Guidelines for The Utilization of Unmanned Aerial Vehicle in Promoting and Enhancing Rice Farming Among Farmers in Song Phi Nong District, Suphanburi Province

Jirayu Kaewphanao* Tannikarn Soonsinpai & Cholvit Jearajit
Faculty of Social Sciences, Srinakharinwirot University, Bangkok, 10110 Thailand

Abstract

This study addresses the critical challenges faced by rice farmers in Thailand, including increasing production costs, labor shortages, and health risks associated with manual agrochemical application, by examining the potential of unmanned aerial vehicles (UAVs) in rice cultivation. The study aims to examine farmers' attitudes toward the use of UAVs in rice cultivation in Song Phi Nong District, Suphanburi Province. It also investigates government and private sector policies in promoting UAV accessibility for farmers, with the goal of proposing guidelines for the integration of UAVs in rice farming. A quantitative research approach was employed, collecting data through surveys from a sample of 400 farmers in Song Phi Nong District, Suphanburi Province. Additionally, a qualitative research method was used to conduct in-depth interviews with 10 experts from government agencies and the private sector. The findings indicate that farmers' attitudes toward UAV-assisted rice cultivation do not significantly differ at the 0.05 statistical level between farmers who use manual labor and those who use UAVs. Most farmers agree that UAVs help in reducing the use of fertilizers and agricultural chemicals, leading to lower production costs, reduced working hours, and decreased direct exposure to chemicals. However, the high cost and complex operational systems of UAV technology present significant barriers to adoption. The in-depth interviews reveal that both the government and private sectors have policies to support and promote UAV technology for farmers. These policies include training programs on UAV operation and financial assistance for acquiring agricultural UAVs. Through content analysis, the researcher developed the DRONE Model, a framework for promoting UAV integration in rice cultivation. This model, distinguished by its five core components (Data-driven agriculture, reduce fertilizers and chemicals, Operation automation, Network collaboration, and Environmental and economic sustainability), offers a comprehensive and innovative approach to sustainable smart farming. The model achieved a suitability score of over 0.5, demonstrating its potential applicability in advancing the agricultural sector in Thailand.

Keywords: Rice cultivation, Attitudes; Promotion guidelines, Unmanned aerial vehicles (UAVs)

*** Jirayu Kaewphanao**
e-mail: Jirayu.kaewphanao@g.swu.ac.th

Introduction

Rice is a vital export crop for Thailand. In 2024, the country exported 9.95 million tons of rice, generating revenue of 225.656 billion baht (Department of Foreign Trade, Ministry of Commerce, 2025). Song Phi Nong District in Suphanburi Province is a lowland area with irrigation canals running through it, making it highly suitable for rice farming. The district has a total rice cultivation area of 140,288 rai, with 7,197 farming households producing approximately 118,302.15 tons of rice annually (Song Phi Nong District Agricultural Office, 2022).

Despite rice's significant economic contribution, more than 4.5 million rice-farming households in Thailand remain in debt, with average liabilities of 200,689 baht per household mostly owed to the Bank for Agriculture and Agricultural Cooperatives (National Statistical Office, 2023). These debts are largely driven by agricultural investments, including land rentals, seed purchases, fertilizers, chemical inputs, labor, machinery, and fuel costs (Samranjit, 2016). The global population increase has led to greater use of fertilizers, pesticides, and other agrochemicals to enhance agricultural productivity. Between 1990 and 2020, the global agricultural sector used approximately 2.7 million tons of agricultural chemicals, valued at 41.1 billion USD (FAO, 2022). In 2023, Thailand imported a total of 5,082,308 tons of fertilizers and pesticides, amounting to 76.548 billion baht (National Statistical Office, Ministry of Digital Economy and Society, 2024). Traditionally, fertilizers and pesticides are applied manually by farm workers, exposing them to hazardous chemicals. This exposure can lead to serious health risks (Angsungnoen, 2015). According to the World Health Organization (WHO), an estimated 385 million of the 860 million farmers worldwide experienced symptoms of acute agrochemical exposure in 2020. Reported symptoms included nausea, vomiting, headaches, muscle spasms, diarrhea, respiratory problems, blurred vision, eye irritation, and skin rashes. Globally, such exposures were associated with approximately 11,000 fatalities. In Thailand, national surveillance data reported 1,120 cases of pesticide poisoning treated in public hospitals in 2024 under the National Health Security system (Ministry of Public Health, 2025).

Beyond health risks, the manual spraying of agrochemicals results in up to 99.9% of the substances dispersing into the environment, causing ecological damage (Angsungnoen, 2015).

These pressing issues highlight an urgent need for sustainable agricultural solutions. Due to the severity of these health and environmental issues, the United Nations has established Sustainable Development Goals (SDGs) related to the agricultural sector. These goals include ending hunger, achieving food security, improving nutrition, promoting sustainable agriculture, reducing mortality and illness caused by hazardous chemicals and pollution, and supporting technological development, research, and innovation in developing countries (Sustainable Development Goals Research and Support Center, 2023).These align with the broader concept of smart farming, which leverages technology to enhance efficiency and sustainability.Thailand's agricultural sector has aligned its policies with these SDGs. The Ministry of Agriculture and Cooperatives has developed a 20-year Agricultural and Cooperative Strategy (2017-2036) to promote "Smart Farming" by

