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Determinants in the Adoption of Alternate Wetting and Drying Technique for Rice Production in a Gravity Surface Irrigation System in the Philippines

Kristine Samoy-Pascual [1,*], Sudhir Yadav [2,*], Gio Evangelista [2], Mary Ann Burac [2], Marvelin Rafael [1], Romeo Cabangon [2], Takeshi Tokida [3], Masaru Mizoguchi [4] and Manuel Jose Regalado [1]

1 Rice Engineering and Mechanization Division, DA-Philippine Rice Research Institute, Science City of Muñoz, Nueva Ecija 3119, Philippines; ml.rafael@philrice.gov.ph (M.R.); mjcregalado@exchange.philrice.gov.ph (M.J.R.)
2 Sustainable Impact Platform, International Rice Research Institute, Los Baños 4031, Philippines; g.evangelista@irri.org (G.E.); m.burac@irri.org (M.A.B.); r.cabangon221@gmail.com (R.C.)
3 Institute for Agro-Environmental Sciences, National Agriculture and Food Research Organization, 3-1-3, Kannondai, Tsukuba 305-8604, Japan; tokida@affrc.go.jp
4 Department of Global Agricultural Sciences, Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan; amizo@mail.ecc.u-tokyo.ac.jp
* Correspondence: kspascual@exchange.philrice.gov.ph (K.S.-P.); s.yadav@irri.org (S.Y.)

Abstract: Alternate Wetting and Drying (AWD) is a well-known low-cost water-saving and climate change adaptation and mitigation technique for irrigated rice. However, its adoption rate has been low despite the decade of dissemination in Asia, especially in the Philippines. Using cross-sectional farm-level survey data, this study empirically explored factors shaping AWD adoption in a gravity surface irrigation system. We used regression-based approaches to examine the factors influencing farmers' adoption of AWD and its impact on yield. Results showed that the majority of the AWD adopters were farmers who practiced enforced rotational irrigation (RI) scheduling within their irrigators' association (IA). With the current irrigation management system, the probability of AWD implementation increases when farmers do not interfere with the irrigation schedule (otherwise they opt to go with flooding). Interestingly, the awareness factor did not play a significant role in the farmers' adoption due to the RI setup. However, the perception of water management as an effective weed control method was positively significant, suggesting that farmers are likely to adopt AWD if weeds are not a major issue in their field. Furthermore, the impact on grain yields did not differ with AWD. Thus, given the RI scheduling already in place within the IA, we recommend fine-tuning this setup following the recommended safe AWD at the IA scale.

Keywords: adoption; AWD; irrigation; rice; water-savings; yield

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1. Introduction

Rice is the staple food for a large part of the world that occupies 162 million (M) ha of arable land. Global rice production is 755 M tons (t), of which 89% comes from Asia [1]. Being one of the top three rice-importing countries globally, this crop has high strategic value for the Philippines, both as a staple and the country's economic growth [2]. In the Philippines, rice is the most extensively grown crop, with 4.72 M ha and with an annual production of 19 Mt. The largest rice production comes from the Central Plain of Luzon, which contributes 19% to the total national rice production [3]. Like many irrigated rice areas in Asia, the majority of the local farmers practice soil puddling during land preparation and maintain flooded conditions throughout the crop duration except near harvest. This flooding practice results in a higher water footprint for rice than any other crop in the agriculture sector. However, water availability for irrigation in the country has declined due to competing demands from various users (i.e., agriculture, domestic, industry) [4].

Furthermore, the declining availability of water sources brought about by the degradation of watersheds aggravates this water-scarce condition [5,6]. In addition, the rice farming in the region has been disrupted by El Niño-Southern Oscillation events that worsened water scarcity and negatively-affected rice production, especially in the dry season [7,8]. Therefore, efficient water management practices are essential to enhance the water productivity of rice, especially in Central Luzon, to contribute to food security in the country.

One widely known water-saving technique introduced in Central Luzon in 2001 is the safe Alternate Wetting and Drying or AWD [5]. Safe AWD involves intermittent irrigation that allows the soil to dry for a few days and re-irrigate based on water level depletion (−15 cm) below soil surface. Safe AWD saves irrigation water by reducing water losses, such as seepage and percolation [9]. Several field experiments and adaptive trials were conducted to investigate the impact of safe AWD on grain yields and water savings, and productivity. For example, the total water use (irrigation + rainfall) was reduced by 15 to 53% without a significant decrease in grain yield under heavy soils and shallow groundwater tables [10–12]. While in loamy soil and deep groundwater table, it resulted in some yield loss but high water savings up to 50% [13]. The majority of the reports showed that water productivity increases relative to farmers' practice [10,14,15]. Participatory adaptive trials and capacity building nationwide were also conducted to promote and disseminate the safe AWD for farmers' adoption [16–18].

