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Alternate Wetting and Drying as Water-Saving Technology: An Adoption Intention in the Perspective of Good Agricultural Practices (GAP) Suburban Rice Farmers in Thailand

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Abstract: The alternate wetting and drying (AWD) as water-saving technology aligns with the good agricultural practices (GAP) principles, particularly in the environmental management of water conservation. Thus, GAP adopters as farmer groups are seen as viable AWD adopters in the initial stages of scaling out the adoption in Thailand. However, the understanding of integrating AWD as water-saving management among GAP adopters remains scant. Using the case of rice GAP farmers in Thailand, the study found a higher probability of adoption intention among GAP compared to non-GAP. AWD perceived advantage, knowledge, and the suitability of rice farms for AWD adoption trials are positively associated with higher adoption intention. While higher fixed cost lowers the probability of adoption, variable cost is positively associated with higher adoption intention in the short-run production decision. In order to scale out the adoption of AWD, farmers' understanding of the safe and proper application of AWD, together with assistance for crop insurance in the case of crop failure, will be crucial. Risks connected with the adoption decision continue to be the biggest barrier to adoption, especially among small-scale farmers.

Keywords: AWD; GAP; rice; adoption; water-saving

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1. Introduction

Consumers' growing environmental and health concerns have driven national and international policymakers to take several actions to improve farm management to increase food safety and sustainability, which has been challenging for the agricultural sector [1]. Globally, the concept of sustainable and safe food production is expanding rapidly, involving more complex technologies, trade-offs (e.g., productivity vs. sustainability), stringent standards, and sending differing messages among farmers, particularly in developing countries [1–4].

Across Asian countries, good agricultural practices (GAP) have been widely promoted to meet the shifting customer demand for safe and sustainable food crops [5]. In addition, GAP responds to international trade requirements where Asian countries export different food crops (such as rice, jackfruits, and mangosteen) to other continents [2,5,6]. For instance, several Asian countries have local versions of GAP, such as Philippine-GAP, Malaysian SALM, Singapore GAP-VF, Indon-GAP, and Q-GAP in Thailand [2].

In Thailand, through the national GAP program, which focuses on food safety, the country has been proactively addressing the issues of meeting the market's demand for food crops [4,7]. The national GAP (Q-GAP) development is driven mainly by the national government under the Ministry of Agriculture and Cooperatives (MOAC). Farmers that can meet the requirements may use the "Q-GAP" logo, where "Q" stands for quality mark, to label their produce [7]. Promoting Q-GAP among Thai farmers seeks to increase Thai customers' trust in food sold in domestic markets and raise Thai products' competitiveness in global markets [2,6]. Aside from food safety, the GAP requirements also focus on three other areas: Quality produce, growers' health and safety, and environmental management [4,7].

Target crops for GAP certification are for exports and domestic consumption, like durian, mangosteen, mango, pineapple, coconut, and rice [7]. Among the crops produced in the country, rice production continued to be a priority for domestic and export markets [8–10]. However, under the GAP principle on environmental management concerns, rice production contributes to the national greenhouse gas emissions (GHG) by 27.19Mt CO_2-eq and accounts for 51.38% of GHG emissions since 2011 [11,12]. In addition, continuous flooding is a common method on rice farms in Thailand, which is said to be ideal for CH_4 and nitrous oxide (N_2O) [1,13]. Sriphirom et al. [12] and Srisopaporn et al. [1] pointed out that reducing GHG emissions and water usage are the two critical components of rice farming for sustainable production following GAP principles.

In 2016, Thailand introduced the adoption of alternate wetting and drying (AWD) as water-saving irrigation technology developed by the International Rice Research Institute (IRRI). The AWD is considered an alternative to continuous flooding that aims to mitigate the impact of drought, reduce GHG emissions and be cost-saving without compromising rice yields [14–16]. Several studies concluded the potential of AWD as cost-effective technology in reducing water input by as much as 25–30% without adversely impacting rice yields [12,15,17,18]. At the same time, Linquist et al. [19] found a 48% reduction in methane emissions from rice cultivation with AWD treatment [18]. Furthermore, lower CH_4 emissions were observed under alternate wetting and drying than continuous flooding [20,21]. Islam et al. [20] conclude that GHG emission-reducing technology (e.g., urea deep placement or UDP) combined with a water-saving management strategy like AWD compared to rice production under continuous flooding conditions is effective.

Given the standards stipulated under GAP, particularly on environmental management and AWD's potential advantages, the Thai government sought farmers' cooperation in AWD adoption for water-saving. GAP adopters as farmer groups are seen as potential AWD adopters in the initial stage of scaling out AWD technology as it aligns with the GAP requirements for adopting water-saving in rice cultivation. While knowledge of the potential effects of adopting AWD has been growing, the understanding of integrating AWD as water-saving management among GAP adopters remains poor globally, particularly in Thailand. Thus, the study aims to answer the following research questions:

1. What factors influences the adoption intention on alternate wetting and drying?
2. What are farmers' perceptions on the promotion of AWD as alternative water-saving technology?
3. What are the policy implications of integrating AWD adoption with good agricultural practices under GAP's principle of sustainable water management in production?