integrating modern technologies and innovations with traditional farming practices. This approach enhances agricultural productivity, improves the competitiveness of Thai farmers, and ensures environmental sustainability Poapongsakorn et al., 2020). Unmanned Aerial Vehicles (UAVs) or drones have become a widely adopted technology in global agriculture [19] (Niu et al., 2020). They are used for mapping agricultural fields, monitoring crop growth, detecting plant diseases, assessing crop quality, and spraying fertilizers and pesticides. UAVs provide distinct advantages, such as high-resolution aerial imaging, precise application of agrochemicals, and reduced human exposure to hazardous substances. These features lower production costs and contribute to better health outcomes for farmers. Thailand has begun integrating drones into rice farming, particularly for fertilizer and pesticide application, as they can cover large areas with high precision compared to manual labor (Department of Agriculture, 2022). Several studies highlight the benefits of UAVs in agriculture. For example, Maikaensarn & Chantharat (2020) found that UAVs reduced rice yield losses by 10-15%, decreased chemical use by 40%, and effectively controlled pests and diseases by 90%. Punyawattoe et al.(2019) studied the effectiveness of UAV-sprayed fungicides in Suphanburi Province, demonstrating that UAVs could apply tebuconazole 50% + trifloxystrobin 25% WG at rates of 3.5 and 5 liters per rai with greater precision and reduced chemical waste compared to conventional methods using backpack sprayers at 40-60 liters per rai. Pannaratcha & Phutharatana (2021) developed a UAV-based imaging system to detect golden apple snail eggs in rice fields in Phetchabun Province, achieving an accuracy of 91.66% in identifying the eggs and a 72.72% success rate in targeted pesticide application.

Although UAVs have the potential to significantly advance the agricultural sector, their adoption among farmers remains limited. This is primarily due to the high costs of purchasing and maintaining UAVs, as well as the complexity of their operating systems, which most farmers are not proficient in using (Chakraborty, 2023). According to the previous research key motivators influencing farmers' acceptance of new technology include ease of use and affordable pricing. In addition, social factors such as receiving promotional information, participating in UAV operation training sessions, or observing UAV use within the local community, can significantly enhance farmers' interest in and acceptance of UAV technology.

Despite its potential, UAV technology has yet to be widely adopted by farmers in Song Phi Nong District, Suphanburi Province, mainly due to high costs, expensive maintenance, and complex operational systems requiring specialized skills (Chakraborty, 2023).

Specifically, there is a notable research gap concerning empirical studies on the attitudes of farmers in this particular local context towards UAV adoption, as well as the effectiveness of existing government and private sector support policies. Therefore, this study aims to assess farmers' attitudes toward UAV adoption in rice farming in Song Phi Nong District. Additionally, it examines government and private sector policies to facilitate UAV adoption among farmers, proposing strategies to enhance UAV accessibility and promote their use in rice cultivation, ultimately contributing to the advancement of Thailand's agricultural sector.

Objectives

1. To study the attitudes and motivations of farmers in Song Phi Nong District, Suphanburi Province, toward the use of unmanned aerial vehicles (UAVs) to promote rice cultivation.
2. To analyze the factors, visions, and support policies from government and private sectors that are crucial in determining guidelines for promoting farmers' access to and acceptance of UAV technology for comprehensive rice cultivation development.
3. To propose a prototype model for the use of UAVs in promoting rice cultivation among farmers in Song Phi Nong District, Suphanburi Province, based on the findings

Research Hypotheses

1. Farmers in Song Phi Nong District, Suphanburi Province, have differing attitudes towards UAV technology.
2. Government and private sectors have increasing policies and guidelines to support widespread farmer access to UAV technology.

Conceptual Framework

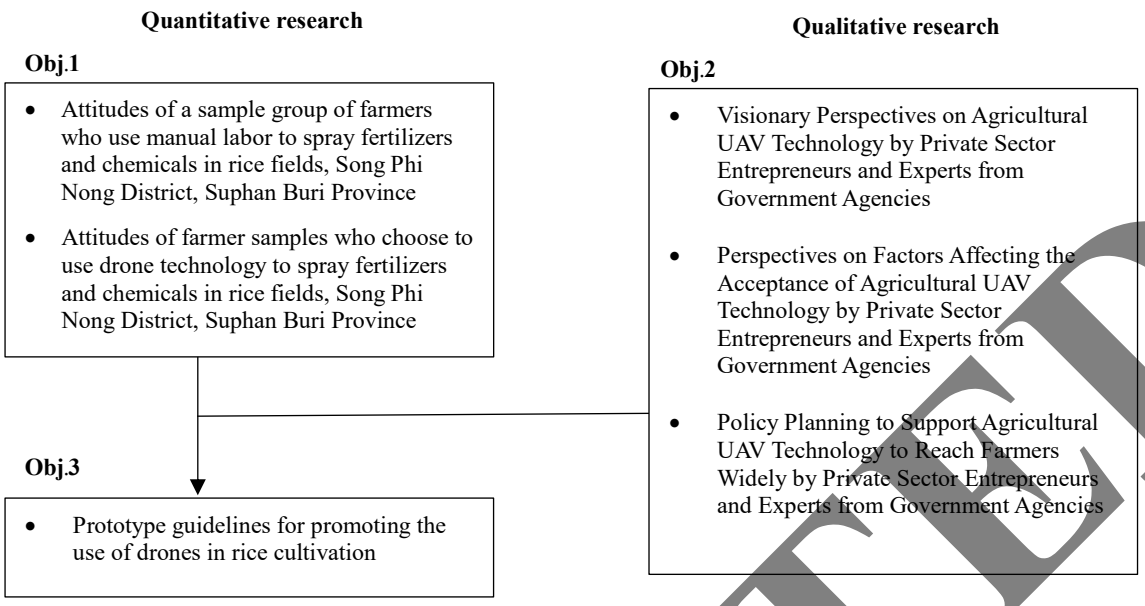

Figure 1 Conceptual Framework

Research Methodology

This study employed a mixed-methods approach, combining quantitative and qualitative research methods. The research process was divided into two main phases to address the study's objectives.

1. Phase 1: Studying the Attitudes and Motivations of Farmers

This phase involved quantitative research, utilizing a questionnaire as the primary data collection instrument to gather farmers' attitudes and opinions.

1.1 Population and Sample

The population for this study consisted of 7,197 rice farmers in Song Phi Nong District, Suphanburi Province 28 (Song Phi Nong District Agricultural Development Plan, 2022).