Moreover, two policy supports were issued to promote safe AWD (i.e., Department of Agriculture-Administrative Order 25–2009 and National Irrigation Administration Memorandum Circular No. 35) in the national irrigation systems. Unfortunately, despite the decade of research and development, the adoption of AWD in the country remains slow and low [19]. Rejesus et al. [20] reported that around 84,784 ha of rice fields are irrigated using AWD. That translates to only 3% of the total irrigated rice area of 3.29 M ha in the country [3]. Hence, there is a need to determine the factors that affect the AWD adoption of farmers at the field scale.

Although several impact adoption studies on water-saving technologies, such as AWD, have already been conducted [21–24], most of these were done under the communal pump or small-scale irrigation system that has a direct benefit from saving water because of the reduction of fuel and labor costs for pumping water. To our knowledge, there is a limited study conducted under a large-scale gravity irrigation system, particularly in the Philippines, that examines factors influencing the farmers' decision to adopt AWD technology. Unlike groundwater as a source of irrigation, the concept of water saving under a large public-managed gravity irrigation system might be less enticing among farmers who were required to pay a minimal fee regardless of the volume of water used. The Free Irrigation Service Act of 2018 [25,26] aggravates this scenario when irrigation water becomes free in the country. Previous studies suggested that farmers' lack of direct incentives in this type of irrigation system limits farmers from appreciating water conservation benefits on the macro-scale [24]. This is especially true in the upstream section of the canal, where water is perceived to be abundant, and water usage is excessive [18]. As a result, downstream farmers unable to get enough water to irrigate their crops. Farmers are more likely to implement water-saving irrigation methods when the irrigation water supply is reliable [27].

Thus, this study aimed to examine the determinants of farmers' adoption of AWD technology under a gravity irrigation system. It also examined the AWD impact yield at actual farmers' fields. We used regression-based approaches and empirical evidence to explain the adoption dynamics of AWD technology in a large-scale gravity irrigation system.

2. Materials and Methods

2.1. Study Area

The study was conducted at the Upper Pampanga River Integrated Irrigation System (UPRIIS), the largest typical public reservoir-backed gravity national irrigation system in Central Luzon (Figure 1). UPRIIS, publicly owned and operated by the National Irrigation Administration (NIA), provides irrigation water to 119,640 ha covering four provinces [7]. It consists of five districts that get water from various run-of-the-river flows and the Pantabangan reservoir [15]. Aside from agricultural use, the reservoir also stores water for hydroelectric power generation. For irrigation, NIA is in charge of the operation and maintenance of the irrigation facilities from the dam to the main and lateral level of the irrigation system. The farmers manage the turnouts and farm ditches through their organized irrigators' associations (IA) and smaller groups within the IA called the turnout service area (TSA). The IAs practice a rotational irrigation scheduling developed and agreed upon during a pre-season meeting with NIA to enable all targeted rice areas to receive water. The canal water flow through different irrigation zones from upstream to downstream. In addition, community deep well pumps owned and operated by farmers' groups and shallow tube wells for individual farmers are also common as a supplementary source of irrigation, especially in downstream areas. The soils in UPRIIS are typically silty clay, silty clay loam, clay loam, and clay textures [15]. The climate has very pronounced dry and wet seasons, with an average annual rainfall of 1500 mm, 89% of which occurs from May to October [28], and rice is planted twice a year.

Figure 1. Location map of the area served by the Upper Pampanga River Integrated Irrigation System in Central Luzon. Red circles show the location of the farm-level survey.

2.2. Sampling Procedure and Data Collection

The data set used in this study was from a 2017 farm-level survey that covered the dry cropping season from December 2016 to April 2017. The survey was conducted through personal interviews using a structured questionnaire. A multi-stage purposive random sampling was used in the selection of farmer-respondents. The first stage was selecting two districts where one district is the nearest or the most upstream section of the main canal of the irrigation system. The other district represents the downstream part of the irrigation system. The second stage was the stratified random selection of two clustered farms or a TSA of an IA per district located upstream, midstream, and downstream toposequence relative to the lateral canal of the irrigation system. Third, in each toposequence, 36 farmers were randomly selected. There were 216 farmer-respondents interviewed. However, due to some data constraints such as missing values, only 163 farmers were included in the analysis. A total of 51 AWD adopters and 112 non-adopters emerged from the final results (Table 1). Farmers who practiced AWD are referred to as AWD adopters.

Table 1. Distribution of respondents in district 1 and 2 under different toposequences.