The remainder of the paper proceeds as follows. First, we provide more background on Thailand's GAP and AWD adoption. Then we present the information on the focus study sites and the methodology used. Afterward, we discuss the results and implications of the study. In the last section, we provide the conclusions and policy implications of the study.

2. Thailand's GAP and AWD Adoption

The increasing concerns about food safety and demand for high-quality food and agricultural products globally drive GAP development in farm production. In 2003, Thailand started to develop its local GAP standard, Q-GAP (Q stands for "quality"), which focuses on food safety, quality produce, environmental management, and safety for growers. Good agricultural practices vary depending on the crop type, production system, and customer needs [5]. Driven by food safety requirements, GAP consists of simple instructions and a checklist for growers to comply, as outlined in Table 1 for GAP requirements in Thailand set by the Thai Agricultural Standard. Certified GAP farm compliant are recognized by the national GAP certifying institution that farms are operating environmentally friendly, sustainable, care for workers' welfare, and safe and high-quality produce [5]. For Thailand, the nationwide promotion of good agricultural practices aims to develop farmers with the changing demand for food agriculture in the domestic and international markets to promote the inclusion of Thai farmers in the mainstream market.

Table 1. Q-GAP requirements for food crops for each production aspect and its relation to the four modules under Thai Agricultural Standard (TAS 9001-2013) on good agricultural practices.

Item	Total Requirements	Count of Related Requirements			
		Food Safety (FS)	Produce Quality (PQ)	Environmental Management (EN)	Worker Health, Safety, Welfare (WHSW)
1. Water	14	7	2	5	0
2. Planting area	11	6	1	6	1
3. Pesticides	21	14	0	4	9
4. Pre-harvest quality management	19	12	5	6	5
5. Harvest and postharvest handlings	14	10	4	0	0
6. Holding, moving produce in planting plots, and storage	9	4	0	0	0
7. Personal hygiene	14	4	0	0	6
8. Record keeping and traceability	20	17	7	4	4
9. Total	122	74	19	25	25

Notes: Table adapted from TAS 9001-213 under Appendix A of [7]. Details of each requirement can be accessed at https://www.acfs.go.th/standard/download/eng/GAP_Food_Crop.pdf accessed on 6 December 2022.

Later in 2013, amendments were made to Thailand's GAP requirements for food crops to align with the ASEAN Economic Community Blueprint (AEC Blueprint). The AEC blueprint aims to strengthen further the ASEAN members' economic integration by establishing a single market and production base to increase the region's competitiveness [22]. As a result, the ASEAN developed the ASEAN GAP, where member states aligned their local GAP standards. For example, Philippine-GAP, Malaysian SALM, Singapore GAP-VF, Indon-GAP, and Q-GAP in Thailand [2]. In addition, two more GAP standards certifying institutions are available in Thailand—ThaiGAP and GLOBAL GAP [6].

Under the Q-GAP, food safety is a priority of the Department of Agriculture and the National Bureau of Agricultural Commodity and Food Standards (ACFS). For instance, 60 percent of the total 122 requirements are related to food safety, followed by environmental management (20 percent) and growers' safety (20 percent), summarized in Table 1. In addition, growers who wish to get certified undergo assessments by an official GAP inspector on the eight production aspects checklist provided under Thai agricultural standards on GAP (e.g., water, planting area, record keeping) outlined in Table 1. At the same time, recertification is done every two years.

Promoting GAP standards in Thailand offers incentives and disincentives for adoption among Thai farmers. Hobbs [3] discussed the possible incentives of GAP adoption (e.g., economic, human capital, regulatory, and legal incentives. On the other hand, several studies have been concerned that stringent requirements under GAPs could marginalize smallholder farmers due to the needed investment in adopting good practices [1–3]. Therefore, to help Thai farmers with the Q-GAP certification, the Department of Agricultural Extension (DAE) provides GAP training services to improve farmers' understanding of Q-GAPs processes and achieve higher potential benefits that could outweigh the cost of certification.

In the current Q-GAP, the focus food crops include major exporting agricultural commodities such as asparagus, mangoes, corn, and rice [1,4]. For rice, Q-GAP farmers must register their rice plots and follow a set of practices under the Q-GAP guidelines. Participation in the program is voluntary and registered farmers will undergo training for good agricultural practices on a specific crop which the Ministry of Agriculture will conduct. During the implementation of GAP, the government provides the inspection and certification to aid farmers in complying with the national GAP standard. Q-GAP for rice has been widely promoted in the country (71 out of 76 provinces in Thailand), and more than 40 thousand farmers have registered already [1]. Most are irrigated rice farms relying on irrigation for cultivation, especially during the dry season.