A sample of 400 farmers from Song Phi Nong District, Suphanburi Province, was selected. The sample was divided into two groups

1) Farmers using manual labor: A total of 379 farmers who manually applied fertilizers and agricultural chemicals were selected using simple random sampling based on Taro Yamane's formula at a 95% confidence level. The formula used was:

$$n=N/(1+N(e2))$$

Where n = sample size,
N = total population (7,197)
and e = margin of error (0.05)

This yielded a sample size of approximately 379 farmers. These farmers were selected by lottery from the list of registered farmers in Song Phi Nong District, with proportional random sampling from each of the 15 sub-districts. Selection criteria included

- Having at least one year of farming experience
- Ability to communicate and respond
- Voluntary participation

2) Farmers using UAVs: A total of 21 farmers who utilized UAVs for spraying fertilizers and agricultural chemicals were selected using purposive sampling. Selection criteria included:

- Having at least one year of experience using UAVs for spraying fertilizers and agricultural chemicals.
- Possessing a certificate of completion from UAV agricultural operation training provided by government or private sectors.
- Voluntary participation.

1.2 Instrument Development and Testing

The questionnaire was developed based on a thorough review of relevant literature, theories, documents, and previous research, aligned with the research framework and objectives. The questionnaire consisted of:

- General demographic information of the farmers.
- Questions on attitudes and motivations towards UAVs.

The questionnaire included both open-ended questions for detailed farmer feedback and 5-point Likert scale rating questions to measure attitudes and opinions (1=Strongly Disagree, 5=Strongly Agree). The interpretation of mean scores followed Best's (1977) criteria

- 1.00 - 1.80: Strongly Disagree
- 1.81 - 2.60: Disagree
- 2.61 - 3.40: Moderate Agreement
- 3.41 - 4.20: Agree
- 4.21 - 5.00: Strongly Agree

The questionnaire underwent rigorous validity and reliability checks. It was reviewed by thesis advisors and experts to identify and correct any deficiencies, ensuring its comprehensiveness and accuracy. Content validity was ensured through expert review, and reliability would typically be assessed using Cronbach's Alpha (though not explicitly stated, this is standard practice for such instruments). Ethical approval was obtained from the Srinakharinwirot University Ethics Committee before data collection.

1.3 Data Collection

Upon obtaining necessary approvals, the researcher distributed questionnaires to the 400 selected farmers in Song Phi Nong District, Suphanburi Province, consisting of 379 manual labor users and 21 UAV users.

1.4 Data Analysis

Quantitative data was analyzed using SPSS statistical software. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to summarize general information. Inferential statistics, specifically One-way ANOVA (Analysis of Variance), was employed to test the hypothesis regarding differences in attitudes between the two farmer groups at a 95% confidence level (p-value < 0.05). It is acknowledged that the unequal sample sizes between the two groups (379 vs. 21) is a limitation, however, ANOVA is generally robust to moderate violations of normality and homogeneity of variances, especially with larger overall sample sizes. Future research might consider reporting effect sizes or using non-parametric tests if assumptions are severely violated.

Even though the sample sizes for each group were unequal, the researchers reported the effect size using eta squared ($\eta 2$) based on Cohen's criteria. The analysis revealed that $\eta 2 = 0.782$, which is considered a very high level. This indicates that the independent variable has a significant influence on the study's outcomes.

2. Phase 2: Examining Perspectives and Influencing Factors (Qualitative Research)

This phase focused on qualitative research using in-depth interviews to collect data on visions, factors influencing UAV acceptance, and supporting policies.

2.1 Key Informants

Ten key experts were selected through purposive sampling, chosen for their expertise and experience in agricultural planning, management, and UAV technology. These included:

1) Two private sector entrepreneurs providing UAV-based spraying services in Song Phi Nong District.
   - Criteria: At least 2 years of experience in providing UAV spraying services, and certified training in UAV agricultural operation.
2) Three private sector entrepreneurs who manufacture and distribute agricultural UAVs.
   - Criteria: Manufacturing or importing agricultural drones and related equipment, distributing at least 100 units, and having repair/service centers in or near Suphanburi Province.
3) Five experts from government agencies, holding positions of significant authority and extensive experience in agricultural development.
   - Criteria: Significant managerial positions, extensive knowledge and experience in planning and development.

2.2 Instrument for Data Collection

In-depth interview guides were developed based on extensive literature review, aligned with the research objectives. The interview questions focused on three main areas:

1. Visions regarding agricultural UAV technology.
2. Factors influencing the acceptance of agricultural UAV technology.
3. Policy planning to promote widespread access to agricultural UAV technology among farmers.

The interview guides were reviewed and approved by thesis advisors and experts for completeness and accuracy, and ethical approval was secured from the Srinakharinwirot University Ethics Committee.

2.2.3 Data Collection

Semi-structured interviews were conducted with the ten selected experts. This approach enabled flexibility to explore emergent themes while ensuring that all key topics were addressed. With participants' permission, the interviews were audio-recorded and transcribed for analysis.

2.2.4 Data Analysis

Data from the in-depth interviews were analyzed using content analysis. Transcribed data were categorized and thematic codes were identified. The findings were then summarized using percentages where applicable and synthesized to form the basis for the proposed DRONE Model.

Result

The study revealed that among the 400 rice farmers sampled in Song Phi Nong District, Suphanburi Province, the majority were male (64.25%), aged between 41-50 years, and had completed lower secondary education. Most farmers practiced both rain-fed (in-season) and irrigated (off-season) rice cultivation, primarily growing Jasmine rice (Hom Mali variety). Their farming areas typically ranged from 16 to 30 rai, and the majority of the rice farmers used leased land to farm

the rice. The rice cultivation practices of farmers in Song Phi Nong District, Suphanburi Province, revealed that the highest cost component was chemicals for pest and disease control, followed by fertilizers, land preparation, seed, and land rental fees, respectively (Table 2). On average, farmers produced approximately 849.93 kilograms of rice per rai, generating an average income of 6,755.50 baht per rai (Table 1).