Location (Toposequence)	Irrigators Association	Toposequence	AWD Adopters	Non-AWD Adopters	Total
District 2 (Upstream)	Agbannawag, Kabanglisan	Upstream	14	16	30
	Biag, Saribiag	Midstream	7	14	21
	Agpapa Walang Tanggihan	Downstream	7	19	26
District 1 (Downstream)	Makaligaya, Bantug Bakal	Upstream	6	22	28
	Kisba, Life Harvest	Midstream	10	20	30
	Malbosa, Roligais	Downstream	7	21	28
		Total	51	112	163

A semi-structured questionnaire was developed for pretesting through a Focus Group Discussion (FGD). Data collected included farmers' demographic traits, land ownership, other sources of irrigation, organizational arrangement about their irrigation scheduling and decision-making, water availability in the canal, awareness, and the toposequence position of farms, including their grain yield for the dry season. The biophysical condition of the farms relative to the toposequence position to the irrigation lateral canals was determined and identified in close coordination with NIA officials. FGD was also conducted before the survey to understand the current water management and governance within IA and NIA.

2.3. Analytical Framework

Farmers generally face a dichotomous dilemma when deciding whether or not to implement a technology. The process of decision-making to adopt or not adopt a technology is assumed to be influenced by myriad factors [29]. The most common approach to evaluate the functional relationship between the probability of adoption and its determinants is a binary choice of the model called probit or logit models with binary dependent variables of 0 and 1 (i.e., whether or not the farmer adopted the AWD technology). This model enables assessing a specific analysis of a farmer's decision to adopt a technology [30]. We used a probit binary choice model to estimate the farmer's probability to adopt the AWD technology in a gravity surface irrigation system, similar to previous research on water-saving technology adoption [21,22,24]. "The probit model assumes an S-shaped response curve such that tail of the curve, the dependent variable, Pr (Y_i = 1), responds slowly to changes in the independent variables. While toward the middle of the curve, i.e., toward the point where $\Pr(Y_i = 1)$ is closest to 0.5, the dependent variable responds more swiftly to changes in the independent variables" [31]. The model was mathematically expressed by Kagoya et al. [29] as:

$$Y_i^* = \beta_0 + \beta_j X_i + \mu_i \tag{1}$$

$$Y_i = \begin{cases} 1\ if\ Y_i^* > 0 \\ 0\ otherwise \end{cases} \tag{2}$$

where Y_i^* is the unobservable or latent variable for technology adoption; X_i is the set of characteristics that determines adoption; Y_i is the observable counterpart, a dummy variable taking the value of 1 if the farmer adopts the AWD technology, 0 if otherwise; μ_i is a random disturbance term associated with the adoption of AWD technology; β_j is the parameter to be estimated; and β_0 is a regression constant.

The probit command in Stata (Version 16, College Station, TX, USA) was used to estimate the ordered probit model, including the option to compute the marginal effects. Parameters for the probit model were attained using standard maximum likelihood estimation. The marginal effects of any variable in a probit model were determined by calculating the change (delta method) observed in the cumulative normal distribution when the variable in question incrementally changes [32].

Since there were no actual measurements on the field water level to confirm the degree of water stress in AWD adopters' plots, the effect of AWD on grain yields was also analyzed. We hypothesized that if the grain yield differences between AWD adopters and non-AWD adopters are not significant, then the AWD practiced by AWD adopters is within the safe AWD recommendation [9]; otherwise, the threshold level for irrigation goes beyond the limit of −15 cm below the soil surface. We initially used a *t*-test to compare the significant differences between the yields of AWD adopters and non-adopters. A multiple regression analysis was also done to determine the predictors of the yield. The regression model considered and passed the assumptions of linearity, normality of errors, no autocorrelation of error, homoscedasticity, and presence of influential outliers.

However, there could be other factors or unobservable characteristics of farmers (e.g., management skills) contributing to the differences in the yield outcome. Thus, a standard treatment effects model was used to correct potential selection bias in estimating the impact of AWD technology adoption on the yield outcome. The standard treatment effects model was estimated using predicted probabilities from the probit as an instrumental variable, with yield as the dependent variable. Asfaw et al. [33], expressed this model mathematically as:

$$R_i = \alpha + \gamma Z_i + \delta Y_i + \varepsilon_i \tag{3}$$

where R_i is a vector of the yield outcome of the j^{th} farmer; Z_i is the vector of exogenous variables believed to affect the yield outcome; ε_i is a random disturbance term associated with the yield outcome Y_i is the observable counterpart, a dummy variable taking the value of 1 if the farmer adopts the AWD technology, 0 if otherwise; γ and the δ are the parameters to be estimated; and α is a regression constant. The main focus is the δ parameter estimation, which represents the impact of AWD technology on the yield outcome.

2.4. Description of Variables

A detailed description of all the variables used in the empirical analysis using the probit model is presented in Table 2. The key explanatory independent variables in the model of AWD adoption are age, education, land ownership, area of rice farm, awareness, other sources of irrigation, perception on the effectiveness of water management as a weed control method, location, toposequence position of farms, and organizational arrangement within IAs about their irrigation water management. Although other factors such as the physical condition of irrigation infrastructure facilities, soil characteristics, and farmers perception on the value of water possibly affecting the AWD adoption, we excluded these variables due to data limitations. The first five variables are typical farmer characteristics used in several adoption studies e.g., [24,34].