Under the Q-GAP standards, water conservation and water-saving related strategies are stipulated under 1.6 and 1.8–1.10 list of GAPs requirements. However, most Thai farmers continually practice continuous flooding in rice cultivation, which uses much water. As part of water-saving irrigation, alternate wetting and drying (AWD) are integrated with GAPs, mainly irrigated rice farms. For rainfed rice farms, direct seeding and selection of water-saving and drought resistance rice varieties are the primary recommended water-saving techniques in aligning with good agricultural practices on water conservation for more sustainable rice production. Direct seeding ensures crop establishment and does not require pre-saturation irrigation, thus reducing water input use [23]. At the same time, irrigated rice field practices direct seeding or alternate wetting and drying, or a combination of both practices. Under an AWD, rice fields are not flooded continuously but allow the soil to dry for several days and be flooded again [15]. The AWD implementation follows the standard guidelines for safe alternate wetting and drying recommended by IRRI [24]. In addition, designated local agricultural extension officers provide training to farmers. Moreover, the training targets farmers who are members and officers of water user groups with more control and participation in irrigation management. As a result, an estimated 38% less water is used under AWD while maintaining the same crop management.

Several irrigated rice farms often experience water shortages during the dry season, especially in downstream areas [25,26]. Integrating AWD under Q-GAP or into farmers' water management practices could allow better water allocation. For instance, safe AWD implementation among upstream irrigated fields could increase available water for downstream areas [15,17,26]. Despite the increasing evidence of safe AWD showing an increase in yield and water production, AWD adoption in Thailand is still scant due to Thai farmers being risk-averse, contradicting the traditional practices of continuous flooding. Moreover, AWD adoption requires collective actions among farmers, especially water users under the same irrigation infrastructure. Controlled irrigation in one area of the irrigation canal will affect the entire field. The situation adds to existing barriers among irrigation officers and extension workers in promoting AWD adoption in Thailand. As Enriquez et al. [14] emphasized, AWD adoption is not straightforward as it involves not only monitoring of the irrigation surface but a collective action among farmers involved in the irrigation system. Hence, GAP farmers as a farmer group could exhibit higher acceptance towards AWD as water-saving technology in rice farming, especially in the early stages of scaling out AWD adoption in the nation.

3. GAP Study Sites and Data Analysis

3.1. GAP Study Sites

Throughout the first half of 2022, a total of 26 GAP-certified farms and 30 non-certified farms were closely interviewed in the suburban areas of Khlong Sam Wa district in Bangkok, Thailand. The information included in the survey is the input and output of rice production and farmers' perception regarding the adoption of alternate and wetting as a water-saving mechanism being promoted in the study area. The area is in upper central Thailand and is bordered by Lam Luk Ka, Nong Chok, Min Buri, Khan Na Yao, Bang Khen, and Sai Mai. The study sites often face water shortages, and irrigation remains challenging for most farms. The introduction of AWD is seen to be a potential water-saving technology among rice farms in the study area. Figure 1 demonstrates the rice cropping calendar integrated with AWD introduced in the study area.