Table 1: General information, rice cultivation costs, production and income from rice cultivation of farmers in Song Phi Nong District, Suphan Buri Province

General Information of Rice Farmers in Song Phi Nong District, Suphanburi Province	(%)
Gender	
Male	64.25
Female	35.75
Age	
31 - 40	23.75
41 - 50	32.25
51 - 60	23.00
61 years and above	21.00
Educational Level	
Lower secondary school	74.00
Upper secondary school	11.50
Bachelor's degree	14.50
Type of Rice Cultivation	
Rain-fed and irrigated rice	100.00
Rice Varieties Cultivated	
Hom Mali (Jasmine rice)	57.00
Hom Pathum	21.25
Jasmine 20	21.75
Farming Area Size	
5 - 15 rai	23.25
16 - 30 rai	52.00
More than 30 rai	24.75
Land Ownership Status	
Leased land	65.00
Public land	35.00

Cost Structure of Rice Cultivation for Farmers in Song Phi Nong District, Suphanburi Province	In-season rice field (Baht/rai)		Off-season rice field (Baht/rai)	
	M	SD	M $\bar{x}$	SD
Land rental fee	551.50	29.77	1,051.23	30.09
Land preparation cost	710.18	7.06	710.78	7.13
Seed cost	665.13	9.63	665.40	9.67
Labor cost for seed sowing	70.38	7.05	70.63	7.21
Fertilizer cost	1,154.45	29.31	2,552.53	29.26
Labor cost for fertilizer spraying	271.85	18.60	271.78	18.05
Cost of chemicals for pest and disease control	2,050.08	27.43	2,052.15	28.90
Labor cost for spraying chemicals for pest and disease control	271.05	18.47	270.23	18.33
Harvesting cost	223.95	15.05	225	15.88
Transportation cost	206.05	14.68	206.1	14.76
Agricultural machinery cost	234.60	10.28	235.9	9.56
Fuel cost for water pumping	350.13	28.78	353.55	29.99

Production and Income	M	SD
Average yield (kilograms/rai)	849.93	30.14
Average income (baht/rai)	6,755.50	433.8

Regarding farmers' attitudes towards the use of unmanned aerial vehicles (UAVs) in rice farming, there was no statistically significant difference (p0.05) between the group of farmers using manual labor and the group using UAVs (Tables 2 and 3).

Farmers who relied on manual labor for spraying fertilizers and agrochemicals in their fields mostly agreed that manual spraying is simple, not complicated, with tools that are easy to purchase and inexpensive. However, this group of farmers also recognized that manual labor for spraying fertilizers and chemicals has drawbacks: workers experience physical fatigue and are directly exposed to chemicals through contact and inhalation, which negatively impacts their health. On the other hand, farmers who chose to use UAV technology for spraying fertilizers and agrochemicals in their fields mostly agreed that UAV spraying reduces the quantity of fertilizers and agrochemicals used, expands the operational area, and improves farmers' health as they avoid direct exposure to chemicals.

Although UAVs offer advantages for promoting agricultural practices, rice farmers in Song Phi Nong District still face challenges in utilizing UAVs for spraying fertilizers and agrochemicals in their fields (Table 4). Farmers expressed the highest level of concern about the high cost of UAVs, the complexity of their operating systems, and the reduction in job opportunities for manual laborers who previously performed spraying tasks.

Table 2 Attitudes of Farmers Using Manual Labor for Spraying Fertilizers and Chemicals in Rice Fields in Song Phi Nong District, Suphanburi Province

Attitudes of Farmers Using Manual Labor for Spraying Fertilizers and Chemicals in Rice Fields	**Sample size: n = 379**			
	$\bar{x}$	**S.D.**	**%**	**Level of Agreement**
1. Farmers are skilled in using handheld sprayers for applying fertilizers and agricultural chemicals in rice fields.	4.91	0.29	98.21	Strongly Agree
2. Spraying fertilizers and agricultural chemicals manually with handheld sprayers is an easy and uncomplicated method.	4.92	0.27	98.36	Strongly Agree
3. Sprayers are easy to purchase and affordable.	4.85	0.36	96.98	Strongly Agree
4. Using manual labor for spraying fertilizers and chemicals provides income for the hired workers.	2.77	0.82	55.41	Moderate Agreement
5. Fertilizers and chemicals sprayed manually are accurately targeted at the rice plants.	4.78	0.42	95.57	Strongly Agree
6. Manual spraying uses a smaller quantity of fertilizers and chemicals.	2.87	0.34	57.36	Moderate Agreement
7. Manual spraying with handheld sprayers causes physical fatigue or exhaustion during the process.	4.72	0.45	94.41	Strongly Agree
8. Manual spraying requires close contact with and inhalation of chemicals.	4.92	0.27	98.36	Strongly Agree
9. Manual spraying has impacts on workers' health.	3.02	0.61	60.32	Moderate Agreement
10. Manual spraying causes chemical dispersion and environmental residues.	1.97	0.51	39.37	Low Agreement
			F	**0.448**
			Sig.	**0.827**

Table 3 Attitudes of Sample Farmers Using Unmanned Aerial Vehicles (UAVs) for Fertilizer and Chemical Spraying in Paddy Fields, Song Phi Nong District, Suphanburi Province