Table 2. Definition of variables.

Variable	Definition
Adoption	1 if farmer adopts alternate wetting and drying (AWD), 0 if otherwise
Age	Age of household head
Education	Years of education of household head (year)
Area cultivated	Total area planted to rice (ha)
Land owned	1 if owned the land, 0 if otherwise
Location	1 if from District 2 (most upstream), 0 otherwise
Toposequence1	1 if the toposequence of the turnout area relative to the lateral canal is upstream, 0 if otherwise
Toposequence2	1 if the toposequence of the field relative to the turnout canal is upstream, 0 if otherwise
Availability of water	1 if water is available when requested, 0 if otherwise
Timing of irrigation	1 if the field is irrigated only when there is no visible water on the soil surface, 0 if otherwise
Field water depth	1 if field water depth after irrigation is <5 cm, 0 if otherwise
Flexibility to irrigate	1 if farmer can influence the irrigation scheduling within a turnout, 0 if otherwise
Other source of irrigation	1 if there is another source of irrigation; 0 if otherwise
Awareness	1 if aware of AWD technology, 0 if otherwise
Rotational irrigation	1 if there is a rotational irrigation scheduling followed, 0 if otherwise
Decision maker	1 if farmer can decide of his irrigation scheduling, 0 if otherwise
Manner of irrigation	1 if the manner of irrigation is plot-to-plot, 0 if otherwise
Field Monitoring	1 if farmer monitors his field during irrigation, 0 if otherwise
Weed control	1 if farmer perceives water management as a good weed control method, 0 if otherwise

We hypothesized that education, age, land ownership, rice farm, and awareness had a significant positive association with AWD adoption. We also included other sources of irrigation as one dummy variable because we expect that the likelihood of farmers adopting the AWD technology would increase due to the presence of supplemental irrigation. The biophysical conditions of the farms were also included, such as the location relative to the main, lateral, and tertiary canals may have a significant negative effect on adoption. We hypothesized that farmers who had more control over their irrigation within IA and water availability in the canal increased the probability of AWD adoption. Therefore, the organizational arrangement within IA relative to irrigation scheduling, decision-making on their irrigation, availability of water in the canal when requested, the flexibility to irrigate when needed, and manner of irrigation among farms (plot-to-plot or plot-by-plot) were also included as the resource and organizational constraints in the adoption. The rice yields of farmers were also asked to compare the yield differences between adopters and non-adopters and explain whether adopters practiced "safe AWD" recommendations based on our premise as explained previously (see analytical framework section). The variety (inbred versus hybrid) was included as one dummy variable because it may affect the yield outcome of the respondents.

2.5. Field Water Measurements

To better understand and gain insights on the actual field water level during a cropping season, we monitored the daily field water level of three randomly selected TSA of a turnout (TO No. 6) of the Bantug-Bakal Irrigators Association in Muñoz, Nueva Ecija during the 2018 dry season (December 2017–April 2018). Each TSA consists of 12–15 plots covering an area of 8–12 ha per TSA. We used 42 field water tubes as observation wells [10] to monitor and measure each plot's daily field water level (Figure 2). Each tube was installed 15 cm below the soil surface and one meter away from the bund for ease of monitoring. The field measurement started 16–34 days after transplanting until the start of terminal drainage.

Figure 2. Turnout service area showing the observation well installed in each plot.

We used a decision logic to classify the water management of each plot, wherein if the water level is >0 in 70% or more of the season, the plot is classified as continuously flooded (CF). Otherwise, if water level > 0 in less than 70% of the season, the plot is classified as AWD.

3. Results

3.1. Descriptive Statistics

Out of the 163 farmer-respondents, 31% were AWD adopters. The average age and level of education varied slightly between groups (Table 3). Rice farmers, on average, were 55 years old and had completed 9.7 years of formal education (equivalent to high school level). The average landholding area of rice was 1.76 ha, which was higher than the national average of 1.18 ha [35]. More than half of farmer-respondents (57%) owned the land they cultivated; the rest were either tenants or renters. Seventy-nine percent of the farmers were aware of and were practicing Rotational Irrigation (RI) scheduling within their IAs however, 87% said water was available in the canal when requested through their IA president. Farmers with another source for supplemental irrigation (such as shallow tube wells) accounted for 32% of the total, while the rest depended solely on canal water. Only 22% of farmers said they could also decide their irrigation schedule while others had to go through their IA president. Fifty-one percent of the farmers did their irrigation plot-to-plot, and 81% perceived that water management flooding was an effective weed control method. About 42% of the farmers said their field water depth after irrigation was <5 cm, and 54% monitored their field during irrigation. Forty-seven percent of the farmers were located in district 2, the nearest to the main canal, while 35% were within the upstream toposequence position relative to the lateral canal, and 44% to the tertiary canal.