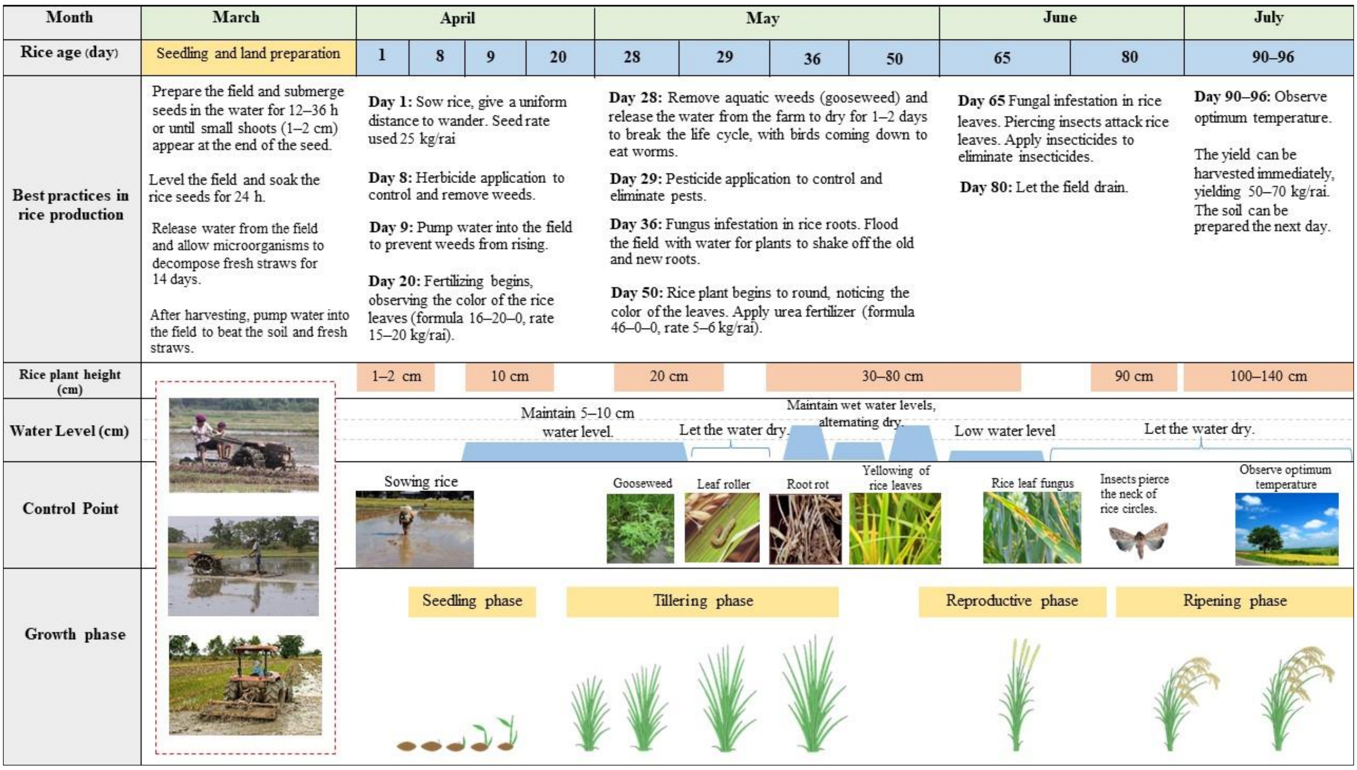


Figure 1. GAP study site's cropping calendar with alternate wetting and drying (AWD) for GAP-certified rice production.

The first part of the production process is seedling and land preparations. During land preparation, farmers drain the field to allow microorganisms to decompose fresh straws. The farmer used a seeding rate of 25 kg/rai. Herbicide and pesticide applications are made during the seedling phase (8th day) and tillering phase (29th day). The tillering phase is a critical phase where aquatic weeds should be removed, and fungal infestations should be controlled. During tillering and reproductive stages, alternate wetting and drying of the field are observed by maintaining a water level of 5–10 cm. A critical control point during the ripening phase is to monitor the optimum field temperature where the height of the plants is around 100–140 cm. Rice yields are harvested immediately within days 90–96, with yields around 50–70 kg/rai.

Based on mapping the cropping calendar practiced among rice farms in the study sites, Table 2 shows the difference in the cost and return of rice production between the certified and non-certified GAP farmers. The total fixed cost incurred by non-GAP farmers (702.67 THB/rai) was significantly higher than GAP farmers (528.51 THB/rai). The highest among the two groups was land rent, followed by depreciation cost, which was highly significant in non-GAP farmers. As for variable cost, there was no significant difference in total variable cost incurred between the two farmer groups. However, looking at the individual cost component items, significant differences exist except for organic fertilizer and bio-fermented water costs. Generally, non-GAP farmers incurred significantly higher variable costs, particularly on seed, chemical fertilizer, herbicides, and fuel. Meanwhile, GAP farmers incurred significantly higher labor, pesticides, and fuel expenses.

Overall, non-GAP farmers have significantly higher total costs than GAP farmers. Moreover, although both farmer groups did not significantly differ in yield per rai, GAP farmers had significantly higher total income and net profit owing to lower total cost and higher selling price. This finding indicates that production costs and product prices affect the profitability of GAP and non-GAP farmers in the study area.

Table 2. Cost and return of rice production by GAP and non-GAP farmers.

Cost Items	GAP	Non-GAP	t-Value
Fixed cost			
Land rent	408.43	425.79	−0.28
Tax	0.30	0.17	0.60
Opportunity cost of land use	59.59	16.50	1.33
Depreciation	60.18	260.21	−10.09 ***
Total fixed cost (TFC)	528.51	702.67	−3.24 ***
Variable cost			
Labor	1085.11	992.91	2.20 **
Seed	347.88	536.79	−4.10 ***
Organic fertilizer	12.51	0.00	-
Bio-fermented water	1.83	0.00	-
Chemical fertilizer	414.49	587.83	−2.73 ***
Herbicides	114.49	172.20	−2.69 ***
Pesticides	80.85	11.24	4.32 ***
Fuel	285.61	421.93	−2.99 ***
Other expenses	182.12	0.00	4.31 ***
Total variable cost (TVC)	2524.90	2722.90	−1.00
Total cost (TFC+TVC)	3053.41	3425.56	−1.91 *
Yield (kg/rai)	755.84	752.21	1.03
Selling price (THB/rai)	7.38	6.77	4.30 ***
Total income (THB/rai)	5710.55	5088.27	3.35 ***
Net profit (THB/rai)	2388.99	1662.71	3.89 ***