Attitudes of Farmers Using UAVs for Fertilizer and Agricultural Chemical Spraying in Paddy Fields	**Sample Farmers (n = 21)**			
	$\bar{x}$	**S.D.**	**%**	**Level of Agreement**
1. The use of UAVs for spraying fertilizers and agricultural chemicals helps reduce the quantity of fertilizers and chemicals applied.	4.76	0.43	95.24	Highest
2. The use of UAVs for spraying fertilizers and agricultural chemicals helps reduce production costs related to fertilizers and agricultural chemicals.	3.86	0.35	77.14	High
3. The use of UAVs for spraying fertilizers and agricultural chemicals eliminates the need for manual spraying or hiring labor for spraying.	5.00	0.00	100.00	Highest
4. The use of UAVs for spraying fertilizers and agricultural chemicals helps reduce labor costs in production.	3.19	0.39	63.81	Moderate
5. The use of UAVs for spraying fertilizers and agricultural chemicals increases the working area coverage.	4.81	0.39	96.19	Highest
6. The use of UAVs for spraying fertilizers and agricultural chemicals helps increase rice yield.	2.90	0.61	58.10	Moderate
7. UAVs can accurately spray fertilizers and agricultural chemicals directly onto the rice plants.	3.71	0.45	74.29	High

Attitudes of Farmers Using UAVs for Fertilizer and Agricultural Chemical Spraying in Paddy Fields	Sample Farmers (n = 21)			
	$\bar{x}$	S.D.	%	Level of Agreement
8. The use of UAVs for spraying fertilizers and agricultural chemicals allows more time for community or family activities.	4.81	0.39	96.19	Highest
9. The use of UAVs for spraying fertilizers and agricultural chemicals prevents direct contact and inhalation of fertilizers and chemicals.	4.81	0.39	96.19	Highest
10. The use of UAVs for spraying fertilizers and agricultural chemicals contributes to better health.	4.81	0.39	96.19	Highest
11. The use of UAVs for spraying fertilizers and agricultural chemicals reduces physical fatigue compared to traditional manual spraying methods.	4.81	0.39	96.19	Highest
12. The use of UAVs for spraying fertilizers and agricultural chemicals helps reduce the residual amounts of fertilizers and agricultural chemicals in the environment.	3.57	0.49	71.43	High
			F	3.283
			Sig.	0.134

Table 4 Challenges in the Use of Unmanned Aerial Vehicles (UAVs) for Spraying Fertilizers and Agricultural Chemicals in Paddy Fields

Challenges in the Use of UAVs for Spraying Fertilizers and Agricultural Chemicals in Paddy Fields	$\bar{x}$	S.D.	Percentage (%)	Level of Agreement
UAVs have a high initial cost.	4.82	0.38	96.40	Highest
UAVs have complex operating systems.	4.85	0.36	97.00	Highest
Farmers lack knowledge and understanding of UAV operation.	3.61	0.49	72.10	High
UAV operators are required to obtain a flight license, which involves a complicated application process.	3.19	0.39	63.80	Moderate
UAV usage leads to a reduction in employment opportunities for laborers.	4.61	0.49	92.25	Highest
UAVs are not suitable for use in all types of paddy field conditions.	3.85	0.36	77.00	High
Government and private sector training programs on UAV operation for farmers are limited.	2.26	0.44	45.20	Low

Based on the content analysis of the in-depth interviews with experts from both governmental and private sector organizations, the key issues for policy planning to promote the widespread adoption of agricultural unmanned aerial vehicle (UAV) technology among farmers can be summarized into the following thematic codes:

Policy	Refers to the policy of:
Policy 1	Providing training and education on the use of unmanned aerial vehicles to farmers and interested individuals.
Policy 2	Establishing agricultural UAV learning centers at provincial agricultural offices.
Policy 3	Developing UAV rental programs for agriculture, enabling farmers with limited financial resources to access the service.
Policy 4	Providing budgetary support and government funding for the procurement of agricultural UAVs.
Policy 5	Promoting research and development of UAVs and related agricultural technologies.
Policy 6	Building networks between government agencies and UAV-related business operators.

Private sector entrepreneurs who provide drone-based agricultural services, such as fertilizer and chemical spraying in Song Phi Nong District, Suphanburi Province, as well as private sector manufacturers and distributors of UAVs, and experts from government agencies, generally agree that the most effective policies to ensure farmers' widespread access to agricultural UAV technology are: training programs to educate farmers and interested parties on the use of agricultural UAVs, and government support in terms of funding and financial resources for the procurement of such drones. Following these priorities are policies aimed at developing rental programs for agricultural UAVs to benefit farmers with limited capital, and policies promoting research into UAVs and agricultural technologies. Also identified are policies for establishing agricultural UAV learning centers at provincial agricultural offices, and policies fostering networks between government agencies and private sector businesses involved in UAV technology (as presented in Table 5).

It is evident that these policies are beneficial in promoting the adoption of technology among Thai farmers to enhance the efficiency of agricultural practices. Based on content analysis and the summary of policies supporting UAV technology for agriculture, as provided by experts from both the public and private sectors, the researcher has developed a prototype DRONE Model as a guideline for promoting the use of UAVs in rice cultivation (see Figure 2).

Table 5 Results of Data Analysis from Interviews with Private Sector Entrepreneurs and Experts from Government Agencies Regarding Policy Planning to Promote Widespread Access to Agricultural UAV Technology among Farmers

(n=10)

Interviewees	Perspectives on Policy Planning to Promote Widespread Access to Agricultural UAV Technology among Farmers					
	Policy 1	**Policy 2**	**Policy 3**	**Policy 4**	**Policy 5**	**Policy 6**
Private sector entrepreneurs providing UAV-based fertilizer and chemical spraying services in Song Phi Nong District, Suphanburi Province						
Person 1	✓		✓			✓
Person 2				✓		
Private sector entrepreneurs manufacturing and distributing UAVs						
Person 1	✓	✓				
Person 2	✓					
Person 3	✓			✓	✓	
Experts from government agencies						
Person 1	✓					
Person 2	✓			✓		
Person 3				✓		
Person 4		✓		✓		
Person 5						✓
Total	**5**	**1**	**2**	**5**	**2**	**1**
Percentage	**50.00**	**10.00**	**20.00**	**50.00**	**20.00**	**10.00**