3.2. Determinants of AWD Adoption

The estimated coefficients of the parameters and the marginal effects in the binary probit model are summarized in Table 4. The likelihood ratio chi-square of 32.03 with a p-value of 0.0218 indicates that the model as a whole is statistically significant and fits significantly better than a model with no predictors. The probit model also correctly predicts 85% of the sample observations. Among the variables that have a significant association with the probability of AWD adoption are the influence of farmers to change the irrigation scheduling within a turnout, awareness of AWD, field water depth, and perception of the effectiveness of water management as a weed control method. However, the sign of the coefficients did not conform to the expected result.

Table 3. Descriptive statistics of sampled population.

Variables	Full Sample (N = 163)		AWD Adopters (N = 51)		Non AWD Adopters (N = 112)	
	Mean	**St. Dev**	**Mean**	**St. Dev**	**Mean**	**St. Dev**
Adoption (%)	31	0.47	-	-	-	-
Age (years)	55.1	13.08	55.9	13.71	54.9	12.80
Education (years)	9.7	2.85	9.2	2.91	9.9	2.81
Area cultivated (ha)	1.76	1.31	1.75	1.12	1.77	1.39
Land owned (%)	57	0.49	49	0.50	61	0.49
Location	47	0.50	55	0.50	44	0.50
Toposequence1 (%)	35	0.48	37	0.48	34	0.48
Toposequence2 (%)	44	0.50	47	0.50	43	0.50
Availability of water (%)	87	0.34	88	0.33	87	0.32
Timing of irrigation (%)	54	0.50	57	0.50	53	0.50
Field water depth (%)	42	0.50	27	0.45	49	0.50
Flexibility to irrigate (%)	66	0.48	55	0.50	71	0.46
Other source of irrigation (%)	32	0.47	25	0.43	35	0.49
Awareness (%)	23	0.42	14	0.35	28	0.45
Rotational irrigation (%)	79	0.41	78	0.42	79	0.41
Decision maker (%)	22	0.42	20	0.40	23	0.43
Manner of irrigation (%)	51	0.50	37	0.58	57	0.00
Field Monitoring (%)	54	0.50	49	0.71	56	0.71
Weed control (%)	81	0.39	90	0.30	77	0.42
Yield (kg/ha)	7024	2067.03	7244	1938.80	6924	2123.75

Table 4. Determinants in the adoption of AWD.

Variables	Coefficient Estimates		Marginal Effects	
	Coefficient	**Std. Error**	**Coefficient**	**Std. Error**
Dependent variable: AWD adoption (1 = if farmer adopts, 0 = otherwise)				
Age	0.0088	0.0092	0.0026	0.0027
Education	−0.0466	0.0440	−0.0137	0.0128
Area cultivated	0.0439	0.1018	0.0129	0.0298
Land owned	−0.4273	0.2606	−0.1255	0.0750 †
Location	−0.0932	0.2870	−0.0274	0.0842
Toposequence1	0.2041	0.2526	0.0599	0.0738
Toposequence2	0.3444	0.2378	0.1011	0.0685
Availability of water	0.1606	0.3562	0.0472	0.1045
Timing of irrigation	0.2669	0.2453	0.0784	0.0714
Field water depth	−0.6264	0.2597 *	−0.1840	0.0723 *
Flexibility to irrigate	−0.4781	0.2411 *	−0.1404	0.0680 *
Other source of irrigation	−0.1388	0.2896	−0.0408	0.0849
Awareness	−0.6093	0.3115 †	−0.1789	0.0884 *
Rotational irrigation	−0.2174	0.2985	−0.0638	0.0873
Decision maker	−0.0755	0.2941	−0.0222	0.0863
Manner of irrigation	−0.3761	0.2448	−0.1104	0.0706
Field Monitoring	−0.0626	0.2603	−0.0184	0.0764
Weed control	0.7598	0.3376 *	0.2231	0.0942 *
Constant	−0.3672	0.9907	-	-
Likelihood Ratio	32.03 *			
Loglikelihood	−85.27			
Pseudo R^2	0.16			

Significant at 0.05 *, 0.10 †.

The coefficient of farmers' influence on irrigation scheduling is significantly negative. This indicates that if a farmer can change their irrigation scheduling within a turnout, it decreases the probability of AWD adoption by 14%, holding other factors constant. This suggests the importance of AWD to be carried out as a group within a contiguous land considering the effect of hydrology with contrasting water regimes (i.e., seepage). Irrigating the field <5 cm showed significant negative effects on the adoption with a marginal effect of 18%. This means that farmers who are likely to adopt AWD prefer to put more water to prolong the flooding condition of their field until the next irrigation scheduling within their turnout.