Notes: 1 rai = 0.16 hectare; 1 THB = 0.030 USD (6 months average exchange rate from July–December 2019); *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

3.2. Data Analysis

To answer the study's first research question, the logit model following the model specification in the study of Aluddin et al. [17] and Rejesus et al. [27] was employed in estimating the probability of AWD adoption intention based on selected predictors. The logit model specified in Equation (1) allows the estimation of the probability of logit change due to a unit change of the predictors. The left-hand side of Equation (1) represents the ratio of the AWD adoption probability $P_r(y = 1)$ and the probability of non-adoption $1 - P_r(y = 1)$. On the right-hand side, the parameters β are the coefficients to be estimated, and X_j is a vector of the selected predictors related to the sociodemographic characteristics of farmers, such as age, education, marital status, household size, and GAP adoption. In addition, farmers' perceptions of the advantages, knowledge, and trial adoptability of AWD technology were also included as predictors in the logit model specified in Equation (1).

$$\ln\left[\frac{P_r(y=1)}{1-P_r(y=1)}\right] = \beta_0 + \beta_j X_j \tag{1}$$

Whereas Equation (2) specifies the marginal effects estimated from the logit model in Equation (1) that allows the interpretation of a logit of the odds ratio in terms of marginal change of the selected predictors to the outcome variable on AWD adoption intention.

$$\text{Marginal effects} = \frac{\partial P_r(y=1)}{\partial x_j} \tag{2}$$

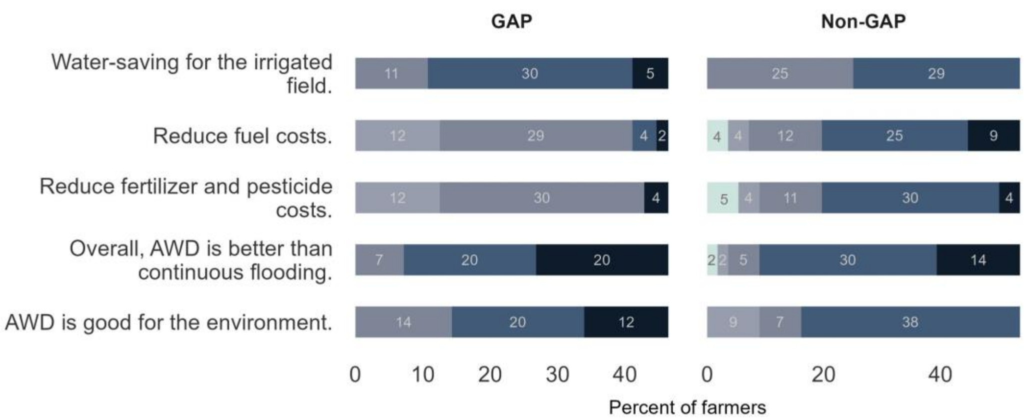
The selected predictors for the logit model are summarized in Table 3. The predictors used are sociodemographic characteristics of the focus farmers, derived cost and return variables (presented in Table 2), and perceptions of farmers on AWD technology. After a series of AWD information drives and demonstrations, farmers were asked whether they intended to adopt or not the alternate wetting and drying as a water-saving strategy on their farm. The adoption intention variable was measured as a binary variable taking the value of 1 for farmers who intend to implement AWD and 0 if otherwise. Likewise, a binary variable is coded as 1 if a farmer is GAP certified and 0 if otherwise. Sociodemographic variables considered in the study include age, education, marital status, and household size. Farmers' age was hypothesized to have a negative relationship with the probability of adoption. This implies that younger farmers have a higher probability of adoption intention than older farmers. Given that AWD is a knowledge-based technology, higher education attainment will influence the probability of adoption among sampled farmers. As most Thai farmers employ family labor in production, the study considered the household size to affect farmers' decision to adopt AWD. A larger household size allows more household members to be available for farm labor.

Table 3. Definitions of variables.

Variables	Description	Type
AWD adoption	=1 if adopted AWD, 0 otherwise	Binary
Age	Age of household head	Continuous
Education	Years of education	Continuous
Marital status	=1 if married, 0 otherwise	Binary
Household size	Number of household members	Continuous
GAP adoption	=1 if adopted GAP, 0 otherwise	Binary
Yield	Yield per rai	Continuous
Variable cost	Total variable cost per rai	Continuous
Fixed cost	Total fixed cost per rai	Continuous
Net profit	Net profit per rai	Continuous
AWD advantages	Farmers' perception of AWD advantages	Composite score
AWD knowledge	Knowledge on AWD	Composite score
AWD trial adoptability	Perceived adoptability on AWD trials	Composite score

Notes: A reliability test was conducted for the items used in generating the composite scores. Alpha values are 0.74, 0.84, and 0.85 for perceived advantage, perceived knowledge, and trial adoptability, respectively.