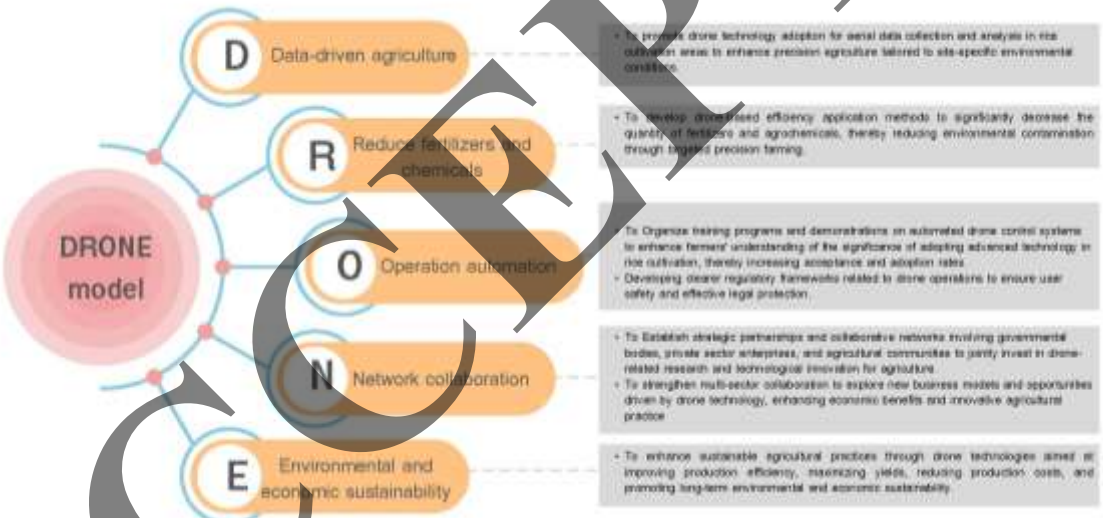

Figure 2 DRONE Model - Guidelines for Promoting the Use of Unmanned Aerial Vehicles in Conjunction with Rice Cultivation

The DRONE model serves as a conceptual framework designed to advance Thailand's agricultural sector toward "Smart Farming". It integrates the application of unmanned aerial vehicles (UAVs) with efficient farm management practices to enhance the quality of life for farmers while promoting environmental and economic sustainability.

The DRONE model framework is composed of five key components, corresponding to the acronym "D.R.O.N.E.," with each element outlining approaches to promote the integration of UAVs in rice cultivation, as follows:

- **D** stands for **Data-driven agriculture**, referring to agriculture powered by data. The researcher proposes the following approach to promote the use of UAVs in rice cultivation

- Launch campaigns to encourage the adoption of UAV technology for aerial surveys and data collection regarding the conditions of rice fields. The data collected will be analyzed to develop optimal management strategies tailored to the specific environmental conditions of each cultivation area.

- **R** stands for **Reduce fertilizers and chemicals**, aiming to decrease the use of fertilizers and agricultural chemicals. The researcher suggests the following approach to promote UAV integration in rice farming

- Enhance the operational efficiency of UAV systems to minimize the volume of fertilizers and agricultural chemicals sprayed over rice fields. This will help reduce the residual accumulation of these substances in the environment.

- **O** stands for **Operation automation**, referring to the automation of control systems using GPS and AI technologies. The researcher recommends the following measures to encourage the use of UAVs in rice cultivation

  - Develop and implement training programs and demonstrations on the automated control of UAVs to build farmers' knowledge and raise awareness of the significance of technological adoption in rice production, thereby fostering greater acceptance.

  - Develop legal frameworks related to the use of UAVs to provide greater clarity, thereby ensuring the safety and protection of users.

- **N** stands for **Network collaboration**, referring to the cooperative networks among government agencies, the private sector, and farmers. The researcher proposes the following approaches to promote the integration of UAVs in rice cultivation

  - Establish collaborative networks between government agencies, private enterprises, and farmers to mobilize research funding, support research projects, and develop cost-effective UAV systems accessible to farmers.

  - Develop partnerships among government agencies, private sector stakeholders, and farmers to create employment opportunities, particularly in providing UAV spraying services for fertilizers and agricultural chemicals, thereby generating new career paths for farmers.

- **E** stands for **Environmental and economic sustainability**, referring to environmental and economic resilience. The researcher proposes the following approaches to promote the integration of UAVs in rice cultivation

  - Develop the application of technology for sustainable agriculture to enhance efficiency in the agricultural sector, improve product quality, reduce production costs, and ultimately achieve both environmental and economic sustainability.

Based on the presentation of the DRONE model to experts for evaluation, it was found that the average score for each assessment item exceeded 0.5 (Table 8), which indicates that the model is of high quality and is suitably designed for proactive dissemination to promote the use of unmanned aerial vehicles in conjunction with rice cultivation. Furthermore, it can be effectively adapted for use with other economic crops as well.

Table 6 Results of the Appropriateness Assessment of the DRONE Model

Assessment Items	Expert No.					Total (Person)	Average Appropriateness Score
	1	2	3	4	5		
Data-driven agriculture: Agriculture driven by data							
- Campaigning for the use of UAVs to survey and collect data on rice cultivation areas, to analyze and develop appropriate field management strategies tailored to specific environments.	1	1	1	1	1	5	1
Reduce fertilizers and chemicals: Reduction of fertilizer and agricultural chemical usage							
- Developing UAV operational systems to enhance efficiency in spraying fertilizers and agricultural chemicals in rice fields, thereby reducing chemical residues in the environment.	1	1	1	1	1	5	1
Operation automation: Automated control using GPS and AI							
- Developing training courses and demonstrations on UAV automated control systems to build knowledge among farmers about the importance of technology in rice production, thereby increasing acceptance.	1	1	1	1	1	5	1
- Improving legislation related to UAV usage to provide clearer regulations for user safety.	1	1	1	1	1	5	1
Network collaboration: Collaboration network among government, private sector, and farmers							
- Establishing collaborative networks among government agencies, private sector, and farmers to fund research and support the development of affordable UAV systems for agriculture.	1	1	1	1	1	5	1
- Developing collaborative networks among government agencies, private sector, and farmers to create employment opportunities for UAV operators providing fertilizer and chemical spraying services.	1	1	1	1	1	5	1
Environmental and economic sustainability: Sustainability in environment and economy							
- Developing the use of technology for sustainable agriculture to improve efficiency in the agricultural sector, enhance product quality, reduce production costs, and achieve long-term environmental and economic sustainability.	1	1	1	1	1	5	1