Unexpectedly, the awareness of AWD is inversely related to AWD adoption with a marginal effect of 18%. In a gravity irrigation system like UPRIIS, awareness of the technology tends to be an unimportant factor in adoption due to the RI scheduling imposed per TSA. This also means that farmers have no control over their irrigation (i.e., only 22% of farmers as decision-makers), so that awareness may play a non-consequential role in their decision to adopt the AWD. The perception of the effectiveness of water management as a weed control method is positive on the adoption. This suggests that when weeds are controlled, farmers tend to adopt AWD. This also means that farmers would prefer to submerge their fields for a few days to control weeds and probably revert to AWD at some point.

Other variables such as age, education, land ownership, farm size, availability of water in the canal when requested, manner of irrigation among field plots, the practice of rotational irrigation scheduling within IA, other sources of irrigation, and toposequence position relative to the source of irrigation showed no significant association with the probability of AWD adoption.

3.3. Effects on Yield

Table 5 shows the standard treatment effects model results using the estimated predicted probabilities from the probit. The estimated AWD adoption coefficient showed no significant impacts on the grain yield, holding other factors constant. A similar result was also obtained using a *t*-test.

Table 5. Effect of AWD adoption on yield.

Variable	Treatment Effect		*t*-Test	
	Coefficient Estimates	***p*-Value**	**Difference, kg/ha**	***p*-Value**
Adopters	−3357.388	0.173	319.295	0.362

Consistent with the above model results, multiple regression analysis shows that AWD adoption did not affect the yield (Table 6; Figure S1). The results show that three explanatory variables have a direct effect on the yields. The factors on location, toposequence of farms relative to the lateral irrigation canal and variety are significant.

The negative significance of the location dummy variable (district) suggests that farmers in District 2 have lower grain yields than District 1. The lower grain yield could be attributed to the variety used in District 2, where a majority of the farmers planted inbred variety.

The toposequence 2 shows positive and significant effects on yield. Farmers whose fields are located upstream of the lateral canal have higher grain yields than at midstream and downstream toposequences of the canal (Figure S2). This suggests that farmers are likely to have higher grain yields when there is access to sufficient water.

The factor on variety shows a negative and significant impact on yield. This suggests that farmers who use inbred variety have lower yields than those who use hybrid seeds.

Table 6. Determinants of yield (N = 163).

Variables	Coefficients	Std. Error
Adoption	105.53	368.79
Age	5.43	12.42
Education	55.42	59.56
Area cultivated	109.92	126.20
Land ownership	344.08	353.63
Location	−897.30	401.21 *
Toposequence 1	822.14	344.63 *
Toposequence 2	123.64	323.52
Availability of water	−129.94	480.06
Timing of irrigation	−28.05	331.97
Variety	−1136.47	363.33 *
Field water depth	128.50	345.31
Flexibility to irrigate	301.09	336.64
Other source of irrigation	−550.36	383.26
Awareness	−725.95	390.18 †
Rotational irrigation	157.54	410.64
Decision maker	425.68	398.51
Manner of irrigation	545.89	343.66
Field Monitoring	−161.90	344.89
Weed control	673.76	415.74
Constant	5820.43	1335.38

Adjusted R^2 = 0.1342; *p*-value = 0.0031; Significant at 0.05 *, 0.10 †.

3.4. Observed Field Water Depth

Figure 3A shows the daily field water level of sampled field plots in the three TSAs. The average field water level varied from −21.9 to 4.9 cm (TSA 1), −8.8 to 6.2 cm (TSA 2), and −19.3 to 4.9 cm (TSA 3). Out of the 48 plots, only 16 were classified as AWD (Figure 3B).