For farmers' perceptions, multiple items were used to reflect the intended factors (i.e., farmers' perceptions) using exploratory factor analysis. Items under the perceived advantages, knowledge, and trial adoptability factors of AWD technology were measured using a five-point Likert scale from 1 as strongly disagree and 5 as strongly agree. Using an exploratory factor analysis, we derived the composite factor score in measuring farmers' perception of AWD advantages, knowledge, and trial adoptability. Figure 2 in the result and discussion section presents the items that underwent the reliability test in the factor analysis.



(a)

Figure 2. *Cont.*

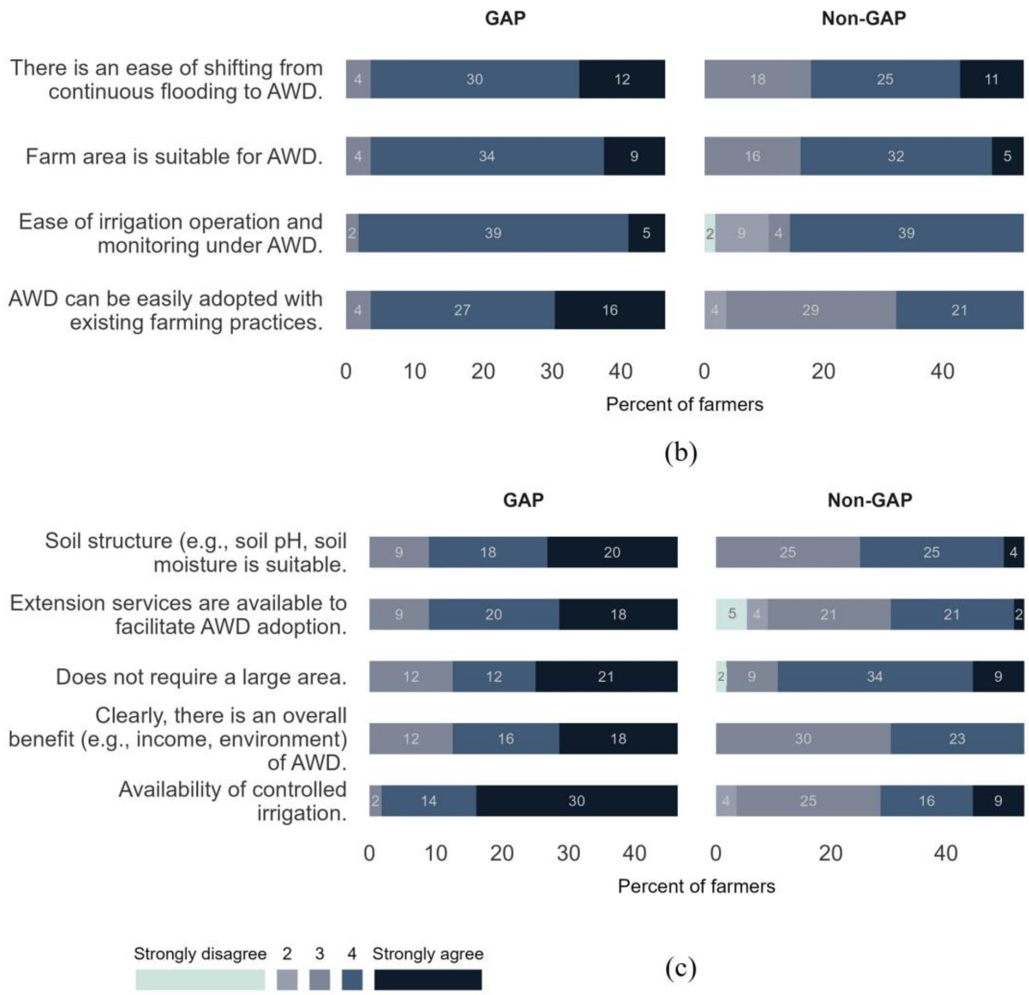


Figure 2. GAP and non-GAP farmers' perceptions of AWD adoption intention regarding the (**a**) innovation advantages, (**b**) ease of adoption, and (**c**) trial capability.

4. Results and Discussion

4.1. Innovation Advantages, Ease of Adoption, and Trial Capability Perceptions on AWD

Introducing change, such as adopting new farming technology, requires an awareness of farmers' behavioral traits [14]. Hence, through a series of interviews, the GAP and non-GAP farmers' perceptions of AWD adoption intention regarding the innovation advantages, ease of adoption, and trial capability are summarized in Figure 2. Before the farmer interviews, AWD-related rice farming demonstrations were conducted to facilitate leveling understanding, particularly for farmers who were less familiar with the technology. A total of 26 GAP and 30 non-GAP farm owners participated in the alternate wetting and drying information drive and farm demonstration.