In selecting experts to evaluate the DRONE Model for the research titled "Guidelines for the Use of Unmanned Aerial Vehicles to Promote and Develop Rice Cultivation for Farmers in Song Phi Nong District, Suphan Buri Province,"

stringent criteria should be established. Emphasis should be placed on individuals possessing comprehensive knowledge and experience in agricultural drone technology, rice cultivation specifically within the Thai context, statistics and research methodologies, and the assessment of innovation suitability for farmers. The application of the Index of Item-Objective Congruence (IOC) in this research is critically important. As a quantitative tool, it assesses the consistency and directness of evaluation items or content with the research objectives, ensuring that the developed DRONE Model is systematically evaluated across all relevant dimensions. This approach guarantees the academic rigor and reliability of the evaluation, ultimately leading to practical and beneficial guidelines for farmers.

The DRONE Model should be tested in field trials, with continuous monitoring and evaluation of its use to support the development of the agricultural sector. Additionally, knowledge should be enhanced and transferred to farmers in various regions across Thailand.

Discussion

The major production cost for rice farming among the sample group of farmers is primarily the cost of chemicals for pest and disease control, followed by the cost of fertilizers, land preparation, seeds, and land rental fees. This finding is consistent with the report in the District Agricultural Development Plan for Song Phi Nong District, Suphanburi Province, for the years 2023–2027, which indicated that the average production cost for rice farmers in Song Phi Nong District is 5,166 Baht per rai, with the main expenses being land rental, herbicides, chemical fertilizers, land preparation, and seeds (Song Phi Nong District Agricultural Office, 2022).

Farmers agreed that the use of UAVs can operate with high precision, effectively reducing the quantity of fertilizers and agricultural chemicals used. This helps to lower production costs, reduce the need for manual labor, save time, and decrease chemical residues in the environment. Additionally, UAVs can increase the working area coverage, improve yields, and positively impact on the health of farmers by reducing their direct exposure to chemicals. These findings align with the research which studied the attitudes of rice farmers in San Kamphaeng District, Chiang Mai Province, toward UAV technology. It was found that farmers agreed on the benefits of UAVs, particularly their faster operation compared to manual labor and their ability to function effectively in all types of rice fields.

Furthermore, Maikaensarn & Chantharat (2020) stated that UAVs can reduce crop losses by approximately 10%–15%, decrease the volume of chemicals used in spraying by 40%, and help prevent pests and diseases by up to 90%.

Despite the many advantages of UAV technology in enhancing agricultural practices, rice farmers in Song Phi Nong District, Suphanburi Province, still have concerns regarding the use of UAVs for spraying fertilizers and chemicals in their fields. These concerns stem from the complexity of the technology, the relatively high initial investment cost, as well as the farmers' lack of knowledge and understanding about the licensing process for UAV operation and agricultural chemical spraying. This lack of knowledge includes understanding both technical aspects and relevant regulations, which limits their ability to fully adopt and benefit from UAV technology in rice cultivation.

Suggestions

Recommendations from the Study

The study found that while rice farmers in Song Phi Nong District, Suphanburi Province, generally hold positive attitudes towards Unmanned Aerial Vehicles (UAVs) in agriculture, recognizing their potential to reduce production costs and enhance yield quality, significant barriers such as operational complexity and high initial costs limit widespread adoption. Based on these findings, the following recommendations are proposed to promote UAV integration

1. **Promoting Knowledge and Operational Skills:** Government agencies, including the Department of Agricultural Extension, Department of Agriculture, and Ministry of Agriculture and Cooperatives, should provide continuous training and education on UAV operation and maintenance to farmers. This will enhance farmers' knowledge and awareness of the technology's importance in rice production, fostering broader acceptance.
2. **Financial Support and Accessibility:** The Ministry of Commerce should establish appropriate pricing for agricultural UAVs to ensure affordability. Concurrently, the Ministry of Finance, in collaboration with state-supervised financial institutions, should implement support policies such as low-interest loans or subsidies to alleviate the financial burden of UAV acquisition for farmers with limited capital.
3. **Establishing Learning Centers and Community Involvement:** The Department of Skill Development, in partnership with the private sector and educational institutions, should establish community-based learning centers and demonstration farms for UAV technology. This will provide farmers with practical, hands-on learning opportunities. Furthermore, promoting contracted UAV spraying services can serve as an initial pathway for technology adoption and generate new income streams within farming communities.
4. **Fostering Group Collaboration and Resource Sharing:** The Department of Community Development, Ministry of Interior, should encourage the formation of community enterprises focused on UAV utilization in agriculture. This collaborative approach, including rental or shared equipment models, can reduce individual farmer costs and increase technology accessibility for smallholder farmers.
5. **Developing Supportive Infrastructure:** The Ministry of Energy should support the establishment of battery charging stations in agricultural communities to facilitate UAV operations. Concurrently, the National Broadcasting and Telecommunications Commission (NBTC) should enhance high-speed internet infrastructure and Kinematic Satellite Surveying (RTK) systems to support real-time data communication and precise positioning for UAVs.
6. **Regulating Air Traffic for Agricultural UAVs:** The Ministry of Transport should establish clear policies and guidelines for managing agricultural UAV air traffic to ensure systematic and safe operations.
7. **Educating on Chemical Residue Management:** The Department of Agricultural Extension, Department of Agriculture, and Ministry of Agriculture and Cooperatives should conduct training programs on the environmental impact and

management of agricultural chemical residues. This will raise awareness that UAV application can significantly reduce chemical dispersion and environmental contamination compared to manual spraying methods.