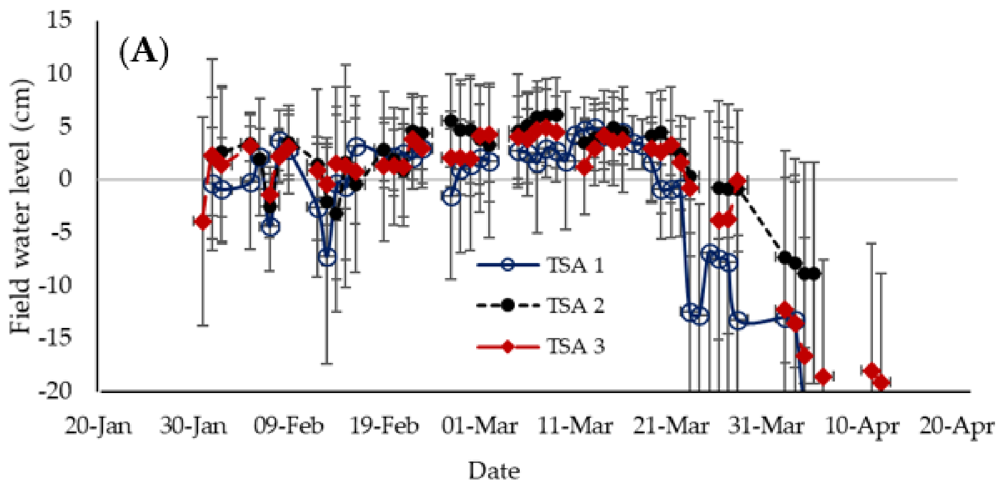

Figure 3. *Cont.*

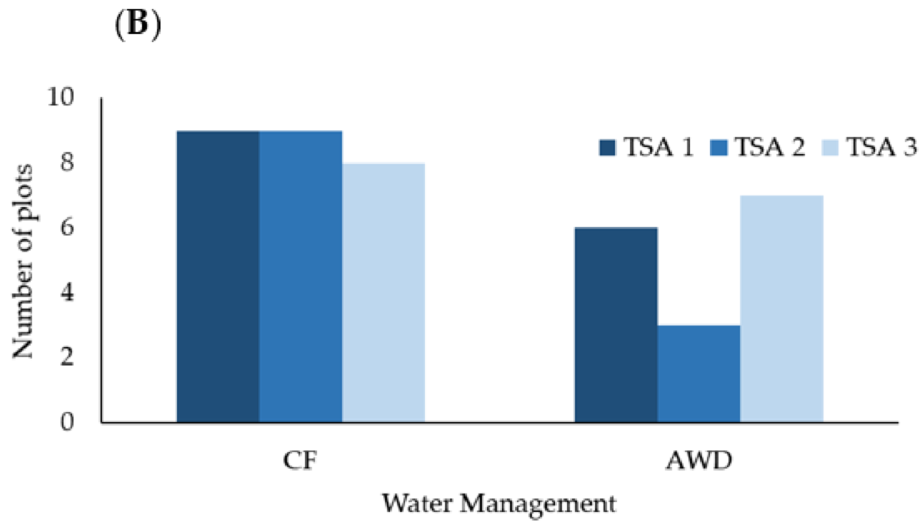

Figure 3. (**A**) Field water level of sampled field plots and (**B**) distribution of plots with different water management in a turnout service area (TSA) during 2018 dry season. CF: Continuously flooded; AWD: Alternate wetting and drying. Error bars represents the standard deviation.

4. Discussion

Farmers have less control over irrigation water in a public-reservoir irrigation system like UPRIIS, as NIA controls the water release schedule via a RI schedule. A closer examination of the descriptive statistics reveals that 79% of the farmer-respondents were fully aware of and practiced RI within their IA. This, in effect, shows that out of the total AWD adopters (n = 51), 79% of these were also within the enforced RI scheduling within a turnout. This means that AWD adoption is closely linked to existing RI scheduling within the IA, albeit the practice may not be the full theoretical description of safe AWD. This is evident in the field water level, wherein some mild to severe AWD were observed during the cropping season (Figure 3A). Out of the total 42 plots, only 38% of these were practicing AWD (Figure 3B). This indicates that there is still an opportunity to improve RI scheduling within a turnout to implement the principle of safe AWD properly. It is also worth noting that our research found no evidence of a difference in responses to water management between upstream and downstream farmers. The result is ambiguous as several authors reported the common upstream-downstream differences in water management e.g., [5,18,36]. One plausible reason is that farmers are already accustomed to the RI scheduling imposed within their IA, so differences in the toposequence position may no longer affect their decision to adopt AWD technology. On the other hand, despite the availability and accessibility of water in the canal, some farmers located upstream may still choose to adopt AWD driven more by their own rational choice than confronted with insufficient water supply (Table 3, i.e., 55% of the total adopters are located in district 2). This aligns with Loeve et al. [27] findings that farmers tend to adopt AWD as long as the water supply is reliable and can be controlled separately for each field or farm.

Interestingly, awareness of AWD was only 23% and had a significant negative effect on the probability of AWD adoption. This contrasts with many previous reports highlighting the importance of awareness on farmers' adoption of improved farm technologies and practices [24,37]. A previous study reported that farmers value risk perception more than technology awareness regarding technology adoption [38]. For example, the perception of farmers on AWD exacerbating weed problems deters them from practicing this technology. Thus, an enabling environment must be developed to influence wider technology adoption. For instance, to reduce the risk of misconception about AWD on weed problems, capacity buildings of farmers on proper land preparation to achieve less weed incidence [39] and appropriate weed management must be overly emphasized in farmers' crop management practices. It is not enough to merely provide a tool or knowledge about new technology to farmers without enabling an environment that could trigger the adoption [40]. The other tenable reasons for the significant negative effects of awareness on the AWD adoption could be that farmers are probably accustomed to the existing practices, which are difficult to change unless innovations are introduced at a system level. It also means that farmers are already bound with their current RI scheduling within the IAs enforced by NIA, and whether or not they are fully aware, the scheduling might be creating some forms of AWD.

