Wahyudy, H. A. (2018). Farm machinery development and utilization system policies for small-scale rice farming. *International Journal on Advanced Science Engineering Information Technology, 3,* 701-707.

Quan, X., & Doluschitz, R. (2021). Factors influencing the adoption of agricultural machinery by Chinese maize farmers. *Agriculture, 11*(11), 1090.

Rogers, E. M. (2003). *Diffusion of innovations* (5th Ed.). New York, NY: Free Press.

Rijk, A. G. (1986). The role of farm mechanization in developing countries: Experiences in Asian countries. In International Rice Research Institute (Ed.). *Small farm equipment for developing countries: Proceedings of the International Conference on Small Farm Equipment for Developing Countries: Past Experiences and Future Priorities, 2-6 September 1986* (pp. 3-22). Manila, Philippines: International Rice Research Institute.

Rijk, A. G. (1989). *Agricultural Mechanization Policy and Strategy: The case of Thailand.* Tokyo, Japan: Asian Productivity Organization.

Sandberg, J., & Alvesson, M. (2020). Meanings of theory: Clarifying theory through typification. *Journal of Management Studies, 58,* 487–516.

Sherry, L. (1997). The boulder valley internet project: Lessons learned. *Technological Horizons in Education Journal, 25(2)*, 68-73.

Tanwattana, P., Janhom, T., Thongpun, S., & Northao, W. (2018). Participatory process for land use change: Haze free agriculture, Nan province, Thailand. *Environmental Journal, 22*(3), 22-30.

Takeshima, H. & Salau, S. (2010). *Agricultural mechanization and the smallholder farmers in Nigeria.* Washington, D.C., USA: International Food Policy Research Institute.

Thailand Development Research Institute (TDRI). (2020). *Farming 4.0 policy.* Bangkok, Thailand: Thailand Development Research Institute.

Thepent, V., & Chamsing, A. (2009). Agricultural mechanization development in Thailand. [Paper presentation]. In *The Fifth Session of the Technical Committee of APCAEM.* Los Banos, Philippines.