8. Promoting UAV Rental Programs: The Ministry of Agriculture and Cooperatives, in collaboration with the Bank for Agriculture and Agricultural Cooperatives (BAAC) and the Ministry of Interior, should support accessible UAV rental services, particularly for smallholder farmers. These services could be managed through cooperatives or community enterprises to ensure equitable resource utilization.

9. Supporting Research and Development: The Ministry of Higher Education, Science, Research and Innovation (MHESI), in conjunction with universities, research institutions, and the private sector, should bolster R&D efforts in UAV technology, sensors, aerial photography, and AI for agriculture. This will foster innovations tailored to Thai agricultural contexts.

Recommendations for Future Research

1. Field Validation of the DRONE Model: The proposed DRONE Model should undergo rigorous field testing, continuous monitoring, and evaluation across various agricultural regions in Thailand. This will help refine the model and facilitate the effective transfer of knowledge to farmers nationwide.

2. Strategic Analysis of Farmer Capabilities: Future research should involve experts from both public and private sectors to analyze the strengths and weaknesses of Thai farmers regarding UAV technology adoption. This analysis can inform the development of strategic plans to enhance farmers' capabilities and ensure they remain competitive with new agricultural innovations.

3. Long-term Systemic Impact Assessment: Comprehensive long-term studies are needed to evaluate the systemic impacts of UAV technology in agriculture across economic, social, health, and environmental dimensions. This will provide a holistic understanding of both positive and potential negative consequences for farmers and communities.

4. In-depth Analysis of Farmer Heterogeneity: Given that the current study found no statistically significant difference in attitudes between manual and UAV-using farmers, future research should delve deeper into differentiating farmer groups. Utilizing statistical methods such as Independent Sample T-Tests could compare attitudes or motivations between groups with varying socio-economic characteristics (e.g., training exposure, educational levels, income brackets). This granular analysis will offer deeper insights into factors influencing technology acceptance and enable more targeted policy interventions and promotion strategies.

References

Angsungnoen, S. (2015). Environmental impacts of pesticide use. Eastern Asia University Academic Journal, Science and Technology Edition, 9(1), 50-63.

Best, J. W. (1977). *Research in education* (3rd ed.). Prentice Hall.

Chakraborty, M. (2023). Drone Technology in Agriculture. *Agriculture & Food: e-Newsletter*. *5*(2). 290-292.

Department of Agriculture. (2022). *Kasetsart University and TATA organize drone training for agricultural future (Drone for Tomorrow)*. https://mgronline.com/smes/detail/9650000085295#google_vignette

Department of Foreign Trade, Ministry of Commerce. (2025). Summary of rice exports for 2024, reaching nearly 10 million tons. https://www.dft.go.th/th-th/showpicture/ArticleId/28857/-67-10

FAO. (2022). *Pesticides use, pesticides trade and pesticides indicators Global, regional and country trend*, 1990–2020. https://www.fao.org/3/cc0918en/cc0918en.pdf

Maikaensarn, V., & Chanthara, M. (2020). Effectiveness Analysis of Drone Use for Rice Production in Central Thailand. In S. Sakata (Ed.) *Structural Changes of Agriculture in the CLMTV Countries and their Socio Economic Impacts* (94-101). Bangkok: Bangkok Research Center.

Ministry of Public Health. (2025). *Pesticide poisoning rates*. https://hdc.moph.go.th/center/public/main / hdc/reports/report.php?source=pformated/format1.php&cat_id=f16421e617aed29602f9f09d951cce68&id=46914a29aebb9e55230cc408f59f2d39

National Statistical Office. (2023). *Household debt in agriculture, 2023*. https://www.nso.go.th/public/e-book/Analytical-Reports/Agricultural_household_debt_66/39/

Pannaratcha, K., & Phutharatana, S. (2021). Development of an image processing system from unmanned aerial vehicles (UAV) for detecting apple snail eggs for rice farmers in Tabao Subdistrict, Mueang District, Phetchabun Province. *Journal of Rajabhat Uttaradit University, Science and Technology Branch (for Local Development), 16*(2), 13-26.

Poapongsakorn, N., Pantakua, K., & Wiwattanaicha, N. (2020). *Agricultural Technology Policy 4.0: Case studies of sugarcane for factories and feed corn*. Thailand Development Research Institute.

Punyawattoe, P., Sutjaritthammajariyangkun, W., Chaiyasing, N., & Supornsin. S. (2019). Efficiency of unmanned aerial vehicles (UAVs) for spraying anti-disease chemicals for rice. *Agricultural Science Journal, 37*(1), 27-36.

Niu, H., Hollenbeck, D., Zhao, T., Wang, D., & Chen, Y. (2020). Evapotranspiration estimation with small UAVs in precision agriculture. *Sensors 20*(22), 6427. https://doi.org/10.3390/s20226427.

Samranjit, P. (2016). *The off-system debt of farmers: The last straw leading to land loss.* Life Thailand Foundation.

Song Phi Nong District Agricultural Office, Suphanburi Province. (2022). *District-level agricultural development plan for Song Phi Nong District, 2023-2027*. Song Phi Nong District Agricultural Office.

Sustainable Development Goals Research and Support Center. (2023). *Sustainable Development Goals*. Retrieved from https://www.sdgmove.com/intro-to-sdgs/

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Author
Kaewphanao et al.

Email
Jirayu.kaewphanao@g.swu.ac.th