The promotion of AWD to Thai farmers is due to the technology's potential to reduce water input. Studies on AWD water-saving potential capacity vary from 15–30%, which translates to less irrigation and a reduction in irrigation cost [14,15]. Between groups, GAP adopters consider AWD a better water-saving technology than its counterpart. However, AWD adoption involves additional investment, such as additional time required to monitor the field and the irrigation surface. Managing and monitoring irrigation can be complex, given the high cases of deflection in a communal resource [28,29]. Enriquez [14] views AWD adoption as viable to a collective organization such as farmer groups (e.g., cooperatives, GAP farmers) to minimize transaction costs. Several studies on water user groups along irrigation systems with high interrelationships among group members exhibit a high level of participation in collective action in irrigation management [25,30,31].

Regarding ease of AWD adoption, Thai GAP farmers show higher perceived readiness than non-GAP. However, a high proportion of farmers still have low awareness about safety, environmental and social impact, or implications of agricultural practices under GAP [4]. In addition, the perceived capacity for AWD trials is more prevalent among GAP than non-GAP farmers. The observed behavior among GAP is due to farmers being accustomed to stringent processes stipulated under the GAP requirements. Moreover, water management under the environmental management module of the TAS requires farmers to innovate in saving water in production. This implies that the promotion of AWD as a water-saving technology will be more suitable and feasible for GAP farmers. Hence, the overall benefits of AWD adoption are perceived to be higher among GAP than non-GAP. In addition, both groups agree that AWD could reduce fuel and fertilizer costs. The application of AWD reduces the irrigation hours and lowers fuel needs in operating the water pumps. In a study by Djaman et al. [32], they found an increase in rice yield and a 30 percent increase in the efficiency of nitrogen use under AWD compared to continuous flooding. The increased efficient use of the inputs improves the nitrogen application rate, which could partially contribute to input cost savings. Similar results were also found by Song et al. [33], where AWD combined with reduced fertilizer application promotes phosphorous use efficiency without yield loss in rice plants.

4.2. Logit Results on the Determinants of AWD Adoption

Table 4 presents the result of the logit model with the associated marginal effects on AWD adoption. Results show that age is significant and negatively associated with the probability of AWD adoption intention. This implies the potential of young Thai farmers to adopt water-saving technology like AWD in rice farming. The negative association of age on AWD adoption intention in the study area was also observed in Bangladesh [17] and the Philippines [27]. Alauddin et al. [17] found that older household heads in Bangladesh show a lower probability of adopting AWD technology. At the same time, marital status and household size are positively associated, but not significantly, with a higher probability of adoption intention in the sampled farmers. The non-significant effect of marital status and household size in adoption studies was found in Northwestern China [34] and Tarlac province in the Philippines [27].

Table 4. Determinants of alternate wetting and drying (AWD).

Variables	Logit	p-Value	Marginal Effects	p-Value
Intercept	−46.5372 *** (16.0507)	0.0037		
Age	−0.1295 * (0.0770)	0.0926	−0.0315 * (0.0184)	0.0874
Education	0.014 (0.4184)	0.9733	0.0034 (0.1017)	0.9733
Marital status	0.3703 (1.6330)	0.8206	0.0914 (0.4054)	0.8216
Household size	0.3059 (0.2664)	0.2509	0.0744 (0.0649)	0.2516
GAP	3.2204 ** (1.4878)	0.0304	0.6485 *** (0.1979)	0.0011
AWD advantages	0.4405 * (0.2478)	0.0755	0.1071 * (0.0573)	0.0616
AWD knowledge	3.5292 ** (1.4438)	0.0145	0.8582 ** (0.3364)	0.0107
AWD trial adoptability	1.7661 *** (0.5658)	0.0018	0.4295 *** (0.1371)	0.0017
AIC	44.1798			
BIC	62.408			
Pseudo R-square	0.8			

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

On the other hand, the study did not find enough statistical evidence on the significance of years spent on education, however, the observed positive effect of education on the probability of AWD adoption corresponds with other related studies (e.g., [17,27,34,35]). At the same time, the observed non-significance of formal years in education among focus groups can be compensated with farmers' tacit knowledge accumulated from years of farming experience. Moreover, perceived AWD knowledge is found to be significant among sampled farmers and positively associated with the probability of adopting AWD. As most farmers show low years of formal education, tacit or experiential knowledge among farmers will be necessary for AWD adoption. The timing of implementing AWD involves years of experience in crop management, and improper implementation of AWD can lead to a reduction in rice yield [12,17].

An increase in AWD adoption's perceived advantages improves the probability of AWD adoption intention. Moreover, the probability of adoption intention is higher for farmers who perceive the current farming area is suitable for AWD trial. This implies that more evidence of the positive impact of AWD adoption and wider information dissemination is beneficial in promoting AWD. As demonstrated by the focus group discussion, farmers' reluctance is rooted in how different the AWD approach is compared to the traditional practices of continuous flooding.