Awareness about AWD may play a significant role under a pump irrigation system because saving water (i.e., reduces fuel cost) is a direct benefit. However, in a gravity-irrigation system, where water is practically free regardless of the volume used, being "aware" of AWD may not necessarily influence a farmer's decision to adopt AWD technology. It can be noted that there have been several participatory adaptive trials and capacity building already conducted with emphasis on safe AWD in the national irrigation system in the country e.g., [16]. In most cases, farmers tend to revert to their usual practices after the end of pilot projects due to the absence of incentive and support [41]. A robust incentive mechanism needs to be put in place to encourage more farmers to adopt AWD in a public-managed gravity irrigation system. Carbon markets (via reduction of GHG emissions through AWD) and water taxes, for example, have the potential to make AWD more appealing [42]. Rejesus et al. [24] suggested emphasizing the "public good" (conservation benefits) aspects of AWD technology for sustainable water use.

Furthermore, with the current implementing rules and regulations of the free irrigation service law [25], we recommend the following: (1) Allocate larger operation and maintenance (O&M) subsidy for those IAs who adopt the AWD; (2) explore the adoption of AWD as a criterion for the O&M subsidy [26]; (3) develop an affordable scheme payment of all unpaid irrigation service fee, amortization, and equity payments (before the law) to those who committed to adopt AWD; and (4) link AWD adopters to opportunities to further build their skills to improve their crop management practices with an emphasis on good land preparation and reduce weeds, pest, and diseases. In addition, NIA can develop compensation or incentive packages for district offices that can implement proper rotational irrigation scheduling based on the principle of safe AWD.

Our findings on the impact of AWD on grain yields reinforce previous reports [5,10,43] that there is no yield penalty relative to farmers' practice. This implies that the AWD adopters are also likely to be more technically efficient in their water management with less irrigation input but yield the same with those non-AWD adopters, holding other factors constant [24]. The non-significant differences in the yield also indicate that the current practice of AWD adopters is probably within the safe AWD because of no yield loss.

5. Conclusions

In Asia, AWD technology is a well-known low-cost water-saving technique for irrigated rice. Despite the potential benefits and significant efforts of creating awareness, AWD scaling and adoption remain low in the Philippines. One of the key challenges in the public-managed and large-scale-gravity irrigation system is economic incentives. The decision on AWD adoption was assumed to be influenced by a combination of the socioeconomic factors, institutional arrangements within the irrigators' association, and biophysical conditions relative to the distance to the water source.

In a typical public-owned gravity irrigation system, irrigation delivery is usually based on rotational irrigation scheduling to cover large hectarages. This setup creates some form of drying period before the next irrigation scheduling during crop growth. Our study showed that AWD adopters are bound within the enforced rotational irrigation scheduling within a turnout of the irrigators' association. With the current irrigation management system, the probability of AWD implementation increases when farmers cannot convince IA officials to change the irrigation schedule. In addition, the probability of adoption increased when farmers put a high depth of water in every irrigation until the following schedule. Since farmers have less influence over the release of water through their rotational irrigation setup, "awareness" of AWD did not seem to play a significant role in the adoption. On the impact on yield, we found no significant differences between AWD adopters and non-adopters.

Reflecting on the results of this study, several recommendations need to be advanced in out-scaling the recommended safe AWD in a large-scale-gravity-surface irrigation system:

1. The rotational irrigation scheduling must be fine-tuned with the recommended safe AWD to avoid pre-emptive flooding and severe drying of the paddy fields;
2. To effectively quantify and monitor the rotational irrigation scheduling based on safe AWD, it is recommended that the country invest in and institutionalize the use of decision-support tools using internet-of-things. This is to estimate the water demand and amount of water to be released and to monitor, verify, and provide irrigation water to a specific region on time;
3. In the foresight, to implement the first two recommendations, there is a need to improve and rehabilitate the physical infrastructures of the irrigation system, especially at the canal level.

Many studies have already reported evidence on AWD's effect at the field level. It is now time to look more closely at opportunities that will spur wide-scale implementation at the irrigation system scale, resulting in substantial irrigation water savings and a lower carbon footprint.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/w14010005/s1, Figure S1: Comparison of grain yield between non-AWD adopters and AWD adopters. The error bar represents the standard error, Figure S2: Grain yields of rice under different toposequence of field relative to the lateral canal. N = 58, 51, and 54 for upstream, midstream, and downstream, respectively. The error bar represents the standard error.

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