On the other hand, adoption intention between GAP and non-GAP shows a higher probability of AWD adoption among GAP farmers. The observed higher adoption intention among GAP farmers can be attributed to the efforts to comply with the stringent requirement of the Ministry of Agriculture under Thai GAP standards. The results provide evidence to support Thailand's agricultural sector in targeting GAP farmers by integrating AWD in the GAP standards for water-saving technology, particularly among rice GAP.

4.3. Cost and Return Effects on GAP Farmer' AWD Adoption Intention

Table 5 presents the estimated effects of the cost and return variables on the probability of AWD adoption. Results reveal that farmers with relatively high yields have a lower probability of AWD adoption. The hesitance of farmers is a natural reaction when confronted with change, especially when farmers have high yields before the proposed intervention. Thus, Thai farmers with relatively high yields may exhibit a lower probability of AWD adoption due to high opportunity costs and risks from the uncertainty of adoption outcomes, while several studies support the positive effect of AWD on yield (e.g., [12,17,18]). Moreover, there are studies reporting the potential reduction in yield with improper AWD application (e.g., [19,36]).

Table 5. Estimates of the effect of cost and return on AWD adoption intention.

Variables	Logit	*p*-Value	Marginal Effects	*p*-Value
Intercept	3.5931 (4.5296)	0.4276		
Yield	−0.0257 ** (0.0116)	0.0275	−0.0064 ** (0.0029)	0.0262
Total variable cost	0.0029 ** (0.0014)	0.0319	0.0007 ** (0.0003)	0.0302
Total fixed cost	−0.0014 (0.0031)	0.6612	−0.0003 (0.0008)	0.6617
Net profit	0.0043 *** (0.0015)	0.0047	0.0011 *** (0.0004)	0.0042
AIC	55.4857			
BIC	65.6124			
Pseudo R-square	0.5795			

Notes: *** $p < 0.01$; ** $p < 0.05$.

For the cost components, higher fixed cost is associated with a lower probability of adoption, while variable cost is positively associated with AWD adoption intention.

Changes in variable inputs occur in the short-run production decision and are positively associated with potential yield. Thus, changes in the short-run farming practices (e.g., AWD adoption) that will increase the potentially higher yield could viably increase the adoption intention. On the other hand, farmers with higher fixed inputs may face a higher risk of adopting new technology, such as the AWD, given that higher sunk costs are incurred when faced with crop failure.

5. Conclusions and Policy Implications

Promoting water conservation through AWD can be challenging given the low literacy rate among farmers in developing countries, as measured by the years spent in formal education. The study assumes that the technology can be integrated with GAP standards under the environmental management module of TAS 9001-2013 for irrigated rice farms in the early stages of scaling out AWD usage in Thailand. In the current state of implementing good agricultural practices in the country, chemical contamination has been the focus of the national GAP. The focus should be gradually extended to other components, such as environmental management, particularly the adoption of water-saving management for rice GAP. The potential of the alternate wetting and drying to meet the criteria related to the water requirement of GAP TAS 9001-2003 will be a great opportunity in scaling out the promotion of AWD adoption. This notion was supported by the study's findings, which showed that GAP farmers were more likely to intend to implement AWDs than non-GAP farmers. This can be attributed to GAP adopters accustomed to the demanding standards they must conform to receive certification. At the same time, the adoption of AWD aligns with the priority of GAP principles for water management. Moreover, we found that perceived advantages, knowledge, and suitability of rice farm areas for AWD trials are positively associated with a higher intention for AWD adoption. In light of these findings, the following discusses the study's recommendations and policy implications.

Since AWD adoption can only be put into practice with a controlled water source like the national irrigation projects, the choice to irrigate will often be taken collectively among water users, and it is anticipated that the implementation will be costly. This suggests that, especially in the early phases of adoption, AWD should be introduced and implemented in an imposed manner through the irrigation authority as a water-saving irrigation method. However, as rice farmers get accustomed to the processes involved in irrigation under AWD, participatory irrigation management integrated with AWD will more likely be viable among farmers.

Moreover, the perceived risks involved with changing irrigation practices are another impediment for the Thai government in scaling out the usage of AWD. Although the adoption of AWD was determined to have a favorable benefit, AWD's adverse effects on rice yield were also reported. Therefore, to mitigate the possible impact of the perceived risks, such as crop failure, it is imperative to develop further farmers' understanding of the safe and proper implementation of AWD (also referred to as "safe AWD" in most studies) and to provide crop insurance.

Poor knowledge, lack of information, and awareness regarding AWD technology among farmers will be additional barriers to promoting AWD adoption. Since AWD is a knowledge-based technology, the first recommendation will depend heavily on the availability of local agricultural extension agencies that can provide accurate information and close coaching toward a safe and effective implementation of AWD. Second, enrolling farmers in crop insurance will be an essential safety net against perceived risks, particularly in situations where crop loss will be unavoidable over the length of AWD adoption trials. Finally, more research is required to understand AWD better as rice yields vary not only on irrigation management but also on soil type, fertility, climate, and combinations of these factors.

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